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Highlights

- Analysis of Scale Effects
- Effect of Water Absorption
- Impact of CFRE Composites
- Analysis of Pyrolysis Kinetics

Discovering Thoughts, Inventing Future

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Analysis of Pyrolysis Kinetics of Biomass Particle Under Isothermal and Non-Isothermal Heating Conditions using Differential Transformation Method

By M. G. Sobamowo, S. J. Ojolo & C. A. Osheku
University of Lagos

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I. Introduction

The important and the centrality of pyrolysis process in the thermochemical biomass conversion processes of biomass have increased the research interests in the studies of the energy conversion processes. In the study of biomass gasification processes, although, overall process of pyrolysis appears simple but the sequence of reactions is complex and involves both endothermic and exothermic processes whose thermodynamics and kinetics are poorly understood [1]. Under such complex phenomena, it is impossible to formulate a complete mathematical model of pyrolysis which will still be mathematically tractable. However, as a compromise between mathematical tractability and accuracy of description, simplified models are employed under certain defined conditions to predict the conversion process of biomass particle. In fact, the need for the simple rationally-based models of pyrolysis as a basis for reactor design has been identified in the survey of low temperature (i.e. less than 600^{0}C) pyrolytic conversion of biomass to usable forms of energy since the complications involved in the numerical solution of a more sophisticated models make them unsuitable for design and prediction purposes [1]. One angle of approach had been adopted to develop simple and economic models which aggregate the more important aspects of the sequence of events as a solid sample is pyrolyzed. The heat conduction equations in a pyrolysizing solid fuel such as wood were first combined with those for heat generation by Bamford [2], assuming a first order single step reaction. The model developed by Bamford has been used by various researchers [3, 4, and 5]. The effects of internal convection and variable transport properties were later incorporated by Matsumoto et al [6], Roberts [7] and Kung [8]. The effect of char formation was considered by Kung [8], and the rate of char removal by oxidation was modelled by Matsumoto et al [6]. Temperature-dependent property variation was also studied by Matsumoto et al [6], Kung [8], Maa and Baille [9], Kansa *et al*. [10], Chan et al, [11]. Multi-step reaction schemes have been presented by Kung [8], Chan *et al*. [11] and Koufopanos *et al*. [12]. The heat of reaction of pyrolysis have been modelled by Lee *et al*. [13], while the effect of anisotropy of the pyrolysing medium has been considered by Kansa *et al*. [10]. Maa and Baille [9] proposed an ‘unreacted shrinking core model’ for high temperatures. Miyanamie [14] studied the effects of heat of reaction and Lewis number on the pyrolysis of solid particle. For the motion of the gases within the solid, a momentum equation was included [10]. Fan *et al.* [15] developed a ‘volume reaction’ model taking into account simultaneous heat and mass transfer in the particle. Pyle and Zaror [1] experimentally investigated the pyrolysis of biomass. Simmons [16] analysed a simplified heat transfer model with an assumed first order reaction for the estimation of an upper bound for biomass particle size in conducting experimental pyrolysis kinetic. Villermaux *et al.* [17] presented a Volatilization Thermal Penetration model (VTP) for any kind of solid reaction where volatilization is controlled by heat conduction from the outer surface. On the

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modeling of pyrolysis of biomass particle, particularly on the studies of the kinetic, thermal and heat transfer effects, Koufopanos *et al*. [12] assumed the pyrolysis process to be primary and secondary kinetic reactions.

Di Blasi [18] analysed the effects of convection and secondary reactions within porous solid fuels undergoing pyrolysis. Melaaen and Gronli [19] presented models on moist wood drying and pyrolysis. Jalan and Srivastava [20] explored kinetic and heat transfer effects on the pyrolysis of a single biomass cylindrical pellet. Ravi [21] proposed a semi-empirical model for pyrolysis of sawdust in an annular packed bed using pseudo-first order reaction for the chemical reaction of the pyrolysis. In their model, Babu and Chaurasia [22] considered time-dependent density and temperature-dependent specific heat capacity of biomass to investigate the dominant design variables in pyrolysis of biomass particles of different geometries in a thermally thick regime. In the recent time, Sheth and Babu [23], presented Kinetic Model for biomass pyrolysis and concluded that pyrolysis in wood is typically initiated at 200°C and lasts till 450-500°C, depending on the species of wood. Yang et al [24] presented that the major stage of biomass pyrolysis occurs between 250-450°C. Mandl *et al*. [25], pointed out in their work that the pyrolysis of softwood pellets takes place at around 425K and char particles and volatiles are formed while Weerachanchai*et al*. [26] submitted that the major decomposition of all biomasses occurred in the range of 250-400°C. Slopiecka *et al*. [27], in their studies of poplar wood, concluded that the decomposition of hemicelluloses and cellulose take place in active pyrolysis in the temperature from 473-653K and 523-623K, respectively. They then added that Lignin decomposes in both stages: active and passive pyrolysis in the range from 453-1173K without characteristics peaks.

Studies on the analysis of biomass kinetics have been based on numerical approach because of the non-linear nature of the developed models. However, the classical way of finding analytical solution is obviously still very important since it serves as an accurate benchmark for numerical solutions. Therefore, as a mean of investigating and presenting the exact effects of various parameters in the pyrolysis kinetics thereby increasing the predictive power, this study also presents the analytical solutions of pyrolysis kinetics of biomass particle using differential transform method (DTM). Although, this concept was introduced by Zhou [40], its applications to both linear and non-linear differential and system of differential equation have fast gained ground or appeared in many engineering and scientific research. The potentiality of the method is displayed in the provisions of symbolic or analytical solutions to both linear and non-linear integral and differential equations without linearization, discretization or perturbation. DTM is capable of greatly reducing the size of computational work while still accurately providing the series solution with fast convergence rate.

As good and accurate the method presents itself, to the best of the authors' knowledge, it has not been applied for the study and the analysis of biomass pyrolysis kinetic and thermal decomposition. Therefore, in this study, differential transformation method is applied to study the pyrolysis kinetics of biomass particle under isothermal and non-isothermal heating conditions. Also, through the solutions of the method for the problems under investigation, simulations are carried out to study the effects of pertinent models parameters, isothermal and non-isothermal heating conditions on the pyrolysis kinetics of biomass particles.

II. Pyrolysis Kinetics and Heat Transfer

Heat is transferred to the biomass particle surface from gaseous surrounding by conduction, radiation and/ or convection and then to the interior of the particle mainly by conduction. The temperature inside the particles increases as the heat penetrates more into the interiors of the solid causing moisture evaporation i.e. drying off the moisture. The rate of drying depends upon the temperature, velocity, and moisture content of the drying gas, as well as the external surface area of the feed material, the internal diffusivity of moisture and the nature of bonding of moisture to that material, and the radiative heat transfer. As the temperature increases, biomass particle decomposes into charcoal, tar and gaseous products. The amounts of each of these products vary depending on the zone temperature, rate of heating, structure, and composition and size of catalysts.

The kinetic scheme as shown in fig.1 describes the process of pyrolysis (primary and secondary) which involves thermal decomposition of biomass into gases, tar (liquid product of biomass pyrolysis, known as bio-oil or pyrolysis oil) and char, and the tar further decompose into char and gases

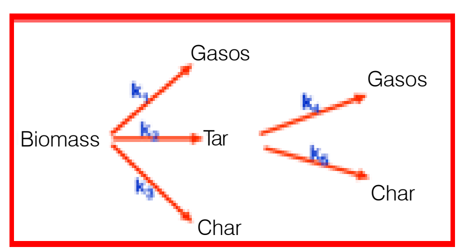

Fig. 1: Two-stage parallel reaction model of biomass pyrolysis

This two-stage parallel reaction model of biomass pyrolysis has previously been used by other researchers [10,13, 17, 18, 19, 21, 35]. According to the two-stage parallel reaction model, the biomass undergoes thermal degradation according to primary reactions $(k_1;\ k_2;\ k_3)$ giving gas, tar and char as

Global Journal of Researches in Engineering (A) Volume XVII Issue VI Version I Year 2017

products. Tar may undergo secondary reactions *(k_4, k_5)*. This model shows to be the most classical models for wood pyrolysis (Prakash and Karunanithi [39].

The kinetic equations of pyrolysis, the heat transfer model and the corresponding initial and boundary conditions are given as

$$\frac{\partial C_B}{\partial t} = -(k_1 + k_2 + k_3)C_B \tag{1a}$$

$$\frac{\partial C_T}{\partial t} = k_2 C_B - \varepsilon(k_4 + k_5)C_T \tag{1b}$$

$$\frac{\partial C_C}{\partial t} = k_3 C_B + \varepsilon k_5 C_T \tag{1c}$$

$$\frac{\partial C_G}{\partial t} = k_1 C_B + \varepsilon k_4 C_T \tag{1d}$$

where

$$k_i = A_i \exp\left[\left(\frac{-E_i}{RT}\right)\right] \qquad i = 1-5$$

The initial conditions for the kinetic equations are;

$$t = 0, C_B = C_{B0}, \quad C_C = C_G = C_T = 0 \tag{2}$$

For the Isothermal condition, $T = T_o$

$$k_i = A_i \exp\left[\left(\frac{-E_i}{RT_o}\right)\right] \qquad i = 1-5 \tag{3}$$

Srivastava [23] assumed that in the thermo-gravimetric analysis, the temperature and time have a linear relationship (non-isothermal heating condition).

This therefore led to the appropriate representation to describe the Srivastava's assumption as;

$$T = T_o + \beta t \tag{4}$$

where T_o is the initial temperature in *K*, β is the heating rate in *K/s* and t is the time in s.

Which makes

$$k_i = A_i \exp\left[\left(\frac{-E_i}{R(T_o + \beta t)}\right)\right] \qquad i = 1-5 \tag{5}$$

The above kinetic models were non-dimensionalized as using the following dimensionless parameters;

$$\bar{C}_B = \frac{C_B}{C_{Bo}} \quad \bar{C}_{G1} = \frac{C_{G1}}{C_{Bo}} \quad \bar{C}_{C1} = \frac{C_{C1}}{C_{Bo}} \quad \bar{C}_{G2} = \frac{C_{G2}}{C_{Bo}} \quad \bar{C}_{C2} = \frac{C_{C2}}{C_{Bo}} \quad C_{C2} = \frac{\bar{C}_{C2}}{C_{Bo}} \tag{6}$$

However, for the sake of cleanliness, the bars are removed in the solutions and the non-dimensionless form of Eqs. (1a-1d) still look like the same equation. In order to avoid seemingly similar equations, the non-dimensionless forms of Eqs. (1a-1e) were not written out in this work.

III. Method of Solution: Differential Transform Method

The simultaneous kinetic models in Eqs. (1a)-(1d) are solved using differential transformation method as introduced by Zhou [50]. The basic definitions and the operational properties of the method are as follows:

If $u(t)$ is analytic in the domain T, then the function $u(t)$ will be differentiated continuously with respect to time *t*.

$$\frac{d^p u(t)}{dt^p} = \varphi(t, p) \text{ for } \quad \text{all } t \in T \tag{7}$$

for $t = t_i$, then $\varphi(t, p) = \varphi(t_i, p)$, where *p* belongs to the set of non-negative integers, denoted as the *p*-domain. We can therefore write Eq. (7) as

$$U(p) = \varphi(t_i, p) = \left[\frac{d^p u(t)}{dt^p}\right]_{t=t_i} \tag{8}$$

where U_p is called the spectrum of $u(t)$ at $t = t_i$

Expressing $u(t)$ in Taylor's series as

$$u(t) = \sum_{p}^{\infty} \left[\frac{(t - t_i)^p}{p!}\right] U(p) \tag{9}$$

where Equ. (9) is the inverse of $U(k)$ us symbol 'D' denoting the differential transformation process and combining (8) and (9), we have

$$u(t) = \sum_{p=0}^{\infty} \left[\frac{(t - t_i)^p}{p!}\right] U(p) = D^{-1}U(p) \tag{10}$$

Global Journal of Researches in Engineering (A) Volume XVII Issue VI Version I Year 2017

Table 3: Operational properties of differential transformation method

S/N	Function	Differential Transform
1	$u(t)\pm v(t)$	$U(p)\pm V(p)$
2	$\alpha u(t)$	$\alpha U(p)$
3	$\frac{du(t)}{dt}$	$(p+1)U(p+1)$
4	$u(t)v(t)$	$\sum_{r=0}^{p} V(r)U(p-r)$
5	$u^m(t)$	$\sum_{r=0}^{p} U^{m-1}(r)U(p-r)$
6	$\frac{d^n u(t)}{dx^n}$	$(p+1)(p+2)\cdots(p+n)U(p+n)$
7	$\sin(\omega t+\alpha)$	$\frac{\omega^p}{p!}\sin\left(\frac{\pi p}{2!}+\alpha\right)$
8	$\cos(\omega t+\alpha)$	$Z(p)=\frac{\omega^p}{p!}\cos\left(\frac{\pi p}{2!}+\alpha\right)$

Using the operational properties of the differential transformation method, the differential transformations of Eqs. (1a)-(1d) under isothermal condition are

$$C_B(p+1) = -\frac{k_1+k_2+k_3}{(p+1)}C_B(p) \tag{11a}$$

$$C_T(p+1) = \frac{k_2}{(p+1)}C_B(p) - \frac{\varepsilon(k_4+k_5)}{(p+1)}C_T(p) \tag{11b}$$

$$C_C(p+1) = \frac{k_3}{(p+1)}C_B(p) + \frac{\varepsilon k_5}{(p+1)}C_T(p) \tag{11c}$$

$$C_G(p+1) = \frac{k_1}{(p+1)}C_B(p) + \frac{\varepsilon k_4}{(p+1)}C_T(p) \tag{11d}$$

The solutions of the of the kinetic equations for the isothermal condition are given as follows:

The analysis of $C_B(p+1)$ *:*

From Equ. (11a), we have

$$C_B(p+1) = \frac{-(k_1+k_2+k_3)}{p+1}C_B(p)$$

Analyzing the differential transform in Eq. (11a), we have

$$C_B(1) = -(k_1+k_2+k_3)C_{Bo}\,,\quad C_B(2) = \frac{(k_1+k_2+k_3)^2}{2}C_{Bo}\,,\quad C_B(3) = \frac{-(k_1+k_2+k_3)^3}{6}C_{Bo}$$

$$C_B(4) = \frac{(k_1+k_2+k_3)^4}{24}C_{Bo}\,,\quad C_B(5) = \frac{-(k_1+k_2+k_3)^5}{120}C_{Bo}\,,\quad C_B(6) = \frac{(k_1+k_2+k_3)^6}{720}C_{Bo}$$

$$C_B(7) = \frac{-(k_1+k_2+k_3)^7}{5040}C_{Bo}\,,\quad C_B(8) = \frac{(k_1+k_2+k_3)^8}{40,320}C_{Bo}\,,\ldots\quad C(n) = (-1)^n\frac{(k_1+k_2+k_3)^n}{n!}C_{Bo}$$

Applying the inverse differential transform,

$$C_B(t) = C_B(0) + C_B(1)t + C_B(2)t^2 + C_B(3)t^3 + C_B(4)t^4 + C_B(5)t^5 + C_B(6)t^6 + C_B(7)t^7 + C_B(8)t^8 + \ldots + C_B(n)t^n \tag{12}$$

After substituting the results in the above analysis into Eq. (12), we have

$$C_B(t) = C_{Bo} - \left[(k_1+k_2+k_3)\right]C_{Bo}t + \left[\frac{(k_1+k_2+k_3)}{2}\right]C_{Bo}t^2 - \left[\frac{(k_1+k_2+k_3)^3}{6}\right]C_{Bo}t^3 + \left[\frac{(k_1+k_2+k)^4}{24}\right]C_{Bo}t^4$$
$$-\left[\frac{(k_1+k_2+k_3)^5}{120}\right]C_{Bo}t^5 + \frac{(k_1+k_2+k_3)6}{720}C_{Bo}t^6 - \left[\frac{(k_1+k_2+k_3)^7}{5040}\right]C_{Bo}t^7 + \left[\frac{(k_1+k_2+k_3)^8}{40,320}\right]C_{Bo}t^8$$

$$-\left[\frac{(k_1+k_2+k_3)^9}{362880}\right]C_{Bo}t^9+\left[\frac{(k_1+k_2+k_3)^{10}}{3628800}\right]C_{Bo}t^{10}-\left[\frac{(k_1+k_2+k_3)^{11}}{39916800}\right]C_{Bo}t^{11}+\left[\frac{(k_1+k_2+k_3)^{12}}{479001600}\right]C_{Bo}t^{12}$$

$$-\left[\frac{(k_1+k_2+k_3)}{6227020800}\right]C_{Bo}t^{13}+\left[\frac{(k_1+k_2+k_3)}{87178291200}\right]C_{Bo}t^{14}-\left[\frac{(k_1+k_2+k_3)}{1307674368000}\right]C_{Bo}t^{15}+\dots \tag{13}$$

Which can be written as

$$C_B(t)=C_{Bo}\left[\begin{array}{l} 1-(k_1+k_2+k_2)t+\frac{(k_1+k_2+k_2)^2}{2}t^2-\frac{(k_1+k_2+k_3)^3}{6}t^3+\frac{(k_1+k_2+k_3)^4}{24}t^4 \\ -\frac{(k_1+k_2+k_3)^5}{120}t^5+\frac{(k_1+k_2+k_3)^6}{720}t^6-\frac{(k_1+k_2+k_3)^7}{5040}t^7+\frac{(k_1+k_2+k_3)^8}{40320}t^8 \\ -\frac{(k_1+k_2+k_3)^9}{362880}t^9+.\frac{(k_1+k_2+k_3)^{10}}{3628800}t^{10}-\frac{(k_1+k_2+k_3)^{11}}{39916800}t^{11}+\frac{(k_1+k_2+k_3)^{12}}{479001600}t^{12} \\ -\frac{(k_1+k_2+k_3)^{13}}{6227020800}t^{13}+\frac{(k_1+k_2+k_3)^{14}}{87178291200}t^{14}-\frac{(k_1+k_2+k_3)}{1307674368000}t^{15}+\dots \end{array}\right] \tag{14}$$

Equ. (14) can be written as

$$C_{B0}(t)=C_{Bo}\sum_{p=0}^{N}\frac{(-1)^p}{p!}(k_1+k_2+k_3)^p t^p=C_{Bo}\,\mathrm{e}^{-((k_1+k_2+k_3)t)} \tag{15}$$

The analysis of $C_T(p+1)$ *:*

From Equ. (11b)

$$C_T(p+1)=\frac{k_2}{(p+1)}C_B(p)-\frac{\varepsilon(k_4+k_5)}{(p+1)}C_T(p)$$

On analyzing the differential transform in Eq. (11b), we have

$$C_T(1)=k_2C_{Bo}$$

$$C_T(2)=-\left\{\frac{k_2(k_1+k_2+k_3)}{2}+\frac{\varepsilon k_2(k_4+k_5)}{2}\right\}C_{Bo}$$

$$C_T(3)=\left\{\frac{k_2(k_1+k_2+k_3)^2}{3}+\left\{\varepsilon k_2(k_4+k_5)\left[\frac{(k_1+k_2+k_3)}{6}+\frac{[\varepsilon(k_4+k_5)]^2}{6}\right]\right\}\right\}C_{Bo}$$

$$C_T(4) = -\left\{ \frac{k_2(k_1+k_2+k_3)^3}{24} + \frac{\varepsilon(k_4+k_5)}{4}\left\{ \begin{array}{l} \dfrac{k_2(k_1+k_2+k_3)^2}{3} \\ +\left\{ \varepsilon k_2(k_4+k_5)\left[\begin{array}{l} \dfrac{(k_1+k_2+k_3)}{6} \\ +\dfrac{[\varepsilon(k_4+k_5)]^2}{6} \end{array} \right] \right\} \end{array} \right\} \right\} C_{Bo}$$

$$C_T(5) = \left\{ \frac{k_2(k_1+k_2+k_3)^4}{120} + \frac{\varepsilon(k_4+k_5)}{5}\left\{ \begin{array}{l} \dfrac{k_2(k_1+k_2+k_3)^3}{24} \\ +\dfrac{\varepsilon(k_4+k_5)}{4}\left\{ \begin{array}{l} \dfrac{k_2(k_1+k_2+k_3)^2}{3} \\ +\left\{ \varepsilon k_2(k_4+k_5)\left[\begin{array}{l} \dfrac{(k_1+k_2+k_3)}{6} \\ +\dfrac{[\varepsilon(k_4+k_5)]^2}{6} \end{array} \right] \right\} \end{array} \right\} \end{array} \right\} \right\} C_{Bo}$$

$$C_T(6) = -\left\{ \begin{array}{l} \dfrac{k_2(k_1+k_2+k_3)^5}{720} \\ +\dfrac{\varepsilon(k_4+k_5)}{6}\left\{ \begin{array}{l} \dfrac{k_2(k_1+k_2+k_3)^4}{120} \\ +\dfrac{\varepsilon(k_4+k_5)}{5}\left\{ \begin{array}{l} \dfrac{k_2(k_1+k_2+k_3)^3}{24} \\ +\dfrac{\varepsilon(k_4+k_5)}{4}\left\{ \begin{array}{l} \dfrac{k_2(k_1+k_2+k_3)^2}{3} \\ +\left\{ \varepsilon k_2(k_4+k_5)\left[\begin{array}{l} \dfrac{(k_1+k_2+k_3)}{6} \\ +\dfrac{[\varepsilon(k_4+k_5)]^2}{6} \end{array} \right] \right\} \end{array} \right\} \end{array} \right\} \end{array} \right\} \end{array} \right\} C_{Bo}$$

and so on

Therefore, the differential transformation solution of C_T is given as

$$C_T(t) = C_T(0) + C_T(1)t + C_T(2)t^2 + C_T(3)t^3 + C_T(4)t^4 + C_T(5)t^5 + C_T(6)t^6 + \ldots + C_T(n)t^n \quad (16)$$

The analysis of $C_C(p+1)$*:*

From Equ. (11c)

$$C_C(p+1)=\frac{k_3}{(p+1)}C_B(p)+\frac{\varepsilon k_5}{(p+1)}C_T(p)$$

Analyzing Eq. (11c) as before, we have

$$C_C(1)=k_3C_{Bo},$$

$$C_C(2)=-\left\{\frac{k_3(k_1+k_2+k_3)}{2}-\frac{\varepsilon k_3k_5}{2}\right\}C_{Bo}$$

$$C_C(3)=\left\{\frac{k_3(k_1+k_2+k_3)^2}{3}-\left\{\varepsilon k_3k_5\left[\frac{(k_1+k_2+k_3)}{6}+\frac{[\varepsilon k_3k_5]^2}{6}\right]\right\}\right\}C_{Bo}$$

$$C_C(4)=-\left\{\frac{k_3(k_1+k_2+k_3)^3}{24}-\frac{\varepsilon k_3k_5}{4}\left\{\begin{array}{l}\dfrac{k_3(k_1+k_2+k_3)^2}{3}\\ +\left\{\varepsilon k_3k_5\left[\begin{array}{l}\dfrac{(k_1+k_2+k_3)}{6}\\ +\dfrac{(\varepsilon k_3k_5)^2}{6}\end{array}\right]\right\}\end{array}\right\}\right\}C_{Bo}$$

$$C_C(5)=\left\{\frac{k_3(k_1+k_2+k_3)^4}{120}-\frac{\varepsilon k_3k_5}{5}\left\{\begin{array}{l}\dfrac{k_3(k_1+k_2+k_3)^3}{24}\\ -\dfrac{\varepsilon k_3k_5}{4}\left\{\begin{array}{l}\dfrac{k_3(k_1+k_2+k_3)^2}{3}\\ -\left\{\varepsilon k_3k_5\left[\begin{array}{l}\dfrac{(k_1+k_2+k_3)}{6}\\ -\dfrac{(\varepsilon k_3k_5)^2}{6}\end{array}\right]\right\}\end{array}\right\}\end{array}\right\}\right\}C_{Bo}$$

$$C_C(6)=-\left\{\begin{array}{l}\dfrac{k_3(k_1+k_2+k_3)^5}{720}\\ -\dfrac{\varepsilon k_3k_5}{6}\left\{\dfrac{k_3(k_1+k_2+k_3)^4}{120}-\dfrac{\varepsilon k_3k_5}{5}\left\{\begin{array}{l}\dfrac{k_3(k_1+k_2+k_3)^3}{24}\\ -\dfrac{\varepsilon k_3k_5}{4}\left\{\begin{array}{l}\dfrac{k_3(k_1+k_2+k_3)^2}{3}\\ -\left\{\varepsilon k_3k_5\left[\begin{array}{l}\dfrac{(k_1+k_2+k_3)}{6}\\ -\dfrac{(\varepsilon k_3k_5)^2}{6}\end{array}\right]\right\}\end{array}\right\}\end{array}\right\}\right\}\end{array}\right\}C_{Bo}$$

and so on

The differential transformation solution of C_C is given as

$$C_C(t)=C_C(0)+C_C(1)t+C_C(2)t^2+C_C(3)t^3+C_C(4)t^4+C_C(5)t^5+C_C(6)t^6+\ldots+C_C(n)t^n \quad (17)$$

The analysis of $C_C(p+1)$*:*

From Equ. (11d)

$$C_G(p+1)=\frac{k_1}{(p+1)}C_B(p)+\frac{\varepsilon k_4}{(p+1)}C_T(p)$$

On analyzing Eq. (26d) as before, we have

$$C_G(1)=k_1C_{Bo}$$

$$C_G(2)=-\left\{\frac{k_1(k_1+k_2+k_3)}{2}-\frac{\varepsilon k_1k_4}{2}\right\}C_{Bo}$$

$$C_G(3)=\left\{\frac{k_1(k_1+k_2+k_3)^2}{3}-\left\{\varepsilon k_1k_4\left[\frac{(k_1+k_2+k_3)}{6}+\frac{(\varepsilon k_1k_4)^2}{6}\right]\right\}\right\}C_{Bo}$$

$$C_G(4)=-\left\{\frac{k_1(k_1+k_2+k_3)^3}{24}-\frac{\varepsilon k_1k_4}{4}\left\{\begin{array}{l}\dfrac{k_1(k_1+k_2+k_3)^2}{3}\\ +\left\{\varepsilon k_1k_4\left[\begin{array}{l}\dfrac{(k_1+k_2+k_3)}{6}\\ +\dfrac{(\varepsilon k_1k_4)^2}{6}\end{array}\right]\right\}\end{array}\right\}\right\}C_{Bo}$$

$$C_G(5)=\left\{\frac{k_1(k_1+k_2+k_3)^4}{120}-\frac{\varepsilon k_1k_4}{5}\left\{\begin{array}{l}\dfrac{k_1(k_1+k_2+k_3)^3}{24}\\-\dfrac{\varepsilon k_1k_4}{4}\left\{\begin{array}{l}\dfrac{k_1(k_1+k_2+k_3)^2}{3}\\-\left\{\varepsilon k_1k_4\left[\begin{array}{l}\dfrac{(k_1+k_2+k_3)}{6}\\-\dfrac{(\varepsilon k_1k_4)^2}{6}\end{array}\right]\right\}\end{array}\right\}\end{array}\right\}\right\}C_{Bo}$$

$$C_G(6)=-\left\{\begin{array}{l}\dfrac{k_1(k_1+k_2+k_3)^5}{720}\\-\dfrac{\varepsilon k_1k_4}{6}\left\{\dfrac{k_1(k_1+k_2+k_3)^4}{120}-\dfrac{\varepsilon k_1k_4}{5}\left\{\begin{array}{l}\dfrac{k_1(k_1+k_2+k_3)^3}{24}\\-\dfrac{\varepsilon k_1k_4}{4}\left\{\begin{array}{l}\dfrac{k_1(k_1+k_2+k_3)^2}{3}\\-\left\{\varepsilon k_1k_4\left[\begin{array}{l}\dfrac{(k_1+k_2+k_3)}{6}\\-\dfrac{(\varepsilon k_1k_4)^2}{6}\end{array}\right]\right\}\end{array}\right\}\end{array}\right\}\right\}\end{array}\right\}C_{Bo}$$

and so on

The differential transformation solution of C_C is given as

$$C_G(t)=C_G(0)+C_G(1)t+C_G(2)t^2+C_G(3)t^3+C_G(4)t^4+C_G(5)t^5+C_G(6)t^6+\ldots+C_G(n)t^n \quad (18)$$

For the purpose of verifying the solution of the differential transformation method, exact analytical solutions using Laplace transform have been developed for Eqs. (1a)-(1d) subject to isothermal condition as

$$C_B=C_{Bo}\,\mathrm{e}^{-((k_1+k_2+k_3)t)} \quad (19a)$$

$$C_T=\frac{k_2C_{Bo}\left[\mathrm{e}^{-((k_1+k_2+k_3)t)}-\mathrm{e}^{-\varepsilon((k_4+k_5)t)}\right]}{\varepsilon(k_4+k_5)-(k_1+k_2+k_3)} \quad (19b)$$

$$C_C=\left\{\frac{k_3\left(1-\mathrm{e}^{-((k_1+k_2+k_3)t)}\right)}{(k_1+k_2+k_3)}-\frac{\varepsilon k_2k_5\left[\dfrac{\left(1-\mathrm{e}^{-((k_1+k_2+k_3)t)}\right)}{(k_1+k_2+k_3)}+\dfrac{\left(1-\mathrm{e}^{-(\varepsilon(k_4+k_5)t)}\right)}{\varepsilon(k_4+k_5)}\right]}{\varepsilon(k_4+k_5)-(k_1+k_2+k_3)}\right\}C_{Bo} \quad (19c)$$

$$C_G = \left\{ \frac{k_1\left(1-e^{-((k_1+k_2+k_3)t)}\right)}{(k_1+k_2+k_3)} - \frac{\varepsilon k_2 k_4\left[\frac{\left(1-e^{-((k_1+k_2+k_3)t)}\right)}{(k_1+k_2+k_3)} + \frac{\left(1-e^{-(\varepsilon(k_4+k_5)t)}\right)}{\varepsilon(k_4+k_5)}\right]}{\varepsilon(k_4+k_5)-(k_1+k_2+k_3)} \right\} C_{Bo} \quad (19d)$$

Table 2: Kinetic constants used in the simulations

i	Reaction	A_i (s^{-1})	E_i (kJ/mol)	Source
1	Biomass→Gas	$1.3\text{x}10^8$	140	[11]
2	Biomass→Tar	$2.0\text{x}10^8$	133	[11]
3	Biomass→Char	$1.08\text{x}10^7$	121	[11]
4	Tar→Gas	$4.28\text{x}10^6$	107	[34]
5	Tar→Char	$1.0\text{x}10^6$	107	[34]

Table 3: Change in enthalpy values used in the simulations

i	Reaction	Δh_i (kJ/kg)	Source
1	Biomass→Gas	-418.0	[11]
2	Biomass→Tar	-418.0	[11]
3	Biomass→Char	-418.0	[11]
4	Tar→Gas	42.0	[12]
5	Tar→Char	42.0	[12]

IV. Results and Discussion

a) *Effects of isothermal heating temperature on pyrolysis yields*

According to the two-stage parallel reaction model used in this work, as the pyrolysis zone temperature increases, the biomass undergoes thermal degradation according to primary reactions giving gas, tar and char as products. Tar also undergoes secondary reactions to give gas and tar. Since the amounts of each of these products vary depending mainly on the zone temperature, the influences of heating conditions on the particle residence time and pyrolysis yield are studied using the differential transformation method. Figs. 2-21 show the effects of isothermal heating temperatures on the particle resident time. Also, the figures demonstrate the agreement between the exact analytical solutions and the approximate analytical solutions developed by using differential transformation method. Figs. 22-25 show the effects of isothermal heating temperature (where the pyrolysis temperature is maintains a selected constant temperature in a pyrolyzing chamber) on the pyrolysis yield. From the results, thermal decomposition takes more time at temperature of 473 K and 573 K than that of higher isothermal heating temperature for the biomass particle of the same size. The figures clearly depict that low temperature pyrolysis produces more char and high temperature pyrolysis enhances the production of gas and tar, i.e. an increase in the isothermal heating temperature increases the yield of gaseous products and the decreases char production.

The reduced production of tar and gas at low isothermal heating temperature may be due to some resistances to mass or heat transfer inside the particles of the biomass which can be broken by high heating temperature thereby resulting in greater primary decomposition of the sample and higher production of gas and tar at the higher temperature. In each case of the isothermal heating, as the pyrolysis reaches completion, the char production becomes constant.

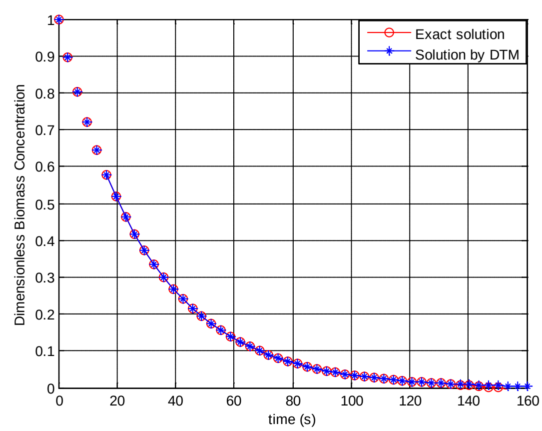

Fig. 2: Biomass concentration against time at an isothermal temperature of 673K

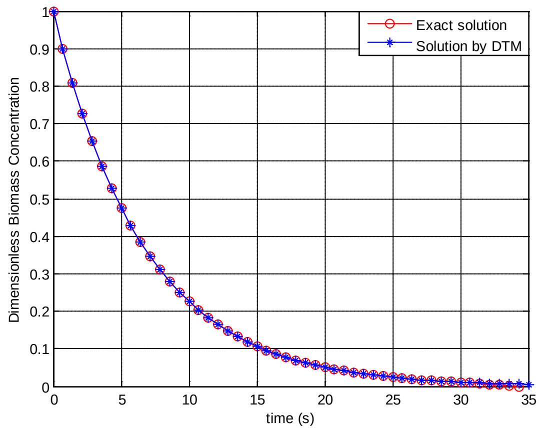

Fig. 3: Biomass concentration against time at an isothermal temperature of 773K

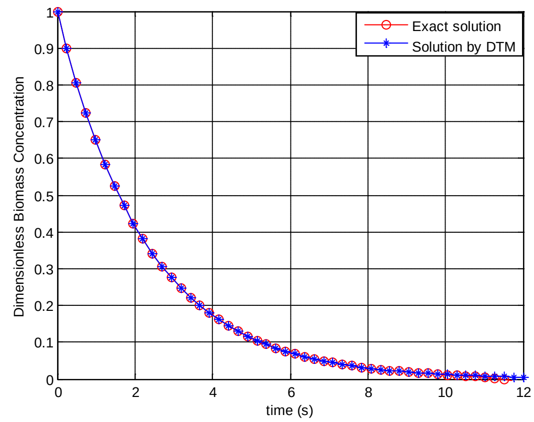

Fig. 6: Biomass concentration against time at an isothermal temperature of 1073K

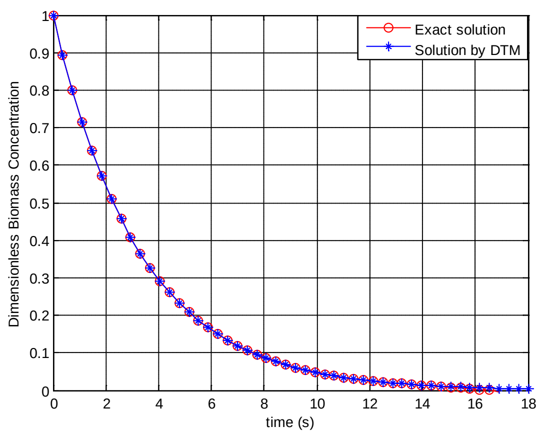

Fig. 4: Biomass concentration against time at an isothermal temperature of 873K

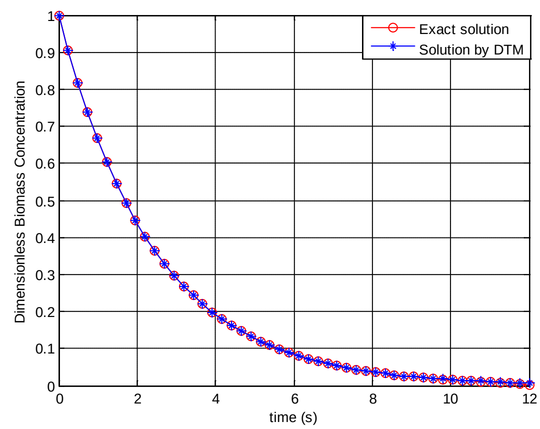

Fig. 7: Biomass concentration against time at isothermal temperature of 1173K

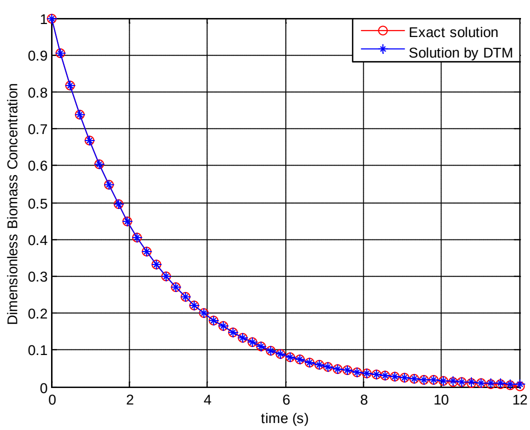

Fig. 5: Biomass concentration against time at isothermal temperature of 973K

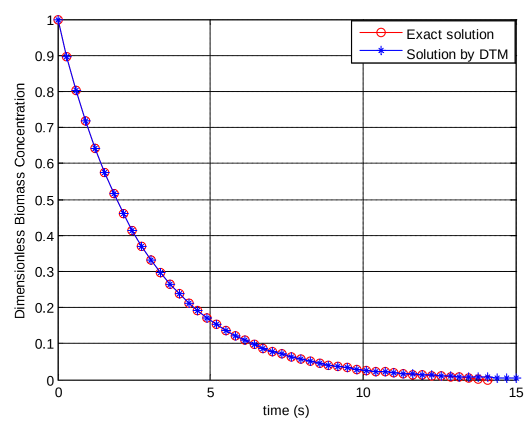

Fig. 8: Comparison of results of Biomass concentration against time at an isothermal temperature of 1273K

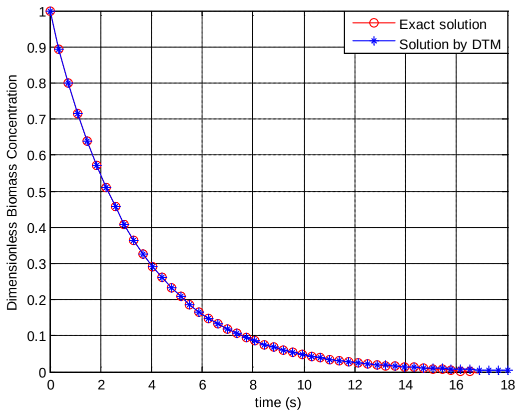

Fig. 9: Comparison of results of Biomass concentration against time at isothermal temperature of 1373K

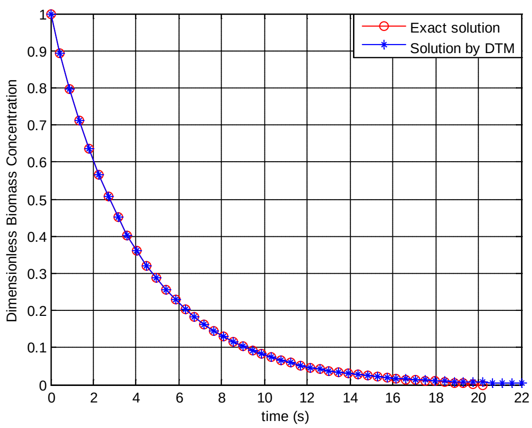

Fig. 10: Comparison of results of Biomass concentration against time at an isothermal temperature of 1473K

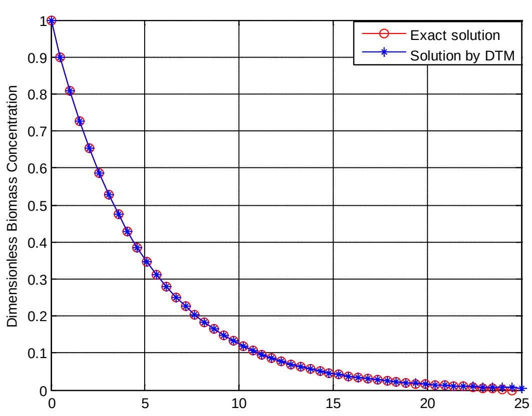

Fig. 11: Comparison of results of Biomass concentration against time at isothermal temperature of 1573K

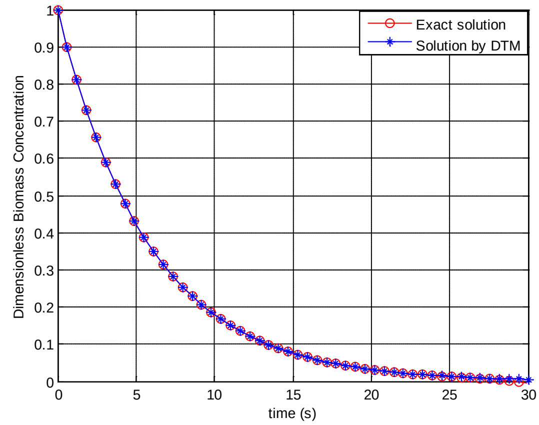

Fig. 12: Comparison of results of Biomass concentration against time at an isothermal temperature of 1673K

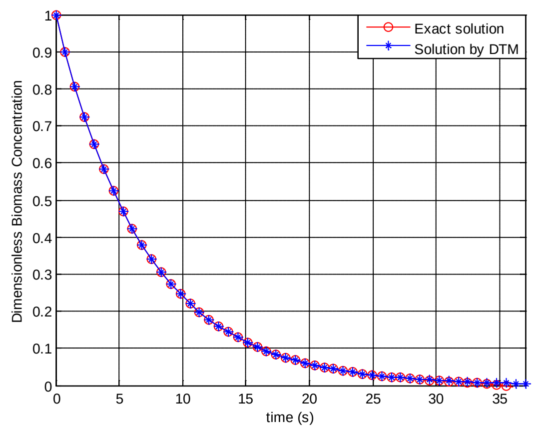

Fig.13: Comparison of results of Biomass concentration against time at isothermal temperature of 1773K

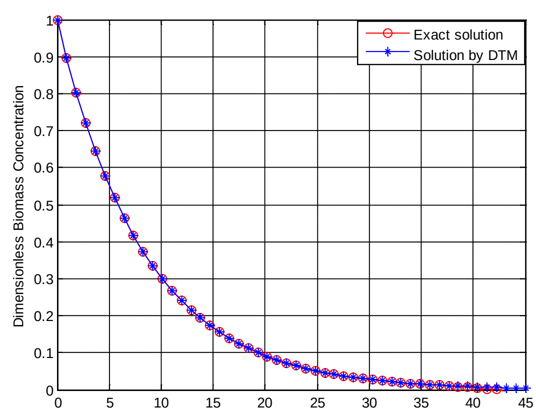

Fig. 14: Comparison of results of Biomass concentration against time at an isothermal temperature of 1873K

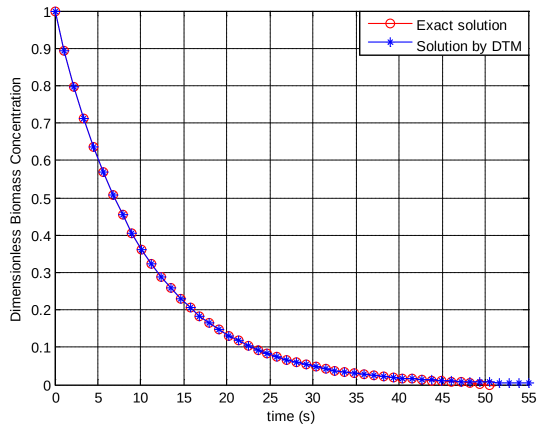

Fig. 15: Comparison of results of Biomass concentration against time at isothermal temperature of 1973K

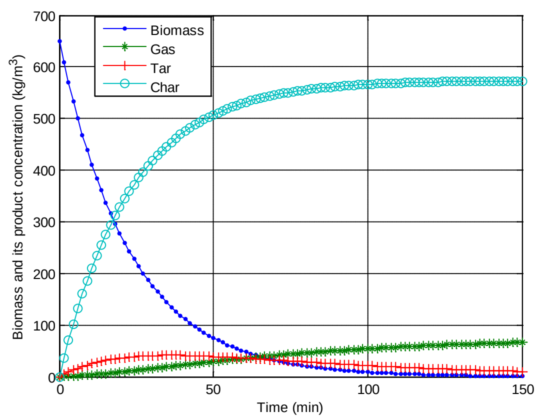

Fig. 16: Biomass concentration against temperature at an isothermal heating temperature of 573K

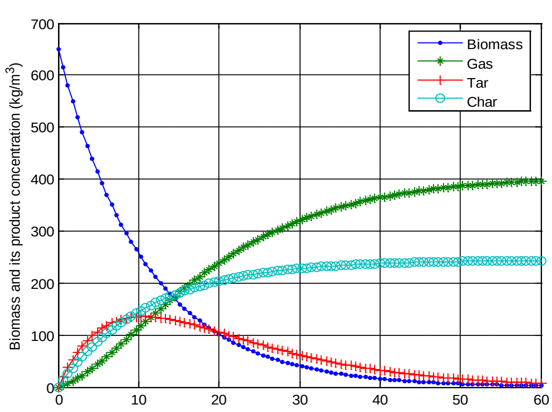

Fig. 17: Production and conversion rate against time at an isothermal heating temperature of 773K

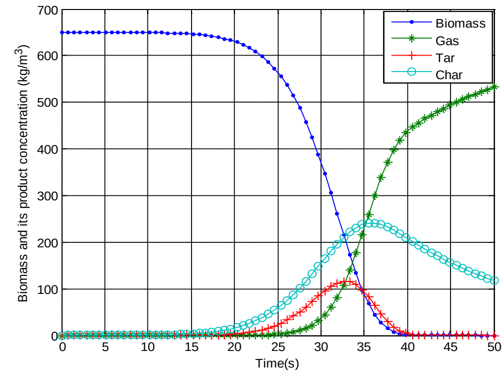

Fig. 18: Biomass and its product concentration variation at heating rate of 10K/s

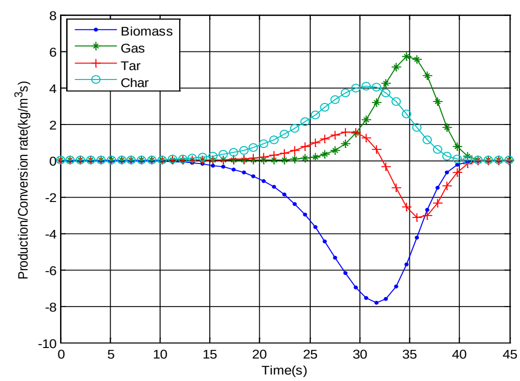

Fig. 19: Production/Conversion rate of Biomass and its Product with time at heating rate of 10K/s

Also, the results show that the tar rate yield increases first and then decreases and the gas yield increases as the pyrolysis temperature increases, but the char yield significantly decreases as the isothermal temperature increases to 573K and 673K. The decrease in the tar yield and sudden increase of gas yield observed at higher temperature may be due to secondary cracking of the pyrolysis liquid in to gaseous product at higher temperature. It could also be deduced from the results that the time required to obtain a certain conversion level decreases with increasing isothermal heating temperature. The trends obtained in this work as shown above are qualitatively the same as reported in literature [24] and [25].

b) Effects of non-isothermal heating rates on biomass pyrolysis yields

As pointed out in the previous section, heating rate is one of the important parameter for the yield of different products from the pyrolysis process. To determine the effects of heating rate on the yields of the biomass pyrolysis, simulations were carried out for different heating rates of as shown in Figs.26-41. The effects of non-isothermal temperature on pyrolysis yields as functions of time are shown in Figs .26-37 while Figs. 38-41 show the effects of non-isothermal temperature on pyrolysis yields as a function of temperature at an initial particle temperature of 373 K. From the figures, the drying or pre-pyrolysis process are shown as zero rate of production and conversion of the products from 0-120 s and 303-473 K which validates the fact that pyrolysis process actually commenced at about 473K as stated in literatures [25]. It is surprising to see that at any heating rate, the production rate of char is higher than that of tar and gas. This may be due to the increase in the resistance for mass and heat transfers offered by the thick layer of the dried biomass i.e. for the gas and tar to evolve from the particle, they have to travel through a dried layer of the biomass which in consequence, comparably reduces their production rates. Also, it should be noted that increasing the heating rates reduces the particle residence time and as the heating rate are increased, the residence time of volatiles at low or intermediate temperatures decreases. Most of the reactions that favour tar conversion to gas occur at higher temperatures. At low heating rates, the volatiles have sufficient time to escape from the reaction zone before significant cracking can occur. Also, most of the decomposition takes place at temperatures lower than 500 K, and no more significant decomposition is produced above 750 K.

On comparing these results with that of isothermal heating conditions, it is shown that the amount of char produced in the non-isothermal heating conditions is lower than in the isothermal heating conditions. This is because the isothermal conditions were carried out at relative low temperature and the residual solid contains compounds that evaporate at higher temperatures. The tar yield was low at lower heating rate and slightly increases with increase in heating rate. The gas yield increases with increase in heating rate while the char yield decreases significantly with increase in heating rate. The increasing of the tar yield with the increase of heating rate may be due to some resistances to mass or heat transfer inside the particles of the biomass, but increasing the heating rate breaks the heat and mass transfer limitation in the pyrolysis and thereby increasing the tar yield and decreasing char formation.

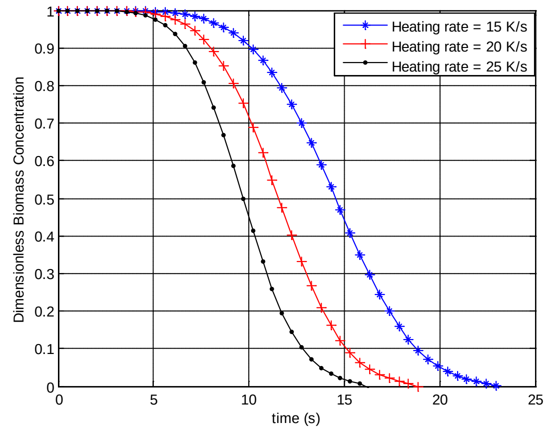

Fig. 20: Biomass concentration against time at non-isothermal condition at an initial temperature of 473K

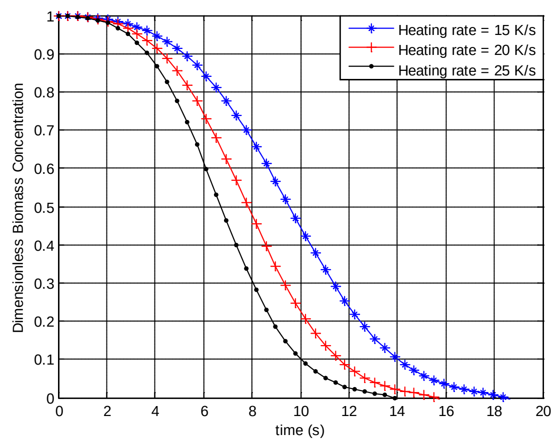

Fig. 21: Biomass concentration against time at non-isothermal condition at an initial temperature of 573K

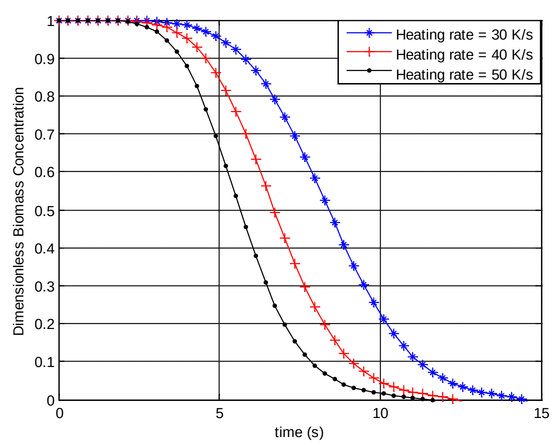

Fig. 22: Biomass concentration against time at non-isothermal condition at an preheating temperature of 473K

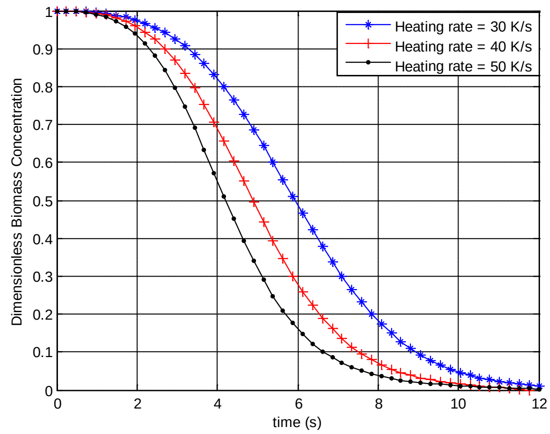

Fig. 23: Biomass concentration against time at non-isothermal condition at an preheating temperature of 573K

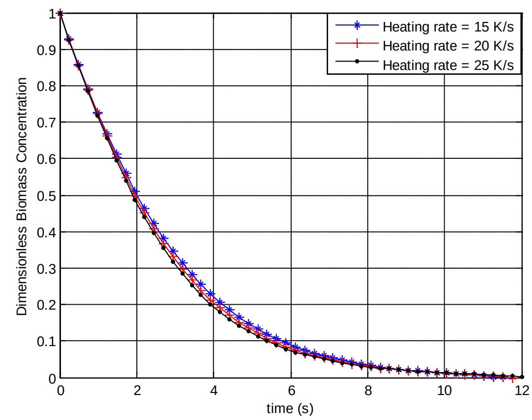

Fig. 26: Biomass concentration against time at non-isothermal condition at an initial temperature of 873K

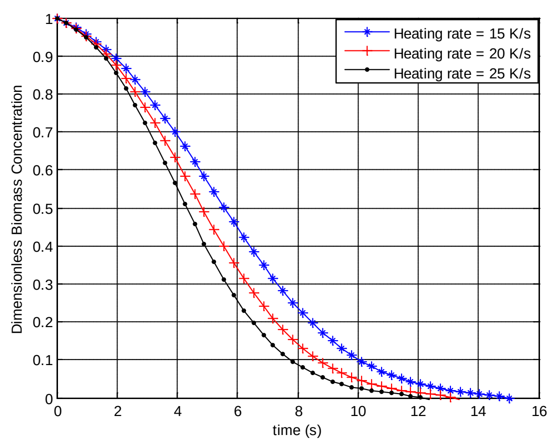

Fig. 24: Biomass concentration against time at non-isothermal condition at an initial temperature of 673K

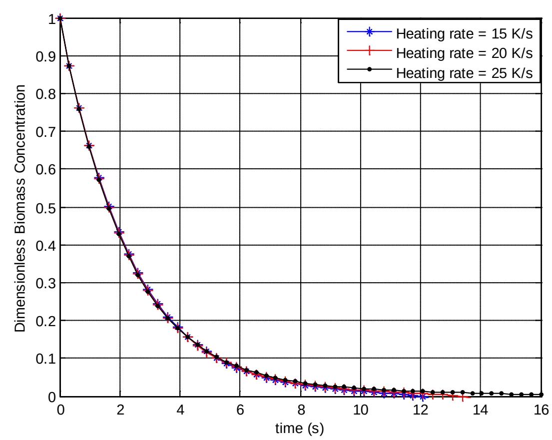

Fig. 27: Biomass concentration against time at non-isothermal condition at an initial temperature of 973K

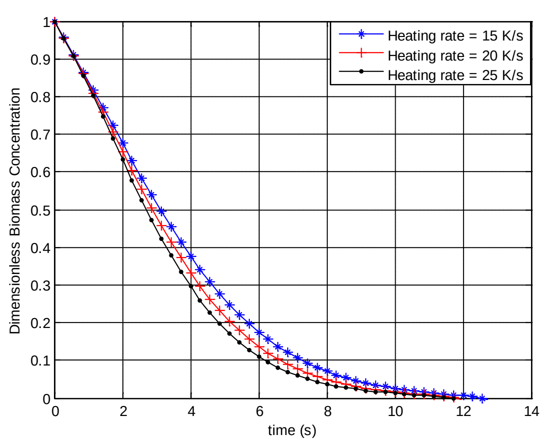

Fig. 25: Biomass concentration against time at non-isothermal condition at an initial temperature of 773K

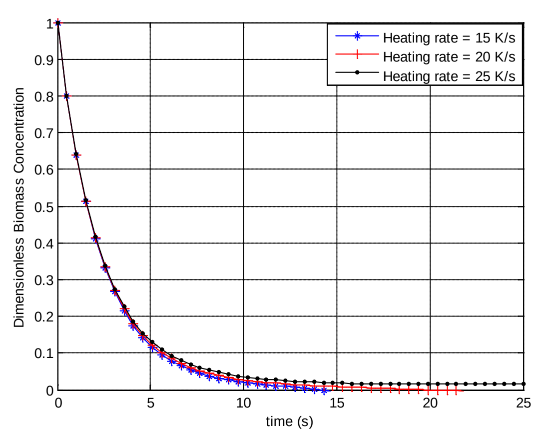

Fig. 28: Biomass concentration against time at non-isothermal condition at an initial temperature of 1073K

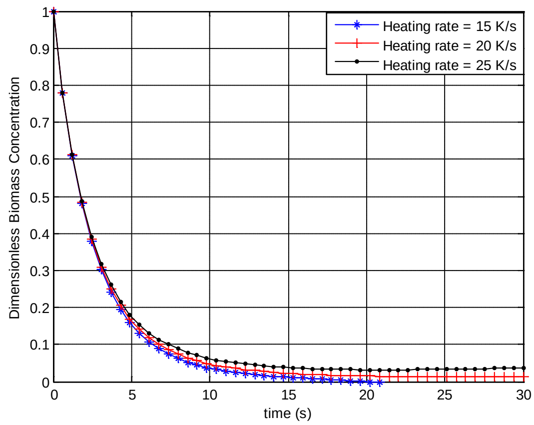

Fig. 29: Biomass concentration against time at non-isothermal condition at an initial temperature of 1173K

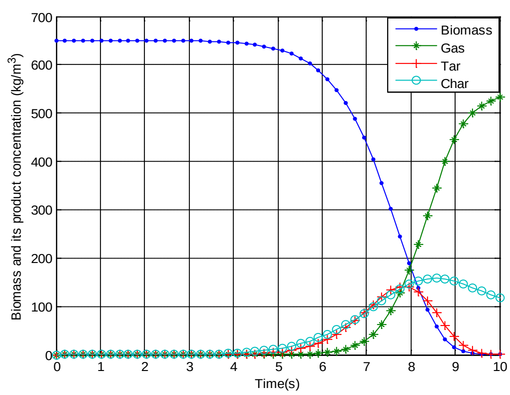

Fig. 30: Biomass and its product concentration variation at heating rate of 50K/s

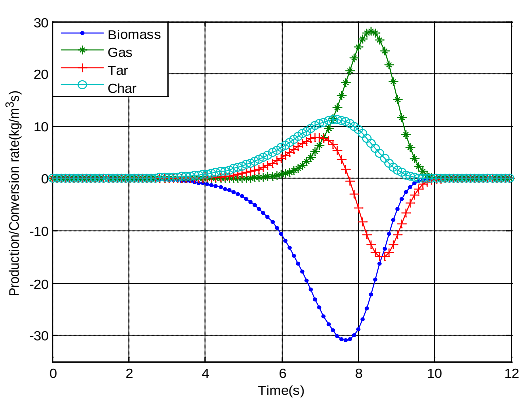

Fig. 31: Production/Conversion rate of Biomass and its Product with time at heating rate of 50K/s

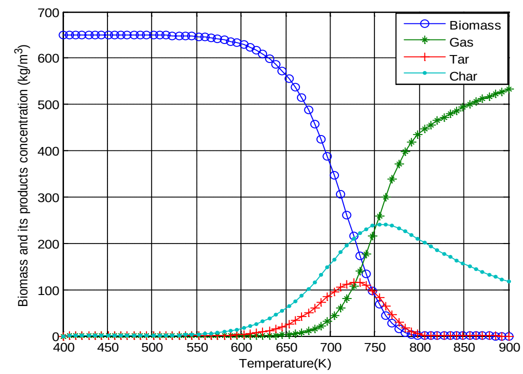

Fig. 32: Biomass and its product concentration variation at heating rate of 10K/s

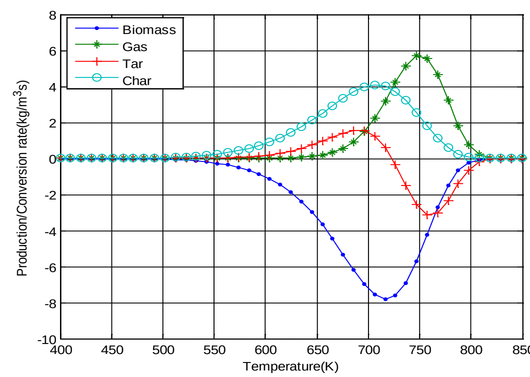

Fig. 33: Production/Conversion rate of Biomass and its Product with temperature at heating rate of 10K/s

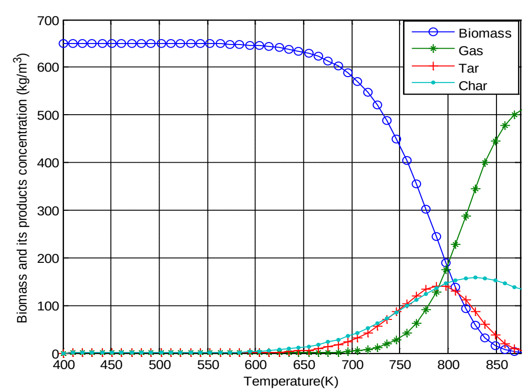

Fig. 34: Biomass and its product concentration variation at heating rate of 50K/s

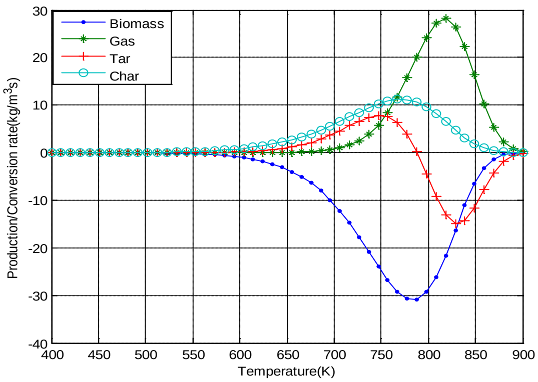

Fig. 35: Production/Conversion rate of Biomass and its Product with temperature at heating rate of 50K/s

From the Figs 38-41, the rate of char production increases gradually between the particle temperatures of 500 K and 573 K, and as the particle temperature increases, as gases and tar evolve from the biomass particle and consequently, the rate of char production increases rapidly from the particle temperature of 500 K to 723 K, after which there is a decrease in the production rate of char (due to the loss of H and O contents of the char at high temperatures) till the whole wood has been pyrolysed. This shows that pyrolysis process is slowed down from 723-873 K (depending on the heating rates). It could also be inferred from the results that the primary pyrolysis rate of tar production starts gradually from about 573 K till 753 K (depending on the heating rates) and then increases rapidly till the whole tar has been converted to char and gas at the final pyrolysis temperature. The extension of the rate-temperature figure to the negative portion of the graph depicts the conversion rate of tar to char and gas.

c) Effects of heating rates on particle residence time

Recently, Lédé and Authier [32] advocated for the criteria for characterizing fast pyrolysis based on temperature and heating rate of solid particles that undergoes a thermal decomposition The effects of heating rates on the particle residence time are shown in Figs. 42-45. For the low heating rates of 0.01-0.1K/s in Figs. 42, it takes hours or days for the pyrolysis to occur and this will definitely enhance the production of charcoal as depicted in Table 4.

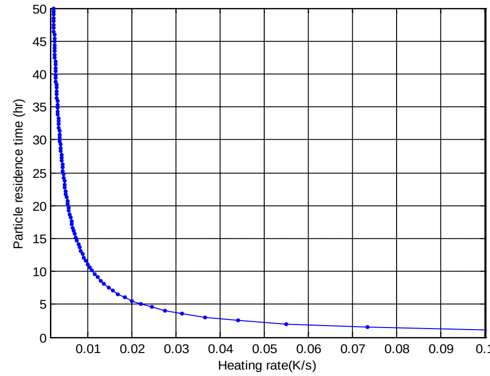

Fig. 36: Variations of biomass particle residence time very low heating rates

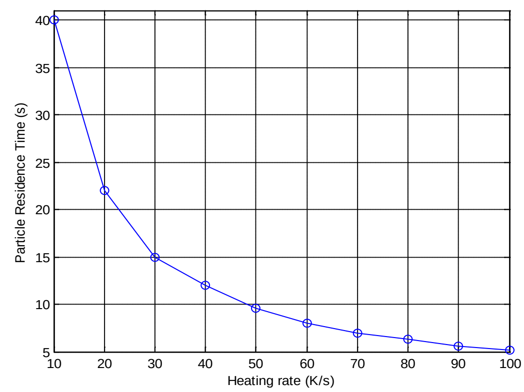

Fig. 37: Variations of biomass particle residence time with heating rates of 10-100K/s

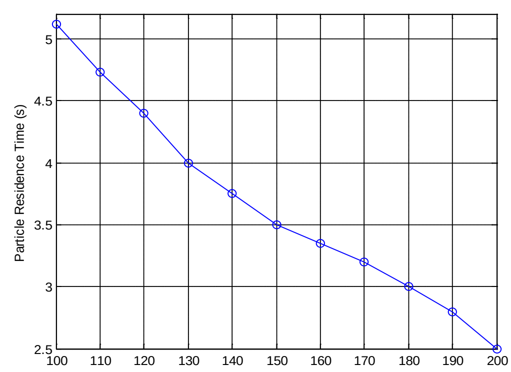

Fig. 38: Variations of biomass particle residence time heating rates of 100-200K,s

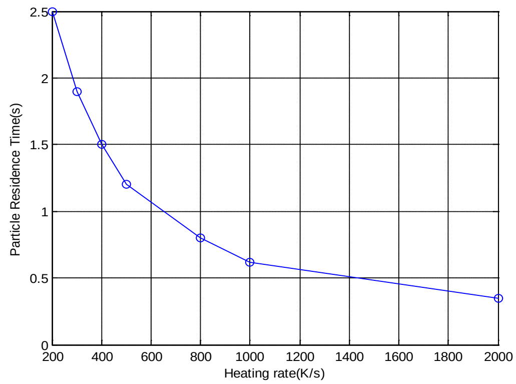

Fig. 39: Variations of biomass particle residence time with heating rates 200-200K/s

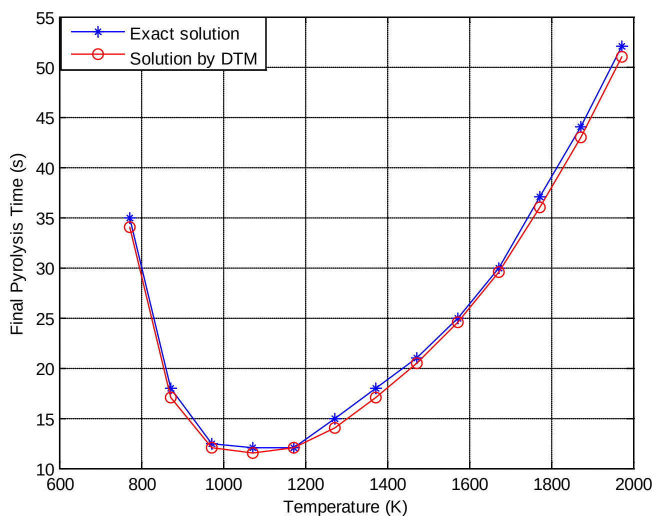

Fig. 40: Effects of heating rates on the particle residence/final pyrolysis time

Table 4: Pyrolysis conditions for different pyrolysis technologies

Pyrolysis technology	Residence time	Heating rate	Temperature (°C)	Product
Carbonization	days	very low	400	charcoal
Conventional	5-30 min	low	600	oil, gas, char
Fast	0.5-5s	very high	650	bio-oil
Flash-liquid	< 1s	high	< 650	bio-oil
Flash-gas	< 1s	high	<650	chemicals, gas
Ultra	< 0.5s	very high	1000	chemicals, gas
Vacuum	2-30 s	medium	400	bio-oil
Hydro-pyrolysis	< 10s	high	< 500	bio-oil
Conventional	< 10s	high	< 700	chemicals

As the heating rates increases, the particle residence time in the reactor decreases and high heating rates favours the production of tar and gas. Therefore, as shown in the table, the length of heating and its intensity affect the rate and extent of pyrolytic reactions, the sequence of these reactions, and composition of the resultant products. Fig. 42-46 indicated the quantitative values of heating rates and residence time for different pyrolysis products. Such data as these are rarely found in open literatures.

V. Conclusion

In this work, differential transformation method has been applied to analyze pyrolysis kinetics of biomass particle under isothermal and non-isothermal heating conditions. The developed analytical solutions to the system of pyrolysis kinetic models were used to study the effects of heating conditions, heating rates on the pyrolysis residence time and technologies. Good agreements were established between the present results and the past works. It is therefore expected that this study will enhance the understanding of the pyrolysis process by giving physical insights into the various factors and the parameters affecting the phenomena.

Nomeclature

A1; A2; A3; A4; A5 frequency factor, 1/s
Bi_m Modified Biot number
C concentration, kg/m^3
C_p specific heat capacity, J/kgK
E activation energy, J/mol
h convective heat transfer coefficient, W/m^2 K
K thermal conductivity, W/mK
k_1; k_2; k_3; k_4; k_5 rate constants, 1/s
Q heat of pyrolysis, J/Kg
r radial distance, m
R radius for cylindrical particle, m
R_g universal gas constant, J/mol
t time, s
T_f reactor final temperature, K
T temperature, K
R' dimensionless radial distance

Greek letters

ρ Bulk density of wood, Kg/m^3
ρ_∞ Ultimate density of wood, Kg/m^3
τ dimensionless time
θ dimensionless temperature
ϵ emissivity coefficient
ε void fraction of particle
σ Stefan Boltzmann constant, W/m^2 K^4
α Heat of reaction number

Subscripts

B virgin biomass
G gases
C char
T tar
G gas
0 initial
f final

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Design and Analysis of Light Weight Agriculture Robot

By Shaik Himam Saheb & Dr. G. Satish Babu
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Abstract- Agriculture is the main source of food for human beings living on earth. The farmer who works in field facing lots of problems due to lack of machinery equipment and human labour. Agriculture robot which is light in weight, having high payload capacity with high speed and stability all these can be controlled in field using programming techniques fully. The body frame of Agriculture robot is made of glass fiber, which is lighter in weight and strength to weight ratio is high compared to the conventional materials like steel or aluminum.

A dynamic model for a multipurpose Agriculture robot which is made of flexible parts will be developed. Drone acts as the main body controlling all works in fields providing the tasks which are controllable. Agriculture robot main task is to perform seed sowing of any agricultural crop mainly we have done work on maize crop. Agriculture robot may be further developed accordingly for the applications of other crops like cotton, mango, onions, and groundnut and also developed for Can performing tasks like plants spraying, cutting, pitting holes, harvesting, security causes, and inspecting crop. In air Agriculture robot works with all necessary operations of Pitch, Yaw and Roll and covers the future applications in different Missions.

GJRE-A Classification: FOR Code: 091399

DESIGNANDANALYSISOFLIGHTWEIGHTAGRICULTUREROBOT

Strictly as per the compliance and regulations of:

Design and Analysis of Light Weight Agriculture Robot

Shaik Himam Saheb[α] & Dr. G. Satish Babu[σ]

Abstract- Agriculture is the main source of food for human beings living on earth. The farmer who works in field facing lots of problems due to lack of machinery equipment and human labour. Agriculture robot which is light in weight, having high payload capacity with high speed and stability all these can be controlled in field using programming techniques fully. The body frame of Agriculture robot is made of glass fiber, which is lighter in weight and strength to weight ratio is high compared to the conventional materials like steel or aluminum.

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I. Motivation

The motivation of the project is Pesticide spraying drones, these drones are the first one which have generated us an idea to make a drone which is also useful for seed sowing purpose also.

PESTICIDE SPRAY WITH DRONE

Farmers are now started using drones for pesticide spraying, Drones can lift around 15 liters of pesticide at one time and cover a pretty large area in one go. This makes it easy for the farmers as he just has to program the drone and left it fly over the field in pre-defined patterns to cover the maximum area with pesticide this is turning out to be a very fast and efficient way of spraying pesticides and also safe as farmer does not inhale the toxic fumes. In India as individual farms are small and use of drones is useless there many companies have equipped with drones. A group of farmers can get together and rent this drone from these companies and spray in their field [1].Thus the idea was generated in our mind why can't we use these type of Drones in Agricultural fields, then we started developing our initial idea and researched finally now transformed as an agriculture robot.

II. About The Project

We have Titled our project as AGRICULTURE ROBOT which is a combination of a Quadcopter and a Seeding System, we had synchronized a seeding system to a X configured quadcopter.

Thus the combination of these two equipments results in the formation our AGRICULTURE ROBOT. Now a brief explanation about Quadcopter and Seeding System Quad copter otherwise called quad rotor helicopter or quad rotor is a multi rotor helicopter that is

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lifted and pushed by four rotors. Quad copters are named rotor make, rather than settled wing flying machine, on the grounds that their lift is created by an arrangement of rotors. In a quad copter, two of the propellers turn one way (clockwise) and the other two turn the other way (counterclockwise) and this empowers the machine to float in a steady arrangement. Right off the bat the engines which we utilized have a conspicuous reason to turn the propellers. Engines are appraised by kilo volts, the higher the kV rating, the speedier the engine turns at a consistent voltage. Next the Electric Speed controller or ESC is the thing that advises the engines how quick to turn at any given time. We require four ESCs for a quad copter, one associated with each engine. The ESCs are then associated specifically to the battery through either a wiring outfit or power circulation board. Numerous ESC1s accompany an inherent battery eliminator circuit (BEC), which enables you to control things like your flight control load up and radio beneficiary without interfacing them straightforwardly to the battery Our Quad copter utilizes four propellers, each controlled by its own particular engine and electronic speed controller and appropriately modify the RPM of each engine so as to self-balance out itself. The Quad copter stage gives security because of the counter pivoting engines. For Hovering over the skies the Micro controller which is utilized is the „brain‟ of the quad copter. It houses the sensors, for example, whirligigs and quickening agents that decide how quick each of the quadcopter‟ engines turn and passes the control signs to the introduced Electronic Speed Controllers (ESCs) and the blend of these signs trains the ESCs to make fine changes in accordance with the engines rotational paces which thusly settles the craft.[2]

As the Quadcopter is synchronized with the Seeding System, whenever the drone flies it will take on the seeding equipment into the air and this system is taken to the place where the seed to get placed or sowed, if the system once reaches the point where to be seed Sowed then the Drone is taken down and when the seeding system hits the ground, then the seed will be got placed on the required spot. Thus AGRICULTURE ROBOT can perform the seed sowing process.

III. Schematic Diagram of Drone

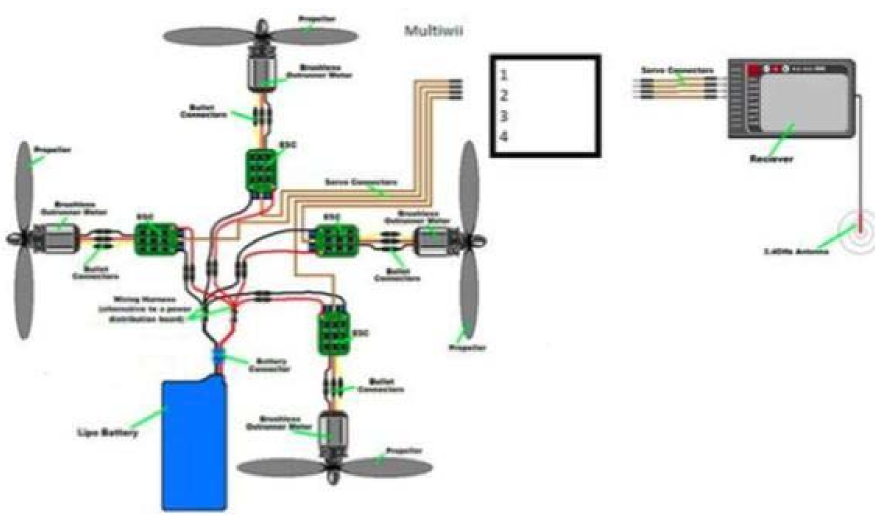

Figure 1.2: Block diagram of Drone

a) Components used for Drone

Table 1.1: Components of Drone

1	Quadcopter Frame	1
2	ESCs	4
3	Brushless motors-1400KV	4
4	Propellers	4
5	Arduino Uno Microcontroller	1
6	Fly sky Transmitter and Receiver –CT6B	1
7	Battery and charger	1
8	Connectors	8

IV. Objective of the Project

The goal of our project is to design, implement, and test a stable flying AGRICULTURE ROBOT that can be used for Seed Sowing. Through this we can made a less affordable device which will be worked for agricultural purpose mainly for seeding Through this we can reduce the working time of a labor in agricultural field for seeding purpose

The final AGRICULTURE ROBOT design had to meet the following specifications:

1. The AGRICULTURE ROBOT must be capable of flying and landing in stable manner.
2. The Seed Sowing process must be done perfectly.
3. Synchronization of quadcopter and seeding system should be done without any imperfection.

a) Problem Definition

There is a lot of reduction rate in labor or human in agriculture in India today as per environmental conditions. Agricultural farmers work with both labour/human with many different types of farm machinery that are used to help with soil preparation, crop planting, harvesting and crop processing. This machinery is highly expensive giving less production rate. Therefore many researchers have been going through worldwide for development in technology in agriculture. There are machines in agriculture working on ground but they are so heavy can‟t be used more & more times which may damage the crop/fields. Each machinery that present in agriculture requires at least one operator. These machinery work depending on season/crop basis only.

On other hand our Agro Bot is light in weight, can work in any type of conditions, It is one man operatable no need of any extra human efforts, completes the work in time, less in cost, high life span, with higher efficiency compared to present machines and labour, can do any work easily, works on battery which is environmental friendly. Useful in all type of works(multiple functioning).the recent successful application of these drones in spraying and ambulance services military operations etc, in Germany and many developed countries used this technology but to only of half part.

Many more large research works are being under going on this technology which is future scope of mankind.

b) Project Plan

The project plan was divided into five major milestones each spaced approximately Ten days apart.

1. Project Description and Plan of Work
2. System Model
3. Components Purchasing
4. Implementation / Hardware / Software
5. Working on field with the working prototype

The sequence that we met these milestones was out of sequence with the required milestones. Experience told us to get the hardware done as soon as possible as this is often requires a lot of time. By doing so, and because of unforeseen difficulties, we fell behind slightly with the System Modeling and flight Controller. After working closely we were able to complete the milestones only slightly behind schedule

c) Limitations

Our Agriculture robot has some of the limitations which may not be considered as major difficulties, on going through our work we have found some disadvantages our product, they are mentioned below.

1. The main limitation of our product is, the seeds in the seeding system are sometimes jamming therefore regular seeding is not taking place.
2. Whenever the seeding system touches the ground for seed sowing, then the balancing of drone is not adjusting i.e. situation of non balancing of drone occurring.
3. Since we have done a small seeding system the numbers of seeds that are inserted in the seeding system are less.

V. Literature Review

a) Introduction

This chapter will explain about the research of the project that has been chosen and explained about the history of go kart. It will review the basic components of the system itself.

The AGRICULTURE ROBOT project required extensive research into UAVs and several mechanical mechanisms, and similar systems. By reviewing others work, we used this insight to develop our system. To this end, research papers from various quadrotor groups were used as guides in the early development of the dynamics and control theory.

b) Existing System

QUEENSLAND agriculturists would now be able to utilize automatons to splash edits after enactment was revised to grasp the innovation. Acting farming pastor Bill Byrne said the innovation would be particularly valuable for applying chemicals in territories with restricted access or troublesome landscape [3].

c) Aerial Sprayer

Aeronautical sprayer is another kind of splashing it is advantageous for the agriculturists having vast Farms. This method by ranchers is not moderate to agriculturists having little and medium homesteads. In aeronautical splashing the showering is finished with the assistance of little helicopter controlled by remote. On that sprayer is joined having numerous spouts and splashed it on the homestead from some height [3].

Figure 1.3: Showing Aerial Sprayer

VI. Description

Indian agriculture needed production and protection materials to achieve high productivity. Agriculture fertilizer and chemical frequently needed to kill insects and growth of crops. The WHO (World Health Organization) estimates there are more than 1 million pesticide cases in every year. In that more than one lakh deaths in each year, especially in developing countries due to the pesticides sprayed by human being. The pesticide affects the nervous system of humans and also leads to disorders in body. A remote controlled UAV (Unmanned Aerial Vehicle) is used to spray the Pesticide as well as fertilizer to avoid the humans from pesticide poison. The UAV is operated by manual flight plans and the Sprayer is manually triggered by RF controlled Nozzle. The vertical take-off and landing quadcopter is used to spray the low volume pesticide in a small area. This project describes the development of quadcopter UAV and the sprayer module. And also discusses the integration of sprayer module to quadcopter system. This model is used to spray the pesticide content to the areas that can't easily accessible by humans. The Universal Sprayer system is used to spray the liquid as well as solid contents which are done by the universal nozzle. Multispectral camera is used to capture the remote sensing images which are used to identify the green fields as well as the edges of crop area. Total payload liftoff weight of quadcopter is 8 kg. Remote sensing images are analyzed by QGIS software [3].

a) Quadcopter Working Principle

The quadcopter is simple design with four rotor propellers with controller (Figure 3). The flight controller is the main part of this vehicle. This ardu pilot controls all the operation commanded by us. The four rotors to create differential thrust and the quadcopter hover and move accordance with the speed of those rotors. There are two types of configuration in quadcopter construction. First one is Plus (+) configuration and another one is Cross (X) Configuration. In this project we used X (Cross) configuration. Both the models are same, but the control of these models slightly different. The cross configuration is easier than plus configuration model. Total mass to lift is 4kg means, the total thrust produced by rotors should be 8 kg. GPS guidance system is used here to navigate the UAV. Pre-Loaded trajectory gives the real time coordinates to ardupilot controller. Based on this GPS coordinates, the microcontroller navigates the UAV [3].

b) Sprayer Module

Sprayer module has two sections, they are 1) Transmitter section (Remote controller), 2) Sprayer with controller. Transmitter section used to control the actuator of sprayer module. The nozzle of sprayer module will be activated by remote control. Wherever need to activate the sprayer, just comment by remote RF transmitter. Sprayer module contains two sections, spraying module and controller. Spraying module contains the spraying content i.e., pesticide or fertilizer and the controller section used to activate the nozzle of sprayer. The command is received from remote controller which is activated manually. Tank contains the chemical content which is going to spray on crops that may be a pesticide or fertilizer. The Nozzle of the sprayer module will be activated by GPS device. This GPS module having the preloaded GPS coordinated, Liquid Pump Motor with Tank. The spraying pump overflow rate is max, 1L/minutes. The maximum spraying height is 4 meters. Flying speed is max. of 5m/s. It covers 2m range of green fields with compatible land edge Coverage Rate [3].

c) Advantages

1. This method can be used in all situations, especially in the places where labours are hard to find [3].
2. Environmental pollution can be reduced when it sprayed from lower altitude [3].

3. It has a great potential to enhance pest management for small as well as the large crop field to entail highly accurate site-specification application [3].

d) Disadvantage

The aerial sprayer system is only used for the purpose of spraying of pesticides, this may not considered as a disadvantage but seed sowing is also a major work done by farmers in agricultural field. In order to reduce that work our system is developed as per conditions.

e) Proposed System

On researching several journals and many UAV systems we have take down a step to introduce a new system in the field of agriculture which will have an unique application. So we have gone through check on what work in agriculture field there are no mechanical system is used is the application that is required by the farmers, by many surveys we have came to known that there is no proper device or machine for SEED SOWING. Hence we have concluded to do a machine that is applicable in the process of seed sowing, so as per required conditions we had designed our system and we named it as „AGRICULTURE ROBOT‟ and also as „AGRO-DRONE‟.

It is the combination of an UAV and a Seeding System which are synchronized each other that will jointly together to perform seed sowing.

f) Literature Conclusion

So, here we have concluded that Agriculture robot is going to be one of the essential component in the agricultural fields which can performs seed sowing, the most required task for growth of any plant or crops. In this project we are going to fabricate seeding equipment and a drone, those two are synchronized each other to perform seeding in the agricultural field. Thereby we can reduce human effort and working time in the field.

VII. Components And Their Specifications

a) Frame

This is the glass fiber quadcopter frame which is very simple and easy to build frame This Flame wheel is one of the most popular frames out there for a number of good reasons.

1. It is relatively inexpensive
2. It is famously durable
3. The centre plate doubles as a power distribution board which tidies things up quite a bit and allowed me to get rid of my ugly DIY wiring harness.
4. The design is really well thought out – it's a compact frame. Plenty of room for receiver, control board, ESCs, and battery, with mounting options and room to spare for a GoPro or other camera setup.
5. As one of the most popular quadcopter frames on the market, there is a wide variety of spare parts and accessories to choose from such as landing gears, gimbals, etc,

Figure 3.1: Quadcopter Frame

Things to consider here are weight, size, and materials. They're strong, light, and have a sensible configuration including a built-in power distribution board (PDB) that allows for a clean and easy build. There are also a ton of spare parts and accessories available from many different websites. There are also a ton of clones out there, most of which include the same built-in PDB and durable construction as the original. Parts and accessories are 100% compatible and interchangeable.

Frames can also be built at home using aluminum or balsa sheet. But results will vary from manufactured frames, both aesthetically and in terms of flight attributes

b) Motors

An electric motor is an electrical machine which converts electrical energy into mechanical energy. There are two types of motors generally used for drones, they are

i. *CW and CCW Motors*

Basically the difference of CW and CCW motor is the prop shaft thread rotation. The intention is to use 2 CW motors and 2 CCW motors on a quad, so that when the motors spin, all four prop nuts lock themselves down. It really matter which one you pick as they are identical motors except the prop shaft thread. But I personally prefer to get all motors of the same threads so I don‟t confuse myself with the different prop nuts.

Item No.	Volts (V)	Prop	Throttle	Amps (A)	Watts (W)	Thrust (G)	RPM	Efficiency (G/W)	Operating temperature(℃)
MT2216 KV900	11.1	T-MOTOR 10*3.3CF	50%	2.8	31.08	300	5200	9.65	38
			65%	3.7	41.07	360	5700	8.77	
			75%	4.7	52.17	420	6300	8.05	
			85%	6.2	68.82	520	6900	7.56	
			100%	7.4	82.14	600	7400	7.30	
		T-MOTOR 11*3.7CF	50%	3	33.30	350	4900	10.51	40
			65%	4.4	48.84	420	5400	8.60	
			75%	5.7	63.27	530	5900	8.38	
			85%	7.3	81.03	630	6500	7.77	
			100%	8.9	98.79	720	7000	7.29	
		T-MOTOR 12*4CF	50%	3.5	38.85	420	4200	10.81	43
			65%	5.8	64.38	560	5000	8.70	
			75%	7.8	86.58	680	5450	7.85	
			85%	10	111.00	820	5900	7.39	
			100%	12	133.20	920	6350	6.91	
	14.8	T-MOTOR 9*3CF	50%	3.4	50.32	370	7000	7.35	46
			65%	4.4	65.12	410	7800	6.30	
			75%	5.3	78.44	470	8500	5.99	
			85%	7.4	109.52	610	9300	5.57	
			100%	8.5	125.80	700	10000	5.56	
		T-MOTOR 10*3.3CF	50%	4.1	60.68	460	6500	7.58	50
			65%	5.6	82.88	570	7300	6.88	
			75%	7.1	105.08	690	7900	6.57	
			85%	9.5	140.60	830	8600	5.90	
			100%	11.2	165.76	940	9300	5.67	
Notes:The test condition of temperature is motor surface temperature in 100% throttle while the motor run 10 min.									

Table 3.1: Motor Power Thrust Data Table

ii. *Motor Specifications*

ABLDC motor (2212/10T, 1400KV)

- No. of Cells: 2 - 3 Li-Poly, 6 - 10 NiCd/NiMH
- Kv: 1400 RPM/V
- Max Efficiency: 78%
- Max Efficiency Current: 6 - 12A (>75%)
- No Load Current: 0.7A @10V
- Resistance: 0.065 ohms
- Max Current: 16A for 60S
- Max Watts:180W
- Weight: 51.5 grams
- Size: 27.8 mm x 31 mm
- Shaft Diameter: 3.2 mm

Figure 3.9: Brushless DC Motor

c) *Theoretical Calculations*

In this chapter we are going to calculate the important parameters of the system which play an essential role in terms of selecting the components, the facrots like capacity, thrust, power, rpm etc. are included in this calculation chapter.

VIII. Calculations for an Esc

a) *Max Amp Rating*

Brushless ESCs are used to control brushless motors that are used on most quadcopters. The maximum amperage an ESC can handle needs to be greater than the motor/prop combination will draw. In terms of ESC, suggesting 20%-50% extra Amps is good rule to ensure your ESC do not burn out. For example Current rating for motor is 22A so ESC you are considering 30A should do fine.

Here is simple formula,

ESC = 1.2-1.5 x max amp rating of motor.

So, we can select ESC between ranges of 26A to 33A.

i. *Voltage from battery*

Make sure your ESCs the ability to withstand the voltage from the chosen battery. If you remember our motor draws max 15amp,So watt value for 3S and 4S will be

At 3S battery 11.1 x 15 = 166.5 Watt
At 4S battery 14.8 x 15 = 222 Watt

Since our motor and esc are not much efficient in capable of 4S battery we used 3S battery only

Since our motor is of max current 16 Amp and we can take the esc of 30A. Due to reason or formulae

ESC (A) =1.2-1.5×MAX AMP OF MOTOR
=1.5×16 =25.

SO, we have chosen the ESC of 30A.

ii. *Thrust Caluclations (Without Seeding System) of Drone*

General required thrust is given by an formula mentioned below it is

Thrust required = (total weight of setup) ×2/4.

Therefore according to the frame, esc, battery and other set up we are getting a weight of 1300 grams. I.e. frame weight is 950 grams and other will roughly weights of 350 grams

Required Thrust = 1300×2/4
= 2600/4
= 650 grams

Here we get the required thrust for each motor should be 650 grams for each motor.

Now we have to calculate the actual amount of thrust that is going to produced by an individual motor.

According to some sources i have found that the thrust generated by motor ia given by following formula

$T= [(eta\times P)^2\times 2\times pi\times r^2\times air\ density]^{1/3}$

Where,

Eta = prop hover efficiency let us take it as 0.7-0.8
P= shaft power
= voltage ×current ×motor efficiency
R = radius of propellers in meters
Air density =1.22kg/m³ Voltage = 10v
Current =16A
Motor efficiency =75%=0. 75
Eta=0.7

Then, thrust is

$T=[(0.7\times 10\times 16\times 0.75)^2\times 2\times 3.14\times 0.127^2\times 1.22]^{0.33}$
$= [(84)^2\times 0.123]^{0.33}$
$= (7056\times 0.123)^{0.33}$
$= 871.92^{0.33}$
$= 9.348$ N

Therefore Thrust calculated
T = 9.348N
= 9.348×0.101 Kg
= 0.943kg
= 943 grams

Hence, the thrust generated by each motor = 943 grams

Since we have 4 motors in the quadcopter, the total thrust generated by all motors is given by multiplying, thrust with 4

Total thrust T = 943×4 grams
= 3772 grams
T = 3.772kg.

If we again choose any less efficiency in motor then we will take some factor of safety, if they work only 70% efficient in the above 70% efficient work we can produce thrust of Thrust T = 3.772×70/100
T = 2.64kg

Therefore the min to min amount of thrust produced by all the motors is 2.64kg

iii. *Thrust Calculation (With Seeding system) of Agriculture Robot*

Required Thrust when we assemble the seeding equipment to the drone. It will be given by

T2= (weight of drone +weight of seeding equipment) ×2/4
T2 = (1300+400) ×2/4
T2 = (1700×2)/4
T2 = 3400/4
T2 = 850 grams

Since the thrust produced by individual motor is 943grams, that thrust is greater than the amount of thrust required with the combination of drone and seeding equipment, so our system will be in safe condition and work effectively.

b) Battery Calculations

We have to calculate the amount of energy it is consuming; hence we have now calculating the source required by the battery.

Max source = discharge rate*capacity
= 20×2200
= 44000
= 44Amp

i. *Discharge Rate*

Discharge rate is simply how fast a battery can be discharged safely. In the RC Li-Po battery world it is called the "C" rating. Remember we should never discharge a Li-Po BATTERY BELOW 80% OF ITS CAPACITY.

So, the max source i.e. ESCs should not exceed 44A, since we have selected a 30A ESC there is no problem, it is perfect battery.

ii. *Propeller Calculations For Thrust*

We have,

Payload Capacity + The weight of the craft itself = Thrust * Hover Throttle %

For example, If you choose 3s Lipo battery to supply power. your propos is 10*4.7 and throttle is 75%.The weight of the craft itself is 1700g and we, want to build our quadcopter which can load 1000 grams.

1000+1700 = T×75%
T = 2700/0.75
T = 3600grams

Global Journal of Researches in Engineering (A) Volume XVII Issue VI Version I Year 2017

This amount of thrust should be provided by 4motors, so we can calculate individual thrust required by

T = 3600/4

T = 900grams

Since the thrust required is 900grams, as we calculated above thrust produced or generated by each motor is 943 grams. The system will be safe or run without any default.

Finally we have concluded to select the 4 propellers of size 8×4.5 inch which 2 are supposed to CW and others for CCW. And they weight of 14gram per pair, so total weight is 28gram

IX. Design of Quadcopter

a) *Introduction*

The design of Quadcopter has been done by using CATIA V5 software. The design is done in such a way that there should not be any damage to the propellers, motors and mechanical equipments. The central hub, spars and the arms are designed individually and assembled. CATIA V5. CATIA is able to read and produce STEP format files for reverse engineering and surface reuse.2D structural parts of quadcopter central hub 3D Design of the Quadcopter parts 3D central hub Arm International Journal of Scientific & Engineering Research, Assembly of the Arm and Central hub complete assembly of the Arm The 2D view of the arm is drawn in the catia v5 software and it is converted in to 3d view by giving thickness of 20mm. like wise the arm stand and the knife edge curvature is designed and converted it in to 3D view. The three parts can be designed individually or at a time by creating another plane on the side wich we need to add the futher design. After sketching that part on the plane and it is converted in to 3D by using 3D tool bar. Scientific & Engineering Research, 6 assembly of central hub and arm.The both parts are sketched and designed individually.

b) *Analysis*

Analysis of Quadcopter design Analsysis of thr parts of the designed quadcopter is done by using ANSYS software. Ansys software is the tool of the FEM analysis. Here we are going to make the analysis of the material by using carbon fibre. The parts are meshed first analysed with the specific boundary conditions and various loads Forces based on motor basis.

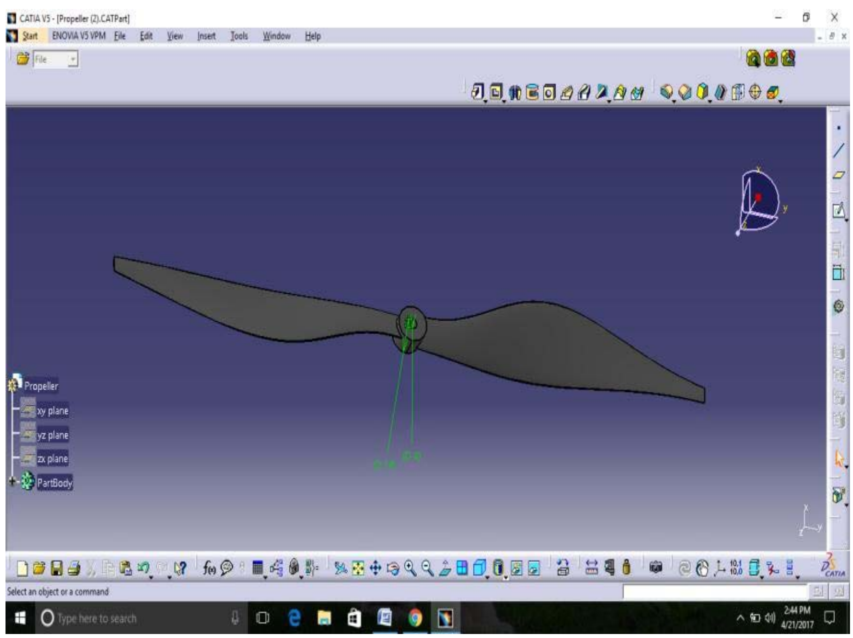

Figure 5.1: Design of Propellers

i. *Design of Propellers*

- Length of Propeller = 80mm
- Pitch diameter of propeller = 45mm
- Shaft hole diameter = 12mm
- Thickness of propeller = 0.3mm

c) *Ground Chasis Plate Dimensions*

Part design involves designing of parts individually and using different workbenches like

1. Product Structure
2. Assembly Design
3. Generative shape design
4. Drafting
5. Material Library
6. Sketcher
7. KOM
8. Sheet metal

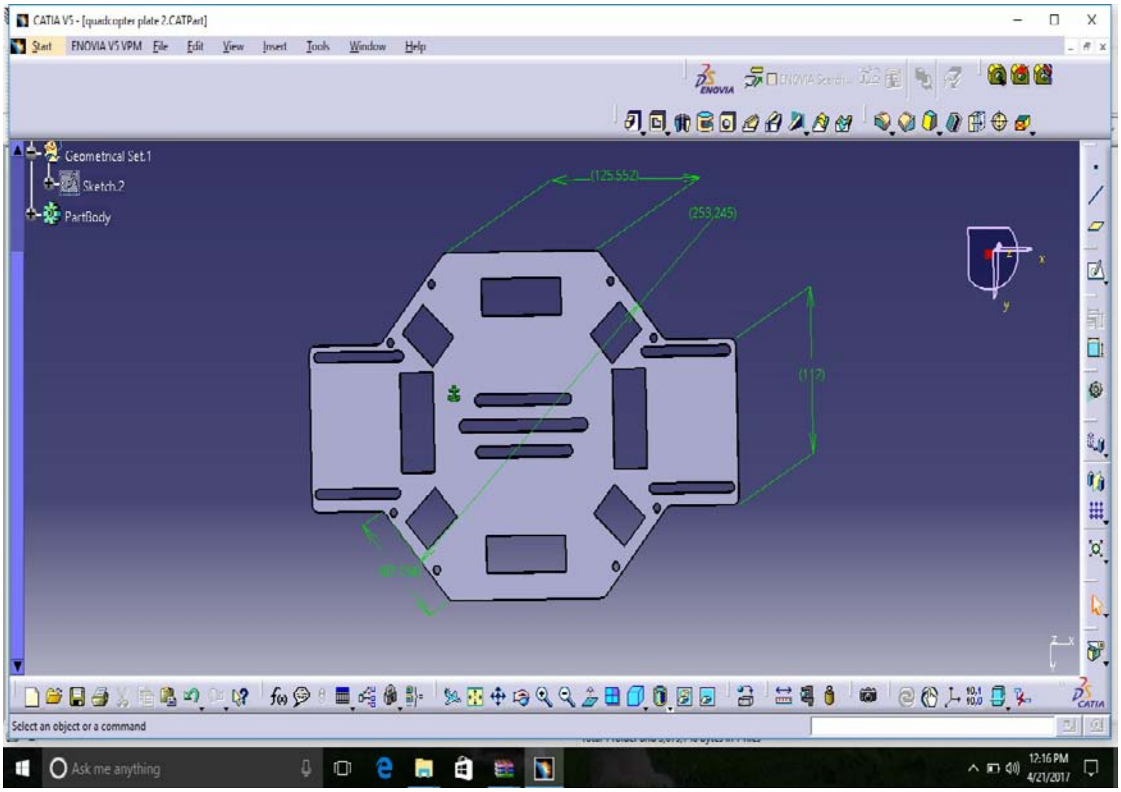

Figure 5.2: Frame of Quadcopter

Horizontal length = 360mm
Vertical length = 234mm
Cross length = 82mm
Cross sectional length = 253mm

d) Chassis of Quadcopter

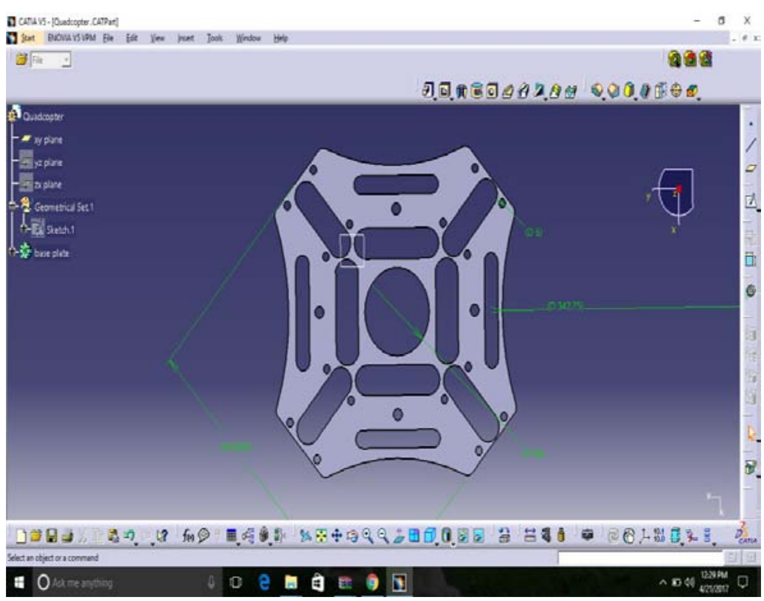

Figure 5.3: Chasis of Quadcopter

i. *Design of Upper Plate*

Outer diameter cut section = 110mm Nut diameter = 6mm

Inner circle diameter = 30mm Vertical length = 80mm Doughnuts = 0.8cm

Drone electrical architecture. The underlying system for the quadcopter in this thesis is named the" Marq Drone" system. This system consists of a flight controller, a radio, and ESCs. Core components of the flight controller include a micro-controller unit, a radio, and an inertial measurement unit. The flight controller communicates with the ESCs through pulse position modulation. More information about PPM can be found here. In addition to communicating with ESCs, the flight controller communicates with a lidar sensor through a universal asynchronous receive and transmit interface. To communicate with devices external to the quadcopter, a USB interface can be used for data acquisition or programming. Another communication method is through a wireless 2.4GHz frequency shift keyed interface for receiving flight commands and transreceiving flight data. Now that all the components involved have been introduced, the I/O of the system can be identified. For the flight controller itself, feedback inputs are from the IMU, sonar, and lidar sensors. The outputs of the system are the four individual PPM signals that are sent to the ESCs. Now that the I/O of the system has been briefly introduced, a control scheme will be derived that uses these I/O to achieve stable flight.

e) *Arm Design*

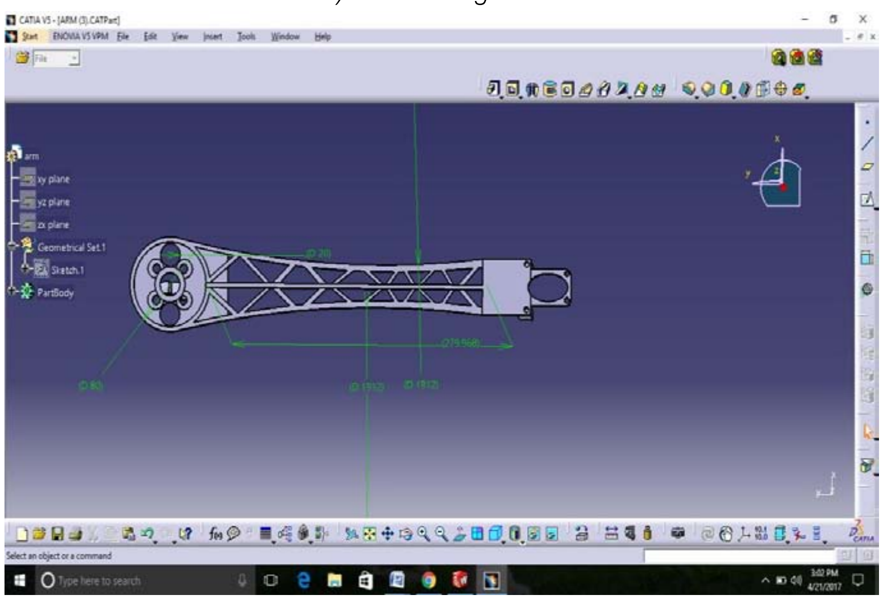

Figure 5.4: Frame part of Quadcopter

Breadth length of arm = 37mm Thickness of arm = 3.7mm

Total Length of arm leg = 150mm Arm leg length = 50mm

Arc curve diameter of leg = 2.4mm

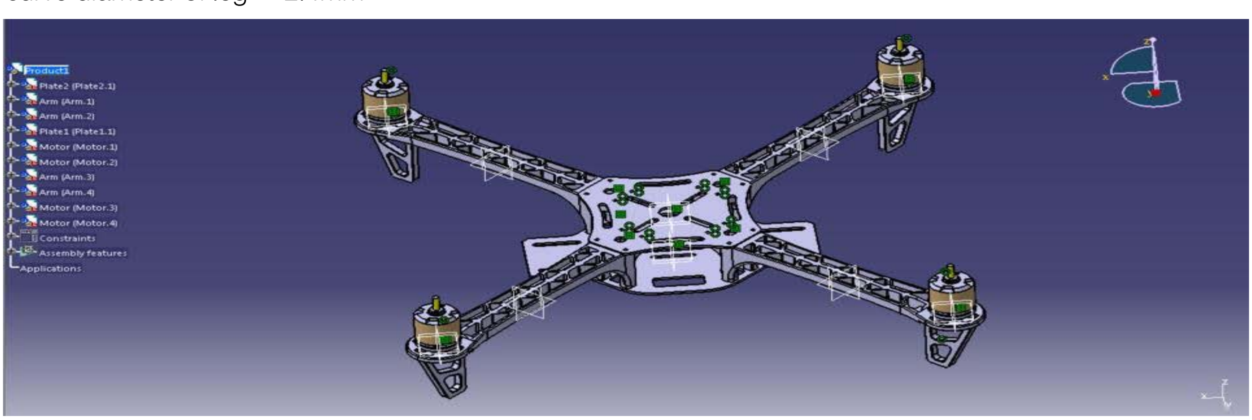

Figure 5.5: Assembly Design of Drone

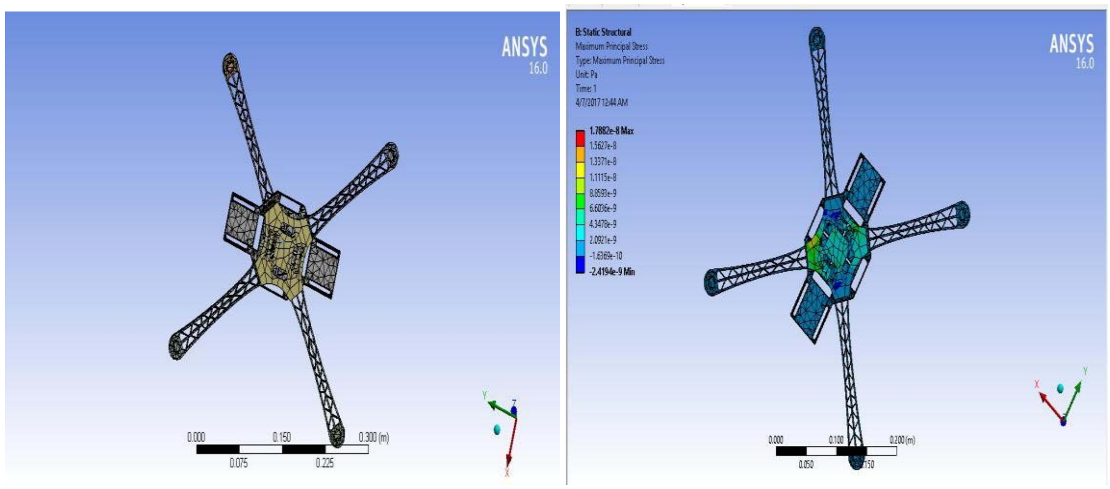

Figure modal and structural analysis of Quadcopter

f) Analysis load data

In Agriculture robot we have undergone modal analysis and structural analysis with different load conditions and forces. we took a force & load of 100KN,200KN,300KN which gave positive results mesh analysis of whole body with stress and strain at every corner of the body. Good deformation capacities with height strength as shown in figure 5.6.

X. Project Description

a) Principle of Operation

Frame Principle: Frame is the structure that holds all the components together. The Frame should be rigid, and be able to minimize the vibrations coming from the motors. Quadcopter frame consists of two to three parts which don‟t necessarily have to be of the same material:

- The center plate where the electronics are mounted
- Four arms mounted to the center plate
- Four motor brackets connecting the motors to the end of the arm Most available materials for the frame are:
- Carbon Fiber
- Aluminum
- Wood, such as Plywood or MDF (Medium-density fiberboard).

Carbon fiber is most rigid and vibration absorbent out of the three materials but also the most expensive. Hollow aluminum square rails are the most popular for the Quadcopters‟ arms due to its relatively light weight, rigidness and affordability. However aluminum could suffer from motor vibrations, as the damping effect is not as good as carbon fiber. In cases of severe vibration problem, it could mess up sensor readings Wood board such as MDF plates could be cut out for the arms as they are better at absorbing the vibrations than aluminum. Unfortunately the wood is not a very rigid material and can break easily in Quadcopter crashes. As for arm length, the term “motor-to-motor distance” is sometimes used, meaning the distance between the centers of one motor to that of another motor of the same arm in the Quadcopter terminology. The motor to motor distance usually depends on the diameter of the propellers.

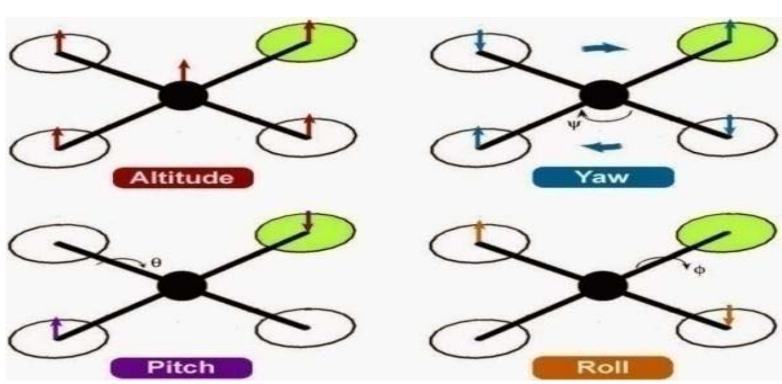

Figure 6.2: Altitude Direction, yaw direction, Pitch direction and roll direction

XI. Software Analysis

In this project we are using Arduino and Digital Radio Software

a) Arduino Analysis

In the project the program is dumped to the controller through Arduino. Arduino is a tool for making computers that can sense and control more of the physical world than your desktop computer. It's an open-source physical computing platform based on a simple microcontroller board, and a development environment for writing software for the board.

The Arduino programming language is an implementation of Wiring, a similar physical computing platform, which is based on the Processing multimedia programming environment.

b) Digital Radio Software

This is the software which is used to set PID Control Settings. Here we can set the different channels to be used for Radio transmitter and Receiver. Model that is used is MODEL-2. Different types of settings are available as:

1. ACRO
2. HELI-120
3. HELI-90
4. HELI-140

XII. Hardware Analysis

There are different steps to be followed in this analysis.

1. Assembling of Frame
2. Soldering for Chassis
3. Connection of ESC"S
4. Fixing of Brushless motors
5. Propellers fixing
6. Synchronization of Transmitter and Receiver
7. Testing the Quadcopter.

a) Frame

Quadcopter frame can be called as the chassis of the quadcopter. The frame can be achieved in different configurations such as +, X, H, etc…the selection of the frame is totally a user defined choice based on his own purposes.

We used HJ 450 Frame. FlameWheel450 (F450) is a multi-rotor designed for all pilots for fun. It can achieve hovering, cruising, even rolling and other flight elements. It can be applied for entertainment, aerial photography, FPV and other aero-modeling activities. When flying, the fast rotating propellers of FlameWheel450 will cause serious damage Safety precautions to be taken are:

1. Keep flying multi-rotor away from objects, such as obstacles, human beings
2. Do not get close to or even touch the working motors and propellers, which will cause serious injury.
3. Do not over load the multi-rotor.
4. Check that the propellers and the motors are installed correctly and firmly before flight.
5. Make sure the rotation direction of each propeller is correct
6. Check whether all parts of multi-rotor are in good condition before flight. Do not fly with old or broken parts.
7. Use DJI parts as much as possible.

Figure 6.6: Axis Frame

b) Soldering

Chassis which is inbuilt with frame has to be soldered for connecting ESC"S. Chassis works as a printed Board for power supply. We have used Insulating material for soldering. While soldering we must make sure that there is no open or close circuit.

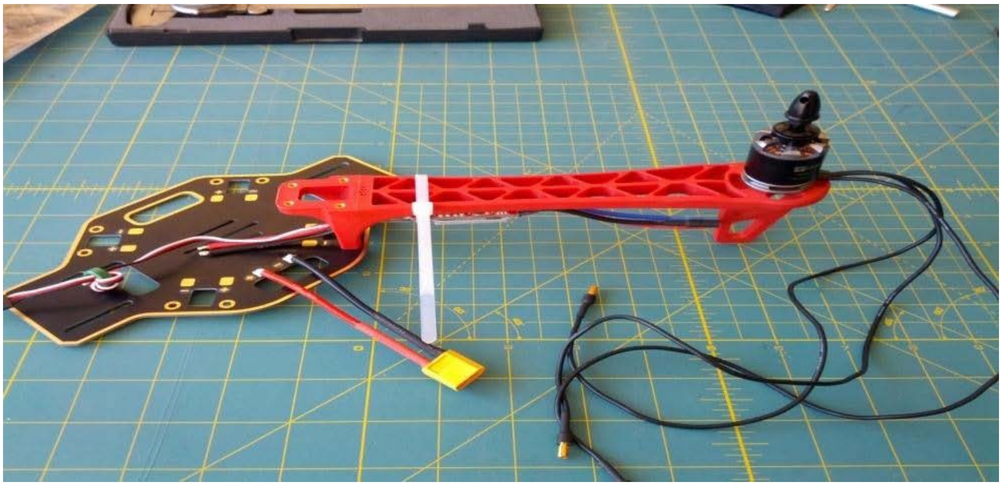

Figure 6.7: Soldered Chassis

XIII. Seeding System

a) Introduction

Maize is one of the important foods, green forage and industrial crops of the world. It is called QUEEN OF THE CEREALS. Maize has highest yield/ha among the cereal crops. It is now grown in all countries except Antarctica and under a more varied range of climates than any other cereal crops. The National Commission on Agriculture observed that maize can substantially contribute to the additional total food grain production by increasing its present contribution from 6-7% to 10%. Though it is mainly used as a food crop in India by the rural population in the form of bread and gruel, it has vast industrial potentialities as well having many as 50 different uses. Ex: it can be put to the manufacture of starch, syrup, alcohol, acetic acid, lactic acid, glucose, paper, rayon, plastic, textiles, adhesives, dyes, synthetic rubber, resin, artificial leather, boot polish etc., Corn oil is 4% USES Green ears find a ready market in the urban areas. The grain is ground into flour for making bread. Maize is being used as a poultry and cattle feed. Stover, whether green or dry is fed to the cattle.

QUALITY Grain contains: Protein- 10%
Oil – 4%
Carbohydrates – 70%
Fat – 5 to 7%
Fiber – 3 to 5%
Minerals – 2%

It is operated in such a way that, where we want to sow the seed then it will be taken down and then the seeding system the pipe of the seeding equipment hits the ground then it will be induced to some force and that will moved in vertical direction.

Table 7.1: Maize Seed Details

Means (± standard deviation) for corn plant height, proportion of green ears in the first harvest and green-ear yield values of three corn cultivars submitted to weed control methods[1/]

Method of weed control	Plant height (cm)	Proportion of green ears at first harvest (%)[2/]	Total unhusked green ears ha^{-1}		Marketable unhusked green ears ha^{-1}		Marketable husked green ears ha^{-1}	
			Number	Yield (kg)	Number	Yield (kg)	Number	Yield (kg)
Hoe-weeding	184 (±16.2) a	62.9 (±26.3) a	49167 (±3837) a	14108 (±1607) a	48269 (±4508) a	13857 (±1835) a	44840 (±7,129) a	8474 (±1439) a
Intercropping with cowpea (BR 14 cultivar)	170 (±7.8) b	51.6 (±18.6) b	48974 (±1198) a	11447 (±959) b	45128 (±1370) a	11038 (±1288) b	37051 (±4348) b	6305 (±1008) b
Intercropping with cowpea (IPA 206 cultivar)	176 (±16.7) ab	46.0 (±18.3) b	48846 (±1905) a	10389 (±1512) b	45585 (±5133) a	10205 (±1811) b	34935 (±8429) b	5701 (±1447) b
No weeding	173 (±16.4) b	52.8 (±25.9) b	47180 (±2275) a	11545 (±2366) b	44344 (±4976) a	11199 (±2337) b	36923 (±11007) b	6310 (±1853) b
Means of corn cultivars	175.8	53.3	48541	11872	45832	11575	38437	6698
Coefficient of variation for plots, %	14.1	32.4	3.9	18.2	9.3	18.0	27.1	28.0
Coefficient of ariation for subplots, %	5.9	19.0	5.8	13.0	10.1	15.7	18.7	19.6

[1/] Means followed by the same letter in the column do not differ by the Tukey's test ($P < 0.05$). [2/] In relation to the total number of green ears harvested in the first of three harvests.

Global Journal of Researches in Engineering (A) Volume XVII Issue VI Version I Year 2017

XIV. Area and Production

Among cereals maize crop occupies 3rd place in the world after wheat and rice. America ranks first in productivity followed by Europe. In these areas maize is used primarily as a source of animal feed. Nearly 54% of the total area is located in South America, Asia and Africa, but they contribute only 33% to the total production of the maize in the world. In these areas, average productivity is low. Maize is consumed primarily as a source of human food. India cultivates 5.4% of the total area and provides 1.7% of the total production of maize in the world.1997-98 World India AP Area [mha] 140 6.30 396000ha. Production [million tons] 420 10.85 1084000t Productivity[kg/ha] 3000 1720 2740 In India, UP ranks first in area production while the productivity is highest in Karnataka. Punjab ranks fourth position. In AP, it is intensively grown in North and South Telangana particularly Karimnagar, Medak, Nizamabad, Warangal an Adilabad districts

a) Working

The seeding system working is explained in the below sentences, the synchronized drone and seeding system are arranged and went for testing in the working field, whenever the drone starts flying it carries the seeding system along with that and the drone will be operated in such a way that, where we want to sow the seed then it will be taken down and then the seeding system the pipe of the seeding equipment hits the ground then it will be induced to some force and that will moved in vertical direction.

The pipe has small hole that it is coincided with the other hole which was present on the other pipe, then through that hole the seeds are dropped to the ground.

Then this will make sure that the seed should be dropped at the place where we want to sow. Thus the seeding is completed.

XV. Design of Seeding System

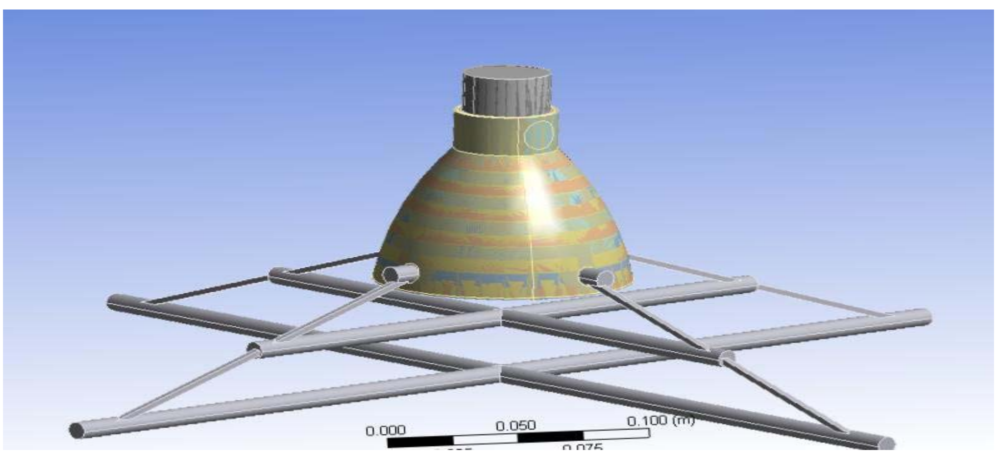

Figure 7.1: Seeding System

a) Applications

The main application of our system and some other extended applications of our system are explained below.

i. *Seed Sowing*

The main objective of our system is to work it as a seed sowing device in agricultural fields, which is a major work in farming. our system performs seed sowing in agricultural lands with high efficiency rate and reduces the working time of labours, we can perform the work done by several humans with our single device.

ii. *Extended Applications*

a. *Aerial Photography*

This application is widely used now a days. Music concerts or any functions where there is large gathering of people, they can be photographed using aerial only.

b. *Military Applications*

1. Tracking
2. Drones with the help of gps can track particular person or vehicle movement
3. Identifying enemy movements
4. In search and rescue operations
5. Many military operations uses drones for live coverage of the mission Rescuing hostages and civilians is the main objectives of these operations. Drones are used to check the condition of the hostages

iii. *Environmental Applications*

a. *Fire Control Quad Copters*

Fires caused in forests due to various reasons are very difficult to control. These can be controlled effectively by means of drone. Drones will carry water of some sort of solutions. Drone installed with gas sensors helps to detect the amount of gases present in the particular area in the atmosphere. These figures can be stored in the memory card or send to us by using gsm module. For using gas sensors we need to use Arduino for interfacing.

b. *Wild life surveillance*

Many wild life species are going to extinct now a days due to radiation, hunters etc. this can be prevented by tracking and surveillance of wild life animals.

XVI. Result

After configuring all the parts, assembling as required, configuring Software and synchronizing the seeding system finally we obtained Agriculture robot which is shown below figure 9.2 it has performed the task of seeding well, As we concluded some limitations of this Agriculture robot those are happened in the work field. We need to test the Acceleration Calibration every time when we change the ground surface area. As per theoretical calculations it was supported to lift 2.64 kg but in practical it was lifted up to 1kg only. Aerial Practical values of Quadcopter are shown below:

Roll(Aileron)	Pitch(Elevator)	Yaw(Rudder)
P Gain: 35	35	50
P Limit: 100	100	20
I Gain: 30	30	50
I Limit: 20	20	11

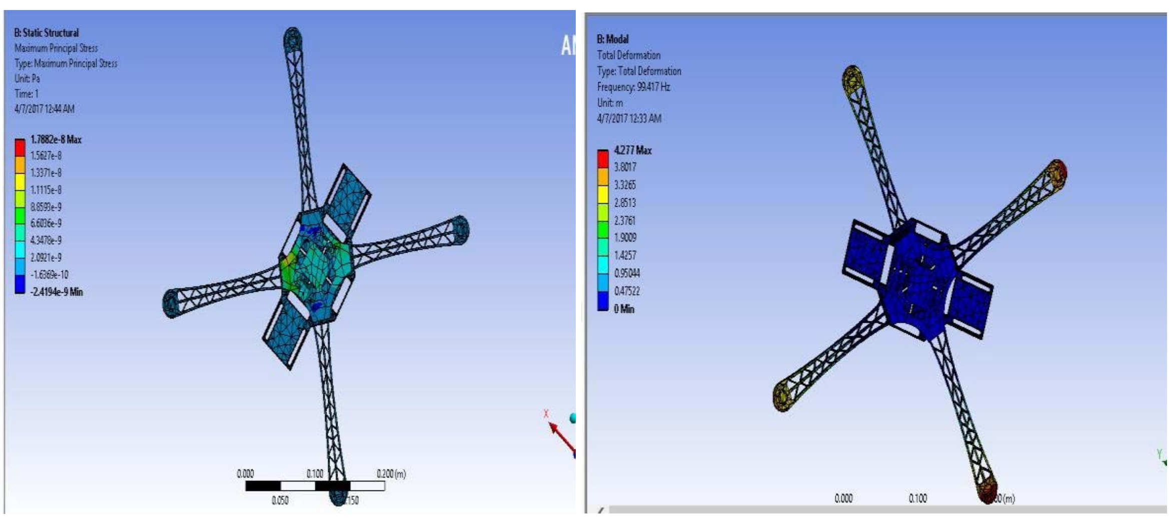

Figure 9.1: Analysis of Agriculture Robot

Figure 9.2: Working of Agriculture Robot

XVII. Conclusion

In this project we have designed an AGRICULTURE ROBOT which is an architecture based on unmanned aerial vehicle(UAVs) and a Seeding System that can be employed to implement a control loop for agricultural applications where AGRICULTURE ROBOT is responsible for seed sowing. Here by we can reduce the human efforts not much but some amount. This will be helpful in performing the seeding task done in agricultural fields in less time. This will reduce the labour cost also and perform the work very accurate. This is completely operated by the radio transmitter and receiver with in the range of signal. If we are getting far away within the signal range then the AGRICULTURE ROBOT will not work properly.

This system may be further developed in many ways, by replacing the seeding system with other equipment's or systems like if cutter is placed then it will be used for cutting crops, if sprayer module is attached to drone then it will be used as pesticide spraying drone, and also if provided with high equipment's and cost then it also performs scanning of plants, security causes, inspecting crop details with specified seeds, fertilizers, pesticides as per soil condition suggested from scientists of agriculture on crops. The process of application is controlled by means of the feedback from the wireless sensors network developed aground level on the crop field.

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Effect of Water Absorption on the Impact Behaviors of CFRE Composites

By U. A. Khashaba, Ramzi Othman & I.M.R. Najjar

King Abdulaziz University

Abstract- This paper is concerned with the effect of water absorption on the impact behavior of woven carbon fiber reinforced epoxy (CFRE) composites. The composite laminates were manufactured using the prepreg technique and then cut to the standard dimensions following the ASTM D 7136. The specimens were immersed in distilled water up to 368 h. The moist specimens were characterized by falling weight tester at different impact energies. The impact results are compared with the results obtained under dry testing conditions. The comparison shows that water-immersed plates absorb almost the same energy as the corresponding dry ones. However, the maximum force obtained with the water-immersed plates is 15%-20% lower than those of the corresponding dry plates. This can be interpreted in terms of the degradation effect the composite material by water absorption.

Keywords: carbon fiber/epoxy composites, water absorption, falling weight impact, absorbed energy, impact force.

GJRE-A Classification: *FOR Code: 091399p*

EFFECTOFWATERABSORPTIONONTHEIMPACTBEHAVIORSOFCFRECOMPOSITES

Strictly as per the compliance and regulations of:

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U. A. Khashaba [α], Ramzi Othman [α] & I.M.R. Najjar [α]

Abstract- This paper is concerned with the effect of water absorption on the impact behavior of woven carbon fiber reinforced epoxy (CFRE) composites. The composite laminates were manufactured using the prepreg technique and then cut to the standard dimensions following theASTM D 7136. The specimens were immersed in distilled water up to 368 h. The moist specimens were characterized by falling weight tester at different impact energies. The impact results are compared with the results obtained under dry testing conditions. The comparison shows that water-immersed plates absorb almost the same energy as the corresponding dry ones. However, the maximum force obtained with the water-immersed plates is 15%-20% lower than those of the corresponding dry plates. This can be interpreted in terms of the degradation effect the composite material by water absorption.

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I. Introduction

Fiber reinforced polymer (FRP) composite laminates are commonly used as light-weight materials in a wide variety of marine applications including sporting equipment as well as military structures. Low-velocity impacts in these applications cannot be avoided via falling tools and equipment, floating ice, struck submerged objects, grounding and collisions. Low-velocity impacts on composite structures can yield degradation of the composite material, which is sometimes hard to detect by external inspection. Impact damage is highly dependent upon the nature of the threat and conditions associated with the impact event. The impacted composite structures have 50%-75% less strength than undamaged structures [1].

Impact behavior of FRP composite structures have special attention by manyresearches [2-10]. However, few of them characterized the impact performance under water environments [8-10], which is the subject of the present study. FRP composites generally absorb energy through fracture mechanisms such as delamination, shear cracking, and fiber breakage; however some portion of the energy may be absorbed through elastic-plastic deformation of the fiber and matrix. The mode of fracture and thus the energy absorbed are influenced by various test and material variables such as: fiber orientation, interface strength, specimen geometry, velocity of impact, and environmental conditions. Aymerich et al. [2-3] studied the impact-induced damage on stitched and unstitched graphite/epoxy laminates. Dau et al. [4] dealt with 3D-interlock composite materials. Kursun et al. [5] investigated the influence of the impactor shape on the post-impact strength of composite sandwich plates. Iqbal et al. [6] were interested in the impact damage resistance in nanoclay-filled CFRE. Arun et al. [8] investigated the effect of sea water on the impact properties of glass/textile fabric polymer hybrid composites using a pendulum type impact testing machine. The specimens were immersed in sea water for 8, 16 and 24 days.

Water absorption can exit in two distinct forms: free water that fills the microcavities of the network and bound water in strong interactions with polar segments [11]. The degradation of the impact strength of glass/polyester composites in water may be due to physical degradation such as matrix "swelling", degradation of matrix resin due to chemical reaction with water and degradation of interfaces bonding between fibers and matrix resin [9].

The present work is a continuation of a previous study [7] on the effect of temperature on the impact behaviors of CFRE composites. The impact tests were carried out using falling weight impact tester at room temperature (RT), 50°C and 75°C. Khashaba and Othman [7] reported thatthe reduction of stiffness and strength at room temperature and 50°C is comparable. The highest reduction in the stiffness and strength is observed at 75°C owing to softening of the epoxy matrix, plasticization of the matrix at the impacted zone, interfacial fiber/matrix debonding, degradation of the matrix properties and increases of the interfacial stress concentration of the re-solidified matrix.

Automotive and aircraft structures are always exposed to water from rains and condensation of atmospheric humidity. Applications, such as boats and marine industries, water pipes and tanks required more data about the effect of water as the main environment on their mechanical properties. Therefore, the main

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objective of the present work is to investigate the impact behavior of carbon fiber reinforced epoxy composites subjected to water environments. The experimental results of Gude et al. [11] showed that the saturation of epoxy (with and without carbon nanotubes) with water absorption is reached after about 265h. Therefore, in the present work the specimens were immersed in distilled water up to 386 h. Subsequently, they are subjected to impact tests using drop-weight machine in accordance with ASTM D 7136.

II. Experimental Work

a) Materials

Carbon fiber reinforced epoxy (CFRE) composite laminates were manufacture dusing 25 layers of T300-3k plain woven carbon fiber fabrics (200g/m^2) and YPH-120-23A/B epoxy matrix by applying the prepreg method. The laminates are fabricated in 500x500x5 mm. The tensile and in-plane shear properties of CFRE composite were determined in some previous works, Khashaba et al. [12-13]. Moreover, the compressive properties are studied in Ref. [14] for non-impacted specimens. The tensile, compression and shear properties are illustrated in Table 1.

Table 1: Tensile, shear and compressive properties of CFRE composite

Tensile [12-13]			In-plane shear [121-13]		Compressive [14]	
Strength σ_t (MPa)	Modulus E_t (GPa)	Poisson's ratio ν	Strength τ (MPa)	Modulus G (GPa)	Strength σ_c (MPa)	Modulus E_c (GPa)
895.28	81.66	0.052	145.41	6.94	633.30	80.90

b) Specimens Preparation

The tested specimens were cut from the fabricated composite laminates to the standard dimensions of the falling mass impact tests according to ASTM D 7136. Three specimens were cut for each experimental condition using abrasive waterjet machine to dimensions of 101.6x152.4x5 ± 0.1 mm. The main advantage of this cutting technique is the elimination of heat generation, which is associated with the conventional machining processes. Heat generation is a main drawback as it can soften the fabricated materials that re-solidified after cooling. In the worst case, the heat generation can burn the matrix. Softening and solidifying of polymer composites is frequently associated with high stress concentration along the cutting path. In addition, the induced stress concentration can lead to premature failure of the specimens when subjected to the mechanical loads of the testing machines. A second advantage of abrasive waterjet machine is that it is dustless cutting technique. This is highly advantages mainly when cutting polymers and fiber-reinforced polymer composites (FRP).Consequently, this technique is environmentally friend and not hazardous.

To evaluate the effect of moisture environments on the impact response of CFRE composites, the specimens were immersed in a tank containing distilled water up to saturation, which is observed after about 368 h. The water in the tank was renewed every 3 days [9]. The moisture weight was measured at different time intervals using high sensitivity (0.0001 g) digital balance of model A & D HR-200. The experimental results of Gude et al. [11] showed that the saturation of epoxy (with and without carbon nanotubes) with water absorption is reached after about 265h.Therefore, the selected immersion time (368 h ≈ 16 days) is enough for saturation of CFRE specimens with distilled water.

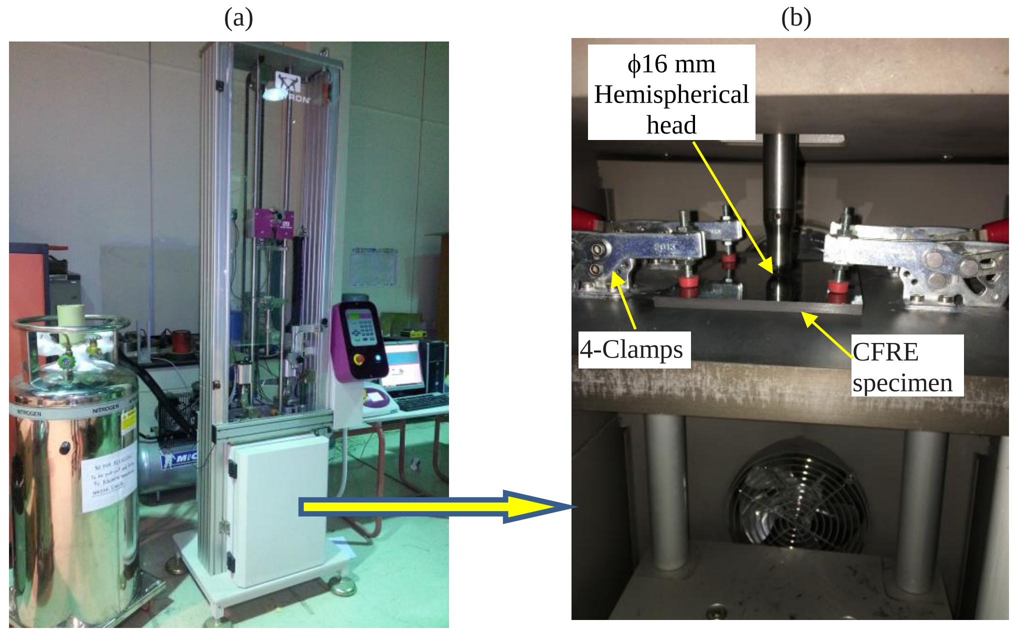

Fig. 1: (a) Falling weight impact tester model CEAST 9340, and (b) specimen clamped inside thermal conditioning chamber of impact tester

c) Impact Tests

Drop weight impact tests were performed at room temperature on CFRE woven composites in accordance with ASTM D 7136 using CEAST 9340 falling weight impact machine shown in Figure 1(a). The specimenwas clamped by four fixtures on a steel plate havinga rectangular window of 125x75 mm^2. The specimen and the fixing frame are fixedinside the thermal conditioning chamber as shown in Figure 1(b). Six energy levels of 1.88J, 30J, 50J, 60J, 75J and 100J were selected to perform impact testes on CFRE composites. Three specimens were tested for each energy level and the average values are considered to evaluate the effect of water immersion on the impact behavior of CFRE composites at different impact energies.

The values of the falling height and impact velocity are automatically evaluated by the machine software. However, they can be determined from Eqs. (1) and (2), respectively, as follows:

$$H = \frac{E_i}{mg} \tag{1}$$

and

$$v_i = \sqrt{\frac{2E_i}{m}} = \sqrt{2gH} \tag{2}$$

where E_i is the impact energy, v_i is the impact velocity, H is the drop-height of the impactor, m is the total mass of the impactor and g is the gravity acceleration ($g =$ 9.81 m/s^2). Table 2 depicts the impact test parameters related to the investigated impact energies.

Table 2: Impact test parameters

Impact Energy (J)	Total Mass (kg)	Impact Height (m)	Impact Velocity (m/s)
1.88	3.632	0.053	1.02
30.13	7.632	0.402	2.81
50.00	12.632	0.403	2.81
60.00	12.632	0.484	3.08
75.00	7.632	1.002	4.43
100.05	12.632	0.807	3.98

The specimens were subjected to transverse impacts at low-velocities (1.02 – 4,43 m/s) with a hemispheric impactor of 16 mm in diameter. The impact testing machine is equipped with a pneumatic anti-rebound device to prevent a second impact on the tested specimen. Knowing the contact force and the impact velocity, the impactor acceleration $a(t)$, velocity $v(t)$, displacement/deformation $u(t)$, and energy $E(t)$,respectively, are calculated in terms of time, as follows [15]:

$$a(t) = -\frac{P(t)}{m}, \tag{3}$$

$$v(t) = v_i - \int_0^t a(\tau)d\tau = v_i - \int_0^t \frac{P(\tau)}{m} d\tau, \tag{4}$$

$$u(t) = \int_0^t v(\tau)\, d\tau, \tag{5}$$

and

$$E(t) = \int_0^t P(\tau)du = \int_0^t P(\tau)v(\tau)\,d\tau \qquad (6)$$

The absorbed energy (E_a) is evaluated by subtracting the residual or rebound energy (E_r) from the impact energy $\left(E_i = \frac{1}{2}mv_i^2\right)$ [16-17]. The residual energy is considered as the energy of the impactor when it rebounds and loses contact with impacted plate, i.e., when the force decreases back to zero. Hence, the absorbed energy (E_a) is evaluated as the asymptotic value of the energy $E(t)$ transferred from the impactor to the composite plate. The absorbed energy ratio (ρ) is calculated as:

$$\rho = 100\frac{E_i - E_r}{E_i} = 100\frac{E_a}{E_i} \qquad (7)$$

In addition, the peak force $(F_{max} = \max Ft$ isevaluated for each test.

III. Results And Discussions

a) *Water absorption and diffusion coefficient*

The total moisture content (G) in composite materials that following Fickian behavior or Fick's diffusion laws can be described as follows[18]:

$$G = \frac{M - M_i}{M_m - M_i} = 1 - \frac{8}{\pi^2}\sum_{j=1}^{\infty}\frac{1}{(2j-1)^2}exp\left[\frac{-(2j-1)^2\pi^2 Dt}{h^2}\right] \qquad (8)$$

where *M* is the moisture content at time *t*, M_i is the initial weight of moisture in the specimen, M_m is the maximum (saturated) moisture content, *h* is the specimen thickness, and *D* is the mass diffusivity in the composite (diffusion coefficient).

The diffusion coefficient is an important parameter in Fick's law, which can be determined by solving the diffusion Eq. (8) for the weight of moisture, and rearranging in terms of the percent moisture content, the following relationship is obtained [18-19]:

$$D = \pi\left(\frac{kh}{4M_m}\right)^2 \qquad (9)$$

where, *k* is the initial slope of a plot of *M*(*t*) versus $t^{1/2}$ as shown in Fig. 2.This figure indicates that the difference between the last two subsequent weight readings approaches zero, which means that the maximum (saturated) moisture content of CFRE specimens is (M_m = 0.066 g) reached after 336 h immersion time. The estimated diffusion coefficient using the above equation is 4.145x10^{-6} mm^2/s.

Since the sample was initially dry, the weight of moisture in the materials is M_i = 0. Thus, the Eq. (8) is reduced to the ratio *G* = M/M_m. Fig. 3 shows comparison between the predicted, Eq. (8), and the measured moisture absorption of T300-3k plain woven carbon fiber/epoxy composite. Because of the series of Eq. (8) is rapid convergence, the first four terms are enough for prediction the ratio (*G*) of the weight of moisture (*M*) at time *t* to the moisture in the fully saturated equilibrium condition (M_m) [20]. It is obvious from Fig. 3 that water absorption of T300-3k plain woven carbon fiber/epoxy composite has good agreement with Fick's law.

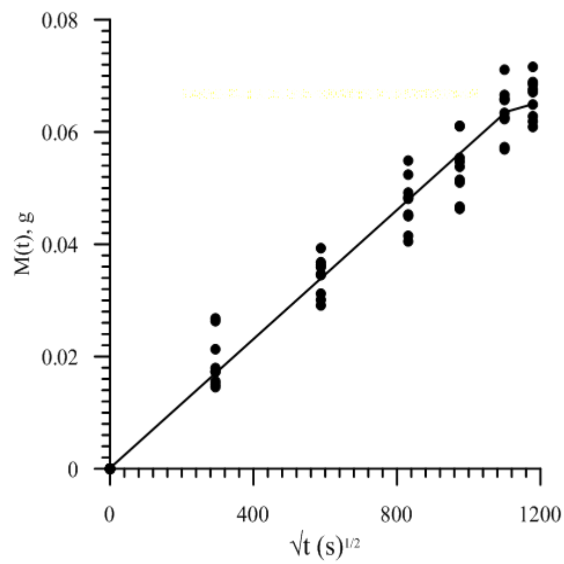

Fig. 2: Water absorption behavior of CFRE composites

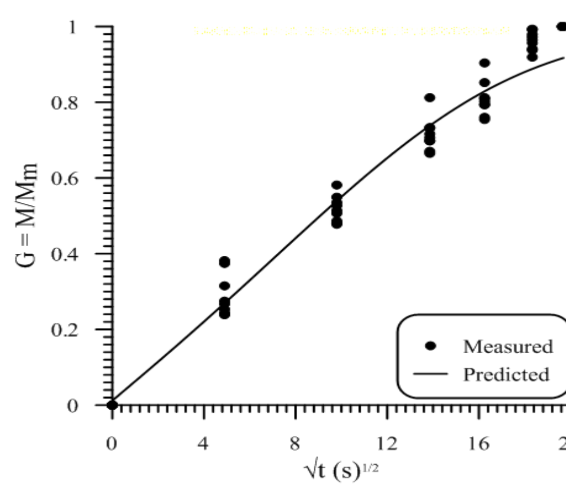

Fig. 3: Comparison of predicted and measured moisture absorption of CFRE composite

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b) Low-velocity impact tests

Fig. 4 shows a typical force-time curve of the water-immersed CFRE composite plates at impact energy of 30J. First, the force increases almost linearly till about 600 micro-seconds. The sharp increase in the force is interpreted in terms of the composite's undamaged elastic behavior. Second, the elastic deformation is followed by sharp drop in the force due to damage initiation. The peak force observed in this elastic range defines the thres hold force that initiates a change in the material stiffness it is also named delamination threshold[21]. Third, the sharp drop in the force is followed by a second nonlinear increase, which describes the damaged elastic behavior of the composite material. This occurs after redistribution of the load on the undamaged composite layers. Fourth, a peak force associated with non-linear plastic behavior was observed due to collapse of CFRE specimen. Finally, the force drops gradually to zero as the impactor rebounds off the composite plate.

The energy transferred from the impactor to the composite specimen of Fig. 4 is indicated in terms of displacement as shown in Fig. 5. It increases almost in a parabolic way till a maximum value corresponding to the kinetic energy of the impactor or the impact energy. Thus decreases as the impactor goes upwards. The impactor loses contact with the composite plate as the displacement decreases back to zero. The value of the energy at this time is absorbed energy by CFRE plate.

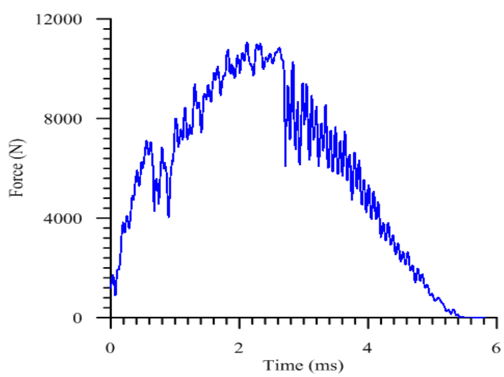

Fig. 4: Force-time variation ($E_i = 30J$)

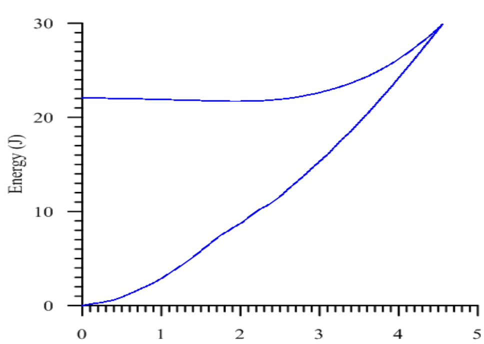

Fig. 5: Energy-displacement relationship ($E_i = 30J$)

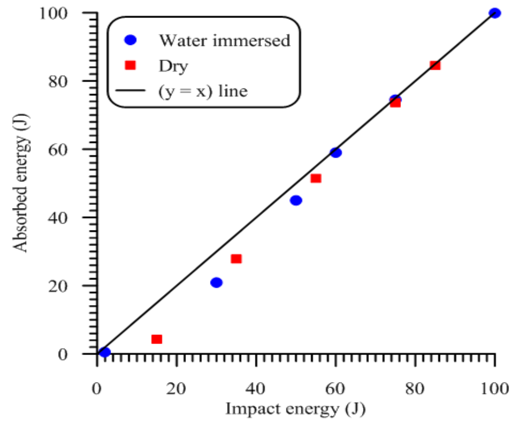

Fig. 6: Absorbed energy vs. impact energy

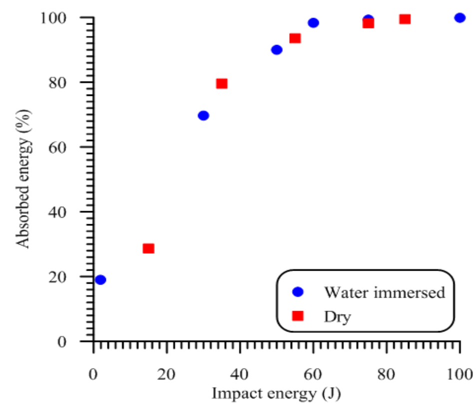

Fig. 7: Absorbed energy ratio vs. impact energy

Fig. 6 shows the absorbed energy for the water-immersed plates at different values of impact energy. At impact energies higher than 60J, the absorbed energy matches the equality line (y=x), which means that the composite plates absorb the total impact energy. On the other hand, at lower impact energies, the absorbed energy comes lies below the equality line (y=x), which means that the composite plates absorb, in this range, only a part of the impact energy. Fig. 7 shows the absorbed energy-to-impact energy ratio for water-immersed and dry plates. The absorbed energies of the saturated CFRE specimens with distilled water have insignificant differences compared with those corresponding to the dry samples, as shown in Figs. 6 and 7. Similar behavior was observed by Imielińska and Guillaumat [22]. They reported that the absorbed energy of woven aramid-glass fiber/epoxy composite was not affected with water immersion ageing.

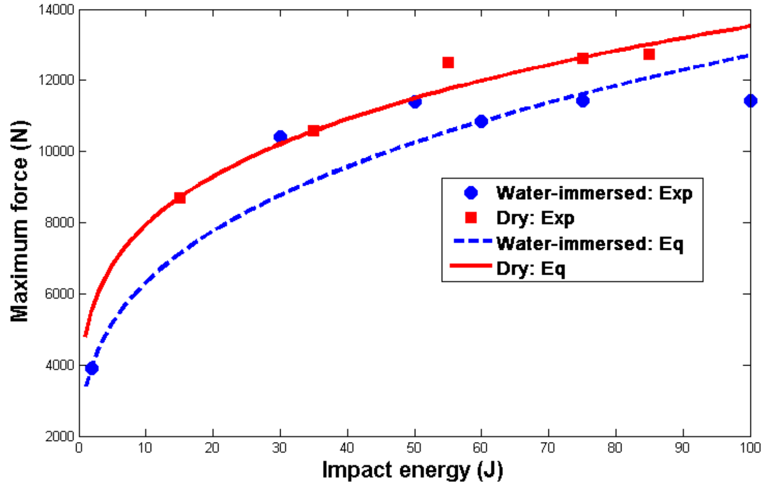

Fig. 8: Maximum force vs. impact energy

Fig. 9: Images of post-impact damage of moist CFRE specimens with 75J: (a) front side, and (b) back side

The maximum force was calculated for different impact energies of dry as well as moist CFRE specimens and the results are illustrated in Fig. 8. The results in this figure showed that the maximum forces of both dry and moist specimens were sharply increases at low impact energies. In this range no perforation of the plates is observed. The maximum force recorded with the water-saturated CFRE plates is comparable to the maximum force measured with the dry CFRE plates in the low impact energy range. Only cross-shaped surface cracks are noticed. On the opposite, the maximum force is almost constant at high impact energy (higher than 50 J).At these impact energies, the composite plates are completely perforated as shown in Fig. 9. In the front side, the impactor leaves a larger printed circular shape, Fig. 9a, on the CFRE specimens with a diameter that is directly proportional with the impact energy. The excessive delaminations on the back side accompanied with long cross-cracks have constructed a 3-D pyramidal shape as shown in Fig. 9b.

The four ends of the cross-crack of the back side were connected together to form the base of the pyramids, while the specimen center represent its vertex.

The maximum forces recorded for the saturated CFRE specimens with distilled water are in the range of 15 to 20% lower than those corresponding to the dry ones. This can be explained be the fact that water absorption degrades the mechanical strength of composite materials in general [23-24] and more particularly CFRE composite materials [25]. Imielińska and Guillaumat [22] attributes this behavior to chemical degradation of resin matrix and fiber matrix interphase region. Water degradation will cause swelling and plasticization of the polyester matrix and debonding at the fiber/matrix interface that may reduce the impact force.

The maximum/peak force measured with the water-immersed or the dry composite plates can be interpolated using the following equation [7, 26-27]:

$$P_{Peak} = -\frac{c}{2}\left(\frac{2E_i}{m}\right)^{\frac{n}{2}} + \sqrt{2K_0E_i + 2^{n-2}c^2\left(\frac{E_i}{m}\right)^n} \qquad (10)$$

where P_{Peak} , K_0, c and n are the maximum force, global plate stiffness, the damping coefficient and a constant to include non-linear effects. The constants obtained by curve fitting and root mean squared error (RMSE) are reported in Table 3.

Table 3: Constants of Eq. (10)

Constants	Water-immersed CFRE	Dry CFRE
K_0 (N/m)	0.2049	0.141
c (N/$(m/s)^n$)	4866.9	6493.1
n	0.3803	0.294
RMSE error (%)	6.4	1.7

IV. Conclusions

In this work, the effect of water absorption on the low-velocity impact behavior of CFRE composite plates was investigated. To this aim, falling weight testing machine was used to impact water-saturated CFRE plates at different values of impact energies. Several conclusions can be drawn:

- For impact energies higher than 60J, 100% of the impact energy is absorbed by the CFRE plate and a perforation is observed.
- The maximum force increases rapidly at low impact energies and tends to an asymptotic/constant value at high impact energies.
- The absorbed energies of the saturated CFRE specimens with distilled water have insignificant differences compared with those corresponding to the dry samples
- The maximum force recorded with the water-saturated CFRE plates is comparable to the maximum force measured with the dry CFRE plates in the low impact energy range.
- The maximum force recorded with the water-saturated plates is 15 to 20% lower than the maximum force measured with the dry plates in the high impact energy range. This is explained in terms of the chemical degradation of resin matrix and fiber matrix interphase region owing to water absorption.

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Analysis of Scale Effects on the Behavior of Composite Structures: Case of Automotive Body

By Wel-Doret Djonglibet, Tikri Bianzeubé, Djeumako Bonaventure, Danwe Raidandi & Guy Edgar Ntamack
University of Ngaoundere

Abstract- For many years, composite materials include automotive industries to improve their performance. Manufacturers are constantly looking for a method of reducing scales presents various advantages. This work aims to show the influence of folds fittings techniques during the downscaling of a multilayer composite structure notched or un-notched, requested static. A numerical study is conducted on the plate-shaped structures. The results confirm the interest of the similarity. Similarities of meaningful relationships appear to be subject to the reproduction of the same modes of deformation and crushing. The results show that there is no difference between "ply level" technique and technology "sub laminate" and the technique of "reducing neutral report."

Keywords: scale effects, behavior, multilayer composites, nicks, similarity.

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Wel-Doret Djonglibet [α], Tikri Bianzeubé [σ], Djeumako Bonaventure [ρ], Danwe Raidandi [Ѡ] & Guy Edgar Ntamack [¥]

Abstract- For many years, composite materials include automotive industries to improve their performance. Manufacturers are constantly looking for a method of reducing scales presents various advantages. This work aims to show the influence of folds fittings techniques during the downscaling of a multilayer composite structure notched or un-notched, requested static. A numerical study is conducted on the plate-shaped structures. The results confirm the interest of the similarity. Similarities of meaningful relationships appear to be subject to the reproduction of the same modes of deformation and crushing. The results show that there is no difference between "ply level" technique and technology "sub laminate" and the technique of "reducing neutral report."

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Nomenclature

E_i : Young's modulus in the longitudinal direction of the material,

ϑ_{ij} : Poisson coefficients in the corresponding plane,

G_{ij} : Shear modulus in the corresponding plane,

with:

NASA: National Aeronautics and Space Administration

UN: Un-Notch

FN: Four-Notch

HN: Half-Notch

SE: Stacking sequence

ES: Static test

β : Scale factor

I. Introduction

Automotive structures integrate the many years since the composite materials for increased performance [AGI01]. A continuing need to increase the capacity leads to develop technological prowess with these materials. The complexity results from various sources: The elementary components, which interact by associating on their respective characteristics; methods of manufacture and the complexity of the geometry, seen point create a significant history within the material as regards their behavior. Designers are constantly in search of new methodologies, experimental approaches and digital tools to facilitate the structural optimization tasks. But experimental studies handicaps and view digital in the automotive sector is the large size of structures and therefore adequate means of testing.

The main objective of this work is to analyze the influence of the dimensions of the behavior of multilayer structures to form plaque, notched and un-notched, carbon / epoxy for body applications, static compression solicited by the similarity of technical. Abaqus software has enabled us to certain assumptions to determine the reactions to the build level based on the number of interface, maximum efforts and energies absorbed by the structures according to slits.

II. Materials and Methods

a) *Materials*

Considering the results of laminated composites of elastic moduli (Table 1) of stacking sequence, carbon/epoxy for conducting our [YCH01] studies. The material is orthotropic. Technical elastic moduli are given in the table below.

Table 1: Composite techniques elasticity Study Modulus.

Modulus of elasticity	E_1 (MP_a)	E_2 (MP_a)	E_3 (MP_a)
Values	16700	16700	11000
Modulus of elasticity	ν_{23} (-)	ν_{12} (-)	ν_{13} (-)
Values	0.178	0.69	0.178
Modulus of elasticity	G_{23} (MP_a)	G_{13} (MP_a)	G_{12} (MP_a)
Values	3300	3300	2450

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i. *Presentation of test specimens and assumptions*

- Presentation of the Specimens

Consider three types of specimens and will be named according to the type of notch:

a. UN for UN-Notched, corresponding to the non-notched specimens. The size of notch is 0;
b. FN for Four-Notched, corresponding to test pieces with a small notch, notch size is 0.25 times the thickness;
c. HN for Half-Notched, corresponding to test pieces with a large gash. The size of notch is 0.5 times the thickness. These test pieces are shown in Figure 1.

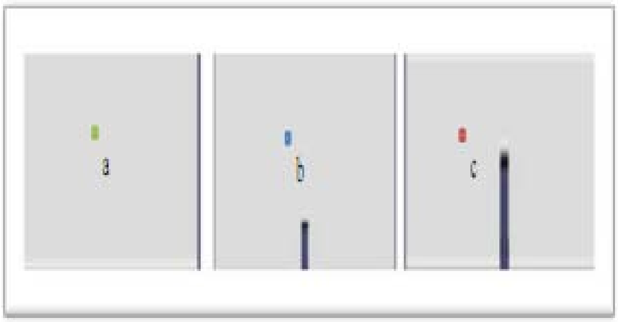

Fig. 1: Geometry of the specimens tested for the construction of a basic digital data studies.

The dimensions of its test pieces are given in Table2 below. Whose thicknesses are generally those used for the manufacture of composite structures for automotive bodies.

Table 2: Dimensions of test specimens.

Ladders	1/4	1/2	1
Length (mm)	50	100	200
Width (mm)	30	60	120
Thickness (mm)	2.4	4.8	9.6
Number of folds	4	8	16
Approximation of the mesh	0.75	1.5	3

- *Test Hypothesis*

a. The specimens are homogeneous, isotropic and homothetic.
b. The specimens undergo amplitude load 2.5 tons, dependent on the integration period of the elements imposed 30s at the right end and will be fitted to the left end.
c. The interactions between the layers and temperature effects will be negligible.

b) *Downscaling Methods*

This is the direct application some of Vaschy-Buckingham theorem. In our study, we will use the geometric similarity Cauchy coupled with reordering techniques ply notched and not notched plate structures form.

This technique is based on several assumptions:

a. The prototype and model are made of the same material;
b. The model is a copy of the prototype,
c. The number of Cauchy remains constant,

A factor called scale factor allows the passage of the prototype model. The table below (tab.3) summarizes the mechanical quantities depending on the model of Cauchy.

Table 3: Mechanical Quantities Cauchy [DDO03].

Variables	Prototype	Model
Shifting	δ	$\beta\delta$
linear dimension	L	βL
Stress	σ	σ
Strain	ε	ε
Energy/Work of a Force	W	$\beta^3 W$
Force	F	$\beta^2 F$

i. *Arrangement techniques ply Laminate composite structures*

The field of study of scale effects is very large, therefore, the literature is full of articles and theses on one or more parameters such as geometry, monitoring of cracking, fiber dimensions, in depending on the size of the specimens. The appearance of the initial cracks, because of damage to the laminated sheets due to the change in the number of pleats was investigated by Lavoie [DDO03]. The latter uses the reordering technique called folds "ply Level". There are two other techniques proposed in a report NASA by Jackson [DDO03], for work carried out on laminates. We will adapt these techniques presented by Jackson to our problem, particularly the "ply Level" and technology "sub laminate" and the technique of "reducing neutral report".

As a reminder, these similarities techniques involve reorganizing the folds for the passage between the prototype and model. There are two main techniques:

a. First, it was the "ply Level" (fig. a), which is to move from a stack to , the transition from n to 2n fold is by doubling each ply of the laminate. The importance of this similarity is characterized by the consistent scaling of the various moduli of the plan (tension-compression) and flexural modulus.
b. The second method called "Sub Laminate" (Fig. b) changes a Laminate stack to the same final as last, the increase is achieved in a balanced form here twice the initial sequence folds. This method allows better scaling plans modules except the flexural modulus.

Note that there are also two other possible techniques:

- The third technique (Fig. c) consists in obtaining from the prototype to reduce the thickness of plies by the reduction factor. This technique is the source of all searches because it is impossible to apply to manufacturing problems.
- The last way is to mirror the basic stack (fig. d).

The figure below (Fig.2) this reordering techniques folds [DDO03].

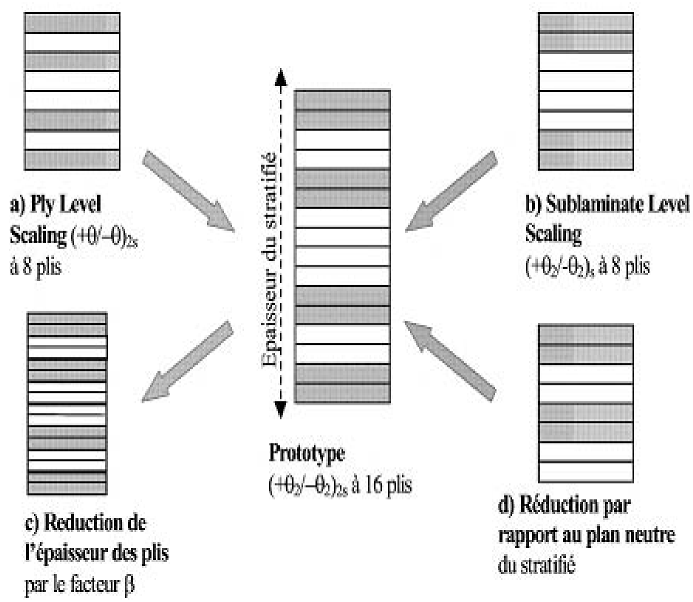

Fig. 2: Technics rearrangement the folds [DDO03].

ii. *Wide passage Method 1/4 scale 1/2 and 1/2 scales on scale 1.*

The method of crossing is one used by Dany Dormegnie [DDO03]. It consists:

- to move from a model 1/4, 4 ply and orientation three model stratifications 1/2, 8 ply, 2,4 and 6 interfaces, oriented respectively ,and et (fig. 3).
- to move from a model 1/2, 8 plies, interface 2, 4, 6 and respective guidance (+2/-2)S , and , to six stratification interface 2, 4, 6, 8 , 12, and 14 (fig. 4).

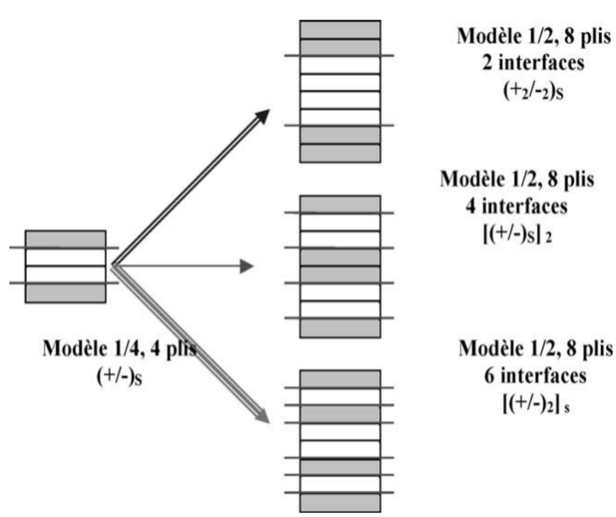

Fig. 3: Scale of Passage 1/4 to 1/2 scale.

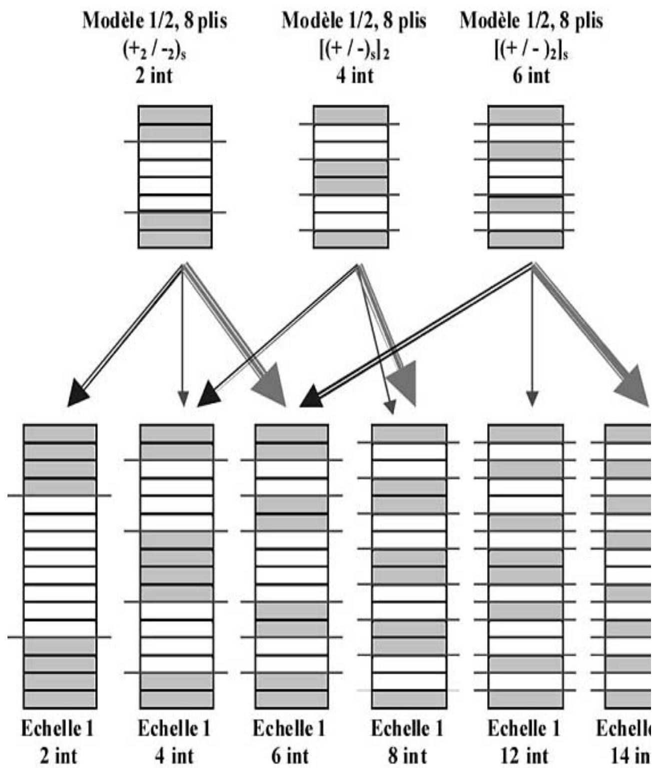

Fig. 4: Methods for determination the stacks of the 1/2 to 1 scale.

III. Results and Discussion

a) Results

The results were obtained through finite element method under the Abaqus software. This method was developed by L. Penazzi and al. and in 2003 and in 2010 by MIREN EGAÑA [LPE03, MEG10].

i. *Presentation of samples tested at the scale ¼*

The fig 5 below respectively show the Strain of the specimens UN, FN and HN at 1/4 scale. While figs 6 provide strain measurements of the specimens UN, FN and HN at 1 scale.

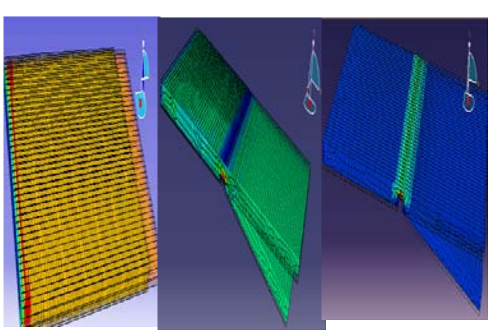

Fig. 5: Specimens UN, FN et HN tested at 1/4 scale [+45/-45]S

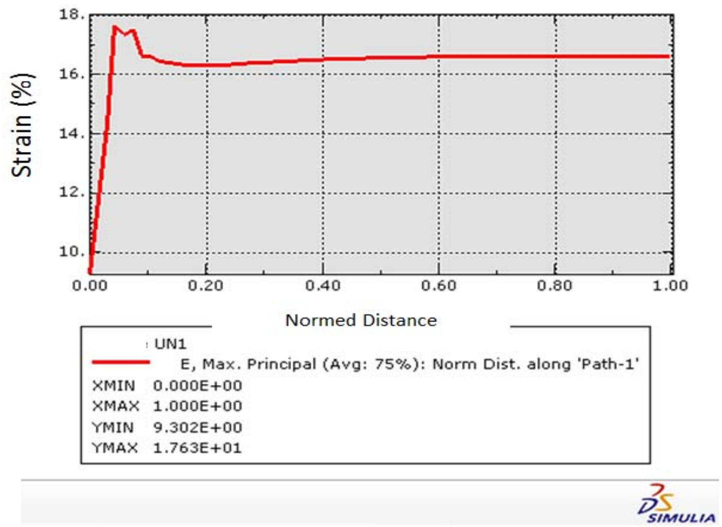

Fig. 6: Strain the prototypes UN1.

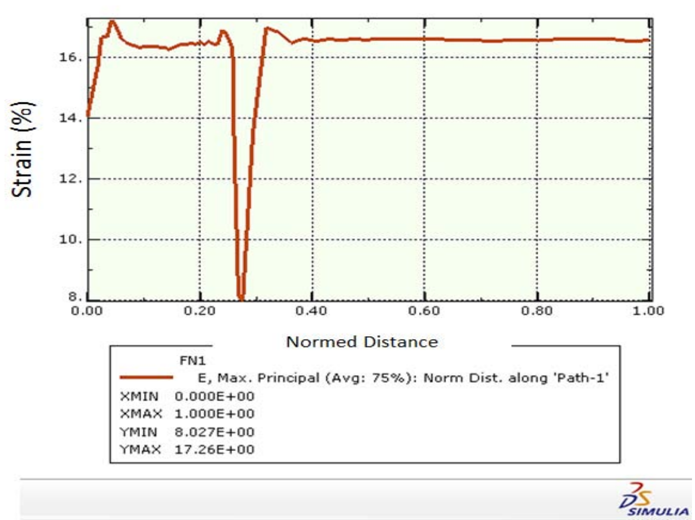

Fig. 7: Strain the Prototypes FN1.

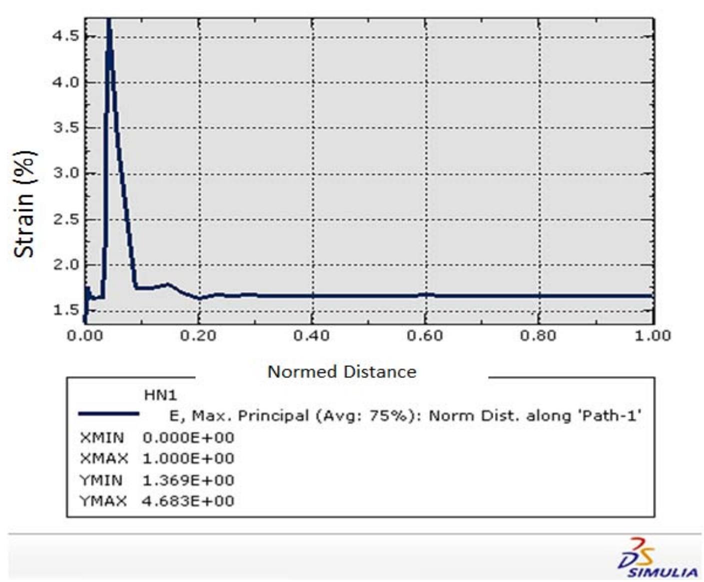

Fig. 8: Strain the Prototypes HN1

ii. *Comparison reactions underrun*

The above fig.7presents the results of the reactions at the recessed portion of the specimens study test. These results will be presented according to the type of taps and the number of interfaces in order to highlight the effect of tiller and the number of interfaces on the behavior of structures.

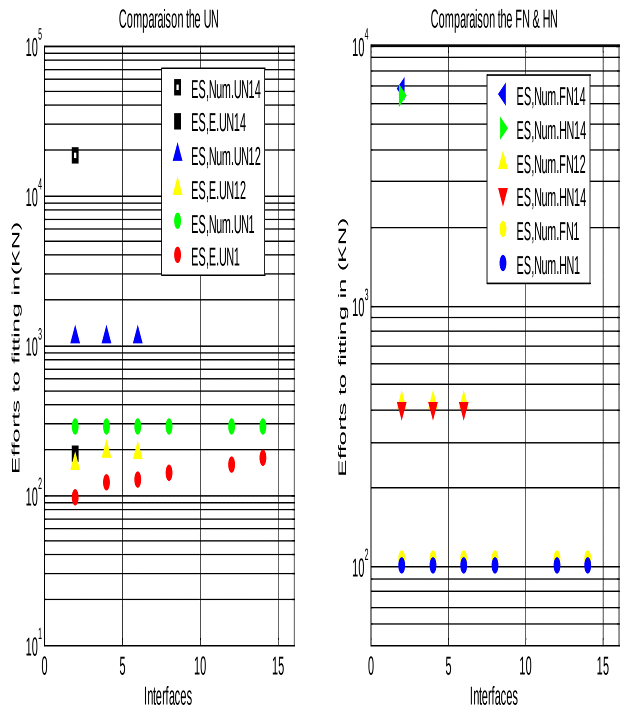

Fig. 9: Maximal responses in the recess as a function of notches and the number of interfaces

iii. *Comparison of Efforts*

The graphs below show the effort peaks in test tubes UN, FN and HN plate to scale 1/4, 1/2 and 1 depending on the notches.

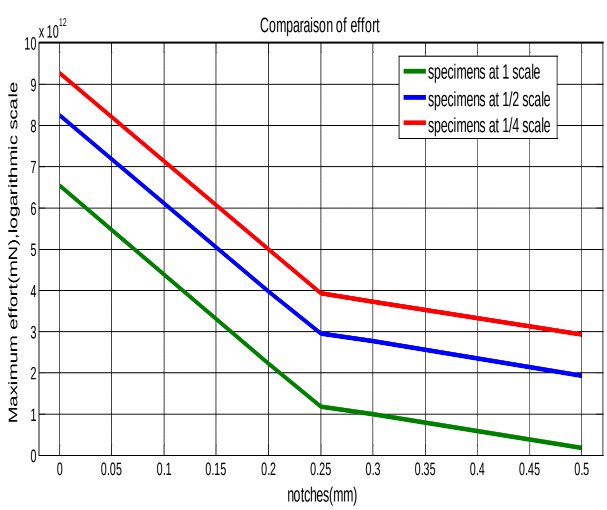

Fig.10: To maximize efforts in terms of cuts

iv. *Comparison of Energy*

The graphs below show the work effort of the specimens UN, FN and HN plate to 1/4, 1/2 and 1 scale depending on the notches.

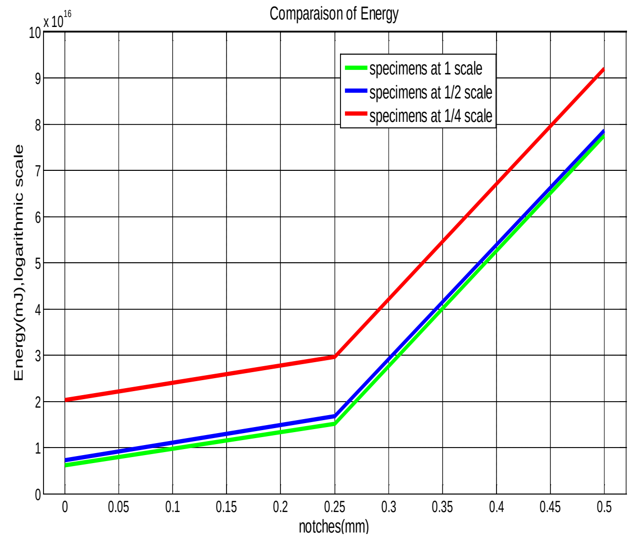

Fig.11: Energy absorbed depending notches

IV. Discussion

The fig. 6, fig. 7 and fig.8show that the deformations are delayed. UN14 the samples show growth of deformation around the recess. This change is certainly due to the existence of embedding reactions that oppose the compressive force. It decreases gradually between 0.020*L and 0.05*L. appears to be constant for values greater than 0.200*L. The peak of the deformation of 1.7630 to 2.500 mm and the minimum is 0. 9304, about 10mm in length. As for FN14 and HN14 samples tested the maximum deformations of 17,560 and 12.34 respectively. To compare the efforts and energies between different scales we use the following steps:

- The values for each stratification in the lower scale are determined from those of the scale 1 and the crushing.
- Efforts to embedding (or level of effort) are determined by the same method as before.
- The highest energies are calculated by the relationship. $W * \delta$.

With W: the peaks efforts and δ: the maximum displacement.

The Cauchy relations of the three parameters: the reactions to the installation, the peaks efforts and energies on one scale are compared to those of the lower scales. The solutions obtained depend on the dispersion of the fillers in the structure. Fig.9 shows that maximum efforts at embedding remain virtually constant for all number of interfaces between deferred orientations folds (vary little 1%). This confirms our first hypothesis static loading (imposed). We clearly observe that efforts to embedding are more important for all types of specimens of small dimensions. These efforts to bearings UN plated structures are more important than those structures in omega unlike crashed. This difference is from more to the fiber properties, the specimen geometry and boundary conditions. While for slotted structures, efforts bearing believe with sizes of notches. We cannot say that in this case there's notch effect. However it can be concluded that the plate's structures in carbon / epoxy more resistant to shocks than structures omega-E glass / epoxy and one has to do to a size effect. The maximum forces (fig.10) in the test specimens linearly uncross when the size of test specimens and the notch size become important. This confirms our last two assumptions of the size effect on the behavior of composite structures [BZP84, BZP04, and WWE39]. The specimens to 1 and 1/2 scale are less resistant to compression than the specimens in 1/4 scale [DDO03] because the presences of notches are obstacles to the uniform redistribution of efforts in test tubes and are considered of initial defects. The energy of curves in Fig.11 believes exponentially. These growths energy are mainly due to the presence of notch, the delamination and the friction between the pleats. There is a similarity in relation to all the parameters presented in scale 1 and 1/2.

V. Conclusions

This work highlights the scale effects on the behavior of multilayer composite structures in carbon / epoxy notched and un-notched. It shows that the plates 1/4 scale absorb a significant amount of energy that the scale plates 1/2 and 1. The results show that there is no difference in behavior between the technical "ply Level", the "sub Laminate" technique and the technique of "reducing neutral report". We can conclude that, for static compression uses the FN or HN plates are solicited.

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Manufacturing and Testing of Braking Material-Amc 3

By Shaik Himam Saheb & M. Naveen Kumar
ICFAI University

Abstract- Braking system is an integral part of automobile mechanism. for certain unique automobiles like go-kart systems, the braking system must be designed with accurate and material importance. this is done to keep in accordance with various parameters such as economy and weight of the automobiles etc. the braking systems have to provide enough force in order to decelerate by completely locking the wheels. the report concentrates on explaining the engineering aspects of designing a braking system and its material for go-kart. this report explains objectiveness, assumptions and calculations made in designing a go-kart braking system.

A comparative study for the braking system made of grey cast iron (i.e; conventional material), Ti-alloy, 7.5 wt% WC and 7.5wt% TiC reinforced Ti-composite and 20% SiC reinforced Al-Cu alloy (AMC1) and 30% SiC reinforced Al-Cu alloy (AMC2) was done. The purpose of this project was to analyze the test results and implement a better perspective for the installation of braking system in a Go-Kart automobile mechanism. The test parameters considered are compressive strength, coefficient of friction, wear rate, specific heat, specific gravity etc. which are believed to be the most important parameters for the operation of a braking system.

GJRE-A Classification: FOR Code: 091399

MANUFACTURINGANDTESTINGOFBRAKINGMATERIALAMC3

Strictly as per the compliance and regulations of:

Manufacturing and Testing of Braking Material-Amc 3

Shaik Himam Saheb [α] & M. Naveen Kumar [σ]

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I. Literature Review

Ding et al. (2000) have designed and manufactured a front brake rotor by semisolid stirring plus liquid forging process. Then the brake rotors are subjected to dynamometer test and the performance of the MMC brake rotor is compared with the conventional cast iron rotor. They have concluded that the MMC rotors have higher wear resistance, low temperature rise, high friction coefficient. Pai et al. (2001) have presented the low cost processing of MMCs, surface treatment of reinforcement, process parameters and the role of alloy additions with the special reference to the Al-graphite system, Al-silicon carbide, and Al-short fibers carbon systems. They have also highlighted the manufacturing of MMC components like piston rings, pistons, cylinder sleeve and connecting rods for light weight automotive applications. Pillai et al. (2001) in their investigation, they have concluded that the semisolid processing of aluminium composites have better properties like minimum interfacial reactions, uniform distribution of reinforcements and high percentage of reinforcement can be added with the matrix alloy. Degischer and Prader (2000) have presented the functions of thematic network in assessing the applications of metal matrix composite materials in all technical fields. They have also presented the role of the thematic network in sharing information on processing, testing, modeling, application and marketing of MMCs. Goni et al. (2000) have suggested that the high processing cost of MMCs, as the important barrier for using it in automotive applications. They have also suggested that the cost of MMC components can be reduced either by locally reinforcing the reinforcement or by reinforcing the MMC inserts in the required positions of the automotive components. Degischer et al. (2001) have presented the functions of thematic network in developing the processing and applications of MMCs. They have also presented the activities of the thematic network in sharing information on processing, testing, modeling, application and marketing of MMCs

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II. About Existing Braking System

Three major problems exist with this aluminum-composite rotor. First, because of the density difference between aluminum and SiC, segregation or inhomogeneous distribution of SiC particles during solidification cannot be avoided. Also, adding SiC particles in an aluminum matrix dramatically reduces the ductility of the material, resulting in low product liability. The third problem is a lack of a solid lubricant, such as graphite. The lack of graphite in the system results in low braking efficiency, adhesive wear, and galling. In a cast iron rotor, graphite is always present in the iron. As the break wears, the graphite is freed from the iron matrix to be used as a solid lubricant on the wear surface.

Apart from These problems there are no disadvantages of the existing braking system but we can further improve the efficiency and performance of the braking system of the automobile by making the new composition of AMC 3 material with composition of the Aluminium of 35% , copper of 40% and silicon carbide of 25% by manufacturing with stir casting technology and it can be proved by the a method of selection for any material ,it is named as a digital logic method.

a) *Experimentation Procedure of New Composition of Brake Material (AMC 3)*

Composition of the AMC 3 material are Aluminium of 35%, copper of 40% and silicon carbide of 25% The experimental arrangement has been

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assembled by the coupling gear-box motor and mild steel four blade stirrer used. The melting of the aluminium (40%) scraps and silicon carbide powder (SiC – 120 grit size) is carried out in the graphite crucible into the coal-fired furnace. First the scraps of aluminium were preheated for 3 to 4 hours at 450°C and SiC powder also heated with 900°C and both the preheated mixtures is then mechanically mixed with each other below their melting points.

This metal-matrix AMC3 is then poured into the graphite crucible and put in to the coal-fired furnace at 1000°C temperature. The furnace temperature was first increases above the composites completely melt the scraps of aluminium and copper and then cooled down just below the components temperature and keep it in a semi-solid state. At this stage the preheated SiC were added with manually mixed with each other. It is very difficult to mix by machine or stirrer when metal-matrix composites are in semi molten state with manual mixing taking place.

Figure 1: Melting of Alloys

When the manual mixing is complete then automatic stirring will carried out for ten minutes with normal 400 rpm of stirring rate The temperature rate of the coal-fired furnace should be controlled at 1000 ± 10°C in final mixing process. After complete the process the slurry has been taken into the sand mould within thirty seconds allow it to solidify. Tests should be taken of solidified samples like hardness and impact tests. This experiment should repeatedly conducted by taking the composition of the composite powder of SiC (25%), weight of aluminium scraps in grams plus weight in grams of SiC powder. Finally we prepared the six sample including rounded bars and square bars. These final samples are now ready for further testing processes of hardness test, impact strength test and microstructure examination.

III. Discussion

The major aim and objectives of this paper is to prepare aluminium, copper based silicon carbide particulate MMCs with an objective to develop a conventional low cost method of producing MMCs and to obtain homogenous dispersion of ceramic material. To achieve these objectives stir casting technique has been adopted. Pure Aluminium, copper and SiC has been chosen as matrix and reinforcement material respectively. These metal-matrixes are very popular, cheap and beneficial for the modern engineering fields. After getting the varying the composition AMC3 samples are ready for the testing. Further we will check the hardness test, impact strength test. A full factorial design for several readings for a given matrix of data would be treated using ANOVA (Analysis of Variance) based on the percentage of SiC around the prospective sample Our main target is to prepare a very hard metal-matrix sample which becomes very popular, cheap and beneficial for the modern engineering era.

1. Graph drawn between all materials compressive strength:

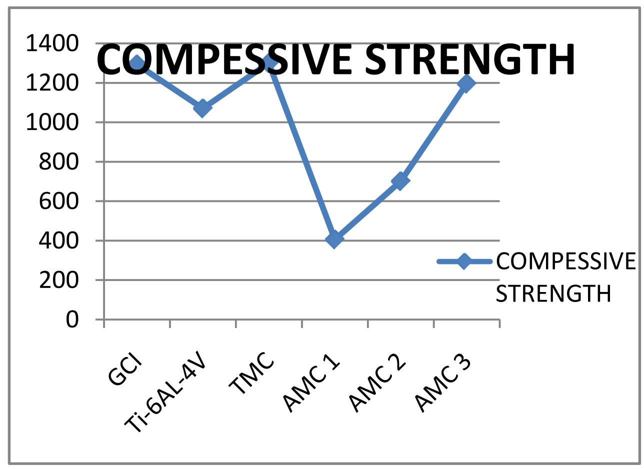
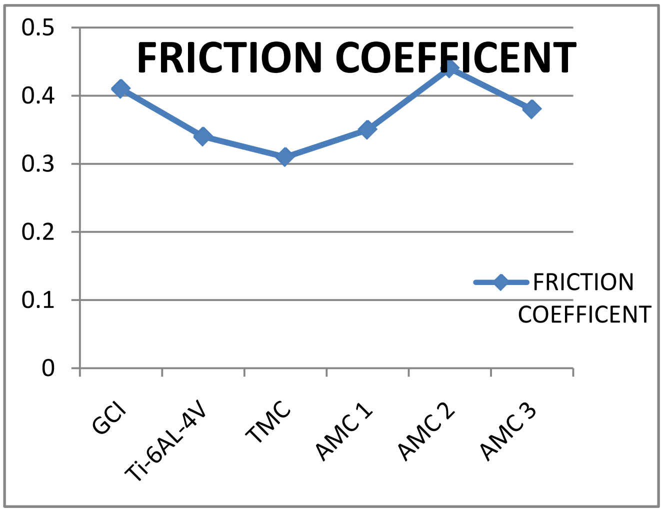


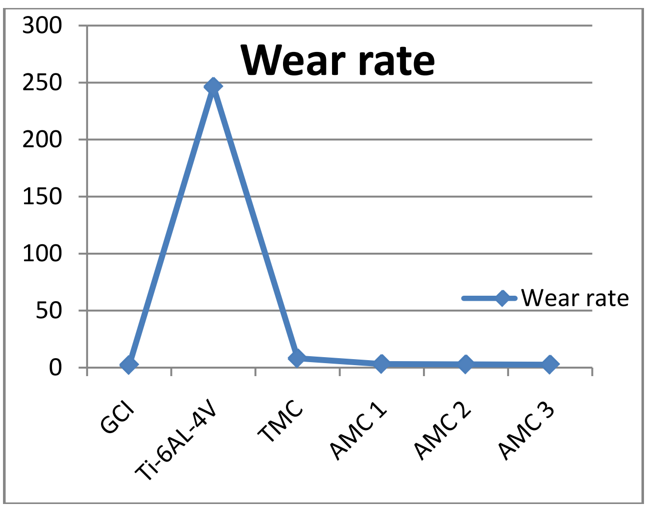
Figure 2: Wear Rate Test and Coefficient of Friction Tests

As this test requires a small piece of sample specimen and it fitted to the pin on disc machine and the tests are conducted with varying the load and speed. this machine also gives the friction coefficient factor as a output with the help of the disc which is fitted to it and it helps the machine to caliber the material surface property of coefficient of friction. We have tested our specimen with this machine and got the results of wear rate test and coefficient of friction tests.

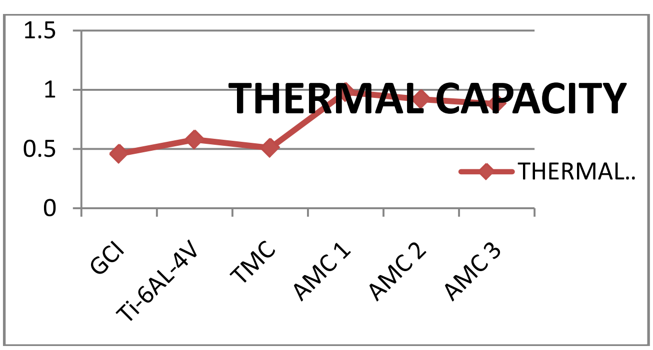
2. Graph drawn between all materials friction coefficient:



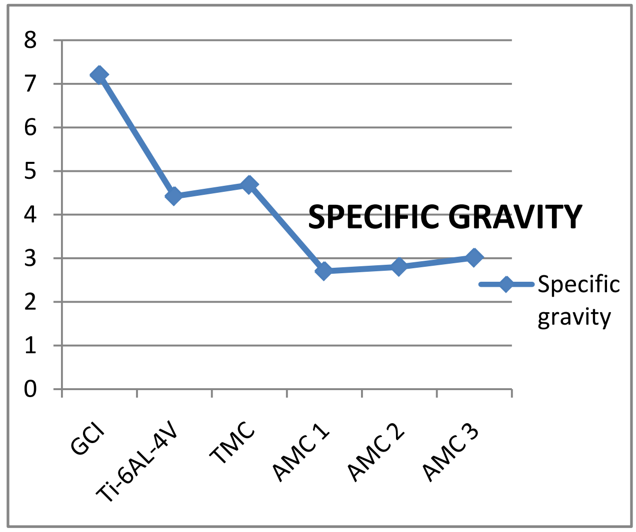
3. Graph drawn between all materials wear rate:



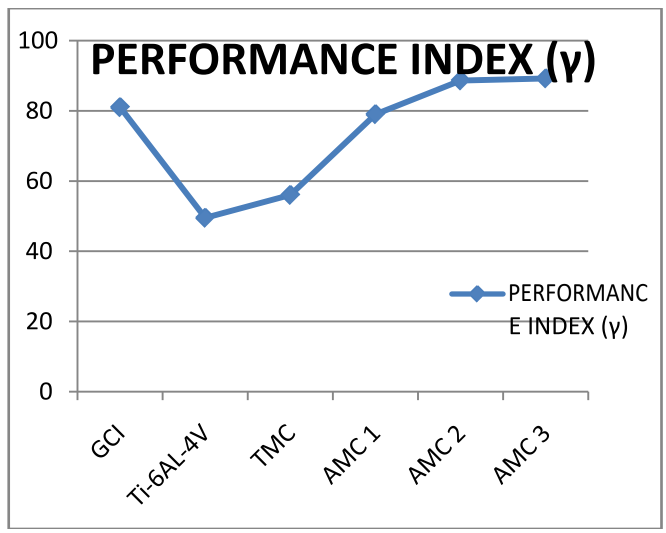
4. Graph drawn between all materials specific heat (or) thermal capacity:



5. Graph drawn between all materials specific gravity:



6. Graph Showing The Performance Index (Γ) Of All Materials:



IV. Results

All the tests carried with all the precautions without having parallax error and the values are rounded values but not the exact or accurate values as we know that mechanical machines will be taken the values on a average.

Therefore the parameters of our AMC 3 material are as follows:

1. Compressive strength : 1195 MPa
2. Friction coefficient factor : 0.38
3. Wear rate factor : 2.67 ($*10^{-6}$ mm^3/N/m)
4. Specific heat(C_p) : 0.88 (KJ/Kg-k)
5. Specific gravity : 3.01 (Mg/m^3)

V. Conclusion

The material selection methods for the design and application of automotive brake disc are developed. Functions properties of the brake discs or rotors were considered for the initial screening of the candidate materials using Ashby's materials selection chart. The digital logic method showed the highest performance index for AMC 3 material and identified as an optimum material among the candidate materials for brake disc. In the digital logic method, the friction coefficient and density were considered twice for determining the performance index and the cost of unit property. This procedure could have overemphasized their effects on the final selection. This could be justifiable in this case as higher friction coefficient and lower density are advantageous from the technical and economical point of view for this type of application Several confronts must be surmounted in order to strengthen the engineering usage of AMC 3 or AMC's such as processing methodology, influence of reinforcement, effect of reinforcement on the mechanical properties and its corresponding applications. The major conclusions derived from the prior works are:

- SiC reinforced with Al and Cu MMCs have higher wear resistance than other MMCs.
- SiC reinforced with Al and Cu MMCs are suitable materials for brake materials as they have high wear resistance.
- The wear resistance of SiC reinforced with Al, Cu MMC is higher than other reinforced MMC.
- AMC 3 exhibits high thermal conductivity and a low thermal expansion co-efficient.
- The wear resistance and compressive strength of AMC 3 is high.

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On the Squeezing Flow of Nanofluid Through a Porous Medium With Slip Boundary and Magnetic Field: A Comparative Study of Three Approximate Analytical Methods

By M. G. Sobamowo, L. O. Jayesimi & M. A. Whaeed
University of Lagos

Abstract- This paper presents a comparative study of approximate analytical methods is carried out using differential transformation, homotopy perturbation and variation parameter methods for the analysis of a steady two-dimensional axisymmetric flow of nanofluid under the influence of a uniform transverse magnetic field with slip boundary condition. Also, parametric studies are carried out to investigate the effects of fluid properties, magnetic field and slip parameters on the squeezing flow. It is revealed from the results that the velocity of the fluid increases with increase in the magnetic parameter under the influence of slip condition while an opposite trend is recorded during no-slip condition. Also, the velocity of the fluid increases as the slip parameter increases but it decreases with increase in the magnetic field parameter and Reynold number under the no-slip condition.

Keywords: nanofluid; squeezing flow; slip boundary; differential transformation method; homotopy perturbation method; variation parameter method.

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M. G. Sobamowo [α], L. O. Jayesimi [σ] & M. A. Whaeed [ρ]

Abstract- This paper presents a comparative study of approximate analytical methods is carried out using differential transformation, homotopy perturbation and variation parameter methods for the analysis of a steady two-dimensional axisymmetric flow of nanofluid under the influence of a uniform transverse magnetic field with slip boundary condition. Also, parametric studies are carried out to investigate the effects of fluid properties, magnetic field and slip parameters on the squeezing flow. It is revealed from the results that the velocity of the fluid increases with increase in the magnetic parameter under the influence of slip condition while an opposite trend is recorded during no-slip condition. Also, the velocity of the fluid increases as the slip parameter increases but it decreases with increase in the magnetic field parameter and Reynold number under the no-slip condition. The approximate analytical solutions are verified by comparing the results of the approximate analytical methods with the numerical method using Runge-Kutta coupled with shooting method. Although, very good agreements are established between the results, the results of variation parameter method provide excellent agreement with the results of numerical method.

Keywords: nanofluid; squeezing flow; slip boundary; differential transformation method; homotopy perturbation method; variation parameter method.

I. Introduction

The flow of nanofluid in a channel, between two contracting or expanding plates and also, over a stretching sheet have aroused research interests in recent times. Among the recent studies, the analysis of squeezing flow of nanofluid or viscous fluid between two parallel plates have increased tremendously due to its various industrial and biological applications. After the pioneer work on squeezing flow by Stefan [1], there have been improved works on the flow phenomena. However, the earlier studies [1-3] on squeezing flow were based on Reynolds equation. Jackson [4] and Usha and Sridhar an [5] pointed out the insufficiencies of the Reynolds equation for some cases of flow situations. Consequently, there have been several attempts and renewed research interests by different researchers to properly analyze and understand the squeezing flows using different analytical and numerical methods [5-26]. Also, effects of magnetic field, flow characteristics and fluid properties on the squeezing flow have been widely investigated under no slip conditions [27–42]. However, in many cases of fluid and flow problems such as polymeric liquids, thin film problems, nanofluids, rarefied fluid problems, fluids containing concentrated suspensions, and flow on multiple interfaces, slip condition prevails at the boundary of the flow process.

Therefore, Navier [43] proposed the general boundary condition which demonstrates the fluid slip at the surface. Such consideration of slip condition in the flow analysis of fluids is of great importance especially when fluids with elastic character are under consideration [44]. In a past study on slip effects on flow conditions of fluids, Ebaid [45] investigated the effects of magnetic field and wall slip conditions on the peristaltic transport in an asymmetric channel. The influence of slip on the peristaltic motion of third-order fluid in asymmetric channel was analyzed by Hayat *et al.* [46]. Also, Hayat and Abelman [47] presented a study on the effects of slip condition on the rotating flow of a third grade fluid in a nonporous medium. Abelman *et al.* [48] extended their work to a porous medium and obtained the numerical solutions for the steady magnetodrodynamics flow of a third grade fluid in a rotating frame. The past efforts in analyzing the squeezing flow problems have been largely based on the applications of various numerical and approximate analytical methods such as differential transformation method (DTM), Adomian Decomposition Method (ADM), homotopy analysis method (HAM), optimal homotopy asymptotic method (OHPM), variational iteration method (VIM). Moreover, most of the studies are based on viscous fluids. To the best of the authors' knowledge, a

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study on squeezing flow of nanofluid under the influences of magnetic field and slip boundary conditions using variation parameter method (VPM) has not been carried out in literature. Also, a comparative study of the three approximate analytical methods (differential transformation, homotopy perturbation and variation parameter methods) has presented in this paper has not been analyzed in past work. Therefore, in the paper, a comparative study of approximate analytical methods is carried out using differential transformation, homotopy perturbation and variation parameter method for the analysis of a steady two-dimensional axisymmetric flow of nanofluid under the influence of a uniform transverse magnetic field with slip boundary condition. The analytical solutions are used to investigate the effects of fluid properties, magnetic field and slip parameters on the squeezing flow.

II. Problem Formulation

Consider a squeezing flow of nanofluid squeezed between two parallel plates which are at distance $2h$ apart and they approach each other with slowly with a constant velocity under in the presence of a magnetic field as shown in Fig. 1. Assuming that the fluid is incompressible, the flow is laminar and isothermal, the governing equations of motion for the quasi steady flow of the nanofluid are given as:

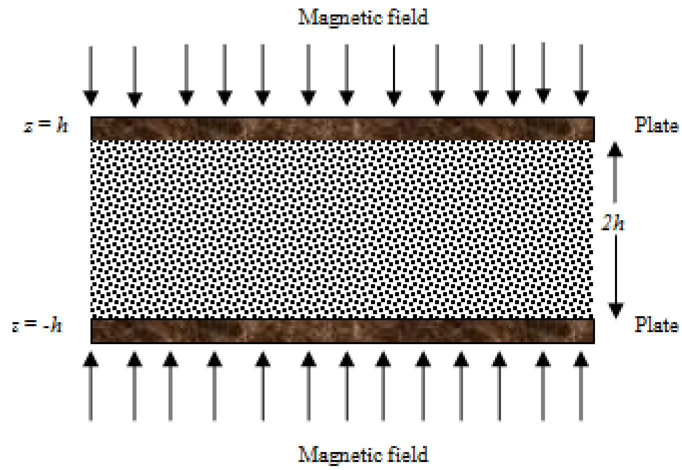

Fig. 1: Model of the MHD squeezing flow of nanofluid between two parallel paltes separated by distance 2h

Assume that the flow is quasi steady, and the Navier-Stokes equations governing such flow when inertial terms are retained are: The equations of motion governing the flow are:

$$\nabla.\tilde{v}=0 \tag{1}$$

$$\left[\rho_f(1-\phi)+\rho_s\phi\right]\left[\frac{\partial\tilde{v}}{\partial t}+(\nabla.\tilde{v})\tilde{v}\right]=\left[\rho_f(1-\phi)+\rho_s\phi\right]f-\nabla.p+\left\{\frac{\mu_f}{(1-\phi)^{2.5}}\left(\nabla^2-\frac{1}{k}\right)-\sigma B_0^2\right\}\tilde{v} \tag{2}$$

Neglecting the body force, the continuity and Navier-Stokes' equation for the problem is given as

$$\nabla.\tilde{v}=0 \tag{3}$$

$$-\left[\rho_f(1-\phi)+\rho_s\phi\right](\tilde{v}\times\tilde{w})+\tilde{\nabla}\left(\frac{\left[\rho_f(1-\phi)+\rho_s\phi\right]}{2}|\tilde{v}|^2+p\right)=\frac{\mu_f}{(1-\phi)^{2.5}}\left(\tilde{\nabla}\times\tilde{w}-\frac{1}{k}\tilde{v}\right)-\sigma B_0^2\tilde{v} \tag{4}$$

Introducing the stream function $\psi(r,z)$, vorticity function $\Omega(r,z)$ and a generalized pressure for the cylindrical coordinate system as follows:

$$u=\frac{1}{r}\frac{\partial\psi}{\partial z},\quad v=-\frac{1}{r}\frac{\partial\psi}{\partial r},\quad \Omega(r,z)=-\frac{1}{r}\lambda^2\psi,\quad p=\frac{\left[\rho_f(1-\phi)+\rho_s\phi\right]}{2}\left(u^2+v^2\right) \tag{5}$$

Eliminating the pressure term from Eqs. (3) and (4), we have

$$\left[\rho_f(1-\phi)+\rho_s\phi\right]\left[\frac{\partial\left(\psi,\lambda^2\psi/r^2\right)}{\partial(r,z)}\right]=-\frac{1}{r}\frac{\mu_f}{(1-\phi)^{2.5}}\lambda^4\psi+\frac{1}{r}\left(\frac{\mu_f}{k(1-\phi)^{2.5}}+\sigma B_0^2\right)\frac{\partial^2\psi}{\partial z^2} \tag{6}$$

where

$$\lambda^2 = \frac{\partial^2}{\partial r^2} - \frac{1}{r}\frac{\partial}{\partial r} + \frac{\partial^2}{\partial z^2} \tag{7}$$

The boundary conditions are given as

$$\begin{aligned} &z = 0, v = 0 \ \ and \ \frac{\partial v}{\partial z} = 0 \\ &z = H, \ \ v = -V_w \ \ and \ \frac{\partial v}{\partial z} = \beta v \end{aligned} \tag{8}$$

Applying a transformation $\psi(r,z) = r^2 f(z)$, the compatibility Eq. (6) reduces to Eq. (9) as

$$f^{iv}(z) - \left(\frac{1}{k} + \frac{\sigma B_0^2 (1-\phi)^{2.5}}{\mu_f}\right) f^{"}(z) + \frac{2\left[\rho_f(1-\phi) + \rho_s\phi\right](1-\phi)^{2.5}}{\mu_f} f(z) f^{"'}(z) = 0 \tag{9}$$

And the slip boundary conditions as

$$\begin{aligned} &f(0) = 0, \ \ f^{"}(0) = 0, \\ &f(h) = \frac{v}{2}, \ \ f^{'}(h) = \gamma f^{"}(h) \end{aligned} \tag{10}$$

Using the following dimensionless parameters in Eq. (11)

$$F^* = \frac{f}{v/2}, \ z^* = \frac{z}{h}, \ R = \frac{\rho_f H v}{\mu_f}, \ G = h\sqrt{\left(\frac{1}{k} + \frac{\sigma B_0^2}{\mu_{nf}}\right)} = \sqrt{\left(Da + m^2\right)}. \tag{11}$$

The dimensionless form of Eq. (9) is given as

$$F^{(iv)}(z) + R\left((1-\phi) + \phi\frac{\rho_s}{\rho_f}\right)(1-\phi)^{2.5} F(z) F^{"'}(z) - G^2 F^{"}(z) = 0 \tag{12}$$

And the dimensionless boundary conditions in Eq. (10) as

$$\begin{aligned} &F(0) = 0, \quad F''(0) = 0 \\ &F(1) = 1, \quad F'(1) = \gamma F''(1) \end{aligned} \tag{13}$$

where the asterisk, * has been omitted in Eqs. (12) and Eq. (13) for the sake of conveniences.

III. Approximate Analytical Methods Of Solution: Differential Transform Method

The differential transform method has widely been used to solve both singular and non-singular perturbed boundary values problems. It gives analytical solution to differential or integral solutions in the form of a polynomial by transforming each term in the differential equation or integral into a recursive form or relation of the equation which follows an iterative procedure for obtaining analytical series solutions of differential equation.

The basic definitions of the method is as follows:

If $u(x)$ is analytic in the domain T, then it will be differentiated continuously with respect to space x.

$$\frac{d^p u(x)}{dx^p} = \varphi(x, p) \quad \text{for} \quad \text{all } x \in T \tag{17}$$

For $x = x_i$, then $\varphi(x,p) = \varphi(x_i, p)$, where p belongs to the set of non-negative integers, denoted as the p-domain. Therefore Eq. (17) can be rewritten as

$$U(p) = \varphi(x_i, p) = \left[\frac{d^p u(x)}{dt^p}\right]_{x=x_i} \tag{18}$$

where U_p is called the spectrum of $u(x)$ at $x = x_i$

If $u(x)$ can be expressed by Taylor's series, the $u(x)$ can be represented as

$$u(x)=\sum_{p}^{\infty}\left[\frac{(x-x_i)^p}{p!}\right]U(p) \qquad (19)$$

where Eq. (19) is called the inverse of $U(k)$ using the symbol 'D' denoting the differential transformation process and combining Eq. (18) and Eq. (19), it is obtained that

$$u(x)=\sum_{p=0}^{\infty}\left[\frac{(x-x_i)^p}{p!}\right]U(p)=D^{-1}U(p) \qquad (20)$$

a) *Operational properties of differential transformation method*

If $u(x)$ *and* $v(x)$ are two independent functions with space (x) where $U(p)$ and $V(p)$ are the transformed function corresponding to $u(x)$ and $v(x)$, then it can be shown from the fundamental mathematics operations performed by differential transformation that.

i. If $z(x)=u(x)\pm v(x)$, then $Z(p)=U(p)\pm V(p)$

ii. If $z(x)=\alpha u(x)$, then $Z(p)=\alpha U(p)$

iii. If $z(x)=\dfrac{d^n u(x)}{dx^n}$, then $Z(p)=(p+1)(p+2)(p+3)...(p+n)U(p+n)$

iv. If $z(x)=u(x)v(x)$, then $Z(p)=\sum_{r=0}^{p}V(r)U(p-r)$

v. If $z(x)=u^m(x)$, then $Z(p)=\sum_{r=0}^{p}U^{m-1}(r)U(p-r)$

vi. If $z(x)=u(x)v(x)$, then $Z(p)=\sum_{r=0}^{p}(r+1)V(r+1)U(p-r)$

vii. If $z(x)=x^m\dfrac{d^n u(x)}{dx^n}$, then $Z(p)=\sum_{l=0}^{p}\delta(l-m-1)(p-l+1)(p-l+2)(p-l+3)...(p-l+n)U(p-l+n)$

viii. If $z(x)=\dfrac{d\ u(x)}{dx}\dfrac{d^3u(x))}{dx^3}$, then $Z(p)=\sum_{l=0}^{p}U(p-l)(l+1)(l+2)(l+3)U(l+3)$

ix. If $z(x)=\dfrac{d\ u(x)}{dx}\dfrac{d^2u(x))}{dx^2}$, then $Z(p)=\sum_{=}^{p}{}^{0}(p-l+1)U(p-l+1)(l+1)(l+2)U(l+2)$

x. If $z(x)=\left(\dfrac{du(x)}{dx}\right)^2$ then $Z(p)=\sum_{l=0}^{p}(p-l+1)U(p-l+1)(l+1)U(l+1)$

xi. If $z(x)=u\dfrac{du(x)}{dx}$, then $Z(p)=\sum_{l=0}^{p}U(p-l)(l+1)U(l+1)$

If $z(x)=\left[\dfrac{d^2u(x))}{dx^2}\right]^2$, then $Z(p)=\sum_{l=0}^{p}(p-l+1)(p-l+2)U(p-l+2)(l+1)(l+2)U(l+2)$

IV. Application of the Differential Transform Method to the Present Problem

The differential transform of (15) and (16) is given by

$$\begin{aligned}&(k+1)(k+2)(k+3)(k+4)F[k+4]\\ &R\left((1-\phi)+\phi\frac{\rho_s}{\rho_f}\right)(1-\phi)^{2.5}\left(\sum_{l=0}^{k}(k-l+3)(k-l+2)(k-l+1)F[l]F[k-l+3]\right)\\ &-G\left((k+1)(k+2)F[k+2]\right)+=0\end{aligned} \tag{21}$$

With differential transformed boundary conditions

$$\begin{aligned}&\tilde{F}[0]=0,\ \tilde{F}[1]=a,\ \tilde{F}[2]=0,\ \tilde{F}[3]=b,\\ &\sum(k+1)F[k+1]=\gamma\sum(k+1)(k+2)F[k+2]\end{aligned} \tag{22}$$

Where *a* and *b* are unknowns to be determined later using the boundary conditions of Eq. (16b). Using Eqs. (21) and (22), the value of $\tilde{F}(i), i=1,2,3,4,5,\ldots 19,20.$ are

$$\tilde{F}[4]=0$$

$$\tilde{F}[5]=\frac{1}{20}\left(bG^2-abR\left((1-\phi)+\phi\frac{\rho_s}{\rho_f}\right)(1-\phi)^{2.5}\right)$$

$$\tilde{F}[6]=0$$

$$\tilde{F}[7]=\frac{1}{840}\left(\begin{aligned}&bG^4-6b^2R\left((1-\phi)+\phi\frac{\rho_s}{\rho_f}\right)(1-\phi)^{2.5}-4abG^2R\left((1-\phi)+\phi\frac{\rho_s}{\rho_f}\right)(1-\phi)^{2.5}\\ &+3a^2b\left(R\left((1-\phi)+\phi\frac{\rho_s}{\rho_f}\right)(1-\phi)^{2.5}\right)^2\end{aligned}\right)$$

$$\tilde{F}[8]=0$$

$$\tilde{F}[9]=\frac{1}{60480}\left\{\begin{aligned}&bG^6-72b^2G^2R\left((1-\phi)+\phi\frac{\rho_s}{\rho_f}\right)(1-\phi)^{2.5}-9abG^4R\left((1-\phi)+\phi\frac{\rho_s}{\rho_f}\right)(1-\phi)^{2.5}\\ &+96ab^2\left(R\left((1-\phi)+\phi\frac{\rho_s}{\rho_f}\right)(1-\phi)^{2.5}\right)^2+23a^2bG^2\left(R\left((1-\phi)+\phi\frac{\rho_s}{\rho_f}\right)(1-\phi)^{2.5}\right)^2\\ &-15a^3bR\left(\left((1-\phi)+\phi\frac{\rho_s}{\rho_f}\right)(1-\phi)^{2.5}\right)^3\end{aligned}\right\}$$

$$\tilde{F}[10]=0$$

$$\tilde{F}[11]=\frac{1}{6652800}\left\{\begin{array}{l} bG^8-414b^2G^4R\left((1-\phi)+\phi\frac{\rho_s}{\rho_f}\right)(1-\phi)^{2.5}-16abG^6R\left((1-\phi)+\phi\frac{\rho_s}{\rho_f}\right)(1-\phi)^{2.5} \\ +1296b^3\left(R\left((1-\phi)+\phi\frac{\rho_s}{\rho_f}\right)(1-\phi)^{2.5}\right)^2+1716ab^2G\left(R\left((1-\phi)+\phi\frac{\rho_s}{\rho_f}\right)(1-\phi)^{2.5}\right)^2+ \\ 86a^2bG^4\left(R\left((1-\phi)+\phi\frac{\rho_s}{\rho_f}\right)(1-\phi)^{2.5}\right)^2-1446a^2b^2\left(R\left((1-\phi)+\phi\frac{\rho_s}{\rho_f}\right)(1-\phi)^{2.5}\right)^3 \\ -176a^3bG^2\left(R\left((1-\phi)+\phi\frac{\rho_s}{\rho_f}\right)(1-\phi)^{2.5}\right)^3+105a^4b\left(R\left((1-\phi)+\phi\frac{\rho_s}{\rho_f}\right)(1-\phi)^{2.5}\right)^4 \end{array}\right\}$$

And so on

According to the definition of DTM, the solution is

$$F(z)=\tilde{F}[0]+z\tilde{F}[1]+z^2\tilde{F}[2]+z^3\tilde{F}[3]+z^4\tilde{F}[4]+z^5\tilde{F}[5]+z^6\tilde{F}[6]+z^7\tilde{F}[7]$$
$$+z^8\tilde{F}[8]+z^9\tilde{F}[9]+z^{10}\tilde{F}[10]+z^{11}\tilde{F}[11]+\ldots \quad (23)$$

a) The basic idea of homotopy perturbation method

In order to establish the basic idea behind homotopy perturbation method, consider a system of nonlinear differential equations given as

$$A(U)-f(r)=0, \quad r\in\Omega \quad (24)$$

with the boundary conditions

$$B\left(u,\frac{\partial u}{\partial\eta}\right)=0, \qquad r\in\Gamma \quad (25)$$

where A is a general differential operator, B is a boundary operator, $f(r)$ a known analytical function and Γ is the boundary of the domain Ω The operator A can be divided into two parts, which are L and N, where L is a linear operator, N is a non-linear operator. Eq.(24) can be therefore rewritten as follows

$$L(u)+N(u)-f(r)=0 \quad (26)$$

By the homotopy technique, a homotopy $U(r,p):\Omega\times[0,1]\to R$ can be constructed, which satisfies

$$H(U,p)=(1-p)\left[L(U)-L(U_o)\right]+p\left[A(U)-f(r)\right]=0, \quad p\in[0,1] \quad (27)$$

Or

$$H(U,p)=L(U)-L(U_o)+p\,L(U_o)+p\left[N(U)-f(r)\right]=0 \quad (28)$$

In the above Eqs. (27) and (28), $p\in[0,1]$ is an embedding parameter, u_o is an initial approximation of equation of Eq.(24), which satisfies the boundary conditions.

Also, from Eqs. (27) and (28), we will have

$$H(U,0)=L(U)-L(U_o)=0 \quad (29)$$

$$H(U,0)=A(U)-f(r)=0 \quad (30)$$

The changing process of p from zero to unity is just that of $U(r,p)$ from $u_o(r)$ to $u(r)$. This is referred to homotopy in topology. Using the embedding parameter p as a small parameter, the solution of Eqs. (27) and (28) can be assumed to be written as a power series in p as given in Eq. (28)

$$U=U_o+pU_1+p^2U_2+\ldots \quad (31)$$

It should be pointed out that of all the values of p between 0 and 1, $p=1$ produces the best result.

Therefore, setting $p=1$, results in the approximation solution of Eq.(24)

$$u=\lim_{p\to1}U=U_o+U_1+U_2+\ldots \quad (32)$$

The basic idea expressed above is a combination of homotopy and perturbation method.

Hence, the method is called homotopy perturbation method (HPM), which has eliminated the limitations of the traditional perturbation methods. On the other hand, this technique can have full advantages of the traditional perturbation techniques. The series Eq.(32) is convergent for most cases.

b) Application of the homotopy perturbation method to the present problem

According to homotopy perturbation method (HPM), one can construct an homotopy for Eq. (16) as

$$H(z,p)=(1-p)\tilde{F}^{(iv)}+p\left[\tilde{F}^{(iv)}+RR\left((1-\phi)+\phi\frac{\rho_s}{\rho_f}\right)(1-\phi)^{2.5}\tilde{F}\tilde{F}'''-G^2\tilde{F}''\right] \tag{33}$$

Using the embedding parameter *p* as a small parameter, the solution of Eqs. (16) can be assumed to be written as a power series in p as given in Eq. (33)

$$\tilde{F}=\tilde{F}_o+p\tilde{F}_1+p^2\tilde{F}_2+p^3\tilde{F}_3+\ldots \tag{34}$$

On substituting Eqs. (34) and into Eq.(33) and expanding the equation and collecting all terms with the same order of p together, the resulting equation appears in form of polynomial in p. On equating each coefficient of the resulting polynomial in p to zero, we arrived at a set of differential equations and the corresponding boundary conditions as

$$p^0:\quad \tilde{F}_0^{(iv)}=0,$$

$$\tilde{F}_0(0)=0,\ \ \tilde{F}_0''(0)=0,\ \ \tilde{F}_0(1)=1,\ \ \tilde{F}_0'(1)=\gamma\tilde{F}_0''(1) \tag{35}$$

$$p^1:\quad \tilde{F}_1^{(iv)}-G^2\tilde{F}_0''+R\left((1-\phi)+\phi\frac{\rho_s}{\rho_f}\right)(1-\phi)^{2.5}\tilde{F}_0\tilde{F}_0'''=0, \tag{36}$$

$$\tilde{F}_1(0)=0,\ \ \tilde{F}_1''(0)=0,\ \ \tilde{F}_1(1)=0,\ \ \tilde{F}_1'(1)=\gamma\tilde{F}_1''(1)$$

$$p^2:\quad \tilde{F}_2^{(iv)}-G^2\tilde{F}_1''+R\left((1-\phi)+\phi\frac{\rho_s}{\rho_f}\right)(1-\phi)^{2.5}\tilde{F}_1\tilde{F}_0'''+R\left((1-\phi)+\phi\frac{\rho_s}{\rho_f}\right)(1-\phi)^{2.5}\tilde{F}_0\tilde{F}_1'''=0, \tag{37}$$

$$\tilde{F}_2(0)=0,\ \ \tilde{F}_2''(0)=0,\ \ \tilde{F}_2(1)=0,\ \ \tilde{F}_2'(1)=\gamma\tilde{F}_2''(1)$$

$$p^3:\tilde{F}_3^{(iv)}-G^2\tilde{F}_2''+R\left((1-\phi)+\phi\frac{\rho_s}{\rho_f}\right)(1-\phi)^{2.5}\tilde{F}_2\tilde{F}_0'''+R\left((1-\phi)+\phi\frac{\rho_s}{\rho_f}\right)(1-\phi)^{2.5}\tilde{F}_1\tilde{F}_1'''$$
$$+R\left((1-\phi)+\phi\frac{\rho_s}{\rho_f}\right)(1-\phi)^{2.5}\tilde{F}_0\tilde{F}_2'''=0, \tag{38}$$

$$\tilde{F}_3(0)=0,\ \ \tilde{F}_3''(0)=0,\tilde{F}_3(1)=0,\ \ \tilde{F}_3'(1)=\gamma\tilde{F}_3''(1)$$

$$p^4:\quad \tilde{F}_4^{(iv)}-G^2\tilde{F}_3''+R\left((1-\phi)+\phi\frac{\rho_s}{\rho_f}\right)(1-\phi)^{2.5}\tilde{F}_3\tilde{F}_0'''+R\left((1-\phi)+\phi\frac{\rho_s}{\rho_f}\right)(1-\phi)^{2.5}\tilde{F}_3\tilde{F}_0'''$$
$$1+R\left((\ -\phi)+1\phi\frac{\rho_s}{\rho_f}\right)(\ -\phi)^{2.5}\tilde{F}_2\tilde{F}_1'''+R\left((\ -\phi)+1\phi\frac{\rho_s}{\rho_f}\right)(\ -\phi)^{2.5}\tilde{F}_1\tilde{F}_2'''$$
$$1+R\left((\ -\phi)+1\phi\frac{\rho_s}{\rho_f}\right)(\ -\phi)^{2.5}\tilde{F}_0\tilde{F}_3'''=0 \tag{39}$$

$$\tilde{F}_4(0)=0,\;\; \tilde{F}_4''(0)=0, \tilde{F}_4(1)=0,\;\; \tilde{F}_4'(1)=\gamma\tilde{F}_4''(1)$$

$$\begin{aligned}p^5:\;\; &\tilde{F}_5^{(iv)}-G^2\tilde{F}_4''+R\left((1-\phi)+\phi\frac{\rho_s}{\rho_f}\right)(1-\phi)^{2.5}\tilde{F}_3\tilde{F}_0'''+R\left((1-\phi)+\phi\frac{\rho_s}{\rho_f}\right)(1-\phi)^{2.5}\tilde{F}_4\tilde{F}_0'''\\ &+R\left((1-\phi)+\phi\frac{\rho_s}{\rho_f}\right)(1-\phi)^{2.5}\tilde{F}_3\tilde{F}_1'''+R\left((1-\phi)+\phi\frac{\rho_s}{\rho_f}\right)(1-\phi)^{2.5}\tilde{F}_2\tilde{F}_2'''\\ &+R\left((1-\phi)+\phi\frac{\rho_s}{\rho_f}\right)(1-\phi)^{2.5}\tilde{F}_1\tilde{F}_3'''+R\left((1-\phi)+\phi\frac{\rho_s}{\rho_f}\right)(1-\phi)^{2.5}\tilde{F}_0\tilde{F}_4'''=0\end{aligned}\tag{40}$$

$$\tilde{F}_5(0)=0,\;\; \tilde{F}_5''(0)=0, \tilde{F}_5(1)=0,\;\; \tilde{F}_5'(1)=\gamma\tilde{F}_5''(1)$$

On solving the above Eqs. (35-40), we arrived at

$$\tilde{F}_0(z)=\frac{3(2\gamma-1)z+z^3}{2(3\gamma-1)}\tag{41}$$

$$\begin{aligned}\tilde{F}_1(z)=&\left\{\frac{3G^2}{3\gamma-1}+\frac{9R\left((1-\phi)+\phi\frac{\rho_s}{\rho_f}\right)(1-\phi)^{2.5}(2\gamma-1)}{2(3\gamma-1)^2}\right\}z^5+\frac{3R\left((1-\phi)+\phi\frac{\rho_s}{\rho_f}\right)(1-\phi)^{2.5}}{2(3\gamma-1)^2}z^7\\ &-\frac{1}{3(2\gamma+1)}\left\{\begin{array}{l}\gamma\left(\frac{60G^2}{3\gamma-1}+\frac{90R\left((1-\phi)+\phi\frac{\rho_s}{\rho_f}\right)(1-\phi)^{2.5}(2\gamma-1)}{(3\gamma-1)^2}+\frac{63R\left((1-\phi)+\phi\frac{\rho_s}{\rho_f}\right)(1-\phi)^{2.5}}{(3\gamma-1)^2}\right)\\ -\left(\frac{12G^2}{3\gamma-1}+\frac{3\;R6\left((1-\phi)+\phi\frac{\rho_s}{\rho_f}\right)(1-\phi)^{2.5}(2\gamma-1)}{(3\gamma-1)^2}+\frac{9R\left((1-\phi)+\phi\frac{\rho_s}{\rho_f}\right)(1-\phi)^{2.5}}{(3\gamma-1)^2}\right)\end{array}\right\}z^3\\ &+\frac{1}{3(2\gamma+1)}\left\{\begin{array}{l}\gamma\left(\frac{60G^2}{3\gamma-1}+\frac{90R\left((1-\phi)+\phi\frac{\rho_s}{\rho_f}\right)(1-\phi)^{2.5}(2\gamma-1)}{(3\gamma-1)^2}+\frac{63R\left((1-\phi)+\phi\frac{\rho_s}{\rho_f}\right)(1-\phi)^{2.5}}{(3\gamma-1)^2}\right)\\ -\left(\frac{12G^2}{3\gamma-1}+\frac{3\;R6\left((1-\phi)+\phi\frac{\rho_s}{\rho_f}\right)(1-\phi)^{2.5}(2\gamma-1)}{(3\gamma-1)^2}+\frac{9R\left((1-\phi)+\phi\frac{\rho_s}{\rho_f}\right)(1-\phi)^{2.5}}{2(3\gamma-1)^2}\right)\end{array}\right\}z\end{aligned}$$

$$-\left\{\frac{3G^2}{3\gamma-1}+\frac{9R\left((1-\phi)+\phi\frac{\rho_s}{\rho_f}\right)(1-\phi)^{2.5}(2\gamma-1)}{(3\gamma-1)^2}+\frac{3R\left((1-\phi)+\phi\frac{\rho_s}{\rho_f}\right)(1-\phi)^{2.5}}{2(3\gamma-1)^2}\right\}z \tag{42}$$

In the same manner, the expressions for $\tilde{F}_2(z),\tilde{F}_3(z),\tilde{F}_4(z),\tilde{F}_5(z),\tilde{F}_6(z)...$ were obtained. However, they are too large expressions to be included in this paper.

Setting $p=1$, results in the approximation solution of Eq. (24)

$$F(z)=\lim_{p\to 1}\tilde{F}(z)=\tilde{F}_o(z)+\tilde{F}_1(z)+\tilde{F}_2(z)+\tilde{F}_3(z)+\tilde{F}_4(z)+... \tag{43}$$

c) The Procedure of Variation Parameter Method

The basic concept of VPM for solving differential equations is as follows: The general nonlinear equation is in the operator form

$$Lf(\eta)+Rf(\eta)+Nf(\eta)=g \tag{44}$$

The linear terms are decomposed into *L* + *R*, with *L* taken as the highest order derivative which is easily invertible and R as the remainder of the linear operator of order less than *L*. where *g* is the system input or the source term and *u* is the system output, *Nu* represents the nonlinear terms.

The VPM provides the general iterative scheme for Eq. (45) as:

$$f_{n+1}(\eta)=f_0(\eta)+\int_0^{\eta}\lambda(\eta,\xi)\left(-Rf_n(\xi)-Nf_n(\xi)-g(\xi)\right)d\xi \tag{45}$$

where the initial approximation $f_0(\eta)$ is given by

$$f_0(\eta)=\sum_{i=0}^{m}\frac{k_i f^i(0)}{i!} \tag{46}$$

m is the order of the given differential equation, k_i s are the unknown constants that can be determined by initial/boundary conditions and $\lambda(\eta,\xi)$ is the multiplier that reduces the order of the integration and can be determined with the help of Wronskian technique.

$$\lambda(\eta,\xi)=\sum_{i}^{m}\frac{(-1)^{i-1}\xi^{i-1}\eta^{m-1}}{(i-1)!(m-i)!}=\frac{(\eta-\xi)^{m-1}}{(m-1)!} \tag{47}$$

From the above, one can easily obtain the expressions of the multiplier for $Lf(\eta)=f^n(\eta)$

$$n=1,\quad \lambda(\eta,\xi)=1$$

$$n=2,\quad \lambda(\eta,\xi)=\eta-\xi$$

$$n=3,\quad \lambda(\eta,\xi)=\frac{\eta^2}{2!}-\eta\xi+\frac{\xi^2}{2!}$$

$$n=4,\quad \lambda(\eta,\xi)=\frac{\eta^3}{3!}-\frac{\eta^2\xi}{2!}+\frac{\eta\xi^2}{2!}-\frac{\xi^3}{3!}$$

$$n=5,\quad \lambda(\eta,\xi)=\frac{\eta^4}{4!}-\frac{\eta^3\xi}{3!}+\frac{\eta^2\xi^2}{2\cdot 2!}-\frac{\eta\xi^3}{3!}+\frac{\xi^4}{4!}$$

$$n=6,\quad \lambda(\eta,\xi)=\frac{\eta^5}{5!}-\frac{\eta^4\xi}{4!}+\frac{\eta^3\xi^2}{2\cdot 3!}-\frac{\eta^2\xi^3}{2\cdot 3!}+\frac{\eta\xi^4}{4!}-\frac{\xi^5}{5!}$$

$$n=7,\quad \lambda(\eta,\xi)=\frac{\eta^6}{6!}-\frac{\eta^5\xi}{5!}+\frac{\eta^4\xi^2}{2\cdot 4!}-\frac{\eta^3\xi^3}{6\cdot 3!}+\frac{15\eta^2\xi^4}{2\cdot 4!}-\frac{\eta\xi^5}{5!}+\frac{\xi^6}{6!}$$

$$n=8,\quad \lambda(\eta,\xi)=\frac{\eta^7}{7!}-\frac{\eta^6\xi}{6!}+\frac{\eta^5\xi^2}{2\cdot5!}-\frac{\eta^4\xi^3}{6\cdot4!}+\frac{\eta^3\xi^4}{6\cdot4!}-\frac{\eta^2\xi^5}{2\cdot5!}+\frac{\eta\xi^6}{6!}-\frac{\xi^7}{7!}$$

$$n=9,\quad \lambda(\eta,\xi)=\frac{\eta^8}{8!}-\frac{\eta^7\xi}{7!}+\frac{\eta^6\xi^2}{2\cdot6!}-\frac{\eta^5\xi^3}{6!}+\frac{\eta^4\xi^4}{24\cdot4!}-\frac{\eta^3\xi^5}{6!}+\frac{\eta^2\xi^6}{2\cdot6!}-\frac{\eta\xi^7}{7!}+\frac{\xi^8}{8!}$$

$$n=10,\quad \lambda(\eta,\xi)=\frac{\eta^9}{9!}-\frac{\eta^8\xi}{8!}+\frac{\eta^7\xi^2}{2\cdot7!}-\frac{\eta^6\xi^3}{36\cdot5!}+\frac{\eta^5\xi^4}{24\cdot5!}-\frac{\eta^4\xi^5}{24\cdot5!}+\frac{\eta^3\xi^6}{36\cdot5!}-\frac{\eta^2\xi^7}{2\cdot7!}+\frac{\eta\xi^8}{8!}-\frac{\xi^9}{9!}$$

Consequently, an exact solution can be obtained when n approaches infinity.
Using the standard procedure of VPM as stated above, one can write the solution of Eq. (15) as

$$F_{n+1}(z)=k_1+k_2z+k_3\frac{z^2}{2}+k_4\frac{z^3}{6}$$
$$-\int_0^z\left(\frac{z^3}{3!}+\frac{z^2\xi}{2!}+\frac{z\xi^2}{2!}+\frac{\xi^3}{3!}\right)\left[R\left((1-\phi)+\phi\frac{\rho_s}{\rho_f}\right)(1-\phi)^{2.5}F_n(\xi)F_n'''(\xi)-G^2F_n''(\xi)\right]d\xi \tag{48}$$

Here, k_1, k_2, k_3, *and* k_4 are constants obtained by taking the highest order linear term of Eq. (15) and integrating it four times to get the final form of the scheme.

The above equation can also be written as

$$F_{n+1}(z)=F(0)+F'(0)z+F''(0)\frac{z^2}{2}+F'''(0)\frac{z^3}{6}$$
$$-\int_0^z\left(\frac{z^3}{3!}+\frac{z^2\xi}{2!}+\frac{z\xi^2}{2!}+\frac{\xi^3}{3!}\right)\left[R\left((1-\phi)+\phi\frac{\rho_s}{\rho_f}\right)(1-\phi)^{2.5}F_n(\xi)F_n'''(\xi)-G^2F_n''(\xi)\right]d\xi \tag{49}$$

From the boundary conditions in Eq. (16)

$$F(0)=0,\quad F''(0)=0$$

Using the above statement and inserting the boundary conditions of Eq. (16) into Eq. (49), we have

$$F_{n+1}(z)=k_1z+\frac{k_2z^3}{6}$$
$$-\int_0^\eta\left(\frac{z^3}{3!}+\frac{z^2\xi}{2!}+\frac{z\xi^2}{2!}+\frac{\xi^3}{3!}\right)\left[R\left((1-\phi)+\phi\frac{\rho_s}{\rho_f}\right)(1-\phi)^{2.5}F_n(\xi)F_n'''(\xi)-G^2F_n''(\xi)\right]d\xi \tag{50}$$

From the iterative scheme, it can easily be shown that the series solution is given as

$$F_0(z)=k_1z+\frac{k_2z^3}{6} \tag{51}$$

Global Journal of Researches in Engineering (A) Volume XVII Issue VI Version I Year 2017

$$F_1(z)=k_1z+\frac{k_2z^3}{6}-\frac{k_1k_2R\left((1-\phi)+\phi\frac{\rho_s}{\rho_f}\right)(1-\phi)^{2.5}z^5}{120}+\frac{G^2k_2z^5}{120}-\frac{R\left((1-\phi)+\phi\frac{\rho_s}{\rho_f}\right)(1-\phi)^{2.5}k_2^2z^7}{5040} \tag{52}$$

$$\begin{aligned}F_2(z)={}&k_1z+\frac{k_2z^3}{6}+\frac{k_1k_2Rz^5}{120}+\frac{R\left((1-\phi)+\phi\frac{\rho_s}{\rho_f}\right)(1-\phi)^{2.5}k_1^2k_2z^7}{1680}-\frac{R\left((1-\phi)+\phi\frac{\rho_s}{\rho_f}\right)(1-\phi)^{2.5}k_2^2z^7}{5040}\\&-\frac{R\left((1-\phi)+\phi\frac{\rho_s}{\rho_f}\right)(1-\phi)^{2.5}k_1k_2G^2z^7}{1260}+\frac{R\left((1-\phi)+\phi\frac{\rho_s}{\rho_f}\right)(1-\phi)^{2.5}k_2^2k_1z^9}{22680}\\&-\frac{R\left((1-\phi)+\phi\frac{\rho_s}{\rho_f}\right)(1-\phi)^{2.5}k_2^2G^2z^9}{30240}+\frac{\left(R\left((1-\phi)+\phi\frac{\rho_s}{\rho_f}\right)(1-\phi)^{2.5}\right)^2k_2^3z^{11}}{1108800}\\&-\frac{\left(R\left((1-\phi)+\phi\frac{\rho_s}{\rho_f}\right)(1-\phi)^{2.5}\right)^3k_2^2k_1^2z^{11}}{1900800}-\frac{R\left((1-\phi)+\phi\frac{\rho_s}{\rho_f}\right)(1-\phi)^{2.5}k_2^2G^4z^{11}}{1900800}\\&-\frac{\left(R\left((1-\phi)+\phi\frac{\rho_s}{\rho_f}\right)(1-\phi)^{2.5}\right)^3k_1k_2^3z^{13}}{38438400}+\frac{\left(R\left((1-\phi)+\phi\frac{\rho_s}{\rho_f}\right)(1-\phi)^{2.5}\right)^2k_2^3G^2z^{13}}{38438400}\\&-\frac{\left(R\left((1-\phi)+\phi\frac{\rho_s}{\rho_f}\right)(1-\phi)^{2.5}\right)^3k_2^4z^{15}}{396249600}\end{aligned} \tag{53}$$

Similarly, the other iterations $F\ z$ $F\ z$ $F\ z$ F $F\ z$ $F\ z$ are obtained. Therefore,

$$\begin{aligned}F(z)=F_2(z)={}&k_1z+\frac{k_2z^3}{6}+\frac{k_1k_2Rz^5}{120}+\frac{R\left((1-\phi)+\phi\frac{\rho_s}{\rho_f}\right)(1-\phi)^{2.5}k_1^2k_2z^7}{1680}-\frac{R\left((1-\phi)+\phi\frac{\rho_s}{\rho_f}\right)(1-\phi)^{2.5}k_2^2z^7}{5040}\\&-\frac{R\left((1-\phi)+\phi\frac{\rho_s}{\rho_f}\right)(1-\phi)^{2.5}k_1k_2G^2z^7}{1260}+\frac{R\left((1-\phi)+\phi\frac{\rho_s}{\rho_f}\right)(1-\phi)^{2.5}k_2^2k_1z^9}{22680}\end{aligned}$$

$$-\frac{R\left((1-\phi)+\phi\frac{\rho_s}{\rho_f}\right)(1-\phi)^{2.5}k_2^2G^2z^9}{30240}+\frac{\left(R\left((1-\phi)+\phi\frac{\rho_s}{\rho_f}\right)(1-\phi)^{2.5}\right)^2k_2^3z^{11}}{1108800}$$
$$-\frac{\left(R\left((1-\phi)+\phi\frac{\rho_s}{\rho_f}\right)(1-\phi)^{2.5}\right)^3k_2^2k_1^2z^{11}}{1900800}-\frac{R\left((1-\phi)+\phi\frac{\rho_s}{\rho_f}\right)(1-\phi)^{2.5}k_2^2G^4z^{11}}{1900800}$$
$$-\frac{\left(R\left((1-\phi)+\phi\frac{\rho_s}{\rho_f}\right)(1-\phi)^{2.5}\right)^3k_1k_2^3z^{13}}{38438400}+\frac{\left(R\left((1-\phi)+\phi\frac{\rho_s}{\rho_f}\right)(1-\phi)^{2.5}\right)^2k_2^3G^2z^{13}}{38438400}$$
$$-\frac{\left(R\left((1-\phi)+\phi\frac{\rho_s}{\rho_f}\right)(1-\phi)^{2.5}\right)^3k_2^4z^{15}}{396249600}+\ldots \tag{54}$$

where the constants k_1 and k_2 are determined using the boundary conditions in Eq. (16) i.e.

$$F(1)=1,\quad F'(1)=\gamma F''(1)$$

The equations are solved for the corresponding values of k_1 and k_2 for the different values of γ.

V. Results and Discussion

The above analyses show the applications of three approximate analytical methods of differential transformation, homotopy perturbation and variation of parameters methods for the analysis of a steady two-dimensional axisymmetric flow of an incompressible viscous fluid under the influence of a uniform transverse magnetic field with slip boundary condition. Using VPM and DTM, closed form series solutions are obtained as they provide excellent approximations to the solution of the non-linear equation with higher accuracy than HPM. Also, the VPM and DTM shows to more convenient for engineering calculations compared to HPM as they appear more appealing than the HPM. However, higher accuracy and high rate of convergence was recorded in VPM than DTM as shown the table, the solution of VPM is used to carry out the parametric study shown in Figs. 2-7.

Table: Comparison of Results

	F(z)			
z	NM	VPM	DTM	HPM
0.00	0.000000	0.000000	0.000000	0.000000
0.10	0.075739	0.075739	0.075739	0.075738
0.20	0.152935	0.152935	0.152935	0.152935
0.30	0.233046	0.233046	0.233046	0.233045
0.40	0.317540	0.317540	0.317540	0.317540
0.50	0.407893	0.407893	0.407893	0.407892
0.60	0.505591	0.505591	0.505591	0.505592
0.70	0.612134	0.612134	0.612134	0.612134
0.80	0.729034	0.729034	0.729034	0.729035
0.90	0.857813	0.857813	0.857813	0.857813
1.00	1.000000	1.000000	1.000000	1.000000

Although, analytically, the VPM and DTM are somehow easier and straight-forward as compared to HPM, there is no search for Wronskian multiplier (as carried out in VPM) or the rigour of developing recursive relations or differential transforms coupled with the search for included unknown parameter that will satisfy second the boundary condition lead to additional computational cost in the generation of the solution to the problem using DTM. This drawback is not only peculiar to VPM and DTM, other approximate analytical methods such as HAM, ADM, VIM, DJM, TAM also required additional computational cost and time for the determination of included unknown parameter that will satisfy second the boundary condition. Also, the VPM and DTM have their own operational restrictions that severely narrow there functioning domains as they are limited to small domain. Using VPM or DTM for large or infinite domain is accompanied with either the application of before-treatment techniques such as domain transformation techniques, domain truncation techniques and conversion of the boundary value problems to initial value problems or the use of after-treatment techniques such as Pade-approximants, basis functions, cosine after-treatment technique, sine after-treatment technique and domain decomposition technique. This is because VPM and DTM were initially established for initial value problems. Amending the methods to boundary value problems especially for large or infinite domains boundary value problems leads to the inclusion of unknown parameters (that will satisfy second the boundary condition) in the solution. This drawback in the other approximation analytical methods is not experienced in HPM as such tasks of before- and after-treatment techniques might not necessarily be required in HPM. This is because HPM is easily applied to the boundary value problems without any included unknown parameter in the solution as found in VPM and DTM.

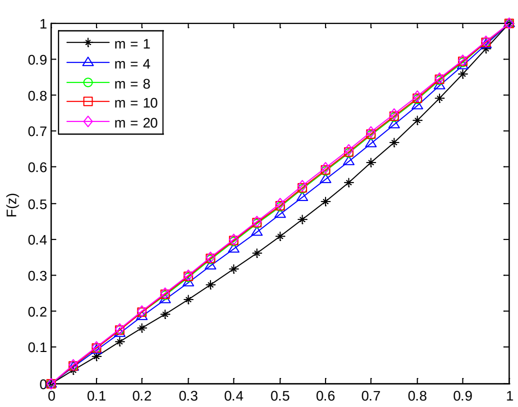

Figure 2: Effects of magnetic parameter on the flow of the fluid under the influence of slip condition behavior

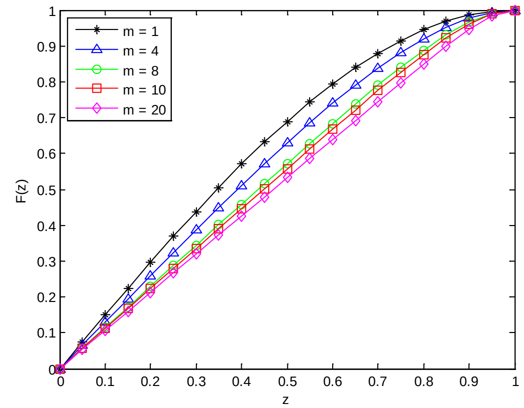

Figure 3: Effects of magnetic field parameter on the flow behavior of the fluid for no-slip condition

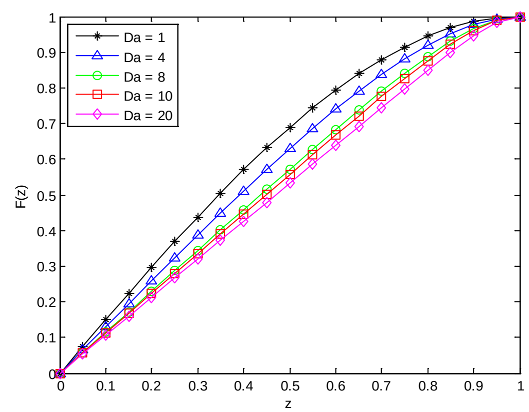

Figure 4: Effects of porous parameter on the flow behavior of the fluid under the influence of slip condition

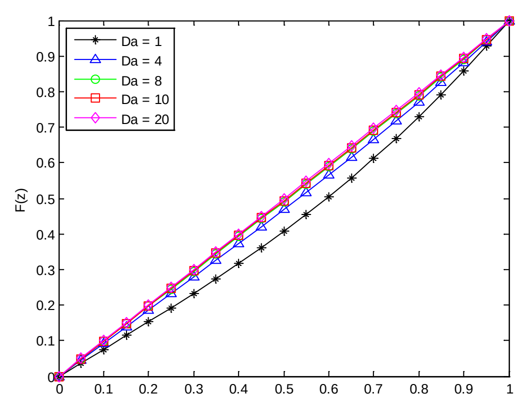

Figure 5: Effects of porous field parameter on the flow behavior of the fluid for no-slip condition

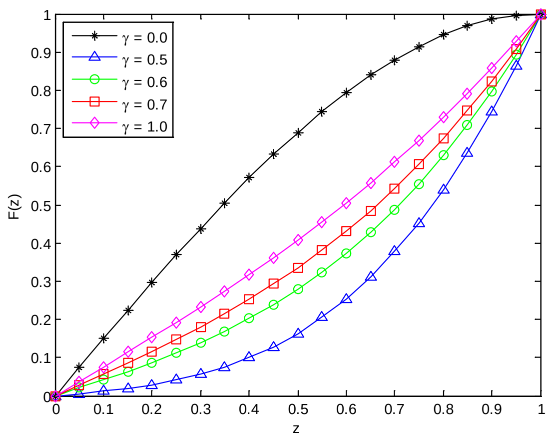

Figure 6: Effects of slip parameter on the flow behavior of the fluid

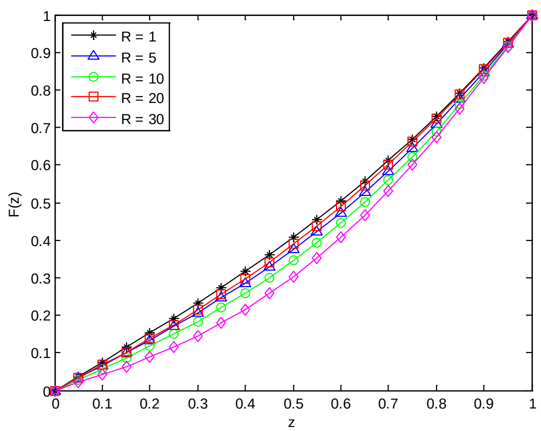

Figure 7: Effects of Reynolds number on the flow behavior of the fluid under the influence of slip condition

In order to get an insight into the problem, the effects of pertinent flow, magnetic field and slip parameters on the velocity profile of the fluid are investigated. Fig. 2 and 4 shows the effects of magnetic field and porous parameter on the velocity of the fluid under the influence of slip condition, while Fig. 3 and 5 depicts the influence of the porous and magnetic on the velocity of the fluid under no-slip condition. It could be inferred from the figures that the velocity of the fluid increases with increase in the porous-magnetic parameter under slip condition while an opposite trend was recorded during no-slip condition as the velocity of the fluid decreases with increase in the porous-magnetic parameter under the no slip condition. Fig. 6 shows the influence of the slip parameter γ on the fluid velocity. By increasing γ, it is observed that the velocity of the fluid increases. Fig. 7 presents the effects of Reynold's number on the velocity of the fluid. It is observed from the figure that by increasing the value R, the velocity of the fluid decreases.

VI. Conclusion

In this work, a comparative study of three approximate analytical methods have been carried out for the analysis of two-dimensional axisymmetric flow of an incompressible viscous fluid through porous medium under the influence of a uniform transverse magnetic field with slip boundary condition. From the analysis, it is established that VPM give higher accurate results than DTM and HPM with faster rate of convergence. Also, from the parametric study, it was established from the results that, the velocity of the fluid increases with increase in the porous-magnetic parameter under slip condition while the velocity of the fluid decreases with increase in the porous-magnetic parameter under no slip condition. By increasing the slip parameter, the velocity of the fluid increases, and the fluid velocity decreases as the Reynolds number increases. The approximate analytical solutions have been verified by comparing the results of the approximate analytical method with the numerical method using Runge-Kutta coupled with shooting method

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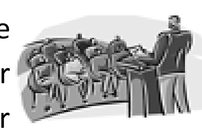

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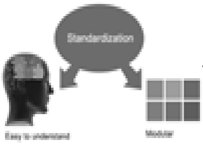

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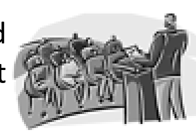

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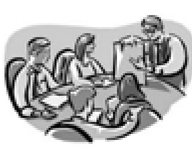

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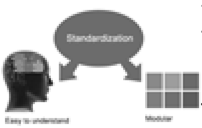

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Complete support for both authors and co-author is provided.

4. MANUSCRIPT'S CATEGORY

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Original research paper: Such papers are reports of high-level significant original research work.

Review papers: These are concise, significant but helpful and decisive topics for young researchers.

Research articles: These are handled with small investigation and applications

Research letters: The letters are small and concise comments on previously published matters.

5.STRUCTURE AND FORMAT OF MANUSCRIPT

The recommended size of original research paper is less than seven thousand words, review papers fewer than seven thousands words also.Preparation of research paper or how to write research paper, are major hurdle, while writing manuscript. The research articles and research letters should be fewer than three thousand words, the structure original research paper; sometime review paper should be as follows:

Papers: These are reports of significant research (typically less than 7000 words equivalent, including tables, figures, references), and comprise:

(a)Title should be relevant and commensurate with the theme of the paper.

(b) A brief Summary, "Abstract" (less than 150 words) containing the major results and conclusions.

(c) Up to ten keywords, that precisely identifies the paper's subject, purpose, and focus.

(d) An Introduction, giving necessary background excluding subheadings; objectives must be clearly declared.

(e) Resources and techniques with sufficient complete experimental details (wherever possible by reference) to permit repetition; sources of information must be given and numerical methods must be specified by reference, unless non-standard.

(f) Results should be presented concisely, by well-designed tables and/or figures; the same data may not be used in both; suitable statistical data should be given. All data must be obtained with attention to numerical detail in the planning stage. As reproduced design has been recognized to be important to experiments for a considerable time, the Editor has decided that any paper that appears not to have adequate numerical treatments of the data will be returned un-refereed;

(g) Discussion should cover the implications and consequences, not just recapitulating the results; conclusions should be summarizing.

(h) Brief Acknowledgements.

(i) References in the proper form.

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The Editorial Board reserves the right to make literary corrections and to make suggestions to improve briefness.

It is vital, that authors take care in submitting a manuscript that is written in simple language and adheres to published guidelines.

Format

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- It may take the discovery of only one relevant paper to let steer in the right keyword direction because in most databases, the keywords under which a research paper is abstracted are listed with the paper.
- One should avoid outdated words.

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References

References follow the Harvard scheme of referencing. References in the text should cite the authors' names followed by the time of their publication, unless there are three or more authors when simply the first author's name is quoted followed by et al. unpublished work has to only be cited where necessary, and only in the text. Copies of references in press in other journals have to be supplied with submitted typescripts. It is necessary that all citations and references be carefully checked before submission, as mistakes or omissions will cause delays.

References to information on the World Wide Web can be given, but only if the information is available without charge to readers on an official site. Wikipedia and Similar websites are not allowed where anyone can change the information. Authors will be asked to make available electronic copies of the cited information for inclusion on the Global Journals Inc. (US) homepage at the judgment of the Editorial Board.

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

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

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

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

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

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

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

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

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

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Key points to remember:

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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.

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· Adhere to recommended page limits

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- Separating a table/chart or figure - impound each figure/table to a single page
- Submitting a manuscript with pages out of sequence

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· 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

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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.

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- 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)

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- Present a justification. Status your particular theory (es) or aim(s), and describe the logic that led you to choose them.
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- Materials may be reported in a part section or else they may be recognized along with your measures.

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- Report the method (not particulars of each process that engaged the same methodology)
- Describe the method entirely
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- 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.

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- 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.
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- Leave out information that is immaterial to a third party.

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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.

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- Sum up your conclusion in text and demonstrate them, if suitable, with figures and tables.
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- 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.
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- 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.

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- 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.
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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
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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

Index

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