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Highlights

- A Cam and Different Translated
- Vacuum Assisted Climbing Device
- Characteristics of a Vertical Axis
- Comparison of Nonlinear Dynamic

Discovering Thoughts, Inventing Future

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Comparison of Nonlinear Dynamic Simulation of Lyapunov Exponent for a Cam and Different Translated Followers with Clearance

By Louay S. Yousuf

Abstract- In this paper, a cam with translated flat-faced and roller followers are analyzed. There is a clearance between the follower and the guide. The dynamic simulation is investigated taking into account the nonlinear dynamic of Lyapunov exponent parameter. The simulation has been done by using Solidworks program. The effect of follower guides' clearances on follower non-periodicity is considered based on Lyapunov exponent technique. Nonlinear dynamic package is used to calculate largest Lyapunov exponent for different angular velocities of the cam. The power spectrum analysis of Fast Fourier Transform and phase plane contour are examined flat-faced and roller followers non-periodicity. The flat- faced follower with follower guide's clearance C=2 mm and cam rotational speed N=1200 rpm has more non-periodic motion than roller follower. The values of largest Lyapunov exponent for flat-faced follower are bigger than the values of largest Lyapunov exponent for roller follower at (C = 2 mm and N = 1200 rpm)

Keywords: (Nonlinear Dynamics Comparison, Cam-Follower Mechanism, Lyapunov Exponent, Dynamics Simulation, Follower Guide's Clearance).

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I. Introduction

The cam and follower mechanism is a complex impacting system. The proposed cam can be used on motor car camshafts to operate the engine valves. many researches has been done using Fast Fourier Transform (FFT) of nonlinear dynamic. Bagci and Kurnool [1] presented a Fourier series Laplace transform to find the follower response at any time and at any cycle. They measured the angular speed of the cam. Also Demeenlenaere and Schutter [2] used a finite Fourier series to design an inverted cam mechanism by considering the cam rotational speed. Yousuf et al. analyzed the dynamic simulation of a polydyne cam with flat-faced follower. The effect of follower guides' clearances for different cam rotational speeds was investigated, [3]. The largest Lyapunov exponents for the simulation and experimental data were analyzed and selected over a range of cam rotational speeds, [4].

The power spectrum of Fast Fourier Transform and phase plane have been examined the follower non-periodicity during follower motion in the y-direction. He used Rosenstein program to calculate largest Lyapunov exponent, [5, 6].

Mahyuddin and Midha used Floquet theory of phase-plane diagram to determine the periodic response of cam-follower system as a single-degree-of-freedom. They presented a linear, second-order, ordinary differential equation to define the parametric stability of a cam and the follower, [7, 8]. Zhou et al. proposed an exhaustive technique to design a displacement function of a disc cam and roller follower by using Fourier series method, [9]. In this paper, the comparison of nonlinear dynamic of Lyapunov exponent is investigated for a cam with different translated follower to maintain the contact between cam and follower. To the best of our knowledge, the comparison of nonlinear dynamic based on different shapes of followers with clearance has not been studied yet.

II. Simulation Procedure

The simulation process has been done by using Solidworks program, [10]. Solidworks program is used to draw polydyne cam, flat-faced follower, roller follower, and followers' guides. The general dimensions of cam-follower mechanism have been shown in Fig. 1 and Fig. 2. The dynamic analysis presents follower displacement driven by a cam rotating at a uniform angular velocity. There is a clearance between the follower and the guides. In simulation process, the follower with three degrees of freedom is considered in which it has translation in x,y directions and rotation about z axis. Four different follower guides' clearances such as C=0.5, 1, 1.5, 2 mm have been used to simulate the non-periodic analysis. The follower non-periodicity is occurred because of the follower guide's clearance and the three degrees of freedom. It can be compared the follower non-periodicity by using the conception of largest Lyapunov exponent. The point with the coordinates (x = 0, y = 140.13 mm, z = 0) has been selected on the follower to present follower motion.

III. Nonlinear Dynamics

The nonlinear dynamic tool of computer algorithm is used to determine the time delay and the embedding dimension dE. The first minimum of the Average Mutual Information (AMI) has been chosen to

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calculate the time delay. The embedding dimension has been found from a Global False Nearest Neighbors (GFNN) analysis, [6, 11]. The global dimensions has been selected when the total percentage of neighboring trajectories reaches zero. Figures (3) and (4) indicate the (AMI) and (GFNN) algorithms for roller and flat-faced follower

IV. Non-Periodicity of Cam-Follower Mechanism

The non-periodicity of translated follower stem has been occurred because of the clearance. The non-periodicity in this system is increased with the increasing of follower guide's clearance value from C = 0.5 mm to 2 mm. The non periodicity phenomena follows the divergence between trajectories during the follower motion with clearance and different degrees of freedom. In this paper, the main cause of follower non-periodicity is the three degrees of freedom.

V. Lyapunov Exponent

Lyapunov exponent is a quantity that represents the amount of separation of neighboring trajectories in state space domain, [12]. The method of Lyapunov characteristic exponents serves as a useful tool to quantify follower nonperiodicity. Specifcally, Lyapunov exponent measures the rates of convergence or divergence of near by trajectories, [13]. Positive values of Lyapunov exponents imply nonperiodicity in follower system while negative values reflect periodic motion. In In this paper, the largest lyapunov exponent has been selected because it determines a notion of predictability for a dynamical system. The maximum Lyapunov exponent λ can be characterized by using Eqn. (1) below, [11, 14].

$$d(t) = De^{\lambda t} \tag{1}$$

The λ is estimated from best-fit linear slopes of average logarithmic divergence over the time between four and ten strides as indicated in Eqn. (2), [11, 6, 14]:

$$y(i) = \frac{1}{\Delta t}\langle ln[d_j(i)]\rangle \tag{2}$$

Figures (5) shows the average logarithmic divergence of largest Lyapunov exponent for a clearance C=1 and 2 mm at cam rotational speed N = 400 rpm.

VI. Frequency Power Spectrum

The power spectrum describes the distribution of power into frequency components composing that signal, [15]. The fast Fourier transform (FFT) tool of computer algorithm is used to convert the signal from its original domain to a representation in the frequency domain and vice verse. The frequency spectrum is examined follower non-periodicity of the dynamic response.

VII. Results and Discussions

Figures (6) and (7) show the phase plane diagram of follower linear displacement and velocity for translated flat-faced and roller followers. The follower non-periodicity varies like a spiral. The follower non-periodicity increase with the increasing of cam rotational speed and foll ower guide's clearance. The follower non -periodicity for flat-fored follower is more chaotic than roller follower for the same cam ratational speed and follower guide's clearance.

Figures (8) and (9) show the amplitude comparison of nonlinear displacement simulation of Fast Fourier Transform based on power spectrum for flat-faced and roller followers. The fundamental frequency due to the nonlinear dynamic of roller follower is clear and obvious because of the quasi periodic motion of the follower. The fundamental frequency of the flat-faced follower is not clear enough because due to the increasing in cam rotational speeds the system completely converted to non-periodic motion of the follower.

Figures (10) and (11) show the comparison of largest Lyapunov exponent varying with cam rotational speeds for flat-faced and roller followers.The largest Lyapunov exponent is increased with the increasing of cam rotational speeds and follower guide's clearance. The values of largest Lyapunov exponent for flat- faced follower are bigger than the values of largest Lyapunov exponent for roller follower due to the increasing in time delay and embedding dimensions values.

VIII. Conclusions

This study analyzed and discussed the comparison of largest Lyapunov exponent of cam and different translated follower mechanism. The simulation has been done by using Solidworks program. The whole values of largest Lyapunov exponent are positive because of the non-periodicity motion of the follower. The flat-faced follower with follower guide's clearance C = 2 mm and cam rotational speed N = 1200 rpm has more non-periodic motion than roller follower. The values of largest Lyapunov exponent for flat-faced follower are bigger than the values of largest Lyapunov exponent for roller follower at (C = 2 mm and N = 1200 rpm).

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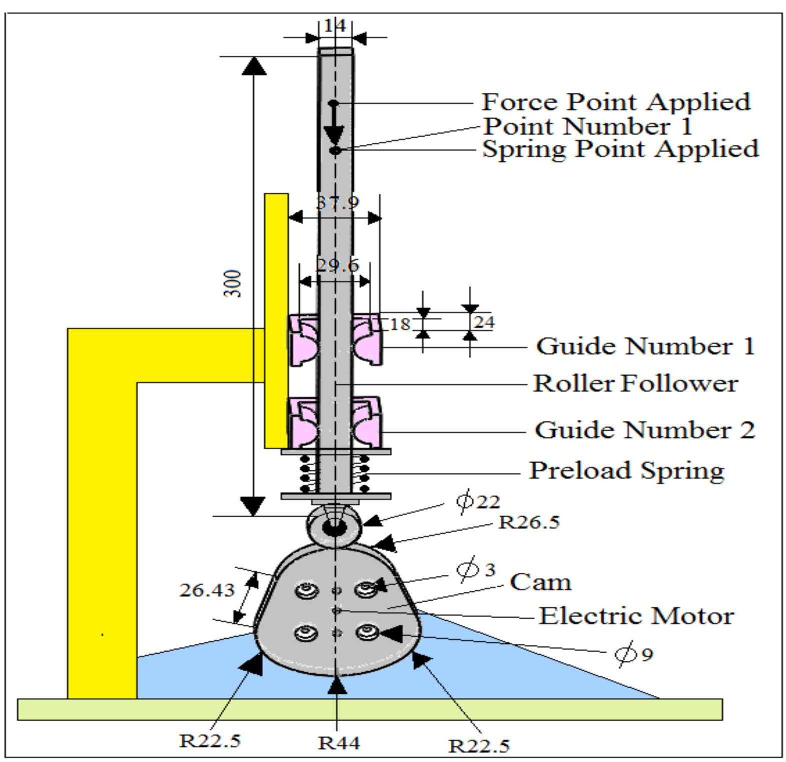

Figure 1: General Dimensions of Polydyne Cam and Roller Follower Mechanism

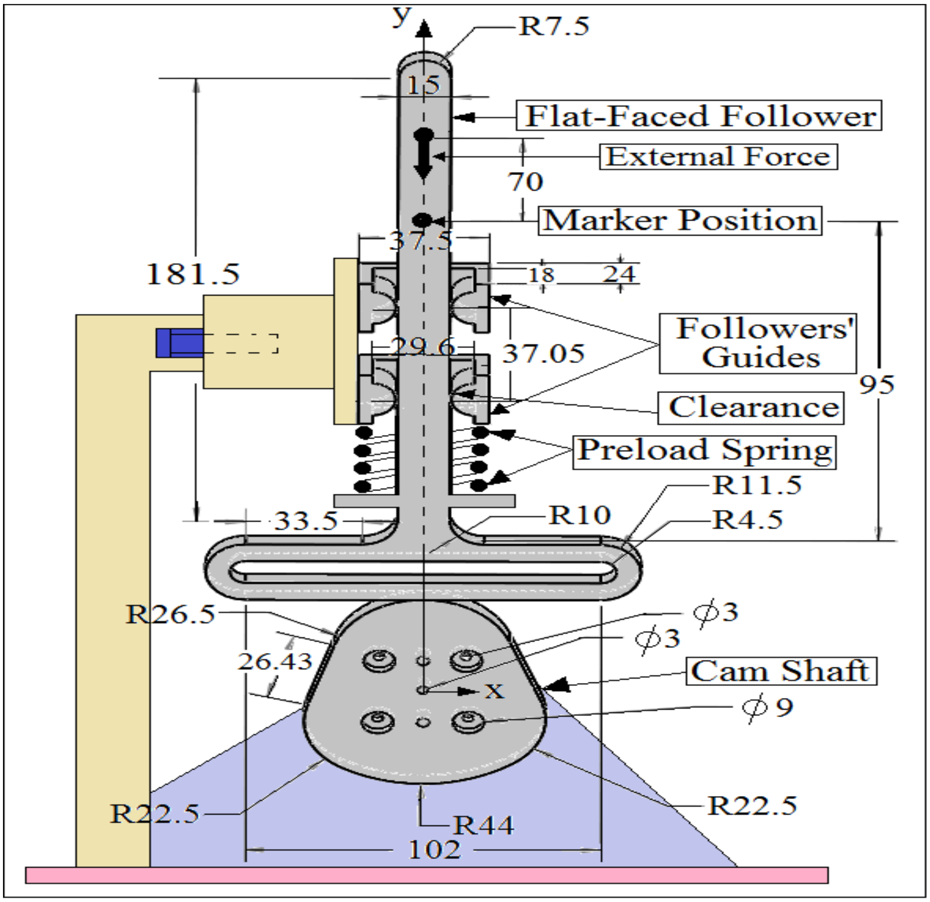

Figure 2: General Dimensions of Polydyne Cam and Flat-Faced Follower Mechanism

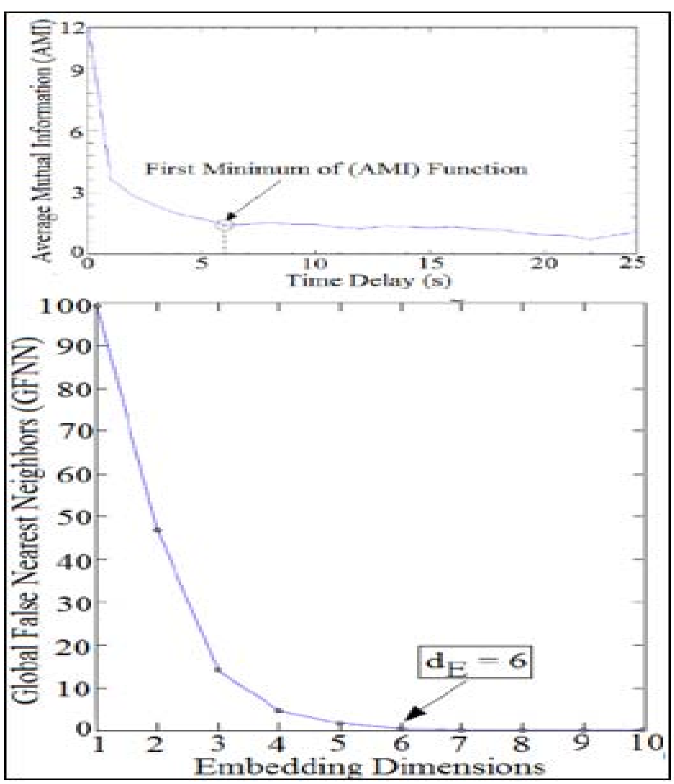

Figure 3: (AMI) and (GFNN) for Translated Roller Follower

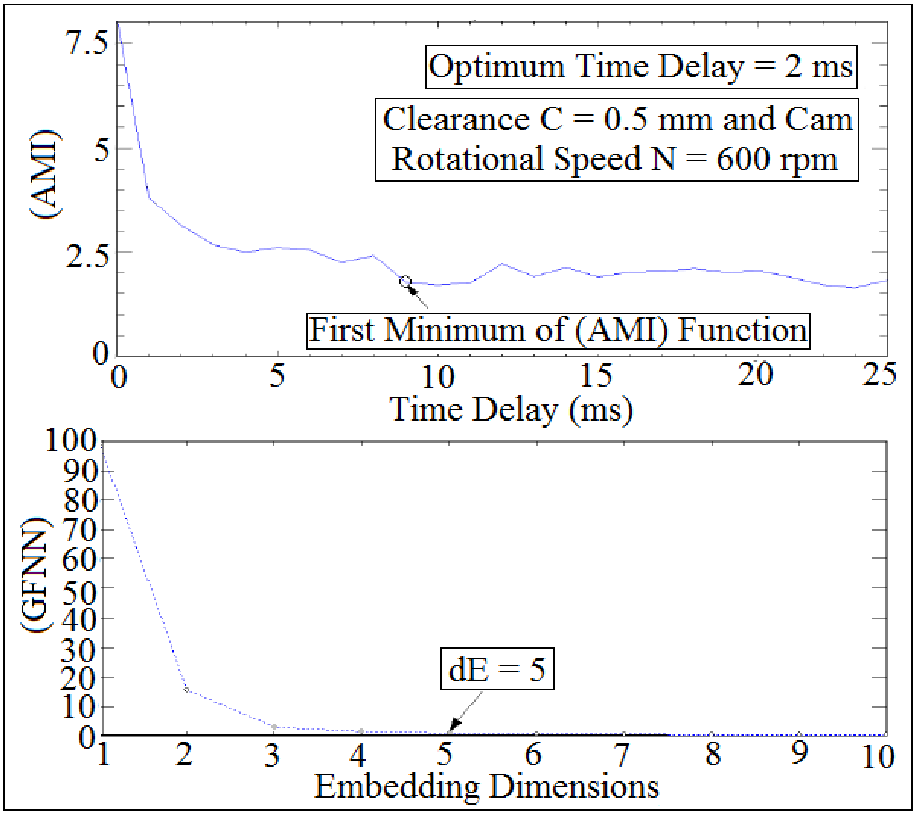

Figure 4: (AMI) and (GFNN) for Translated Flat-Faced Follower

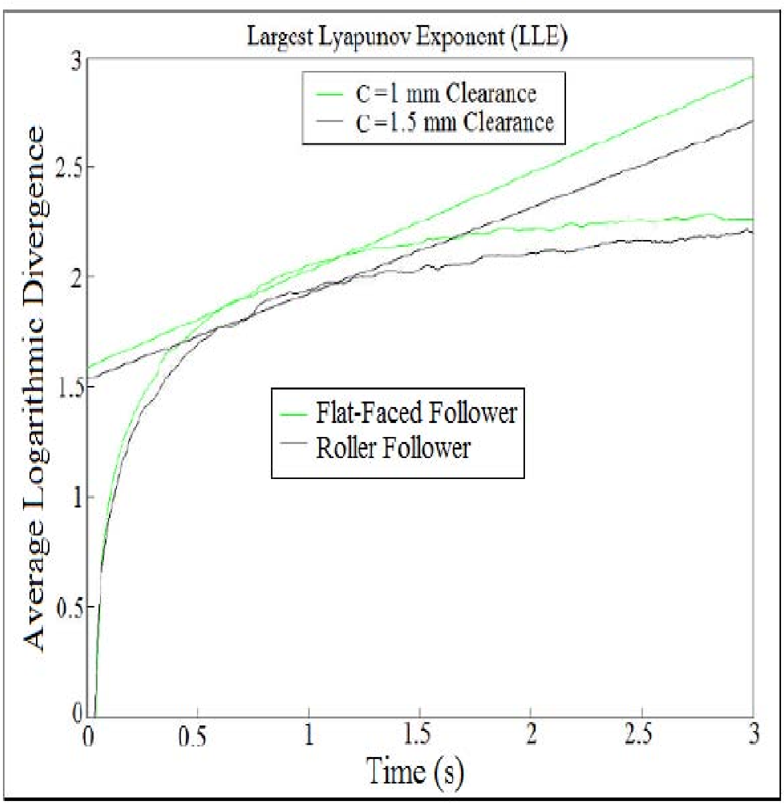

Figure 5: Average Logarithmic Divergence Comparison of roller and Flat-Faced Followers at N = 400 rpm

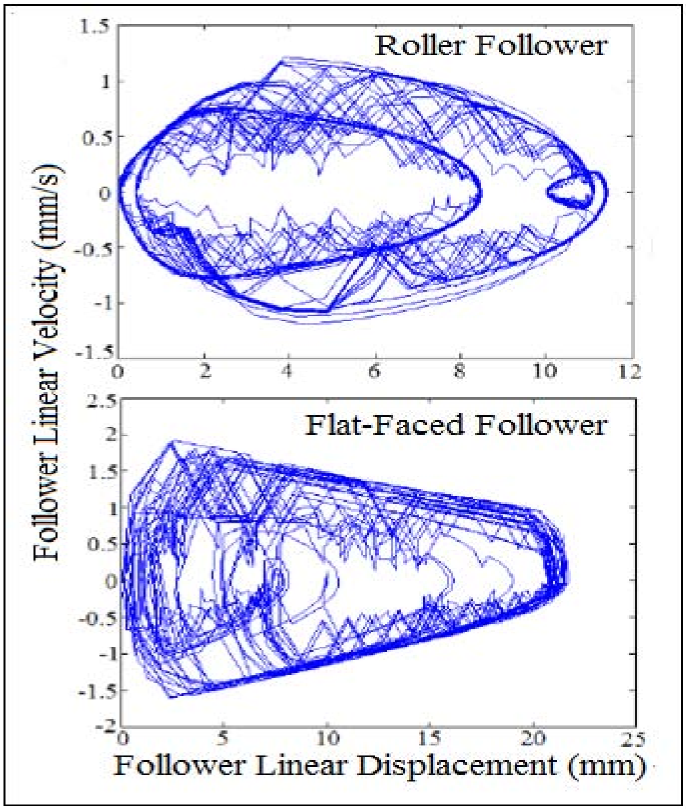

Figure 6: Phase-Plane Diagram Comparison of Roller and Flat-Faced Followers at C = 0.5 mm and N = 600 rpm

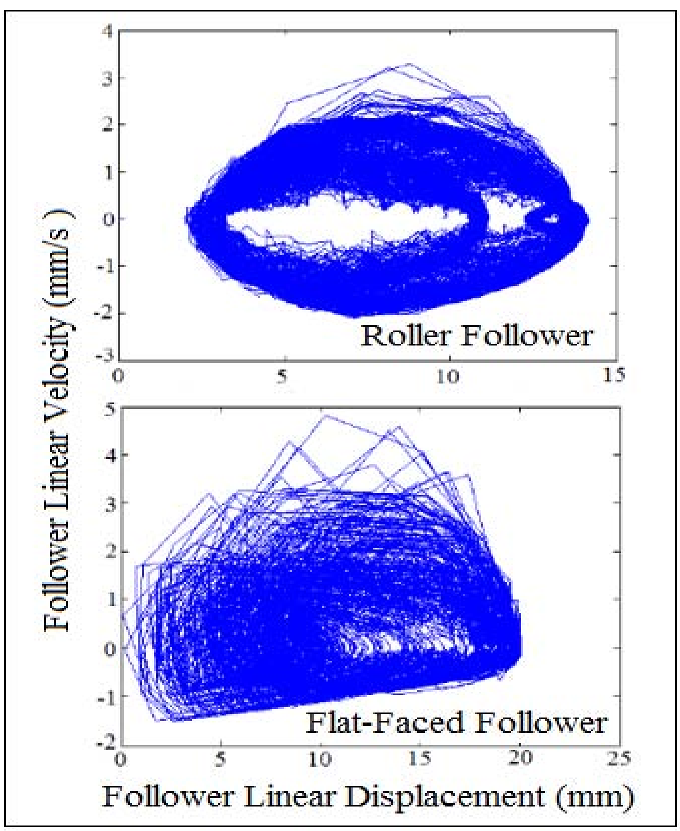

Figure 7: Phase-Plane Diagram Comparison of Roller and Flat-Faced Follower at C = 2 mm and N = 1200 rpm

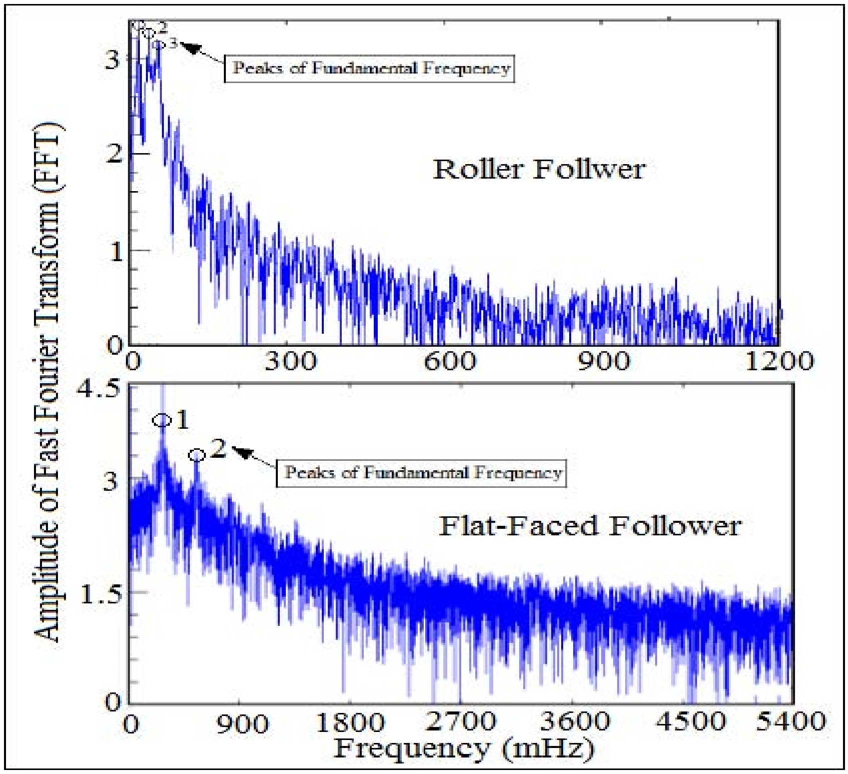

Figure 8: Amplitude Comparison of Roller and Flat-Faced Followers at C = 0.5 mm and N = 600 rpm

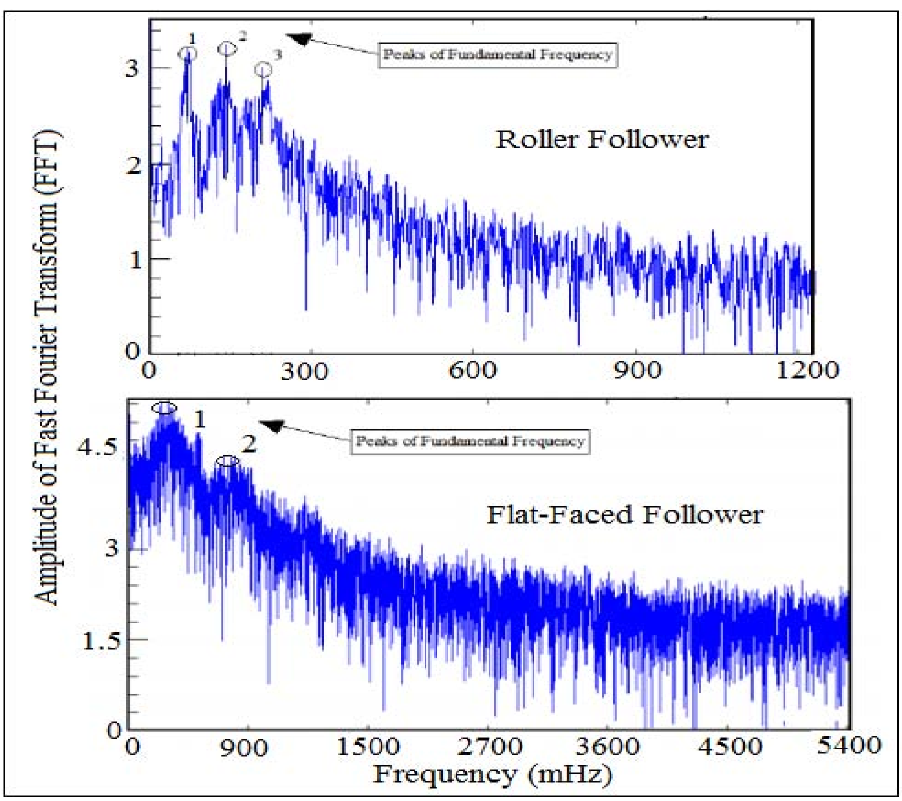

Figure 9: Amplitude Comparison of Roller and Flat-Faced Followers at C = 2 mm and N = 1200 rpm

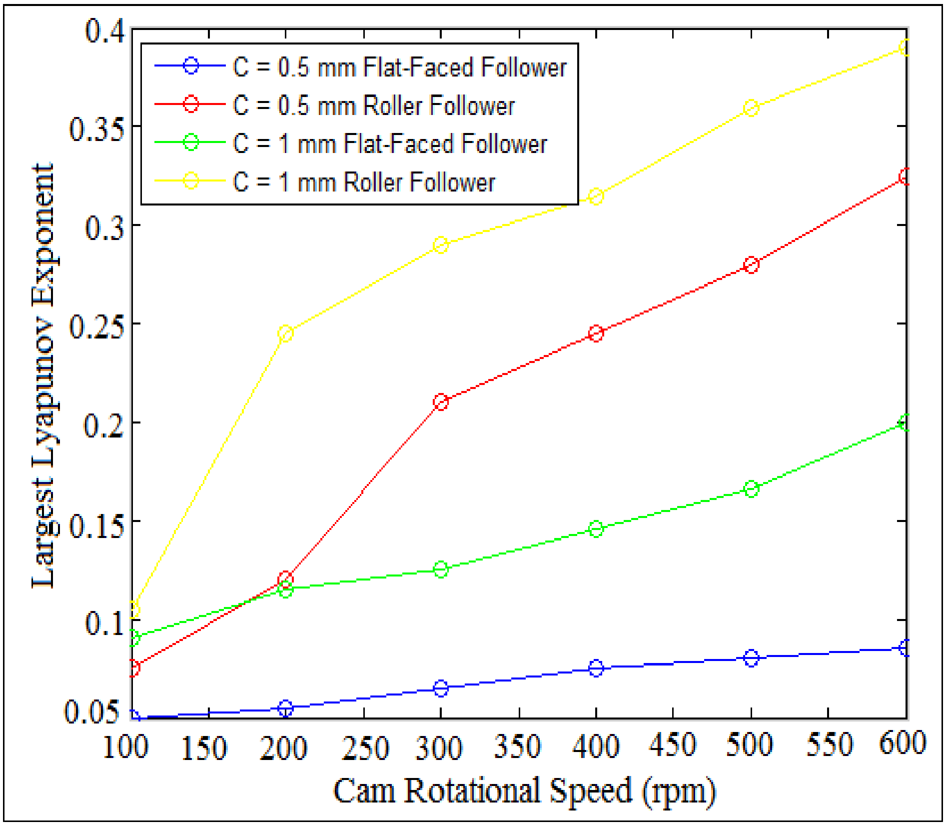

Figure 10: Largest Lyapunov Exponent Versus Cam Rotational Speeds for Roller and Flat Faced Followers at C = 0.5 mm and C = 1 mm

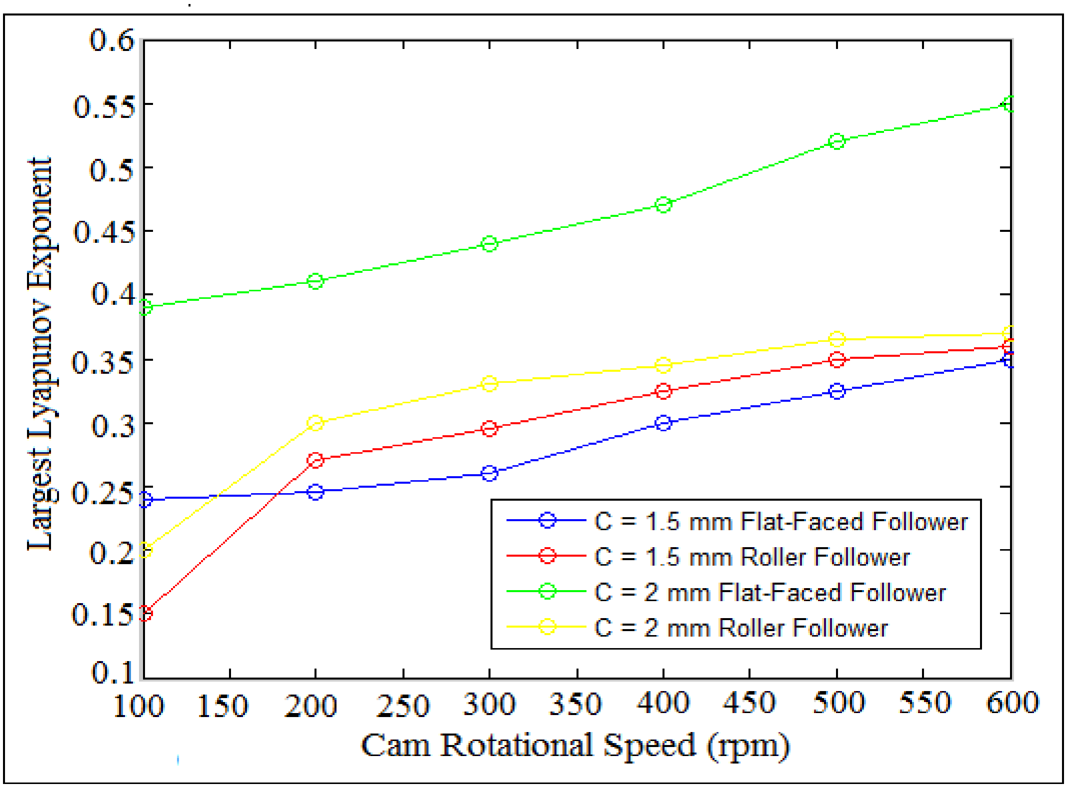

Figure 11: Largest Lyapunov Exponent Versus Cam Rotational Speeds for Roller and Flat-Faced Followers at C=1.5 mm and C = 2 mm

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Multilayer Electro Magneto Elastic Actuator for Nanomechanics

By Sergey M. Afonin
University of Electronic Technology

Abstract- In this paper, we consider the generalized structural diagram of the multilayer electro magneto elastic actuator or the multilayer piezo actuator for the nanomechanics in contrast to Cady and Mason's electrical equivalent circuits for the calculation of the piezo transmitter and receiver, the vibration piezo motor. From the solution of the general equation of the electro magneto elasticity, the matrix equation for the equivalent quadripole of the multilayer electro magneto elastic actuator, and its boundary conditions we receive the generalized structural-parametric model, the structural diagram and matrix transfer function of the multilayer actuator.

Keywords: multilayer electro magneto elastic actuator, multilayer piezo actuator, equivalent quadripole, structural diagram, structural-parametric model, matrix transfer function

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Keywords: multilayer electro magneto elastic actuator, multilayer piezo actuator, equivalent quadripole, structural diagram, structural-parametric model, matrix transfer function.

I. Introduction

At present, we use the multilayer electro magneto elastic actuator on the piezoelectric, piezomagnetic, electrostriction, and magnetostriction effects for precise alignment in the range of movement from nanometers to tens of micrometers in nanomechanics systems for nanotechnology and adaptive optics. We receive the parametric structural schematic diagram of the multilayer piezo actuator for nanomechanics in contrast to Cady and Mason's electrical equivalent circuits for the calculation of the piezo transmitter, the piezo receiver, and the vibration piezo motor [1 – 12]. The parametric structural schematic diagram of the multilayer electro magneto elastic actuator is obtained with the mechanical parameters of displacement and force [14 −20].The piezo actuator use for actuation of mechanisms, systems, or management based on the piezo effect, and convert electrical signals into mechanical movement or force. The investigation of the static and dynamic characteristics of the multilayer piezo actuator is necessary for the calculation of nanomechatronics systems. We apply multilayer piezo actuator in nanotechnology for scanning tunneling microscopy and atomic force microscopy [6 − 32].

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II. Parametric Structural Schematic Diagram

In this paper, we have the parametric structural schematic diagram and the matrix transfer function of the multilayer electro magneto elastic actuator for the nanomechanics from its the structural-parametric model. In general, the equation for the electro magneto elasticity of the multilayer electro magneto elastic actuator [12, 14, 16, 31] has the form

$$S_i = \nu_{mi}\Psi_m(t) + s_{ij}^{\Psi}T_j(x,t) \quad (1)$$

where $S_i = \partial\xi(x,t)/\partial x$ is the relative displacement along axis *i* of the cross-section of the actuator, therefore, we obtain $\Psi = E, D, H$ the generalized control parameter in the form E_m in Figure 1 for the voltage control, D_m for the current control, H_m for the magnetic field strength control along axis *m*, T_j is the mechanical stress along axis *j*, ν_{mi} is the coefficient of electro magneto elasticity, for example, d_{mi} piezo module or magnetostriction coefficient, s_{ij}^{Ψ} is the elastic compliance with $\Psi = \text{const}$, and the indexes *i* = 1, 2, … , 6, *j* = 1, 2, … , 6, *m* = 1, 2, 3, with 1, 2, 3 are perpendicular coordinate axes.

The multilayer piezo actuator on Figure 1 consists from the piezo layers or the piezo plates connected electrically in parallel and mechanically in series.

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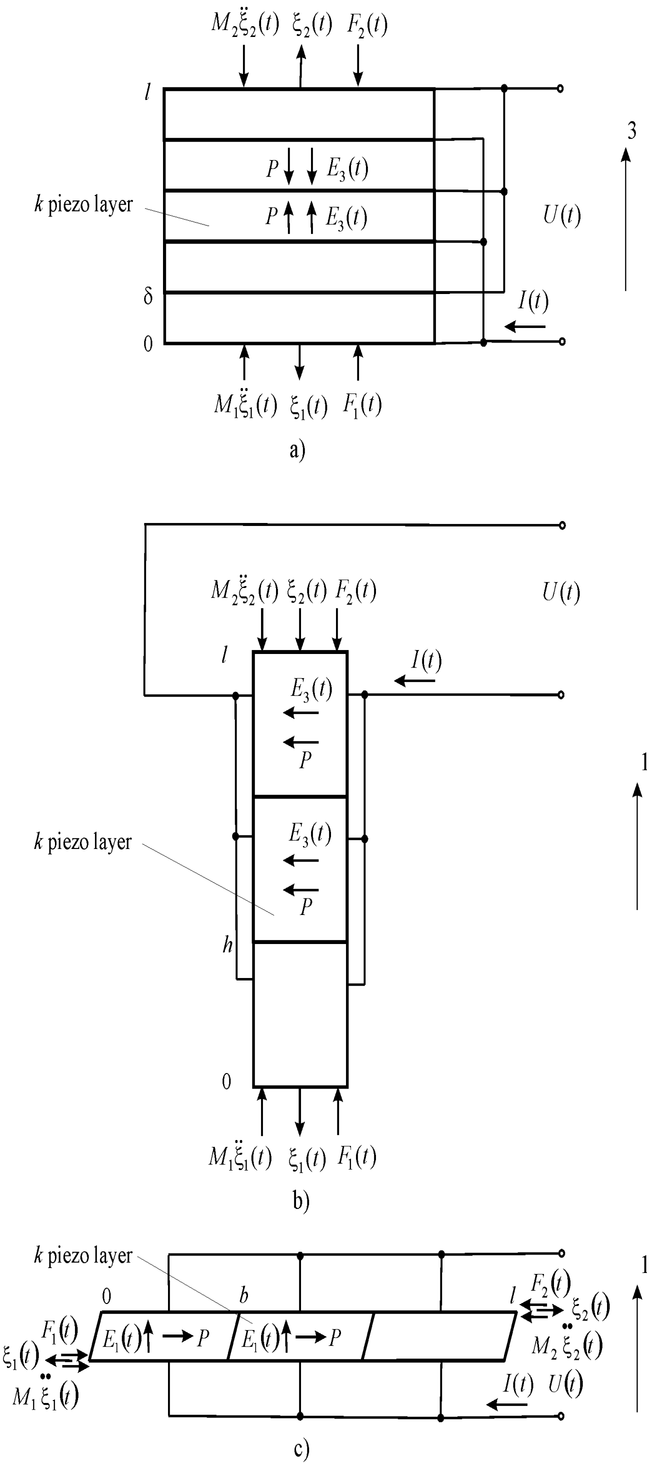

Figure 1: Multilayer piezo actuator a) for longitudinal piezo effect b) for transverse piezo effect, c) for shift piezo effect

For example, we consider the matrix equation for the Laplace transforms of the forces and the displacements [16] at the input and output ends of *k* the piezo layer of the multilayer piezo actuator from *n* the piezo layers. We drew the equivalent *T*-shaped quadripole of *k* the piezo layer in Figure 2.

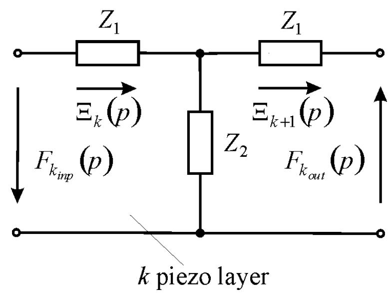

Figure 2: Quadripole for *k* piezo layer

The circuit of the multilayer piezo actuator on Figure 2 is compiled from the equivalent *T*-shaped quadripole for *k* the piezo layer and the forces equations, acting on the faces the piezo layer. Therefore, we have the Laplace transforms of the forces on the input and output faces of *k* the piezo layer of the multilayer piezo actuator in the form of the system of the equations for the equivalent *T*-shaped quadripole

$$F_{k_{inp}}(p) = -(Z_1+Z_2)\Xi_k(p) + Z_2\Xi_{k+1}(p)$$

$$-F_{k_{out}}(p) = -Z_2\Xi_k(p) + (Z_1+Z_2)\Xi_{k+1}(p) \qquad (2)$$

where $Z_1 = \frac{S_0\gamma\,\mathrm{th}(\delta\gamma)}{s_{ij}^{\Psi}}$, $Z_2 = \frac{S_0\gamma}{s_{ij}^{\Psi}\,\mathrm{sh}(\delta\gamma)}$ are the resistance of the equivalent quadripole of *k* the piezo layer, δ is the thickness on Figure 1 a, $\gamma = \frac{p}{c^{\Psi}} + \alpha$, α are the coefficient of wave propagation and the coefficient of attenuation, *p* is the Laplace operator, c^{Ψ} is the speed of sound with $\Psi = \mathrm{const}$, $F_{k_{inp}}(p)$, $F_{k_{out}}(p)$ are the Laplace transform of the forces at the input and output ends, $\Xi_k(p)$, $\Xi_{k+1}(p)$ are the Laplace transforms of the displacements at input and output ends of *k* the piezo layer in Figure 2.

Accordingly, we have for Figure 2 the Laplace transforms the following system of the equations for *k* the piezo layer in the form

$$-F_{k_{inp}}(p) = \left(1+\frac{Z_1}{Z_2}\right)F_{k_{out}}(p) + Z_1\left(2+\frac{Z_1}{Z_2}\right)\Xi_{k+1}(p)$$

$$\Xi_k(p) = \frac{1}{Z_1}F_{k_{out}}(p) + \left(1+\frac{Z_1}{Z_2}\right)\Xi_{k+1}(p) \qquad (3)$$

the matrix equation for *k* the piezo layer

$$\begin{bmatrix} -F_{k_{inp}}(p) \\ \Xi_k(p) \end{bmatrix} = [M]\begin{bmatrix} F_{k_{out}}(p) \\ \Xi_{k+1}(p) \end{bmatrix} \qquad (4)$$

and the matrix $[M]$ in the form

$$[M]=\begin{bmatrix} m_{11} & m_{12} \\ m_{21} & m_{22} \end{bmatrix}=\begin{bmatrix} 1+\frac{Z_1}{Z_2} & Z_1\left(2+\frac{Z_1}{Z_1}\right) \\ \frac{1}{Z_2} & 1+\frac{Z_1}{Z_2} \end{bmatrix} \quad (5)$$

Where $m_{11}=m_{22}=1+\frac{Z_1}{Z_2}=\mathrm{ch}(\delta\gamma)$,

$m_{12}=Z_1\left(2+\frac{Z_1}{Z_1}\right)=Z_0\mathrm{sh}(\delta\gamma)$, $m_{21}=\frac{1}{Z_2}=\frac{\mathrm{sh}(\delta\gamma)}{Z_0}$, $Z_0=\frac{S_0\gamma}{s_{ij}^{\Psi}}$

For the multilayer piezo actuator the Laplace transforms the displacement $\Xi_{k+1}(p)$ and the force $F_{k_{out}}(p)$ acting on the output face of k the piezo layer correspond the Laplace transforms of displacement and force acting on the input face of $k+1$ the piezo layer. The force on the output face for the k the piezo layer equal in magnitude and opposite in direction to the force on the input face for $k+1$ the piezo layer

$$F_{k_{out}}(p)=-F_{k+1_{inp}}(p) \quad (6)$$

From equation (3) the matrix equation for n the piezo layers

$$\begin{bmatrix} -F_{1_{inp}}(p) \\ \Xi_1(p) \end{bmatrix}=[M]^n\begin{bmatrix} F_{n_{out}}(p) \\ \Xi_{n+1}(p) \end{bmatrix} \quad (7)$$

with the matrix of the multilayer piezo actuator Figure 1 a in the form

$$[M]^n=\begin{bmatrix} \mathrm{ch}(n\delta\gamma) & Z_0\mathrm{sh}(n\delta\gamma) \\ \frac{\mathrm{sh}(n\delta\gamma)}{Z_0} & \mathrm{ch}(n\delta\gamma) \end{bmatrix}$$

Accordingly, in general, the matrix for the equivalent quadripole of the multilayer electro magneto elastic actuator Figure 1 a-c has the following form

$$[M]^n=\begin{bmatrix} \mathrm{ch}(l\gamma) & Z_0\mathrm{sh}(l\gamma) \\ \frac{\mathrm{sh}(l\gamma)}{Z_0} & \mathrm{ch}(l\gamma) \end{bmatrix}$$

Therefore, we have from the equation (7) the equivalent quadripole of the multilayer piezo actuator on Figure 1 a-c for the longitudinal piezo effect with length of the multilayer piezo actuator $l=n\delta$, for the transverse piezo effect with $l=nh$, for the shift piezo effect with $l=nb$, where δ,h,b are the thickness, the height, the width for k the piezo layer.

Equations of the forces acting on the faces of the multilayer piezo actuator

$$\begin{aligned} &\text{at } x=0,\ T_j(0,p)S_0=F_1(p)+M_1p^2\Xi_1(p) \\ &\text{at } x=l,\ T_j(l,s)S_0=-F_2(p)-M_2p^2\Xi_2(p) \end{aligned} \quad (8)$$

where $T_j(0,p)$, $T_j(l,p)$ are the Laplace transforms of mechanical stresses at the two ends of the multilayer piezo actuator.

The Laplace transform of the displacement and the force for the first face of the multilayer piezo actuator

at $x=0$ and $\Xi_1(p)$, $F_1(p)$

the Laplace transforms of the displacement and the forces for the second face of the piezo actuator

at $x=l$ and $\Xi_2(p)=\Xi_{n+1}(p)$, $F_2(p)=F_{n_{out}}(p)$

Let us construct the structural-parametric model of the multilayer electro magneto elastic actuator Figure 1 a-c. From equation (1) the Laplace transform of the caused force, which causes the deformation, has the following form

$$\begin{aligned} F(p)&=\nu_{mi}S_0\Psi_m(p)/s_{ij}^{\Psi} \\ \chi_{ij}^{\Psi}&=s_{ij}^{\Psi}/S_0 \end{aligned} \quad (9)$$

Accordingly, we have the equations for the generalized structural-parametric model and the generalized parametric structural schematic diagram of the multilayer electro magneto elastic actuator on Figure 3. We receive the structural-parametric model in result analysis of the equation of the caused force and the system of the equations for the equivalent quadripole of the multilayer electro magneto elastic actuator, the forces on its faces in the following form

$$\begin{aligned} \Xi_1(p)&=\left[\frac{1}{M_1p^2}\right]\left\{-F_1(p)+\left(\frac{1}{\chi_{ij}^{\Psi}}\right)\left[\begin{array}{l}\nu_{mi}\Psi_m(p)-\left[\frac{\gamma}{\mathrm{sh}(l\gamma)}\right]\times \\ \left[\mathrm{ch}(l\gamma)\Xi_1(p)-\Xi_2(p)\right]\end{array}\right]\right\} \\ \Xi_2(p)&=\left[\frac{1}{M_2p^2}\right]\left\{-F_2(p)+\left(\frac{1}{\chi_{ij}^{\Psi}}\right)\left[\begin{array}{l}\nu_{mi}\Psi_m(p)-\left[\frac{\gamma}{\mathrm{sh}(l\gamma)}\right]\times \\ \left[\mathrm{ch}(l\gamma)\Xi_2(p)-\Xi_1(p)\right]\end{array}\right]\right\} \end{aligned} \quad (10)$$

where $\nu_{mi}=\begin{cases} d_{33},d_{31},d_{15} \\ g_{33},g_{31},g_{15} \\ d_{33},d_{31},d_{15} \end{cases}$, $\Psi_m=\begin{cases} E_3,E_1 \\ D_3,D_1 \\ H_3,H_1 \end{cases}$, $s_{ij}^{\Psi}=\begin{cases} s_{33}^E,s_{11}^E,s_{55}^E \\ s_{33}^D,s_{11}^D,s_{55}^D \\ s_{33}^H,s_{11}^H,s_{55}^H \end{cases}$ $c^{\Psi}=\begin{cases} c^E \\ c^D \\ c^H \end{cases}$, $\gamma=\begin{cases} \gamma^E \\ \gamma^D \\ \gamma^H \end{cases}$, $l=\begin{cases} n\delta \\ nh \\ nb \end{cases}$.

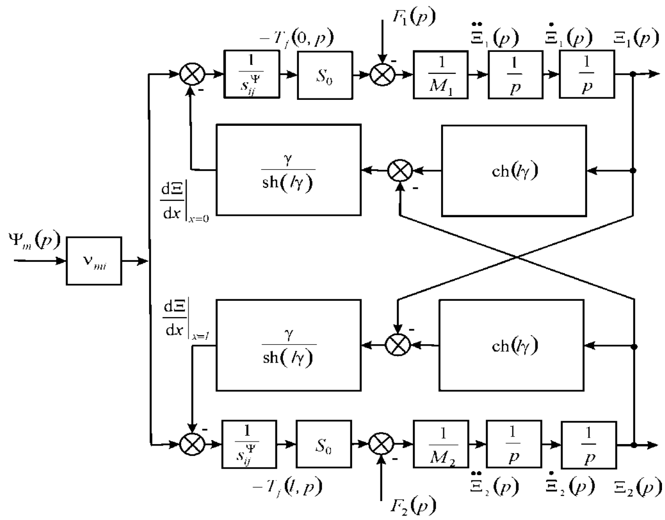

Figure 3: Generalized structural diagram of multilayer electro magneto elastic actuator

The Laplace transform of the caused force at the longitudinal piezo effect for the multilayer piezo actuator has the form

$$F(p)=d_{33}S_0E_3(p)/s_{33}^E\,, \tag{11}$$

$$\chi_{33}^E=s_{33}^E/S_0$$

The structural-parametric model of the multilayer piezo actuator for the longitudinal piezo effect has the form

$$\Xi_1(p)=\left[\frac{1}{M_1p^2}\right]\left\{-F_1(p)+\left(\frac{1}{\chi_{33}^E}\right)\left[\begin{matrix}d_{33}E_3(p)-\left[\dfrac{\gamma}{\mathrm{sh}(l\gamma)}\right]\times\\ \left[\mathrm{ch}(l\gamma)\Xi_1(p)-\Xi_2(p)\right]\end{matrix}\right]\right\}$$

(12)

$$\Xi_2(p)=\left[\frac{1}{M_2p^2}\right]\left\{-F_2(p)+\left(\frac{1}{\chi_{33}^E}\right)\left[\begin{matrix}d_{33}E_3(p)-\left[\dfrac{\gamma}{\mathrm{sh}(l\gamma)}\right]\times\\ \left[\mathrm{ch}(l\gamma)\Xi_2(p)-\Xi_1(p)\right]\end{matrix}\right]\right\}$$

For the transverse piezo effect the Laplace transform of the caused force

$$F(p)=d_{31}S_0E_3(p)/s_{11}^E \tag{13}$$

$$\chi_{11}^E=s_{11}^E/S_0$$

The structural-parametric model of the multilayer piezo actuator for the transverse piezo effect has the form

$$\Xi_1(p)=\left[\frac{1}{M_1p^2}\right]\left\{-F_1(p)+\left(\frac{1}{\chi_{11}^E}\right)\left[\begin{matrix}d_{31}E_3(p)-\left[\dfrac{\gamma}{\mathrm{sh}(l\gamma)}\right]\times\\ \left[\mathrm{ch}(l\gamma)\Xi_1(p)-\Xi_2(p)\right]\end{matrix}\right]\right\}$$

(14)

$$\Xi_2(p)=\left[\frac{1}{M_2p^2}\right]\left\{-F_2(p)+\left(\frac{1}{\chi_{11}^E}\right)\left[\begin{matrix}d_{31}E_3(p)-\left[\dfrac{\gamma}{\mathrm{sh}(l\gamma)}\right]\times\\ \left[\mathrm{ch}(l\gamma)\Xi_2(p)-\Xi_1(p)\right]\end{matrix}\right]\right\}$$

For the shift piezo effect the Laplace transform of the caused force

$$F(p)=d_{15}S_0E_1(p)/s_{55}^E \tag{15}$$

$$\chi_{55}^E=s_{55}^E/S_0$$

The structural-parametric model of the multilayer piezo actuator for the shift piezo effect has the form

$$\Xi_1(p)=\left[\frac{1}{M_1p^2}\right]\left\{-F_1(p)+\left(\frac{1}{\chi_{55}^E}\right)\left[\begin{array}{l}d_{15}E_1(p)-\left[\frac{\gamma}{\mathrm{sh}(l\gamma)}\right]\times\\ \left[\mathrm{ch}(l\gamma)\Xi_1(p)-\Xi_2(p)\right]\end{array}\right]\right\}$$

(16)

$$\Xi_2(p)=\left[\frac{1}{M_2p^2}\right]\left\{-F_2(p)+\left(\frac{1}{\chi_{55}^E}\right)\left[\begin{array}{l}d_{15}E_1(p)-\left[\frac{\gamma}{\mathrm{sh}(l\gamma)}\right]\times\\ \left[\mathrm{ch}(l\gamma)\Xi_2(p)-\Xi_1(p)\right]\end{array}\right]\right\}$$

We drew the structural schematic diagram of the actuator from the generalized structural-parametric model of the multilayer electro magneto elastic actuator for the nanomechanics.

III. Matrix Transfer Function

From equation (10) we receive the matrix transfer function of the multilayer electro magneto elastic actuator with *n* the layers in the following form

$$\begin{bmatrix}\Xi_1(p)\\ \Xi_2(p)\end{bmatrix}=\begin{bmatrix}W_{11}(p) & W_{12}(p) & W_{13}(p)\\ W_{21}(p) & W_{22}(p) & W_{23}(p)\end{bmatrix}\begin{bmatrix}\Psi_m(p)\\ F_1(p)\\ F_2(p)\end{bmatrix} \quad (17)$$

Therefore, in general, we have the matrix transfer function of the multilayer electro magneto elastic actuator in the form

$$[\Xi(p)]=[W(p)][P(p)]$$

$$[\Xi(p)]=\begin{bmatrix}\Xi_1(p)\\ \Xi_2(p)\end{bmatrix}\ [W(p)]=\begin{bmatrix}W_{11}(p) & W_{12}(p) & W_{13}(p)\\ W_{21}(p) & W_{22}(p) & W_{23}(p)\end{bmatrix}\ [P(p)]=\begin{bmatrix}\Psi_m(p)\\ F_1(p)\\ F_2(p)\end{bmatrix} \quad (18)$$

where $[\Xi(p)]$, $[W(p)]$, $[P(p)]$ are the matrices of the displacements, the transfer functions and the control parameters

$$W_{11}(p)=\Xi_1(p)/\Psi_m(p)=\nu_{mi}\left[M_2\chi_{ij}^{\Psi}p^2+\gamma\mathrm{th}(l\gamma/2)\right]/A_{ij}$$

$$\chi_{ij}^{\Psi}=s_{ij}^{\Psi}/S_0$$

$$A_{ij}=M_1M_2\left(\chi_{ij}^{\Psi}\right)^2p^4+\left\{(M_1+M_2)\chi_{ij}^{\Psi}/\left[c^{\Psi}\mathrm{th}(l\gamma)\right]\right\}p^3+$$
$$\left[(M_1+M_2)\chi_{ij}^{\Psi}\alpha/\mathrm{th}(l\gamma)+1/\left(c^{\Psi}\right)^2\right]p^2+2\alpha p/c^{\Psi}+\alpha^2$$

$$W_{21}(p)=\Xi_2(p)/\Psi_m(p)=\nu_{ij}\left[M_1\chi_{ij}^{\Psi}p^2+\gamma\mathrm{th}(l\gamma/2)\right]/A_{ij}$$

$$W_{12}(p)=\Xi_1(p)/F_1(p)=-\chi_{ij}^{\Psi}\left[M_2\chi_{ij}^{\Psi}p^2+\gamma/\mathrm{th}(l\gamma)\right]/A_{ij}$$

$$W_{13}(p)=\Xi_1(p)/F_2(p)=$$

$$W_{22}(p)=\Xi_2(p)/F_1(p)=\left[\chi_{ij}^{\Psi}\gamma/\mathrm{sh}(l\gamma)\right]/A_{ij}$$

$$W_{23}(p)=\Xi_2(p)/F_2(p)=-\chi_{ij}^{\Psi}\left[M_1\chi_{ij}^{\Psi}p^2+\gamma/\mathrm{th}(l\gamma)\right]/A_{ij}$$

We receive the generalized parametric structural schematic diagram and the generalized matrix transfer function from the generalized structural-parametric model of the multilayer electro magneto elastic actuator to calculate its static and dynamic characteristics for the nanomechanics. Let us consider, for example, the voltage-controlled multilayer piezo actuator for the longitudinal piezo effect with the inertial load $m << M_1$, $m << M_2$ and $F_1(t)=F_2(t)=0$ and the static displacements of its faces in the following form

$$\xi_1(\infty)=\lim_{t\to\infty}\xi_1(t)=\lim_{\substack{p\to 0\\ \alpha\to 0}}pW_{11}(p)(U_m/\delta)/p$$

thus

$$\xi_1(\infty)=d_{33}nU_mM_2/(M_1+M_2)$$

and

$$\xi_2(\infty)=\lim_{t\to\infty}\xi_2(t)=\lim_{\substack{p\to 0\\ \alpha\to 0}}pW_{21}(p)(U_m/\delta)/p$$

thus

$$\xi_2(\infty)=d_{33}nU_mM_1/(M_1+M_2)$$

where U_m is the amplitude of the voltage, m is the mass of the multilayer piezo actuator, M_1, M_2 are the load masses. For the voltage-controlled multilayer piezo actuator from the piezo ceramics PZT at d_{33} = $4\cdot 10^{-10}$ m/V, n = 8, U = 150 V, M_1 = 1.5 kg and M_2 = 6 kg we obtain the static displacements of the faces of the multilayer piezoactuator $\xi_1(\infty)$ = 384 nm, $\xi_2(\infty)$ = 96 nm, $\xi_1(\infty)+\xi_2(\infty)$ = 480 nm.

We derive the transfer function with concentrated parameters of the multilayer piezo actuator for the longitudinal piezo effect with the voltage control for the elastic-inertial load and one fixed face and its structural diagram in Figure 4.

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$$W(p)=\frac{\Xi_2(p)}{U(p)}=\frac{d_{33}n}{\left(1+C_e/C_{33}^E\right)\left(T_t^2p^2+2T_t\xi_t p+1\right)} \qquad (19)$$

$$T_t=\sqrt{M_2/\left(C_e+C_{33}^E\right)}, \quad \xi_t=\alpha l^2 C_{33}^E\Big/\left[3c^E\sqrt{M_2\left(C_e+C_{33}^E\right)}\right]$$

where $U(p)$ is the Laplace transform the voltage, T_t, ξ_t are the time constant and the damping coefficient, $C_{33}^E=S_0/\left(s_{33}^E l\right)$ is the rigidity.

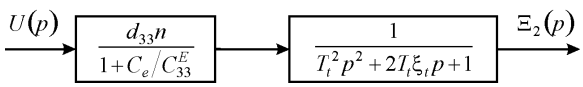

Figure 4: Structural diagram of voltage-controlled multilayer piezo actuator for longitudinal piezo effect and elastic-inertial load

Let us construct from (19) the transient response of the multilayer piezo actuator for the longitudinal piezo electric effect with the voltage control. This expression for the transient response of the voltage-controlled the multilayer piezo actuator for the longitudinal piezo effect and elastic-inertial load is determined in the form

$$\xi(t)=\xi_m\left[1-\frac{e^{-\frac{\xi_t t}{T_t}}}{\sqrt{1-\xi_t^2}}\sin\left(\omega_t t+\varphi_t\right)\right]$$

$$\xi_m=\frac{d_{33}nU_m}{1+C_e/C_{33}^E}, \quad \omega_t=\sqrt{1-\xi_t^2}\Big/T_t, \quad \varphi_t=\mathrm{arctg}\left(\sqrt{1-\xi_t^2}\Big/\xi_t\right)$$

where ξ_m is the steady-state value of displacement and U_m is the amplitude of the voltage. For the voltage-controlled multilayer piezo actuator with one fixed face from the piezo ceramics PZT with the longitudinal piezo effect and elastic-inertial load we obtain at $M_1\to\infty$, $m<<M_2$, U_m = 60 V, d_{33} = $4\cdot10^{-10}$ m/V, n = 10, M_2 = 4 kg, C_{33}^E = $6\cdot10^7$ N/m, C_e = $0.4\cdot10^7$ N/m the steady-state value of the displacement ξ_m = 225 nm and the time constant T_t = $0.25\cdot10^{-3}$ s. The discrepancy between the experimental data and calculation results is no more than 5%.

IV. Results and Discussions

We have the equations for the generalized structural-parametric model and the generalized structural diagram of the multilayer electro magneto elastic actuator. We receive the matrix transfer functions and the structural diagram of the multilayer electro magneto elastic actuator from the set of equations describing the structural parametric model of the multilayer actuator for the nanomechanics. The solution of the matrix equation for the equivalent quadripole of the multilayer electro magneto elastic actuator with the Laplace transform is used for the construction the structural diagram of the multilayer actuator.

As a result of the joint solution of the general equation of electro magneto elasticity, the matrix equation for the equivalent quadripole of the multilayer electro magneto elastic actuator, and its boundary conditions we receive the generalized structural-parametric model and the generalized structural diagram of the multilayer actuator.

V. Conclusion

We consider the generalized structural-parametric model, the structural diagram and the matrix transfer function of the multilayer electro magneto elastic actuator for the nanomechanics. We receive the structural diagram of the multilayer piezo actuator for the transverse, longitudinal, and shift piezo effects.

From the general equation of electro magneto elasticity, the force that causes the deformation, the system of the equations for the equivalent quadripole of the multilayer actuator, and the forces on its faces, we obtain generalized structural-parametric model and generalized structural diagram of the multilayer electro magneto elastic actuator for the nanomechanics.

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Development of the Performance Characteristics of a Vertical Axis Wind Turbine

By Adeyanju Anthony A, Manohar K. & Poonwassie S.
University of the West Indies

Abstract- Performance curves aid in energy assessment and performance monitoring of wind turbines and can be used as a guide for turbine applications where a generic comparison between different types can be made before selection.

This study design, build and carried out a performance analysis on a lift-type Vertical Axis Wind Turbine (VAWT). It was discovered that the efficiency of the wind turbine increased with tip speed ratios. A maximum tip speed ratio of 1.08 was achieved under limited wind speeds which meant that the rotational speed of the device was the same as the wind velocity. This occurred for a rotor solidity of 0.51. This implied that the wind turbine operated like a drag - type design since these have tip speed ratios less than or equal to 1.

Keywords: *efficiency, drag-type, tip speed ratio, solidity.*

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DEVELOPMENTOFTHEPERFORMANCECHARACTERISTICSOFAVERTICALAXISWINDTURBINE

Strictly as per the compliance and regulations of:

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This study design, build and carried out a performance analysis on a lift-type Vertical Axis Wind Turbine (VAWT). It was discovered that the efficiency of the wind turbine increased with tip speed ratios. A maximum tip speed ratio of 1.08 was achieved under limited wind speeds which meant that the rotational speed of the device was the same as the wind velocity. This occurred for a rotor solidity of 0.51. This implied that the wind turbine operated like a drag-type design since these have tip speed ratios less than or equal to 1.

A maximum efficiency of 24.4% was achieved at this tip speed ratio. It was also observed that the prototype began spinning in wind speeds as low as 0.95m/s with no assistance needed as VAWT are not self-starting and have low starting torques. There was also an exponential increase in power output of the wind turbine with increasing wind speeds.

Keywords: efficiency, drag-type, tip speed ratio, solidity.

I. General Background

The performance curve of a wind turbine depicts the relationship between the Efficiency and Tip Speed Ratio at varying wind speeds and is an important characteristic of wind turbines. Horizontal Axis Wind Turbines (HAWT) are the most common types of turbines presently where they are utilized in irrigation systems, water pumping and electricity generation. Despite possessing numerous advantages, Vertical Axis Wind Turbines (VAWT) are not as common as they have few drawbacks such as low starting torques required for operation. Performance curves aid in energy assessment and performance monitoring of wind turbines and can be used as a guide for turbine applications where a generic comparison between different types can be made before selection. Wind turbines must operate at their optimum tip-speed ratio to enhance its efficiency, maximizing the amount of power extracted from the wind stream. Due to its rarity, a prototype Vertical Axis Wind Turbine was built and its performance characteristics are developed and analyzed upon testing.

II. Vertical Axis Wind Turbines

Vertical axis wind turbines incorporate either straight or curved blades (seen on Darrieus rotors) where their axes are spun perpendicular to the wind stream. Vertical axis wind turbines possess the ability of capturing wind energy from any direction. Despite this, vertical axis wind turbines have not benefitted from years of development that have been undertaken by their Horizontal axis counterparts (Paraschiviou, 2002). Both lift-type VAWT and HAWT contain approximately the same efficiencies however, Horizontal Axis designs are still commonly used presently. Vertical Axis Wind Turbines are often classified in accordance to their aerodynamic and mechanical characteristics, their lifting surfaces or their movement of the rotor's blades about a vertical axis along a path in a horizontal plane. There a presently four types of vertical axis wind turbines.

i. Articulating straight-blade Giromill,
ii. Savonnius Rotor (drag-driven device),
iii. Variable-geometry Musgrove which permits reefing of the blades and
iv. The "Jump rope" shaped Darrieus rotor where the blades are fixed.

The H-Rotor or Giromill as shown in Figure 1 is a variation of the Darrieus concept and is most commonly used. It is also a vertical axis type wind turbine in the shape of an H (Hemami, 2012). The vertical segments consist of the active blades which are connected to the output shaft by middle segments (usually arms). The blades are also constructed with an airfoil cross-section; hence these types of turbines work on the principle of lift and have relatively high tip-speed ratios. These lift forces on the blades create a torque that enable rotation. When two blades are incorporated in the design, the H-rotor operation begins to pulsate since the downward blade moves 180° to 360° wake of the upwind blade hence capturing less energy than the other blade. Due to this effect, H-Rotor turbines consist of three or more blades in the design to allow for smoother operation.

Vertical Axis Wind Turbines have several advantages over the Horizontal Axis designs. Some include:

(i) Components such as generator or gearbox can be positioned on the ground or low levels for easy access and maintenance.
(ii) They do not need any yaw mechanism to turn them in the direction of the wind (Hau, 2006).
(iii) Increased safety since components located at low levels would keep workers away from climbing tall towers for maintenance and repair purposes.

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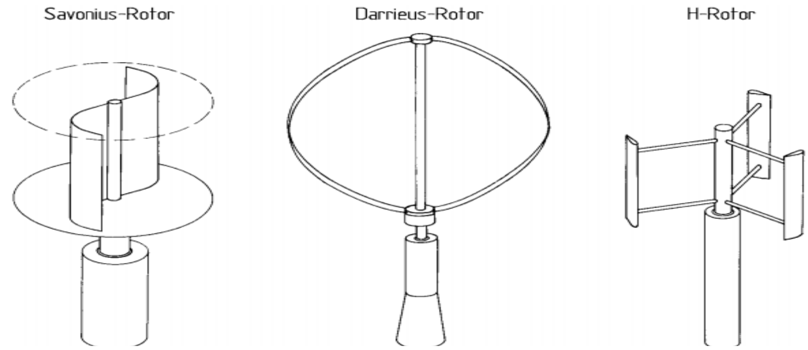


Figure 1: Showing the different configurations of a VAWT

a) Power absorbed in the Wind Stream

Wind turbines are responsible for the transformation of kinetic energy available in the wind stream into mechanical energy. This energy can further be converted into electrical energy once a generator is connected to the system (Hansen, 2015). The maximum available energy, P_{max} once the wind speed attains zero velocity is theoretically given as follows:

$$P_{max} = \frac{1}{2} \times \rho \times A \times V_o^{\,3}$$

Where ρ = density of air in kg/m^3,
A = area where wind speed has been reduced,
V_o = velocity of wind in m/s.

This equation is useful as it demonstrates the increase in power with the cube of the wind as well as an increase with density and area. However, the velocity of the wind cannot be reduced to zero hence a power coefficient, C_p is introduced known as the Coefficient of Performance. This provides the relationship between the actual power extracted and maximum available power in the wind. For ideal turbines, a theoretical C_p value, denoted as the Betz' Limit is given as $\frac{16}{27} = 0.593$. Practically, most wind turbines do not operate near this limit with modern optimized turbines reaching up to 50% efficient at most.

b) Wind Turbine Aerodynamics

An object placed in a path of a wind stream experiences two forces from the wind. These forces are known as aerodynamic forces and can be broken down into a lift force and a drag force. Figure 2 demonstrates a simple rectangular object placed in the path of a wind travelling. When the wind passes over the plate, the plate is pushed, and this is due to the force component that is parallel to the wind direction. However, depending on the angle of the plate, the incoming wind causes a pressure difference on both sides. This pressure difference forces the plate to be pushed upwards as shown in Figure 2. The component of the force that is parallel to the wind stream is called the drag force while the one that is perpendicular is known as the lift force. One of the main factors that gives rise to this movement is the angle of attack with respect to the wind and the object. When the angle of attack is small, the lift force is greater than the drag force and as the angle of attack increases, the drag force significantly increases. Figure 4 shows the lift forces acting on a VAWT in the wind.

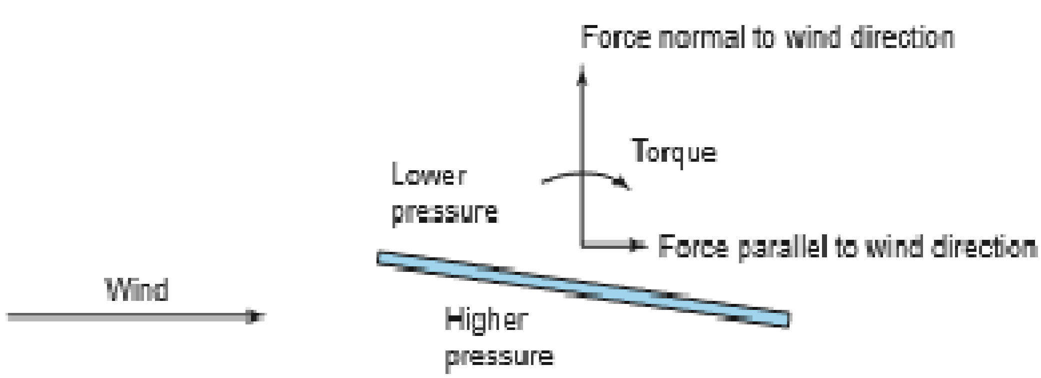


Figure 2: Showing the forces acting on an object submerged in moving air

Wind turbines that rely on lift forces to produce the torque required for rotation incorporates the use of airfoil blades which are similar in concept to plane wings as shown in Figure 3. The same concept applies to the airfoil cross section like that described for the plate shown in Figure 2. These airfoil blades can provide larger lift forces that cause a coupling effect, allowing them to spin quite faster than those that work on the principle of drag while providing a higher efficiency. The blades of VAWT can be supported with the horizontal struts in different orientations. The three main types of blades support can be categorized as (i) cantilever support, (ii) simple support, and (iii) overhang support. To minimize the parasitic drag, cantilever or one horizontal supporting strut per blade is preferred (Ramkissoon, Manohar and Adeyanju 2015). There are a wide variety of different airfoil cross sections with the National Advisory Committee for Aeronautics, NACA, designing many with varying profiles and characteristics.

As shown in Figure 3, the cross section of an airfoil can be broken down into several parts. These are:

a) *Leading Edge* – This is the edge where the incoming air hits the airfoil first.
b) *Trailing Edge* – This is the edge where the air flowing over the surface leaves the aerofoil.
c) *Cambered Airfoil* – Simply known as an asymmetric type airfoil where the 2 side profiles vary.
d) *Chord Line* – The line which connects both the leading and trailing edge.
e) Good airfoils should meet the following requirements:

- Gradual curves,
- Sharp trailing edge,
- Round leading edge,
- Smooth surfaces,
- High lift to drag ratio.

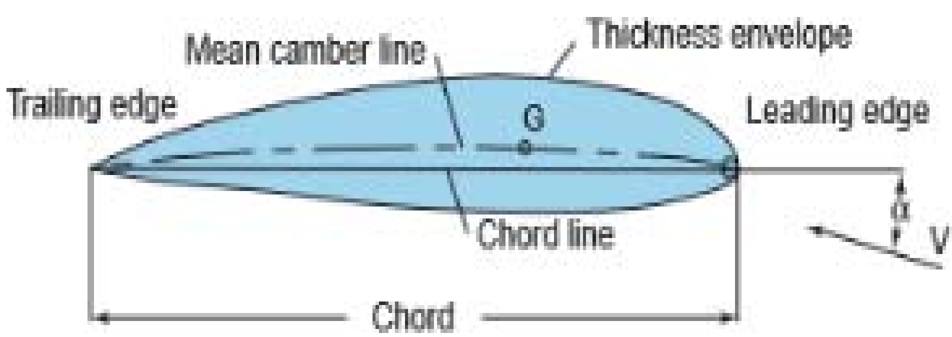


Figure 3: Showing the different parts of an airfoil

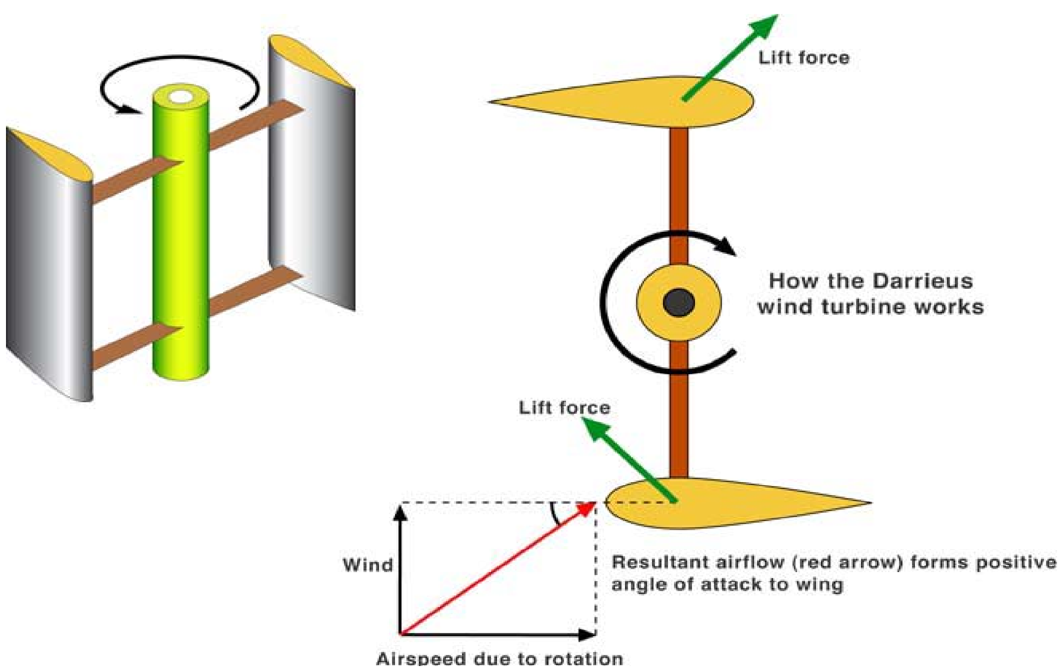


Figure 4: Showing the lift forces acting on a rotating VAWT

c) Developing the Performance Curves for Wind Turbines

Designing and obtaining the performance characteristics of wind turbines are influenced by three main indicators. These are the variation of power, torque and thrust with wind speed (Burton, 2001). Power determines the amount of energy captured and harnessed by the turbine's rotor, the developed torque contributes to the sizing of any gearbox required when matching a generator to a turbine's output while rotor thrust often has significant influence on tower design. Hence assessing and expressing the performance by means of non-dimensional characteristic performance curves is most appropriate regardless of its operational conditions. In making assumptions that no deterioration of aerodynamic performance of the rotor blades occurs, the non-dimensional aerodynamic performance of the rotor blades will be dependent on the tip speed ratios. The tip speed ratio of a wind turbine is a non-dimensional factor and is characterized by the relationship between wind speed and rate of rotation of the rotor. Hence the coefficient of performance, power, torque and thrust parameters can all be expressed as a function of tip speed ratios.

The Coefficient of Performance, C_p of a wind turbine can be obtained from the equation:

$$C_p = \frac{P_{out}}{P_{in}} = \frac{P_{out}}{0.5 \, x \, \rho \, x \, A \, x \, V^3}$$

Where P_{out} is the output mechanical power from the turbine (Watts),
P_{in} is the power input from the wind stream (Watts),
ρ is the air density at area of operation (kg/m^3)
A = rotor area (m^2)
V = velocity of the wind (m/s).
The Tip-Speed Ratio can be calculated as follows:

$$\lambda = \frac{r \, x \, \omega}{V}$$

where r = radius of rotor (m),
ω = rotational speed of turbine (rad/s),
V = velocity of wind (m/s).

The maximum theoretical efficiency of a wind turbine is given by the Betz' Limit of approximately 59% (Ragheb, 2014).

However, most wind turbines in practical operate below this limit and this is shown in Figure 5 where the performance curves for various turbines were developed. For 2-bladed turbines, it can be observed that the maximum efficiency achieved is 45% at an operational tip-speed ratio of 0.6 while efficiencies of 10% and 22% are achieved at its cut-in and cut-out speeds respectively. Hence this data provides an indication that the turbine should operate at its optimum tip-speed ratio to maximize efficiency. The number of blades of a wind turbine contributes to another non-dimensional parameter known as solidity. Solidity is known as the ratio of blade area to the rotor swept area.

Horizontal Axis Wind Turbines with a low number of blades are categorized as low solidity rotors which constitutes to a low fraction of the solid area swept by the turbine's rotor. Due to this, the rotor must now spin faster to extract maximum power from the wind since most of the wind passes unperturbed through the several gaps in the fewer blades present at low speeds. The faster moving rotor would increase the solid area swept by the blades hence allowing the wind turbine to properly harness the energy available.

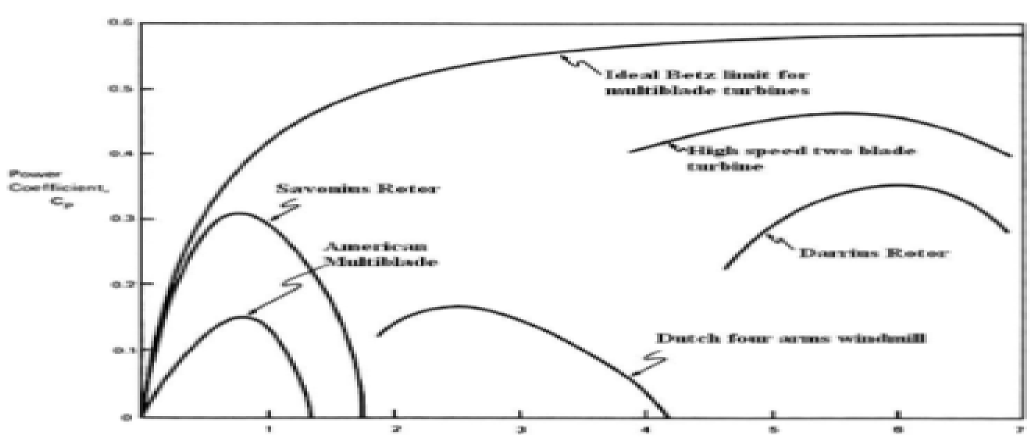


Figure 5: The Coefficient of Performance and Tip Speed Ratio Curves for Various Configurations of Wind Turbines

III. Methodology

A small model was designed and built for testing as shown in Figure 6. NACA 0018 cross-section was chosen to create the airfoil blades due to its thick cross-section and ease of manufacture. The airfoil coordinates were generated online using NACA's Airfoil Plotter and the shape of the airfoil was produced with a chosen design chord length of 0.13m as shown in Figure 7.

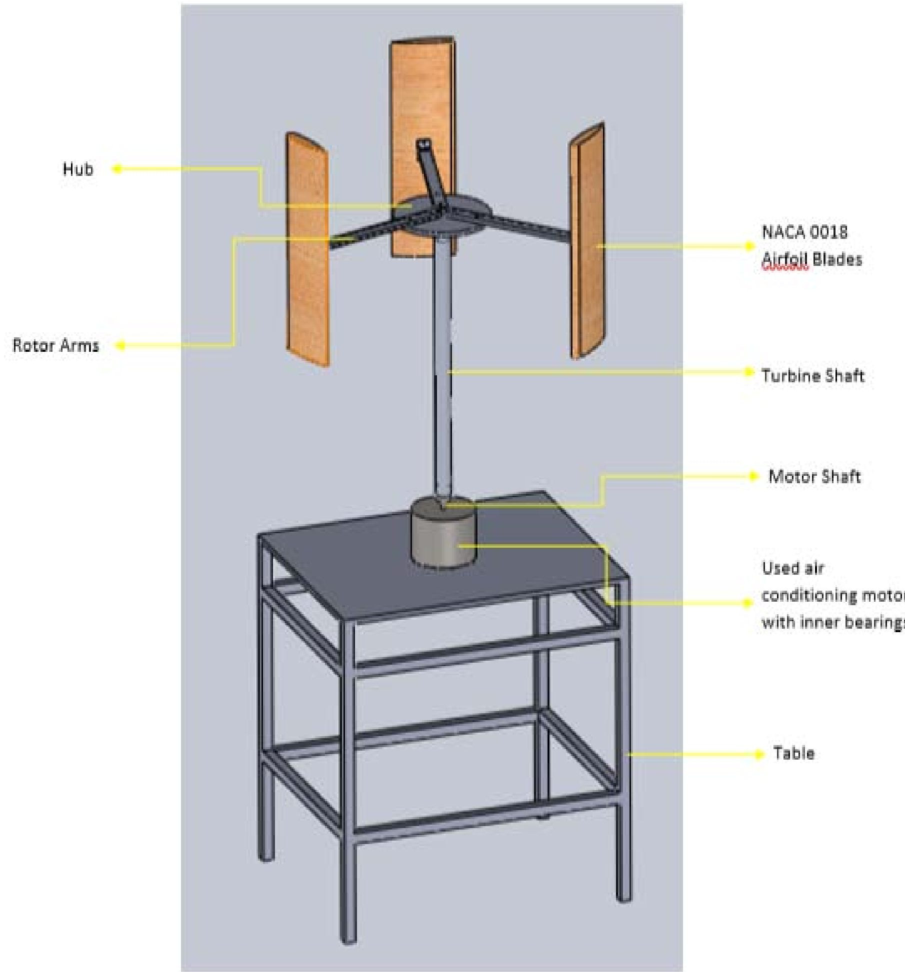
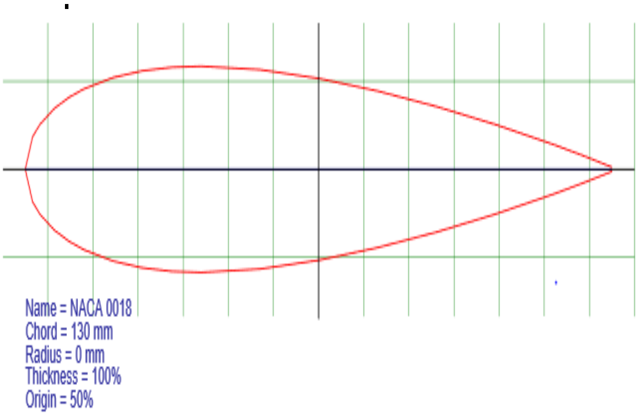


Figure 6: Showing a labelled drawing of the Final Design

Cedar wood was used to construct the blades due to its high strength to weight ratio and its ability to be easily carved into its required shape. Aluminum was the chosen material for the shaft, hub and rotor arms where a hollow 0.038m diameter pipe was used for the shaft at a design length of 0.66m. The hub was constructed using a standard 0.10m thick aluminum sheet with a chosen design diameter of 0.23m. Three hollow aluminum bars measuring 0.03m x 0.01m were used for the rotor arms at a length of 0.36m each. Each blade was mounted onto the arms via two L-shaped aluminum brackets at their centers. The brackets were adjusted to ensure that the blades' chord line was perpendicular to the rotor arms.

NACA 0018

1.00000	0.00189
0.95000	0.01210
0.90000	0.02172
0.80000	0.03935
0.70000	0.05496
0.60000	0.06845
0.50000	0.07941
0.40000	0.08705
0.30000	0.09003
0.25000	0.08912
0.20000	0.08606
0.15000	0.08018
0.10000	0.07024
0.07500	0.06300
0.05000	0.05332
0.02500	0.03922
0.01250	0.02841
0.00000	0.00000
0.01250	-0.02841
0.02500	-0.03922
0.05000	-0.05332
0.07500	-0.06300
0.10000	-0.07024
0.15000	-0.08018
0.20000	-0.08606
0.25000	-0.08912
0.30000	-0.09003
0.40000	-0.08705
0.50000	-0.07941
0.60000	-0.06845
0.70000	-0.05496
0.80000	-0.03935
0.90000	-0.02172
0.95000	-0.01210
1.00000	-0.00189



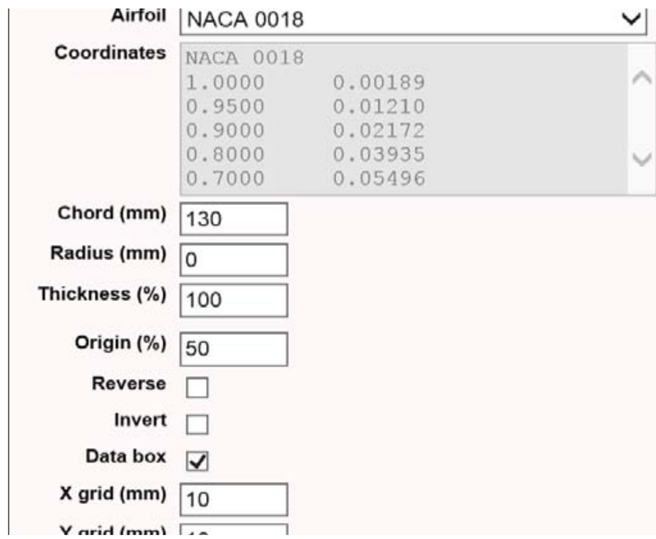


Figure 7: NACA 0018 Airfoil Cross-Section and Coordinates

To allow for rotation, a used air-conditioning motor was used where the wind turbine's shaft was fixed onto the motor's shaft. The motor's shaft was mounted onto the motor bearings found inside. This was selected due to ease of rotation and lack of friction generated by the inner bearings. The entire wind turbine was then bolted onto a wooden table with steel legs of 0.77m tall which was fixed onto the ground during testing for increased height and stability. The height of the entire device including the table measured approximately 1.7m. A Solid Works simulation of the rotor arms is provided in Figures 8, 9 and 10. Figure 8 shows the stress analysis of the rotor arm, Figure 9 the factor of safety while Figure 10 highlighted the displacement plot.

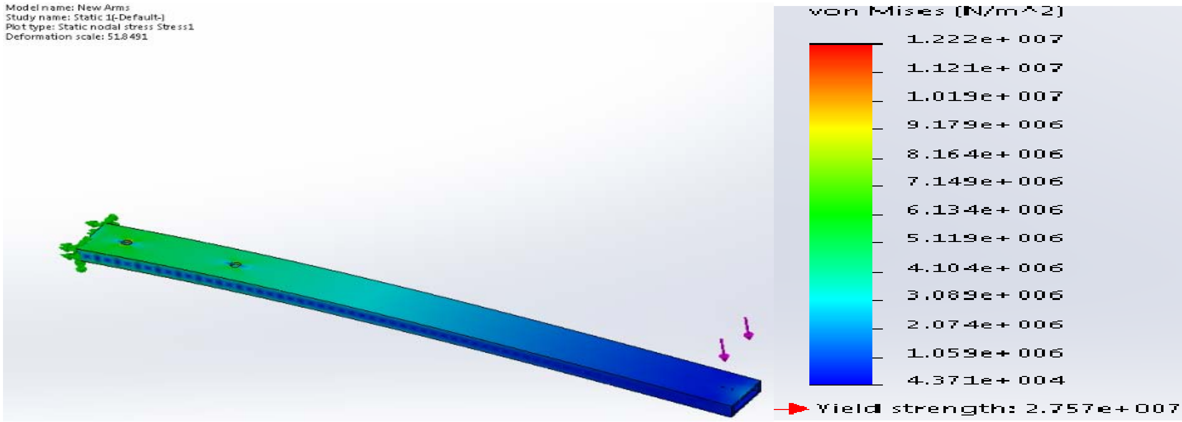


Figure 8: Stress Plot of the rotor arm on SolidWorks Simulation

The Stress Plot of the rotor arm obtained on Solid Works Simulation highlighted that the maximum stresses induced in the component due to the weight of the blades did not exceed the yield strength of the material used. This showed that the arms did not fail under the required loading.

From Figure 9, it can be shown that a minimum factor of safety of 2.3 was achieved from the program. A factor of safety of 3 was utilized for the design calculations with both sets of values being almost consistent. The maximum deflection of the arm was found to be 6.945 x 10^{-001} mm as shown in Figure 10.

When conducting the simulation, a fixed-joint was used in the program while a static load of 6.11N was applied to the free end where the blade is to be positioned.

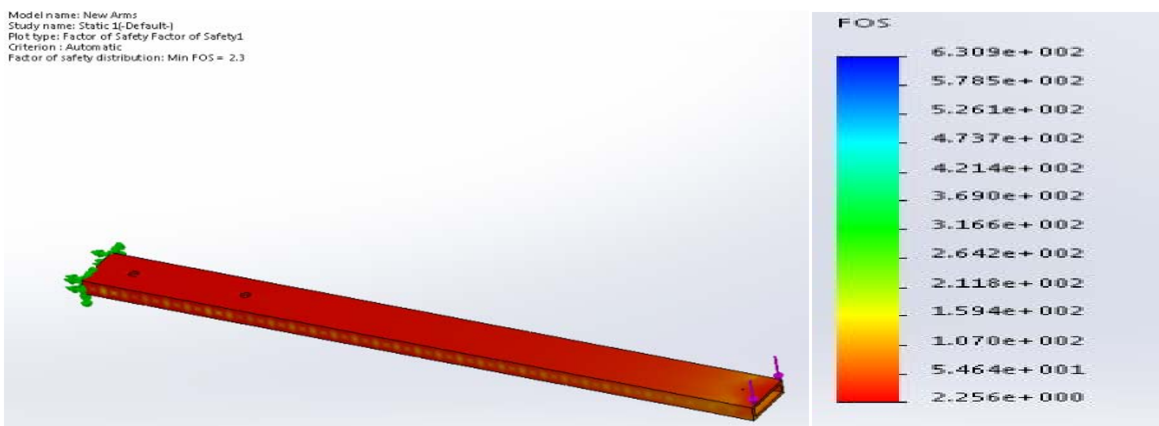


Figure 9: Factor of Safety Plot on Solid Works Simulation

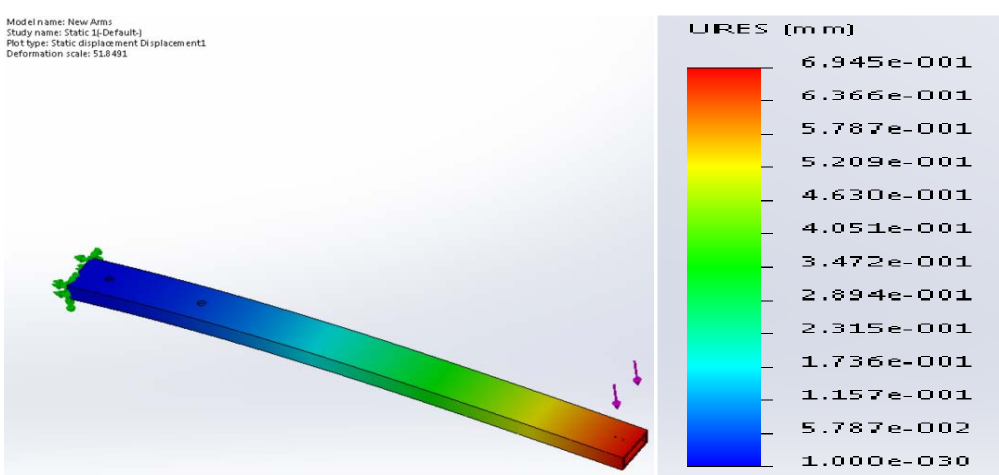


Figure 10: Displacement Plot on Solid Works Simulation

a) Experimentation and Data Collection

The wind turbine was tested on a hill top at Gran Couva, Trinidad so as to achieve a wide range of wind speeds for data analysis. The hill top was selected due to the absence of buildings and structures which contribute to wind shear and turbulence of the wind.

To obtain the power output of the wind turbine at different wind speeds, a simple dynamometer system was constructed as shown in Figure 11.

A spring scale was used to measure the force output as opposed to a self-calibrated spring since the spring balance had already been calibrated from the factory and would produce more accurate results. A simple spring was also not utilized because upon extension, the spring can sag at the center due to its horizontal layout, affecting the readings. A small rubber belt of circular cross-section was chosen.

Figure 11: Showing the dynamometer built

Table 1: Showing the measured values of rotational speed and mass reading at different wind speeds

Wind Speed (m/s)	Revolutions per minute (RPM)	Mass Reading on Spring Scale (kg)	Force (N)
0.95	10.50	0.060	0.59
1.12	20.63	0.080	0.78
1.44	25.02	0.12	1.18
1.84	34.38	0.22	2.16
1.93	36.38	0.24	2.35
2.67	55.95	0.42	4.12
3.14	59.97	0.60	5.89
3.68	83.08	0.72	7.06
4.15	107.05	0.80	7.85
4.24	119.37	0.80	7.85

A flat-type rubber belt provided too much friction with the rotating pulley mounted onto the shaft, creating a "jumping" action during contact. Hence a thin rubber belt of circular cross section was settled upon which provided sufficient frictional contact with the pulley. The spring scale was bolted onto a wooden block where one end of the belt was attached, and the other end connected to a hand-adjustable wooden block. The angle of wrap was varied to ensure sufficient frictional contact of the belt was made with the pulley during rotation.

The force exerted by the turbine's shaft and rotational speed of the shaft were recorded at different wind speeds as shown in Table 1.

Since parameters such as wind speed, rotational speed and force output needed to be measured simultaneously, three persons were involved in recording the values. The results obtained were then utilized in obtaining the Tip Speed Ratios and Efficiencies of the wind turbine at different wind speeds as shown in Table 2.

Table 2: Showing the calculated values of Tip Speed Ratio and Coefficient of Performance

Tip Speed Ratio (TSR)	Coefficient of Performance (%)
0.44	14.80
0.69	19.61
0.73	22.90
0.75	23.60
0.76	23.00
0.78	24.00
0.84	24.08
0.89	23.40
1.02	23.40
1.04	24.40

IV. Results and Discussion

Based on the results obtained from Table 2, a graph of Coefficient of Performance against Tip Speed Ratio was plotted as shown in Figure 12. This figure provides information on how the efficiency of the turbine varies with a non-dimensional parameter known as the tip speed ratio. Vertical Axis Wind Turbines (VAWT) operating on the concept of lift usually have tip speed ratios greater than 1 which implies that they are capable of rotating faster than the wind stream. The graph can also be used to determine the optimum operating conditions of the wind turbine. This is where at a certain value of tip speed ratio, the wind turbine has the highest efficiency and must be designed to operate in these conditions.

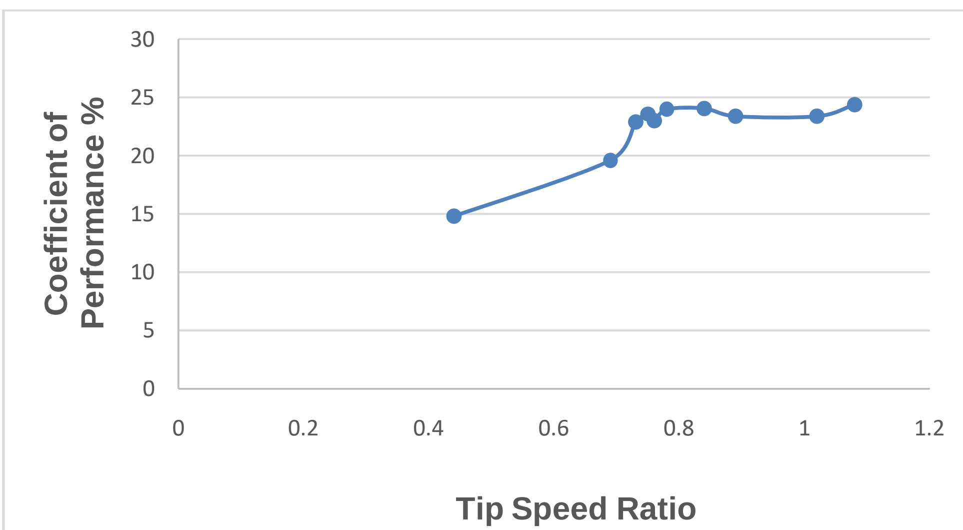


Figure 12: Graph Showing the Coefficient of Performance against Tip Speed Ratio

However, the optimum conditions of the prototype were not obtained due to a limited range of wind speeds available during testing. As shown in Figure 12, there is an increase in turbine efficiency with an increase in tip speed ratio. However, due to practical conditions the absence of a wide range of wind speeds limited the results obtained hence a maximum tip speed ratio of 1.08 was achieved with a coefficient of performance of 24.4%. This was achieved for a rotor solidity of 0.51.

At low tip speed ratios, less than 1, it can be observed from Figure 13 that the wind turbine generally has low efficiencies. This occurs because the rotor spins quite slowly, allowing the incoming air to pass through the gaps in the rotor. Hence, the wind turbine is not able to maximize the energy from the wind. The efficiency increases with tip speed ratio until it reaches its optimum conditions. This is usually represented by a peak in the curve as shown in Figure 13.

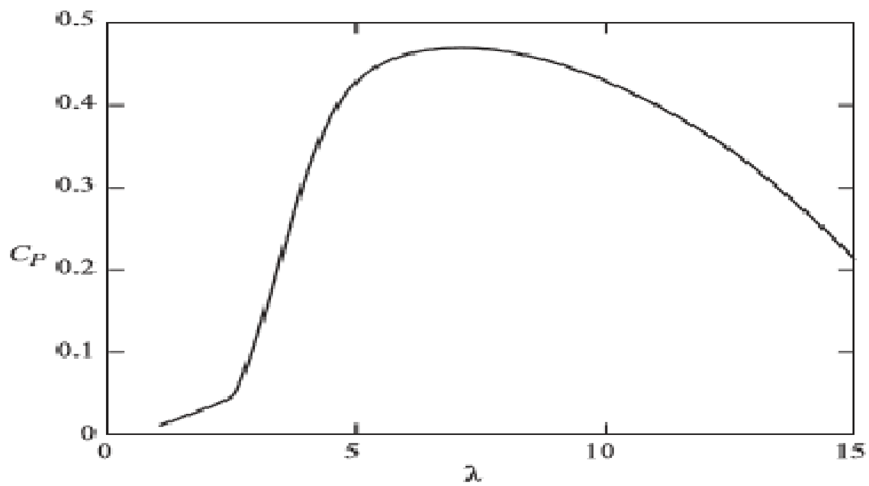


Figure 13: Showing the plot of Coefficient of Performance against Tip Speed Ratio for a 3-bladed Horizontal Axis Wind Turbine

After reaching its optimum operating conditions, the efficiencies tend to decrease with increasing tip speed ratios despite the turbine spinning at high speeds. This occurs because the rotor rotates very quickly acting as a solid wall. The incoming wind is now blocked from penetrating the turbine's rotor and the turbine is not able to harness enough energy from the wind. Theoretically, wind turbines can extract approximately 59% of the wind energy.

Based on the results obtained, the maximum efficiency of the turbine under limited testing conditions was found to be 24.4% with the potential to be more efficient at higher wind speeds and tip speed ratios. A fairly low rotor solidity of 0.51 provides an indicator of the potential of the wind turbine to attain higher efficiencies. The use of the handmade dynamometer could have played a part in limiting the power output due to slippage between the belt and rotating pulley inducing power losses and affecting the efficiency of the device at varying wind speeds. The presence of the rotor arms could have also affected the air flow over the airfoil, therefore inducing losses and affecting the efficiency of the device.

Vertical Axis Wind Turbines are known to have low starting torques where some of them make use of a starter motor for rotation to commence. Upon testing the prototype, it was found that the wind turbine started spinning at a wind speed as low as 0.95m/s. No assistance was given to the device to start spinning. A graph of power output against wind speed for the prototype was plotted as shown in Figure 14.

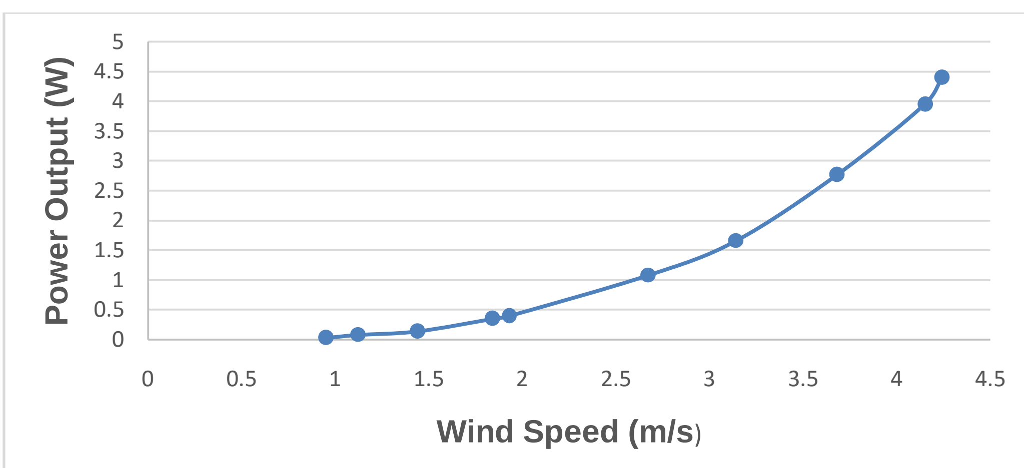


Figure 14: Graph Showing the Power Output against Wind Speed

It can be observed that the wind turbine started producing power at approximately 1.5m/s where there is an exponential increase of power generated by the device with increasing wind speeds.

For an increase in wind velocity, it can be observed that there is an increase with the tip speed ratios as well as shown in Figure 15.

The tip speed ratios increase up to approximately 1.08 at a wind speed of 4.24m/s. This means that the wind turbine was spinning about the same speed of the wind which is not consistent with lift-type devices. However, at higher wind speeds, there could have been higher tip speed ratios, greater than 1, indicating that the turbine is rotating quicker than the speed of the wind.

At high tip speed ratios, usable power can be extracted from the turbine for generating electricity.

At high speeds, wind turbines are subjected to high stresses that can cause the components to fall apart. Wind turbines are usually designed with stall, a similar concept experienced by aircrafts. Wind turbines can either be stall-regulated or pitch-regulated. Pitch-regulated wind turbines usually consist of an active control system where the pitch angle is varied. This is performed by turning the blade about its own axis where the torque and rotational speed are significantly reduced at high wind speeds.

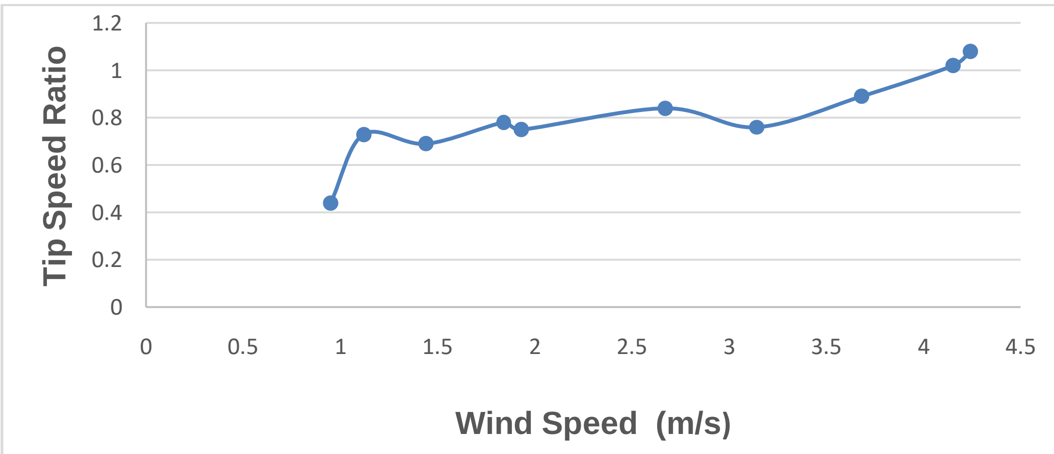


Figure 15: Graph Showing Tip Speed Ratio against Wind Speed

The blades pitch, causing turbulence of the wind flowing over the airfoil surface breaking up the lift and inducing drag forces. Pitch-regulated wind turbines experience increasing power up to rated wind speed after which the power output remains constant. Stall-regulated wind turbines however, depend on their blade design to reduce lift forces at high wind speeds, reducing the power output of the turbine. A stall mechanism was not incorporated in the prototype and the rotating turbine was decelerated and stopped by hand due to the absence of a braking mechanism.

V. Conclusion

The main objective of this project was to design, build and test of a Vertical Axis Wind Turbine (VAWT). A lift-type device was constructed, and two days of testing were performed at a hill-top. Upon testing, the following data was obtained:

The wind turbine began spinning in wind speeds as low as 0.95m/s.

There was an increase in turbine efficiency with tip speed ratio which was consistent with existing lift-type turbines.

Under limited wind speeds, a maximum tip-speed ratio of 1.08 for a rotor solidity of 0.51 was achieved which meant that the turbine was spinning just as quickly as the wind. However, lift-type VAWT usually have tip speed ratios greater than 1 and this could have been obtained at higher wind speeds.

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Vacuum Assisted Climbing Device

By Shyam Lal Sharma & Shahzad Ali

Abstract- Vacuum Assisted Climbing Device is a new way to climb vertical surfaces like wall,buildings easily and faster than the conventional methods like ladders and ropes etc.

This device works on the vacuum to climb the vertical surfaces as its name indicate and this vacuum is utilized by two suction pads which are available in the hands of the climber and the suction pads are connected with the suction motor (vacuum pump) with the hoses.

Keywords: suction pads, vacuum pressure (suction force), suction motor (vacuum motor).

GJRE-A Classification: FOR Code: 091399

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This device works on the vacuum to climb the vertical surfaces as its name indicate and this vacuum is utilized by two suction pads which are available in the hands of the climber and the suction pads are connected with the suction motor (vacuum pump) with the hoses.

With the help of vacuum suction pad we can climb vertical surfaces like wall easily and without causing damage to the contact surface, their suction force should be designed by considering both external condition and the loads of working equipment.

In this project we performed a basic experiment on the vacuum suction force of suction pads attached to a vertical wall under various load condition.

This mechanism enables a person to climb up wall and remain suspended with no handholds.

Keywords: suction pads, vacuum pressure (suction force), suction motor (vacuum motor).

I. Introduction

Vacuum Assisted Climbing Device is a wall climbing machine which uses vacuum as a source to climb the vertical surface through the suction which utilizes the vacuum, created by the vacuum pump (suction motor).

This is a wall climbing machine which uses its vacuum pumps (suction motor) to produce a grip against the wall surfaces. It can climb up to any height on any surface including glass, brick or without a rope. But the most important element was to come up with technology that can grip to any vertical surface.

So we developed this machine which is made from two pads and suction motor which are connected to each other with the hoses for air suction and wire for the electrical supply. The pads are made up of MDF (medium density fiber) board and the latex rubber.

The suction pads are designed after the pressure and force calculation which is done by using the pressure at the end of the suction line and the area of the suction pad (inner and outer area of the pads have to be measured) .

As we know in the many industries suction pads are used for material handling even in robotics the suction cups are used to hold the object and provide a complete grip to the user.

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Thus we design the suction pad which are connected to the suction motor which sucks the air from the pad's inner area and create the vacuum which enable the pad to stick on the wall without damaging it and provide a proper grip to the user.

The effectiveness of the pads are totally depend on the vacuum pump and the area of the pad and the material of the rubber which works as blocking agent or make the pad leakage free.

The rubber which we use to make the pad is latex rubber which has good water and temperature resistant property and is stronger than the natural rubber which also increases the life and the efficiency of the pad.

We have tried to make the complete device as light as it possible which allow the user to make irritation less effort to climb the vertical surfaces, and we use the synthetic plastic strips to make the leg linkage which is used to tow the heavy loads like vehicle and heavy containers as we need to carry all the load on a single pad with this linkage on hold position or while stepping upward.

We can climb the wall by using the ON/OFF switch which is provided near to the handle of the pad by active and inactive the pad with this switch along with the movement of the corresponding leg linkage.

II. Methodology

After some research, a human climbing mechanism known as PVAC (Personnel Vacuum Assisted Climber) engineered by Utah University UG students was found. As papers about their work were not available, a from-the-scratch approach was adopted for designing.

To check the feasibility of the we perform an experiment with the suction pad which was made up of plywood and the home vacuum cleaner pump, which was enable to stick on the wall. The initial prototype system could bear a load of up to a 100kg, which was encouraging.

The dimension of the suction pads were obtained from design analysis and for this reverse engineering approach was adopted in designing the equipment.

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Fig. 2.1: Front view of suction pad while looking from face and the rubber used in the suction pad.

Fig. 2.2: Picture of a suction pad while testing

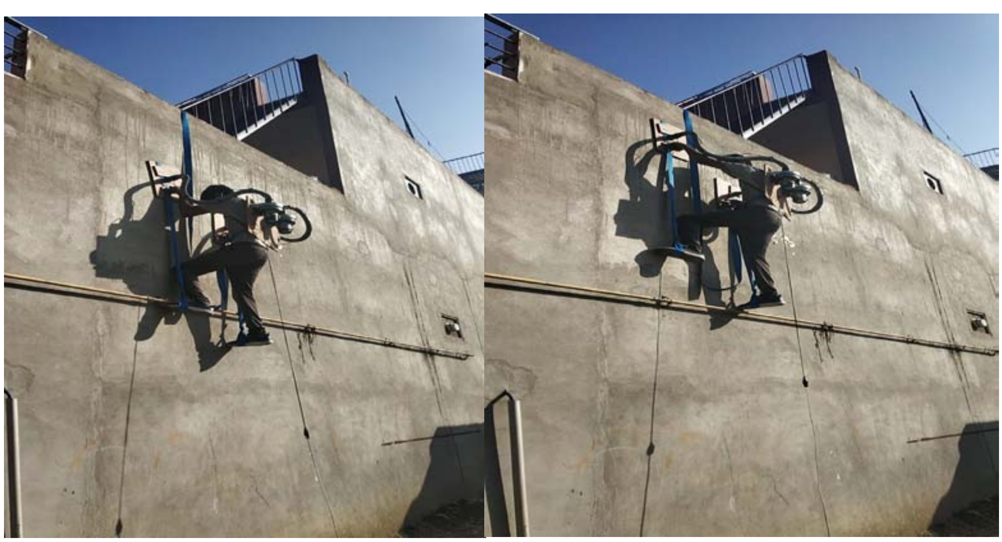

Fig. 2.3: Climbing with the help of VACD

III. Components of Vacuum Pssisted Climbing Device

a) Vacuum pump (Suction motor)

It is the heart of the system which runs the complete system by creating the vacuum in the suction pad cavity, which allows the pads to stick on the surface of the wall with the help rubber.

b) Electric source and wires

An A.C power supply has to provide the system so that vacuum pump (suction motor) can run and whole system can start their function.

3. Hose pipelines

It creates the connection between vacuum pump and the suction pad which help and provide a path to the vacuum pump to suck the air from the pad cavity.

c) Suction pads

Suction pads are the second most important part of the system by which a climber can climb the wall and whole weight would be bear by the suction pad at halt position, thus it must be strong enough to bear a sustainable load of the climber and some objects that would be carried by the climber.

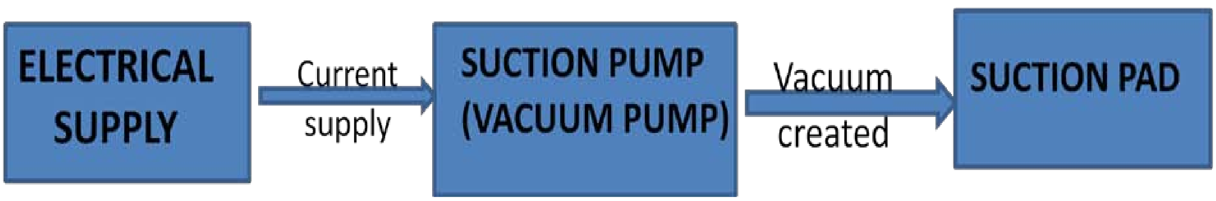

Fig. 3.1: Block diagram of a vacuum assisted climbing device working component

IV. Designing Parameters

In order to find the maximum normal load acting on the equipment, the vacuum pressure generated by the motor is measured. A vacuum gauge is used for finding the pressure at the suction end.

Vacuum pressure at the end of the suction line

= 200mmHg (mm of mercury) (note 1mmHg= 0.00133bar)
= 200mmHg = 0.26675 bar.

Standard atmospheric pressure (P.atm) = 1.013 bar
Absolute pressure at the end of suction line (Pab)
=(Standard atmospheric pressure)–(vacuum pressure at the end of suction line).

=(1.013 – 0.2667)

= 0.7462 bar.

Area of suction pad

Inside area = 0.2794×0.2286 m2 = 0.0638m2
Outside area = 0.3556 × 0.3048 m2 = 0.108 m2

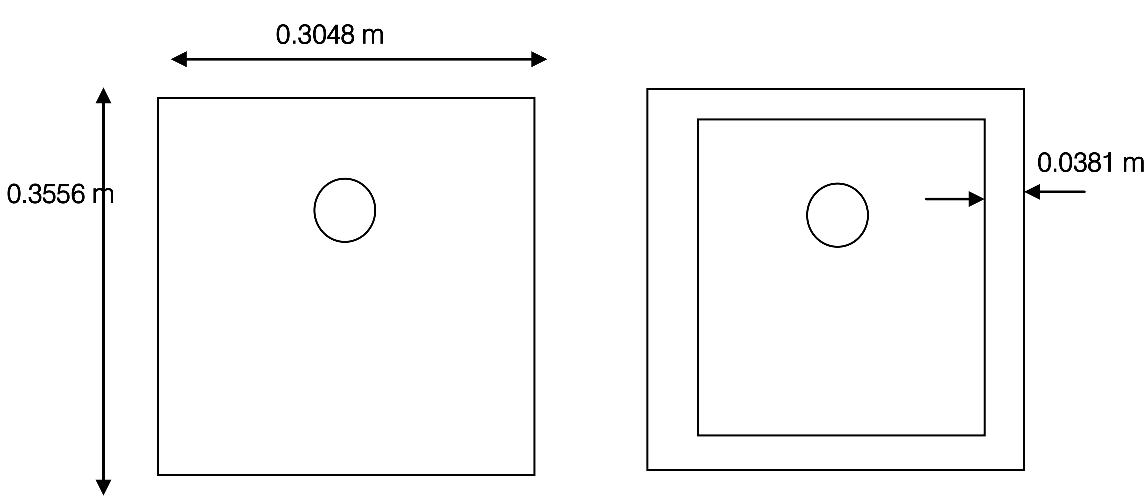

Fig. 4.1: Pads Dimensions Pressure Force

Pressure Force

Pressure Force = Pout × A out – Pin × A in

= (1.013 × 0.108 - 0.7462 × 0.0638)

= (10940.4-4760.76) N

= 6179.64 N~6000 N

Maximum normal load

Maximum normal load (in kg) = 6000/ 9.8

= 612.24 ~600 kg.

There is a safe altitude up to which the equipment can safely operate. Also it depends upon the load acting on equipment. Since he machine has an ultimate normal load capacity of 600 kg, margin of 200 kg is given. SO the ultimate is 400 kg.

Safe load

Assuming factor of safety= 3

Note:-As per standardization we need to take higher value of the fos for lifting device thus we take it 3.

Safe load = 400/3

=133.33~120 kg

= 120 Kg

V. Fabrication

a) The properties of the rubber used for pads

1. Latex rubber is generally made up of around (55 to 65)% water and (30 to 40)% of rubber material.
2. It also contain sugar, resin, protein and ash, it undergoes exposure to sulfur, carbon black and oil which make the latex stronger.
3. The most ideal working temperature range is between -55 degrees Celsius and 82 degree Celsius.
4. It is water resistant and stronger than natural rubber.

b) Procedure to make pads and the complete device

- Firstly cut the MDF (Mean Density Fiber) board in the desired dimensions.
- Then cut the latex rubber in the desired dimensions.
- Then drilled a hole of 0.0508m in the board to fix the hoses.
- Then remove some material from the MDF board where the rubber needs to be fixed, with the help of emery paper.
- Then paste the latex rubber with the help of araldite and clamp them for overnight and let it dry.
- Once the rubber is pasted on the board then make the wire and hose connection with the vacuum motor (suction motor).
- Add an ON/OFF switch on the each pad.
- In this device two vacuum pump and two pads are used.

VI. Conclusion

Firstly we have tested the pad with suction motor having the capacity of 600W but there was some leakage in the pad thus test was failed then we had glued the rubber on the plywood pad again to remove the leakage.

Second time we used the suction motor having capacity of 1500W and we used MDF (Medium Density Fiber) board which is light in weight and has good strength to carry load and design the pads as per the calculation after the final test we conclude this vacuum assisted climber is the best option for the wall climbing. This vacuum assist wall climber gives chance to carry heavy work to the climb and its bonding would withstand 100kg load.

We make the entire system with less weighted and aesthetics and ergonomic consideration this assist wall climber reduce the human efforts. The equipment provides high load carrying capacity. The designing and testing stages were successful and performance of the equipment was found excellent.

The future scope of the equipment includes addition of the individual sensors in each suction pad and addition of the compact batteries.

Each time suction pad and adhere to surface, the pressure inside the suction pad varies. It is necessary to ensure that the suction created is sufficient for holding the weight.

Another scope is addition of compact high power batteries. This will increase the flexibility of the operation. Also addition of battery level sensor is a need to indicate battery level.

In the future the mechanism can be automated with the help of sensors and the artificial intelligence which may increase its durability and the life of the machine.

Acknowledgement

On the very outset of this report, we would like to extent our sincere & heartfelt obligation towards the entire personage who helped us in this Endeavour. Without their active guidance, help, cooperation & encouragement, we would not have made headway in this paper.

We are extremely thankful to our faculty guide *Mr. Shyam Lal Sharma (Assistant Professor ME dept.)* for their valuable guidance and support for completion of this paper.

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Last but not the least, gratitude goes to all my friends who directly or indirectly helped us to complete this paper.

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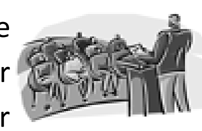

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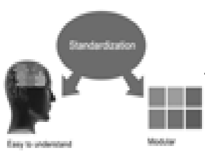

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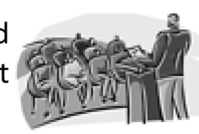

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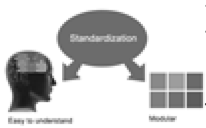

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Numerical methods used should be transparent and, where appropriate, supported by references.

Abbreviations

Authors must list all the abbreviations used in the paper at the end of the paper or in a separate table before using them.

Formulas and equations

Authors are advised to submit any mathematical equation using either MathJax, KaTeX, or LaTeX, or in a very high-quality image.

Tables, Figures, and Figure Legends

Tables: Tables should be cautiously designed, uncrowned, and include only essential data. Each must have an Arabic number, e.g., Table 4, a self-explanatory caption, and be on a separate sheet. Authors must submit tables in an editable format and not as images. References to these tables (if any) must be mentioned accurately.

Figures

Figures are supposed to be submitted as separate files. Always include a citation in the text for each figure using Arabic numbers, e.g., Fig. 4. Artwork must be submitted online in vector electronic form or by emailing it.

Preparation of Eletronic Figures for Publication

Although low-quality images are sufficient for review purposes, print publication requires high-quality images to prevent the final product being blurred or fuzzy. Submit (possibly by e-mail) EPS (line art) or TIFF (halftone/ photographs) files only. MS PowerPoint and Word Graphics are unsuitable for printed pictures. Avoid using pixel-oriented software. Scans (TIFF only) should have a resolution of at least 350 dpi (halftone) or 700 to 1100 dpi (line drawings). Please give the data for figures in black and white or submit a Color Work Agreement form. EPS files must be saved with fonts embedded (and with a TIFF preview, if possible).

For scanned images, the scanning resolution at final image size ought to be as follows to ensure good reproduction: line art: >650 dpi; halftones (including gel photographs): >350 dpi; figures containing both halftone and line images: >650 dpi.

Color charges: Authors are advised to pay the full cost for the reproduction of their color artwork. Hence, please note that if there is color artwork in your manuscript when it is accepted for publication, we would require you to complete and return a Color Work Agreement form before your paper can be published. Also, you can email your editor to remove the color fee after acceptance of the paper.

Tips for Writing a Good Quality Engineering Research Paper

Techniques for writing a good quality engineering research paper:

1. Choosing the topic: In most cases, the topic is selected by the interests of the author, but it can also be suggested by the guides. You can have several topics, and then judge which you are most comfortable with. This may be done by asking several questions of yourself, like "Will I be able to carry out a search in this area? Will I find all necessary resources to accomplish the search? Will I be able to find all information in this field area?" If the answer to this type of question is "yes," then you ought to choose that topic. In most cases, you may have to conduct surveys and visit several places. Also, you might have to do a lot of work to find all the rises and falls of the various data on that subject. Sometimes, detailed information plays a vital role, instead of short information. Evaluators are human: The first thing to remember is that evaluators are also human beings. They are not only meant for rejecting a paper. They are here to evaluate your paper. So present your best aspect.

2. Think like evaluators: If you are in confusion or getting demotivated because your paper may not be accepted by the evaluators, then think, and try to evaluate your paper like an evaluator. Try to understand what an evaluator wants in your research paper, and you will automatically have your answer. Make blueprints of paper: The outline is the plan or framework that will help you to arrange your thoughts. It will make your paper logical. But remember that all points of your outline must be related to the topic you have chosen.

3. Ask your guides: If you are having any difficulty with your research, then do not hesitate to share your difficulty with your guide (if you have one). They will surely help you out and resolve your doubts. If you can't clarify what exactly you require for your work, then ask your supervisor to help you with an alternative. He or she might also provide you with a list of essential readings.

4. Use of computer is recommended: As you are doing research in the field of research engineering then this point is quite obvious. Use right software: Always use good quality software packages. If you are not capable of judging good software, then you can lose the quality of your paper unknowingly. There are various programs available to help you which you can get through the internet.

5. Use the internet for help: An excellent start for your paper is using Google. It is a wondrous search engine, where you can have your doubts resolved. You may also read some answers for the frequent question of how to write your research paper or find a model research paper. You can download books from the internet. If you have all the required books, place importance on reading, selecting, and analyzing the specified information. Then sketch out your research paper. Use big pictures: You may use encyclopedias like Wikipedia to get pictures with the best resolution. At Global Journals, you should strictly follow here.

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

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

8. Make every effort: Make every effort to mention what you are going to write in your paper. That means always have a good start. Try to mention everything in the introduction—what is the need for a particular research paper. Polish your work with good writing skills and always give an evaluator what he wants. Make backups: When you are going to do any important thing like making a research paper, you should always have backup copies of it either on your computer or on paper. This protects you from losing any portion of your important data.

9. Produce good diagrams of your own: Always try to include good charts or diagrams in your paper to improve quality. Using several unnecessary diagrams will degrade the quality of your paper by creating a hodgepodge. So always try to include diagrams which were made by you to improve the readability of your paper. Use of direct quotes: When you do research relevant to literature, history, or current affairs, then use of quotes becomes essential, but if the study is relevant to science, use of quotes is not preferable.

10. Use proper verb tense: Use proper verb tenses in your paper. Use past tense to present those events that have happened. Use present tense to indicate events that are going on. Use future tense to indicate events that will happen in the future. Use of wrong tenses will confuse the evaluator. Avoid sentences that are incomplete.

11. Pick a good study spot: Always try to pick a spot for your research which is quiet. Not every spot is good for studying.

12. Know what you know: Always try to know what you know by making objectives, otherwise you will be confused and unable to achieve your target.

13. Use good grammar: Always use good grammar and words that will have a positive impact on the evaluator; use of good vocabulary does not mean using tough words which the evaluator has to find in a dictionary. Do not fragment sentences. Eliminate one-word sentences. Do not ever use a big word when a smaller one would suffice.

Verbs have to be in agreement with their subjects. In a research paper, do not start sentences with conjunctions or finish them with prepositions. When writing formally, it is advisable to never split an infinitive because someone will (wrongly) complain. Avoid clichés like a disease. Always shun irritating alliteration. Use language which is simple and straightforward. Put together a neat summary.

14. 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 for your topic. You may also maintain your arguments with records.

15. Never start at the last minute: Always allow enough time for research work. Leaving everything to the last minute will degrade your paper and spoil your work.

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

17. Never copy others' work: Never copy others' work and give it your name because if the evaluator has seen it anywhere, you will be in trouble. Take proper rest and food: No matter how many hours you spend on your research activity, if you are not taking care of your health, then all your efforts will have been in vain. For quality research, take proper rest and food.

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

19. Refresh your mind after intervals: Try to give your mind a rest by listening to soft music or sleeping in intervals. This will also improve your memory. Acquire colleagues: Always try to acquire colleagues. No matter how sharp you are, if you acquire colleagues, they can give you ideas which will be helpful to your research.

20. Think technically: Always think technically. If anything happens, search for its reasons, benefits, and demerits. Think and then print: When you go to print your paper, check that tables are not split, headings are not detached from their descriptions, and page sequence is maintained.

21. Adding unnecessary information: Do not add unnecessary information like "I have used MS Excel to draw graphs." Irrelevant and inappropriate material is superfluous. Foreign terminology and phrases are not apropos. One should never take a broad view. Analogy is like feathers on a snake. Use words properly, regardless of how others use them. Remove quotations. Puns are for kids, not grunt readers. Never oversimplify: When adding material to your research paper, never go for oversimplification; this will definitely irritate the evaluator. Be specific. Never use rhythmic redundancies. Contractions shouldn't be used in a research paper. Comparisons are as terrible as clichés. Give up ampersands, abbreviations, and so on. Remove commas that are not necessary. Parenthetical words should be between brackets or commas. Understatement is always the best way to put forward earth-shaking thoughts. Give a detailed literary review.
22. Report concluded results: Use concluded results. From raw data, filter the results, and then conclude your studies based on measurements and observations taken. An appropriate number of decimal places should be used. Parenthetical remarks are prohibited here. Proofread carefully at the final stage. At the end, give an outline to your arguments. Spot perspectives of further study of the subject. Justify your conclusion at the bottom sufficiently, which will probably include examples.
23. Upon 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 for 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 of your research.

Informal Guidelines of Research Paper Writing

Key points to remember:

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

Final points:

One purpose of organizing a research paper is to let people interpret your efforts selectively. The journal requires the following sections, submitted in the order listed, with each section starting on a new page:

The introduction: This will be compiled from reference matter and reflect the design processes or outline of basis that directed you to make a study. As you carry out the process of study, the method and process section will be constructed like that. The results segment will show related statistics in nearly sequential order and direct reviewers to similar intellectual paths throughout the data that you gathered to carry out your study.

The discussion section:

This will provide understanding of the data and projections as to the implications of the results. The use of good quality references throughout the paper will give the effort trustworthiness by representing an alertness to prior workings.

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

General style:

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

To make a paper clear: Adhere to recommended page limits.

Mistakes to avoid:

- Insertion of a title at the foot of a page with subsequent text on the next page.
- Separating a table, chart, or figure—confine each to a single page.
- Submitting a manuscript with pages out of sequence.
- In every section of your document, use standard writing style, including articles ("a" and "the").
- Keep paying attention to the topic of the paper.

- Use paragraphs to split each significant point (excluding the abstract).
- Align the primary line of each section.
- Present your points in sound order.
- Use present tense to report well-accepted matters.
- Use past tense to describe specific results.
- Do not use familiar wording; don't address the reviewer directly. Don't use slang or superlatives.
- Avoid use of extra pictures—include only those figures essential to presenting results.

Title page:

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

Abstract: This summary should be two hundred words or less. It should clearly and briefly explain the key findings reported in the manuscript and must have precise statistics. It should not have acronyms or abbreviations. It should be logical in itself. Do not cite references at this point.

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

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

Reason for writing the article—theory, overall issue, purpose.

- Fundamental goal.
- To-the-point depiction of the research.
- Consequences, including definite statistics—if the consequences are quantitative in nature, account for this; results of any numerical analysis should be reported. Significant conclusions or questions that emerge from the research.

Approach:

- Single section and succinct.
- An outline of the job done is always written in past tense.
- Concentrate on shortening results—limit background information to a verdict or two.
- Exact spelling, clarity of sentences and phrases, and appropriate reporting of quantities (proper units, important statistics) are just as significant in an abstract as they are anywhere else.

Introduction:

The introduction should "introduce" the manuscript. The reviewer should be presented with sufficient background information to be capable of comprehending and calculating the purpose of your study without having to refer to other works. The basis for the study should be offered. Give the most important references, but avoid making a comprehensive appraisal of the topic. Describe the problem visibly. If the problem is not acknowledged in a logical, reasonable way, the reviewer will give no attention to your results. Speak in common terms about techniques used to explain the problem, if needed, but do not present any particulars about the protocols here.

The following approach can create a valuable beginning:

- Explain the value (significance) of the study.
- Defend the model—why did you employ this particular system or method? What is its compensation? Remark upon its appropriateness from an abstract point of view as well as pointing out sensible reasons for using it.
- Present a justification. State your particular theory(-ies) or aim(s), and describe the logic that led you to choose them.
- Briefly explain the study's tentative purpose and how it meets the declared objectives.

Approach:

Use past tense except for when referring to recognized facts. After all, the manuscript will be submitted after the entire job is done. Sort out your thoughts; manufacture one key point for every section. If you make the four points listed above, you will need at least four paragraphs. Present surrounding information only when it is necessary to support a situation. The reviewer does not desire to read everything you know about a topic. Shape the theory specifically—do not take a broad view.

As always, give awareness to spelling, simplicity, and correctness of sentences and phrases.

Procedures (methods and materials):

This part is supposed to be the easiest to carve if you have good skills. A soundly written procedures segment allows a capable scientist to replicate your results. Present precise information about your supplies. The suppliers and clarity of reagents can be helpful bits of information. Present methods in sequential order, but linked methodologies can be grouped as a segment. Be concise when relating the protocols. Attempt to give the least amount of information that would permit another capable scientist to replicate your outcome, but be cautious that vital information is integrated. The use of subheadings is suggested and ought to be synchronized with the results section.

When a technique is used that has been well-described in another section, mention the specific item describing the way, but draw the basic principle while stating the situation. The purpose is to show all particular resources and broad procedures so that another person may use some or all of the methods in one more study or referee the scientific value of your work. It is not to be a step-by-step report of the whole thing you did, nor is a methods section a set of orders.

Materials:

Materials may be reported in part of a section or else they may be recognized along with your measures.

Methods:

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

Approach:

It is embarrassing to use vigorous voice when documenting methods without using first person, which would focus the reviewer's interest on the researcher rather than the job. As a result, when writing up the methods, most authors use third person passive voice.

Use standard style in this and every other part of the paper—avoid familiar lists, and use full sentences.

What to keep away from:

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

Results:

The principle of a results segment is to present and demonstrate your conclusion. Create this part as 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. Use statistics and tables, if suitable, to present consequences most efficiently.

You must clearly differentiate material which would usually be incorporated in a study editorial from any unprocessed data or additional appendix matter that would not be available. In fact, such matters should not be submitted at all except if requested by the instructor.

Content:

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

What to stay away from:

- Do not discuss or infer your outcome, report surrounding information, or try to explain anything.
- Do not include raw data or intermediate calculations in a research manuscript.
- Do not present similar data more than once.
- A manuscript should complement any figures or tables, not duplicate information.
- Never confuse figures with tables—there is a difference.

Approach:

As always, use past tense when you submit 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 section.

Figures and tables:

If you put figures and tables at the end of some details, make certain that they are visibly distinguished from any attached appendix materials, such as raw facts. Whatever the position, each table must be titled, numbered one after the other, and include a heading. All figures and tables must be divided from the text.

Discussion:

The discussion is expected to be the trickiest segment to write. A lot of papers submitted to the journal are discarded based on problems with the discussion. There is no rule for how long an 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 implications of the study. The purpose here is to offer an understanding of your results and support all of your conclusions, using facts from your research and generally accepted information, if suitable. The implication of results should be fully 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 the prospect, and let it drop at that. Make a decision as to whether each premise is supported or 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 an experiment might be personalized to accomplish a new idea.
- Give details of all of your remarks as much as possible, focusing on mechanisms.
- Make a decision as to whether the tentative design sufficiently addressed the theory and whether or not it was correctly restricted. Try to present substitute explanations if they are sensible alternatives.
- One piece of 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 other available information. Present work done by specific persons (including you) in past tense.

Describe generally acknowledged facts and main beliefs in present tense.

The Administration Rules

Administration Rules to Be Strictly Followed before Submitting Your Research Paper to Global Journals Inc.

Please read the following rules and regulations carefully before submitting your research paper to Global Journals Inc. to avoid rejection.

Segment draft and final research paper: You have to strictly follow the template of a research paper, failing which your paper may get rejected. You are expected to write each part of the paper wholly on your own. The peer reviewers need to identify your own perspective of the concepts in your own terms. Please do not extract straight from any other source, and do not rephrase someone else's analysis. Do not allow anyone else to proofread your manuscript.

Written material: You may discuss this with your guides and key sources. Do not copy anyone else's paper, even if this is only imitation, otherwise it will be rejected on the grounds of plagiarism, which is illegal. Various methods to avoid plagiarism are strictly applied by us to every paper, and, if found guilty, you may be blacklisted, which could affect your career adversely. To guard yourself and others from possible illegal use, please do not permit anyone to use or even read your paper and file.

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Please note that following table is only a Grading of "Paper Compilation" and not on "Performed/Stated Research" whose grading solely depends on Individual Assigned Peer Reviewer and Editorial Board Member. These can be available only on request and after decision of Paper. This report will be the property of Global Journals.

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

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