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Inventory Management System

Discovering Thoughts, Inventing Future

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Improved Inventory Management System for a Jute Mill - A Case Study

By Md. Arafat Hossain, Shubhra Kanti Das, Kawser Hossain & Joyanta Paul
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Abstract- This project work has been carried out for investigating the existing Inventory Management system of the Eastern jute Mills Limited,Khulna, Bangladesh. Eastern Jute Mills Limited manufactures jute products such as hessian, sacks, and jute carpet backing clothes. Itwas founded in 1967 and is based in Khulna, Bangladesh. It also operates as a subsidiary of Bangladesh Jute Mills Corporation. Forinvestigating the Inventory related data and information, the necessary data has been collected from this Jute Mill. By close look of thepresent inventory management system and discussing with the executive personals of the Eastern Jute Mills Limited, Khulna, A clearconception of the existing Inventory Management system has been gained. ABC analysis has been carried out for annual demand. RawJute purchasing procedure has been examined and storing procedure has been observed by close observation to find out the majordrawback of the existing inventory management system. Finally it has been focused to suggest an improved Inventory Managementsystem for the Eastern Jute Mills Limited, Khulna.

Keywords: inventory management, demand, lead time, holding cost, depreciation, ABC analysis.

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Improved Inventory Management System for a Jute Mill - A Case Study

Md. Arafat Hossain [α], Shubhra Kanti Das [σ], Kawser Hossain [ρ] & Joyanta Paul [Ѡ]

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I. Introduction

In Operations Management, inventory refers to any scarceresource that remains idle in anticipation of satisfying afuture demand for it. [1]

An inventory is a stock or store of goods. [1] Inventorymanagement is an important concern for the managers in alltypes of businesses. Effective inventory management isessential for realizing the full potential of any value chine.[2] Inventory primarily arises because of differences in thetiming or rate of supply and demand and is used to balancethese. Inventory may also occur due to economic batch sizesfor an operation, WIP, product seasonality and investmentfor new product ranges. [3]

Holding inventory is often interpreted as carrying an assetbut also means carrying risk in terms of obsolescence,deterioration and quality faults [4]. In financial termsinventory impacts the balance sheet, cash flow and profitand loss accounts. Operationally inventory affectsproduction efficiencies and on-time delivery. In his book"The Goal" Goldratt [5] identifies inventory as a keycomponent for measuring business performance in amanufacturing environment.

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Inventory represents an important decision variable at allstages of product manufacturing, distribution and sales. [6]In the above sense, the term covers not only materials invarious stages of pro-cessing one is likely to see in a factorybut all the human and nonhuman resources maintained butnot currently used by an organization in order to meetanticipated demand for its products and services. [1]

II. Objectives

The objectives of the project work were:

a) To study the present inventory management systemof the Eastern Jute mills, Khulna.
b) To figure out the limitations and drawbacksassociate with the existing inventory managementsystem of the Eastern Jute mills, Khulna.
c) To suggest some methods to prosecute theinventory management system of the Eastern Jutemills, Khulna.

III. Why Inventoryis Necessaryfora Jute Mill

Jute is the main raw material in a Jute Mill. But Raw Jute isnot available throughout the year. It is only available June toSeptember. So the whole demand of the jute throughout theyear is stocked by purchasing the Raw Jute in this timeperiod. So an effective inventory management system canplay a vital role in a jute mill to make the mill profitable.

IV. Objectives of Inventory Management

The objective of inventory management is to achievesatisfactory levels of customer service while keepinginventory costs within reasonable bounds. So inventoryproblem involves the formulation of decision rules thatanswer two important questions:

a) When is it necessary to place an order (or set up forproduction) to replenish inventory?
b) How much is to be ordered (or produced) for theeach replenishment [1]?

The decision rules must aim at satisfying anticipateddemand minimum cost or maximum profit [1].

V. Functions of Inventory

The functions of inventory are described as follows: [7]

a) To meet the anticipated customer demand.
b) For smooth production requirements.
c) To protect against stock outs: Delayed deliveriesarid unexpected increases in demand increase therisk of shortages.
d) To hedge against price increases: Occasionally, afirm will suspect that a substantial price increase isabout to made and purchase larger-than-normalamounts to avoid the increase, the ability to storeextra goods also allows a firm to take advantage ofprice discounts for larger orders.
e) To permit operations: The fact that productionoperations take a certain amount of time means thatthere will be generally being some work-in-processinventory.
f) To prevent stock out. Stock out means running outof the inventory of a stock keeping unit. [9]

VI. Steps Followed to Completethe Project Work

a) At first, the rules and principle of the inventorymanagement system was studied intensively to gainthe proper managerial knowledge about inventorymanagement.
b) Secondly, a close look on the inventorymanagement system of Eastern Jute Mills, Khulnawas given by collecting data of purchasing goodsfor the production, having discussion with theconcerned personnel and visiting the Eastern JuteMills of Khulna to observe how goods are kept.
c) Thirdly, the drawbacks associated with theinventory management system of Eastern Jute Millof Khulna were figured out by means of case study.
d) Lastly, some suggestions were given to meet theanticipated demand and to eliminate the drawbacksand to maintain the inventory management systemof Eastern Jute Mills of Khulna with moreefficiently.

VII. Data Collection and Calculation

a) Lead Time Calculation

- Estimate the required items = 4 days
- Advertisement = 7 days
- Item verification = 7 days
- Item preparing = 7 days
- Tender receiving time = 10 days
- Tender verification for comparative statements =14 days
- Get order = 4 days
- Order preparing = 25 days
- Inspection the ordering products = 5 days
- Deliver the products = 5 days

In total = 88 days
So, Lead time = 88 days

VIII. Determination of Inventory Related Cost

Holding Cost: The holding cost includes handling,insurance, taxes, carrying cost of goods or raw materials.

- Bank interest on the money invested in inventory =9%
- Depreciation: Batching to batching = 0.50%,Preparing to winding = 0.95% , Beaming =0.05%,Weaving = 4%, Finishing = 1%, Jute to jute = 0.5%
- Insurance = 0%
- Expense of running mills = 14%

So, Total holding cost C_H = 30%

Shortage cost: This Cost arises when the Actual demandcan't be met by the existing stock.

Lower ordering costs: If you buy a larger quantity of an itemless frequently, the ordering costs are less than buyingsmaller quantities over and over again. (The costs of holdingthe item for a longer period of time, however, will begreater.) [8]

In Case of Eastern Jute Mills, Shortage cost is Totally Zero. This is because the actual demand is alwaysmet by the existing stock.

Ordering cost: This cost takes place by ordering fromoutside supplier or by producing the items internally.

- Cost of publicity and advertisement = 95000 Taka
- Cost due to the telephone calls= 60000 Taka
- Postage and telegram = 5000 Taka

So, Ordering cost, CR = 160000 Taka

IX. Equations of Optional Replenishment

Table 1 : Necessary equations of the optional replenishment system

Description	Equation
Safety stock	$B = zS_D\sqrt{\frac{t}{2}+L}$
Maximum inventory	$M = D\left(\frac{t}{2}+L\right)+B$
Reorder point	$R = D_L + B$
Holding cost	$C_H = c_H\left(\frac{M+B}{2}\right)$
Order size when L<t	$Q_i = M - Q(T_i)$
Order size when L>t	$Q_i = M - [Q(T_i)+O(T_i)]$

M = Maximum inventory, B = Safety stock, R = Reorder point, C_H = Cost of holding 1 unit per unit time, C_H =Holding cost, z = Number of standard deviation away fromthe mean, S_D = Daily standard deviation, D = Demand perday, D_L = Lead time demand, L = Lead time, t = Reviewperiod, Q_t= Order size, $Q(T_i)$ = Inventory on hand atreview time, $O(T_i)$ = Inventory ordered but not received.

X. Identifying Critical Inventory Items with ABC Analysis

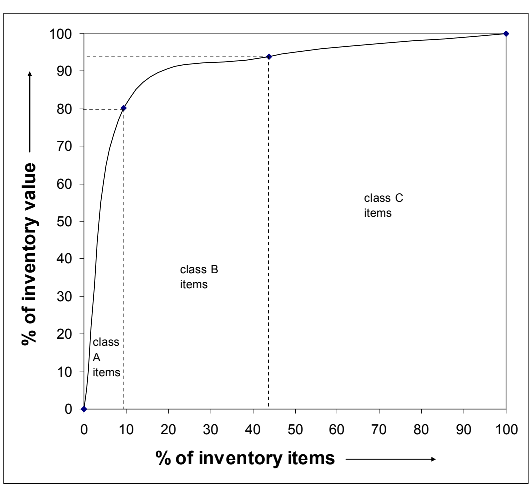


Figure 1 : ABC analysis showing relationship between percentage ofinventory items and percentage of inventory value

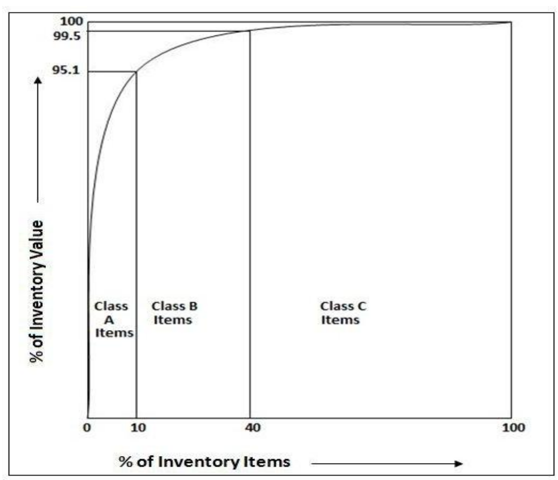
As figure shows, class A typically represents only about 20percent of the items but account for 80 percent of the dollarusage. Class B items account for another 30 percent of theitems but only 15 percent, of the dollar usage. Finally, 50percent of the items fall in class C, representing a mere 5percent of the dollar usage.

Table 2 : ABC analysis for annual demand of Eastern Jute Mills

Total number of items = 10

SL	Raw materials	Unit	Amounts	Per unit price (Taka)	Total price (taka)
1.	Raw Jute	Tons	7260	43467	315570420
Total Class of A items =					315570420
2.	Baling hoops	Kg	44928	74	3324672
3.	Paperboard tubes	Pieces	1320	729	962280
4.	Jute batching oils	Litter	221748	46	10200408
Total Class of B items =					14487360
5.	Baling pins	Kg	2400	84	201600
6.	Baling buckles	Kg	4800	78	374400
7.	Polythin Sheet	Kg	630	143	90090
8.	Emulsifier	Kg	432	260	112320
9.	Starch	Kg	20364	40	814560
10.	Dyes Chemicals	Kg	90	493	44370
Total Class of C items =					1637340

Figure 2 : ABC analysis for the annual demand of the EasternJute Mills



Total price of 10 items = 315570420 + 14487360 +1637340 = 331695120 Taka Now,

Total number of Class-A items = 1

% of Class-A items = $\frac{1}{10} \times 100$ = 10 %

Total price of Class-A items = 315570420 Taka

% of price of Class-A items = $\frac{315570420}{331695120} \times 100$ = 95.1 %

Total number of Class-B items = 3

% of Class-B items = $\frac{3}{10} \times 100 = 30$ %

Total price of Class-B items = 14487360 Taka

% of price of Class-B items = $\frac{14487360}{331695120} \times 100 = 4.4\%$

Total number of Class-C items = 6

% of Class-C items = $\frac{6}{10} \times 100 = 60$ %

Total price of Class-C items = 1637340 Taka

% of price of Class-C items = $\frac{1637340}{331695120} \times 100 = 0.50$ %

XI. Sample Calculation for Itemno-1 (RawJute) for1 Year Review Period

Unit price, b = 43467 taka
Annual demand = 7260 tons
Percentage of value invested in inventory, f =30%
Service level = 85%
So, z= 1.0364 (from normal distribution curve)
Daily Standard deviation, SD = 9.45
Lead time, L = 88 days
There is one holiday is a week in Eastern jute mills andgenerally there are 52 weeks in a year.
So, number of working days in a year in Eastern jutemills =365 – (1×52) days = 313 days
Review period, t = 313 days

Demand per day, D = $\frac{7260}{313}$ = 23.19 tons.

Safety stock, B = $_zS_D$=1.0364 × 9.45 × $\sqrt{\frac{313}{2} + 88}$ = 153

Maximum stock, M = D ($\frac{t}{2} + L$)

+ B = 23.19 $\frac{313}{2}$ + 88) +153 = 5823

Reorder point, R = (lead time demand, DL) + B

= $\frac{7260}{313}$ × 88 + 153 = 2194

So, holding cost, C_H = c_H ($\frac{M+B}{2}$) = b × f × ($\frac{M+B}{2}$)

($\frac{M+B}{2}$) = 43467 × 0.3 × ($\frac{5823+153}{2}$) = 38996419 Taka

Table 3 : Holding cost for raw materials for 1 year review period

SL	Raw materials	Unit	Unit price (b)	Annual demand	Holding Cost (C_H) Taka
1	Raw Jute	Tons	43467	7260	38996419
2	Baling hoops	Kg	74	44928	411877
3	Baling pins	Kg	84	2400	24885
4	Baling buckles	Kg	78	4800	46215
5	Paper board tubes	Pieces	729	1320	119192
6	Jute batching oils	Litter	46	221748	1258808
7	Polythin Sheet	Kg	143	630	11111
8	Emulsifier	Kg	260	432	13845
9	Starch	Kg	40	20364	100518
10	Dyes Chemicals	Kg	493	90	5472
Total Holding Cost =					40988342

1 year review period has been taken under consideration.

Now, total holding cost = 40988342 Taka.

So, total incremental cost,

TIC = C_H + C_R

= (40988342 + 160000) Taka

= 41148342 Taka

XII. Result

ABC analysis is obtained for the annual demand. In case ofthe annual demand, Class- A item is the raw jute whichcovers 10 percent of total raw materials and holds about 95percent of total value. Class- B holds the 30 percent of totalitems and covers around the 3.5 to 4.5 percent of total valueand Class- C holds 60 percent of total items and coversaround the 0.5 percent of total value. The total incrementalcost of the 1 year review period is 41148342 Taka. Thisincremental cost is the summation of the entire three unitsand it has been calculated based on the annual demand ofthe Eastern Jute Mills.

XIII. Suggestion

Here are some suggestions to improve the existing inventorymanagement system of the eastern Jute Mills.

a) Especially Raw Jute (Class- A item) should be putunder extreme high control because only the RawJute holds around 95 percent of inventory value. Ifthe wastage of the raw jute can be minimized, itwill be possible to minimize the total holding cost.

b) It is necessary to provide the more space to storethe raw jute. If more spaces are provided and arenot stored more compactly, the wastage will beminimized. The raw jute should be process beforestorage. It can minimize the total wastage and canminimize the total holding cost.

c) By proper maintenance and replacement of parts,these machines can perform as close to a new one.It is necessary to install the new or automaticmachineries to decrease the loose of raw materials.

d) In today's business environment, even small andmid-sized businesses have come to rely oncomputerized inventory management systems. [10]So the inventory management of the mill should berelied on the computerized inventory managementsystem. A computerized inventory managementsystem is more accurate and reliable.

But if the inventory management system is estimated by 2review period (July to December and January to June) in ayear, it will be easier process and can be made manyimportant decisions quickly.

XIV. Discussion

For studying the entire inventory management system of theEastern Jute Mills, the inventory related data has beencollected from the Hessian unit, Sacking unit and CBC unit.Each unit has some individual needs and produces theindividual products. The overall requirements of the annualdemand of the Eastern Jute Mills have also been collected.The motive of this work is to adopt a suitable inventorymanagement system which will serve as a model. From thepresented data, total inventory costs for 1 year review havebeen figured out.

XV. Conclusion

The Depreciation and wastage is high in Eastern Jute Millswhich leads to a greater holding costs and finally greaterincremental cost. By close observation, it is seen that theraw jute is under loose control that leads the greaterdepreciation and wastage of raw jute. There are spaces tostock the raw jute. But the spaces are not sufficient. Byclose observation, it is seen that the Raw Jute is stored inmore compactly that can leads to more wastage. Normallyhuge amount of jute is bought at a time because it isavailable in June to September. Technology used in jutemanufacturing sector did not change much. Most of themachines in jute mills are old and have passed the usualfunctional period. Due to the use of extreme old machine,the operation can't be performed smoothly and the materialsare being loosen at a considerable rate. The expense ofrunning mill is about the 14 percent which also added withthe holding cost. The old machineries take huge amount ofpower but can't provide sufficient performance. Because ofthis reason the expense of running mill is high. Eastern JuteMills estimates its Inventory management system for every1 year (July to June). It is more complex to estimate the totalinventory at a time.

References Références Referencias

1. Dervitsiotis, Kostas N, "Operation Management" McGraw-Hill Book Company, United States of America, 1981.
2. Ritzman, Larry P, Krajewski, Lee J, "Operation Management" Seven Edition, India, 2007.
3. Geoff Relph, FIOM, Inventory Matters Limited, Witek Brzeski, IBM Business Consulting Services, Gail Bradbear, MIOM, IBM Industrial Practice. "The first steps to inventory management" (control December 2002/2003).
4. Zetie, S, "Stockholding: The Real Cost". BPICS Control April/May, 1990.
5. Goldratt, E, "The Goal", (2nd Edition). Gower Publishing, 1993.
6. Temeng, V. A, Eshun, P. A, Essey, P. R. K, "Application of Inventory Management Principles to Explosive Products Manufacturing and Supply – A Case Study." International Research Journal of Finance and Economics, 2010.
7. Stevenson, William J, "Production Operation management" Sixth Edition, McGraw-Hill Book Company, 1999.
8. Muller, M, "Essentials of Inventory Management" United states of America, 2003.
9. http://en.wikipedia.org/wiki/Inventory
10. http://www.inc.com/encyclopedia/inventory- control-systems. html

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Analytical Investigation of Cargo Motion Lengthwise the Wagon under the Action of Plane Force System

By Khabibulla Turanov

Urals State University of Railway Transport (USURT), Russia

Abstract- For the first time in the theory of solid cargo fastening there has been investigated a case when the cargo is in motion in relation to the wagon floor with acceleration For the first time in the theory of solid cargo fastening there has been investigated a case when the cargo is in motion in relation to the wagon floor with acceleration For the first time in the theory of solid cargo fastening there has been investigated a case when the cargo is in motion in relation to the wagon floor with acceleration $\overline{a}_r$, its speed being at this moment equal to $\overline{v}_r$. There have been set out the results of analytical investigation of cargo shift in dynamics and accordingly elongation and tension in flexible fastening elements under the action of plane force system. It has been established that the longitudinal force perceived by the flexible fastening elements in value is smaller than the force obtained when inertia in relative motion (at rest) is not taken into account. Hence, the cargo shift lengthwise the wagon in this case will be smaller. This, in its turn, will affect the decrease of elongation value and consequently the decrease of the effort of every flexible element, thus increasing their load-carrying capacity.

Keywords: cargo, thrust bars, flexible fastening elements, cargo shift in dynamics, efforts in flexible fastening elements.

GJRE-A Classification : FOR Code: 091399p

ANALYTICALINVESTIGATIONOFCARGOMOTIONLENGTHWISETHEWAGONUNDERTHEACTIONOFPLANEFORCESYSTEM

Analytical Investigation of Cargo Motion Lengthwise the Wagon under the Action of Plane Force System

Khabibulla Turanov

Summary- For the first time in the theory of solid cargo fastening there has been investigated a case when the cargo is in motion in relation to the wagon floor with acceleration $\overline{a}_r$, its speed being at this moment equal to $\overline{v}_r$. There have been set out the results of analytical investigation of cargo shift in dynamics and accordingly elongation and tension in flexible fastening elements under the action of plane force system. It has been established that the longitudinal force perceived by the flexible fastening elements in value is smaller than the force obtained when inertia in relative motion (at rest) is not taken into account. Hence, the cargo shift lengthwise the wagon in this case will be smaller. This, in its turn, will affect the decrease of elongation value and consequently the decrease of the effort of every flexible element, thus increasing their load-carrying capacity.

Keywords: cargo, thrust bars, flexible fastening elements, cargo shift in dynamics, efforts in flexible fastening elements.

I. Formulation of a Problem

Formulas derived for determining efforts in flexible fastening elements of the cargo under the action of longitudinal and vertical forces presented in Appendix 8-Technical conditions [1, 2], (as has been pointed out in [3 – 22]) have been the result of incompletely solved problems when the longitudinal force value perceived by fastening means according to the gravity power of cargo *G* is understated (i. e. is always within the limits (0,97 ÷ 1,2)G) while during shunting collisions in a hump-yard or emergency braking this force may vary within – (1,2 ÷ 2)G . Moreover, they don't take into account the efforts of preliminary twisting of every fastening wire *R*0, without which the cargo is not liable to dispatching. Just because due to effort *R*0 the cargo is pressed against the wagon floor, friction force is increased. In [1, 2] there is no mention of the notion «shift of the cargo lengthwise the wagon" and hence, no mention of "elongation of each fastening element" to the value of which the efforts in each fastening elements are according to Hooke's law directly proportional. As a result, the efforts of each fastening element have one and the same value, which disagrees with reality. It should be noted that in [3 – 22] a technical problem of cargo fastening under the action of space force system and, as a special case, under the action of plane force system, is solved within the fundamental law of dynamics during relative motion at rest. Unfortunately, there has not been yet considered the case when the cargo is moving lengthwise the wagon floor with acceleration $\overline{a}_r$ its speed at the moment being equal to $\overline{v}_r$ [23, 24].

On this basis it can be noted that determining of cargo shift lengthwise the wagon floor and correspondingly elongation and efforts in each fastening element during cargo motion with acceleration lengthwise the wagon floor at a given relative speed is an urgent technical problem for transport research.

a) Problem Formulation In Dynamics (It is for the first time that the problem is set)

To derive an analytical formula of cargo shift lengthwise the wagon, elongation and efforts in flexible fastening elements in case of the cargo moving in relation to the wagon floor with acceleration $\overline{a}_r$ at speed $\overline{v}_r$, as in case of motion of deformable thread on an imperfect curved surface [25].

b) Problem Specification

As in [7], let us consider the case, when cargo with gravity force $\overline{G}$, located on the wagon on down grade at angle ψ_0 (rad. 0.006 ÷ 0.021 or 0.344 ÷ 1.2 degrees which agrees with grade within 6 ÷ 21°/◦◦) in the mode of both brake release and service braking is kept from lengthwise shifting by flexible fastening elements. The contours of the cargo when it is placed on the wagon the effective area makes it possible to use thrust and/or spacer wooden bars (Fig. 1a, b).

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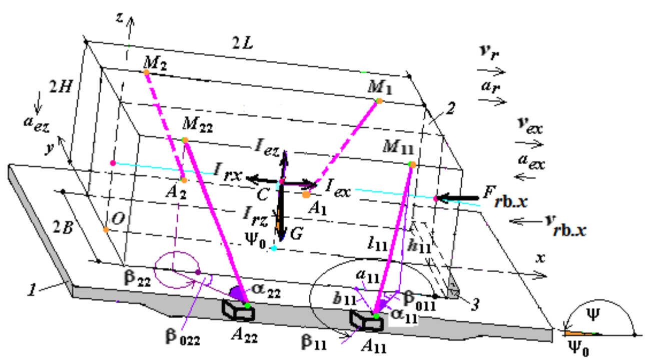

Figure 1 a: Diagram of allocating cargo and thrust bar on the wagonmoving down grade on the tangent
1 – wagon , 2 – cargo, 3 – thrust bar

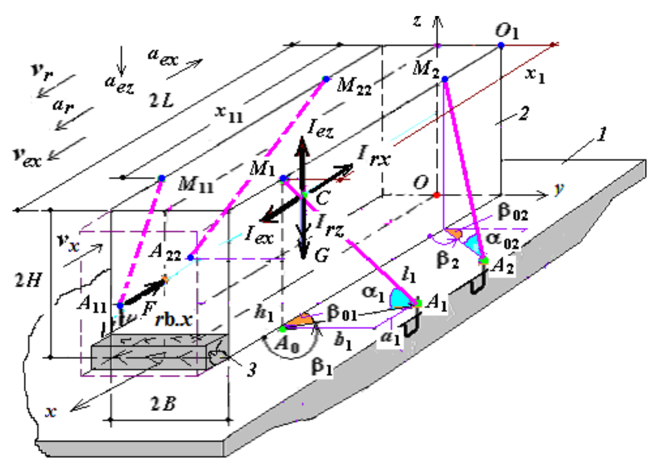

Figure 1 b: Diagram of allocating cargo and thrust bar on the wagonmoving on a tangent

In Fig. 1 a, b as an example the following symbols are accepted: A_1M_1, $A_{11}M_{11}$ and A_2M_2, $A_{22}M_{22}$ are flexible fastening elements of both directions; M_1, M_2, M_{11}, M_{22} are shipping loops (eyelets) [17]. It also has symbols: $I_{rx} = (-Ma_{rx})$ and $I_{rz} = (-Ma_{rz})$ – inertia forces in relative motion on lengthwise and vertical axes; $\bar{I}_{ex}$ – lengthwise and vertical transferring inertia forces; $\bar{F}_{rb.x}$ – aerodynamic resistance force [24].

c) Man-Made Assumption

In working out a computable model as in [17] we assume wagon frame to be the major constrain for the cargo (object) and flexible elastic fastening elements and thrust bar to be additional constraints [10, 18, 23, 24].

We assume that effective longitudinal and vertical forces are perceived by flexible elastic fastening elements $A_{11}M_{11}$ and $A_{22}M_{22}$ located oppositely the action of longitudinal forces while fastening elements of opposite direction A_1M_1 and A_2M_2 sag (Fig. 1a). Fastening elements A_1M_1 and A_2M_2, as applied to Fig. 1b,on the contrary, perceive external forces while $A_{11}M_{11}$ and $A_{22}M_{22}$ sag (i.e. lose a constraint). An additional constraint (a thrust bar) is also a non-ideal and non-retentive (single-sided) one, it prevents the cargo from shifting from the contact plane to one side (to the right) and not keeping it from shifting to the other side (to the left).

Let us assume that flexible fastening elements are pre-tensioned by efforts $R0_i$ (for example, $R0_1 = R0_{11} = R0_2 = R0_{22} = 20$ kN), and they increase normal constituent $\bar{N}$ of constraint reaction (platform floor), therefore, cargo and floor cohesion force $\bar{F}_{coh}$ (and hence sliding friction $\bar{F}_{slid.x}$ meaning that $\bar{F}_{slid.x} < \bar{F}_{coh.}$).

As it is known [7, 10, 18], external constraint reaction (non-ideal) $\bar{R}$ is resolved into normal $\bar{N}$ and tangent $\bar{F}_\tau$ component, i.e. $\bar{R} = \bar{N} + \bar{F}_\tau$. Coordinates x_R, y_R (or x_N, y_N), points of application of external constraints reaction $\bar{R}$ are not known and are to be defined.

d) Formation of Dynamic Model

We apply theoretically to the mass center of material system (cargo) C just as in Fig. 1a,b the active force – gravity force $\bar{G}$, inertia force at relative motion along the lengthwise $I_{rx} = (-Ma_{rx})$ and vertical axis $I_{rz} = (-Ma_{rz})$, longitudinal and vertical transferring inertia forces $\bar{I}_{ex}$ and $\bar{I}_{ez}$ and direct them from the object and also aerodynamic resistance force $\bar{F}_{rb.x}$ which we direct to the object. We will take into account the fact that these forces exert influence on the external constraints (platform and fastening means). As to the object (cargo), we formally apply external forces (reactive forces) – normal component $\bar{N}$ of wagon floor reaction and tangent component of this reaction as ultimate friction force (the force of cargo cohesion with wagon floor) $\bar{F}_{coh}$ or sliding friction force $\bar{F}_{slid.x}$; reactions $\overline{R0}_i$ of preliminary twistings of fastening wire and bar reaction $\bar{R}_{bar.x}$ (Fig.2 a, b) [17].

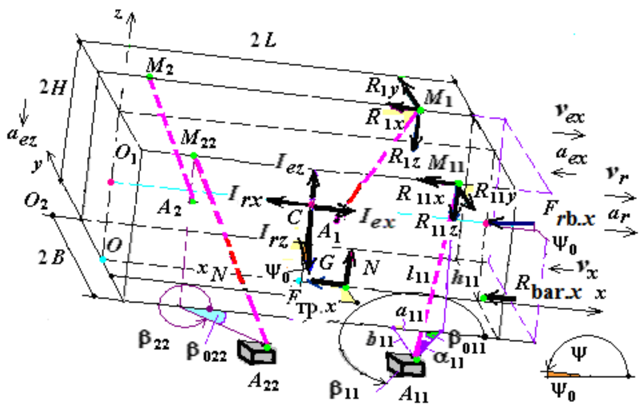

Figure 2 a: Dynamic model of cargo on the wagon moving along the tangent on down grade

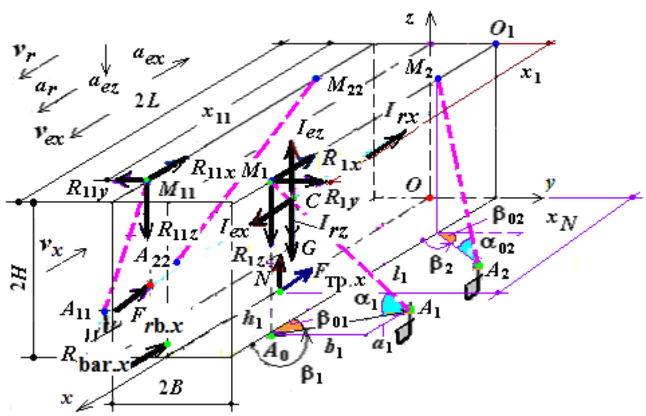

Figure 2 b: Dynamic model of cargo on the wagon moving on a tangent

Longitudinal and vertical transferring inertia forces $\bar{I}_{ex}$ and $\bar{I}_{ez}$ will experience external constraints (platform floor and thrust bar). It is only the thrust bar, not the pre-tensioned flexible elastic fastening elements that will experience longitudinal transferring inertia force $\bar{I}_{ex}$. Flexible fastening elements may experience the action of external forces only when there takes place a shift of thrust bars with a bend of fastening items (nail).

II. Methods of Solution

The formation of dynamic and constructing a mathematical model of cargo movement on a wagon is based on classical concepts and provisions of theoretical mechanics (for example, Constraint and their reactions, the Principle of ties release of the fundamental law of dynamics of the relative motions of records) [23, 24]).

a) Problem Analytical Solution

Unlike in [7, 10, 18], for deriving an engineering formula we will use the fundamental law of relative transferring cargo motion during rolling stock movement along tangent described by the equation in vector form

$$M\bar{a}_r = \bar{F} + \bar{R} + \bar{I}_e + \bar{I}_C \,, \qquad (1)$$

where $\bar{a}_r$ is cargo relative acceleration (or acceleration of cargo relative to the wagon floor).

As applied to the problem in question $\bar{F} = \bar{G}$ is active force, $\bar{R} = \bar{N} + \bar{F}_\tau$ is reactive force, $\bar{I}_e \in \left(\bar{I}_{ex}, \bar{I}_{ez}\right)$ are longitudinal and vertical transferring inertia forces, $\bar{I}_C$ is Carioles inertia force (for the problem in question it is assumed to be equal to zero).

Let us assume that as in [25], cargo is in motion lengthwise the wagon floor with acceleration $\bar{a}_r$ and let its speed be $\bar{v}_r$ at the moment. Then equation (1) in projections upon coordinate axes *Ox* and *Oz* is presented in the form

$$I_{ex} + \left(G_x - F_{\text{rb}.x}\right) - F_x - F_{\tau x} - R_{\text{bar}.x} = Ma_{rx}\,; \qquad (2)$$

$$-\left(G_z - I_{ez}\right) - F_z - F_{\text{rb}.z} + N = Ma_{rz}\,, \qquad (3)$$

where $I_{rx} = (-Ma_{rx})$, $I_{rz} = (-Ma_{rz})$ and $G = \{G_x, G_z\}$ is projection of inertia force in relative motion onto coordinate axes *Ox* and *Oz* ; $\bar{I}_{ex}$, $\bar{I}_{ez}$ and $F_{\text{rв}} = \{F_{\text{rв}.x}, F_{\text{rв}.z}\}$ are active forces; $F^{(i)} = F_{(i)} = \{F_x, F_z\}$, $\overline{N}$ and $\overline{F_{\tau x}}$, $\overline{R}_{\text{bar}.x}$ are reactive forces. At that, F_x and F_z are orthogonal projections of elastic forces (effort) of *i*-flexible elements with allowance made for wire preliminary twisting of fastening $R0_i$ of additional constraint (cargo fastening flexible element) onto coordinate axes *Ox* and *Oz*; $\overline{N}$ and $\overline{F_{\tau x}} = \overline{F}_{\text{slid}.x}$ are so far unknown normal

Oz; $\overline{N}$ and $\overline{F_{\tau x}} = \overline{F}_{\text{slid}.x}$ are so far unknown normal and tangent components of wagon reaction (constraints) $\overline{R}$; $\overline{R}_{\text{bar}.x}$ is a design value of reactions of fastening thrust elements (thrust bars) calculated according to the chosen number of fastening elements (nail) in agreement with clearance outline. Designation to the power *i*of elastic force $\overline{F}^{(i)}$ means that the force is dependent on the number of fastening elements but it doesn't mean that it is to be summed according to *i*. Elastic force $\overline{F}^{(i)}$ has only one value.

III. Results of Solution

a) Mathematical Solution of The Problem

In compliance with this and applied to (2) and (3) the following can be derived

$$G_x = G\sin(\psi_0)\,;\; F_x = \sum_{i=1}^{n_p} R_{ix} + \sum_{i=1}^{n_p} R0_{ix};\; F_{rb.x} = F_{rb}\cos(\psi_0)\,; \tag{2a}$$

$$G_z = G\cos(\psi_0)\,;\; F_z = \sum_{i=1}^{n_p} R_{iz} + \sum_{i=1}^{n_p} R0_{iz};\; F_{rb.x} = F_{rb}\sin(\psi_0)\,; \tag{3a}$$

According to the Coulomb law we'll write down

$$F_\tau \le fN\,, \tag{4}$$

where f is sliding friction coefficient $f = 0{,}7f_{\text{coh}}$ with allowance made for f_{coh} being the coefficient of cohesion friction between contact surfaces of cargo and wagon floor which are accepted according to reference data) [7, 10, 17, 18].

Substituting (4) in (3) we'll find

$$F_\tau = f\left[(G_z - I_{ez}) + F_z + F_{rb.z}\right],$$

or taking into account (3,a) we have

$$F_\tau = f\left[(G\cos(\psi_0) - I_{ez}) + \sum_{i=1}^{n_p} R_{iz} + \sum_{i=1}^{n_p} R0_{iz} + F_{rb}\sin(\psi_0)\right] \tag{5}$$

Just as in [10, 17, 18] let us present expression (5) in the form

$$F_\tau = F_\tau^{\text{elast.}} + F_\tau^{e}\,, \tag{6}$$

where $F_\tau^{\text{elast.}}$ and F_τ^{e} are friction forces of elastic and external forces

$$F_\tau^{\text{elast.}} = f\sum_{i=1}^{n_p} R_{iz} \tag{6a}$$

$$F_\tau^{e} = f\left[(G\cos(\psi_0) - I_{ez}) + \sum_{i=1}^{n_p} R_{iz} + \sum_{i=1}^{n_p} R0_{iz} + F_{rb}\sin(\psi_0)\right] \tag{6 b}$$

Substituting (2a) in (2) taking into account (6) we'll get

$$I_{ex} + G\sin(\psi_0) - \sum_{i=1}^{n_p} R_{ix} - \sum_{i=1}^{n_p} R0_{ix} - F_\tau^{\text{elast.}} - F_\tau^{e} -$$
$$- F_{rb}\cos(\psi_0) - R_{\text{bar}.x} = Ma_{rx}.$$

Let us rewrite the above expression taking into account (6a) and (6b)

$$I_{ex} + G\sin(\psi_0) - \sum_{i=1}^{n_p} R_{ix} - \sum_{i=1}^{n_p} R0_{ix} - f\sum_{i=1}^{n_p} R_{iz} -$$
$$- f\left[(G\cos(\psi_0) - I_{ez}) + \sum_{i=1}^{n_p} R0_{iz} + F_{rb}\sin(\psi_0) \right] - \qquad (7)$$
$$- F_{rb}\cos(\psi_0) - R_{\text{bar}.x} = Ma_{rx}.$$

After elementary manipulations with the above expression we determine projections of elastic forces (effort or tension) of *i*-flexible fastening elements onto axis *Ox*

$$\sum_{i=1}^{n_p} R_{ix} + f\sum_{i=1}^{n_p} R_{iz} = I_{ex} + G\big(\sin(\psi_0) - f\cos(\psi_0)\big) + fI_{ez} -$$
$$- \sum_{i=1}^{n_p}\big(R0_{ix} + fR0_{iz}\big) - F_{rb}\big(\cos(\psi_0) + f\sin(\psi_0)\big) - R_{\text{bar}.x} - Ma_{rx}.$$

We rewrite the derived expression in the form

$$\sum_{i=1}^{n_p} R_{ix} + f\sum_{i=1}^{n_p} R_{iz} = \Delta F_x, \qquad (8)$$

where $\Delta F_x = \Delta F_{\text{long.}}$ are longitudinal forces perceived by flexible and thrust cargo fastening elements

$$\Delta F_x = I_{ex} + G\big(\sin(\psi_0) - f\cos(\psi_0)\big) + fI_{ez} -$$
$$- \sum_{i=1}^{n_p}\big(R0_{ix} + fR0_{iz}\big) - F_{rb}\big(\cos(\psi_0) + f\sin(\psi_0)\big) -$$
$$- R_{\text{bar}.x} - Ma_{rx}.$$

Here we are to take into account the fact that $\overline{R}_{\text{bar}.x}$ is a design value of fastening thrust elements reactions (thrust bars) calculated either according to arbitrarily chosen or just as in [22] in accordance with scientifically grounded number of fastening elements (nail) in agreement with clearance outline. For example, it is in this way that reactions of thrust bars are determined (12 [21]):

$[R_{\text{nail}}]$ = 1, 08 is an assumed value of force per one fastening item (nail), (Table 32 Appendix 14 to International Rail Freight Transportation Agreement);

$n_{\text{bar}.x}$ is accepted number of thrust bars according to cargo location and fastening scheme, item (Fig. 1);

k_1 is a strength coefficient of fastening thrust bars, taking into account the state of wagon floor, items (usually accepted to be 0,5 ÷ 0,6);

$n_{\text{nail}.x}$ is accepted value of needed number of nails per each thrust bar, item;

$R_{\text{bar}.x} = k_1 \cdot n_{\text{nail}.x} \cdot n_{\text{bar}.x} \cdot [R_{\text{nail}}]$ is allowable load per one fastening item (nail) (46 Appendix 14 to). For example, for a nail with ∅4and length 100 ÷ 120 mm

$[R_{\text{nail.}}]$ = 0,047 кН, for a nail of ∅6 and length 150 ÷ 200 mm $[R_{\text{nail.}}]$ = 1,08 кN. According to the standards of European countries for a fastening item of ∅5mm and length 100 ÷ 150 $[R_{\text{nail.}}]$ = 1, 25 кN, and for an item of ∅6mm and length 150 ÷ 200mm $[R_{\text{nail.}}]$ = 1,5 кN [26].

By introducing notions of "shearing" and "retentive" forces [7, 10, 11, 18] we rewrite the above expression

$$\Delta F_x = F_{\text{shear.}} - F_{\text{ret.}}, \tag{9}$$

where

$$F_{\text{shear.}} = I_{ex} + G\sin(\psi_0) ; \tag{10a}$$

$$F_{\text{reet.}} = f\left(G\cos(\psi_0) - I_{ez}\right) + \sum_{i=1}^{n_p}\left(R0_{ix} + fR0_{iz}\right) + \\ + F_{rb}\left(\cos(\psi_0) + f\sin(\psi_0)\right) + R_{\text{bar}.x} + Ma_{rx}. \tag{11}$$

From now on, for simplicity of problem solving we'll study a case when cargo is retained lengthwise the wagon by *i*-flexible fastening elements ($i = \overline{1, n_p}$) and thrust bar (Fig.1). Then according to the method of determining deformations at minor displacement we project a new point position first onto "original" or "old" direction of thrust element [17, 18 – 21]. As a thrust element is arbitrarily located in space for calculating the projection it is necessary to make use of the method of double projection the way it is done in theoretical mechanics for arbitrarily located force [10, 15, 18]. Based on this we'll derive a formula for finding elongation of fastening flexible elements depending on cargo shift along wagon Δx and fastening geometrical parameters

$$\Delta l_i = \Delta x \frac{a_i}{l_i}, \tag{12}$$

where l_i is the length for each flexible elastic fastening element, m: $l_i = \sqrt{a_i^2 + b_i^2 + h_i^2}$ taking into account the fact that a_i, b_i and h_i are projections of each flexible fastening element onto longitudinal *Ox*, crosswise *Oy*, and vertical axis Oz.

It is obvious that elongation in the flexible elastic fastening element will occur only when there is cargo shift lengthwise the wagon at value Δx .

According to [7, 10, and 15] the movement of cargo lengthwise the wagon as one-mass oscillatory system can be presented in the following way (Fig. 3).

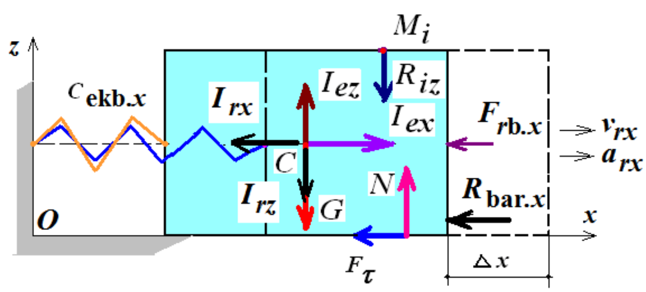

Figure 3 : Cargo movement lengthwise the wagon as one-mass oscillatory system

Here, just as in [7], the sum of projections of the efforts of flexible fastening elements $\overline{R}_{ix}$ onto the longitudinal axis which were according to Hooke's law the results of cargo shift lengthwise the wagon Δx is replaced by a spring with equivalent rigidity $c_{\text{ekb}.x}$ stretched out at the value of the shift. In its turn, spring with equivalent rigidity $c_{\text{ekb}.x}$ (Fig. 3) stretched out at

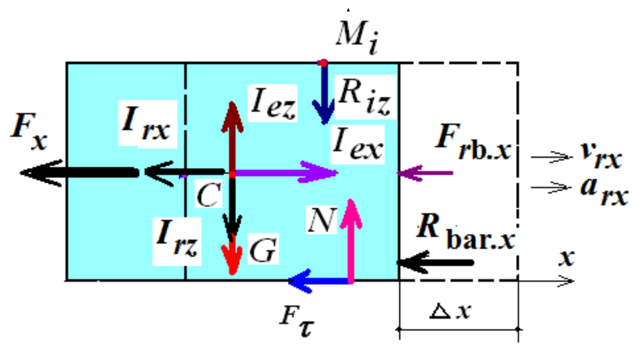

Figure 4 : Dynamic model of cargo loaded by longitudinal and vertical forces.

Designations in Fig. 3 and 4 are the same as in Fig. 2, except $c_{ekb.x}$ being equivalent (either reduced or generalized) rigidity of flexible fastening elements along longitudinal axis *Ox*.

In expressions (8) and (11) projections of elastic forces (effort and tension) of *i*-flexible elastic fastening elements onto longitudinal and vertical axes *Ox* and *Oz* are determined according to the formulas

$$\sum_{i=1}^{n_p} R_{xi} = \sum_{i=1}^{n_p} c_i \frac{a_i}{l_i} \cdot \Delta l_i \; ; \; \sum_{i=1}^{n_p} R0_{xi} = \sum_{i=1}^{n_p} R0_i \frac{a_i}{l_i} \; ; \tag{13}$$

$$\sum_{i=1}^{n_p} R_{zi} = \sum_{i=1}^{n_p} c_i \frac{h_i}{l_i} \cdot \Delta l_i ; \; \sum_{i=1}^{n_p} R0_{zi} = \sum_{i=1}^{n_p} R0_i \frac{h_i}{l_i}, \tag{14}$$

or taking into account (12),

$$\sum_{i=1}^{n_p} R_{xi} = \sum_{i=1}^{n_p} c_i \frac{a_i}{l_i} \cdot \Delta x \cdot \frac{a_i}{l_i} \; ; \; \sum_{i=1}^{n_p} R0_{xi} = \sum_{i=1}^{n_p} R0_i \frac{a_i}{l_i} \; ; \tag{13a}$$

$$\sum_{i=1}^{n_p} R_{zi} = \sum_{i=1}^{n_p} c_i \frac{a_i}{l_i} \cdot \Delta x \cdot \frac{h_i}{l_i} ; \; \sum_{i=1}^{n_p} R0_{zi} = \sum_{i=1}^{n_p} R0_i \frac{h_i}{l_i}, \tag{14a}$$

where c_i is rigidity of *i*-flexible fastening element (kN/m): are projections a_i and h_i are projections of i-flexible fastening elements onto longitudinal and vertical axes: l_i is length of i-flexible fastening element; Δx is cargo shift lengthwise the wagon; $R0_i$ is tension of preliminary twistings of *i*-flexible fastening element (kN) (we'll assume 20 kN); $i = \overline{1, n_p}$ is a number of flexible elastic fastening elements.

In formulas (13) and (14) rigidity of *i*-flexible fastening element (kN/m) with a number of threads n_i (item), diameter d_i(mm) and $l_i$of length (m) of fastening wire:

$$c_i = \frac{10^{-6} \pi E}{4} d_i^2 \frac{n_i}{l_i} = 7{,}854 \cdot d_i^2 \frac{n_i}{l_i}, \tag{15}$$

where*E* is elasticity module of annealed fastening wire (usually assumed $E = 1 \cdot 10^7$ kN/m^2, and for steel cable $E = 2{,}1 \cdot 10^8$ kN/m^2); 10^{-6} is conversion factor of wire diameter mm into m.

Putting the first expressions (13a) and (14a) in (8) we obtain

$$\sum_{i=1}^{n_p} c_i \frac{a_i}{l_i} \cdot \Delta x \cdot \frac{a_i}{l_i} + f \sum_{i=1}^{n_p} c_i \frac{a_i}{l_i} \cdot \Delta x \cdot \frac{h_i}{l_i} = \Delta F_x,$$

or

$$\sum_{i=1}^{n_p} c_i \left(f \frac{h_i}{l_i} + \frac{a_i}{l_i} \right) \cdot \Delta x \cdot \frac{a_i}{l_i} = \Delta F_x.$$

The above expression with consideration for (15) has the form

$$7{,}854 d_i^2 \sum_{i=1}^{n_p} \frac{n_i}{l_i} \left(f \frac{h_i}{l_i} + \frac{a_i}{l_i} \right) \cdot \Delta x \cdot \frac{a_i}{l_i} = \Delta F_x.$$

Hence we can find cargo shift lengthwise the wagon

$$\Delta x = \frac{\Delta F_x}{7{,}854 d_i^2 \sum_{i=1}^{n_p} \frac{n_i}{l_i}\left(f \frac{h_i}{l_i} + \frac{a_i}{l_i} \right) \cdot \frac{a_i}{l_i}}, \quad (16)$$

where $\Delta F_x = \Delta F_{\text{long.}}$ – is longitudinal force, determined by formula (9), (10) and (11) with consideration for second expressions (13), (14):

$$F_{\text{shear.}} = I_{ex} + G\sin(\psi_0); \quad (10)$$

$$F_{\text{ret.}} = f\left(G\cos(\psi_0) - I_{ez}\right) + \sum_{i=1}^{n_p} R0_i \left(f \frac{h_i}{l_i} + \frac{a_i}{l_i} \right) + \quad (11a)$$

$$+ F_{rb}\left(\cos(\psi_0) + f\sin(\psi_0)\right) + R_{\text{bar}.x} + Ma_{rx}.$$

Here, if aerodynamic resistance force $\overline{F}_{\text{rb}}$ acts from the cargo rear back, this force should be put in the formula with a negative sign with consideration for coordinates of its application.

Just as in [7, 10, 15) cargo shift lengthwise the wagon Δx is the distance from the cargo butt surface that is able to provide joint performance of flexible and thrust fastening means if a thrust bar is nailed to the wagon floor from the cargo butt at a distance less than Δx.

It can be observed from (16) that first, cargo shift lengthwise the wagon will occur only when $\Delta F_{\text{long}} > 0$ and second, breakup of flexible fastening elements will not take place only on condition that $\Delta x \le [\Delta x]$ where $[\Delta x]$is an allowable value of cargo shift lengthwise the wagon (mm) determined according to value $[R_i]$ (Table 30 Appendix 14 to International Rail Freight Transportation Agreement).

Summarizing the results of mathematical modeling of fastening of cargo asymmetrically (or symmetrically) located on the wagon it can be noted that there has been derived an analytical formula for determination of cargo shift lengthwise the wagon Δx withconsideration for physical-geometrical character-ristics of flexible elements (i.e. E, n, d, l), values of external forces ($\overline{G}, \overline{I}_x, \overline{I}_z, \overline{F}_{\text{rb}}, \overline{R}_{\text{bar.x}}, M\overline{a}_{\text{rx}}$), perceived by flexible fastening elements, thrust bar and cargo and the state of cargo contact surfaces and wagon floor taken into account by friction coefficient (*f*).

In a special case when a wagon with cargo is moving on a tangent without braking and in the release schedule from (10) and 11a) there will be excluded descend angle ψ (i. e. $\psi_0 = 0$). In these cases (10) and (11a) will be

$$F_{\text{shear.}} = I_{ex}; \quad (10b)$$

$$F_{\text{ret.}} = f\left(G - I_{ez}\right) + \sum_{i=1}^{n_p} R0_i \left(f \frac{h_i}{l_i} + \frac{a_i}{l_i} \right) + F_{rb} +$$

$$+ R_{\text{bar}.x} + Ma_{rx}. \quad (11b)$$

Let us recall that in (11b) vertical transferring inertia force $\bar{I}_z$ occurs only during the movement of the wagon on a tangent without braking and in release schedule as in during schedule – $\bar{I}_z = 0$.

In case of shunting collision in a marshaling hump-yard $\bar{F}_{rb} = 0$ and $\bar{I}_z = 0$ (Fig.1b and 2b). That is why (11b) will have a simple form of:
(11в)

While solving practical problems by using formula (9) or (16) just as in [10, 15, 17, 18] let us assume that maximum regulatory values of longitudinal transferring accelerations $\bar{a}_{ex}^{\max} = \bar{a}_{ex}$ are equal to $a_{ex} = 0{,}3\text{g}$ – on a tangent, $a_{ex} = (0{,}7 \div 1{,}2)\text{g}$ during service brake application, $a_{ex} = (1{,}2 \div 2)\text{g}$ during wagon collisions in a hump-yard ,and vertical transferring accelerations $\bar{a}_{ez}^{\max} = \bar{a}_{ez}$ occurring because of deviations in track maintenance standards , – $a_{ez} = (0{,}46 \div 0{,}66)\text{g}$. In accordance with this statement it is possible to accept $I_{ex} = 0{,}3G$ on a tangent, $I_{ex} = (0{,}7 \div 1{,}2)G$ in service braking, $I_{ex} = (1{,}2 \div 2)G$ during wagon collisions in a hump-yard and $I_{ez} = (0{,}4 \div 0{,}66)G$.

Using the derived value of cargo shift lengthwise the wagon Δx, just as in [10, 18] in compliance with Hooke's law (as the product of (15) multiplied by (12)) we determine effort (tension) R_i in *i*-flexible fastening element, kN:

$$R_{\text{elast}.i} = 7{,}854 d_i^2 \frac{n_i}{l_i} \Delta l_i \le [R_i], \quad (17)$$

or with consideration for (12)

$$R_{\text{elast}.i} = 7{,}854 d_i^2 \frac{n_i}{l_i} \Delta x \frac{a_i}{l_i} \le [R_i], \quad (17a)$$

where $[R_i]$ is allowable value of effort in fastenings, determined according to the Table 30 Appendix 14 to International Rail Freight Transportation Agreement depending on a number of threads n_i and wire diameter d_i.

Effort (tension) R_i in a flexible fastening element is according to axiom: to every action there is an equal reaction is equal to the reaction in this element.

IV. Conclusion

a) For the first time in the theory of fastening of solid-state goods there has been derived a formula for determining "retentive" force with allowance made for reactions of thrust fastening elements and inertia forces in relative motion on condition that the cargo moves in relation to the wagon floor with acceleration R_i its speed at the moment being $\bar{v}_r$.

b) When considering cargo motion in relation to the wagon floor with acceleration $\bar{a}_r$ at speed $\bar{v}_r$ it should be noted that longitudinal force perceived by flexible fastening is smaller in value than the force the value of which was obtained without taking into account the inertia force in relative motion (*at rest*). Therefore, cargo shift lengthwise the wagon in this case will also be smaller. This, in its turn, will affect the decrease of elongation value and hence the decrease of the effort of each fastening element meanwhile increasing their loading capacity.

The results obtained in analytical investigation are an important contribution to the theory of cargo fastening.

References Références Referencias

1. Technical requirements for cargo location and fastening in wagons and containers. –M.: Urtrans, 2003. – 544 pp.
2. Appendix 14 to International Rail Freight Transportation Agreement "Cargo allocation and fastening regulations in wagons and containers". – Moscow.: Planeta (Planet), 2008. – 191 pp.
3. Turanov Kh.T. Method of cargo fastening calculation / Kh.T.Turanov, E.D. Pserovskaya, G.A. Turanova // Railway transport, 2001. No. 1. – pp. 56-57.
4. Turanov Kh.T. Calculation of cargo fastening in wagon collisions / Kh.T. Turanov, E.D. Pserovskaya, D.Yu. Korolyova // Railway transport, 2002. №3 pp.43-44.
5. Turanov Kh.T. Modeling of tensions in flexible fastening elements / Kh.T. Turanov, S.A. Sitnikov, A.L. Rykov// Transport science and technology. – 2007. – No. 1. – pp.19-24.

6. Turanov Kh.T. Loading capacities of flexible elastic fastening elements in cargo location with mass center displacement lengthwise the wagon / Kh.T. Turanov, E.N. Timukhina, D.V. Volkov// Urals Transport . – 2007. – No.4. – pp.25-35.
7. Turanov Kh.T. Mathematical modeling of cargo shift lengthwise the wagon under the action of longitudinal and vertical forces / Kh.T. Turanov, M.A. Khadzhimukhametova // Transport: science, engineering and operation. 2008. No.7. – pp.27-31.
8. Turanov, Kh. Analytical modeling cargoes displacement in wagon and tension in fastening / Kh. Turanov, E. Timukhina // Transport Problems, 2008. T. 3, No. 3. - pp. 69–76.
9. Turanov, Kh. Analytical basis of technology asymmetrical allocation of cargo masses common centre in wagons / Kh. Turanov // Transport Problems, 2009. T. 4, No.1. -pp. 77–86.
10. Turanov Kh.T. Theoretical mechanics in cargo handling problems: monograph / Kh.T. Turanov. – Novosibirsk: Science, 2009. - 376 p.
11. Turanov Kh.T.Modeling of technology of cargo fastening under the action of spatial force system / Kh.T. Turanov, V.A. Olentsevich // Urals Transport. – 2010. №3 – pp.35-38.
12. Turanov Kh.T. Mathematical modeling of stress loading of cargo fastening flexible elements with a pad under the action of spatial force system. / Kh.T. Turanov, E.N. Timukhina. // Urals Transport.2011, No. 1. – pp.29-34.
13. Turanov Kh.T. Mathematical modeling of joint fixation of flexible and elastic cargo fastening elements under the action of spatial force system / Kh.T.Turanov, E.N. Timukhina // Herald of the Rostov State Railway University. 2011, No. 1. – pp.136-145.
14. Turanov, Khabibulla. Working out of generalized dynamic model of cargo fixation with cargo pads jointly with flexible and thrust elements under the action spatial force system / Khabibulla Turanov, Elena Timukhina // Transport Problems, 2011, vol. 6, №3 - PP. 79– 88.
15. TuranovKh.T. Interaction of open rolling stock and solid-state cargo:teaching aid for railway universities / Kh.T. Turanov. – M: Federal State Educational Institution "Railway methodical training center". 2011. – 374 p.
16. Turanov Kh.T. Generalized mathematical model of cargo fixation with pads jointly with flexible and thrust elements under the action spatial force system / Kh.T. Turanov // Herald of the Rostov State Railway University. 2012. No.2 pp.145-152.
17. Turanov Khabibulla. Special problems on cargo handling operations: teaching aid for students of railway universities / Khabibulla Turanov. – Saarbrücken, Germany: LAP LAMBERT Palmarium Academic Publishing, 2012. – 423 p.
18. Turanov Khabibulla. The theory of fastening solid-state cargo on open rolling stock: monograph / Khabibulla Turanov. – Saarbrücken, Germany: LAP LAMBERT Palmarium Academic Publishing, 2012. – 259p.
19. Turanov Kh.T. New methods of calculation of elastic elements of cargo fixation on a wagon against longitudinal shift / Kh.T. Turanov // Transport: science, engineering and operation. – 2013 No. 2. – pp. 17-24.
20. Turanov Kh.T. An example of calculation of elastic elements of cargo fixation on a wagon against longitudinal shift / Kh.T. Turanov // Transport: science, engineering and operation. – 2013 No. 2. – pp.40-46.
21. Turanov Kh.T. New methods of determining longitudinal shift in the simultaneous presence of elastic and thrust cargo fastening elements in the wagon / Kh.T. Turanov // Transport: science, engineering and operation. – 2013 No. 6. – pp.3-9.
22. Turanov Kh.T. Calculation of longitudinal shift of cylindrically shaped cargo and efforts in fastening elements by varying the number of fastening elements / Kh.T. Turanov, E.D. Pserovskaya // Urals Transport. . – 2013. No. 3. – pp.37-43.
23. Loitsyansky L.G. The course of theoretical mechanics. V.II. Dynamics / L.G. Loitsyansky, A.I. Lurje // - M.: Nauka (Science), 1983. – 640p. – p.347.
24. Turanov Kh.T. Theoretical mechanics in special problems of freight traffic: teaching aid for students of railway universities / Kh.T. Turanov. – Novosibirsk: Nauka (Science), 2012. – 447 p.
25. Urazbaev M.T. The fundamentals of mechanics of weighty deformable flexible thread: monograph / . M.T. Urazbaev. – Tashkent: Publishing house of Academy of Sciences of Uz SSR, 1951. – 91 p.
26. Nils Anderson, Peter Anderson, Robert Bylander, Sven Sokjer, Petersen and Bob Zether. Equipment for Rational Securing of Cargo on railway Wagons / VINNOVA Report/Rapport VR 2004:05 // http://www.vinnova.se/upload / EPiStorePDF /vr-04-05.pdf.

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Performance Improvement of a Domestic Refrigerator by using PCM (Phase Change Material)

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Abstract- The paper investigates the performance improvement provided by a phase change material associated with the evaporator in a domesticrefrigerator. The heat release and storage rate of a refrigerator is depends upon the characteristics of refrigerant and its properties. Theusage of PCM as TS will help to improve the COP (Coefficient of performance) of new refrigeration cycle by introducing a new sub coolingroutine. The analysis of the experiment exemplifies the improvement of the system coefficient of performance considerably. Using water asPCM and for a certain thermal load it is found that the coefficient of performance of the conventional refrigerator increased by 55-60%.This improvement by sub cooling can be done for single evaporator refrigeration system. Because of prolonging of the compressor off timeby using the latent heat of energy of the PCM capsulated ice, used as the thermal energy storage material, has been investigatednumerically. We can have better food quality due to lower hysteresis cycles of on/off for a given period of operation.

Keywords: phase change material, refrigerator, cop, compressor.

GJRE-A Classification : FOR Code: 091399

PERFORMANCE IMPROVEMENTOFADOMESTICREFRIGERATORBYUSINGPCMPHASECHANGE MATERIAL

Strictly as per the compliance and regulations of:

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Rezaur Rahman [α], Md. Arafat Hossain [σ], ShubhraKanti Das [ρ] & Adnan Hasan [ω]

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I. Introduction

The most alarming environmental disorder namely "GlobalWarming" refers to the rising temperature of Earth'satmosphere and ocean and its projected continuation. Theheat from the Sun is entrapped in the Earth and thusincreases the temperature of the atmosphere by Green houseEffect. Refrigeration system is directly and invisiblyresponsible for Global Warming problem. For the typicalhome of the early 1990s, a frost-free refrigerator or freezerwas the second most expensive home appliance to operatebesides the water heater. Appliance makers were requiredto include labels listing an estimate of the annual cost ofrunning each appliance so consumers could compare costsand energy usage.[1]

A refrigerator (colloquially fridge) is a common householdappliance that consists of a thermally insulatedcompartment and a heat pump (mechanical, electronic, orchemical) that transfers heat from the inside of the fridge toits external environment so that the inside of the fridge iscooled to a temperature below the ambient temperature ofthe room. [2]

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Domestic refrigerators are among the most energydemanding appliances in a household due to their continuous operation. [3]

The domestic refrigerator is one found in almost all thehomes for storing food, vegetables, fruits, beverages, andmuch more. [4]

Materials that can store thermal energy reversible over along time period are often referred to as latent heat storagematerials. [5]

II. Objectives

The objectives of the performance improvement of thedomestic refrigerator by using the phase change material(PCM) are given below,

a) To fabricate the experimental set up by modifyingthe domestic refrigerator with PCM basedrefrigerator.
b) To observe the effects of phase change material(PCM) in compressor effect on COP.
c) To observe the difference on the Coefficient ofperformance (COP) of the refrigerator cycle withPCM and without PCM.

III. Overview of Phase Change Material (PCM)

PCMs latent heat storage can be achieved through solid–solid, solid–liquid, solid–gas and liquid–gas phase change.However, the only phase change used for PCMs is thesolid–liquid change.

Thermal Energy Storage through Phase Change materialhas been used for wide applications in the field of airconditioning and refrigeration especially at industrial scale.[6]

A *phase-change material (PCM)* is a substance with ahigh heat of fusion which, melting and solidifying at acertain temperature, is capable of storing and releasinglarge amounts of energy. [7]

Even though the thermal conductivity of phase changematerials (PCM) is usually not high, it is sufficient toenhance the global heat transfer conditions of an evaporatorwith air as external fluid and natural convection as heattransfer mechanism. [8]

IV. Vapor Compression Refrigeration Cycle (Without PCM)

The vapor-compression uses a circulating liquid refrigerantas the medium which absorbs and removes heat from thespace to be cooled and subsequently rejects that heatelsewhere. Figure depicts a typical, single-stage vaporcompressionsystem. All such systems have fourcomponents: a compressor, a condenser, a Thermalexpansion valve (also called a throttle valve or Tx Valve),and an evaporator. Circulating refrigerant enters thecompressor in the thermodynamic state known as asaturated vapor and is compressed to a higher pressure,resulting in a higher temperature as well. [9]

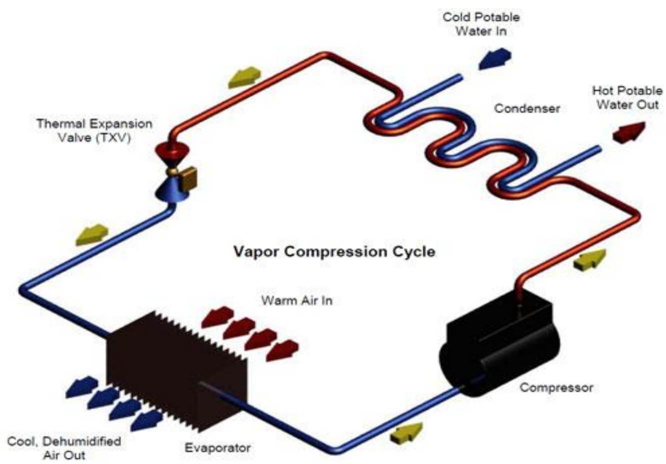

Figure 1 : Vapor compression refrigeration system

V. Using PCM as Latent Heat Storage System

In the conventional household refrigerator the compressorworks in ON/OFF mode. The refrigerant of the evaporatorcoil takes the cabinet coil takes the cabinet heat duringcompressor ON mode. If PCM is used in the cabinet then itwill take most of the heat by changing its phase from solidto liquid. The temperature is constant until the meltingprocess in finished. Moreover, if the PCM is touched withthe evaporator coil the stored heat energy of PCM will beextracted by the refrigerant through conduction methodduring compressor on mode. The conduction transfer isfaster than the natural convection heat transfer. In theconventional refrigerator the cabinet heat is extracted by therefrigerant through natural convection. So the PCM willimprove the heat transfer performance of the evaporatoralso.

A mathematical model of parallel plate's field with a phasechange material that absorbs heat from the flow of warmmoist air was developed and validated. In this study, effectsof the design and the operating condition on theperformance of the system are discussed only for themelting process and the interaction with the refrigerationsystem is not studied.[10]

VI. Working Mechanism of Vapor Compression Refrigeration with PCM

In the model with mechanism showing below the followingassumptions have been made:

a) The thermo physical properties of the materials areconstant with temperature.
b) The solidification/melting processes are slowenough to consider that heat transfer in the solidand liquid phase is in quasi steady-state.
c) The thermal resistance of the evaporator and thethermal contact resistance between the Evaporatorand the PCM are neglected.
d) Vapor compression cycle is considered to be in thesteady-state.

The liquid PCM passed through a coil or any path whichsurrounds the whole evaporator. The evaporator chamber iscovered with another box which has the passage or storagecavity for PCM. When the compressor On-state is on actionthe liquid PCM releases the heat and become solid and therefrigerant takes the heat. Evaporator and PCM box (tocover the evaporator and food cabinet) are shown in thefollowing figure.

Figure 2 : Step 1 Conventional Evaporator

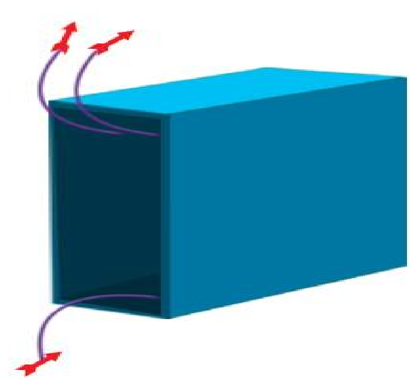

Figure 3 : Step 2 PCM box with PCM passage

When the compressor is in off-state the temperature rises inthe evaporator or food cabinet by placing new foods oropening the door of the refrigerator. When this heat rises inthermostat temperature the compressor starts again andconsumes electricity. In such condition the surroundedPCM takes the extra heat by convection from the foodcabinet keep it far from the thermostat temperature. Thiscertainly increases the off-state of the compressor thusreduces power consumption and increase compressor andcondenser life. Heat releases from the PCM to becomeSolid and covering food cabinet to consume heat in Off-stateare shown in the following figure.

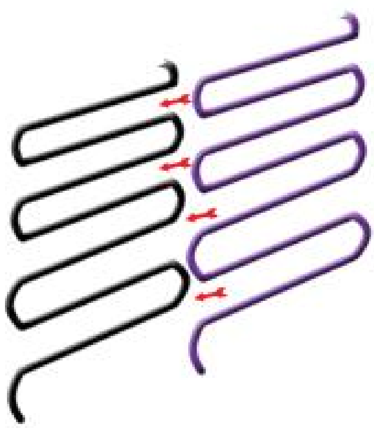

Figure 4 : Step 3 Heat releases from PCM (Compressor On)

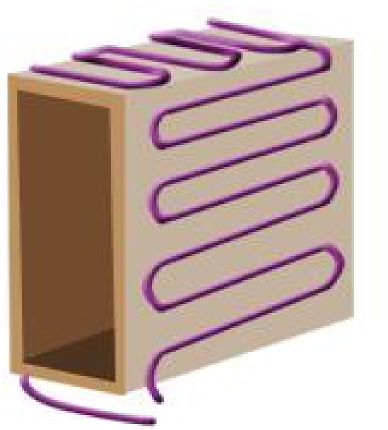

Figure 5 : Step 4 Heat taken from the food

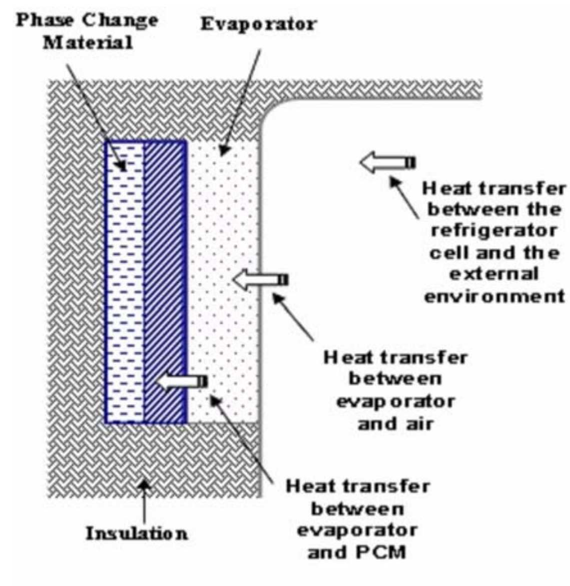

Figure 6 : Schematic Model of the refrigerator with PCM

VII. Data Collection and Result

The following data have been collected for each test run atthe steady state condition of the system.

- P_1= Compressor suction/Evaporator outletpressure(bar)
- P_3=Evaporator Inlet Pressure(bar)
- T_1= Compressor suction Temperature (˚C)
- T_2=Compressor discharge/condenser Inlet
- Temperature(˚C)
- T_3=Condenser Outlet Temperature(˚C)
- T_4=Evaporator Inlet Temperature(˚C)
- t=Time

Table 1 : Experimental Data without Phase Change Material (PCM)

Time Reading taken	Evaporator inlet Pressure P_1 bar	Condenser outlet Pressure P_3 bar	Compressor inlet Temp T_1 ° C	Compressor outlet Temp T_2 ° C	Condenser inlet Temp T_3° C	Condenser outlet Temp T_4° C
11.10 am	0.27	9	26	50	33	17
11.25 am	0.4	8.5	27	53	36	17
11.40 am	0.44	9	26	58	37	19
11.55 am	0.47	9.5	27	61	37	18
12.1 pm	0.51	10	27	65	39	21
12.25 pm	0.34	10.2	26	67	38	19
12.40 pm	0.44	10.2	22	72	41	18
12.55pm	0.44	10.2	22	72	39	18
1.10 pm	0.57	10.4	20	72	41	19
1.25 pm	0.57	10.6	20	72	42	19

Table 2 : Experimental Data with Phase Change Material

Time Reading taken	Evaporator inlet Pressure P_1 bar	Condenser outlet Pressure P_3 bar	Compressor inlet Temp T_1 ° C	Compressor outlet Temp T_2 ° C	Condenser inlet Temp T_3° C	Condenser outlet Temp T_4° C
10.00 am	0.44	11	30	56	48	22
10.15 am	0.61	11.5	31	59	49	23
10.30 am	0.68	12.4	33	63	53	25
10.45 am	0.78	12.8	34	65	58	27
11.00 am	0.98	14	35	68	59	30
11.15 am	1.02	15.5	35	70	57	32
11.30 am	1.02	15.5	35	73	58	33
11.45 am	1.02	15.5	35	75	62	33
12.00 Pm	1.09	16	34	77	62	32
12.15 pm	1.09	16	34	77	61	32

Table 3 : COP found in each test run without and with PhaseChange Material (PCM)

Number of observation	COP found in Vapor compression Refrigerator Without PCM	COP found in Vapor compression Refrigerator With PCM
1	6.12	9.85
2	5.55	9.42
3	6.12	9.45
4	5.5	9.04
5	5.13	9
6	6.78	9
7	5.1	9
8	5.11	8.91
9	5.02	8.82
10	5.02	8.91

a) Effect of PCM on Coefficient of Performance (COP)

- *At step 1*

$$COP_{WITHOUTPCM} = \frac{h1-h4}{h2-h1} \text{ [9] } = \frac{410-230}{445-410} = 5.78$$

$$COP_{WITHPCM} = \frac{h1-h4}{h2-h1} = \frac{435-232}{455-435} = 10.25$$

Percentage of COP improved for the use of Phase ChangeMaterial (PCM)

$$= \frac{10.25-5.78}{5.78} \times 100\% = 77.33\,\%$$

- *At step 2*

$$COP_{WITHOUTPCM} = \frac{h1-h4}{h2-h1} = \frac{420-220}{456-420} = 5.55$$

$$COP_{WITHPCM} = \frac{h1-h4}{h2-h1} = \frac{430-232}{451-430} = 9.42$$

Percentage of COP improved for the use of Phase ChangeMaterial (PCM)

$$= \frac{9.42-5.55}{5.55} \times 100\% = 69.7\%$$

- *At step 3*

$$COP_{WITHOUTPCM} = \frac{h1-h4}{h2-h1} = \frac{422-226}{454-422} = 6.12$$

$$COP_{WITHPCM} = \frac{h1-h4}{h2-h1} = \frac{433-232}{433-453} = 9.45$$

Percentage of COP improved for the use of Phase ChangeMaterial (PCM)

$$= \frac{9.45-6.12}{6.12} \times 100\% = 54.41\,\%$$

- *At step 4*

$$COP_{WITHOUTPCM} = \frac{h1-h4}{h2-h1} = \frac{425-218}{462-425} = 5.5$$

$$COP_{WITHPCM} = \frac{h1-h4}{h2-h1} = \frac{434-235}{456-434} = 9.04$$

Percentage of COP improved for the use of Phase ChangeMaterial (PCM)

$$= \frac{9.04-5.5}{5.5} \times 100\% = 64.36\,\%$$

- *At step 5*

$$COP_{WITHOUTPCM} = \frac{h1-h4}{h2-h1} = \frac{427-232}{465-427} = 5.13$$

$$COP_{WITHPCM} = \frac{h1-h4}{h2-h1} = \frac{434-236}{456-434} = 9.00$$

Percentage of COP improved for the use of Phase ChangeMaterial (PCM)

$$= \frac{9.00-5.13}{5.13} \times 100\% = 75.43\,\%$$

- *At step 6*

$$COP_{WITHOUT\ PCM} = \frac{h1-h4}{h2-h1} = \frac{420-226}{458-420} = 5.10$$

$$COP_{WITHPCM} = \frac{h1-h4}{h2-h1} = \frac{436-238}{458-436} = 9.00$$

Percentage of COP improved for the use of Phase ChangeMaterial (PCM)

$$= \frac{9.00-6.78}{6.78} \times 100\% = 19.5\,\%$$

- *At step 7*

$$COP_{WITHOUTPCM} = \frac{h1-h4}{h2-h1} = \frac{420-226}{458-420} = 5.10$$

$$COP_{WITHPCM} = \frac{h1-h4}{h2-h1} = \frac{438-240}{460-438} = 9.00$$

Percentage of COP improved for the use of Phase ChangeMaterial (PCM)

$$= \frac{9.00-5.10}{5.10} \times 100\% = 76.47\%$$

- *At step 8*

$$COP_{WITHOUTPCM} = \frac{h1-h4}{h2-h1} = \frac{427-232}{466-427} = 5.11$$

$$COP_{WITHPCM} = \frac{h1-h4}{h2-h1} = \frac{438-242}{460-438} = 8.91$$

Percentage of COP improved for the use of Phase ChangeMaterial (PCM)

$$= \frac{8.91-5.11}{5.11} \times 100\% = 74.36\,\%$$

- *At step 9*

$$COP_{WITHOUTPCM} = \frac{h1-h4}{h2-h1} = \frac{426-225}{466-426} = 5.02$$

$$COP_{WITHPCM} = \frac{h1-h4}{h2-h1} = \frac{438-244}{460-438} = 8.82$$

Percentage of COP improved for the use of Phase ChangeMaterial (PCM) $= \frac{8.82-5.02}{5.02} \times 100\% = 75.69\%$

- *At step 10*

$$COP_{WITHOUTPCM} = \frac{h1-h4}{h2-h1} = \frac{426-225}{466-426} = 5.02$$

$$COP_{WITH\ PCM} = \frac{h1-h4}{h2-h1} = \frac{442-246}{464-442} = 8.91$$

Percentage of COP improved for the use of Phase ChangeMaterial (PCM) $= \frac{8.91-5.02}{8.91} \times 100\% = 77.49\ \%$

VIII. Discussion

Experiments were carried out under certain thermal loadswith water as PCM. Here the effect PCM in certainquantities in this case 5 liters at certain thermal loads on theperformance parameter of house hold refrigerator. Thenumber of compressor on-off cycle within a certain periodof time for different PCMs and without PCM can bepointed up. Use of water as PCM imposes a great impact onCOP improvement at certain thermal loads. Using water asPCM and certain thermal load it is found that the 55-60%COP improvement has been achieved by the PCM inrespect without PCM in conventional refrigerator.

During the compressor running the refrigerant takes thechamber heat byfree convection in case of without PCM,which is slower heat transfer process in respect toconduction process. But PCM most of the heat in thecabinet is stored in the PCM during compressor runningtime. Since the conduction heat transfer process is fasterthan the free convection process the cooling coil
temperature does not require dropping very low to maintaindesired cabinet temperature. As result the evaporator worksat high temperature and pressure with PCM. Moreover, dueto high operating pressure and temperature of theevaporator the density of the refrigerant vapor increases, asa result the heat extracted from the evaporator by the fixedvolumetric rate compressor is higher than without PCM.

IX. Conclusion

Experiment tests have been carried out to investigate theperformance improvement of a household refrigerator usingtwo different phase change materials of different quantitiesat different loads. The following calculation have beendrawn-

a) In case of without PCM and with PCM the COP ishigher at low thermal load while it decreases withit decreases with the increase of thermal load.

b) Depending on the PCM and the thermal loadaround 55-60% COP improvement has beenachieved by the PCM in respect to without PCM.

c) Use of PCM decreases the fluctuation of thecabinet temperature. At higher load this effect isnot so significant.

References Références Referencias

1. "The Advent of Mechanical Refrigeration Alters DailyLife and National Economies Throughout the World –Science and Its Times: 1800-1899". Retrieved 2007-05-20.
2. http://en.wikipedia.org/wiki/Refrigerator
3. MARQUES, C., DAVIES, G., MAIDMENT, G.,EVANS, J. A. "application of phase change materials todomestic refrigerators." 9th International ConferenceonPhase-Change Materials and Slurries for Refrigerationand Air Conditioning, 2010.
4. http://www.brighthubengineering.com/hvac/66729-domestic- refrigerator-parts-and-their-working/
5. http://www.iolitec.de/en/Heat-Storage-Heat-Transport/phase-changing-materials.html
6. Tulapurkar, Chetan. "Phase change materials fordomestic refrigerators to improve food quality and prolongcompressor of time." International refrigeration and airconditioning conference. 2010.
7. http://en.wikipedia.org/wiki/Phase_change_material Azzouz, K. Leducq, D. Guilpart, J. Gobin, D."Improving the energy efficiency of a vapor compressionsystem using a phase change material" Second Conferenceon Phase Change Material & Slurry : Scientific Conference& Business Forum. 15 – 17 June 2005 Yverdon-les-Bains,Switzerland.
8. Perry, R.H. and Green, D.W. (1984). Perry's ChemicalEngineers' Handbook (6thEdition ed). McGraw Hill, Inc.
9. ISBN ISBN 0-07-049479-7. (see pages 12-27 through 12-38).
10. Simard A.P., Lacroix M., (2003), Study of thethermal behavior of a latent heat cold storage unit operatingunder frosting condition. Energy convers. Manag. 44, 1605-1624.

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Laminar Flow around an Array of 3D Protruding Heaters Mounted in Cross-Stream Direction

By Felipe Baptista Nishida & Thiago Antonini Alves
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Abstract- Numerical analysis was performed to investigate the characteristics of the laminar fluid flow around an array of 3D protruding heaters mounted on the bottom substrate of a parallel plane channel using the ANSYS/Fluent® 14.0 commercial software. The fluid flow was considered to have constant properties under steady state conditions. In the channel inlet, the velocity profile was uniform. This problem is associated with forced flow over the electronic components mounted on printed circuit boards. The conservation equations and their boundary conditions were numerically solved in a single domain through a coupled procedure. The discretization of the equations was based on the Control Volumes Method. The algorithm SIMPLE was used to solve the pressure-velocity couple. Due to the non-linearity of the momentum equation, the correction of the velocity components and the pressure were under-relaxed to prevent instability and divergence. After a study of the computational mesh independence, the numerical results were obtained, displayed as a 3D non-uniform mesh with 212,670 control volumes. This computational mesh was more concentrated near the solid-fluid interface regions due to the larger primitive variable gradients in these regions. An investigation was done on the effects of the Reynolds numbers where the Reynolds numbers ranged from 100 to 300 and was dependent on the heights of the protruding heaters. The main characteristics of the fluid flow consisted of a small recirculation upstream of the heaters, the formation of horseshoe vortices around the protruding heaters' side walls and a large recirculation region downstream of the heaters.

Keywords: laminar flow, 3D protruding heaters, streamlines, recirculation, horseshoe vortices.

GJRE-A Classification : FOR Code: 091399p

LAMINARFLOWAROUNDANARRAYOF3DPROTRUDINGHEATERSMOUNTEDINCROSSSTREAMDIRECTION

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Felipe Baptista Nishida [α] & Thiago Antonini Alves [σ]

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Keywords: laminar flow, 3D protruding heaters, streamlines, recirculation, horseshoe vortices.

I. Introduction

The search for improvements and technological innovations by means of industrial development and academic research on the cooling of electronic equipment in the last two decades has been very intense. The most common method of heat transfer in source elements is still convection cooling, utilizing air as the work fluid. This choice was made because air is easily available, the devices required to move it are normally low cost, and it is 100% non-polluting (Nishida, 2012). In this work, problems motivated by the Level 2 of electronic packaging, associated with the thermal control of one row of 3D protruding heaters mounted on a printed circuit board (PCB) were considered, as shown in Fig. 1 (Alves, 2010). The available space for the heaters can be limited and the cooling process must be done through forced convection with moderate velocities (low *Reynolds* number) due to operational limitations and noise reduction. Under such conditions, there may not be enough space to work with heat sinks in these concentrate heat dissipation components. These components can be simulated by protruding blocks mounted on a parallel plate channel.

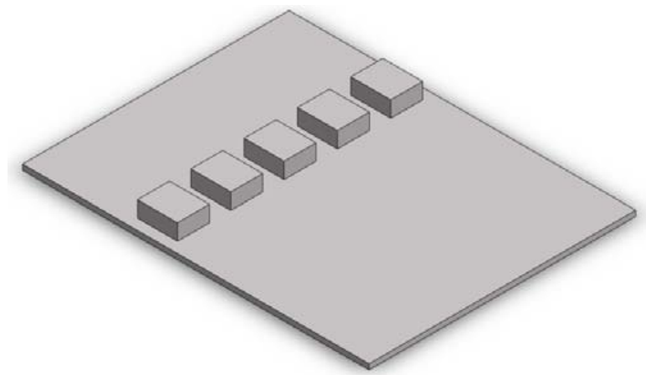

Figure 1 : Configuration of one row of 3D protruding heaters mounted on a PCB

Hwang & Yang (2004) presented a numerical study of the vortices structures of the flow (in a range of *Reynolds* numbers from low to moderate) around a cubic obstacle mounted on a plate in a channel. The main characteristics of the flow were horseshoe vortices upstream the obstacle, side vortices around the side faces of the cube, and "hair pin" vortices near the wake region. It was observed that as the flow approached the cube, an adverse pressure gradient produced a separate 3D boundary layer, allowing laminar horseshoe vortices to form. It was also noticed that as the *Reynolds* number increased, the structure of the horseshoe system became more complex and the number of vortices increased in pairs. Van Dijk& De Lange (2007) conducted a numerical study of a flow over one cubic obstacle mounted on the base of a parallel plate channel, considering either compressible or incompressible laminar flow. The *Reynolds* number was investigated in a range from 50 to 250, and the *Mach* number was varied between 0.1 and 0.6. The main flow characteristics around the obstacle were the formation of horseshoe vortices, vortices developing on the side

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walls of the obstacle, and, downstream of the obstacle there was a wake with two counter-rotating vortices. It was noticed that the shape and size of these flow characteristics are determined mainly by the Reynolds number, verifying that for greater *Reynolds* numbers, the horseshoe vortices as well as the wake region extended over a significantly broader area. The correlation between the separation and reattachment point position with the *Reynolds* number was also presented. Other studies relating to the flow around 3D protruding heater(s) were performed by Castro & Robins (1977), Tropea&Gacktatter (1985), Martinuzzi&Tropea (1993), Okamotoet *al.* (1997).

II. Analysis

The basic configuration representing the treated problem for one of the 3D protruding heaters is indicated in Fig. 2. In this case, the channel has a height, H, length, L, and width, W. The substrate has the same length and width as the channel with a thickness, t. The heater has a length, L_h, height, H_h, width, W_h and it is located at a distance, L_u, from the channel entry. The space between the heaters is $2Ws$. The cooling process occurred through a forced laminar flow with constant properties under steady state conditions. In the channel entrance, the flow velocity profile (u_0) was considered uniform.

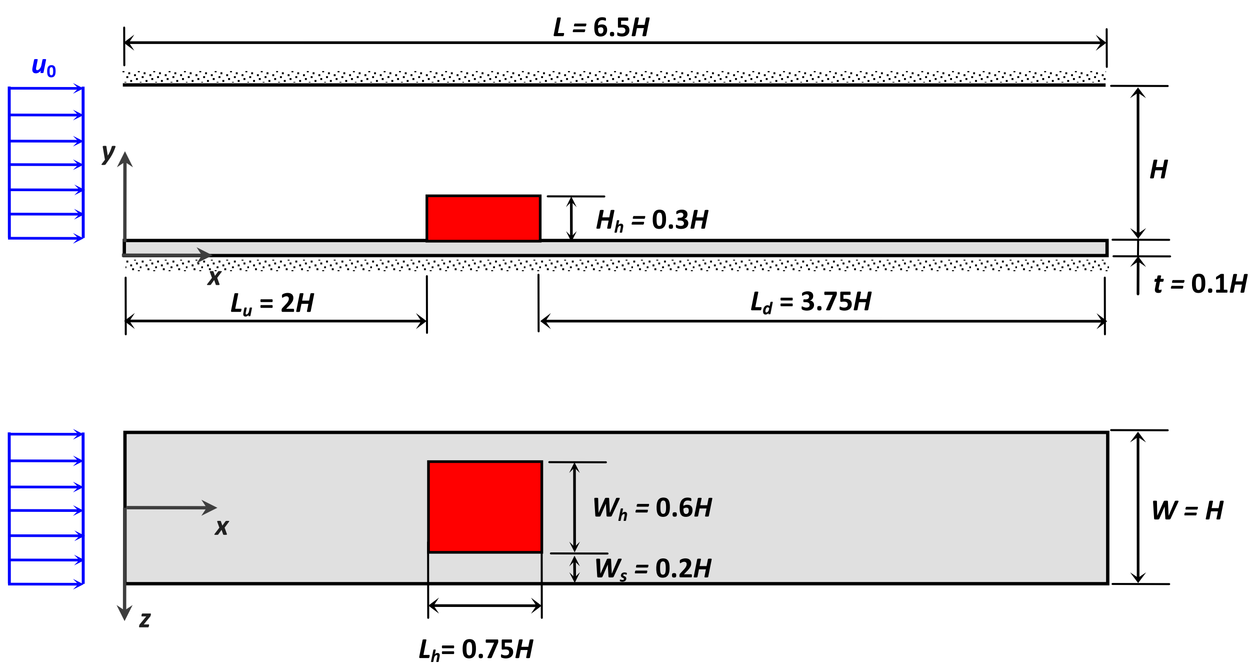


Figure 2 : Basic configuration representing the problem for one of the 3D protruding heaters

a) *Problem Formulation*

The mathematical model of the present problem was performed for a single domain: the solid regions (protruding heater and substrate) and the fluid flow in the channel. Due to the problem symmetries, the conservation equations were formulated for the domain with length, L, width, $W/2$ and height, $(H + t)$, as Fig. 3 shows.

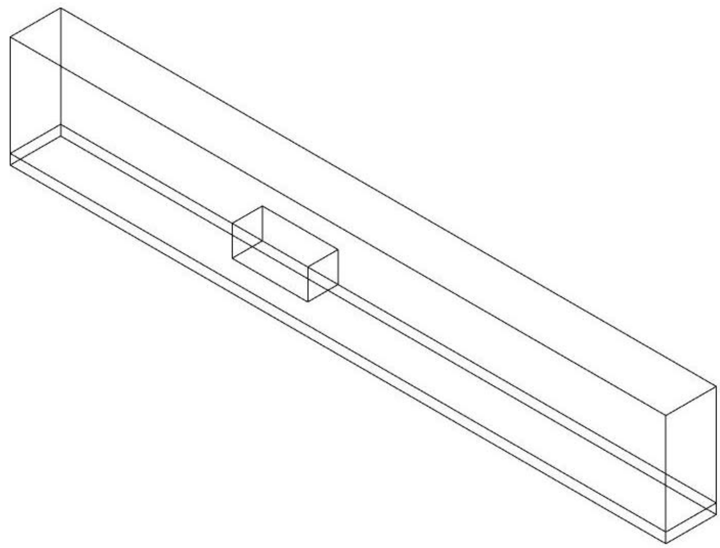


Figure 3 : Domain of the mathematical model analyzed

The governing equations cover the conservation principles in the considered domain. Steady state conditions, constant properties and negligible viscous dissipation were assumed. The occasional effects of oscillation in the flow are not being considered in this modeling: a typical procedure adopted in similar problems, i.e. Alves&Altemani (2012), Zeng &Vafai (2009) e Davalath&Bayazitoglu (1987).

- Mass Conservation *(Continuity Equation)*

$$\nabla \cdot \boldsymbol{u} = 0 \qquad (1)$$

- Momentum Conservation (Navier-Stokes Equation)

$$\rho(\boldsymbol{u} \cdot \nabla)\boldsymbol{u} = -\nabla p + \mu \nabla^2 \boldsymbol{u} \qquad (2)$$

The boundary conditions of the flow were uniform velocity (u_0) at the channel inlet, and null velocity at the solid-fluid interfaces (no-slip condition). At the channel outlet, the flow had its diffusion neglected in the *x* direction. In the solution domain at the lateral boundaries, the symmetry condition (periodic condition) was applied for the velocity fields (same geometry in each of the 3D protruding heater).

b) Fluidynamic Parameters of Interest

The solution of the governing equations output the velocity and pressure distributions in the considered domain. The numerical solutions of the primary variables distribution (u, v, w, p) were utilized to define the derived quantities. The *Reynolds* number in the channel was based on the protruding heater height (H_h) and calculated as

$$Re = \frac{\rho u_0 H_h}{\mu} = \frac{u_0 H_h}{\upsilon}. \qquad (3)$$

The local skin friction coefficient, $C_f(\xi)$, can be written as

$$C_f(\xi) = \frac{\tau_p(\xi)}{\left(\frac{\rho u_0^2}{2}\right)}. \qquad (4)$$

$\tau_p(\xi)$ is the local sheer stress in a surface of the heater.

The mean friction coefficient, $\bar{C}_f$, can be written as

$$\bar{C}_f = \frac{\bar{\tau}_p}{\left(\frac{\rho u_0^2}{2}\right)}. \qquad (5)$$

$\bar{\tau}_p$ iis the mean shear stress at the heater surfaces.

The *Darcy-Weisbach* (or *Moody*) friction factor can be defined in terms of the total pressure drop in the channel (Δp) by the equation

$$f = \frac{\Delta p\, H}{\left(\frac{\rho u_0^2}{2}\right)} \qquad (6)$$

c) Numerical Solution

The governing equations and their boundary conditions were numerically solved utilizing the Control Volume Method (Patankar, 1980) through the commercial software *ANSYS/Fluent*®14.0. The algorithm *SIMPLE* (*Semi-Implicit Method for Pressure Linked Equations*) was used to treat the pressure-velocity couple. The boundary conditions were applied at the edges of the analyzed domain (Fig. 3). After a mesh independency study, the numerical results were obtained with a non-uniform 3D mesh containing 212,670 control volumes. This mesh was more concentrated in the regions near the solid-fluid interfaces due to the larger gradients in the primitive variables of these regions, as shown in Fig. 4. Due to the non-linearity in the *Momentum* Equation, the velocity components and the pressure correction were under-relaxed to prevent instability and divergence. The stop criteria of the iterative solving process was established for absolute changes in the primitive variables smaller than four significant figures between two consecutive iterations, while the global mass conservation in the domain was satisfied in all of the iterations. The numerical solutions were processed in a microcomputer with an *Intel*®*Core*™ 2 *Duo* E7500 2,94GHz processor and 4GB of RAM. The processing time of a typical solution was approximately 10 minutes.

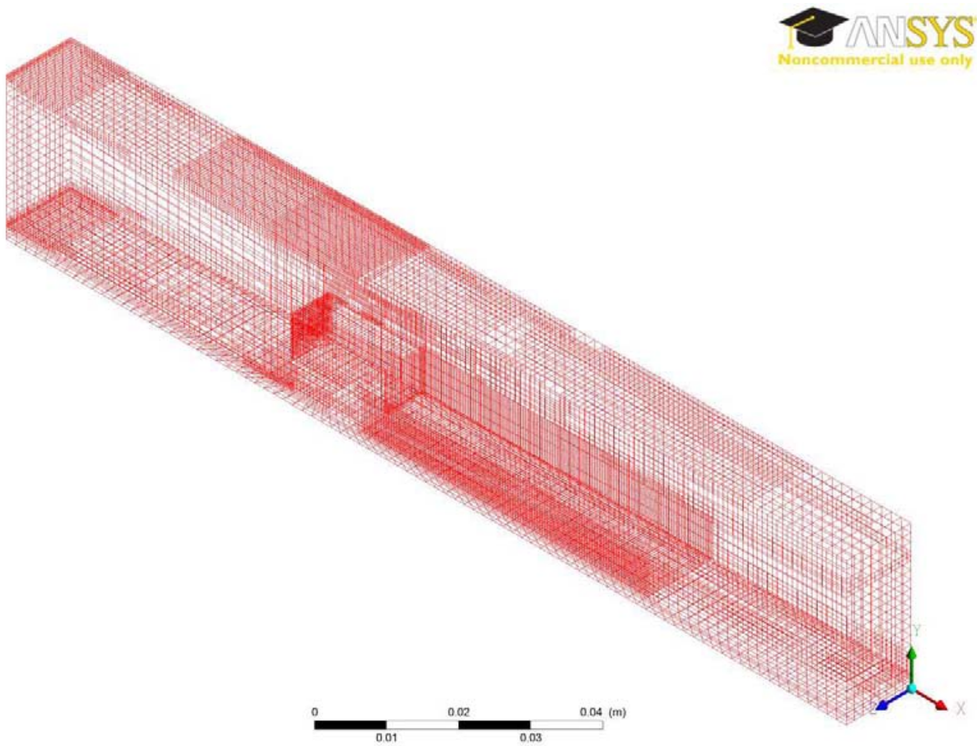
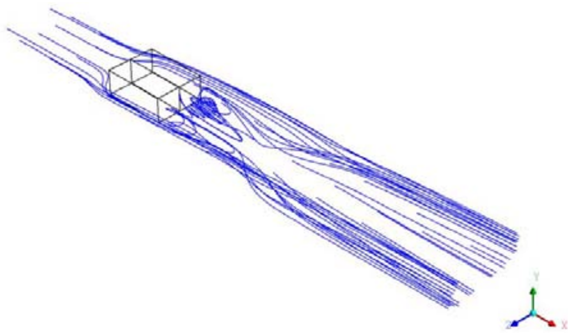


Figure 4: 3D non-uniform mesh (3D perspective view)

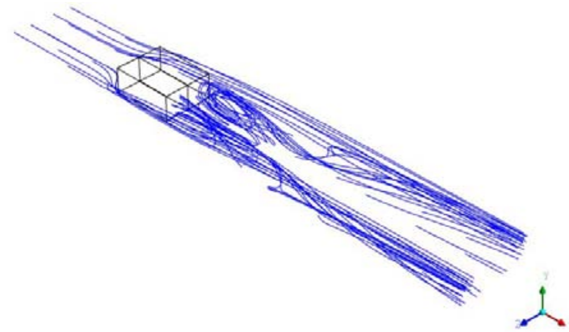
III. Results and Discussion

Typical geometry and property values, relevant to the electronic components mounted on printed circuit board cooling applications, were used to obtain the numerical results (BAR-COHEN *et al.*, 2003). The geometric configuration showed in Fig. 2, were assumed considering a space H = 0.0254m between the parallel plates. Air was considered the cooling fluid. The fluid properties were considered constant, obtained at 300 K (INCROPERA *et al.*, 2008). The effects of the *Reynolds* numbers Re = 100, 150, 200, 250, and 300 were investigated. According to Morris &Garimella (1996), the flow is laminar for this range of Re.

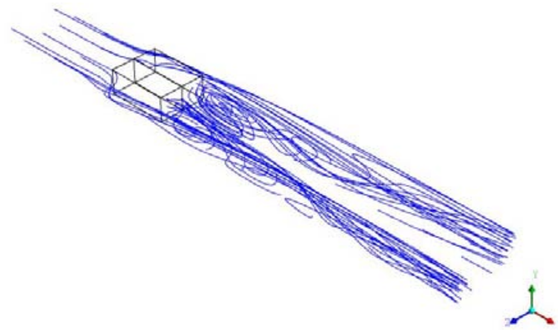
In Figure 5, the streamlines over a 3D protruding heater, in a perspective view, are presented for *Reynolds* numbers of 100, 200, and 300. The main characteristics of the laminar flow are the horseshoe vortices which start upstream the heater and develop around the heater's lateral surfaces; a small recirculation upstream the protruding heater; the detachment of the fluid's boundary layer at the top of the heater causing a recirculation (reverse flux); and a large recirculation region downstream the heater due to the flow reattachment. It is interesting to state that the fluid flow development around the 3D protruding heaters' lateral surfaces does not freely happen due to the small space between the heaters.



(a) Re = 100



(b) Re = 200

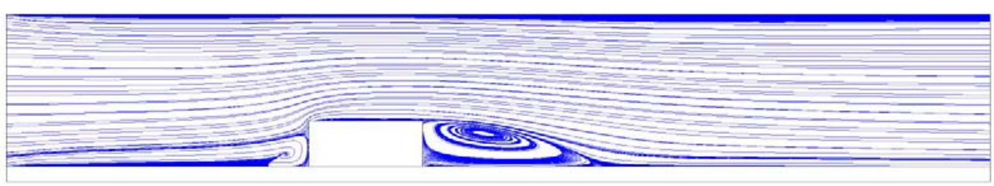


(c) Re = 300

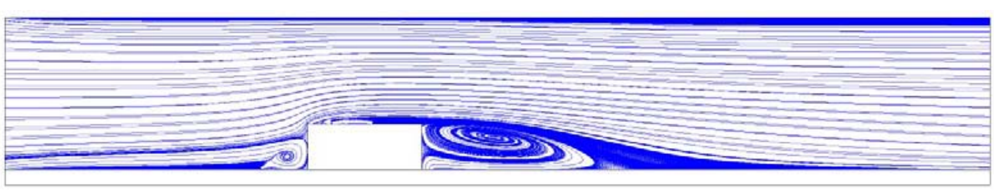
Figure 5 : Streamlines over a protruding heater (perspective 3D view)

In Figures 6, 7, and 8, streamlines are presented for the planes *xy*, *xz* e *yz*, respectively, for different *Reynolds* numbers. The characteristics of the flow over a 3D protruding heater can be better observed.

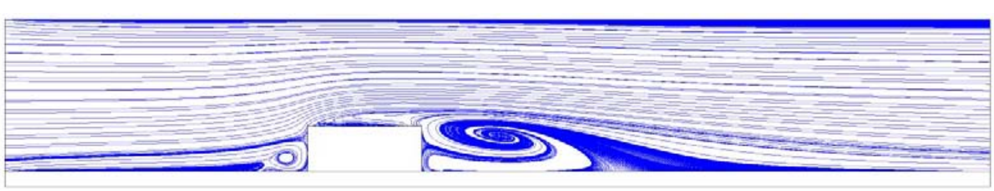
In Figure 6, as earlier mentioned, it can be observed a small recirculation upstream the heater, a detachment of the fluid boundary layer at the top of the heater making a recirculation (reverse flux), and a large recirculation downstream the heater due to the flow reattachment.



(a) Re = 100



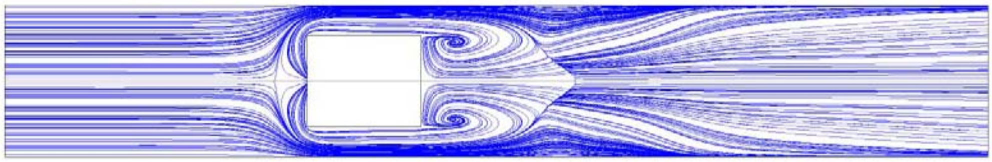
(b) Re = 200



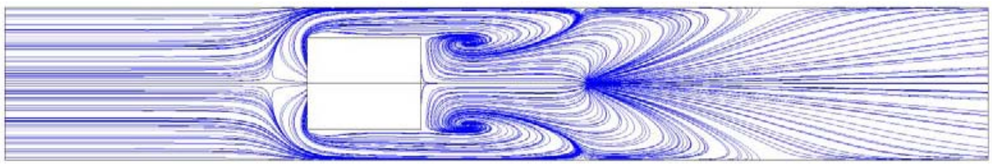
(c) Re = 300

Figure 6 : Streamlines over a protruding heater on the plane xy for z = 0

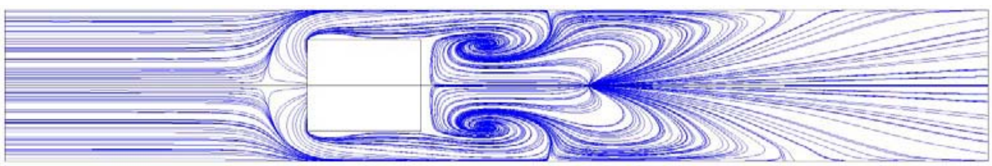
In Figure 7, it is observed that the behavior of the streamlines downstream the recirculation region of a protruding heater becomes more complex when the *Reynolds* number is increased. It is also noticed that the recirculation length increases with the *Re*, in other words, the reattachment point of the fluid boundary layer gets further downstream the heater. It is emphasized that the fluid flow development around the 3D protruding heaters' lateral surfaces does not freely happen due to the small space between the heaters.



(a) Re = 100



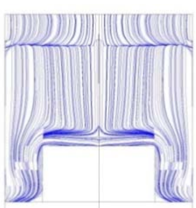
(b) Re = 200



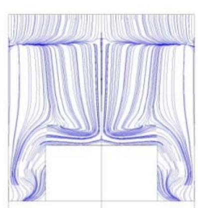
(c) Re = 300

Figure 7 : Streamlines over a protruding heater on the plane xz for y = 0,16H

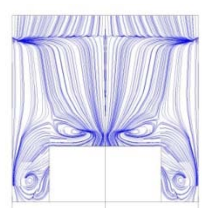
In Figure 8, it is seen that the laminar flow complexity over the protruding heater is greater with a larger *Reynolds* number.



(a) Re = 100



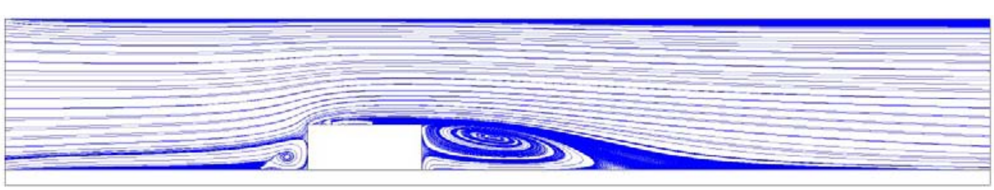
(a) Re = 200



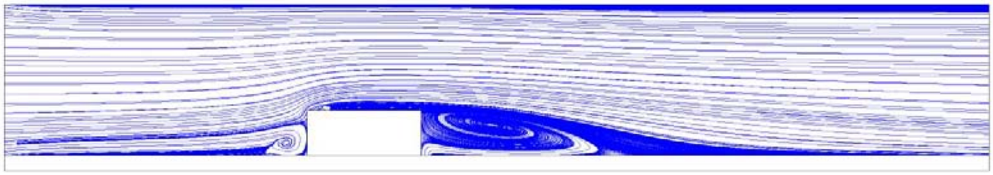
(a) Re = 300

Figure 8 : Streamlines over a protruding heater on the plane ***yz*** **for** ***x***= 2,375*H*

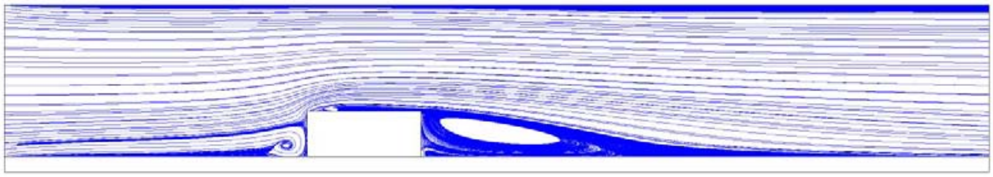
In Figure 9, the laminar flow streamlines around a 3D protruding heater are presented in the plane xy for different positions of z considering Re = 200.



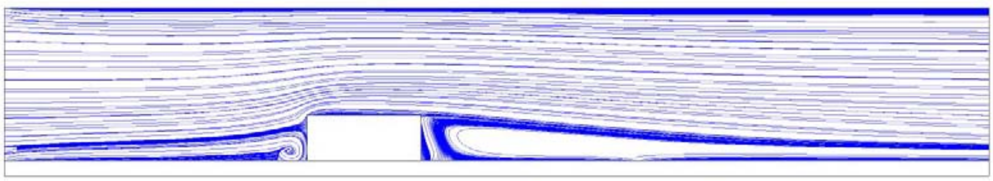
(a) z = 0



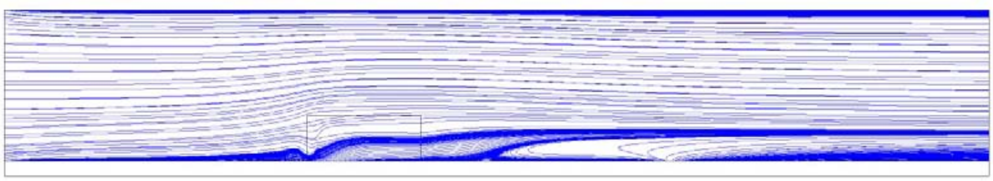
(b) z = 0,08H



(c) z = 0,16H



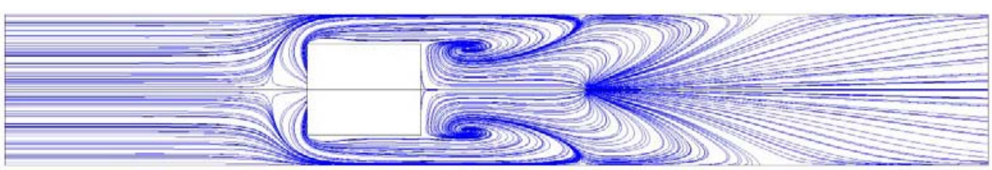
(d) z = 0,24H



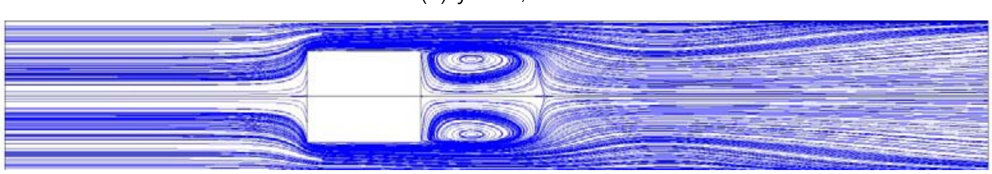
(e) z = 0,32H

Figure 9 : Streamlines over a protruding heater on the plane ***xy*** considering *Re* = 200

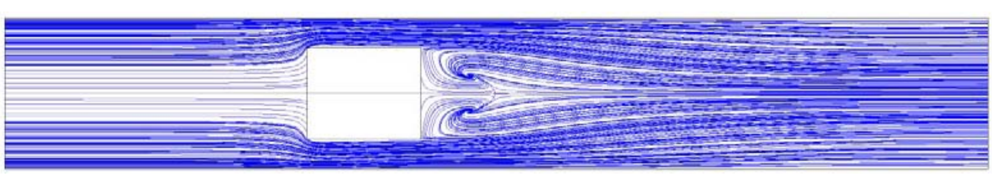
In Figure 10, the laminar flow streamlines around a 3D protruding heater are presented in a plane *xz* for different positions of *y*, considering *Re* = 200.



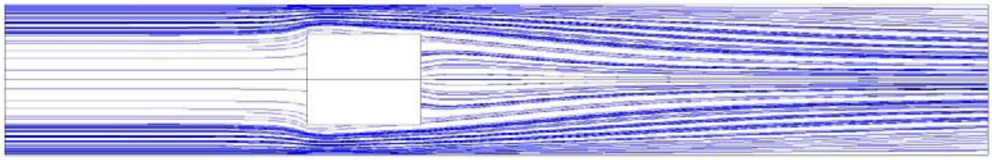
(a) y = 0,16H



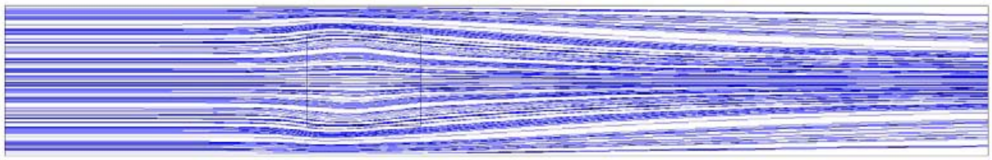
(b) y = 0,24H



(c) y = 0,32H



(d) y = 0,40H



(e) y = 0,44H

Figure 10 : Streamlines over a protruding heater on the plane *xz* considering *Re* = 200

The recirculation length (L_{rec}) downstream the protruding heater, or the distance between the base of the heater's rear surface and the reattachment point of the fluid's boundary layer, is presented in function of *Reynolds* in Tab. 1. The same results are shown in Fig. 11, where it is observed that the recirculation length varies linearly with *Re*. A correlation with deviations smaller than 0.35% is presented in Eq. (7). From all presented results, the greatest length (L_{rec}) was approximately 2.75*H*, ensuring that the recirculation is always in the studied domain.

Table 1 : Length Lrec of the recirculation downstream the protruding heater

Re	L_{rec}/H
100	1.19
150	1.60
200	2.00
250	2.43
300	2.84

$$\left(L_{rec}/H\right) = 0.0083\,Re + 0.3602\,, \qquad (7)$$

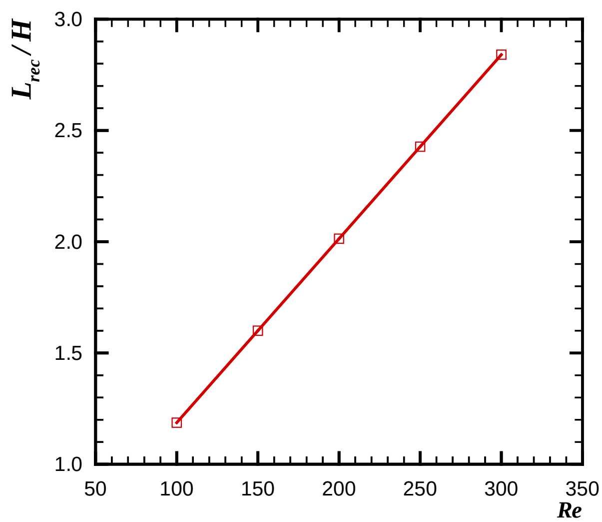
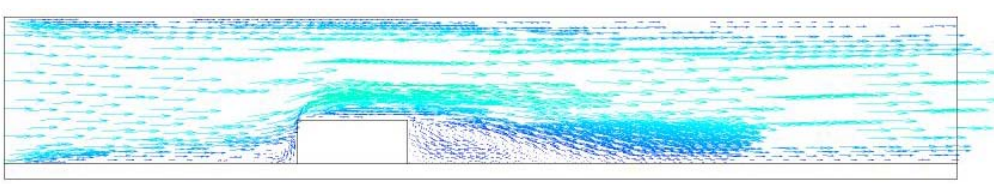
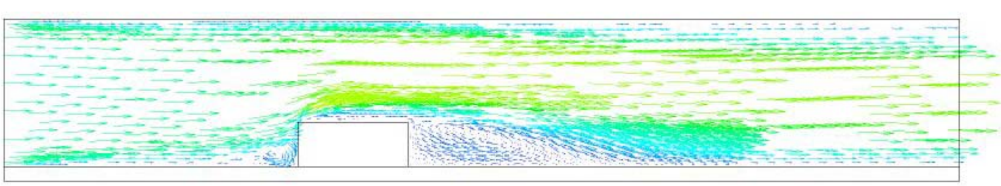


Figure 11 : Length L_{rec} of the recirculation downstream the protruding heater

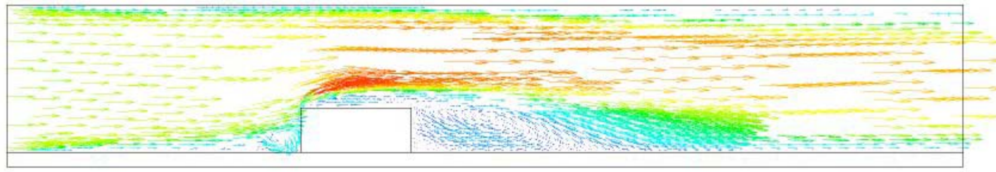
In Figures 12, 13, and 14 the air laminar flow velocity profiles are presented for the planes *xy*, *xz* e *yz*, respectively. The same fluid dynamic behavior is observed when compared with Figs. 6, 7, and 8.



(a) Re = 100



(b) Re = 200



(c) Re = 300

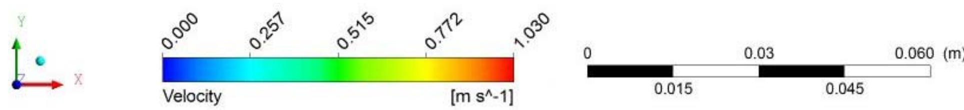
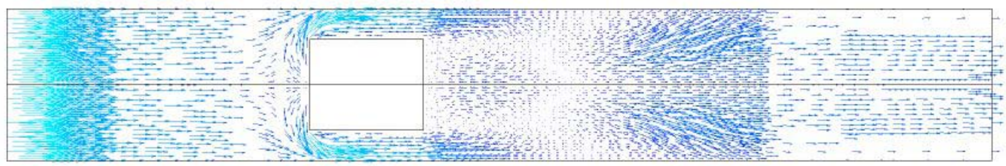
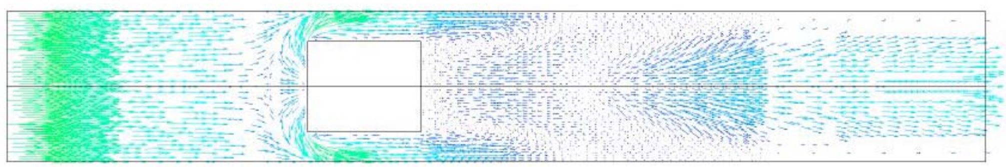


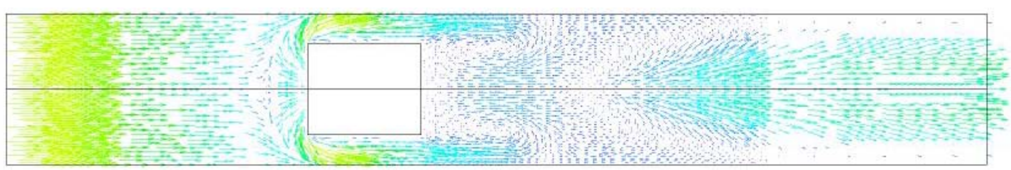
Figure 12 : Air velocity profile over a protruding heater on the plane xy for z = 0



(a) Re = 100



(b) Re = 200



(c) Re = 300

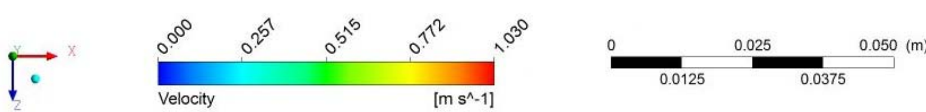
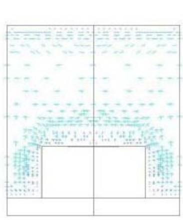
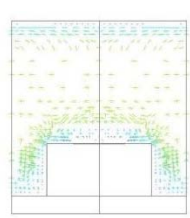


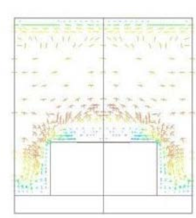
Figure 13 : Air velocity profile over a protruding heater on the plane ***xz* for *y*** = 0,16*H*



(a) Re = 100



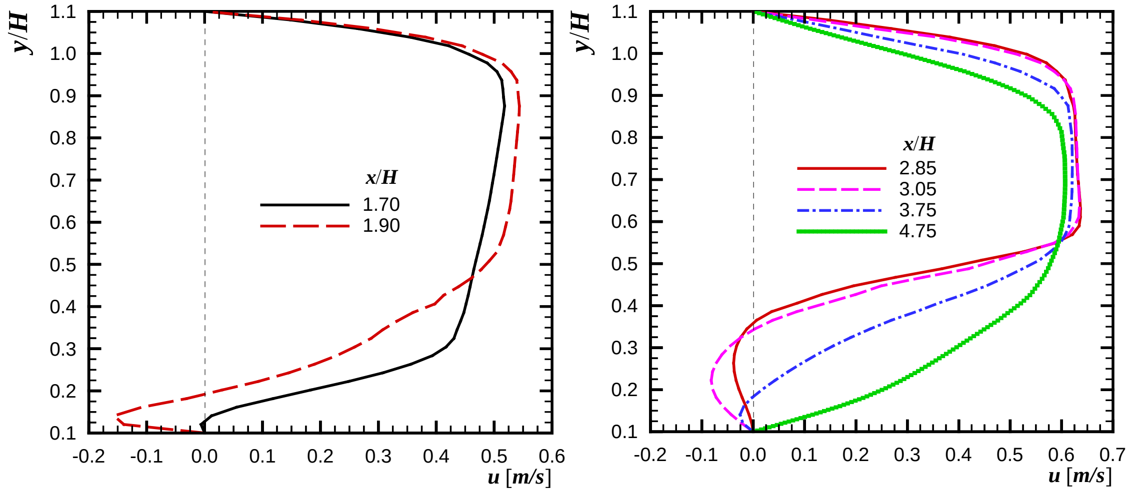
(a) Re = 200



(a) Re = 300

Figure 14 : Air velocity profile over a protruding heater on the plane ***xz* for *y***= 2,375*H*

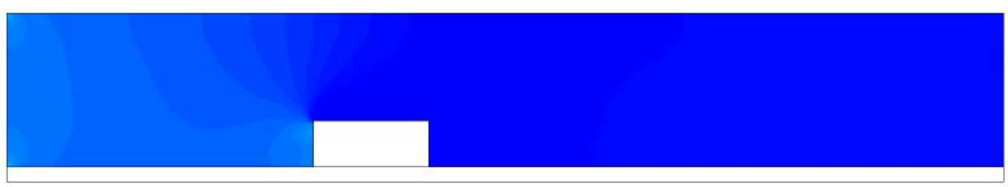
The air velocity profiles along the *y* direction of two positions upstream the heater and four positions downstream the heater are shown in Figs. 15(a) e 15(b), respectively, considering *Re* = 200. The recirculations' behavior can be better observed from the *x* direction velocity component values. A negative velocity value (*u*) represents a reverse flux in relation to the main flow.



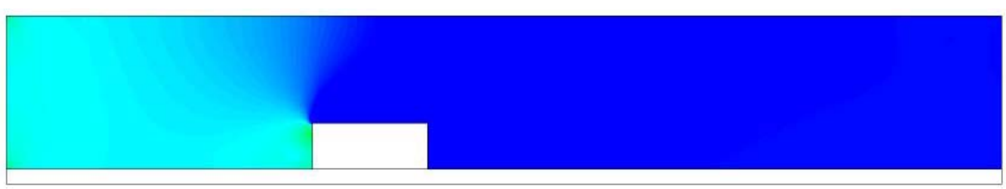
(a) Region upstream the heater (b) Region downstream the heater

Figure 15 : Air velocity profile along the y direction for different positions for *Re* = 200

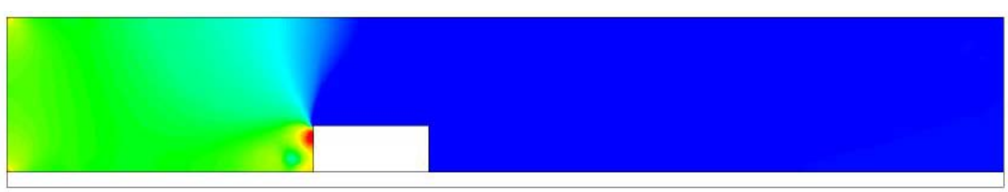
In Figures 16, 17, and 18 are presented pressure distributions of the air laminar flow for the planes *xy*, *xz* e *yz*, respectively. As expected, the region upstream the protruding heater has a greater pressure than the downstream region. Independently of the *Reynolds*number, the largest pressures found are around the 3D heater's front surface due to the stagnation point. Furthermore, the larger the *Re*, the larger the pressure gradients are close to the stagnation.



(a) Re = 100



(b) Re = 200



(c) Re = 300

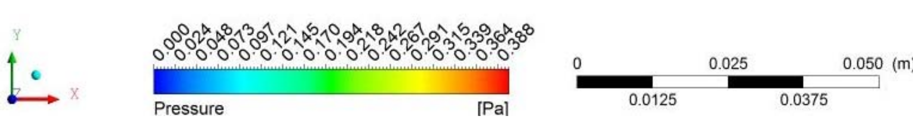
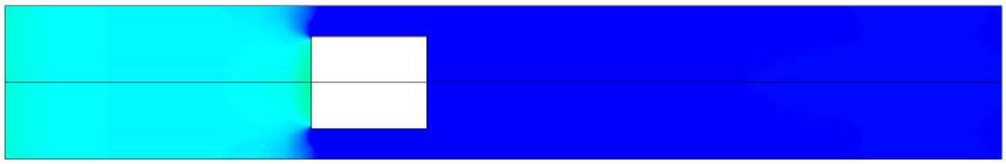
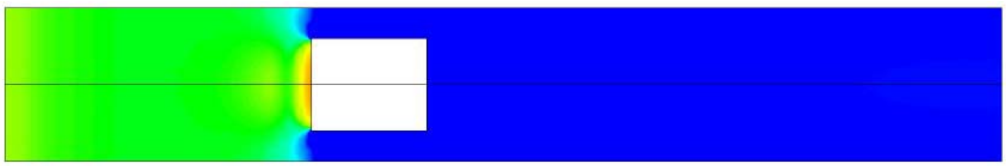


Figure 16 : Air pressure distribution map on the *xy*plane for*z* = 0

(a) Re = 100



(b) Re = 200



(c) Re = 300

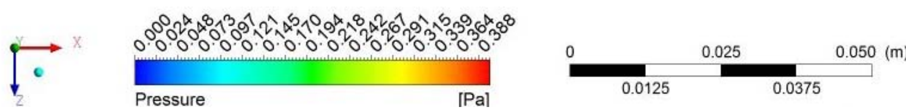
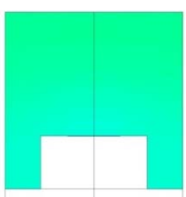
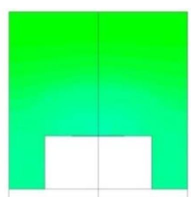


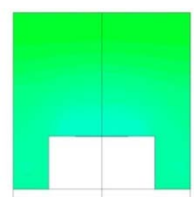
Figure 17 : Air pressure distribution map on the ***xy***plane for***z*** = 0,16H



(a) Re = 100



(a) Re = 200



(a) Re = 300

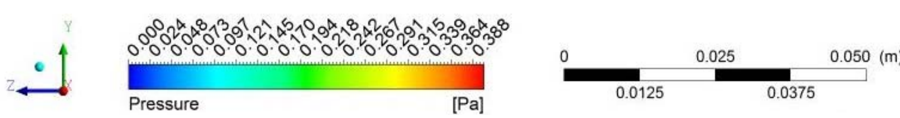
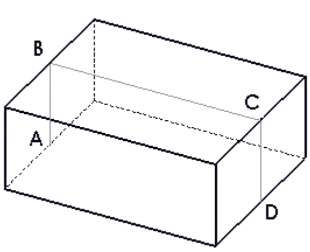
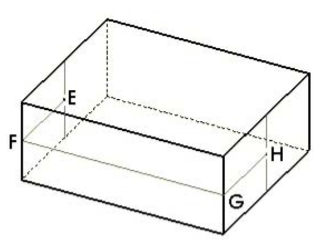


Figure 18 : Air pressure distribution map on the ***xy***plane for***z*** = 2,375H

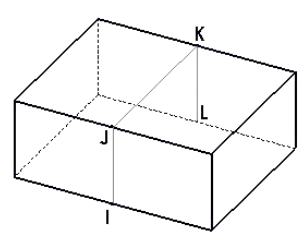
In order to assist the identification of the lines of interest on the different faces of the 3D protruding heater, notation presented in Fig. 19 is used in this work.



(a) line ABCD



(b) line EFGH



(c) line IJKL

Figure 19 : Identification of the lines of interest on the faces of a 3D protruding heater

Figure 20 shows the local skin friction coefficient distribution along the central line of the channel's superior wall (x; 1,1H; 0) in function of the *Reynolds* number. The behavior of $C_{f,x}$ in function of x can be observed. It is noticed that $C_{f,x}$ dramatically falls in the parallel plate channel's inlet, it lightly increases in the region close to the protruding heater, decreases in the region downstream the heater, and remains constant after approximately x = 4,5H for all *Reynolds* values.

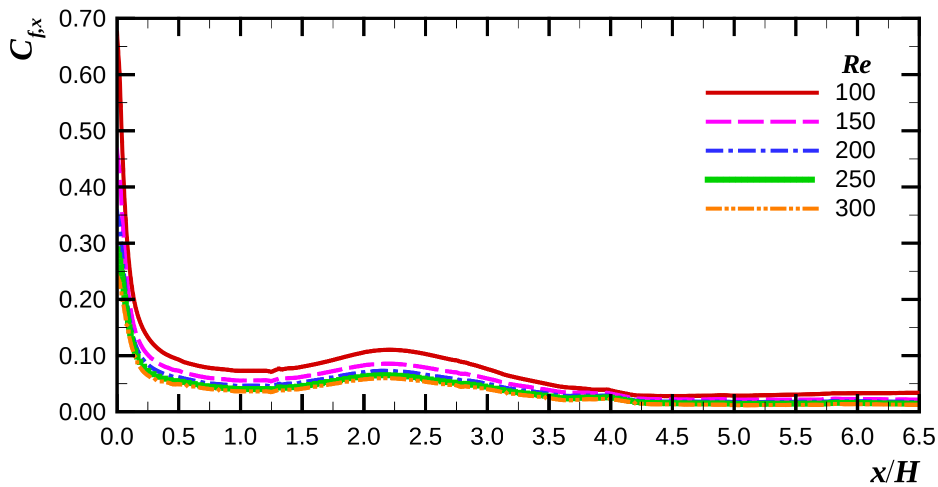


Figure 20 : Local skin friction coefficient distribution along the central line of the channel's superior wall

Figure 21 presents the local skin friction coefficient distribution along the length of the central line of the channel's bottom wall in a region upstream the 3D protruding heater (1,2H ≤ x ≤ 2,0H; 0,1H; 0) in function of *Reynolds*. From the behavior of $C_{f,x}$ in function of x for lower *Re* numbers, such as, *Re* = 100 and 150, it appears that only one horseshoe vortices is formed, however two horseshoe vortices are formed for higher *Reynolds* numbers, *Re* = 200, 250, and 300.

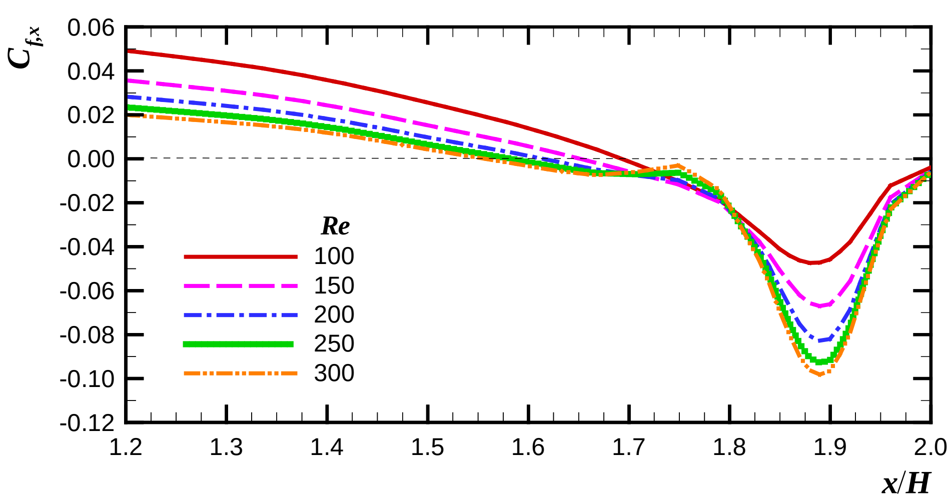


Figure 21 : Local skin friction coefficient distribution along the central line of the channel's bottom wall, in a region upstream the protruding heater

Figures 22(a), 22(b) e 22(c) ilustrate the variations of the friction coefficient along the lines ABCD, EFGH e IJKL, respectively, on the 3D protruding heaters' surfaces. It is observed that in Figure 22(a) on the front surface of the heater, $C_{f,y}$ is negative, showing that there is a flow from the central region (stagnation point) to the side of the protruding heater. On the superior (top) surface of the heater, there is a region of negative values of $C_{f,x}$, except for *Re* = 100, representing the fluid's boundary layer separation, and the region of flow recirculation (reverse flux) in the clockwise direction. On the rear surface of the heater, $C_{f,y}$ is positive, indicating that the recirculation downstream the protruding heater occurs in the clockwise direction. The laminar flow characteristics along the lines EFGH e IJKL on the surfaces of a 3D protruding heater can be explained in a similar way trough the analysis of Figs. 22(b) e 22(c), respectively.

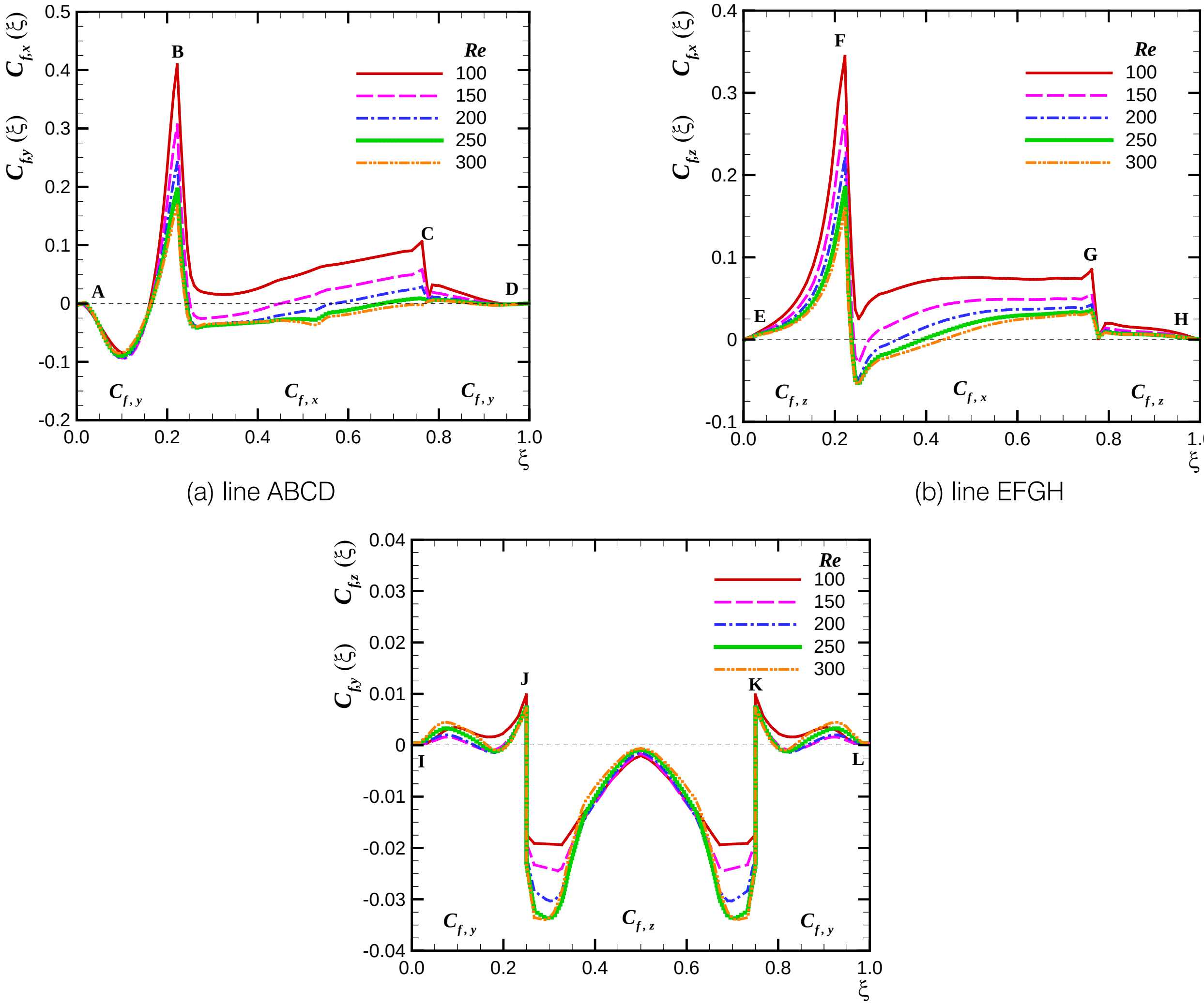


Figure 22 : Local skin friction coefficient distribution

The results for the *Darcy-Weisbach*(or *Moody*) friction factor and the mean friction coefficient can be correlated with deviations smaller than 1.5% using

$$\bar{C}_f = 0{,}051\,Re^{-0{,}359}, \quad (8)$$

$$f = 0{,}204\,Re^{-0{,}359}. \quad (9)$$

Figures 23 and 24 illustrate the behavior of the mean friction coefficient and the *Darcy-Weisbach*(or *Moody*) friction factor, respectively, in function of the *Reynolds* number. As expected, these fluid-dynamic parameters decrease with the increasing *Re*.

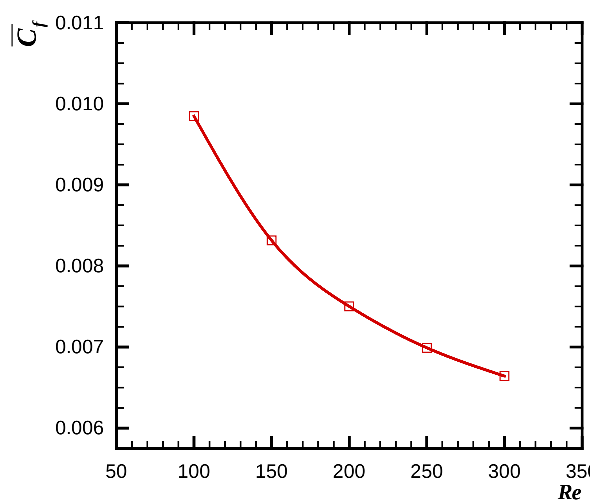


Figure 23 : Mean friction coefficient in function of the *Reynolds* number

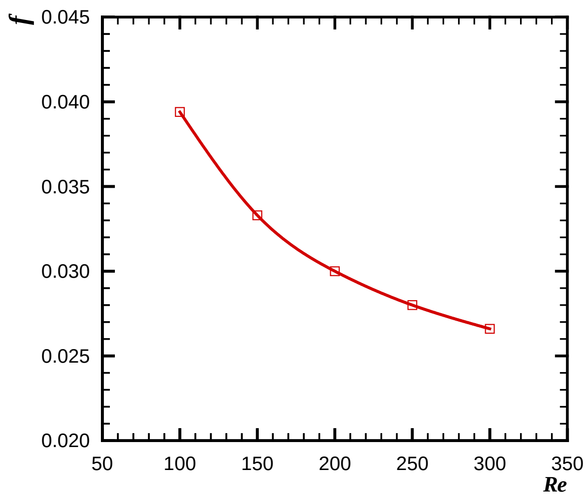


Figure 24 : *Darcy-Weisbach* (*or Moody*) friction factor in function of the Reynolds number

IV. Conclusions

In this work, a numerical analysis of the laminar flow around an array of 3D protruding heaters mounted on the bottom wall (substrate) of a parallel plate channel was made utilizing the commercial software *ANSYS/Fluent*® 14.0. Air was considered as the cooling fluid. The cooling process occurred through a forced laminar flow with constant properties under steady state conditions. At the channel's inlet, the velocity profile of the flow was uniform. The conservation equations and the respective boundary conditions were numerically solved in a single domain that incorporated the regions of solid and fluid, through a coupled procedure utilizing the Control Volume Method. The occasional effects of oscillation in the flow were not considered. Due to the problem symmetries, the basic configuration of the problem was reduced to the one in Fig. 2 and the solution domain utilized was showed in Fig. 3. Typical geometry and property values, relevant to the electronic components mounted on printed circuit board cooling applications, were used to obtain the numerical results. The geometric configuration showed in Fig. 2, were assumed considering a space H = 0.0254m between the parallel plates. The effects of the *Reynolds* number, based on the protruding heaters height, were inspected for Re = 100, 150, 200, 250, and 300. The flow in the channel was always laminar for the range of Re investigated.

The behavior of the laminar flow over the 3D protruding heaters mounted in cross-stream direction was showed through the streamlines. The streamlines over a 3D protruding heater were presented for *Reynolds* numbers of 100, 200, and 300. The main characteristics of the laminar flow were the horseshoe vortices which start upstream the heater and develop around the heater's lateral surfaces; a small recirculation upstream the protruding heater; the fluid's boundary layer detachment at the top of the heater causing a recirculation (reverse flux); and a large recirculation region downstream the heater due to the flow reattachment. The recirculation length (L_{rec}) downstream the protruding heater varies linearly with Re. The velocity magtintudes, the recirculation directions and the pressure distributions at the different regions of the air laminar flow, were presented for the planes *xy*, *xz* e *yz*. The local skin friction distribution on the walls of the parallel plate channel and on the 3D protruding heater surfaces, were also showed.

It is interesting to state that the fluid flow development around the 3D protruding heaters lateral surfaces does not freely happen due to the small space between the heaters. The fluid-dynamic symmetry conditions of the blocks were dominant and the corresponding flow was different than a single 3D protruding heater with free domain in the cross-stream direction to the flow.

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The authors recognize the Universidade Tecnológica Federal do Paraná – UTFPR/Campus Ponta Grossa.

References Références Referencias

1. J.Y. Hwang & K.S. Yang, "Numerical study of vortical structures around a wall-mounted cubic obstacle in channel flow", *Phy.Fluids*Vol. **16**, pp. 402-020, (2004).
2. A. Van Dijk& H.C. De Lange, "Compressible laminar flow around a wall-mounted cubic obstacle", *Comp. Fluids* Vol. 36, pp. 949-960, (2007).
3. I.P. Castro & A.G. Robins, "The flow around a surface-mounted cube in uniform and turbulent streams", *J. Fluid Mech.* Vol. **79**, pp. 307–335, (1977).
4. R.J. Martinuzzi& C. Tropea "The flow around surface mounted prismatic obstacle placed in fully developed channel flow", *J. Fluids Eng.* Vol. **115**, pp. 85–92, (1993).
5. C.D. Tropea& R. Gackstatter, "The flow over two-dimensional surface-mounted obstacles at low Reynolds numbers", *J. Fluids Eng.* Vol. **107**, pp. 489–494, (1985).
6. S. Okamoto, T. Katsumata, N. Abe & M. Kijima, "Flow past repeated ribs of a square section mounted on a ground plate", *Trans. Jpn. Soc. Mech. Eng.* Vol. **63B**, pp. 3834–3842, (1997).
7. T.A. Alves, *Resfriamento conjugado de aquecedoresdiscretosemcanais.*Tese (DoutoradoemEngenhariaMecânica) – Faculdade de EngenhariaMecânica, UniversidadeEstadual de Campinas, Campinas, (2010).
8. T.A. Alves& C.A.C. Altemani, "An invariant descriptor for heaters temperature prediction in conjugate cooling", *Int. J. Thr. Sci.* Vol. **58**, pp. 92–101, (2012).

9. J. Davalath& Y. Bayazitoglu, “Forced convection cooling across rectangular blocks”, *J. Heat Tr.,* Vol. **109**, pp. 321–328, (1987).
10. Y. Zeng & K. Vafai, “An investigation of convective cooling of an array of channel-mounted obstacles”, *Num. Heat Tr., Part A,* Vol. **55**, pp. 967–982, (2009).
11. S.V. Patankar, *Numerical heat transfer and fluid flow.* Hemisphere Publishing Corporation, (1980).
12. A. Bar-Cohen, A.A. Watwe& R.S. Prasher, *Heat transfer in electronic equipment.* In: A. Bejan& A.D. Kraus (Eds.) *Heat transfer handbook.* John Wiley & Sons, (2003). Chap.**13**, pp.947-1027.
13. F.P. Incropera, D.P. Dewitt, T.L. Bergman & A.S. Lavine, *Fundamentos de transferência de calor e de massa.*LivrosTécnicos e CientíficosEditora, (2008).
14. G.K. Morris & S.V. Garimella, “Thermal wake downstream of a three-dimensional obstacle”. *Exp. Th. Fluid Sc.,* Vol. **12**, pp. 65-74, (1996).
15. F.B. Nishida, *Análisenumérica do escoamento laminar e da transferência de calor de aquecedores 3D protuberantesmontadosemumaplaca de circuitoimpressoutilizandodiferentesfluidos de resfriamento.* Monografia (Trabalho de Conclusão de Curso de Graduação) – UniversidadeTecnológica Federal do Paraná, Ponta Grossa, (2012).

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Integrated Review of Thermo-Physical Properties of Different Ceramic Coatings to make them Suitable for Internal Combustion Engines

By K. R. Sharma & Debasish Das

National Institute of Technology, India

Abstract- Thermal barrier coating using many ceramic powders is being done in internal combustion engines for more than two decades now. Thermal spray techniques are extensively used for coating of these powders over piston top, cylinder walls and valves of the engine. These coatings have to bear thermal stresses during combustion in the engine thus wear and tear of ceramic coating occurs. The present paper is a review of the research work that has been done to study different ceramic coatings to understand stresses in coatings, porosity and crack penetration by applying thermal shock tests and thermal torch experiment. Also the best ceramic coating material has been suggested suitable as thermal barrier coating for application in internal combustion engines.

Keywords: lower heat rejection (lhr), plasma spray technique, partially stabilized zirconia (psz), residual stress, thermal barrier coating (tbc), thermally grown oxide.

GJRE-A Classification : FOR Code: 240503p, 291404, 850402

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Integrated Review of Thermo-Physical Properties of Different Ceramic Coatings to make them Suitable for Internal Combustion Engines

K. R. Sharma [α] & Debasish Das [σ]

Abstract- Thermal barrier coating using many ceramic powders is being done in internal combustion engines for more than two decades now. Thermal spray techniques are extensively used for coating of these powders over piston top, cylinder walls and valves of the engine. These coatings have to bear thermal stresses during combustion in the engine thus wear and tear of ceramic coating occurs. The present paper is a review of the research work that has been done to study different ceramic coatings to understand stresses in coatings, porosity and crack penetration by applying thermal shock tests and thermal torch experiment. Also the best ceramic coating material has been suggested suitable as thermal barrier coating for application in internal combustion engines.

Keywords: lower heat rejection (lhr), plasma spray technique, partially stabilized zirconia (psz), residual stress, thermal barrier coating (tbc), thermally grown oxide.

I. Introduction

The ceramic coatings on metallic materials have shown significant improvements since 1970. For the aim of the thermal barrier coatings, thermal expansion, thermal conductivity, wear properties, creep and corrosion resistance are important properties. The flame spray and plasma spray techniques are the two main coating techniques used these days. The application of ceramic for thermal barrier coating in adiabatic engines started from 1980. First of all gas turbine wings were used in the area, and then piston, cylinder liner, valve, piston crown surface were used for ceramic coatings.

The experimental bonding strength values of ceramic coatings given by some researchers [1-4] show clear changes. Literature data on the bonding strength of ceramic coatings demonstrated that the plasma-sprayed ceramic coatings have a higher bonding strength than flame-sprayed coatings do [5]. Eichhorn F et al. [6] has shown that a bonding strength value of pure alumina was less than the bonding strength of stabilized alumina. The bonding strength of a ceramic coatingwith a bonding coating is higher than that of without bonding coating. The work of Unger R H andGates et al. [7,8] shows that the adhesion strength between the substrate and the ceramic coating could be improved by a NiAl bonding coating.

Few researchers have shown that within the coating materials zirconia ceramics as wear resistance material have been extensively considered for engineering applications [9-11].

Latest works expose that microstructure and mechanical properties, such as grain size [12-16], porosity [17], hardness [18, 19], fracture toughness [20], have strong effect on abrasive sliding wear resistance of bulk ceramics and coatings under dry or lubrication circumstances. Due to reduction in the grain size of ceramics their mechanical properties would be improved [21, 22], which is helpful in improving the abrasive sliding wear resistance of bulk ceramics and coatings [23-25].

II. Plasma Spraying Technique

The plasma powder is getting through plasma gas and sprayed on substrate, this phenomenon is known to be plasma spraying technique. At plasma spray technique, the coating powder can be sent by a plasma gas. Between two electrodes plasma is formed and powder is deposited in plasma arc. The plasma gas is usually argon or nitrogen. At plasma spraying technique, when argon, hydrogen or nitrogen gases are used, oxidation problem is minimized. For this reason, plasma spraying techniques have found useful application. One of the advantages of plasma spraying is that it makes possible to coat with high melting point materials.

III. Experimental Studies

a) Thermal Torch Experiment (Flame Punching Experiment)

In this experiment for application to certain area, thermal barrier coatings are exposed to flame. In this area, some deformation is observed and lower working temperature is required. Thermal torch experiment is applied to measure the strength of coating layer to hot flame. In the experiment work of some researchers [5-7]

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flame is applied with a distance of 10mm using an oxy-acetylene torch. Pressure of acetylene is kept 100 kPa. Heat is directly applied to sample and punching times are measured. The sample dimensions are chosen according to ASTM standard to be as 100x50x1.5 mm.

a) Thermal Shock Experiment

There are many applications areas of thermal barrier coating and one of them is used in high temperature requirement area. In this area samples are exposed to thermal cycling. Thermal shock experiment is aimed to find the place in which the sample destroyed. The thermal shock experiment is applied according to ASTM C 385-58 standard. During the experiment, samples are heated at certain temperature and waited for uniform distribution of temperature and are put immediately into water to provide thermal shock.

IV. Results and Discussions

a) Thermal Resistance

In the work of Serdar et al. [26] the test results were evaluated on the basis of the time required for drilling a hole through the coated specimens. Results are shown in table 1. As it can be seen from table 2 ceramic coating greatly enhances the life of the complete composite structure. It can also be seen from table 1 that zirconia with NiAl bonding coating supplied the maximum performance (deforming in 47 s) and chromium-oxide with NiAl bonding coating illustrated the second performance (with 37 s) and finally alumina with NiAl bonding coating was deformed within 31 s giving the weakest performance. Figs. 1-4 show the view of deformed samples with/without bonding coating. During the flame tests on thermal barrier coatings resistance to high temperatures is observed as these ceramics extend the life of composite structure. The life of base materials definitely increases with the application of ceramic coating.

Table 1 : Thermal torch experimental results [26]

Coating materials	Deformed time (s)
Zirconia (ZrO_2)without NiAl bonding coating	39
Zirconia (ZrO_2)with NiAl bondingcoating	47
Alumina (Al_2O_3)without NiAl bonding coating	29
Alumina (Al_2O_3)with NiAl bonding coating	31
Chromium-oxide (Cr_2O_3) without NiAlbonding coating	33
Chromium-oxide(Cr_2O_3) with NiAlbonding coating	37

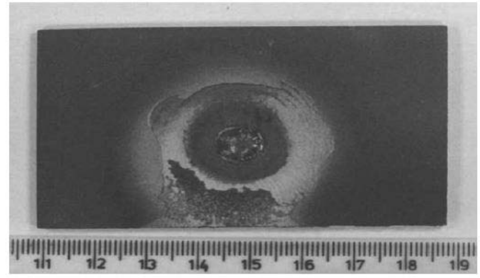

Figure 1 : Deformed Cr2O3 (Chromium-oxide) sample without bonding coating after flame torch experiment [26]

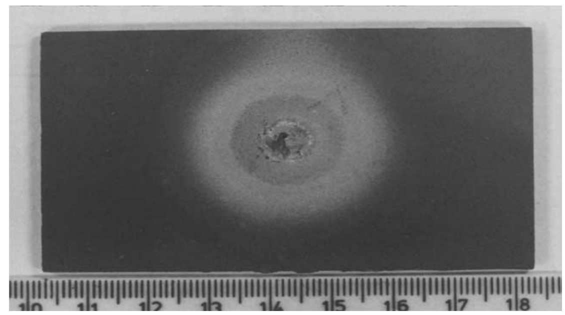

Figure 2 : Deformed Cr2O3 (Chromium-oxide) sample with bonding coating after flame torch experiment [26]

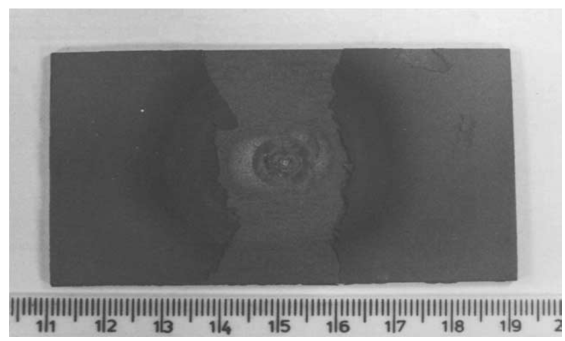

Figure 3 : Deformed Al2O3 (Alumina) sample without bonding coating after flame torch experiment [26]

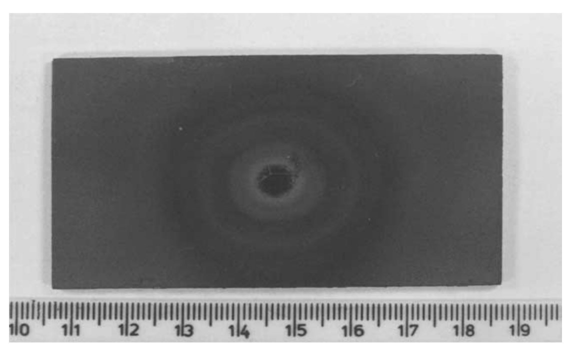

Figure 4 : Deformed Al2O3 (Alumina) sample with bonding coating after flame torch experiment [26]

b) Thermal Shock Properties

Table 2 shows the test results of thermal shock experiment shown by Serdar et al. [26]. In this test zirconia coated samples deformed at 1040 oC after 37 s and this is the best result in the experiment. Then chromium-oxide coated specimens performed the second thermal shock resistance and they are deformed at 960 oC after 33 s, and finally the alumina coated samples are deformed at 920 oC in 31 s. After thermal shock experiment it can be seen that vertical cracks are initiated in all samples and the reason for the formation of vertical cracks can be explained by thermal shock due to high cooling rate of the tests. In alumina and zirconia coated samples, the cracks are formed in much less quantity compared to other coated samples [11, 27-29].

Thermal shock tests are applied to the coated specimens in order to observe their mechanical behaviour under the stresses due to thermal expansion mismatch between the coating and the substrate. It has been shown that coatings are resistance to rapid changes in temperature in spite of the difference in their thermal expansion coefficients.

Table 3 : Thermal shock experimental results [26]

Coating materials	Substrate	Deformed time (s)	Deformed temperature (ºC)
Zirconia (ZrO_2)	With bonding coating	37	1040
	Without bonding coating	35	1000
Alumina (Al_2O_3)	With bonding coating	31	920
	Without bonding coating	20	700
Chromium-oxide (Cr_2O_3)	With bonding coating	33	960
	Without bonding coating	21	720

V. Conclusions

Thermal barrier coated samples are directly exposed to flame (for example combustion rooms in rocket and gas turbines). The view of flame application area shows significant deformation. For this reason, lower working temperature is chosen and figure of merit is decreased. There are many different usage areas of thermal barrier coatings. One of them is the high temperature area. The coating is exposed to thermal cycling. The time of cycling is lower in engine with piston. In literature, piston crown surface, cylinder cover and valve parts are coated with ceramics. Beside these, piston rings and cylinder liner are coated with ceramics. With the thermal shock and the thermal torch experiments, it is shown that the coated materials have higher resistance to high temperatures. Zirconia coating has the best properties in thermal shock and thermal punching experiments. With zirconia coating the figure of merit of engine part will be increased.

References Références Referencias

1. Ambroz A, Kaspar J. Zvaranie 1982;10:363.
2. Mattıng A, Delventhal B. Metalloberflache 1966;20:424.
3. Demırcı M. M.Sc Thesis, Marmara University, Istanbul, 1994.
4. Vural M, Zeytin S, Ucisik AH. Plasma-sprayed oxide ceramics on steel substrates. Surf Coat Technol 1997;97:347–54.
5. Berndt CC. Plasma Spray coating. Department of MaterialsEngineering. Clayton, Victoria: Monash University; 1985.
6. Eıchhorn F, Metzler J. Metalloberflache 1968;22:225.
7. Unger RH. In: Proceedings of the National Thermal SprayConference, Orlando, FL, 1987;365–70.
8. Gates WD, Dıaz AM, Aquılıno SAJ. Prosthetic Dent 1993;69:12.
9. Stachowiak GB, Stachowiak GW, Evans P. Wear and friction characteristics of ion-implanted zirconia ceramics. Wear 2000;241: 220–7.
10. Sun Y, Li B, Yang D, Wang T, Sasaki Y, Shii KI. Unlubrication friction and wear behaviour of zirconia ceramics. Wear 1998;215: 232–6.
11. Hannink RHJ, Murray MJ, Scott HG. Friction and wear of partially stabilized zirconia: basic science and practical applications. Wear 1984;100:355–66.
12. He Y, Winnubst L, Burggraaf AJ, Verweij H, Vander varstPGTh, de With B. Grain-size dependence of sliding wear in tetragonal zirconia polycrystals. J Am Ceram Soc 1996;79(12): 3090–6.
13. ZumGahr KH, Bundschuh W, Zimmerlin B. Effect of grain size on friction and sliding wear of oxide ceramics. Wear 1993;162– 164:269–79.
14. Wang D, Mao Z. Abrasive Wear of tetragonal zirconia polycrystal ceramics. J Chin Ceram Soc 1995;23(5):518–24.
15. Yang CT, Wei WJ. Effects of material properties and testing parameters on wear properties of fine-grain zirconia (TZP). Wear 2000;242:97–104.
16. Moulzolf SC, Lad RJ, Blau PJ. Microstructural effects on the friction and wear of zirconia films in unlubricated sliding contact. Thin Solid Films 1999;347:220–5.
17. He Y, Winnubst L, Burggraaf AJ, Verweij H, Vander VarstPGTh, de With B. Influence of porosity on friction and wear of tetragonal zirconia polycrystal. J Am Ceram Soc 1997;80(2): 377–80.

18. Strafford KN, Datta PK, Gray JS. Surface engineering practice processes, fundamentals and application and wear, West Sussex, 1990, p. 19–21.
19. Zhu Y, Yukimura K, Ding C, Zhang P. Tribological properties of nanostructured and conventional WC–Co coatings deposited by plasma spraying. Thin Solid Films 2001;388: 277–82.
20. Fischer TE, Anderson MP, Jahanmir S. Influence of fracture toughness on the wear resistance of yttria-doped zirconium oxide. J Am Ceram Soc 1989;72(2):252–7.
21. Theunissen GSAM, Bouma JS, Winnubst AJA, Burggraag AJ. Mechanical properties of ultra-fine grained zirconia ceramics. J Mater Sci 1992;27(14):4429–38.
22. He YJ, Winnubst AJ, Sagel-Ransijn CD, Burggraaf AJ, Verweij H. Enhanced mechanical properties by grain boundary strengthening in ultra-fine grained TZP ceramics. J Eur Ceram Soc 1996;16(6):601–12.
23. Stewart DA, Shipway PH, McCartney DG. Abrasive wearbehaviour of conventional and nanocomposite HVOF-sprayed WC–Co coatings. Wear 1999;225–229: 789–98.
24. Dogan H, Findik F, Morgul O. Friction and wear behaviour of implanted AISI316LSS and comparison with a substrate. Mater Des 2002;23(7):605–10.
25. Dogan H, Findik F, Oztarhan A. Comparative study of wear mechanism of surface treated AISI 316L stainless steel. IndLubrTribol 2003;55(2–3):76–83.
26. Salman S, Kose R, Urtekin L, Findik F. An investigation of different ceramic coating thermal properties. Materials and Design 27 (2006) 585-590.
27. Salman S, Cizmecĭoglu Z. Stud ies of the correlation between wear behaviour and bonding strength in two types of ceramic coating. J Mater Sci 1998;33:4207–12.
28. Salman S. Ph.D Thesis, YildizTehnical University; 1995.
29. Urtekin L. M.Sc Thesis, Dumlupinar University, Kutahya;2001.

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I. Introduction

Biomass has been recognized as a major renewable energy source to supplement declining fossil fuel sources of energy. It is the most popular form of renewable energy and currently biofuel production is becoming very much promising. Transformation of energy into useful and sustainable forms that can fulfill and suit the needs and a requirement of human beings in the best possible away is the common concern of the scientists, engineers and technologists. From the view point of energy transformation, fixed bed pyrolysis is more attractive among various thermo chemical conversion processes because of its simplicity and higher conversion capability of biomass and its solid wastes into liquid product.

In South Asian developing countries, especially in Bangladesh the generation of biomass waste is quite high. Along with other residues these waste accumulatedis creating disposal problems. Also direct burning of these wastes creates a serious environmental problem. As carbonaceous solid wastes are the source of energy, therefore, the potential of recovering these wastes into useful form of energy by pyrolysis into liquid fuel should be considered. In this way the waste would be more readily useable and environmentally acceptable. This liquid of high heating value can easily be transported, can be burnt directly in the thermal power plant; can easily be injected into the flow of conventional petroleum refinery, can be burnt in a gas turbine or upgraded to obtain light hydrocarbon transport fuel. The solid char can be used for making activated carbon. The gas has high calorific value, sufficient to be used for the total energy requirements of the pyrolysis plant. Recently some work has been carried out with biomass solid waste as feedstock at the Fluid Mechanics Laboratory of Mechanical Engineering Department of Rajshahi University of Engineering & Technology (RUET), Rajshahi, to obtain liquid fuel using fixed bed pyrolysis technology.

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II. Pyrolysis Technology: a Brief Overview

a) Chemical Reaction of Pyrolysis Process

Pyrolysis an attractive method to recycle scrap tires has recently been the subject of renewed interest. Pyrolysis of tires can produce oils, chars, and gases, in addition to the steel cords, all of which have the potential to be recycled. Tire pyrolysis liquids (a mixture of paraffins, olefins and aromatic compounds) have been found to have a high gross calorific value (GCV) of around 41-44 MJ/kg, which would encourage their use as replacements for conventional liquid fuels [1, 2, 3]. In addition to their use as fuels, the liquids have been shown to be a potential source of light aromatics such as benzene, toluene and xylene (BTX), which command a higher market value than the raw oils [4, 5]. Similarly, the liquids have been shown to contain monoterpenes such as limonene [1-methyl-4-91-methylethenyl)-cyclohexene] [6, 7].

Pyrolytic char may be used as a solid fuel or as a precursor for the manufacture of activated carbon [8, 9]. It was found that another potentially important end use of the pyrolytic carbon black (CBp) may be as an additive for crude bitumen [10]. Some of the previous research group studied the composition of evolved pyrolysis gas fraction and reported that it contains high concentration of methane, ethane, butadiene and another hydrocarbon gases with a GCV of approximately 37 MJ/m3, a value sufficient to provide the energy required by the pyrolysis process [11].

Pyrolysis can be presented by the following equation

$$CaH_bO_c + HeatH_2 \longrightarrow O + CO_2 + H_2 + CO + CH_4 + C_2H_6 + CH_2O + \ldots\ldots + \text{Tar(liquid oil)} + \text{Char}$$

b) Selected Biomass Waste

Pine seeds were selected as the feed material for this study. Polyalthialongifolia in the genus Swietenia, is extensively cultivated in India, Sri Lanka, Bangladesh etc as avenue tree. It is a semi evergreen tree, about 30-35m tall. Fruit shape is oval, fruit length is 1 to 3 inches, fruit covering dry or hard, the fruit color is brown.

c) Reasons for selecting pine seeds as biomass waste

- A large amount (250000 tons/yr) of pine seeds are not utilized which is grown in Bangladesh
- The production of oil from pine seeds may provide the use of a renewable resource, and at the same time adding value to agricultural products.

Table 1 : Approximate composition of pine seeds [19]

Moisture	5%
Crude Protein	31.6%
Oil	10-12%
Soluble sugar	5.15%
Fat	44.9%
Ash	4.5%

d) Fixed Bed Pyrolysis System

Pyrolysis may be either fixed bed pyrolysis or fluidized bed pyrolysis. In fixed bed pyrolysis, a fixed bed pyrolyser is used. The feed material in the reactor is fixed and heated at high temperature. As the feed is fixed in the reaction bed (reactor), it is called fixed bed pyrolysis. In this process, the feed material is fed into the reactor and heat is applied externally. Liquid petroleum or other inert gas is used for making inert condition and for helping the gaseous mixture to dispose of the reactor.

The losses in fixed bed pyrolysis are relatively less than fluidized bed pyrolysis. Moreover, fluidized bed pyrolysis is more complex. This project work is based on fixed bed pyrolysis.

e) Feed Preparation

The pine seeds are collected and dried. It is then crushed into smaller sizes. These are <1.18mm, 1.18mm, 2.36mm, and 4.75mm in dia. It is dried with the help of oven. Thus the feed material is prepared.

III. Experimental Procedure

The following procedures are employed for experimental operation:

a) Feed material was weighed and filled into the reactor.
b) The experimental set-up was assembled.
c) High temperature adjustable gaskets were used to seal the joints and fittings of the hot parts of the connecting pipe, reactor and condenser.
d) Ice was placed into the condenser.
e) The reactor was heated externally by a biomass heater at different temperatures and these temperatures were measured by thermometer.
f) The N2 gas was passed through reactor through a heated pipe and this flow was controlled by the use of a gas flow meter valve.
g) The operation time was recorded by means of a stopwatch.
h) When the operation was completed a small flow of N2 gas was allowed to pass through the system to prevent back flow of air which might react with hot gases when the reactor was still hot.
i) It is dismantle when the rig was cooled enough to be handled. The char was collected from the reactor bed and weighed. All data are recorded in tabular form.
j) All the parts of the system were cleaned and the heating value of the liquid and char was measured by a bomb calorimeter before reassembling for the next run.

IV. Effect of Feed Particle Size

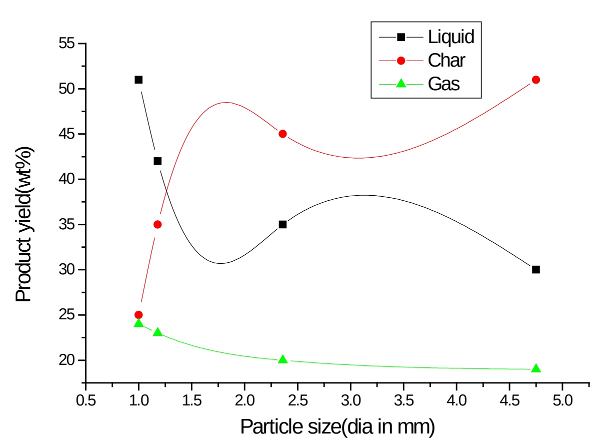

Figure 1 : Effect of feed particle size on product yield (<1.18 mm, 1.18 mm, 2.36 mm and 4.75mm) for reactor temperature 450~550oC

Figure 1 represents the percentage weight of liquid and solid char products for different particle size of feed at a bed temperature of 500oC and an operating time of 90 minutes. It is observed that at 500oC the percentage of liquid collection is a maximum of 51% of total biomass feed for particle size of <1.18 mm .A less amount of liquid is obtained from the larger particle size feed. This may be due to the fact that the larger size particles are not sufficiently heated up so rapidly causing incomplete pyrolysis that reduced liquid product yield.

V. Effect of Reaction Temperature

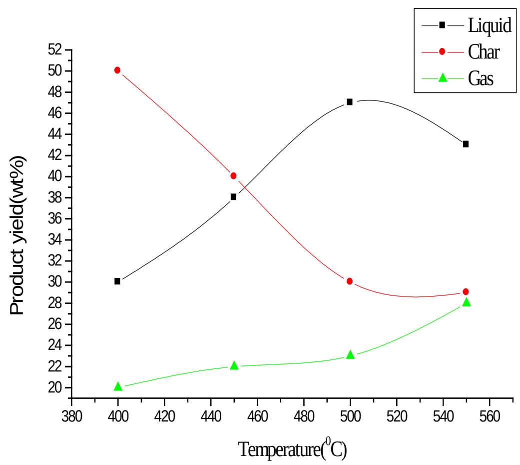

Figure 2 : The effect of operating temperature on product yield

Figure 2 shows the variation of percentage weight of liquid, char and gaseous products at different bed temperature with particle size of < 1.18mm. From this it is found that the maximum liquid products yield is obtained at a temperature of 500oC, and this is 47%wt of total biomass feed. At lower temperature the liquid product yield is decreasing while with the increase of temperature above 5000C, the liquid product yield is again deteriorating. With the increase of temperature the solid char yield is decreasing above 5000C and increasing below 5000C. It may be caused at lower temperature less than 5000C, complete reaction cannot be taken place.

VI. Effect of Running Time

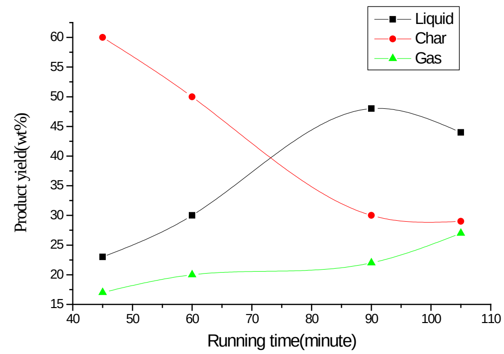

Figure 3 : Effect of running time on product yield for reaction bed temperature 450~5000C and for feed particle size 1.18 mm

Figure 3 shows the variation of product yield (wt %) of liquid, solid char and gas products at a temperature of 5000C for feed particle of size of < 1.18mm. The maximum liquid product is 48 wt% of biomass feed while the solid char product is 30wt% of dry feed at 90 minutes. It is observed that lower and greater running time than of that of 90 minutes the liquid product yield is not optimum that may be due to insufficient pyrolysis reaction and higher rate of gas discharge respectively. Secondary cracking reaction has taken place by which the amount of permanent gas product is increased. So, at temperature higher than 5000C liquid product is decreased.

VII. Comparison of Pine Seeds oil with Petroleum Products and Biomass Derived Pyrolysis oil

The comparison of physical characteristics of pine seeds oil with other biomass derived pyrolysis oil and petroleum products is shown in Tables 3 and 4.

Table 2 : Comparison of pine seeds pyrolysis oil with biomass derived pyrolysis oil

Analysis	Pine Seed oil	Date Seed oil [12]	Waste Paper oil [13]	Sugarcane bagasse oil[14]	Jute stick oil [15]
Kinematic viscosity at 35°C (cSt)	12.15	6.63	2.00	89.34	12.8
Density (kg/m^3)	1240	1042.4	1205	1198	1224
Flash Point (°C)	60	126	200	105	>70
HHV(MJ/kg)	24.22	28.636	13.10	20.072	21.091

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Table 3 : Physical characteristics of the pine seeds pyrolysis oil and its comparison

Analysis	Pine Seed oil	Fast Diesel [16]	Diesel [17]	Heavy Fuel Oil[18]	Wood Waste [17]
Kinematic viscosity at 35^{0}C (cSt)	12.15	1.3-3.3.3#	2.61*	200#	66.99
Density (kg/m^3)	1240	780	827.1*	980*	1180.2
Flash Point (^{0}C)	60	75	53	90-180	59
HHV(MJ/kg)	24.22	45-46	45.18	42-43	19.80

#at 500C *at 200C

From the comparison it is shown that the viscosity of pine seeds oil is favorable than other pyrolysis oils. It has HHV of 24.22 MJ/kg.

VIII. Conclusion and Discussion

The objectives of the study are fulfilled by using the biomass waste in the form of pine seeds with fixed bed pyrolysis system. The fixed bed pyrolysis of solid pine seed has a maximum oil yield of 51wt% of biomass feed particle size of <1.18mm at a reactor bed temperature of 500oC and a gas flow of 5 liter/ minute with the running time of 90 minute. The physical properties analysis showed that the oil is heavy in nature with moderate viscosity. The oil possessed favorable flash point. The heating value of the oil is moderate. From the comparison it is shown that the viscosity of pine seeds oil is favorable than other pyrolysis oils. It has HHV of 24.22 MJ/kg.

References Références Referencias

1. Diez, C., Martinez, Cara, O., Calvo, L.F., Cara, J., Moran, A., 2004. Pyrolysis of tires. Influence of the final temperature of the process on emissions and the calorific value of the products recovered. Waste Management 24. 463-469.
2. Cunliffe, A.M., Williams, P.T., 1998. Composition of oils derived from the batch pyrolysis of tires. Journal of Analytical and Applied Pyrolysis 44 (3), 131-152.
3. Laresgoiti, M.F., Caballero, B.M., De Marco, I., Torres, A., Cabrero, M.A., Chomon, M.J.J., 2004. Characterization of the liquid products obtained in tire pyrolysis. Journal of Analytical and Applied Pyrolysis 71, 917-934.
4. Cunliffe, A.M., Williams, P.T., 1998. Composition of oils derived from the batch pyrolysis of tires. Journal of Analytical and Applied Pyrolysis 44 (3), 131-152.
5. Laresgoiti, M.F., Caballero, B.M., De Marco, I., Torres, A., Cabrero, M.A., Chomon, M.J.J., 2004. Characterization of the liquid products obtained in tire pyrolysis. Journal of Analytical and Applied Pyrolysis 71, 917-934.
6. Cunliffe, A.M., Williams, P.T., 1998. Composition of oils derived from the batch pyrolysis of tires. Journal of Analytical and Applied Pyrolysis 44 (3), 131-152.
7. Roy, C., Chaala, A., Darmstadt, H., 1999. Vacuum pyrolysis of used tires End-used for oil and carbon black products. Journal of Analytical and Applied Pyrolysis 51 (4), 201-221.
8. Barbooti, M.M., Mohamed, T.J., Hussain, A.A., Abas, F.O., 2004. Optimization of pyrolysis conditions of scrap tires under inert gas atmosphere. Journal of Analytical and Applied Pyrolysis 72, 165-170.
9. Cunliffe, A.M., Williams, P.T., 1998. Composition of oils derived from the batch pyrolysis of tires. Journal of Analytical and Applied Pyrolysis 44 (3), 131-152.
10. Roy, C., Chaala, A., Darmstadt, H., 1999. Vacuum pyrolysis of used tires End-used for oil and carbon black products. Journal of Analytical and Applied Pyrolysis 51 (4), 201-221.
11. Islam, M.R., et al. Feasibility study for thermal treatment of solid tire wastes in Bangladesh by using pyrolysis technology. Waste Management (2011). doi; 10.1016/j.wasman.2011.04.017.
12. M. Uazzal Hossain Joardder and M. MontasirIquebal,2003. Design, Fabrication and Performance Study of a Biomass solid waste Pyrolysis System for Alternative Liquid Fuel Production.
13. Islam, M. N. Islam M. N. Beg, M. R .A, Islam M. R. (2004). A work on pyrolytic oil from fixed bed pyrolysis of municipal solid waste and its characterization. Renewable Energy 30, 413-420.
14. Islam, M.R, Islam, M.N. and Islam, M.N. 2003. The fixed bed pyrolysis of sugarcane bagasse for liquid fuel production. Proc. of the Int. Conf. on Mechanical Engineering (ICME2003), Bangladesh, pp.26-28.
15. Islam, M.R., Nabi, M.N. and Islam, M.N. 2001. Characterization of biomass solid waste for liquid fuel production. Proc. of 4'h Int. Conf. on Mechanical Engineering (ICME2001), Bangladesh, pp.77-82.
16. Harker, J.H. and Bachurst J, R., 1981. Fuel and Energy, London: Academic Press.
17. Andrews, R.G. and Patniak,P. C., 1996. Feasibility of utilizing a biomass derived fuel for industrial gas turbine applications. In: Bridgwater AV, Hogan EN, editor. Bio-Oil Production & Utilization, Berkshire: CPL Press, pp. 236-245.

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18. Rick, F. and V ix, U., 1991.Product standards for pyrolysis products for use as fuel in industrial firing plants. In: Bridgwater AV, Grassi G, editor. Biomass Pyrolysis Liquids Upgrading and utilization, London: Elsevier Science, pp. 177- 218.
19. Web link http://www.bestenergies.com/companies /bestpy rolysis.html

Nomenclature

BTX benzene, toluene and xylene
CBppyrolytic carbon black
GCV gross calorific value
HHV higher heating value

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Investigate the Behavior of Carbon Percentage and Sintering Temperature on Microstructure and Densification Parameter of Iron-Based Powder Preform

By Gaurav Awasthi, T.K Mishra, Atish Sanyal & Ajay Tiwari
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Keywords: iron powder, graphite contents, microstructure and powder metallurgy.

GJRE-A Classification : FOR Code: 091499

INVESTIGATETHEBEHAVIOROFCARBONPERCENTAGEANDSINTERINGTEMPERATUREONMICROSTRUCTUREANDDENSIFICATIONPARAMETEROFIRONBASEDPOWDERPREFORM

Strictly as per the compliance and regulations of:

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Gaurav Awasthi [α], T.K Mishra [σ], Atish Sanyal [ρ] & Ajay Tiwari [ω]

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Keywords: iron powder, graphite contents, microstructure and powder metallurgy.

I. Introduction

Powder compaction is a popular route for the production of light engineering components such as automotive parts. A common production process consists of cold compaction in a closed-die or in an isostatic press followed by sintering. Most of the densification takes place in the cold compaction step by rate-independent plasticity. Sintering of iron powder with graphite, iron powder with copper and graphite, iron powder with nickel and graphite, iron powder with phosphorus, and iron powder with boron was studied by Narasimhan (2001). Deng, X. Piotrowski, G. Chawla, N. Narasimhan(2008) investigate relationship between microstructure and fatigue crack growth in detail. The density, matrix microstructure, and the degree of pore clustering had a significant effect on the crack growth,describe and explain the fatigue behavior of the steels. A method of making iron-carbon materials in order to obtain materials with a low content of impurities (especially oxygen) and sufficiently high density was developed by Kostikov et al. (2008). A. Gökçe and F. Fındık reported in 2008 that the Green and theoretical density increased with the increment of compaction pressure. WalidMoustafa Mohammed El Sabagh(2011) investigation behavior of Compacted Graphite Iron analyzing Microstructurebehavior on Fracture and Machining and also described the compacted graphite iron mechanical properties. Herbert Danninger, Christian Gierl, HaraldGschiel, Magdalena Dlapka at el reported in (2011) that Iron-carbon use as master alloy give the relation of high density tosintered temperature effect. Xiaoxun Zhang, Fang Ma, Kai Ma & Xia Li in (2012) giving behavior of Graphite Content on various Temperatureand effect on Microstructure and Mechanical Properties by iron based Powder Metallurgy Parts. ChandanaPriyadarshiniSamal, at el reported in (2012) about Microstructure and Mechanical Property Study of Cu-graphite Metal Matrix Composite Prepared by Powder Metallurgy Route. S.B. Halesh, P. Dinesh in 2013 (International Journal of Engineering and Innovative Technology) investigate about Development of Sintered Iron Based Ternary Alloy for Wear Resistant Applications.

Carbon in small quantities is added to iron, 'Steel' is obtained. Since the influence of carbon on mechanical properties of iron is much larger than other alloying elements. The atomic diameter of carbon is less than the interstices between iron atoms and the carbon goes into solid solution of iron. As carbon dissolves in the interstices, it distorts the original crystal lattice of iron.

This mechanical distortion of crystal lattice interferes with the external applied strain to the crystal lattice, by mechanically blocking the dislocation of the crystal lattices. In other words, they provide mechanical strength. Obviously adding more and more carbon to iron (up to solubility of iron) results in more and more distortion of the crystal lattices and hence provides increased mechanical strength. However, solubility of more carbon influences negatively with another important property of iron called the 'ductility' (ability of iron to undergo large plastic deformation). The a-iron or ferrite is very soft and it flows plastically. Hence we see

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that when more carbon is added, enhanced mechanical strength is obtained, but ductility is reduced. Increase in carbon content is not the only way, and certainly not the desirable way to get increased strength of steels. More amount of carbon causes problems during the welding process. We will see later, how both mechanical strength and ductility of steel could be improved even with low carbon content. The iron-carbon equilibrium diagram is a plot of transformation of iron with respect to carbon content and temperature. Iron-carbon ability in powder metallurgy not such developed and structural properties need to explore.

II. Materials Preparation

In order to obtain iron-based powder metallurgy specimens and study the effects of graphite content and temperature on its microstructure properties, the iron powder and the graphite powder purchased from Qualikems Fine Chem PVT. LTD, Vadodara, Gujarat. Specification of Iron and Graphite powder are as follows-

a) Iron Powder Specification

Atomized IRON powder of purity 99.5% and finer than 44µm was used throughout the experiments with 300 meshes.

Element	Cu	Manganese	Sulphide	Nickel	Lead (Pb)	Zinc (Zn)	Sulfuric acid insoluble
Wt%	0.0005	0.05	0.02	0.05	0.002	0.01	0.05

b) Graphite powder content

Graphite powder of 325 meshes.

Element	C	Fe	H2O	Other
wt%	98.0	0.045	0.5	1.45

Four groups of 16g of iron and graphite powder were stirred well and mixed uniformly. Then, four groups of powder mixture were produced and their graphite contents were 0%, 2%, 5% and 10%, respectively. These powder mixtures were used to make compact specimen in the experiments.

III. Powder Blending and Mixing

- Taking fine particles powder of iron and other additive then mixing process in involvement of binder to for primarily joining.
- Graphite used as binder for iron/steel powder. This is done through an annealing process where the bonding between particles is caused by diffusion.
- Add lubricants (<5%), such as graphite and stearic acid, to improve the flow characteristics and compressibility of mixtures.
- Air or inert gases to avoid oxidation Liquids for better mixing, elimination of dusts and reduced explosion hazards.

IV. Sample Preparation

a) Powder Compaction

A cylindrical die with a diameter of 12 mm was adopted to compact the powder. The cotton with graphite used to wipe and clean the mold wall. Powder mixture of 16 g of weight is taken and put into the die. A UTM (ultimate tensile machine) hydraulic press is used to compact the powder and the load put on the die is 100Kilonewtonand the holding time is 15 minutes.

Then, the compacted specimen was ejected from the die.

Figure 1 : punch, die and cougher

b) Powder Sintering

The specimens were sintered in a muffle furnace. Every single sample three temperature ranges 700, 850, 1000 degree centigrade, holding time is 20 minutes and cooling with the furnace.

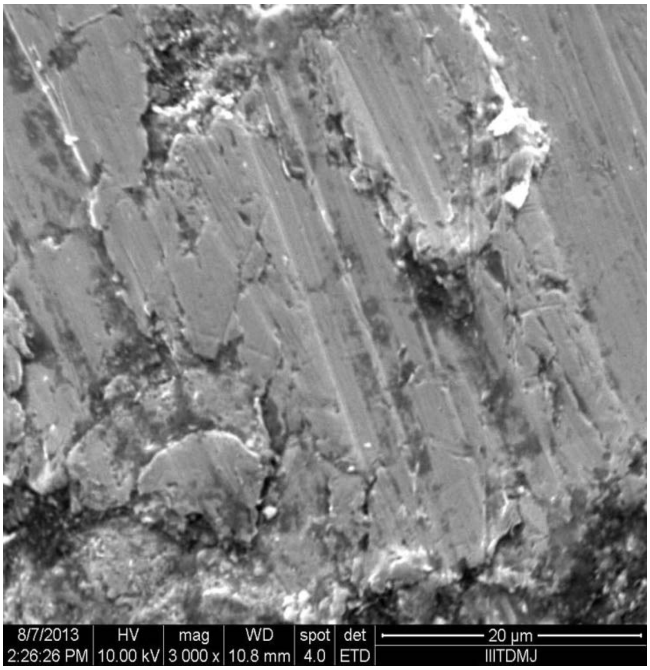
c) Finishing Operation

Grinder, Amery paper is use in operation of minimizing mechanical surface damage that must be removed by subsequent polishing operations. The metallographic specimens were polished and then etched by nitric acid and alcohol solution.

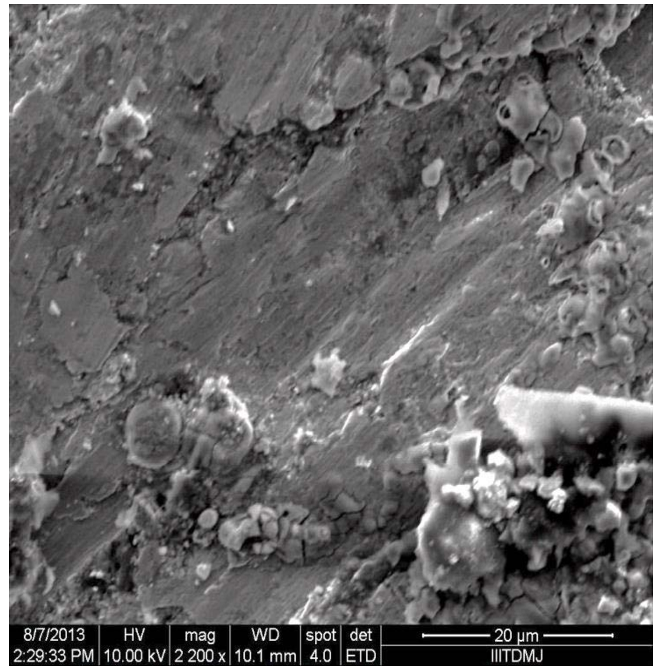
V. Experiment

a) Microstructure Observation

In this study, both temperature and graphite content were considered as the effective factors on the microstructure properties of the sintered specimen. The specimens were produced at three sintering temperatures, 700°C, 850°C and 1000°C, respectively, and with four graphite contents, 0%, 2%, 5% and 10%, respectively. The polished and etched specimens were examined by scanning electron microscopy (SEM) and the magnification 10 to 40μm. The effects of temperature and graphite content on the microstructure of the iron-based powder sintered products by metallographic analysis were shown



(a)



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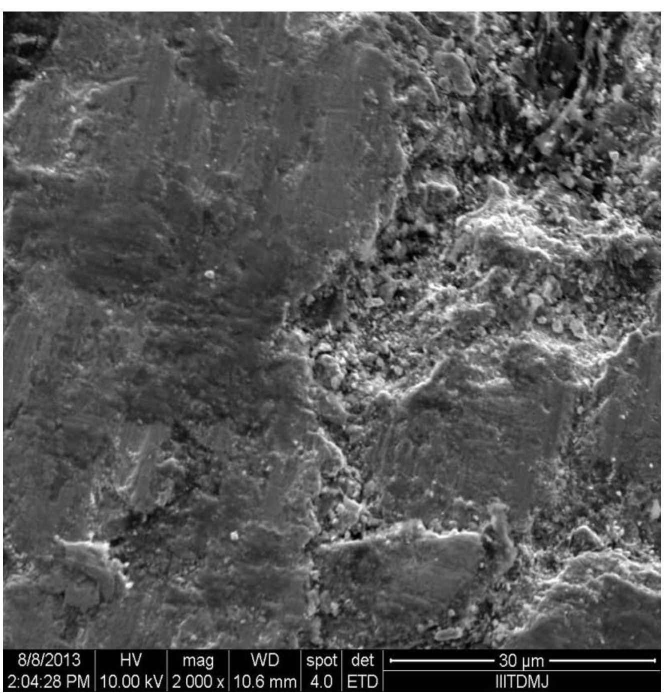

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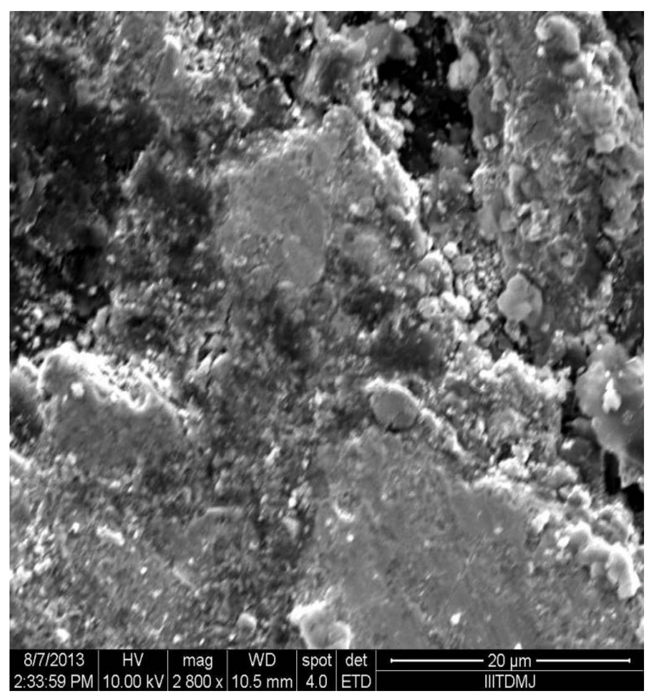


(d)

Image 1 : Microstructure of the iron-based PM parts sintered at 700°C with different graphite content: (a) 0%, (b) 2%, (c) 5% and (d) 10%

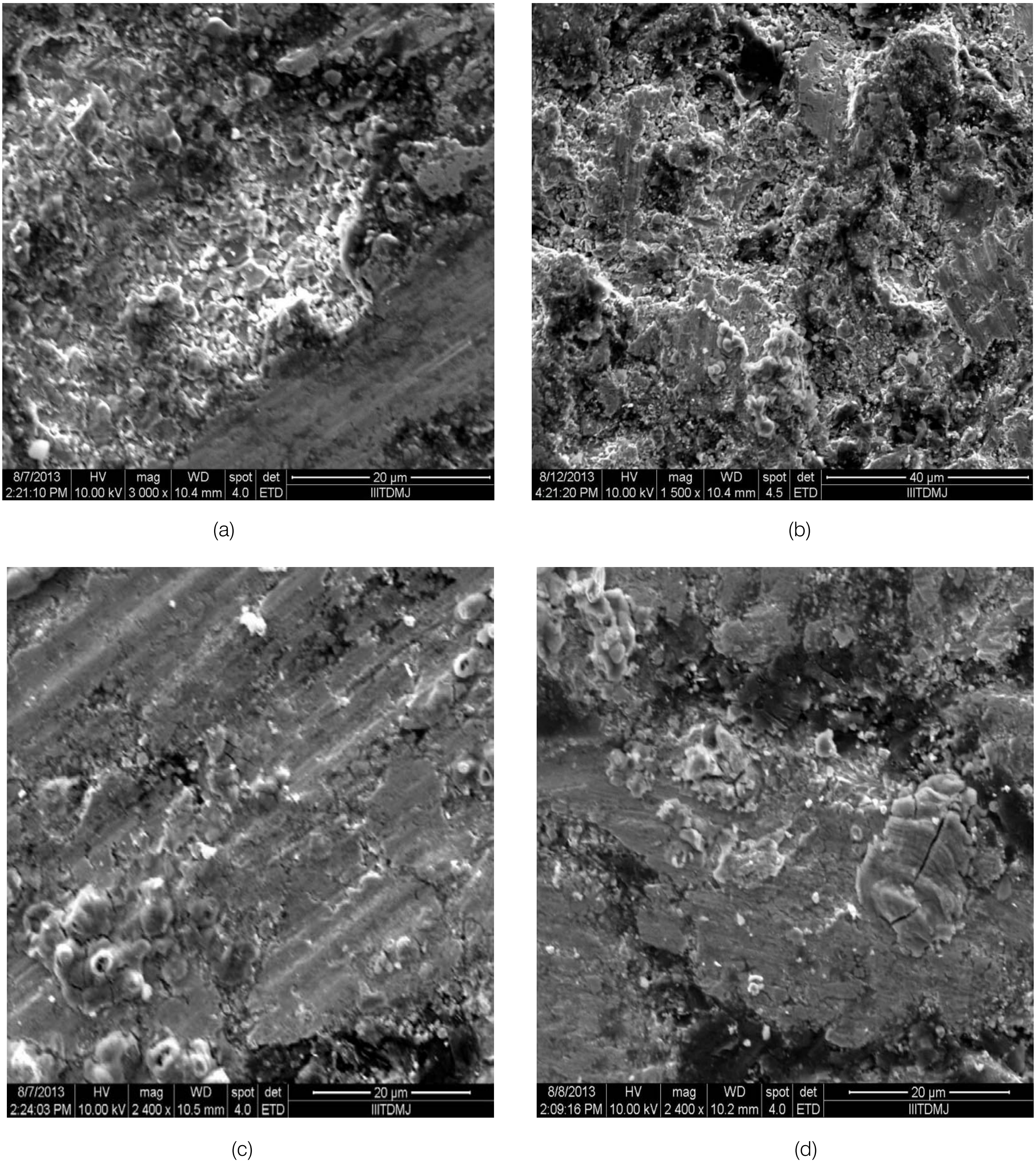
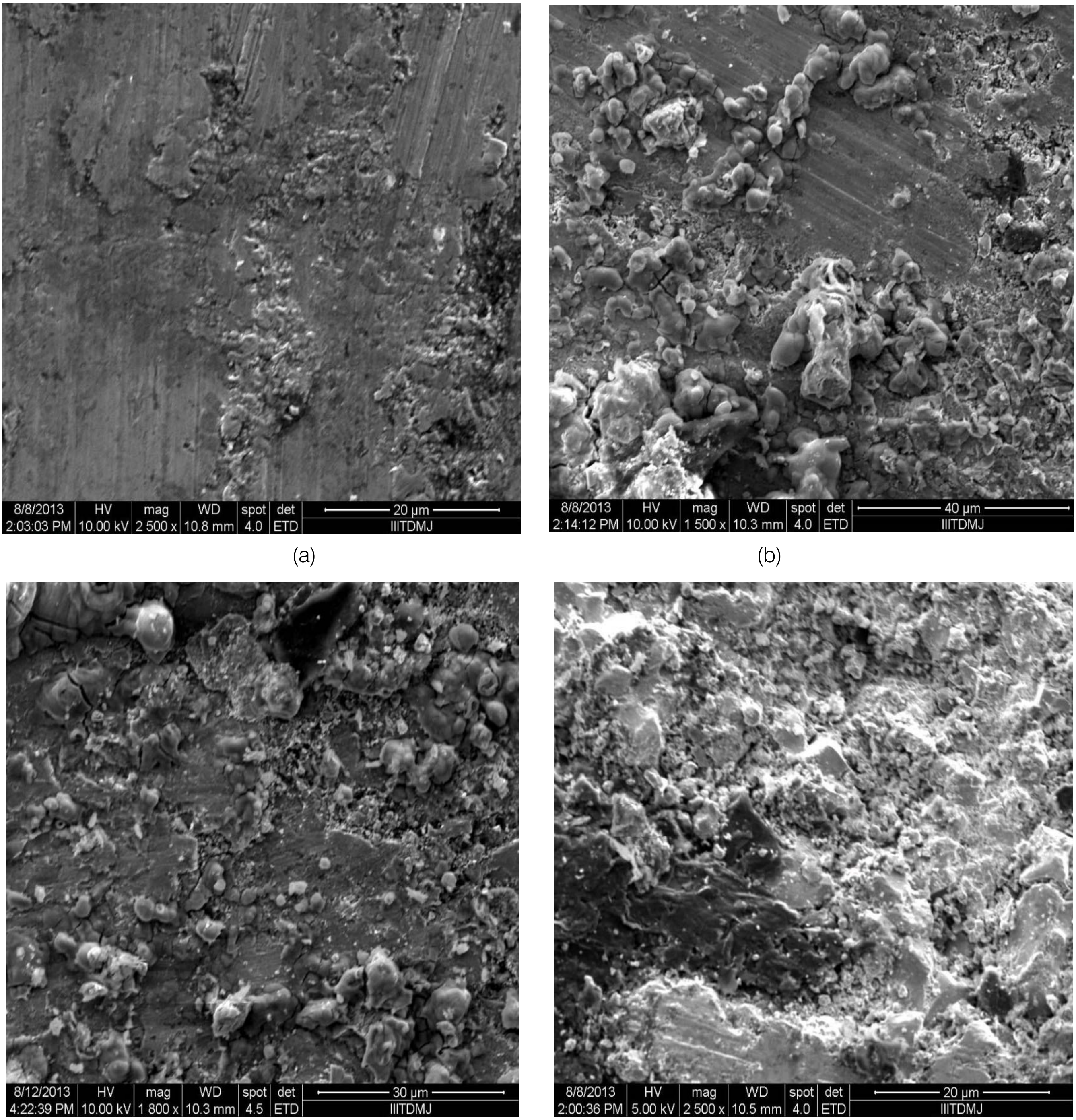


Image 2 : Microstructure of the iron-based PM parts sintered at 850°C with different graphite content: (a) 0%, (b) 2%, (c) 5% and (d) 10%



(c) (d)

Image 3 : Microstructure of the iron-based PM parts sintered at 1000°C with different graphite content: (a) 0%, (b) 2%, (c) 5% and (d) 10%

The microstructures of the sintered specimens with the graphite content from 0% to 10% were shown in above figures. It can be seen that as the graphite content increases from 0% to 10%, the microstructure of the iron-based powder sintered specimen changes gradually from ferrite (white microstructure) and a small amount of pearlite (black and white lamellar microstructure) to pearlite and a small amount of ferrite. A small amount of cementite (Fe_3C) also appeared in the microstructure when the graphite content increased to 2%. It also can be seen that the austenite grain size increases gradually when the graphite content increases. This is mainly because that the degree of superheat increases as the graphite content increases when the sintering temperature is constant, thus contributing to the growth of austenite grain. In 5% cast iron formed in the sample flakes of graphite formed above the surface, packs of austenite increases as percentage of graphite increases. As percentage increases 2 to 5 % Spheroidal structure increases in images. Then graphite percentage increases 5 to 10% white area increase for ever temperature and packs of austenite escape in images, there is clearly to main surface saw in the images white and other one is black layered and as per temperature increases the white region increases.

Comparing the microstructures of the sintered specimens at 700°C to 1000°C from Image 1 Image 2 and Image 3, it can be concluded that with the sintering temperature increasing, the micro structures of the sintered interface become uniform. This is mainly because of the formation of many meshes of grain boundary and their interactions with the interwoven pores. The excess vacancies at the edge of the sintering neck and on the surface of micro-pores are easy to pass the adjacent grain boundary and diffuse or absorb. The higher the sintering temperature, the greater the coefficient of the atomic diffusion within the particle, and the faster the sintering carried out. When temperature increases graphite given the three form flake, compacted, spheroidal.

b) Density

Density of the specimen can be calculated by

$$\rho = {}^{m}/_{v}$$

Where , v and ρ is the mass, the volume and the density of the sintered specimen, respectively then

$$v = \frac{\pi d^2 l}{4}$$

Where d, l is diameter and length of the sintered specimen, respectively.

So

$$\rho = \frac{4m}{\pi d^2 l}$$

c) Result table

No.	Iron (wt %)	Graphite (wt%)	Temperature (°C)	Diameter (mm)	Length (mm)	Mass (g)	Density (g/cm^3)
1	100	0	1000	12	23	15.52	5.96
2	100	0	850	12	24	16.68	6.14
3	100	0	700	12	23	15.70	6.03
4	98	2	1000	12	24.5	17.33	6.25
5	98	2	850	12	22	15.90	6.39
6	98	2	700	12	23.5	16.79	6.31
7	95	5	1000	12	22	15.66	6.29
8	95	5	850	12	22.5	16.54	6.49
9	95	5	700	12	24	17.33	6.38
10	90	10	1000	12	22.3	14.14	5.60
11	90	10	850	12	24	15.73	5.81
12	90	10	700	12	24	15.68	5.77

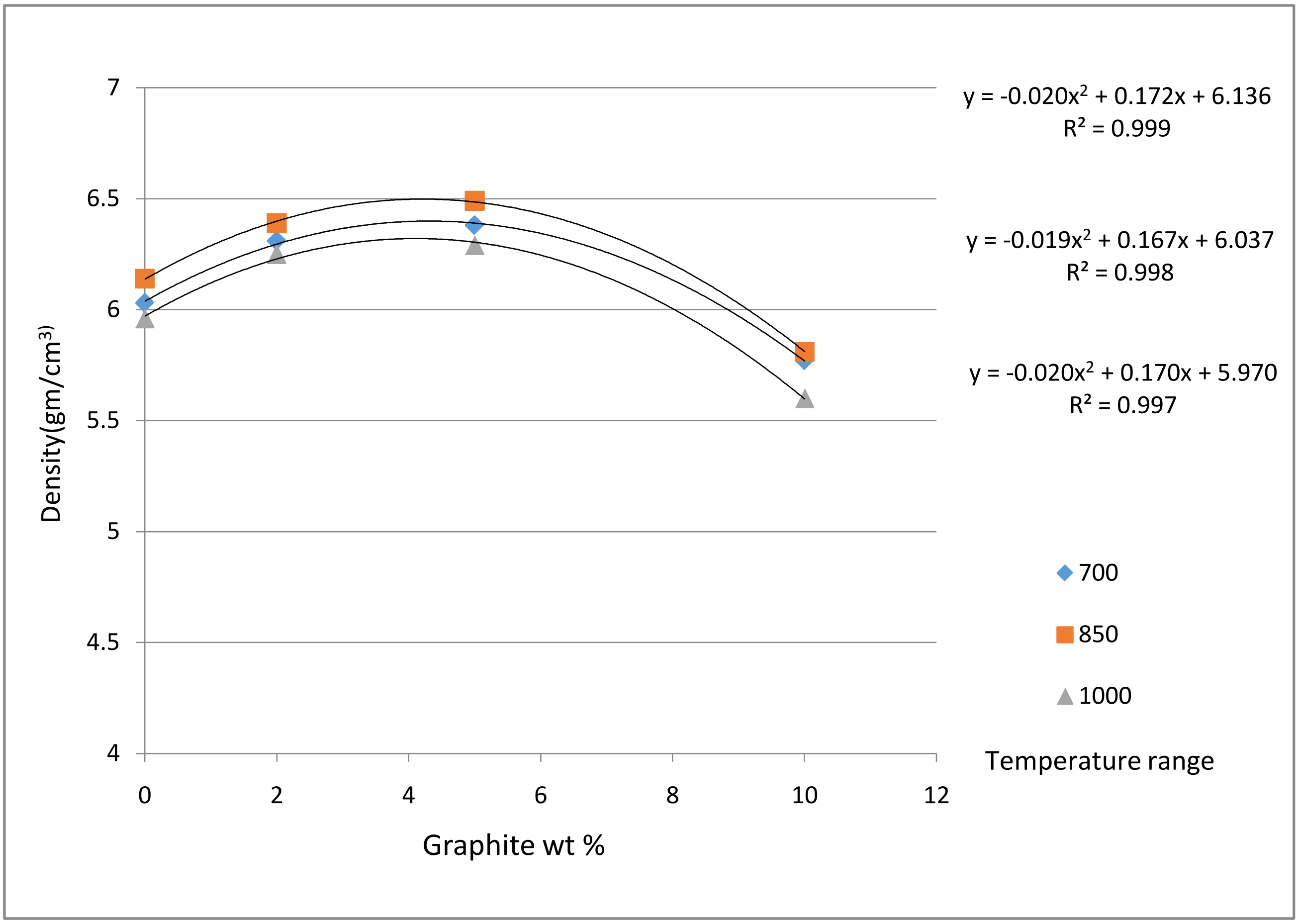


Figure 2 : effect of graphite wt % on temperature and density

VI. Conclusion

a) As graphite content increases from 0% to 2%, the microstructure of the iron-based powder sintered specimen changes gradually from ferrite and a small amount of pearlite to pearlite and a small amount of ferrite. After 2% of graphite contents the microstructure was found pearlite and ferrite. As graphite increase up to 5% gray cast iron structure and at 1000º C temperature range white cast iron structure found on the surfaces.

b) After 5% of graphite contents ferrite and cementite microstructure observed. White cast iron formed around 8% of graphite contents and free carbon particles seen on the surfaces.

c) The BCC structural ferrite properties shown in 700℃ and FCC structure austenite form in 1000℃.

d) The austenite grain size increases gradually when the graphite content increases.

e) The maximum value of density was found maximum between the range 2% to 5% of graphite contents.

f) Maximum density was found at the temperature 850ºC Sintering temperature range 700,850 and 1000℃ best result finding at 850℃ and followed by 700ºC and 1000ºC.

References Références Referencias

1. A.Salak. (1995). Ferrous Powder Metallurg. Cambridge UK: Cambridge Int. Sci. Pub.
2. ALKAN, A. (2011). PRODUCTION AND ASSESMENT OF COMPACTED GRAPHITE IRON DIESEL ENGINE BLOCKS.
3. Components, H. H. handbook. Hoganas publication.
4. Deng, X., Piotrowski, G., Chawla, N., &Narasimhan. (2008). Fatigue crack growth behavior of hybrid and prealloyed sintered steels. K.S. Materials Science & Engineering.
5. E.Dieter, G. Mechanical metallurgy. McGraw-Hill.
6. Herbert Danninger, C. G. (2011). IRON-CARBON MASTERALLOY – A PROMISING APPROACH FOR INTRODUCING CARBON INTO HIGH DENSITY SINTERED.
7. Mohammed El Sabagh, W. M. (2011). The Effect of Compacted Graphite Iron Microstructure on Fracture and Machining.
8. N.Dautzenberg, J. (1977). Reaction Kinetics during Sintering of Mixed Alloyed Steels of Iron and Graphite Powders.

9. NorazianaParimin, A. L. (2009). A STUDY OF MICROSTRUCTURE AND HARDNESS ON Fe-Co/SiC Composites. NUCLEAR and Related TECHNOLOGIES.
10. S.Upadhyaya, G. (2002). Powder metallurgy technology. CAMBRIDGE INTERNATIONAL SCIENCE PUBLISHING.
11. Verma, N., &Anand, S. (2007). Effect of Carbon Addition and Sintering Temperatures on Densification and Microstructural Evolution of Sinter-Hardening alloy steel.
12. Xiaoxun Zhang, F. M. (2012). Effects of Graphite Content and Temperature on Microstructure and Mechanical Properties of Iron-Based Powder Metallurgy Parts. Materials Science Research, 7.

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Economic Analysis of Combined Concrete Bed Energy Storage and Solar Collector System

By Adeyanju A. A.
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It was discovered that spherical shaped concrete of size 0.065m diameter has the highest blower cost of $TT37.83/day at 0.045m3/s due to low porosity and high pressure drop while concrete size 0.11m diameter has the lowest blower cost of $TT0.16/day at 0.0094m3/s.Also, spherical shaped concrete of size 0.065m diameter has the highest storage system daily cost of $TT38.83/day at 0.045m3/s while concrete size 0.11m diameter has the lowest daily cost of $TT1.16/day at 0.0094m3/s.

Keywords: economic analysis, concrete, packed-bed, storage system, solar collector.

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ECONOMICANALYSISOFCOMBINEDCONCRETEBEDENERGYSTORAGEANDSOLARCOLLECTORSYSTEM

Strictly as per the compliance and regulations of:

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Nomenclature

G = Air mass velocity through the bed$(\mathrm{kg/m^2s})$

α = *Solar* absorptance

τ = *Solar* transmittance

t = time

m = mass (kg)

$\dot{m}$ = mass flow rate of air (kg/s)

T = *Temperature* (K)

h = heat transfer coefficient$(\mathrm{W/m^2}K)$

W = Width of the solar collector(m)

$\$TT$ = Trinidad and Tobago Dollars

subscript:

a = ambient

ab = absorber

p = plate

r = radiative

c/ct = concrete/copper tube

s = solar

conv = convective

g = glazing

fa = air above absorber

fb = air below absorber

I. Introduction

Energy economics is a specialized field used to make decisions on energy purchases, selection of competing energy generation technologies, and financing of energy technologies. A thorough study of this subject is beyond the scope of this research, but every engineer should have a basic understanding of energy economics in order to bridge the gap between engineering decision analysis and economic decision analysis. The most efficient energy conversion technology may not be the most cost effective.

Any economic-based decision on energy or energy technology will include some type of analysis involving capital and recurring costs. The scope of the analysis can vary significantly. The particular choice of analysis will depend on the desired basis for comparison. Typically, these various analysis methods are subsets of three general methods [1]:

1. Determine largest possible savings in energy costs for a fixed budget;
2. Determine the minimum budget required to achieve a specified reduction in energy costs or utilization; and
3. Determine return-on-investment for an alternative energy system.

The type of analysis chosen has much to do with type of energy project being considered. For instance, a short-lived project will not be affected by the future value of money, but a project which is expected to take decades will certainly be affected by future costs. The cost effectiveness of the short-lived project may be

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accomplished using a simple payback method. The long-lived project may be better assessed through a life cycle analysis (LCA). Simple Payback Method determines the time period to recover capital costs. Typical considerations are[2]:

i. Accumulation of savings
ii. No future value of money
iii. No interest on debt
iv. No comparison to fuel costs

The Simple Payback Method penalizes projects with long life potentials in part because any savings beyond payback period are ignored. There is no accounting for inflation or for escalation of future savings in fuel costs that historically have increased at a faster rate than inflation.

Life Cycle Analysis, once called Engineering Economic Analysis, considers the total cost over anticipated useful life, where useful life is the lesser of lifetime or obsolescence. Analysis may include: Capital costs, operating costs, maintenance costs and contracts, interest on investment, fuel cost, salaries, insurance, salvage value and taxes.

Life Cycle Analysis (LCA) may account for all costs including indirect costs paid by society but not reflected as cash flow. An example would be health and environmental costs associated with pollution due to electric power generation from coal; a cost not directly paid by the power generating utility. The difficulty with life cycle analysis is that many of the costs are in the future and can only be estimated with some unknown uncertainty. New technologies may also result in unanticipated obsolescence that, in hindsight, will turn a `cost effective' decision into an investment loss.

For the purposes here, Life Cycle Analysis encompasses many variations. All of the economic evaluation analysis methods are attempting to do two things. The first is to manipulate costs and savings in time to some common basis. The second is to assess these costs against some comparative objective; i.e., (i) which energy system has the lowest total expense, (ii) which system maximized return on investment, (iii) which system will maximize savings in energy costs. Some common evaluation methods [3]are:

1. Life-Cycle Cost Method (LCC): all future costs are brought to present values for a comparison to a base case. The base case may be a conventional energy system, design variations in alternative energy systems, or the alternative of not making the investment. LCC is commonly used to determine the `cost- minimizing' option.
2. Levelized Cost of Energy (LCOE): seeks to convert all costs (capital and recurring) to a value per energy unit that must be collected (or saved) to ensure expenses are met and reasonable profits collected. Future revenues are discounted at a rate that equals the rate of return that might be gained on an investment of similar risk; often called the `opportunity cost of capital'. LCOE is often used to compare competing energy producing technologies.
3. Net Present Value (NPV): (also known as Net Benefits, Net Present Worth, Net Savings Methods) determines the difference between benefits and expenses with everything discounted to present value. NPV is used for determining long-term profitability.
4. Benefit-to-Cost Ratio (BCR): (also known as Savings-to-Investment Ratio) is similar to NPV, but utilizes a ratio instead of a difference. Benefits usually imply savings in energy cost. What to include in the numerator (benefits) and denominator (costs) varies and care should be taken when assessing a reported benefit-to-cost ratio. This method is often used when setting priorities amongst competing projects with a limited budget. Projects with the largest ratio get the highest priority.
5. Overall Rate-of-Return (ORR): determines the discount rate for which savings in energy costs are equal to total expenditures. This is equivalent to determining the discount rate that results in a zero NPV. Previous methods require a specifying a discount rate; this method solves for the discount rate. This method enables cash flow to be expressed in terms of the future value at the end of the analysis period.
6. Discounted Payback Method (DPM): determines the time period required to offset the initial investment (capital cost) by energy savings or benefits.

Unlike the simple payback method, the time value of money is considered. DPM is often used when the useful life of the project or technology is not known.

The performance of the concrete bed storage system is influenced by various design and operational parameters such as size and configuration of the concrete, size of bed, air mass flow rate,void fraction within the bed, thermal and physical properties of concrete, and inlet temperature of air.

For efficient applications, many scientists have studied the performance and approximate designing methods of packed bed energy storage system. Clark and Beasley [4] have developed one and two dimensional numerical models for the dynamic response of both fluid and solid temperatures in a packed bed and have studied the effects of void fraction, flow distribution, wall heat capacity, and wall energy losses on the dynamic response of the packed bed subjected to an arbitrary time dependent inlet and initial temperatures. Clark and Nabozny [5] also developed a computer program for formulating the dynamic response and thermal storage capacity of a packed bed storage unit for both charging and recovery modes. Saez and McCoy [6] model includes axial thermal dispersion as well as intra particle conduction. Rao and Suri [7] investigated both analytical and theoretical unsteady state heat transfer through packed bed storage of homogenous spheres. Chandra and Willits [8] conducted an experimental study and concluded that pressure drop is affected by rock size, bed porosity, and air flow rate. They also discovered that volumetric heat transfer coefficient depend only on rock size and air flow rate.

This study carried out the economic analysis of combined packed bed storage and solar collector system using the present value methods which can be used to bring all future costs, which may occur in different years, back to today's value of money. In this way, the cost effectiveness of different energy technologies can be compared on an equal basis.

II. Methodology

a) Theoretical Analyses of the Combined Packed Bed Storage and Solar Collector System

Figure 1.0 shows the schematic of the combined packed bed energy storage system and solar collector system.The size of the duct was 3 x 0.5 x 0.0254m. The packed bed storage system consists of packed spherical shaped concrete imbedded with copper tubes, an inlet plenum chamber and outlet plenum chamber. The copper tube was of type L and of 0.00635m standard size. The outside diameter of the copper tube was 0.02223m, the inside diameter was 0.01994m, wall thickness of 0.01143m, length 1.32m, number of copper tubes were 4 of two passes with radius 0.115m. The spherical shaped concrete was made of ratio 1:1.2:1.1 of cement, sand and gravel, respectively. Storage tank having 0.70 m diameter was made of MS sheet of 3.00 mm thickness. The tank was 1.07 m high, including lower and upper plenums of height 0.25 m each resulting to packed bed height of 0.47 m. Tank was insulated with fiber glass to minimize the heat losses.

The entry and exit lengths were 0.65 and 0.96m respectively, including the inlet plenum and outlet plenum height of 0.3 m each.

The solar air heater (SAH) has (1.90 x 0.80 x 0.1 m3) outer dimensions. The top of the SAH was covered with a single transparent glass layer. High transmissivityto solar radiation glass cover of 0.005m thickness. The gap spacing between the absorber plate and the glass cover is about 0.05m. The air heater frame was constructed from wooden plate of 0.012m thickness except at the bottom which has 0.019m thickness. The absorber plate which is made of aluminum plate having 0.0015m thickness was painted with matt black layer to increase the absorptivity of the solar radiation and thereby reduces the temperature gradient between the inside and outside surfaces. The air was heated while passing between the transparent glass cover and absorber plate. The system was insulated from all sides and bottom by a 0.05m thickness fine wood frame to reduce the heat losses to ambient air. The whole air heater was oriented to face south and tilted 100 with respect to the horizontal to maximize the solar radiation incident on the air heater.

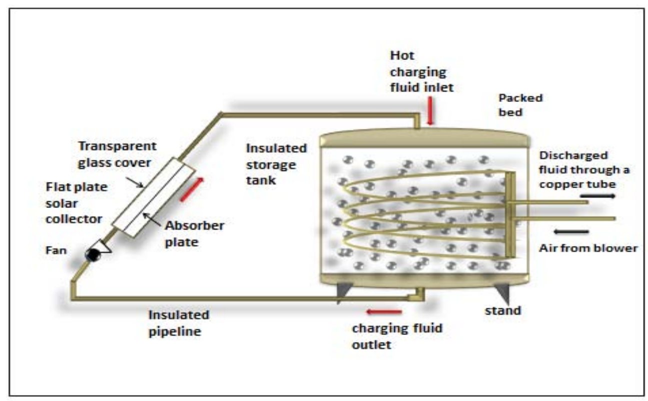

Figure 1.0 : Schematic of Combined Packed Bed Energy Storage and Solar Collector System

Therefore, the design of the concrete bed in this study has been made for the above design and operational parameters of combined packed bed energy storage system and solar collector system.

III. Daily Energy Stored in the Packed Bed

The energy balance equations for different components of the solar collector air heater and the packed bed energy storage system and their initial and boundary conditions are given below [9].

a) Solar Collector Air Heater

$$m_g C_g \frac{\partial T_g}{\partial t} = \alpha_g H + h_{r,ab,g}\left(T_{ab} - T_g\right) - h_{conv,g,fa}\left(T_g - T_{fa}\right) - h_{g,a}\left(T_g - T_a\right) \quad (1)$$

$$m_{fa} C_{fa} \frac{\partial T_{fa}}{\partial t} + \left(\frac{\dot{m}}{W}\right) C_{fa} \frac{\partial T_{fa}}{\partial x} = h_{conv,ab,fa}\left(T_{ab} - T_{fa}\right) + h_{conv,g,fa}\left(T_g - T_{fa}\right) \quad (2)$$

$$m_{ab}C_{ab}\frac{\partial T_{ab}}{\partial t}=\tau_g\alpha_{ab}H-h_{r,g,ab}\left(T_{ab}-T_g\right)-h_{conv,ab,fa}\left(T_{ab}-T_{fa}\right)-h_{r,ab,p}\left(T_{ab}-T_p\right)-h_{conv,ab,fb}\left(T_{ab}-T_{fb}\right) \quad (3)$$

$$m_{fb}C_{fb}\frac{\partial T_{fb}}{\partial t}+\left(\frac{\dot{m}}{W}\right)C_{fb}\frac{\partial T_{fb}}{\partial x}=h_{conv,ab,fb}\left(T_{ab}-T_{fb}\right)-h_{conv,p,fb}\left(T_{fb}-T_p\right) \quad (4)$$

$$m_pC_p\frac{\partial T_p}{\partial t}=h_{r,ab,p}\left(T_{ab}-T_p\right)+h_{conv,p,fb}\left(T_{fb}-T_p\right)-U_r\left(T_p-T_a\right) \quad (5)$$

b) *Packed Bed*

$$\rho_fC_f\varepsilon\frac{\partial T_f}{\partial t}+GC_f\frac{\partial T_f}{\partial x}=h_{Vf(c/ct)}\left(T_{c/ct}-T_f\right) \quad (6)$$

$$\rho_{c/ct}C_{c/ct}\left(1-\varepsilon\right)\frac{\partial T_{c/ct}}{\partial t}=h_{Vf(c/ct)}\left(T_f-T_{c/ct}\right) \quad (7)$$

c) *Initial and boundary conditions*

$$T_f\left(x,0\right)=T_{fi}=T_a\left(1\right) \text{ and } T_b\left(x,0\right)=T_b=T_{ia}\left(1\right) \quad (8)$$

$$T_{fa}\left(x,0\right)=T_{fb}\left(x,0\right)=T_a\left(1\right) \text{ and } T_{ab}\left(x,0\right)=T_p\left(x,0\right)T_g\left(x,0\right)=T_a\left(1\right) \quad (9)$$

$$T_{fa}\left(0,t\right)=T_a = \text{inlet temperture for solar air heater, if } \left[T_b\left(F_L,t\right)<T_a\right] \quad (10)$$

Where, F_L is the flow length

$$T_{fa}\left(L,t\right)=T_{fb}\left(0,t\right)$$

$$T_{fb}\left(L,t\right)=T_{fo} = \text{outlet air temperture for solar air heater for the bed.} \quad (11)$$

The temperatures of the air T_f and solids T_b within the packed bed at different locations and times were calculated by solving the above equations which use the finite difference method.

The daily energy stored $Q_s\left(KWh\right)$ was calculated as follows:

$$Q_s=\frac{\sum_{i=0}^{n-1}\left[\frac{\left\{T_b\left(i\right)+T_b\left(i+1\right)\right\}}{2}-T_a\left(1\right)\right]}{n\left(3.6\times10^6\right)}m_bC_bA_b \quad (12)$$

Where, $T_b\left(i\right)$ is the packed bed temperature at the ith zone and n is the number of zones.

The radiative $h_{r,ab,g}$ and $h_{r,ab,p}$, wind related convective $\left(h_{g,a}\right)$ and conductive $\left(U_r\right)$ heat transfer coefficients were calculated by using the standard heat transfer relations summarized in [10]. The forced convective heat transfer coefficients for the air heater $h_{conv,g,fa}$, $h_{conv,ab,fa}$, $h_{conv,ab,fb}$, and $h_{conv,p,fb}$, were calculated by using the relation derived by Tan and Charters [11]. The heat transfer coefficient between air and concrete and copper tube in the bed $\left(h_{Vf(c/ct)}\right)$ were computed by using the Coutier and Farber [12] relation which can be written as follows.

$$h_{Vf(c/ct)} = 700\left(\frac{G}{D_{c/ct}}\right)^{0.76} \quad (13)$$

IV. Daily Cost of the Storage System (DC)

In order to calculate the daily cost (DC) of the packed bed solar thermal energy storage system together with the solar air heater device, the different cost factors were calculated as given below [9].

a) *Daily blower cost (DBC)*

$$DBC = \frac{0.746\left(\dot{m}\Delta p c_{KW/h} h\right)}{\eta_m} \quad (14)$$

$c_{KW/h}$ = cost of electricity in KW/h

η_m = Electric motor efficiency

The pressure drop Δp can be determined using the relation:

$$\Delta p = f\left(\frac{F_L}{D_{c/ct}}\right)\left(\frac{G^2}{\rho_f}\right)\left(\frac{1-\varepsilon}{\varepsilon^3}\right) \quad (15)$$

$$\text{friction factor } (f) = \frac{150(1-\varepsilon)}{R+1.75} \quad (16)$$

$$R = \frac{GD_{c/ct}}{\mu} \quad (17)$$

b) *Daily capital cost of the bed and the solar air heater devices (DCC)*

$$DCC = CR\left(\frac{CI}{300}\right) \quad (18)$$

Where, Capital recovery (CR)

$$CR = \left[\frac{(CI - SV)}{SPWF}\right] + SV \times i \quad (19)$$

$SPWF$ = Series present forth factor (Table 1.0)

$$\text{Capital investment or first cost of the solar system } (CI) = \text{Material cost + Blower cost + Paint cost + Fabrication cost} \quad (20)$$

$$\text{Salvage Value } (SV) = 0.1(CI) \quad (21)$$

Daily Salvage Value (DSV)

$$(DSV) = \frac{(SFF)(SV)}{300} \quad (22)$$

$$\text{Where, Salvage Fund Factor } (SFF) = \frac{i}{\left[(i+1)^n - 1\right]} \quad (23)$$

i = interest rate rapid on borrowed, earned or saved money

c) *The Daily Maintenance Cost (DMC)*

The daily maintenance cost of the packed bed storage and the solar air heater device were considered to be 10% of the daily capital cost (DCC) of the system.

The Daily Cost (DC) of the system was then calculated and presented as shown in Figure 3.0.

Table 1.0 : Series Present worth Factors (SPWF).Factors for computing annual cost of investment over "N" years of life at the interest rates shown [2]

				Interest rate					
N	6%	8%	10%	12%	14%	16%	18%	20%	N
1	0.943	0.926	0,909	0.893	0.877	0.862	0.847	0.833	1
2	1.833	1.783	1,736	1.690	1,647	1.605	1.566	1.528	2
3	2.673	2.577	2.487	*2.402*	2.322	2.246	2.174	2.106	3

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4	3.465	3.312	3.170	3.037	2.914	2.798	2.690	2.589	4
5	4.212	3.993	3.791	3.605	3.433	3.274	3.127	2.991	5
6	4.917	4.623	4.355	4.111	3.889	3.685	3.498	3.326	6
7	5.582	5.206	4.868	4.564	4.288	4.039	3.812	3.605	7
8	6.210	5.747	5.335	4.968	4.639	4.344	4.078	3.837	8
9	6.802	6.247	5.759	5.328	4.946	4.607	4.303	4.031	9
10	7.360	6.710	6.145	5.650	5.216	4.833	4.494	4.192	10
11	7.887	7.139	6.495	5.938	5.453	5.029	4.656	4.327	11
12	8.384	7.536	6.814	6.194	5.660	5.197	4.793	4.439	12
13	8.853	7.904	7.103	6.424	5.842	5.342	4.910	4.533	13
14	9.295	8.244	7.367	6.628	6.002	5.468	5.008	4.611	14
15	9.712	8.559	7.606	6.811	6.142	5.575	5.092	4.675	15
16	10.106	8.851	7.824	6.974	6.265	5.668	5.162	4.730	16
17	10.477	9.122	8.022	7.120	6.373	5.749	5.222	4.775	17
18	10.828	9.372	8.201	7.250	6.467	5.818	5.273	4.812	18
19	11.158	9.604	8.365	7.366	6.550	5.877	5.316	4.843	19
20	11.470	9.818	6.514	7.469	6.623	5.929	5.353	4.870	20

$DC = DCC = DMC = DPC - DSV$ (24)

V. Results and Discussions

For the numerical calculation the cost of absorbing paint was assumed as TT$ 7.0/m2, solar collector cover glass as TT$ 18.0/m2, air duct material as TT$ 23.0/m2, absorber plates as TT$ 19.0/m2, concrete materials as TT$ 44.0/m2 , fiberglass (insulation) as TT$ 12.0/m2 , wood as TT$ 15.0/m2 , and sheet metal as TT$ 45.0/m2. The cost of the blower is TT$ 650.0 and the cost of electricity as 27 cents. The rate of interest (i) was assumed as 10% and life of device (n) as 10 years. The fabrication cost was considered to be 25% of the capital investment. The operational time was considered as 300 days/year and 9 hours/day. Figures 78.0 and 79.0 shows the daily blower cost and daily cost of the entire packed bed storage system respectively as function of air flow rate for spherical shaped concrete of diameter 0.065m, 0.08m and 0.11m.

Spherical shaped concrete of size 0.065m diameter has the highest blower cost of $TT37.83/day at 0.045m3/s due to low porosity and high pressure drop while concrete size 0.11m diameter has the lowest blower cost of $TT0.16/day at 0.0094m3/s as shown in Figure 2.0.

Also, Spherical shaped concrete of size 0.065m diameter has the highest storage system daily cost of $TT38.83/day at 0.045m3/s while concrete size 0.11m diameter has the lowest daily cost of $TT1.16/day at 0.0094m3/s as shown in Figure 3.0.

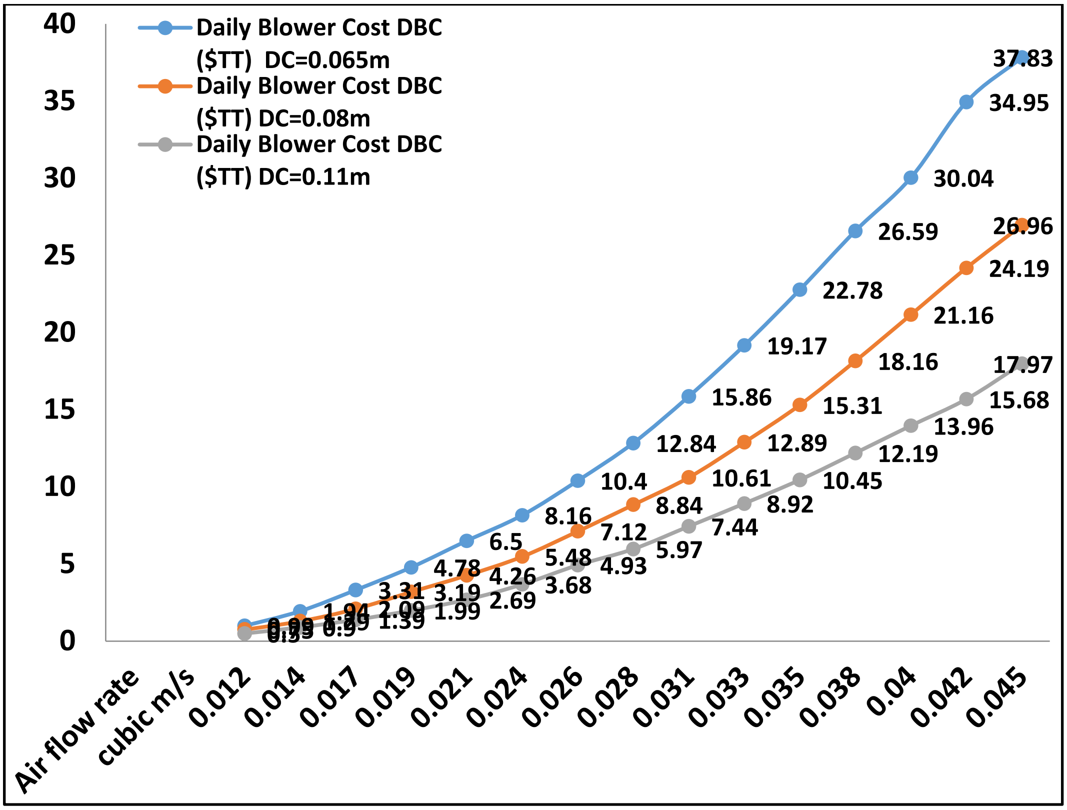

Figure 2.0 : Daily blower cost as function of air flow rate for different spherical shaped concrete of diameter 0.065, 0.08 and 0.11m

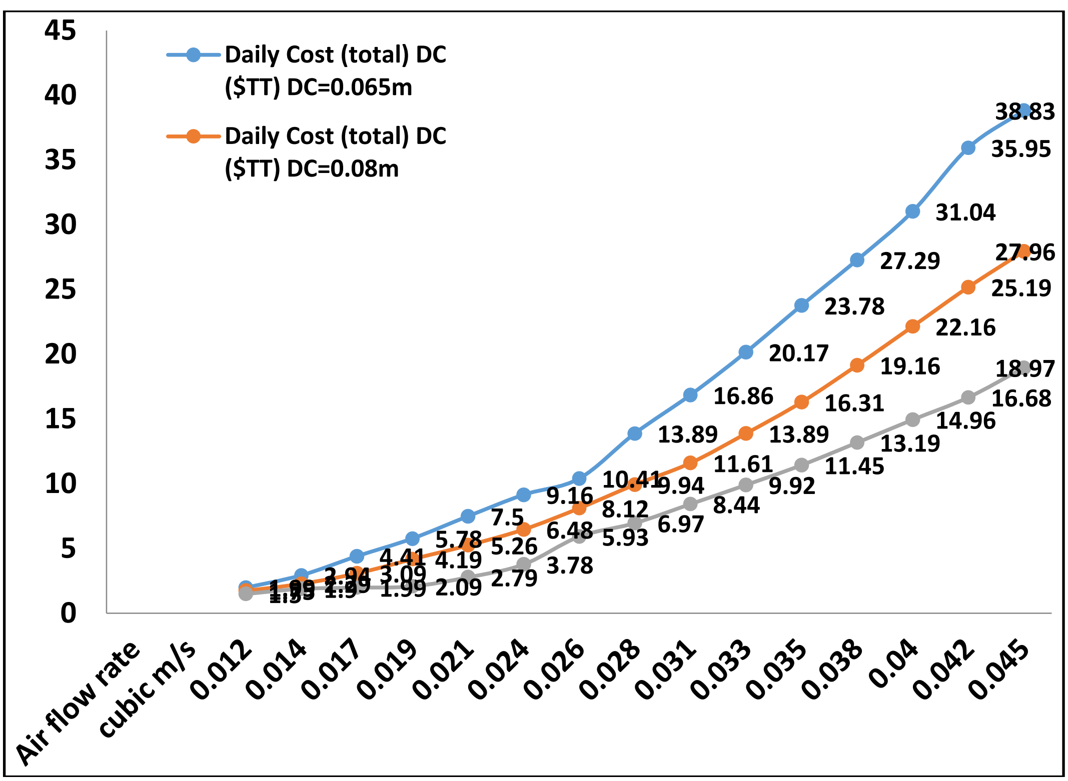

Figure 3.0 : Daily cost of the entire packed bed storage system as function of air flow rate for spherical shaped concrete of diameter 0.065, 0.08 and 0.11m

VI. Conclusion

The price of the combined packed bed energy storage and solar collector system needs to be determined, which allows the gross income calculation. Additional costs for the annual operation and maintenance was taken into account.

From the above discussion it was discovered that spherical shaped concrete of size 0.065m diameter has the highest blower cost of $TT37.83/day at 0.045m3/s due to low porosity and high pressure drop while concrete size 0.11m diameter has the lowest blower cost of $TT0.16/day at 0.0094m3/s. Also, spherical shaped concrete of size 0.065m diameter has the highest storage system daily cost of $TT38.83/day at 0.045m3/s while concrete size 0.11m diameter has the lowest daily cost of $TT1.16/day at 0.0094m3/s.

References Références Referencias

1. Krieth, F and D.Y. Goswami. 2007. Handbook of Energy Efficiency and Renewable Energy. CRC Press.
2. Thumann, A. and S.C. Dunning. 2008. Plant Engineers and Managers Guide to Energy Conservation. The Fairmont Press, Inc., 9th edition, 2008.
3. Vanek, M. F. and L.D. Albright. 2008. Energy Systems Engineering - Evaluation and Implementation. The McGraw-Hill Companies, Inc.
4. Clark, J.A. and Beasley D.E. 1982. Dynamic Response of a Packed Bed Thermal Storage Unit.Prog. Solar Energy, pp. 525-530. International Solar Energy Society.
5. Clark, J. A. and Nabozny R. I. 1977. Heat Storage and Thermal Transfer Aspects of the Dynamic Behavior of a Packed Bed. Paper Presented at the International Meeting on Solar Heating of Buildings and Water. Univ. De Liege, Liege, Belgium. 12-14 September 1977.
6. Saez, A. E. and McCoy B. J. Dynamic Response of A Packed Bed Thermal Storage System. A Model for Solar Air Heating.Solar Energy 29 No. 3.
7. Rao, S. K. and Suri R.K. 1969. Thermal Characteristics of Homogeneous Packed Beds with Steady Fluid Flow.Journal of Mechanical Engineering 50 (1).
8. Chandra P. and Willits D. H. 1981. Pressure Drop and Heat Transfer Characteristics of Air-Rock Bed Thermal Storage System.Solar Energy 27 No.6.
9. Choudhury, C; P. M. Chauhan and H. P. Garg. 1995. Economic Design of a Rock Bed Storage Device for Storing Solar Thermal Energy. Journal of Solar Energy 55: 29 – 37.
10. Duffie, J. A., and W. A. Beckman. 2006. Solar Engineering of Thermal Processes. New York: John Wiley.
11. Tan, H. and W. W. S. Charters. 1969. Effect of Thermal Entrance Region on Turbulent Forced Convective Heat Transfer for an Isometrically Heated Rectangular Duct with Uniform Heat Flux. Journal of Solar Energy 12.
12. Coutier, J. and E. Farber. 1982. Two Applications of a Numerical Approach of Heat-Transfer Process within Rock Beds. Journal ofSolar Energy 29 (6): 451- 462.

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Design and Construction of a Wind Tunnel with Microcontroller based Isokinetic Probe for Sampling Aerosol Particle

By Masud M. H., Noor M. M. & Akhter M. S.
Rajshahi University of Engineering and Technology, Bangladesh

Abstract- Wind tunnel is a simple but marvelous element of scientific research and expanding empire of application day by day. Wind tunnel has been used in racing cars, airplanes, weather patterns, skydiving simulations and for aerofoil testing in laboratories. In this study, a wind tunnel with isokinetic probes has been designed, fabricated and tested for sampling aerosol particles. The cross section of the wind tunnel is circular having six inch in diameter. The type of flow in the tunnel is open, uniform and the cross sectional area is constant throughout the tunnel. In this work, an atomizer generates polydisperse aerosols in a generation chamber and monodispersetest aerosols are produced by separating the polydisperse aerosols in an improved virtual impactor. The monodisperseaerosols are passed through the wind tunnel and sampling is done in the tunnel. Isokinetic sampling probes have been designed, fabricated and installed at different locations of the tunnel for sampling generatedmonodisperse aerosol particles. Probe velocity measuring device by using pressure sensor named (MPXV5050GP) is also fabricated for making the sample isokinetic.

It has been found that the sampling of aerosols is better than the conventional sampling in the outlet pipe in respect of less particle loss. The monodisperse aerosols in the wind tunnel help us to carryout research on aerosol properties and to calibrate the air pollution measuring instruments available in the market.

Keywords: aerosol; wind tunnel; atomizer; isokinetic probe; pressure sensor.

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I. Introduction

An aerosol is defined as a colloidal system of solid or liquid particles in a gas. An aerosol includes both the particles and the suspending gas, which is usually air. This term developed analogously to the term hydrosol, a colloid system with water as the dispersing medium. Primary aerosols contain particles introduced directly into the gas; secondary aerosols form through gas-to-particle conversion [1]. Aerosols vary in their dispersity. A mono disperse aerosol, producible in the laboratory, contains particles of uniform size. Most aerosols, however, as poly disperse colloidal systems, exhibit a range of particle sizes. Liquid droplets are almost always nearly spherical, but scientists use an equivalent diameter to characterize the properties of various shapes of solid particles, some very irregular. In our experiment we produced monodisperse aerosol. An important element of aerosol technology is the production of test aerosols for instrument calibration, aerosol research, and the development and testing of air cleaning and air sampling equipment. Monodisperse aerosols are used to calibrate particle-size measuring instruments and to determine the effect of particle size on sampling devices [2]. In our experiment the mono disperse aerosol is used for sampling in the wind tunnel and to calibrate particle size measuring instrument. Several researches have contributed to experimental aerosol science by developing instruments and experimental techniques for calibrating optical counters [3, 4, 5, 6] diffusion batteries [7] and fluidized-bed aerosol generators for aerosol research.

The process of atomization is one in which a liquid jet or sheet is disintegrated by the kinetic energy of the liquid itself or by exposure to high velocity air or gas as a result of mechanical energy applied externally through a rotating or vibrating device(Lefebvre, 1989).There are several basic processes associated with all methods of atomization, such as the conversion of bulk liquid into a jet or sheet and the growth of disturbances which ultimately lead to disintegration of the jet or sheet into ligaments and then drops [8]. In 1888, Toledo's Dr. Allen De Vilbiss developed an atomizer. De Vilbiss used the atomizer to spray a small dose of medicine down the throats of his patients. Later on, the atomizer was repurposed as a spray finisher. In the early 1900s, atomizers began to be used to hold perfume[9].There are three basic types of nozzles currently been used

- High and intermediate pressure single-fluid nozzles (mean droplet diameters in the range of 30 to 100 μm)
- Low pressure single- fluid nozzles (range 200 to 300 μm).
- Twin-fluid nozzle (mean diameters of 100 to 200 μm)

There are mainly three types of twin fluid atomizer. They are air blast atomizer, air-assist atomizer, Effervescent atomizer [10]. In our experiment three types of atomizer for different air inlet diameter, constricted area diameter and exit nozzles diameters was fabricated

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and installed at the bottom of the generation chamber. Here atomizer generates polyd- isperse aerosols in a generation chamber and monod- isperse aerosols are produced by spreading the polydisperse aerosols in an improved virtual impactor. The collection efficiency of the virtual impactor has been calculated numerically and tested with large-scale equipment [11]. The monodisperse aerosols are passed through the wind tunnel and sampling is done in the tunnel.

The wind tunnel is a tool used in aerodynamic research to study the effects of air moving past solid objects. In another word a wind tunnel consists of a closed tubular passage with the object under test mounted in the middle [12]. A wind tunnel is generally sort of a duct or pipe shape and air is either blown or pulled out of the tunnel by a fan or other drive system (a machine which creates force).One of the most important sections of the tunnel is what is called the "test section". This is the area where the model to be tested is placed. It can be of different type which has different use. And the tunnels are manufactured for different purposes. But no wind tunnel is used ever for the sampling of aerosol particle. In our experiment a wind tunnel is manufactured and installed for the sampling of aerosol particle. The shape of the wind tunnel which is designed and manufactured in our experiment is circular having six inch in diameter. The type of flow in the tunnel is open, uniform and the cross sectional area is constant uniform throughout the tunnel. The reason for which diameter of both wind tunnel and generation chamber is same. Is that if the diameter of the tunnel is greater than the generation chamber then stream line will diverge and for the reason wall deposition become higher and finally the loss of aerosol particle. If the opposite phenomenon is occurred then the steam line will converge and particle loss will increase due to coalescence of particles.

Isokinetic sampling is a procedure to ensure that a representative sample of aerosol enters the inlet of a sampling tube when sampling from a moving aerosol stream. The Isokinetic or constant velocity sampling is the preferred method for determining particulate concentrations in fluid streams. In other word Isokinetic sampling is a procedure to ensure that a representative sample of aerosol enters the inlet of a sampling tube when sampling from a moving aerosol stream [13]. For isokinetic sampling, isokinetic sampling probe must be used. Sampling from fluid streams of air, flue gas, steam, or any media that contains entrained particles is very difficult. If the fluid is homogenous, the sampling is relatively simple since the fluid has the same consistency throughout the flow area. This is not the case with fluids having entrained particles. Particle concentration changes because of the flow pattern inside the fluid stream. There are two major problems in getting a correct sample. The large cross section area of the flue gas duct results in flow segregation due to many reasons [14].Taking a large number of samples from points across the duct avoids the effect of this segregation. The sample is drawn out of the flue gas duct by suction from each point through a sampling tube. If the sampling velocity at the point of sampling is less than the fluid velocity, then all the particles, especially the smaller size particles, will not enter the sampling tube. If the velocity is more, then more particles will enter the tube, again especially the smaller particles. Both conditions produce samples with wrong concentration. For avoiding these errors the isokinetic sampling probe is introduced.

The air velocity measuring device is done by micro controlling base programming. By using U tube manometer and the air pressure sensor the velocity of aerosol particle is measured. So that isokinetic sampling probe can be designed for our sampling purpose.

II. Experimental Setup

The photographic view of the experimental setup is shown in Fig. 1. The compressed atmospheric air from a floor mounted compressor is filtered by high pressure filter placed on its way to the atomizer. Three rotameters are used to measure the air flow rate at three different positions namely in the atomizer entrance, in the clean air tube entrance, and on the way of major flow. Poly-disperse aerosols are produced by the atomizer which draws air and liquid through two separate passages installed at the bottom of the generation chamber.

(a) (b)

Figure 1 : Photographic view of experimental setup of aerosol generation system (a) without wind tunnel and(b) with wind tunnel

The atomizer was designed according to Bernoulli's principle where the liquid is sucked into the atomizer by siphoning. There is a constricted area inside the atomizer and a liquid line is connected to the atomizer through the constricted area. When air is passed through the atomizer, the velocity of air increases at the constricted area and according to Bernoulli's principle pressure will be decreased to the atmospheric pressure as the velocity increases. As the liquid is contained at the atmospheric pressure there creates a pressure differential (vacuum pressure) inside the atomizer. Due to the pressure differential the liquid is sucked into the atomizer by siphoning and breaks into fine small droplets that are delivered to the outlet [15]. For our experiment we manufactured three atomizers, the specifications of whose are given below:

- for atomizer no. 1, air inlet diameter=18 mm, diameter of the constricted area=3mm, exit nozzles diameters= 4.5 mm, 5.5 mm, 6 mm, 6.5 mm and liquid jet diameter=2 mm. For atomizer no.2, air inlet diameter=18 mm, diameter of the constricted area=2.5 mm, exit nozzles diameters= 4.0 mm, 4.5 mm and liquid jet diameter=1.5 mm. For atomizer no.3,air inlet diameter=18 mm, diameter of the constricted area=3.75 mm, exit nozzles diameters= 4.5 mm, 5.5 mm, 6 mm, 6.5 mm, liquid jet diameter=2 mm

The produced aerosols by the atomizer move vertically upward and pass through the improved virtual impactor stage which separates smaller particles from larger particles. A clean air core is also provided at the entrance of the virtual impactor with a view to reducing the fine particle contamination in the minor flow. The major flow, which is ultimately released to the atmosphere, is drawn from the virtual impactor stage by a blower. The rest of the total flow, called minor flow, is passed through the designed wind tunnel. While passing through the wind tunnel, aerosol is sampled by the isokineting sampling probe at different location of the tunnel. Finally the particle size distribution is measured by optical particle counter (OPC) SOLAIR-3100 as shown in Fig. 2.The specification of the OPC is given in appendix1.

*Figure 2 :*Solair-3100 1.0 Cfm Optical Particle Counter

The fabricated isokinetic sampling probe is shown in Fig. 3

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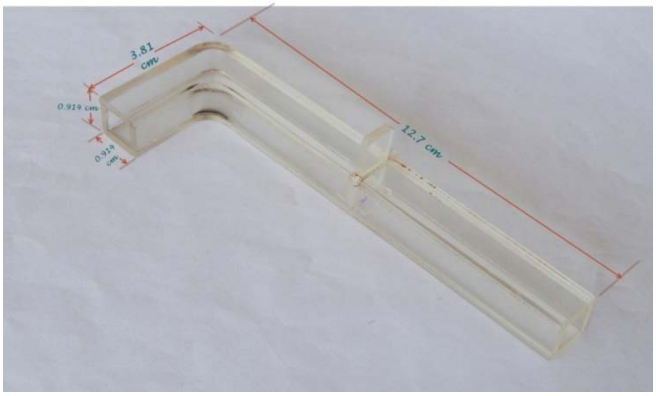

Figure 3 : Isokinetic sampling probe

For designing the isokinetic sampling probe velocity at different points is measured in the wind tunnel. The measuring point of velocity is shown in the experimental setup indicated by name as positions of probe.The velocity in the probe is measured by using an air pressure sensor named(MPXV5050GP).

Fig. 4 shows the system circuit of microcontroller based air velocity measuring system. Fig.5 shows the block diagram of the same. The system mainly consists of air velocity detection system and microcontroller with LCD interfacing.

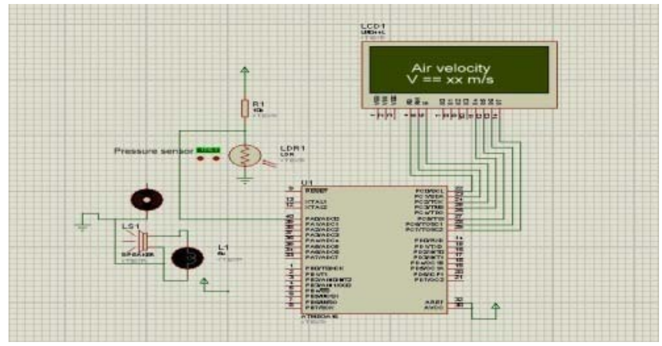

Figure 4 : Circuit diagram of microcontroller based Air velocity measuring system

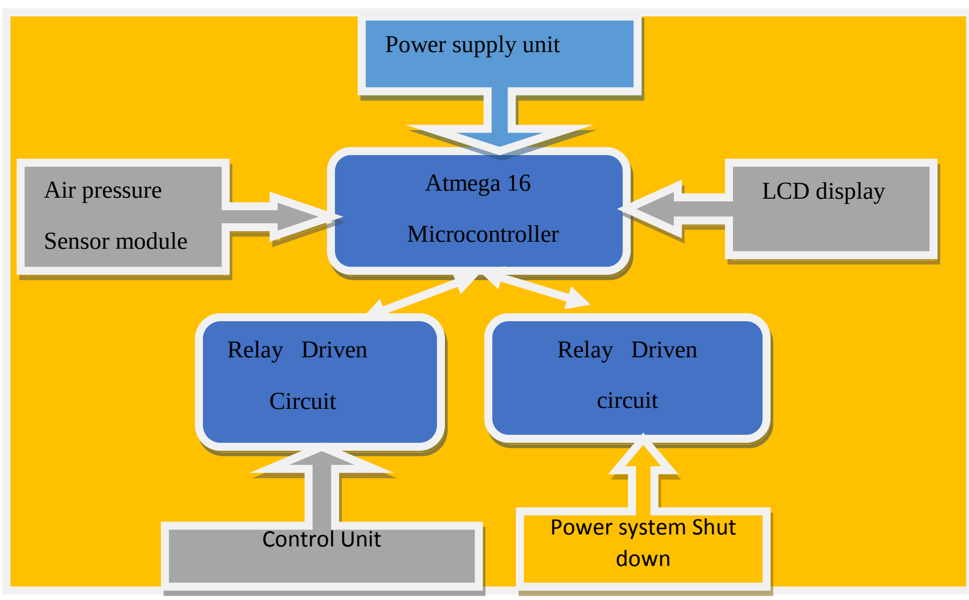

Figure 5 : Block diagram of microcontroller based Air velocity measuring system

The microcontroller controls the whole system. It controls the valve position according to the change in velocity occurring in the isokinetic sampling probe. The input/ output ports of the microcontroller is used for this [16].

The assembled circuit board with the pressure sensor (MPXV5050GP) is shown in Fig. 6 whose working principle is already shown in the block diagram (Fig. 5).

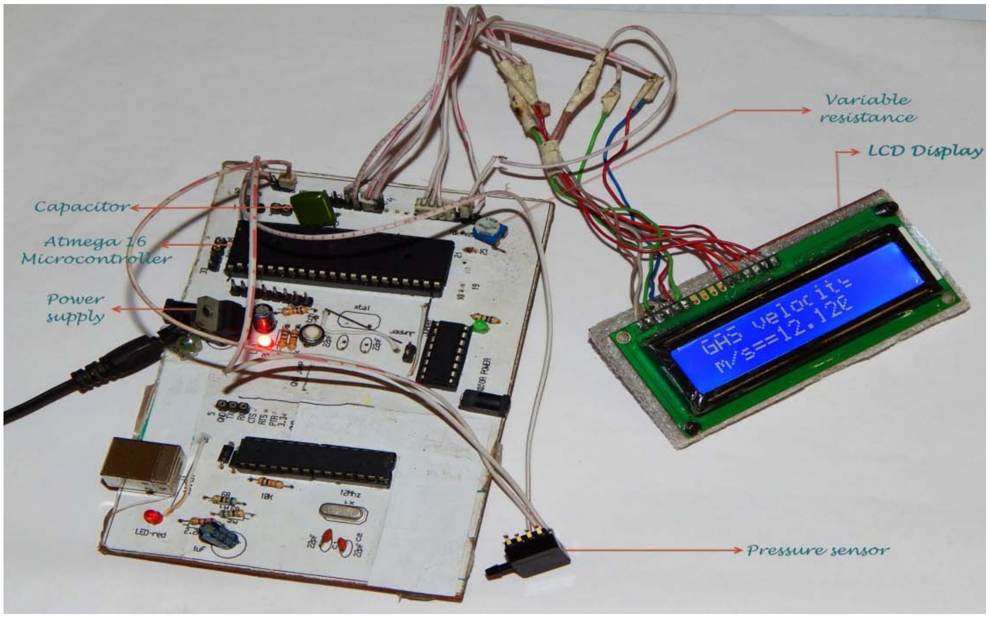

Figure 6 : Circuit board with the all necessary attachment

The sensor probe has been designed by calculating the air velocity. Aerosol is collected and counted by optical particle counter by using the probe.

III. Results and Discussion

Figures 7, 8 and 9 show the particle size distribution without wind tunnel and microcontroller based isokinetic probe for atomizer no.1 to atomizer no.3 respectively at constant air flow rate of 180 lpm, liquid consumption of 138ml/hr and minor flow rate of 15lpm. In all the diagram Dc denoted diameter of constriction and Do denote outer nozzle diameter.

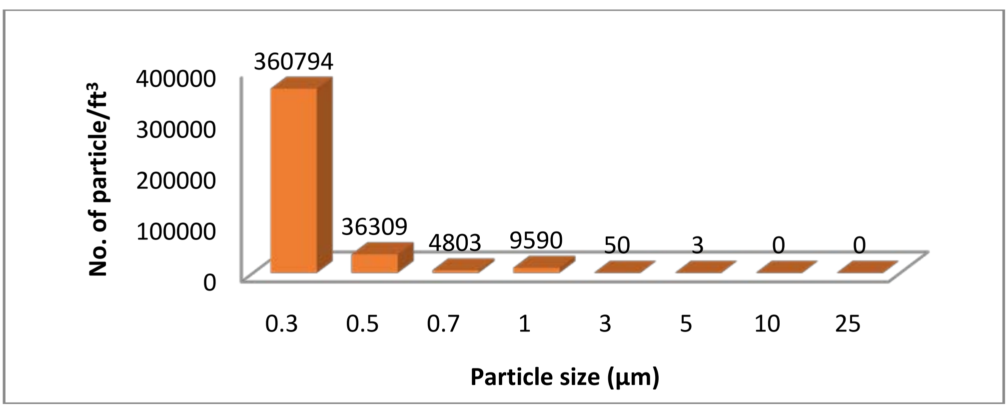

Figure 7 : Particle size distribution by atomizer no.1 without wind tunnel

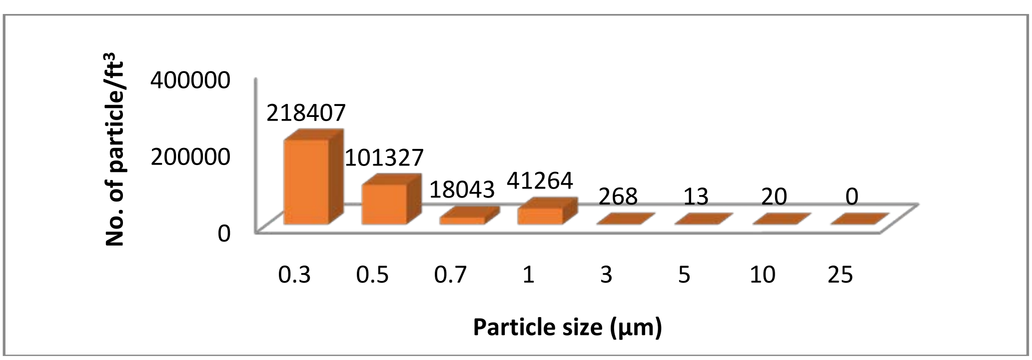

Figure 8 : Particle size distribution generated by atomizer no.2 without wind tunnel

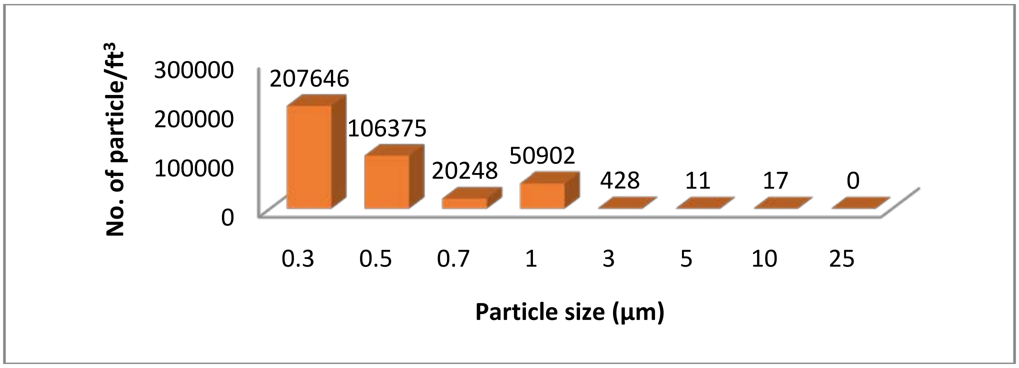

Figure 9 : Particle size distribution generated by atomizer no.3 without wind tunnel

Figs. 11, 12 and 13 show the particle size distributions for different atomizers for the same flow conditions with the wind tunnel and microcontroller based isokinetic sampling probes.

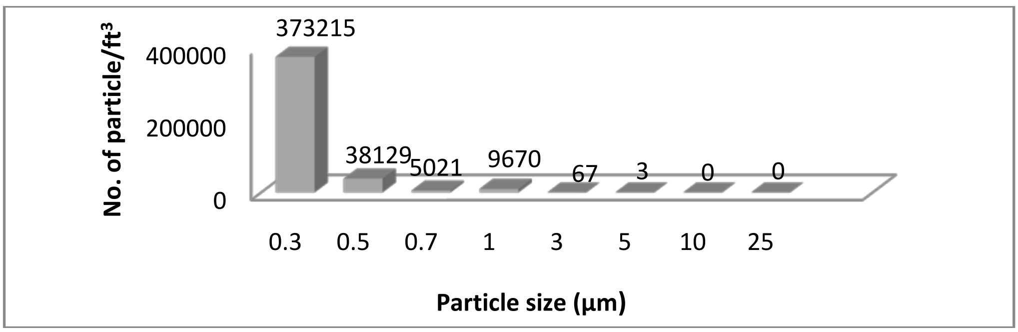

Figure 10 : Particle size distribution generated by atomizer no.1 with wind tunnel

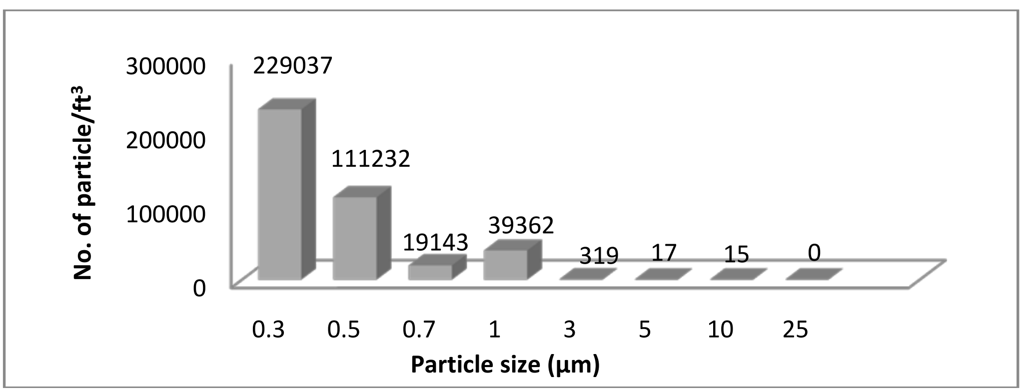

*Figure 11 :*Particle size distribution generated by atomizer no.2 with wind tunnel

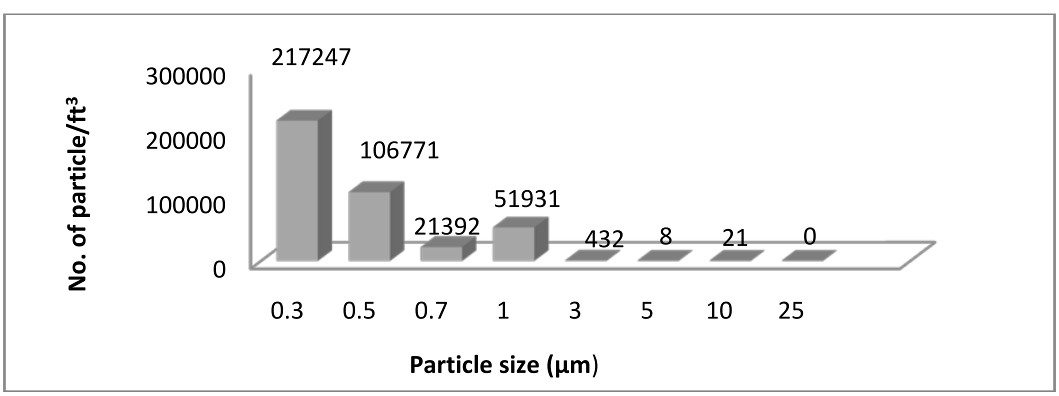

Figure 12 : Particle size distribution generated by atomizer no.3 with wind tunnel

From the above diagram it is clear that the loss of particle is reduced in case of the introduction of the wind tunnel and isokinetic sampling probes. Table 1 shows the comparison between the sampling of particles with and without wind tunnel and isokinetic sampling probes.

Table 1 : Sampling of particles with and without wind tunnel and isokinetic sampling probes

Atomizer	Total no. of particle without wind tunnel	Total no. of particle with wind tunnel	Avg. arithmetic mean diameter of particle without wind tunnel	Avg. arithmetic mean diameter of particle with wind tunnel
1	411549	426105	0.34	0.33
2	379342	399125	0.52	0.51
3	385627	397802	0.47	0.45

From the above table is clear that the introduction of wind tunnel as well as the microcontroller based isokinetic probe helps us to measure aerosol particle more preciously by minimizing the loss of aerosol in the flow passage.

- Experimental results show that aerosol sampling with the wind tunnel fitted with microcontroller based sampling probes is better (lower particle loss) compared to that without wind tunnel and sampling probe.

IV. Conclusion

From the experimental results, the following conclusions may be drawn:

- And wind tunnel has been designed, fabricated and tested for efficient monodisperse test aerosol sampling.
- A microcontroller based isokinetic sampling probe has also been designed, fabricated and used for sampling monodisperse test aerosols.

V. Acknowledgements

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Appendix I

Specification of SOLAIR-3100 Optical Particle Counter (OPC)

Channel Thresholds	Standard & Optional, 6&8 channels: 0.3, 0.5, 0.7, 1, 3, 5, 10, 25 µm.
Flow rate	1.0 CFM(28.3LPM)
Counting efficiency	50% @ 0.3µm; 100% for particles> 0.45µm
Laser source	Extreme life laser source
Zero count level	<one count per five minutes
Concentration limits	500000 particles/ft^3 @5% coincidence loss.
Calibration	NIST traceable.
Count modes	Concentration, manual, automatic, beep
Data storage	Stores up to 3000 sample records of particle an environmental data, plus location and time.
Communication Modes	Ethernet TCP/IP. RS485/ Modbus, USB, USB flash drive.
Supporting Software	LMS XChange Data Transfer Software Optional: LMS Express, LMSNet
Analog Inputs	Up to four optional 4-20mA analog sensors.
Printer	Thermal printer, optional, specify at time of order.
Sample Output	Internally filtered to HEPA standards (>99.97%@0.3µm
Vacuum Source	Internal clean pump, flow controlled
Power	100-240 VAC,50-60 Hz
Battery	Li-Ion, removable & rechargeable
Operating temp/RH	50°F to 104°F(10°C to 40°C)/20% to 95% non condensing.

References Références Referencias

1. http://en.wikipedia.org/wiki/Aerosol
2. William C. Hinds, (1982), Aerosol Technology, John Wiley & Sons, USA.
3. Whitby, K.T, & Liu, B. Y. H. (1967), Generation of countable pulses by high concentrations of sub countable sized particles in the sensing volume of optical counters, journal of colloid and Interface Science, 25,537-546.
4. Liu, B.Y.H., Berglund, R.N., & Agarwal, J.K.(1974a), Experimental studies of optical particle counters, Atmospheric environment, 8, 717-732.
5. Willcke, K., & Liu, B. Y. H. (1976), Single particle optical counter, Principle and application. In B.Y. Liu (Ed.), Fine particles: Aerosol generation, measurement, sampling and analysis (pp. 697-792), New York, NY; Academic Press.
6. Szymanski, W.W., & Liu, B. Y. H. (1986), on the sizing accuracy of laser optical particle counters. Particle & particle system characterization, 3,1-7.
7. Sinclair, D., Countess, R. J., Liu, B. Y. H., & pui, D. Y. H.(1976). Experimental verification of diffusion battery theory. In 68th annual meeting of the air pollution control association (pp.661-663), Boston, MA.
8. Lefebvre, A. H., (1989, Atomization and Sprays, Hemisphere publishing Corp., USA.
9. http://www.ehow.com/about_5085139_history-atomizers.html
10. N. Ashgriz, Handbook of Atomization and Sprays, Springer New York.
11. Yoshida, H., Fujii, K. Yomimoto, Y, Masuda, H. and Iinoya, k. (1978 chem.Engn.)Tokoyo 4, 419.
12. http://en.wikipedia.org/wiki/Wind_tunnel
13. William C. Hinds, (1982), Aerosol Technology, John Wiley & Sons, USA.
14. http://www.brighthubengineering.com/power-plants/98903-what-is-isokinetic-sampling/
15. http://en.wikipedia.org/wiki/Bernoulli%27s_principle
16. www.electronics-tutorials.ws/security system.html

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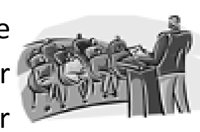

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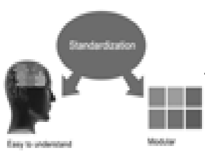

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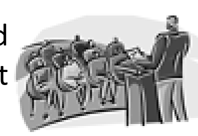

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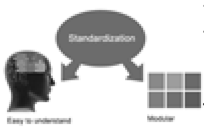

After nomination of your institution as "Institutional Fellow" and constantly functioning successfully for one year, we can consider giving recognition to your institute to function as Regional/Zonal office on our behalf.
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"

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3. Submission of Manuscripts,

4. Manuscript's Category,

5. Structure and Format of Manuscript,

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10. Bookmarks are useful: When you read any book or magazine, you generally use bookmarks, right! It is a good habit, which helps to not to lose your continuity. You should always use bookmarks while searching on Internet also, which will make your search easier.

11. Revise what you wrote: When you write anything, always read it, summarize it and then finalize it.

12. Make all efforts: Make all efforts to mention what you are going to write in your paper. That means always have a good start. Try to mention everything in introduction, that what is the need of a particular research paper. Polish your work by good skill of writing and always give an evaluator, what he wants.

13. Have backups: When you are going to do any important thing like making research paper, you should always have backup copies of it either in your computer or in paper. This will help you to not to lose any of your important.

14. Produce good diagrams of your own: Always try to include good charts or diagrams in your paper to improve quality. Using several and unnecessary diagrams will degrade the quality of your paper by creating "hotchpotch." So always, try to make and include those diagrams, which are made by your own to improve readability and understandability of your paper.

15. Use of direct quotes: When you do research relevant to literature, history or current affairs then use of quotes become essential but if study is relevant to science then use of quotes is not preferable.

16. Use proper verb tense: Use proper verb tenses in your paper. Use past tense, to present those events that happened. Use present tense to indicate events that are going on. Use future tense to indicate future happening events. Use of improper and wrong tenses will confuse the evaluator. Avoid the sentences that are incomplete.

17. Never use online paper: If you are getting any paper on Internet, then never use it as your research paper because it might be possible that evaluator has already seen it or maybe it is outdated version.

18. Pick a good study spot: To do your research studies always try to pick a spot, which is quiet. Every spot is not for studies. Spot that suits you choose it and proceed further.

19. Know what you know: Always try to know, what you know by making objectives. Else, you will be confused and cannot achieve your target.

20. Use good quality grammar: Always use a good quality grammar and use words that will throw positive impact on evaluator. Use of good quality grammar does not mean to use tough words, that for each word the evaluator has to go through dictionary. Do not start sentence with a conjunction. Do not fragment sentences. Eliminate one-word sentences. Ignore passive voice. Do not ever use a big word when a diminutive one would suffice. Verbs have to be in agreement with their subjects. Prepositions are not expressions to finish sentences with. It is incorrect to ever divide an infinitive. Avoid clichés like the disease. Also, always shun irritating alliteration. Use language that is simple and straight forward. put together a neat summary.

21. Arrangement of information: Each section of the main body should start with an opening sentence and there should be a changeover at the end of the section. Give only valid and powerful arguments to your topic. You may also maintain your arguments with records.

22. Never start in last minute: Always start at right time and give enough time to research work. Leaving everything to the last minute will degrade your paper and spoil your work.

23. Multitasking in research is not good: Doing several things at the same time proves bad habit in case of research activity. Research is an area, where everything has a particular time slot. Divide your research work in parts and do particular part in particular time slot.

24. Never copy others' work: Never copy others' work and give it your name because if evaluator has seen it anywhere you will be in trouble.

25. Take proper rest and food: No matter how many hours you spend for your research activity, if you are not taking care of your health then all your efforts will be in vain. For a quality research, study is must, and this can be done by taking proper rest and food.

26. Go for seminars: Attend seminars if the topic is relevant to your research area. Utilize all your resources.

27. Refresh your mind after intervals: Try to give rest to your mind by listening to soft music or by sleeping in intervals. This will also improve your memory.

28. Make colleagues: Always try to make colleagues. No matter how sharper or intelligent you are, if you make colleagues you can have several ideas, which will be helpful for your research.

29. Think technically: Always think technically. If anything happens, then search its reasons, its benefits, and demerits.

30. Think and then print: When you will go to print your paper, notice that tables are not be split, headings are not detached from their descriptions, and page sequence is maintained.

31. Adding unnecessary information: Do not add unnecessary information, like, I have used MS Excel to draw graph. Do not add irrelevant and inappropriate material. These all will create superfluous. Foreign terminology and phrases are not apropos. One should NEVER take a broad view. Analogy in script is like feathers on a snake. Not at all use a large word when a very small one would be sufficient. Use words properly, regardless of how others use them. Remove quotations. Puns are for kids, not grunt readers. Amplification is a billion times of inferior quality than sarcasm.

32. Never oversimplify everything: To add material in your research paper, never go for oversimplification. This will definitely irritate the evaluator. Be more or less specific. Also too, by no means, ever use rhythmic redundancies. Contractions aren't essential and shouldn't be there used. Comparisons are as terrible as clichés. Give up ampersands and abbreviations, and so on. Remove commas, that are, not necessary. Parenthetical words however should be together with this in commas. Understatement is all the time the complete best way to put onward earth-shaking thoughts. Give a detailed literary review.

33. Report concluded results: Use concluded results. From raw data, filter the results and then conclude your studies based on measurements and observations taken. Significant figures and appropriate number of decimal places should be used. Parenthetical remarks are prohibitive. Proofread carefully at final stage. In the end give outline to your arguments. Spot out perspectives of further study of this subject. Justify your conclusion by at the bottom of them with sufficient justifications and examples.

34. After conclusion: Once you have concluded your research, the next most important step is to present your findings. Presentation is extremely important as it is the definite medium though which your research is going to be in print to the rest of the crowd. Care should be taken to categorize your thoughts well and present them in a logical and neat manner. A good quality research paper format is essential because it serves to highlight your research paper and bring to light all necessary aspects in your research.

Informal Guidelines of Research Paper Writing

Key points to remember:

- Submit all work in its final form.
- Write your paper in the form, which is presented in the guidelines using the template.
- Please note the criterion for grading the final paper by peer-reviewers.

Final Points:

A purpose of organizing a research paper is to let people to interpret your effort selectively. The journal requires the following sections, submitted in the order listed, each section to start on a new page.

The introduction will be compiled from reference matter and will reflect the design processes or outline of basis that direct you to make study. As you will carry out the process of study, the method and process section will be constructed as like that. The result segment will show related statistics in nearly sequential order and will direct the reviewers next to the similar intellectual paths throughout the data that you took to carry out your study. The discussion section will provide understanding of the data and projections as to the implication of the results. The use of good quality references all through the paper will give the effort trustworthiness by representing an alertness of prior workings.

Writing a research paper is not an easy job no matter how trouble-free the actual research or concept. Practice, excellent preparation, and controlled record keeping are the only means to make straightforward the progression.

General style:

Specific editorial column necessities for compliance of a manuscript will always take over from directions in these general guidelines.

To make a paper clear

· Adhere to recommended page limits

Mistakes to evade

- Insertion a title at the foot of a page with the subsequent text on the next page
- Separating a table/chart or figure - impound each figure/table to a single page
- Submitting a manuscript with pages out of sequence

In every sections of your document

· Use standard writing style including articles ("a", "the," etc.)

· Keep on paying attention on the research topic of the paper

· Use paragraphs to split each significant point (excluding for the abstract)

· Align the primary line of each section

· Present your points in sound order

· Use present tense to report well accepted

· Use past tense to describe specific results

· Shun familiar wording, don't address the reviewer directly, and don't use slang, slang language, or superlatives

· Shun use of extra pictures - include only those figures essential to presenting results

Title Page:

Choose a revealing title. It should be short. It should not have non-standard acronyms or abbreviations. It should not exceed two printed lines. It should include the name(s) and address (es) of all authors.

Abstract:

The summary should be two hundred words or less. It should briefly and clearly explain the key findings reported in the manuscript--must have precise statistics. It should not have abnormal acronyms or abbreviations. It should be logical in itself. Shun citing references at this point.

An abstract is a brief distinct paragraph summary of finished work or work in development. In a minute or less a reviewer can be taught the foundation behind the study, common approach to the problem, relevant results, and significant conclusions or new questions.

Write your summary when your paper is completed because how can you write the summary of anything which is not yet written? Wealth of terminology is very essential in abstract. Yet, use comprehensive sentences and do not let go readability for briefness. You can maintain it succinct by phrasing sentences so that they provide more than lone rationale. The author can at this moment go straight to shortening the outcome. Sum up the study, with the subsequent elements in any summary. Try to maintain the initial two items to no more than one ruling each.

- Reason of the study - theory, overall issue, purpose
- Fundamental goal
- To the point depiction of the research
- Consequences, including definite statistics - if the consequences are quantitative in nature, account quantitative data; results of any numerical analysis should be reported
- Significant conclusions or questions that track from the research(es)

Approach:

- Single section, and succinct
- As a outline of job done, it is always written in past tense
- A conceptual should situate on its own, and not submit to any other part of the paper such as a form or table
- Center on shortening results - bound background information to a verdict or two, if completely necessary
- What you account in an conceptual must be regular with what you reported in the manuscript
- Exact spelling, clearness of sentences and phrases, and appropriate reporting of quantities (proper units, important statistics) are just as significant in an abstract as they are anywhere else

Introduction:

The **Introduction** should "introduce" the manuscript. The reviewer should be presented with sufficient background information to be capable to comprehend and calculate the purpose of your study without having to submit to other works. The basis for the study should be offered. Give most important references but shun difficult to make a comprehensive appraisal of the topic. In the introduction, describe the problem visibly. If the problem is not acknowledged in a logical, reasonable way, the reviewer will have no attention in your result. Speak in common terms about techniques used to explain the problem, if needed, but do not present any particulars about the protocols here. Following approach can create a valuable beginning:

- Explain the value (significance) of the study
- Shield the model - why did you employ this particular system or method? What is its compensation? You strength remark on its appropriateness from a abstract point of vision as well as point out sensible reasons for using it.
- Present a justification. Status your particular theory (es) or aim(s), and describe the logic that led you to choose them.
- Very for a short time explain the tentative propose and how it skilled the declared objectives.

Approach:

- Use past tense except for when referring to recognized facts. After all, the manuscript will be submitted after the entire job is done.
- Sort out your thoughts; manufacture one key point with every section. If you make the four points listed above, you will need a least of four paragraphs.

- Present surroundings information only as desirable in order hold up a situation. The reviewer does not desire to read the whole thing you know about a topic.
- Shape the theory/purpose specifically - do not take a broad view.
- As always, give awareness to spelling, simplicity and correctness of sentences and phrases.

Procedures (Methods and Materials):

This part is supposed to be the easiest to carve if you have good skills. A sound written Procedures segment allows a capable scientist to replacement your results. Present precise information about your supplies. The suppliers and clarity of reagents can be helpful bits of information. Present methods in sequential order but linked methodologies can be grouped as a segment. Be concise when relating the protocols. Attempt for the least amount of information that would permit another capable scientist to spare your outcome but be cautious that vital information is integrated. The use of subheadings is suggested and ought to be synchronized with the results section. When a technique is used that has been well described in another object, mention the specific item describing a way but draw the basic principle while stating the situation. The purpose is to text all particular resources and broad procedures, so that another person may use some or all of the methods in one more study or referee the scientific value of your work. It is not to be a step by step report of the whole thing you did, nor is a methods section a set of orders.

Materials:

- Explain materials individually only if the study is so complex that it saves liberty this way.
- Embrace particular materials, and any tools or provisions that are not frequently found in laboratories.
- Do not take in frequently found.
- If use of a definite type of tools.
- Materials may be reported in a part section or else they may be recognized along with your measures.

Methods:

- Report the method (not particulars of each process that engaged the same methodology)
- Describe the method entirely
- To be succinct, present methods under headings dedicated to specific dealings or groups of measures
- Simplify - details how procedures were completed not how they were exclusively performed on a particular day.
- If well known procedures were used, account the procedure by name, possibly with reference, and that's all.

Approach:

- It is embarrassed or not possible to use vigorous voice when documenting methods with no using first person, which would focus the reviewer's interest on the researcher rather than the job. As a result when script up the methods most authors use third person passive voice.
- Use standard style in this and in every other part of the paper - avoid familiar lists, and use full sentences.

What to keep away from

- Resources and methods are not a set of information.
- Skip all descriptive information and surroundings - save it for the argument.
- Leave out information that is immaterial to a third party.

Results:

The principle of a results segment is to present and demonstrate your conclusion. Create this part a entirely objective details of the outcome, and save all understanding for the discussion.

The page length of this segment is set by the sum and types of data to be reported. Carry on to be to the point, by means of statistics and tables, if suitable, to present consequences most efficiently.You must obviously differentiate material that would usually be incorporated in a study editorial from any unprocessed data or additional appendix matter that would not be available. In fact, such matter should not be submitted at all except requested by the instructor.

Content

- Sum up your conclusion in text and demonstrate them, if suitable, with figures and tables.
- In manuscript, explain each of your consequences, point the reader to remarks that are most appropriate.
- Present a background, such as by describing the question that was addressed by creation an exacting study.
- Explain results of control experiments and comprise remarks that are not accessible in a prescribed figure or table, if appropriate.
- Examine your data, then prepare the analyzed (transformed) data in the form of a figure (graph), table, or in manuscript form.

What to stay away from

- Do not discuss or infer your outcome, report surroundings information, or try to explain anything.
- Not at all, take in raw data or intermediate calculations in a research manuscript.
- Do not present the similar data more than once.
- Manuscript should complement any figures or tables, not duplicate the identical information.
- Never confuse figures with tables - there is a difference.

Approach

- As forever, use past tense when you submit to your results, and put the whole thing in a reasonable order.
- Put figures and tables, appropriately numbered, in order at the end of the report
- If you desire, you may place your figures and tables properly within the text of your results part.

Figures and tables

- If you put figures and tables at the end of the details, make certain that they are visibly distinguished from any attach appendix materials, such as raw facts
- Despite of position, each figure must be numbered one after the other and complete with subtitle
- In spite of position, each table must be titled, numbered one after the other and complete with heading
- All figure and table must be adequately complete that it could situate on its own, divide from text

Discussion:

The Discussion is expected the trickiest segment to write and describe. A lot of papers submitted for journal are discarded based on problems with the Discussion. There is no head of state for how long a argument should be. Position your understanding of the outcome visibly to lead the reviewer through your conclusions, and then finish the paper with a summing up of the implication of the study. The purpose here is to offer an understanding of your results and hold up for all of your conclusions, using facts from your research and generally accepted information, if suitable. The implication of result should be visibly described. Infer your data in the conversation in suitable depth. This means that when you clarify an observable fact you must explain mechanisms that may account for the observation. If your results vary from your prospect, make clear why that may have happened. If your results agree, then explain the theory that the proof supported. It is never suitable to just state that the data approved with prospect, and let it drop at that.

- Make a decision if each premise is supported, discarded, or if you cannot make a conclusion with assurance. Do not just dismiss a study or part of a study as "uncertain."
- Research papers are not acknowledged if the work is imperfect. Draw what conclusions you can based upon the results that you have, and take care of the study as a finished work
- You may propose future guidelines, such as how the experiment might be personalized to accomplish a new idea.
- Give details all of your remarks as much as possible, focus on mechanisms.
- Make a decision if the tentative design sufficiently addressed the theory, and whether or not it was correctly restricted.
- Try to present substitute explanations if sensible alternatives be present.
- One research will not counter an overall question, so maintain the large picture in mind, where do you go next? The best studies unlock new avenues of study. What questions remain?
- Recommendations for detailed papers will offer supplementary suggestions.

Approach:

- When you refer to information, differentiate data generated by your own studies from available information
- Submit to work done by specific persons (including you) in past tense.
- Submit to generally acknowledged facts and main beliefs in present tense.

Administration Rules Listed Before Submitting Your Research Paper to Global Journals Inc. (US)

Please carefully note down following rules and regulation before submitting your Research Paper to Global Journals Inc. (US):

Segment Draft and Final Research Paper: You have to strictly follow the template of research paper. If it is not done your paper may get rejected.

- The **major constraint** is that you must independently make all content, tables, graphs, and facts that are offered in the paper. You must write each part of the paper wholly on your own. The Peer-reviewers need to identify your own perceptive of the concepts in your own terms. NEVER extract straight from any foundation, and never rephrase someone else's analysis.
- Do not give permission to anyone else to "PROOFREAD" your manuscript.
- Methods to avoid Plagiarism is applied by us on every paper, if found guilty, you will be blacklisted by all of our collaborated research groups, your institution will be informed for this and strict legal actions will be taken immediately.)
- To guard yourself and others from possible illegal use please do not permit anyone right to use to your paper and files.

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Topics	Grades		
	A-B	**C-D**	**E-F**
Abstract	Clear and concise with appropriate content, Correct format. 200 words or below	Unclear summary and no specific data, Incorrect form Above 200 words	No specific data with ambiguous information Above 250 words
Introduction	Containing all background details with clear goal and appropriate details, flow specification, no grammar and spelling mistake, well organized sentence and paragraph, reference cited	Unclear and confusing data, appropriate format, grammar and spelling errors with unorganized matter	Out of place depth and content, hazy format
Methods and Procedures	Clear and to the point with well arranged paragraph, precision and accuracy of facts and figures, well organized subheads	Difficult to comprehend with embarrassed text, too much explanation but completed	Incorrect and unorganized structure with hazy meaning
Result	Well organized, Clear and specific, Correct units with precision, correct data, well structuring of paragraph, no grammar and spelling mistake	Complete and embarrassed text, difficult to comprehend	Irregular format with wrong facts and figures
Discussion	Well organized, meaningful specification, sound conclusion, logical and concise explanation, highly structured paragraph reference cited	Wordy, unclear conclusion, spurious	Conclusion is not cited, unorganized, difficult to comprehend
References	Complete and correct format, well organized	Beside the point, Incomplete	Wrong format and structuring

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