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Fabrication and Testing of Compressed Air Car Viswanadha Institute of Technology and Management

By Anirudh Addala & Srinivasu Gangada
Viswanadha Institute of Technology and Management

Abstract - This research aims to examine the performance of a car which takes air as the working medium. *Air car* is a car currently being developed which is still in the R&D stage all over the world. Review on the availability and the impact of the fossil fuels in the present and future generations led us to design a vehicle which runs by renewable energy sources. As the world is hard pressed with the energy and fuel crisis, compounded by pollution of all kinds, any technology that brings out the solution to this problem is considered as a bounty. In one of such new technologies, is the development of a new vehicle called as "*Compressed Air Car*", which does not require any of the known fuels like petrol, diesel, CNG, LPG, hydrogen etc., this works on compressed air. This replaces all types of till date known fuels and also permanently solves the problem of pollution, since its exhaust is clean and cool air.

Though some of the renewable energy sources like solar energy, bio fuels are currently in practice, we focused on *pneumatic technology*. Since pneumatic applications are wide all over the world, basic components and other equipment are easily available and the fabrication is not so tough. The basic principle involved in this concept is that compressed air is capable enough to provide sufficient thrust which in turn can propel the car. This report is a detailed description of the fabrication, working and testing of the compressed air car.

Keywords : *compressed air motor (cam)/ pneumatic wrench, compressed air technology, eco-friendly, global conditions, renewable energy handling.*

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FABRICATION AND TESTING OF COMPRESSED AIR CAR VISWANADHA INSTITUTE OF TECHNOLOGY AND MANAGEMENT

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Anirudh Addala [α] & Srinivasu Gangada [σ]

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I. Introduction

Fossil fuels (i.e., petroleum, diesel, natural gas and coal), which meet most of the world's energy demand today, are being depleted rapidly. Also, their combustion products are causing global problems, such as the greenhouse effect, ozone layer depletion, acid rains and pollution, which are posing great danger for our environment, and eventually, for the total life on our planet. These factors are leading automobile manufacturers to develop cars propelled by alternative energies. Hybrid cars, Fuel cell powered cars, Hydrogen fueled cars will be soon into the market as a result of it.

One possible alternative is the *Air-Powered Car*. Air, which is abundantly available and is free from pollution, can be compressed to higher pressures at a very low cost, is one of the prime option since Whereas so far all the attempts made to eliminate the pollution has however reduced it, but complete eradication is still rigorously pursued. Compressed air utilization in the pneumatic applications has been long proven. Air motors, pneumatic engines, actuators and other equipments are in use. Compressed air was also used in some of the vehicle for boosting the initial torque.

Compressed air has been used since the 19th century [10] to power mine locomotives, and was previously the basis of naval torpedo propulsion. The major problem with this car is the lack of torque produced by the "engines". The costs involved to compress the air to be used in a vehicle are inferior to the costs involved with a normal combustion engine. Air is abundant, economical, transportable, storable and, most importantly, nonpolluting. The technology involved with compressed air reduces the production costs of vehicles with 20% because it is not necessary to assemble a refrigeration system, a fuel tank, spark plugs or mufflers. Air itself is not flammable.

The mechanical design of the motor is simple and robust. The tanks used in an air compressed motor can be discarded or recycled with less contamination than batteries. The tanks used in a compressed air motor have a longer lifespan in comparison with batteries, which, after a while suffer from a reduction in performance. Refueling can be done at home using an air compressor or at service stations. Reduced vehicle weight is the principle efficiency factor of compressed-air car. The rate of self-discharge is very low opposed to batteries that deplete their charge slowly over time.

Therefore, the vehicle may be left unused for longer periods of time than electric cars. Lower initial cost than battery electric vehicles when mass produced.

Compressed air is not subject to fuel tax. Lighter vehicles would result in less wear on roads. The price of fueling air powered vehicles may be significantly cheaper than current fuels.

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II. Comparative Study

Comparison of several types of green car basic characteristics (Values are overall for vehicles in current production and may differ between types)				
Type of vehicle/ power train	Fuel economy (mpg equi valent)	Range	Production cost for given range	Reduction in CO_2 compared to conventional
Conventional ICE	10-78	Long (400-600 mi)	Low	0%
Biodiesel	18-71	Long (360-540 mi)	Low	100%
All-electric	battery	Shorter (73-150 mi)	High	varies
Compressed air	30-60	380 mi	Medium	100 %

[1-4]

III. Other Developments in Compressed Air Car Technology

Currently some new technologies regarding compressed air cars have emerged. A Republic of Korean company has created a pneumatic hybrid electric vehicle car engine that runs on electricity and compressed air. The engine, which powers a pneumatic-hybrid electric vehicle (PHEV) [10][13], works alongside an electric motor to create the power source. The system eliminates the need for fuel, making the PHEV pollution-free. The system is controlled by an ECU in the car, which controls both power packs i.e. the compressed-air engine and electric motor. The compressed air drives the pistons, which turn the vehicle's wheels. The air is compressed, using a small motor, powered by a 48-volt battery, which powers both the air compressor and the electric motor. Once compressed, the air is stored in a tank. The compressed air is used when the car needs a lot of energy, such as for starting up and acceleration. The electric motor comes to life once the car has gained normal cruising speed. The PHEV system could reduce the cost of vehicle production by about 20 per cent, because there is no need for a cooling system, fuel tank, spark plugs or silencers.

IV. How Compressed Air can Drive a Car

The laws of physics dictate that uncontained gases will fill any given space. The easiest way to see this in action is to inflate a balloon [13]. The elastic skin of the balloon holds the air tightly inside, but the moment you use a pin to create a hole in the balloon's surface, the air expands outward with so much energy that the balloon explodes.

Compressing a gas into a small space is a way to store energy. When the gas expands again, that energy is released to do work. That's the basic principle behind what makes an air car move.

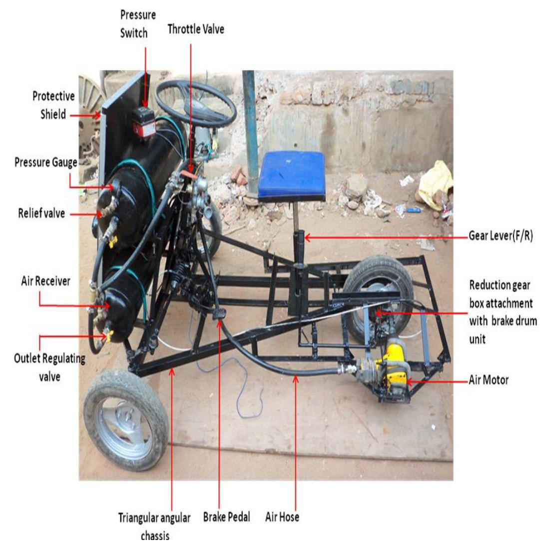

Figure 1 : Layout of Compressed Air Car

Air car will have air compressor built into it. After a brisk drive, we can take the car home, put it into the garage and plug in the compressor. The compressor will use air from around the car to refill the compressed air tank. Unfortunately, this is a rather slow method of refueling and will probably take up few minutes for a complete refill. If the idea of an air car catches on, air refueling stations will become available at ordinary gas stations, where the tank can be refilled much more rapidly with air that's already been compressed. Filling your tank at the pump will probably take about three minutes.

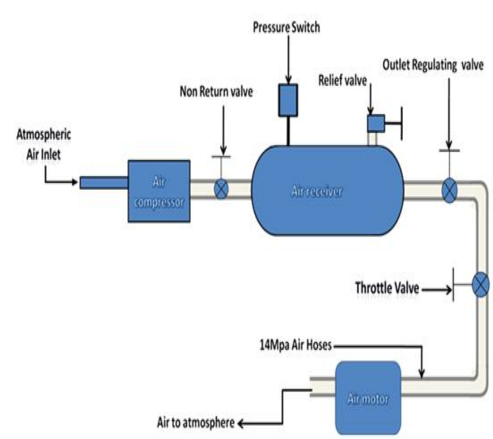

Figure 2 : Line Diagram of Compressed Air Car

This air car will almost certainly use *Compressed Air Motor (CAM)/ Pneumatic wrench.* Air car propelled with this engine will have tanks that will probably hold compressed air to about 11.03bar pressure. Its accelerator operates a valve on its tank that allows air to be released into the hoses and then into the motor, where the pressure of the air's expansion will push against the vanes and turn the rotor. This will produce enough power for speeds of about 15-20 kilometers per hour.

V. Work Division into Sub Assemblies

The entire work is categorized into 5 phases. Each phase consists of a series of operations followed by the next phase. Several changes were made in the design depending upon the physical stability of the car.

a) Preparatory Work

Detailed study of the project, formulating the methods, Design preparation, abstract preparation, project formulation.

b) Sub Assembly 1

Parts accumulation, inspecting the components, pre-processing of components.

c) Sub Assembly 2

Pre-processing of the prepared design.

d) Sub Assembly 3

Fabrication, Painting, Testing.

e) Sub Assembly 4

Evaluation.

VI. Technical Specifications

1. Compressor
2. Reciprocating compressor
3. Single stage
4. Hermetically sealed
5. 1.5 HP, 3000 rpm

Table 6.2 : Overall Dimensions

Component	Dimension in mm
Wheel rim diameter	280
Wheel diameter	380
Wheel width	75
Front track length	1070
Ground clearance	280
Tank thickness	3
Bearing OD	35
Bearing ID	15
Bearing thickness	10

Table 6.3 : Details of Compressed Air Car

Input power consumption	79.2 Watts
Time of filling(for 2 cylinders)	6 minutes
Cost of filling(@unit charge 5/-)	Rs. 0.32
Air consumption	340 l/min
Cylinder storing pressure	11.03bar
Working pressure	6.2bar
Cylinder storing capacity each	38lts
Output power	2.169 kW

Table 6.4 : Specifications of Air Motor

Idle speed	4500 rpm
When connected to wheel	1650 rpm
On load speed	300 rpm
Weight	4.5 kgs
Torque	677 N-m
Air inlet (PT)	1/4 inch
Air Hose (ID)	3/8 inch

VII. Chassis Design Parameters

Chassis Fabrication: Chassis is made by triangular angular incorporating arc welding at various sections. It includes:

1. Lap joint welds
2. Butt welds
3. T joint welds.

The end joints are butt welded and some internal angular sections are lap welded. The steering column support is given by welding a hollow shaft with a T weld to the front frame of the chassis.

a) Wheel Mounting

After the completion of chassis, wheels are mounted; two on the front side and one on the rear side. Inclination is provided between the front and rear side of the chassis frame for steering compensation.

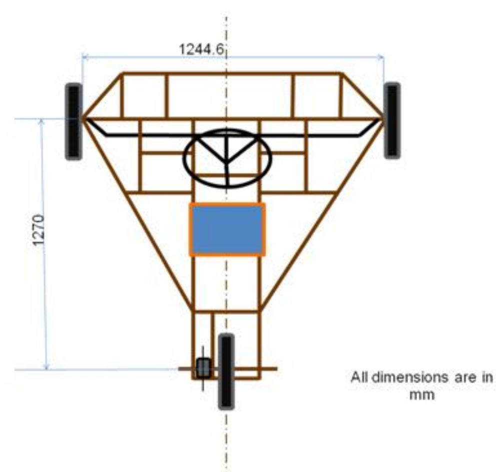

Figure 3 : Frame Model of Compressed Air Car

b) Rear Wheel Settings

The rear wheel is given priority because power drive and braking system are given to this wheel. The wheel spindle is aligned with the wheel centre. This is given supports on either side of the wheel. The spindle is extended on either side of the wheel. One side is for power transmission compensation and the other side is for brake setup compensation. Rests of the components are mounted on the chassis at the requisite positions according to the design parameters. A number of modifications were done in the design during the tests performed after installation of each and every module.

VIII. Pressure Cut off Switch

This is a device designed to monitor a process pressure and provide an output when a set pressure (set point) is reached. A pressure switch does this by applying the process pressure to a diaphragm or piston to generate a force which is compared to that of a pre-compressed range spring.

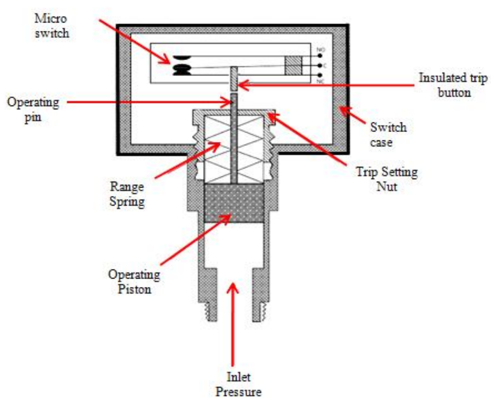

Figure 4 : Sectional view of Pressure Switch

A pressure switch is used to detect the presence of fluid pressure. Most pressure switches use a diaphragm or bellow as the sensing element. The movement of this sensing element is used to actuate one or more switch contacts to indicate an alarm or initiate a control action. Pressure switches have different designs with different sensing elements. One of the most common is the one with diaphragms or bellows as the sensing elements. The one I will discuss here uses a piston as the pressure sensing element. In any case, the operating principle for this piston type is the same with a diaphragm or bellow type pressure switch.

IX. Rotary Vane Air Motor

A pneumatic motor or compressed air engine is a type of motor which does mechanical work by expanding compressed air [10]. Pneumatic motors generally convert the compressed air to mechanical work through either linear or rotary motion. Linear motion can come from either a diaphragm or piston actuator, while rotary motion is supplied by either a vane type air motor or piston air motor. Pneumatic motors have existed in many forms over the past two centuries, ranging in size from hand held turbines to engines of up to several kilo Watts. Some types rely on pistons and cylinders, others use turbines. Many compressed air engines improve their performance by heating the incoming air, or the engine itself. Pneumatic motors have found widespread success in the hand-held tool industry and continual attempts are

Figure 5 : Pneumatic Motor

expand their use to the transportation industry. Pneumatic actuation is commonly used in industrial and commercial applications for its low cost, compact size, high power-to-weight ratio, reliability, and low maintenance. In many cases, these characteristics make it preferable over electric actuation, especially when a supply of air is readily available. The major limitation of classic pneumatic actuators, rotary or linear, has been their reduced precision in controlled motion. This is mainly caused by air compressibility and friction in the valve and actuator, which make the pump-line-actuator dynamic system highly nonlinear. Novel hardware and pneumatic servo control solutions have been proposed to cope with these problems, and impressive results have been achieved in force control and speed regulation. Nevertheless, these complex solutions require special care, and so most practical applications are still limited to unregulated pneumatic motion. However, pneumatic motors must overcome inefficiencies before being seen as a viable option in the transportation industry.

Rotary Vane Air motors feature durable construction with precision heavy-duty bearings throughout, and multiple blade rotors for smooth power. There is a wide range of speeds and torques as well as a choice of foot, face, or flange mounting. These motors require air line lubrication for long, trouble-free service. Mount the lubricator as close to the motor as possible. These motors perform satisfactorily in high temperature areas up to 200°F *(93° C)* [7].

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X. Power Transmission

The power transmission undergoes the following processes. Air is stored in the tank at a pressure of 11.03bar. From the tank, air flow is synchronized by a regulator. This maintains pressure to the downstream

Figure 6 : Entire View of Power Transmission

Components as long as there is a pressure difference between the reservoir and the required operating pressure. Controlled discharge from the tank is proportional to the release of butterfly valve. From there, air is boosted to the pneumatic wrench inlet. Hence this compressed air expands at the rotor blades where its pressure energy is converted to rotational energy of the rotor. Ultimately spindle connected to the rotor is given drive in turn is given to the rear wheel.

XI. Braking System

a) Principle of Braking System

While operating the braking system the kinetic energy of the moving vehicle is converted into heat energy.

b) Drum Brakes

The concept here is simple, two semicircular brake shoes sit inside a spinning drum which is attached to the wheel. When you apply the brakes, the shoes are expanded outwards to press against the inside of the drum. This creates friction, which creates heat, which transfers kinetic energy, which slows you down. As the brakes are applied, the cable which is connected to one end of the lever is pulled and the other end transfers the forces against the brake shoes and in turn forces them to expand outwards. The return spring is what pulls the shoes back away from the surface of the brake drum when the brakes are released. This is the simple working of the braking system which is incorporated in Compressed Air Car for easy halt of the vehicle because of the low speed ranges.

Fig 7 : Brake Dru

Fig 8 : Brake Pedal

XII. Steering System

Like most things in a car, the concept of steering is simple -you turn the steering wheel, the front wheels turn accordingly, and the car changes direction. How that happens though is not quite so simple. So for our project Compressed Air Car we used Rack And Pinion type Steering System. In a rack and pinion

Figure 9 : Steering linkages

System, toothed bar with the tie rods attached to each end. On the end of the steering column there is a simple pinion gear that meshes with the rack. When you turn the steering wheel, the pinion gear turns, and move the rack from left to right. Changing the size of the pinion gear alters the steering ratio. This steering mechanism follows the Ackerman's Steering Principle which is very best suited for our project to eliminate the weight of the vehicle because of the simple construction of the steering mechanism.

XIII. Suspension System

Figure 10 : Coil Spring

The suspension points of the vehicle for a chassis should be considered before the chassis itself. Suspension and all the chassis requirements will involve much compromise. For this text into consideration we thought of coil spring type of suspension. This is because the vehicle weight is so much optimized because of internal physics involving in the propulsion of the Compressed Air Car as well they store energy and subsequently releases it. These can easily withstand the weight excreted and avoid uneven forces on the tire causing loss of traction. It absorbs the shocks and disturbances created while the vehicle is in dynamic phase. This also protects the tanks which are stored with compressed air while the vehicle is passing through any ditches or bumps. This is the simple suspension system attached for Compressed Air Car.

XIV. Testing and Performance

a) Road Testing

Car was tested at various pressures of compressed air keeping the vehicle dynamics into consideration. Maximum permissible load was tested and the result depicted fair values.

Brake tests were conducted and the joint efficiencies were observed. They withstood the impacts and could resist the jerks.

b) Leak Testing

Leak testing is required by most codes prior to initial operation and each piping system must be tested to ensure leak tightness. The field test is normally a hydrostatic leak test. There are several other types of testing depending on service fluid and there are six different testing methods that can be used at most construction sites.

1. Hydrostatic testing which uses water under pressure.
2. Pneumatic testing which uses gas or air under pressure.
3. In-service testing which involves a walk down for leakage when the system is put into operation.
4. Vacuum testing which uses negative pressure to check for leakage.
5. Static head testing which is normally done for drain piping with water with a known static head pressure left in a standpipe for a set period of time.
6. Tracer leak method for inert gas leak detection.

c) Pneumatic Leak Testing

The fluid medium used for pneumatic testing is either compressed air or Nitrogen gas. The test pressure by code is usually 1.1 times the design line pressure. Pneumatic testing involves the potential hazard of releasing energy stored in the compressed gas. Care must be taken by gradually increasing pressure in steps up to the test pressure, holding only as long as the code requires, then reducing to the design pressure for inspection of the joints. The inspection of joints is done utilizing a soapy water mix that bubbles when air is escaping.

d) Soap solution test

This is one of the simplest and cheapest methods to spot the leaks in a pneumatic circuit. A soap solution is prepared and is applied at all the joints, fixtures of the hoses, valves, reservoir connections and other sensitive parts. This solution is applied after the tanks are filled to a rated level. All the valves are opened and air starts rushing through the connections. Whenever there is a leak present, with the movement of air molecules, soap bubbles start emerging at the leak spot. Thus the leak spot is observed.

XV. Safety features of the Air Car

a) The CATS air tanks store 0.036m3 of air at 6.8 bars of pressure (two tanks have a capacity of 78 liters, and they store 0.078 m3 of air at a pressure of 6.8bars), just like tanks already used to carry liquefied gases on some urban buses.
b) That means that the tanks are prepared and certified to carry an explosive product: methane gas. In the case of an accident with air tank breakage, there would be no explosion or shattering for the tanks that are not metallic but made of glass fiber.
c) The tanks would crack longitudinally, and the air would escape, causing a strong buzzing sound with no dangerous factor.
d) It is clear that if this technology has been tested and prepared to carry an inflammable and explosive gas, it can also be used to carry air.

XVI. Disadvantages

Just like the modern car and most household appliances, the principle disadvantage is that of indirect energy use. Energy is used to compress air, which - in turn - provides the energy to run the motor. Any indirect step in energy usage results in loss. For conventional combustion engine cars, the energy is lost when oil is converted to usable fuel - including drilling, refinement, labor and storage. For compressed-air cars, energy is lost when electrical energy is converted to compressed air. Once the tanks are exhausted, car cannot be driven until it is refilled at the nearest filling station.

XVII. Starting Procedure

1. Take the seating position.
2. Open the outlet valve of one cylinder.
3. Now slowly open the regulator and increase the air discharge.
4. Steer the vehicle properly.
5. Regulate the check valve gently and maintain the required speed.

6. When the air in a tank is exhausted close the corresponding valve and open the outlet valve of the parallel cylinder.
7. While applying the brakes, close the throttle valve (regulator) and then the pedal as to be applied.
8. While engaging and disengaging the forward and reverse gear the car is to be brought to rest (motor rpm=0) and then the direction is to changed.
9. Shut off the valves when not in use.

XVIII. Service Manual

a) Lubricate the following parts periodically

1. Front wheel bearings.
2. Rear wheel bearing.
3. Pneumatic motor.
4. Steering linkages.

b) Clean the following periodically

1. Pneumatic motor, wheels and universal joints.
2. Steering links.
3. Tanks.

c) Check all the valves periodically

d) Check all the fittings regularly

XIX. The Activities and Related Results of the Project

During the first phase of project, design parameters are considered and components are collected, processed and upgraded. During the second phase of project, research has been done and the prototype is brought to present stage by performing the above functions.

XX. Places

Our project is carried out in various sections. Some of the spares which were supposed to be machined to the required dimensions were fabricated by us at the Padmakar Engineering company workshop. The main assembly works, testing, and painting were done at our college premises.

XXI. Problems

This is a typical live project. Some of the problems associated with this project are;

1. Accumulation of accessories was the toughest job and elapsed more time.
2. Transportation problems: heavy components are requisite for this project. Their shipping was intricate.
3. Several mechanical operations were integrated which required trained persons for performing them.
4. Compressed air tank is a major component which requires strict attention, otherwise accidents may take place.
5. All assembly processes must be done perfectly and rigidly.

XXII. Conclusions

The technology of compressed air vehicles is not new. In fact, it has been around for years. Compressed air technology allows engines/ motors that are both nonpolluting and economical. After one year of research and development, our compressed air car is brought into existence. Unlike electric or hydrogen powered vehicles, compressed air car is not expensive. Compressed air car is affordable and have a performance rate whose power to weight ratio stands up to 0.0373kW/kg. For arriving at a fair power to weight ratio, we considered possible factors which would result to minimize the weight of the car. For this we designed 3 wheeled vehicle. The entire chassis is fabricated with 1 inch angular frames. Unlike conventional transmission systems which include clutch, counter shaft, fly wheel, propeller shaft, differential, our pneumatic motor is coupled to the rear wheel with intermediate gear box which greatly reduces the transmission losses and weight of the vehicle. It also occupies lesser space compared to a four wheeler. This car gives an economy of about Rs.1 per kilometer. At the same time the well to wheels efficiency of the vehicle need to be improved. This is a revolutionary design which is not only eco friendly, pollution free, but is also very economical. This addresses both the problems of fuel crisis and pollution. However excessive research is needed to completely prove the technology for both its commercial and technical viability. Our motto is to bring peace and tranquility to earth from pollution.

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Mathematical Modeling of Temperature Lapse Rate in Solar Chimney Power Plant

By Shashank.B. Thakre, L.B. Bhuyar, Sachin.V. Dahake & Pankaj Wankhade

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Keywords : collector, turbine, chimney, mathematical models, review.

GJRE-A Classification : FOR Code: 850506, 090607

MATHEMATICAL MODELING OF TEMPERATURE LAPSE RATE IN SOLAR CHIMNEY POWER PLANT

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Shashank.B. Thakre α, L.B. Bhuyar σ, Sachin.V. Dahake ρ & Pankaj Wankhade ω

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I. Introduction

The widespread use of solar energy, as an alternate and non depletable resource for agriculture and industry as well as other applications, is dependent on the development of solar systems which possess the reliability, performance and economic characteristics that compare favorably with the conventional systems. The solar chimney power plant system, which is composed of the solar collector, the chimney and the turbine, has been investigated all over the world since the German researcher Jorg Schliaich first made the brainchild in the 1970s. The main objective of the collector is collecting solar radiation to heat up the air inside. As the air density inside the system is less than that of the environment at the same height, natural convection affected by buoyancy which acts as driving force comes into existence. Due to the existence of the chimney, the cumulative buoyancy results in a large pressure difference between the system and the environment, then the heated air rises up into the chimney with great speed. If an axis-based turbine is placed inside the chimney where there is a large pressure drop, the potential and heat energy of the air can be converted into kinetic energy and ultimately into electric energy.

II. Description of the System

A typical solar chimney power plant consists of a solar hot air collector, a solar chimney and a turbine with generator. All three essential elements have been familiar from time immemorial. A solar chimney power plant simply combines them in a new way [1,2,3], as is shown in Fig. 1. Air is heated by solar radiation under a low circular transparent cover open at the periphery; this and the natural ground below it form a hot air collector. In the middle of the cover is a vertical chimney with large air inlets at its base. The joint between the cover and the chimney base is airtight. As hot air is lighter than cold air it rises up the chimney. Suction from the chimney then draws in more hot air from the collector, and cold air enters from the outer perimeter. Thus solar radiation causes a constant up-draught in the chimney. The energy that the hot air contains is converted into mechanical energy by pressure staged wind turbines at the base of the chimney, and into electrical energy conventional generators.

The characteristics of this solar chimney power plant are listed below.

- Efficient solar radiation use. The hot air collector used in the system, can absorb both direct and diffused radiation. Thus the solar chimney can operate on both clear and overcast days. The other major large-scale solar thermal power plants, which are often driven by high temperature steam generated from solar concentrators, can only use direct radiation.

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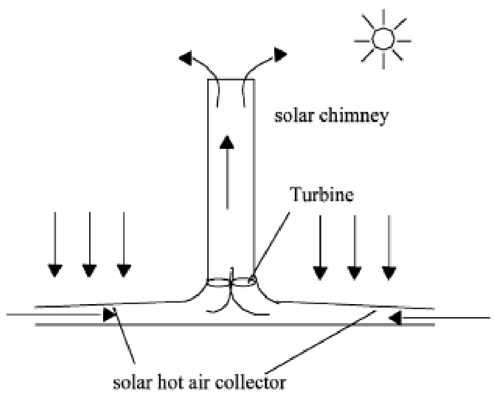

Fig. 1 : Schematic diagram of a solar chimney power plant

Free dual functions, natural energy storage and greenhouse effect. The collector provides storage for natural energy, as the ground under the transparent cover can absorb some of the radiated energy during the day and releases it into the collector at night. Thus solar chimneys also produce a significant amount of electricity at night. The collector itself can also be used as a greenhouse, which will benefit agriculture production accordingly.

- Low operation cost. Unlike conventional power stations, and also other solar–thermal type power stations, solar chimneys do not need cooling water. This is a key advantage in northwestern China where there have already been problems with drinking water.
- Low construction cost. The building materials needed for solar chimneys, mainly concrete and transparent materials, are available everywhere in sufficient quantities.
- Particularly important is that no investment in a high-tech manufacturing plant is needed, as both wind turbine and solar collectors are well- developed industrial products.

III. Mathematical Models Developed

Xinping Zhou et.al., (2009) developed a theoretical model for evaluating maximum height and optimum height of chimney for maximum power output. The models proposed are as follows.

The electric power generated by the turbine generators, Pout, can be expressed as

$$P_{out} = \eta_{tg} \Delta p_t . V . A_c \tag{1}$$

Where η_{tg} is the efficiency of turbine generators. Total energy conversion efficiency can be expressed as the ratio of Pout to solar radiation input on the collector.

$$\eta = \frac{P_{out}}{\pi R_{coll}^2 G} \tag{2}$$

The maximum chimney height can be found out by using expression

$$H_{Max} = \frac{c_p \dot{m}}{U \pi D} . \ln\left(\frac{\pi^2 U D G \eta_{coll} R_{coll}^2}{c_p \dot{m}^2 \left(g - \gamma_\infty c_p\right)} + 1 \right) \tag{3}$$

Pasumarthi and Sherif (1998) conducted extensive research work on experimental and theoretical performance of a demonstration solar chimney model as part I of their research work. The purpose of the investigation on which this paper partly reports was to demonstrate that the solar chimney technology is a viable alternate energy technology suitable and adaptable to hot-climate areas such as those of Florida. Other objectives included developing a mathematical model that could predict the performance characteristics of solar chimneys and validate model results against experimental data. The theoretical models proposed are as follows. The collector was divided into 25 sections, starting from air entering the collector till the air entering the base of the chimney. Collector: A simple energy balance across a section of the collector yields the fluid temperature at the outlet of that section. For example, the exit temperature at the first section can be evaluated using

$$t_{f.avg} = t_a + \frac{q_u}{\dot{m} c_p} \tag{4}$$

The temperature $t_{f.avg}$ so obtained becomes the inlet temperature for the second section and so on. The temperature attained by the air at the end of the 25th section is the temperature of the air entering the chimney section.

Chimney: The velocity at the exit of each chimney section can be found using following equation.

$$\rho_{ch} a_{ch.\sec} v_i^2 + 1 = \rho_{ch} a_{ch.\sec} v_i^2 + (\rho_a - \rho_{ch}) g a_{ch.\sec} \Delta z - \tau_w P e \Delta z \tag{5}$$

Wind turbine generator: The wind turbine placed inside the chimney converts translational energy of the flow field into rotational energy.

$$P_{Max} = \frac{16}{27}\left(\frac{1}{2}\rho a v^3\right) \tag{6}$$

The electric power output can be related to the kinetic power by the following equation:

$$P_{elec} = \eta_{gen} P_{\max} \tag{7}$$

Typical values of the generator efficiency η_{gen} vary from 75% to 85%. A value of 80% for η_{gen} is used throughout this analysis. An overall efficiency can be defined for the solar chimney as the ratio of the useful electric power output and the insolation over the area of the collector:

$$\eta_{overall} = \frac{P_{elec}}{Sa_{coll}} \tag{8}$$

Having developed the models for the analysis, the authors finally concluded that mathematical model capable of predicting the performance of solar chimney systems has been developed. The model is capable of estimating the temperature and power output of solar chimneys as well as examining the effect of various ambient conditions and structural dimensions on the power output.

The potential of solar chimney for application in rural areas of developing countries is discussed by Onyango, F.N and Ochieng, R.M., (2006). The authors have considered the appropriateness of a solar chimney to rural villages and highlight some features of such a power generating plant. A mathematical correlation was developed for temperature ratio τ, and the instantaneous electric power produced by a single turbine P_i, for square collector of side L, a circular chimney of radius R and velocity V, at which the air impinges on the rotor blades. The important expressions are as follows.

$$\tau = \left(\frac{T_s - T_H}{T_m - T_s} \right) \tag{10}$$

Where, τ is the difference between the collector surface temperature and the temperature at the turbine (T_s–T_H) to the difference between the air mass temperature under the roof and the collector surface temperature (T_m–T_s), Where T_s and T_H are the temperatures at the surface covered by a selective material and at any position H in the covered area A and h is the convective transfer coefficient.

If it is assumed that the area swept by the rotor is the same as the cross-sectional area of the chimney, the instantaneous electric power Pi produced by a single turbine is readily derived as

$$P_i = \frac{16}{27}\left(\frac{1}{2} \rho_m \pi R^2 V^3 \right) \tag{11}$$

Where, ρ_m is the density of the air at temperature Tm and the factor of 16/27 is the ideal limit for the extraction of power.

Further can be written as,

$$P_i = 3.0x10^{-31} \beta \left(\frac{L^{15}}{H^{12} R^4} \right) \tau^{15} \tag{12}$$

Where at 300 K and one atmosphere

$$\beta = \left(\frac{\rho_m k^5}{\alpha^5 C_p^{15} \nu^7 \rho_a{}^{15}} \right) = 1.148X10^{-12} \tag{13}$$

Substituting the known the constants in equation (13) for dry air at one atmospheric pressure and ambient temperature (T = 300 K), the instantaneous power reduces to

$$P_i = 4.48X10^{-43} \left(\frac{L^{15}}{H^{12} R^4} \right) \tau^{15} \tag{14}$$

Thermal and technical analyses of solar chimneys were carried out by Bernardes, M.A. and Weinrebe, A. (2003). In the research work, an analysis for the solar chimneys was developed, aimed particularly at a comprehensive analytical and numerical model, which describes the performance of solar chimneys. This model was developed to estimate power output of solar chimneys as well as to examine the effect of various ambient conditions and structural dimensions on the power output. Results from the mathematical model were compared with experimental results and the model was further used to predict the performance characteristics of large-scale commercial solar chimneys. The results show that the height of chimney, the factor of pressure drop at the turbine, the diameter and the optical properties of the collector are important parameters for the design of solar chimneys.

Mullet (1987) presented an analysis to derive the overall efficiency of the solar chimney. The author found that the overall efficiency is directly related to the height of the chimney and he demonstrated it to be about 1% for the height of 1000m and finally concluded that the solar chimney is essentially a power generator of large scale.

The equations developed by the researcher are as follows.

Driving force inside the chimney is given by,

$$\Delta p = 11.67 \left(1 - \frac{K_0}{K_1} \right) h \tag{15}$$

Where, K_0 = Ambient temperature (293 k)
K_1 = Air temperature in the chimney.
h = Height of the chimney.

Velocity of air flowing inside the chimney is given as,

$$V = \left[\frac{2\Delta Kgh}{K_0} \right]^{1/2} \tag{16}$$

Where, ΔK = Temperature rise in K

K_0 = Ambient temperature (293 k)

Power rating: The mechanical power rating can be obtained as the rate of delivery of kinetic energy at the top of the chimney.

$$W = \rho_1 \sqrt{2} \left[\frac{\Delta Kgh}{K_0} \right]^{3/2} \tag{17}$$

Where, ρ_1 = Density of air at temperature K_1.

W = Mechanical power rating.

Overall efficiency;

η_1 is assumed to be 80% with a reasonable rise in temperature.

$\eta_2 = 0.033 \times 10^{-3}$ h

η_3 is assumed to be in the range of 40 to 80 %.

$\eta = \eta_1 \times \eta_2 \times \eta_3$

= 1.07%

Zhou et.al., (2007) conducted experiments on a model having 8 PVC pipes measuring 0.35m radius and 1m height. Eight peaces of pipes were taken to get variation in height of the chimney. In the similar fashion diameter of chimney was made to vary from 1m to 5m. A multiple-blade designed on the operating principle of turbine blade was installed at the base of the chimney. The generator, commercially available, was a permanent magnetism motor with direct current. The updraft drove the turbine, which drove the generator to generate electricity. In the course of experimental measuring, the turbine-generator is under no load conditions. Platimum resistance thermometer sensors (Pt 100) were used to measure hot air temperatures; a mercury thermometer with an accuracy of ±0.5 1C was fixed outside the equipment to measure ambient temperature; a thermal anemometer with an accuracy of ±0.01 m/s was used to measure the velocity of airflow. Measurements were sampled every 10 min. Further a mathematical model based on energy balance has been developed to predict the performance of the solar chimney thermal power generating equipment for different conditions. The models are as follows.

$$V = \sqrt{2gH_{ch}\left(T_0 - T_\infty\right)/T_\infty} \tag{18}$$

Where, V denotes hot air velocity at the solar collector outlet.

Power output of the total system can be found as

$$P_{out} = \frac{1}{3}\eta_w \rho A_{ch} V^3 \tag{19}$$

Where η_w is the turbine efficiency, usually between 50% to 90%.

On the basis of results obtained the researchers finally concluded that the simulated power outputs are basically in agreement with the results calculated with the measurements, which validates the mathematical model of the solar chimney thermal power generating system. Furthermore, based on the simulation and the specific construction costs at a specific site, the optimum combination of chimney and collector dimensions can be selected for a required electric power output.

Analytical and numerical investigation of the solar chimney power plant systems was carried out by Tengzhen et.al., (2006). Different models were developed by the authors for determining static pressure, driving force, power output and efficiency. The authors felt that there is a surge in the use of the solar chimney power plant in the recent years which accomplishes the task of converting solar energy into kinetic energy and also the existing models are insufficient to accurately describe the mechanism. Therefore a more comprehensive model is presented by the authors to evaluate the performance of a solar chimney power plant system, in which the effects of various parameters on the relative static pressure, driving force, power output and efficiency have been further investigated.

The density difference may be expressed in terms of the volume coefficient of expansion as

$$\Delta p = \frac{\pi g \rho_0 \beta_0 q}{C_p \dot{m}} H R_{coll}^2 \tag{20}$$

The maximum power output can be expressed as the product of driving force and the volumetric flow rate and shows that the air properties, the chimney height, the collector radius and the solar radiation have significant effect on the maximum power output.

$$P_{\max} = \frac{\rho_0}{\rho} \frac{\pi g}{C_p T_0} H R_{coll}^2 q \tag{21}$$

The maximum efficiency of the system can be expressed by,

$$\eta_{\max} = \frac{\rho_0}{\rho} \frac{gH}{C_p T_0} \tag{22}$$

Which, demonstrates the functional dependence of the system maximum efficiency on the air density, the inlet temperature and the chimney height.

It can be anal sized from above literature that more emphasis is given in development of models for obtaining velocity of flow through the chimney, power generated by the plant and heat flow through the collector, but significant efforts for determination of adiabatic temperature lapse rate is not done, hence in this paper an attempt is made for obtaining the adiabatic temperature lapse rate with the help of simple mathematical model.

IV. Mathematical Correlation for Adiabatic Lapse Rate

Adiabatic lapse rate is given by

$$-\frac{dT}{dz} = \frac{g}{Cp} \qquad (23)$$

Above equation can be written as

$$-dT = \frac{g}{Cp} dz$$

Integrating the above equation with limits T_1 to T_h, we get,

$$\int_{T1}^{Th} -dT = \frac{g}{Cp}\int_{Z_1}^{Z_h} dz$$

$$-\int_{T1}^{Th} T = \frac{g}{Cp}\int_{z1}^{zh} Z + A$$

$$-(T_h - T_1) = \frac{g}{Cp}(Z_h - Z_1) + A$$

$$\text{or, } (T_1 - T_h) = \frac{g}{Cp}(Z_h - Z_1) + A \qquad (24)$$

at Z = 0, $T_h = T_1$

where,

Z – is the height at which turbine is installed.

T_1 – Temperature of air at Z=0.

T_h – Temperature of air at exit of the chimney.

Substituting in (2)

$$0 = \frac{g}{Cp}(Z_h) + A$$

Therefore,

$$A = -\frac{g}{Cp}(Z_h) \qquad (25)$$

Substituting the value of (3) in (2), we get,

$$(T_1 - T_h) = \frac{g}{Cp}(Z_h - Z_1) - \frac{g}{Cp}Z_h$$

Therefore,

$$T_1 = T_h - \frac{g}{Cp}Z_1 \qquad (26)$$

The temperature of air at any height (Z+h) can similarly be expressed as

$$T_{(Z+h)} = T_h - \frac{g}{Cp}(Z_1 + h) \qquad (27)$$

$$T_{(Z+h)} = T_h - \frac{g}{Cp}Z_1 - \frac{g}{Cp}h \qquad (28)$$

But from equation (26)

$$T_h - \frac{g}{Cp}Z_1 = T_1$$

Therefore, equation (28) reduces to

$$T_{(Z+h)} = T_1 - \frac{g}{Cp}h$$

or

$$T_{(Z+h)} = -\frac{g}{Cp}h + T_1 \qquad (29)$$

This equation is comparable with an equation of straight line of the form

$$y = mx + c$$

It indicates that the plot between $T_{(Z+h)}$ and T_1 should yield a straight line. The slope of this line 'm' represents the value $-\frac{g}{Cp}$ from which the ratio $-\frac{g}{Cp}$ can be calculated and T_1 represents the intercept on Y-axis.

V. Conclusion

It is concluded that the mathematical models developed by the different researcher are quite useful for predicting the performance of solar chimney power plant. The theoretical mathematical model developed in the present study is quite useful for obtaining the adiabatic temperature lapse rate for a long chimney where the heat flow from the walls of the chimney cannot be measured accurately.

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Experimental Investigation of Performance and Emission Characteristics by Different Exhaust Gas Recirculation Methods used in Diesel Engine

By R.Senthilkumar , K.Ramadoss & R.Manimaran
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Abstract - This project aims at the experimental investigation of the effects of hot and cold Exhaust gas recirculation (EGR) methods on emissions and efficiency of the engine. This experiment is conducted in single cylinder, 4-stroke, direct injection diesel engine. A heat exchanger arrangement is provided for obtaining different EGR methods. The performance parameters were studied with and without exhaust gas recirculation of different methods with 10%, 15% and 20% of EGR. The recycled exhaust gas lowers the oxygen concentration in the combustion chamber and increases the temperature of intake charge which lowers the flame temperature and leads to lower NO_x formation. Experimental results shows that the cold EGR is much effective than the hot and intermediate EGR for the reduction of NO_x emission. The increase in temperature of EGR gases causes the combustion temperature which leads to increase in formation of NO_x. By increasing the cooled EGR rates reduces the emissions more significantly.

Keywords : diesel engine, EGR (exhaust gas recirculation), EGR percentage.

GJRE-A Classification : FOR Code: 650203

EXPERIMENTAL INVESTIGATION OF PERFORMANCE AND EMISSION CHARACTERISTICS BY DIFFERENT EXHAUST GAS RECIRCULATION METHODS USED IN DIESEL ENGINE

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Experimental Investigation of Performance and Emission Characteristics by Different Exhaust Gas Recirculation Methods used in Diesel Engine

R. Senthilkumar [α], K. Ramadoss [σ] & R.Manimaran [ρ]

Abstract - This project aims at the experimental investigation of the effects of hot and cold Exhaust gas recirculation (EGR) methods on emissions and efficiency of the engine. This experiment is conducted in single cylinder, 4-stroke, direct injection diesel engine. A heat exchanger arrangement is provided for obtaining different EGR methods. The performance parameters were studied with and without exhaust gas recirculation of different methods with 10%, 15% and 20% of EGR. The recycled exhaust gas lowers the oxygen concentration in the combustion chamber and increases the temperature of intake charge which lowers the flame temperature and leads to lower NO_x formation. Experimental results shows that the cold EGR is much effective than the hot and intermediate EGR for the reduction of NO_x emission. The increase in temperature of EGR gases causes the combustion temperature which leads to increase in formation of NO_x. By increasing the cooled EGR rates reduces the emissions more significantly.

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I. Introduction

The compression ignition engines are widely used owing to its high thermal efficiency and low maintenance cost. In spite of all these benefits, diesel engine exhaust is one of the major sources of atmospheric pollution in the world, accounting for about 60% of the total pollutants dumped into the atmosphere. UBHC, CO, NO, etc., are the major constituents of the engine exhaust pollutants and efforts are throughout the world to find effective means to control them. Thus the fields of diesel fuel alternative and diesel emission control are alive. A Diesel engine is a type of heat engine that uses the internal combustion process to convert the energy stored in the chemical bonds of the fuel into useful mechanical energy[1][4,7,9]. This occurs in two steps. First; the fuel reacts chemically (burns) and releases energy in the form of heat. Second the heat Causes the gases trapped in the cylinder must move piston to expand. The reciprocating motion of the piston is then converted into rotational motion by the crankshaft. Then the fuel enters the cylinder where the heated compressed air is present; however, it will only burn when it is in a vaporized state and intimately mixed with the supply of oxygen. The first minute droplets of fuel enter the combustion chamber and are quickly vaporized. The vaporization of the fuel causes the air surrounding the fuel to cool and it requires time for air to reheat sufficiently to ignite the vaporized fuel. But once ignition has started, the addition heat from combustion helps to further vaporize the new fuel entering the chamber as long as oxygen is present. Engine deposits constitute a serious problem in the compression-ignition engine. Solid or semisolid carbonaceous matter builds up because of incomplete combustion. The compression-ignition engine exhaust gases contain Oxides of Nitrogen, carbon monoxide, organic compounds that are unburned or partially burned or partially burnt hydrocarbons, visible smoke and soot (or particulates).

a) Literature Review

Alain Maiboom [1] has studied the effect of exhaust gas recirculation in direct injection diesel engine. The experimental results shows that the increase of inlet temperature at constant EGR rate has contrary effects on combustion and emissions, thus sometimes giving opposite tendencies as traditionally observer, as the reduction of NO_x emissions with increased inlet temperature. At low-load conditions, very low-NOx and particulate matter emissions can be obtained with high EGR rates at constant pressure, because the combustion is delayed due to the high dilutions. This is accompanied with an increase of BSFC, CO and hydrocarbon emissions. For some operating conditions, EGR at constant AFR is a way to drastically reduce NO_x emissions without important penalty on BSFC and soot emissions. S.Swami Nathan [2] as investigated the possibility to operate a HCCI engine with reasonably high thermal efficiencies in a

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wide range of BMEP's with acetylene as the sole fuel. The intake charge temperature and amount of EGR have to be controlled based on output of engine thus leads to low NO emissions and smoke. At high BMEP's the hot EGR leads to knock, it can be avoided by proper control over the temperature and amount of re-circulated exhaust. P.V.Walke [3] have done the experimental investigation on the impact of exhaust gas recirculation on the diesel engine performance and observed that with increasing rates of EGR at different torque there is a marginal decrease in brake thermal efficiency. Increase in EGR the concentration of NOx decreases. M.Gomaa [4] studied the effects of EGR rates on diesel engine and shows that the CO emissions increased with various EGR rate. The possible reason may be lower excess oxygen available for combustion. Lower excess oxygen results in rich air fuel mixture at different locations inside the combustion chamber. The NO in combustion chamber is reduced due to higher pressure and higher temperatures during combustion. L.Niranjan [5, 11] has done an experimental investigation on the effects of cold and hot EGR using bio-diesel as fuel. From their result they conclude the NOx emission is increased due to increase in temperature of the EGR gases causes the combustion temperature to increase, as well as causing the combustion gases to spend longer periods at higher temperatures. Hatim Machrafi [6] have numerically investigated the influence of EGR on the HCCI engine. They have studied the effect of CO on the auto ignition process. Regarding the effect of CO on this study suggest that CO can be either promote or inhibit auto ignition delay. V.Pradeep and R.P.Sharma [7,12] investigates the use of HOT EGR for NOx control in a C.I engine fuelled with bio-diesel. Full load NO emission from bio-diesel with EGR, was found lower than that of without EGR and it shows that the BTE was found to be comparable with and without EGR at all loads.

Hitoshi Yokomura, Koji mori [8,9] studied Expansion of EGR Area with Venturi EGR System the application. The application of EGR to diesel engines achieves larger reductions in NOx emissions under a high load condition than a low-load condition for the same EGR rate. In other words, under the high-load condition, a low EGR rate produces the same NOx emission reduction effect as a high EGR rate under the low-load condition[10]. The venturi EGR system expands the EGR-feasible range without adversely affecting fuel economy caused by an increase of pumping loss, and it is thus an effective system for turbocharged diesel engines.

II. Methodology

The test engine is a single cylinder, direct injection, water cooled Compression Ignition engine. The experimental setup is shown in fig.1. An orifice box is connected to the inlet manifold and the air mass flow rate is measured using the manometer connected to the orifice box.

The EGR system consists of a piping system taken from the engine exhaust pipe, and an orifice meter to used measure the flow rate of the exhaust gases and a control valve. The amount of exhaust gas recycling into the inlet manifold is controlled by means of two valves, one in the inlet pipe and other in the pipe line connecting the exhaust line and the inlet manifold.

The re-circulated exhaust gas flows through another orifice meter with inclined manometer for measuring the flow rate, before mixing with the fresh air. Cold EGR is attained by cooling the re-circulated exhaust gas. The exhaust gas recirculation line is connected to a parallel flow heat exchanger having water as the cold fluid. Thermometers are connected to inlet and exit of the cold and hot fluids in the heat exchanger.

The probe of exhaust gas analyzer is inserted into the exhaust pipe for emission measurement. The engine is loaded using rope brake dynamometer. The load on the engine is noted down. The photographs of experimental setup are shown in appendix.

a) Texvel Engine Specifications

Type : single cylinder ,four stroke cycle, vertical engine

Bore in mm	-	85
Stroke in mm	-	110
Rated RPM	-	1500
Rated power output in kW	-	6.5
Loading	-	Rope braking
Connecting rod length	-	235mm
Compression ratio	-	18:1
Rated speed	-	1500 rpm
Orifice diameter	-	0.016

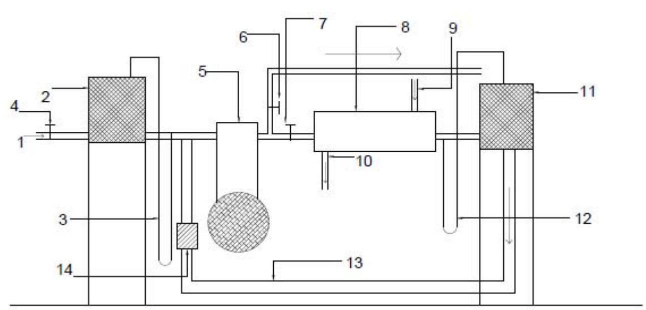

Figure 1 : Schematic Diagram of Experimental setup

1. Air inlet
2. Air inlet Orifice box
3. Air inlet manometer
4. Air inlet control valve
5. CI engine
6. Exhaust gas control valve

7. EGR control valve
8. Heat exchanger
9. Water inlet
10. Water outlet
11. Exhaust gas Orifice box
12. Exhaust gas manometer
13. EGR pipe
14. Particulate filter

III. Results and Discussion

Performance and emission tests were carried out with and without exhaust gas recirculation of different methods of 10%, 15%, 20% and 25% of EGR. The tests are conducted at the rated speed of 1500 rpm at various loads. Based on the experimental data the graphs were drawn. These graphs show the variation of specific fuel consumption, mechanical efficiency, Brake thermal efficiency, Indicated power, BMEP and IMEP with respect to Brake power for various percentages and methods of EGR.

Specific fuel consumption is found to be high at all loads with and without EGR. Brake thermal efficiency with 10% EGR was comparable without EGR at all loads. Indicated thermal efficiency with cold EGR is better as compared with hot and intermediate EGR but it relatively low without EGR. NO_x emission from hot EGR is comparatively higher than without EGR. Cold EGR of higher rates shows much effective in reducing NO_x emission.CO2 emission at 10% cold EGR percentages is very high than that of higher EGR rates.CO emissions with EGR was increased in part loads and decreases with higher loads as compared without EGR.

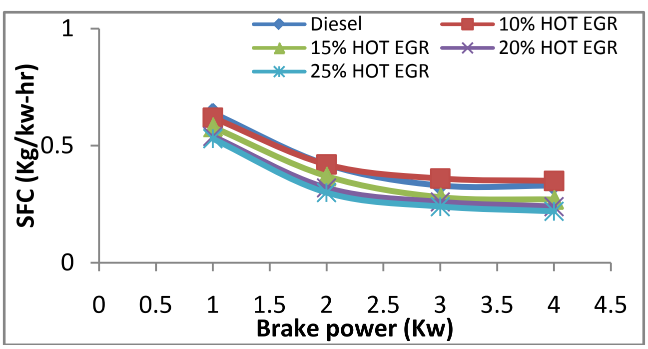

Figure 1 : BP Vs SFC for various hot EGR ratios

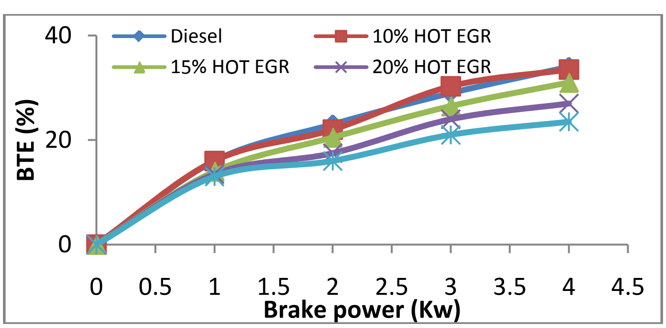

Figure 2 : BP Vs BTE for various hot EGR ratios

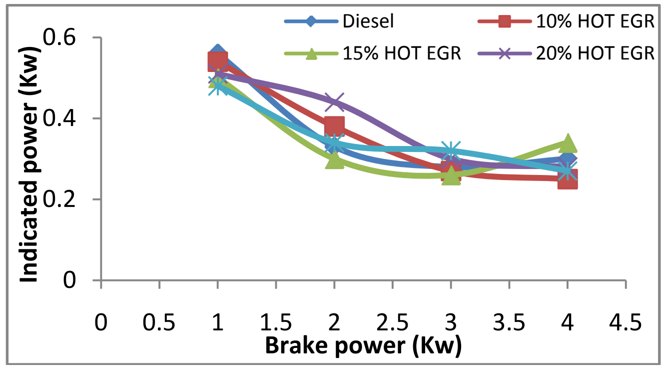

Figure 3 : BP Vs IP for various cold EGR ratios

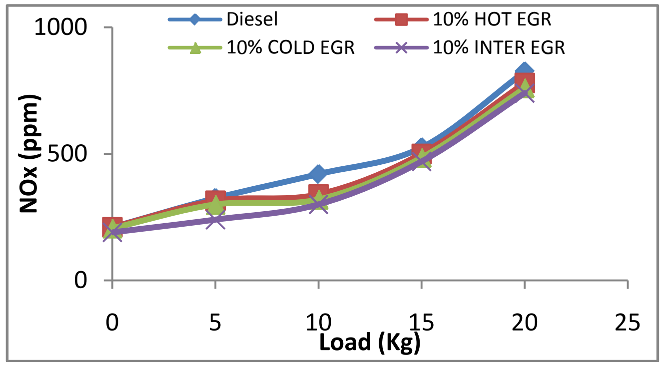

Figure 4 : LOAD Vs NO_x for 10% EGR

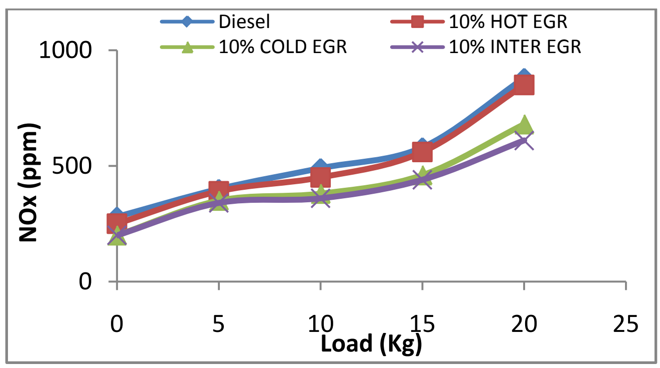

Figure 5 : LOAD Vs NO_x for 15% EGR

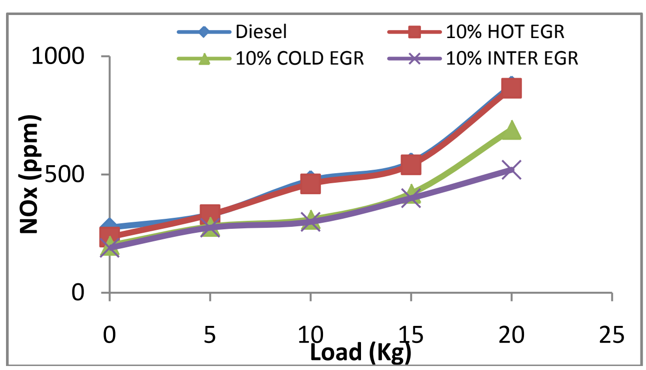

Figure 6 : LOAD Vs NO_x for 20% EGR

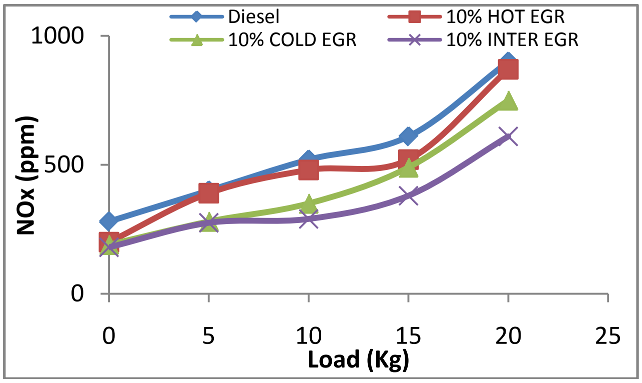

Figure 7 : LOAD Vs NO_x for 25% EGR

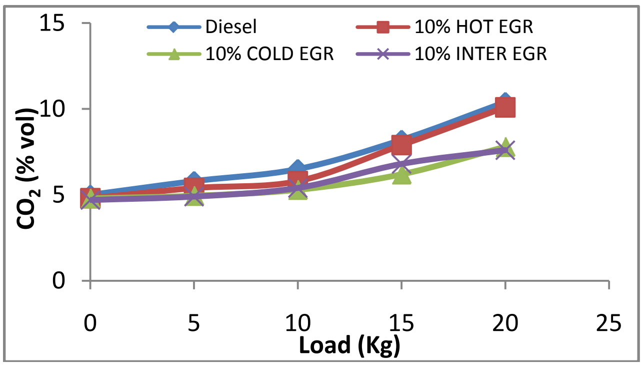

Figure 8 : LOAD Vs CO_2 for 10% EGR

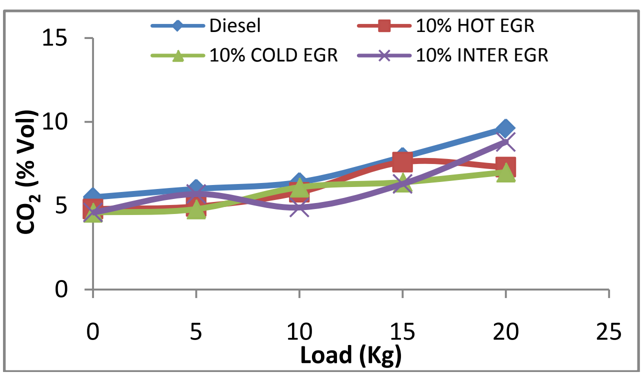

Figure 9 : LOAD Vs CO_2 for 15% EGR

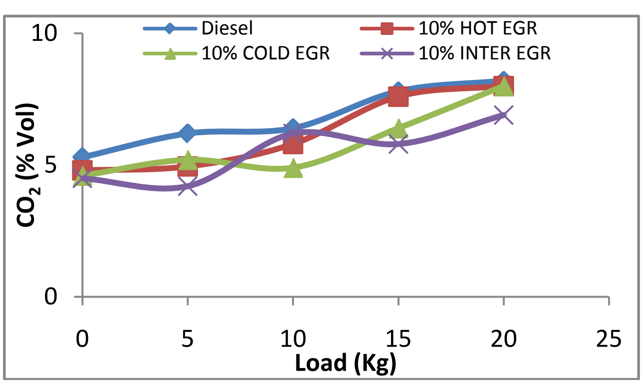

Figure 10 : LOAD Vs CO_2 for 20% EGR

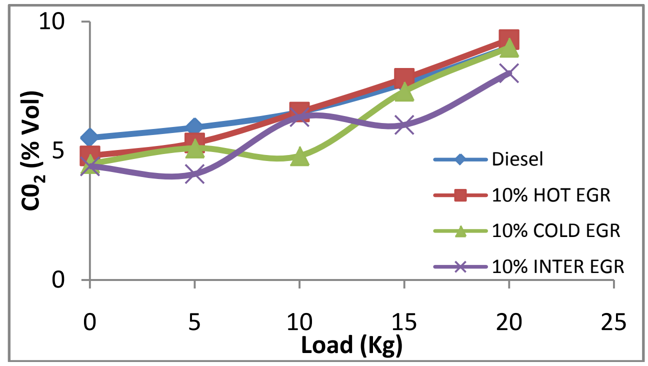

Figure 11 : LOAD Vs CO_2 for 25% EGR

IV. Conclusion

From the experimental results obtained, we infer that exhaust gas recirculation resulted in NOx reduction with slight decrease in the efficiency. NOx is increasing at partial loads and decreasing at higher loads. The trade-off between NO_x formation and other gases are diverging with load conditions. Also the results shows that cold EGR is much effective than hot EGR. From gas behavior 15-25% of cold EGR reduces the formation of NOx very well. Future researches can be carried out by experiments on EGR with other techniques like alternative fuels and variable geometry turbocharger for compromising the decrease in performance.

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Mathematical Correlations Developed for Solar Chimney Power Plant - A Critical Review

By Shashank.B. Thakre, L.B. Bhuyar, Sachin.V. Dahake & Pankaj Wankhade
PRMI T & R.Badnera

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GJRE-A Classification : FOR Code: 850506, 090607

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Strictly as per the compliance and regulations of :

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Shashank.B. Thakre [α], L.B. Bhuyar [σ], Sachin.V. Dahake [ρ] & Pankaj Wankhade [ω]

Abstract - A solar chimney power plant consists of a large greenhouse-type collector surrounding a tall chimney. The air, heated within the collector, passes through an inlet guide vane (IGV) cascade and then through a transition section to a turbine that powers a generator. The transition section contains the turbine inlet guide vanes that support the whole chimney and guides the flow entering the turbine. There is a surge in the use of the solar chimney power plant in the recent years which accomplishes the task of converting solar energy into kinetic energy. The existing models are sufficient to accurately describe the mechanism and evaluate the performance of a solar chimney power plant system, in which the effects of various parameters on the relative static pressure, driving force, power output and efficiency. This paper aims at the segregation of the different mathematical models presented by the various researches, which are developed to evaluate the performance of solar chimney power plant, which will help the budding researcher to develop their own model as well as to evaluate the performance of solar chimney power plant.

Keywords : collector, turbine, chimney, mathematical models, review.

I. Introduction

THE widespread use of solar energy, as an alternate and non depletable resource for agriculture and industry as well as other applications, is dependent on the development of solar systems which possess the reliability, performance and economic characteristics that compare favorably with the conventional systems. The solar chimney power plant system, which is composed of the solar collector, the chimney and the turbine, has been investigated all over the world since the German researcher Jorg Schliaich first made the brainchild in the 1970s. The main objective of the collector is collecting solar radiation to heat up the air inside. As the air density inside the System is less than that of the environment at the same height, natural convection affected by buoyancy which acts as driving force comes into existence. Due to the Existence of the chimney, the cumulative buoyancy results in a large pressure difference between the system and the environment, then the heated air rises up into the chimney with great speed. If an axis-based turbine is placed inside the chimney where there is a large pressure drop, the potential and heat energy of the air can be converted into kinetic energy and ultimately into electric energy

II. Description of the System

A typical solar chimney power plant consists of a solar hot air collector, a solar chimney and a turbine with generator. All three essential elements have been familiar from time immemorial. A solar chimney power plant simply combines them in a new way [1,2,3], as is shown in Fig. 1. Air is heated by solar radiation under a low circular transparent cover open at the periphery; this and the natural ground below it form a hot air collector. In the middle of the cover is a vertical chimney with large air inlets at its base. The joint between the cover and the chimney base is airtight. As hot air is lighter than cold air it rises up the chimney. Suction from the chimney then draws in more hot air from the collector, and cold air enters from the outer perimeter. Thus solar radiation causes a constant up-draught in the chimney. The energy that the hot air contains is converted into mechanical energy by pressure staged wind turbines at the base of the chimney, and into electrical energy conventional generators.

The characteristics of this solar chimney power plant are listed below.

- Efficient solar radiation use. The hot air collector used in the system, can absorb both direct and diffused radiation. Thus the solar chimney can operate on both clear and overcast days. The other major large-scale solar thermal power plants, which are often driven by high temperature steam generated from solar concentrators, can only use direct radiation.
- Free dual functions, natural energy storage and greenhouse effect. The collector provides storage for natural energy, as the ground under the transparent cover can absorb some of the radiated energy during the day and releases it into the collector at night. Thus solar chimneys also produce a significant amount of electricity at night. The

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collector itself can also be used as a greenhouse, which will benefit agriculture production accordingly

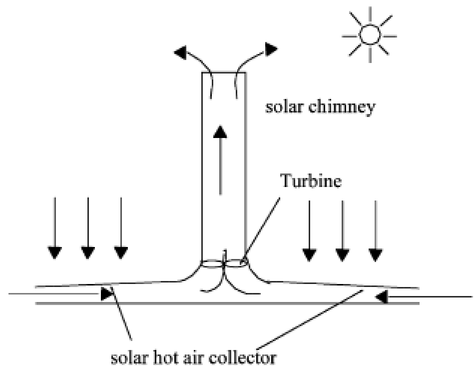

Fig. 1 : Schematic diagram of a solar power plant

- Low operation cost. Unlike conventional power stations, and also other solar–thermal type power stations, solar chimneys do not need cooling water. This is a key advantage in northwestern China where there have already been problems with drinking water.
- Low construction cost. The building materials needed for solar chimneys, mainly concrete and transparent materials are available everywhere in sufficient quantities.

Particularly important is that no investment in a high-tech manufacturing plant is needed, as both wind turbine and solar collectors are well- developed industrial products.

III. Mathematical Models Developed

Xinping Zhou et.al. (2009) developed a theoretical model for evaluating maximum height and optimum height of chimney for maximum power output. The models proposed are as follows.
The electric power generated by the turbine generators, Pout, can be expressed as

$$P_{out} = \eta_{tg} \Delta p_t . V . A_c \quad (1)$$

Where η_{tg} is the efficiency of turbine generators. Total energy conversion efficiency can be expressed as the ratio of Pout to solar radiation input on the collector

$$\eta = \frac{P_{out}}{\pi R_{coll}^2 G} \quad (2)$$

The maximum chimney height can be found out by using expression,

$$H_{Max} = \frac{c_p \dot{m}}{U \pi D} . \ln\left(\frac{\pi^2 U D G \eta_{coll} R_{coll}^2}{c_p \dot{m}^2 (g - \gamma_\infty c_p)} + 1 \right) \quad (3)$$

Pasumarthi and Sherif (1998) conducted extensive research work on experimental and theoretical performance of a demonstration solar chimney model as part I of their research work. The purpose of the investigation on which this paper partly reports was to demonstrate that the solar chimney technology is a viable alternate energy technology suitable and adaptable to hot-climate areas such as those of Florida. Other objectives included developing a mathematical model that could predict the performance characteristics of solar chimneys and validate model results against experimental data. The theoretical models proposed are as follows. The collector was divided into 25 sections, starting from air entering the collector till the air entering the base of the chimney.

Collector: A simple energy balance across a section of the collector yields the fluid temperature at the outlet of that section. For example, the exit temperature at the first section can be evaluated using

$$t_{f.avg} = t_a + \frac{q_u}{\dot{m} c_p} \quad (4)$$

The temperature $t_{f.avg}$ so obtained becomes the inlet temperature for the second section and so on. The temperature attained by the air at the end of the 25th section is the temperature of the air entering the chimney section.

Chimney: The velocity at the exit of each chimney section can be found using following equation.

$$\rho_{ch} a_{ch.sec} v_i^2 + 1 = \rho_{ch} a_{ch.sec} v_i^2 + (\rho_a - \rho_{ch}) g a_{ch.sec} \Delta z - \tau_w Pe \Delta z \quad (5)$$

Wind turbine generator: The wind turbine placed inside the chimney converts translational energy of the flow field into rotational energy.

$$P_{Max} = \frac{16}{27}\left(\frac{1}{2}\rho a v^3\right) \quad (6)$$

The electric power output can be related to the kinetic power by the following equation:

$$P_{elec} = \eta_{gen} P_{\max} \quad (7)$$

Typical values of the generator efficiency η_{gen} vary from 75% to 85%. A value of 80% for η_{gen} is used throughout this analysis. An overall efficiency can be defined for the solar chimney as the ratio of the useful

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electric power output and the insolation over the area of the collector:

$$\eta_{overall} = \frac{P_{elec}}{Sa_{coll}} \quad (8)$$

Having developed the models for the analysis, the authors finally concluded that mathematical model capable of predicting the performance of solar chimney systems has been developed. The model is capable of estimating the temperature and power output of solar chimneys as well as examining the effect of various ambient conditions and structural dimensions on the power output.

The potential of solar chimney for application in rural areas of developing countries is discussed by Onyango, F.N and Ochieng, R.M., (2006). The authors have considered the appropriateness of a solar chimney to rural villages and highlight some features of such a power generating plant. A mathematical correlation was developed for temperature ratio τ, and the instantaneous electric power produced by a single turbine P_i, for square collector of side L, a circular chimney of radius R and velocity V, at which the air impinges on the rotor blades. The important expressions are as follows.

$$\tau = \left(\frac{T_s - T_H}{T_m - T_s}\right) \quad (10)$$

Where, τ is the difference between the collector surface temperature and the temperature at the turbine (T_s–T_H) to the difference between the air mass temperature under the roof and the collector surface temperature (T_m–T_s), Where T_s and T_H are the temperatures at the surface covered by a selective material and at any position H in the covered area A and h is the convective transfer coefficient.

If it is assumed that the area swept by the rotor is the same as the cross-sectional area of the chimney, the instantaneous electric power Pi produced by a single turbine is readily derived as

$$P_i = \frac{16}{27}\left(\frac{1}{2}\rho_m \pi R^2 V^3\right) \quad (11)$$

Where, ρ_m is the density of the air at temperature Tm and the factor of 16/27 is the ideal limit for the extraction of power.
Further can be written as,

$$P_i = 3.0x10^{-31}\beta\left(\frac{L^{15}}{H^{12}R^4}\right)\tau^{15} \quad (12)$$

Where at 300 K and one atmosphere

$$\beta = \left(\frac{\rho_m k^5}{\alpha^5 C_p^{15} \nu^7 \rho_a^{\ 15}}\right) = 1.148X10^{-12} \quad (13)$$

Substituting the known the constants in equation (13) for dry air at one atmospheric pressure and ambient temperature (T = 300 K), the instantaneous power reduces to

$$P_i = 4.48X10^{-43}\left(\frac{L^{15}}{H^{12}R^4}\right)\tau^{15} \quad (14)$$

Thermal and technical analyses of solar chimneys were carried out by Bernardes, M.A. and Weinrebe, A. (2003). In the research work, an analysis for the solar chimneys was developed, aimed particularly at a comprehensive analytical and numerical model, which describes the performance of solar chimneys. This model was developed to estimate power output of solar chimneys as well as to examine the effect of various ambient conditions and structural dimensions on the power output. Results from the mathematical model were compared with experimental results and the model was further used to predict the performance characteristics of large-scale commercial solar chimneys. The results show that the height of chimney, the factor of pressure drop at the turbine, the diameter and the optical properties of the collector are important parameters for the design of solar chimneys.

Mullet (1987) presented an analysis to derive the overall efficiency of the solar chimney. The author found that the overall efficiency is directly related to the height of the chimney and he demonstrated it to be about 1% for the height of 1000m and finally concluded that the solar chimney is essentially a power generator of large scale.

The equations developed by the researcher are as follows.
Driving force inside the chimney is given by,

$$\Delta p = 11.67\left(1 - \frac{K_0}{K_1}\right)h \quad (15)$$

Where, K_0 = Ambient temperature (293 k)
K_1 = Air temperature in the chimney.
h = Height of the chimney.
Velocity of air flowing inside the chimney is given as,

$$V = \left[\frac{2\Delta K g h}{K_0}\right]^{1/2} \quad (16)$$

Where, ΔK = Temperature rise in K
K_0 = Ambient temperature (293 k)
Power rating: The mechanical power rating can be obtained as the rate of delivery of kinetic energy at the top of the chimney.

$$W = \rho_1 \sqrt{2} \left[\frac{\Delta Kgh}{K_0} \right]^{3/2} \tag{17}$$

Where, ρ_1 = Density of air at temperature K_1.
W = Mechanical power rating.
Overall efficiency;
η_1 is assumed to be 80% with a reasonable rise in temperature.
$\eta_2 = 0.033 \times 10^{-3}$ h
η_3 is assumed to be in the range of 40 to 80 %.
$\eta = \eta_1 \times \eta_2 \times \eta_3$
= 1.07%

Zhou et.al., (2007) conducted experiments on a model having 8 PVC pipes measuring 0.35m radius and 1m height. Eight peaces of pipes were taken to get variation in height of the chimney. In the similar fashion diameter of chimney was made to vary from 1m to 5m. A multiple-blade designed on the operating principle of turbine blade was installed at the base of the chimney. The generator, commercially available, was a permanent magnetism motor with direct current. The updraft drove the turbine, which drove the generator to generate electricity. In the course of experimental measuring, the turbine-generator is under no load conditions. Platinum resistance thermometer sensors (Pt 100) were used to measure hot air temperatures; a mercury thermometer with an accuracy of ±0.5 1C was fixed outside the equipment to measure ambient temperature; a thermal anemometer with an accuracy of ±0.01 m/s was used to measure the velocity of airflow. Measurements were sampled every 10 min. Further a mathematical model based on energy balance has been developed to predict the performance of the solar chimney thermal power generating equipment for different conditions. The models are as follows.

$$V = \sqrt{2gH_{ch}\left(T_0 - T_\infty\right)/T_\infty} \tag{18}$$

Where, V denotes hot air velocity at the solar collector outlet.
Power output of the total system can be found as

$$P_{out} = \frac{1}{3}\eta_w \rho A_{ch} V^3 \tag{19}$$

Where η_w is the turbine efficiency, usually between 50% to 90%.

On the basis of results obtained the researchers finally concluded that the simulated power outputs are basically in agreement with the results calculated with the measurements, which validates the mathematical model of the solar chimney thermal power generating system. Furthermore, based on the simulation and the specific construction costs at a specific site, the optimum combination of chimney and collector dimensions can be selected for a required electric power output.

Analytical and numerical investigation of the solar chimney power plant systems was carried out by Tengzhen et.al. (2006). Different models were developed by the authors for determining static pressure, driving force, power output and efficiency. The authors felt that there is a surge in the use of the solar chimney power plant in the recent years which accomplishes the task of converting solar energy into kinetic energy and also the existing models are insufficient to accurately describe the mechanism. Therefore a more comprehensive model is presented by the authors to evaluate the performance of a solar chimney power plant system, in which the effects of various parameters on the relative static pressure, driving force, power output and efficiency have been further investigated.

The density difference may be expressed in terms of the volume coefficient of expansion as

$$\Delta p = \frac{\pi g \rho_0 \beta_0 q}{C_p \dot{m}} H R_{coll}^2 \tag{20}$$

The maximum power output can be expressed as the product of driving force and the volumetric flow rate and shows that the air properties, the chimney height, the collector radius and the solar radiation have significant effect on the maximum power output.

$$P_{\max} = \frac{\rho_0}{\rho} \frac{\pi g}{C_p T_0} H R_{coll}^2 q \tag{21}$$

The maximum efficiency of the system can be expressed by,

$$\eta_{\max} = \frac{\rho_0}{\rho} \frac{gH}{C_p T_0} \tag{22}$$

Which demonstrates the functional dependence of the system maximum efficiency on the air density, the inlet temperature and the chimney height.

Padki and Sherif (1999), developed a set of differential equations is to analyze a solar chimney. The equations are integrated by making a few simplifying assumptions and expressions for the power generated, as well as, the efficiency are obtained in closed form algebraic formulas.

Initially, the solar chimney was conceived as a constant-diameter chimney, and a pilot plant was built according to that design (Richards, 1982; Mullet, 1987). But in the author’s opinion, however, the next significant step in the improvement of the system design would come with the design of an optimally shaped chimney, probably of a converging type. A shape of this kind would have two basic advantages:

Firstly, it would act as a funnel to accelerate the flow, and secondly, would be structurally much more stable than the constant-diameter chimney.

The analysis presented here is primarily concerned with the movement of hot air within the chimney. This hot air is assumed to enter the chimney with a vertical velocity v_i, which is the result of the buoyancy force. The governing equations for the air movement within the chimney are those of the continuity, momentum and energy.

Continuity equation:

$$\frac{1}{v}\frac{dv}{dz}+\frac{1}{A}\frac{dA}{dz}+\frac{1}{\rho}\frac{d\rho}{dz}=0 \tag{23}$$

Momentum equation:

$$v\frac{dv}{dz}=\left(\frac{\rho_a-\rho}{\rho}\right)g \tag{24}$$

Energy equation:

$$\frac{d}{dz}\left[\rho\left(c_pT+\frac{v^2}{2}+gz\right)\right]=losses \tag{25}$$

The mass flow rate into the chimney can be expressed in terms of the ambient air density and the temperature rise as,

$$\dot{m}=\rho_aA_i\left(2gh_0\Delta T_iT_a\right)^{1/2}/\left(\Delta T_i+T_a\right) \tag{26}$$

The available power can be expressed as,

$$power=\sqrt{\left(\frac{2\left(gh_0\Delta T_i\right)^3/T_aA_i^3}{A_c^2\left(T_a+\Delta T_i\right)}\right)} \tag{27}$$

The efficiency of the solar chimney can be written as,

$$\eta_{chim}=\frac{gh_0}{c_pT_a}\left[\frac{A_i}{A_c}\right] \tag{28}$$

Equations for power and chimney efficiency are very useful because they indicate the effects of the various geometrical and operating parameters on the chimney performance in a closed form. The important geometrical parameters are seen to be the entrance area, A_i, the exit area, A_e, and the height of the chimney entrance above the ground, h_0. Note that the actual height of the chimney does not come explicitly into the picture.

The work presented by Pretorius and Kroger (2006), critically evaluated the performance of a large scale solar chimney power plant. The effect of including a recently developed convective heat transfer equation, more realistic turbine inlet loss coefficient and better quality collector roof glass was investigated. The influence of various types of soil on the plant power output was established. The study concludes that the new heat transfer equation, expressed as, reduces the

$$h=\frac{0.2106+0.0026v_w\left(\rho T_m/\mu g\Delta T\right)^{1/3}}{\left(\mu T_m/g\Delta Tc_pk^2\rho^2\right)^{1/3}} \tag{29}$$

Annual plant power output by 11.7%. The more realistic turbine inlet loss coefficient only accounts for a 0.6% rise in annual plant power production, while utilizing better quality glass increases the annual plant power output by 3.4%. Simulation models employing Limestone and Sandstone soil produce virtually similar results to the original model using Granite. The inclusion of the improved convective heat transfer equation fundamentally changes the performance characteristics of the solar chimney power plant.

IV. Conclusion

It is concluded that the mathematical models developed by the different researcher are quite useful for predicting the performance of solar chimney power plant. Taking into account the earlier research as a base, the subsequent researcher incorporated the various losses which were not taken into account by the former researcher thereby improving the accuracy of predicting the performance of solar chimney power plant.

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"Thickness and Shape Optimization of Filter Sheet by Non-Linear FEA"

By Ms. Shweta A. Naik
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Abstract - Filter Sheets are non standard components and hence the guidelines for design are loose under the ASME and the TEMA code. The usual engineering practice is to extend the ever current design is available with an increased factor of safety. However this results in excessively heavy designs, resulting in increasing costs (e.g. Material, transport, assembly and installation).Hence in such designs there is maximum scope for optimization. Optimization goals are focused on Installing maximum possible filter tubes in a single plate thus increasing the capacity – Shape Optimization and Designing an optimal thickness for filter sheet assembly component for maximum economy – Material optimization. The Project execution phases consist of Analyzing a proposed for both Shape and Material optimization and submission of reports to clients, (In this phase we analyze only 1/6th portion of the assembly) Based on approval and feedback of client, designing the entire assembly and submitting drawings and models for approval) On approval of client proceed with analysis of the entire model created in phase 2. Performing actual hydro tests on the assembly after manufacturing, and evaluating effectiveness of FEA analysis. Preparing Information sheets and guideline processes for future project implementation. The challenges for FEA validation are Performing Shape Optimization and making filter pattern in accordance with manufacturability and ergonomic evaluations. FEA validation should certify a FOS of 5, as required by the guidelines of the Saudi Arabia Oil Code. FEA validation being comparable in case of Hydro Test performance on actual installation of assembly. The outputs of FEA work shall be a shape Optimized Filter Sheet assembly, with maximum productivity and maximum economy. Deformation and Stress Certification for performance in Hydro Test which shall take place at 2.5 times the actual working conditions.

Keywords : asme and tema code, fea validation, ergonomic evaluation.

GJRE-A Classification : FOR Code: 091399

THICKNESS AND SHAPE OPTIMIZATION OF FILTER SHEET BY NON-LINEAR FEA

Strictly as per the compliance and regulations of :

"Thickness and Shape Optimization of Filter Sheet by Non-Linear FEA"

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Keywords : asme and tema code, fea validation, ergonomic evaluation.

I. Introduction

Filter Sheets are non standard components used in Oil & Natural gas Industry for filtration. The usual engineering practice is to extend the ever-current design is available with an increased factor of safety. Around the world, for environmental reasons, oil refineries equipped with a Filter Unit have to face the challenge of particulate emission reduction. The refinery would not be able to meet the tighter limits with its existing Filter Unit flue gas cleanup equipment. The 3rd stage blowback filter option would enable industries to meet current particulate emission requirements and also get close to if not already meet particulate emission a number of years in advance of 2010 requirements. Existing tube sheet Filter assembly as shown in fig.1 have less filtration capacity due to less number of filter tubes. Existing assembly model design is less advanced and flexible. We are going to increase the number of filter tube for increasing the filtration capacity.Fig.2 shows proposed tube sheet assembly with increase number of tubes. The filtration capacity of proposed design can improve by using optimum pitch layout for filter candle. So to optimized the shape and weight of proposed filter sheet assembly considering various design constraints without affecting their functional characteristics.

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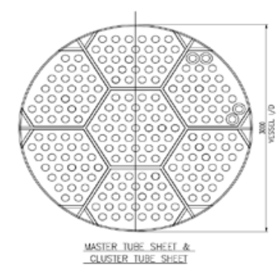

Fig. 1 : Existing filter sheet *Fig. 2 :* Proposed sheet

Due to Coagulation in filter, the Internal pressure increases with time. Due to this internal pressure, the tube sheet in filter is deflected for some time it will break and the joint break. Ignition temp of Natural gas is around 300^{0}C .The impurities which are present in it having temp near about 110^{0}C. In Middle East Region, during operation due to high temp it gets ignited and Explosion of overall plant is there. To avoid this model of the tube sheet is require to improve. Finite element based modeling is the best way to improve model of tube sheet assembly. Analysis require for Validation of FEA results with tested (actual) results. After validation we have base for modeling and simulation of proposed assembly.

The proposed filter unit contains seven chambers as shown in fig3.It has six circular sector filter sheets and one central hexagonal filter sheet. The thickness of the chamber wall depends upon Internal working pressure, factor of safety and Welding allowances. The filter sheets consist of holes in which filter candles are inserted. The capacity of filtration depends upon the number of candles used in filter sheet assembly. The central Hexagonal filter sheet has no input system so it is not a part of analysis.

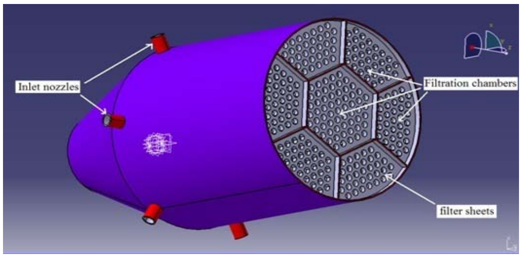

Figure 3 : Proposed model of air filter unit

This entire unit is divided into seven different chambers. The central, hexagonal chamber has more filtration capacity than others. Each chamber is intented to filter a different gas allowing primary mixing of these gases. Inlet nozzles are provided to each chamber. Each inlet has flow control valve to control the flow of gas, thus enabling the control of percentile of each gas. Special filter candles, which remove flue gas particles as small as 2 micron, are proposed to be employed. The filter elements should be removed if the dirty filter P (differential pressure) is higher than the 0.7 bar as per operational guidelines. The refining industries require to design and analyze the filter assembly for achieving following properties: –

a) High mechanical strength for longer filter life
b) Low pressure drop for less interruption of process flow.
c) Clean ability by pulse jet or back flushing to reduce maintenance costs.
d) Increased filtration area, particularly with pleated elements.
e) Increased dirt-holding capacity.
f) Low in weight & Low implementation cost.

Fig-4 shows the four pitch pattern. Among the four we select the 60^0 pitch pattern. The Design of proposed filter sheet are based on the following assumptions:

i) The plate is flat, of uniform thickness, and of homogeneous isotropic material.
ii) The thickness is not more than about one-quarter of the least transverse dimension, and the maximum deflection is not more than about one-half the thickness.

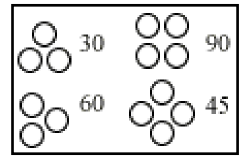

Figure 4 : Pitch Pattern

iii) All forces-loads and reactions are normal to the plane of the plate.
iv) The plate is nowhere stressed beyond the elastic limit. For convenience in discussion, it will be assumed further that the plane of the plate is horizontal.

a) Manufacturing and Testing

Manufacturing of the filter sheet is done by Casting and machining .In machining the holes are Drilled and Reamed, then applying the Heat treating process. In Gulf countries they preferred Gas cutting or Rolled plates. For testing of Filter sheet, Non-Destructive Ultrasonic Testing machine is used. In other words, NDT allows parts and material to be inspected and measured without damaging them. Fig 5 shows different parts.

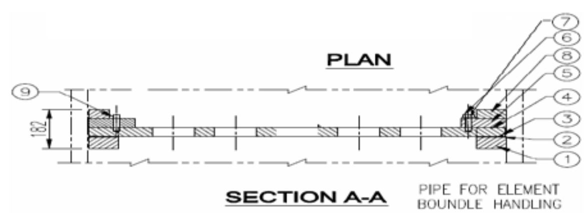

Figure 5 : Section of Filter sheet

Table 1 : Part list

9	LOCKING PIN	SS 304	Dia16x 75 lg	6	REMOVABLE
8	TOP SUPPORT	SA 516 Gr.70	40 thk	4	WELDED TO SHELL
7	WASHER(M16)	SS 304	M16 (spring)	2	STD
6	ALLEN BOLT	SS 304	Dia16x 60lg	2	STD
5	PACKING PLATE	SS 304L	40 thk	4	REMOVABLE
4	FILTER SHEET	SA 240 TYPE 304L	40 thk	1	REMOVABLE
3	SQ.GASKET	RUBBER	Sq. 8X8	1	GLUID TO TUBE SHEET
2	GASKET PLATE	SS 304L	12 thk	1	REMOVABLE
1	BASE SUPPORT	SA 516 Gr.70	50 thk	1	WELDED TO SHELL
P.N.	DESCRIPTION	MATL	SIZE	QTY	REMARKS

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b) Boundary Conditions

Non-Linear Analysis of filter sheet is done by applying the following different seven conditions, for the same we consider 1/6th portion of the filter sheet as shown in fig.

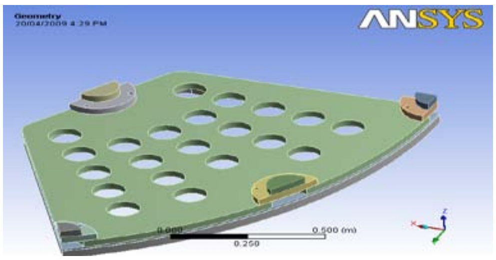


Figure 6 : Filter sheet assembly with different parts

1. To be analyzing given filter sheet for its self weight.
2. To be analyzing given filter sheet for differential pressure of 0.07MPa without self weight.
3. To be analyzing given filter sheet for differential pressure of 0.07MPa with self weight.
4. To be analyzing given filter sheet for hydro test with 2.5 times of given pressure of 0.07 MPa without self weight.
5. To be analyzing given filter sheet for hydro test with 2.5 times of given pressure of 0.07 MPa with self weight.
6. To be analyzing given filter sheet for back pressure of 0.07 MPa without self weight.
7. To be analyzing given filter sheet for back pressure of 0.07 MPa with self weight.

Top support and base support are welded to the shell. Therefore these are act as a fixed support.

c) Non-Linearity

Nonlinear structural behavior arises from a number of causes, which can be grouped into these principal categories: Geometric Non-linearity, Material Non-linearity, Contact Non-linearity.

Contact forms a distinctive and important subset to the category of changing-status nonlinearities. When two bodies comes in contact but Homoginity is lost, Contact Non-linear Analysis is there and force is transmitted from one body to other body. In this project we have different materials Stainless Steel (SS), Structural steel (SA) & Neoprene rubber. Neoprene rubber has material nonlinearity as shown in following graphs.

There are five types of Contact Non-Linearity, these are-

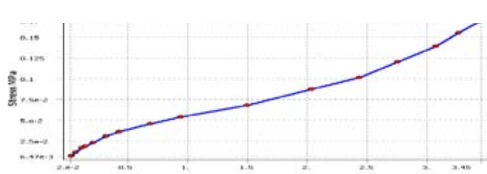


Figure 7 : Neoprene Rubber > Biaxial Test Data

Always Bonded (Welded), Bonded (Glued joint), Standard contact, Sliding (No Separation), No Separation (Always).

In Locking Pin, there is No Separation type of Contact. Body cannot have loose contact. It is generally sliding in a groove. It only applies to regions of faces. In Top Tupport, there is Always Bonded (Welded) type of Contact. It behaves always as a linear. In Packing Plate, there is No Separation type of Contact. Body cannot have loose contact. It is generally sliding in a groove. It only applies to regions of faces. In Square Gasket, there is No Separation (always) type of Contact. Body cannot have loose contact. It is generally sliding in a groove. In Filter sheet, there is Bonded (Glued joint) type of Contact. This is the default configuration for contact regions. If contact regions are bonded, then no sliding or separation between faces or edges is allowed. In Gasket Plate, there is No Separation type of Contact. Body cannot have loose contact. It is generally sliding in a groove. It only applies to regions of faces. Separation of faces in contact is not allowed, but small amounts of frictionless sliding can occur along contact faces. In Base Support, there is Always Bonded (Welded) type of Contact. It behaves always as a linear.

II. Meshing of Filter Sheet Assembly

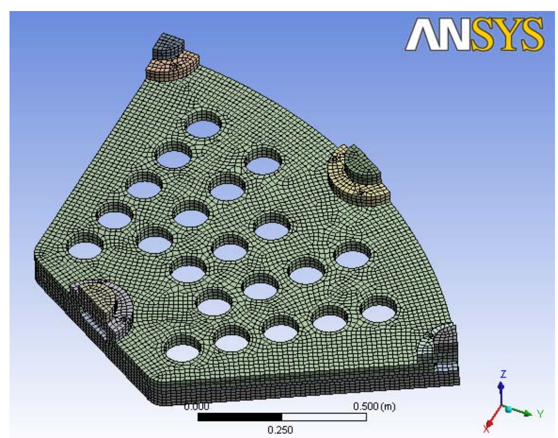


Figure 8 : Meshed model of Filter sheet

Solid 95 is a higher order version of the 3-D 8-node solid element. It can tolerate irregular shapes without as much loss of accuracy. Solid 95 has plasticity, creep, stress stiffening, large deflection, and large strain capabilities. In this project work, the filter sheet assembly model is meshed with hexahedron elements as shown in figure. Mapped face Meshing is given to 21 holes in the filter sheet as well as Base support. Filter sheet assembly along with all the parts are meshed as shown in fig 8 with Hex-dominant and Aesize given to 15mm or 0.015m. The elements created are 28401 whereas number of nodes present are 126636.

After meshing is done, solve this model for different seven conditions, different values for stress and deformation is there. Filter sheet is to be analyzed by different seven condition. Figure 9 shows the five different point at which the Stress value is maximum near at the base support for the worst condition i.e. at Hydro test –without weight which is having maximum stress value among all the conditions and fig-10 shows maximum deformation for worst condition.

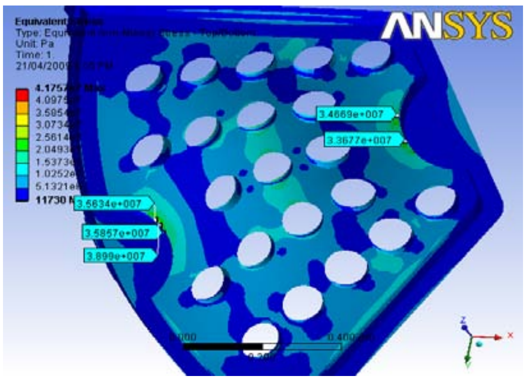


Figure 9 : Five points where stress value is maximum

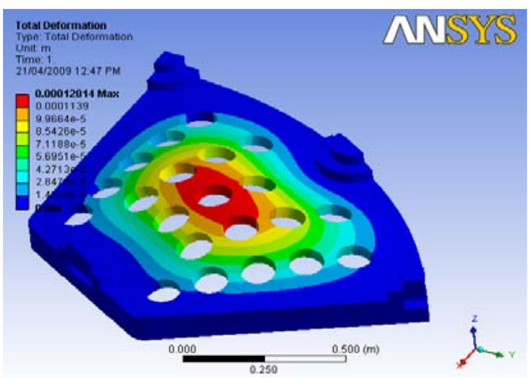


Figure 10 : Maximum Deformation

Result: Maximum Equivalent Stress=4.1757 e7 Pa
Maximum Deformation=.00012814 m

III. Mass Modeling

In filter sheet assembly, filters are to be hanged on filter sheet. These filters are shown as a mass model. The mass model is modeled by using RBE3 (Rigid Body Element).Figures 11 show the Filter tube sheet Assembly with considering the weight of the tubes. Weight of each tube is 45 kg.

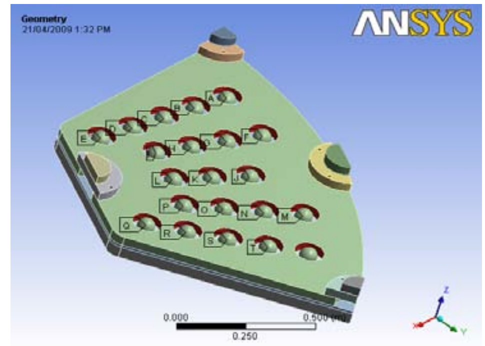


Figure 11 : Filter sheet with Considering Point mass

Figure 12 shows the four different point at which the Stress value is maximum near at the base support for the worst condition i.e. at Hydro test –without weight which is having maximum stress value among all the conditions considering the point mass.

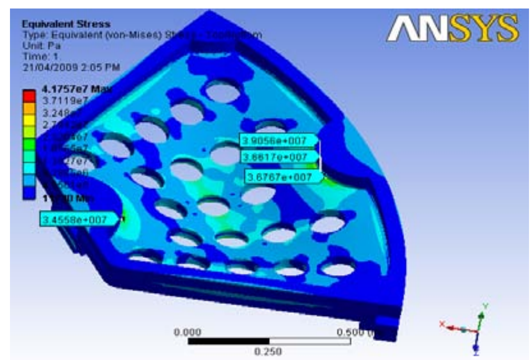


Figure 12 : Four points where stress value is maximum

Analyzed the 1/6th portion of Existing filter sheet having 21 holes for mesh size 15 mm. Following table shows Von mises stresses and Deformation value for without point mass and considering the mass of tubes(Each tube weight = 45 kg) for all seven conditions.

Table 2 : Stress & Deformation for Mesh size 15 mm

S.N	Conditions	Mesh size =15 mm = 0.015 m			
		Without Point Mass		With Point Mass	
		Von Mises Stress (Pa)	Deformation (m)	Von Mises Stress(Pa)	Deformation (m)
1	Self Weight	7.2964 e5	2.2804 e-6	5.2877 e6	1.8405 e-5
2	Differential Pressure-Without wt	1.6705 e7	5.1273 e-5	1.6705 e7	5.1273 e-5
3	Differential Pressure-With wt	1.5976 e7	4.8994 e-5	1.1419 e7	3.2932 e-5
4	Hydro test-Without wt	4.1757 e7	0.00012814	4.1757 e7	0.00012814

5	Hydro test-With wt	4.1028 e7	0.00012586	3.6472 e7	0.00010979
6	Back Pressure-Without wt	1.6682 e7	5.1288 e-5	1.6682 e7	5.1288 e-5
7	Back Pressure-With wt	1.7411e7	5.3569 e-5	2.197 e7	6.9675 e-5

IV. Experimental Validation

For all new product lines, initial Design should follow SOC-306.

All new product equipments shall be tested at 2.5 times the operating pressure using Hydro test. The Hydro test shall have slow built up of pressure, from base pressure to test pressure over a period of 120 min. The equipment shall be maintained at test pressure for 30 min. The pressure shall be gradually reduced to base pressure within a period of 45 min. After test, all components shall be subjected to NDT (Non Destructive Test), the following NDT shall be done-Visual Inspection-No surface irregularities must be present and Pre Dyed components should have no loss of dye due to leakage.

Ultra Sonic Testing–Post Test, internal damage shall get amplified if any, and shall be recorded in an Ultra Sonic Test. The test performance of the assembly should be completely elastic, this shall be verified by checking the dimensions of product for any permanent yield.

a) Hydro Test Condition

Working fluid - Water with Anti Scaling Additives
Test Pressure - 2.5 x 0.07 MPa

Leak Inspection -Sensors (LDR) on the top side of Filter Assembly.

Remark-Simultaneous testing of all 7 chambers was done. Filter holes were plugged with caps of SA 204.

b) Test Execution Details

Begin Time	:	09.00 hr Base
Pressure	:	0 MPa (Empty vessel)
Peak Pressure Time	:	11.00 hrs
Peak Pressure	:	0.175 MPa
Pressure relief begins Time	:	11.30 hrs
LDR Warning	:	Zero
Pressure Drop Warning	:	Zero

Visual Inspection Details involved No leak observed on Top Side of Assembly, No visible damage observed after test and Plug Adhesion intact after test.

According to Auditors Remark,

1) Code requirements have been met by the analysis.
2) The Mesh is satisfactorily fine enough to generate accurate results.
3) The boundary conditions were inspected. The maximum Stress in Filter sheet is 32 MPa, however nominal value if calculated is much lower, it satisfy FOS is 5.
4) Gasket plate shows peak pressure of 34 MPa.however it is observed to significant stress raiser due to vicinity of contact and relatively less thickness of the plate compared to the other components.
5) Material Non Linearity may not be modeled in future analysis as it will have negligible effect on accuracy and unnecessary increases solution time.

V. Design Optimization

As we see there is chance for design optimization, we checked for two different optimizations, Shape optimization and Thickness optimization

a) Shape Optimization

For shape optimization we tried with increasing filter mounting holes. While increasing filter mounting holes we didn't violate minimum centre distance between two holes. We could increase holes from 21 to 28. For 28 holes we analyze the filter sheet assembly as shown in fig 13 with keeping same boundary conditions as were for 21 holes. We directly analyzed for the worst case.

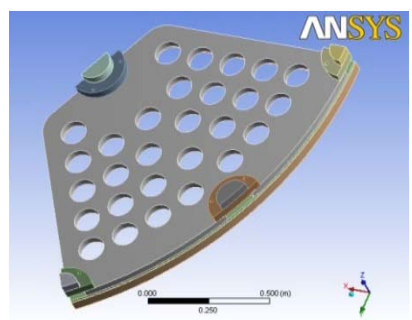


Figure 13 : Proposed Filter sheet model

Following are the results after solving proposed tube sheet having 28 holes for the worst condition with and without point mass with refined mesh size is taken as 15mm which shows that design is safe. Therefore shape can be optimized upto 28 holes. Max Equivalent stress = 4.2636 e7 Pa

Max. Deformation = 0.00014293 m

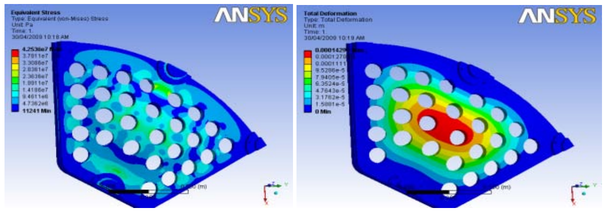


Figure 14 : Equivalent stress & max deformation for Hydro test without wt condition

b) Thickness Optimization

Following are the results after solving proposed tube sheet for shape and thickness optimization for the worst condition with and without point mass with refined mesh size is taken as 15mm.

Max Equivalent stress = 5.3959 e7 Pa
Max. Deformation = 0.00020162 m

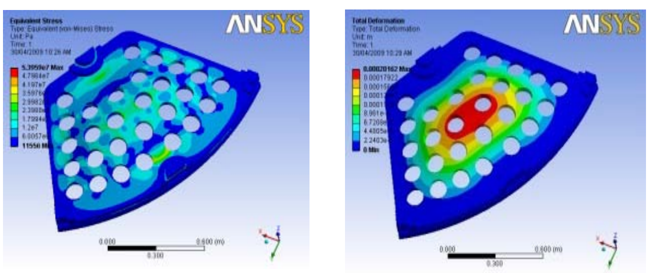
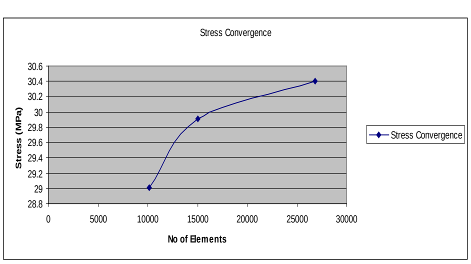


Figure 15 : Equivalent stress & max deformation for Hydro test without wt condition

VI. Mesh Sensitivity Analysis

Size of elements influences the convergence of the solution directly and hence it has to be chosen with care. If the size of elements is small, the final solution is expected to be more accurate. However, we have to remember that the use of elements of smaller size will also mean more computational time. As the number of elements increases, the size of each element must decrease, and consequently the accuracy of the model generally increases. Gasket plate having 12 mm thickness which is less as compared to others. The Gasket plate having contact on both sides Therefore there is not reliable stress concentration. Hence we should rely more on probe values as there is stress concentration.



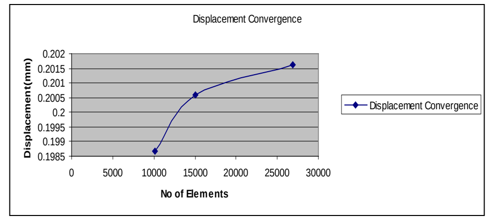


Figure 16 : Stress& Displacement Convergence

For shape & thickness optimization, the Stress and Displacement Convergence is as shown in figure 16 for worst condition. As the no of element goes on increasing corresponding stress and displacement goes on increasing. The above graph of obtained for any general finite element analysis shows how the accuracy of the analysis increases with increasing element numbers.

VII. Conclusion and Future Scope

a) Conclusion

Analysis results are reliable as seen in Mesh Sensitivity convergence and actual Testing. FEA Validation shows we can increase efficiency of Filter sheet by increasing number of tubes and still maintaining Factor of Safety 5.Thickness Optimization also indicates material saving and it is concluded that the optimized thickness and shape be sent for CFD analysis to check suitability.

b) Future Scope

Currently inlet to central plate is not designed. If such a inlet is designed then its structural analysis is recommended in the future. In such analysis, we will have to reassess the performance of peripheral shell.

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- 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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