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EVOLUTION OF EMPIRICAL QUANTITATIVE RELATIONSHIP BASED MATHEMATICAL MODEL FOR CONCRETE MIXER ENERGIZED BY HUMAN POWERED FLYWHEEL MOTOR

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ABSTRACT

Today's world is facing the problem of power crisis, because most of the power generation units are running on thermal energy, which basically need coal for generation of electricity. Since, it is well known that the coal as a natural wealth is remained in limited amount. Therefore today's world is looking for an alternative energy source. As far as the situation of tribal areas are concerned the people needs an alternative energy source to run their household, agricultural, constructional machines and equipment as there is scarcity of electricity. An alternative energy sources are available like (a) Human energy (b) Wind energy (c) Solar energy (d) Tidal energy. Keeping human energy as an epic centre, Dr.Modak has developed the concept as Human Powered Flywheel Motor and he has worked over last four decades. Several applications have been tried with HPFM. Through this research a concrete mixer is a new application is considered with HPFM as energy source. The system is designed and developed. Experimentation is conducted according to plan of experimentation. The data obtained from the experimentation is then used to formulate the mathematical models. The models are then considered for the quantitative and qualitative analysis.

KEYWORDS: Concrete Mixer, Human Powered Flywheel Motor, Dimensional Analysis, Mathematical Model Optimization, Sensitivity.

INTRODUCTION

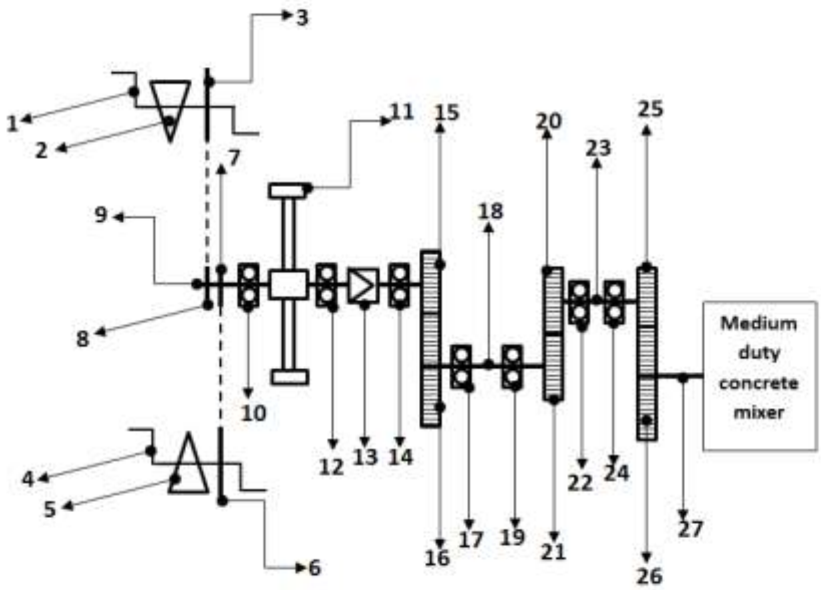
Study reveals that ample evidences are available which show that the use of human power for agricultural applications in ancient period. However at the genesis of 19th century in European and western countries the use of human power is used for several applications with the help of bicycle mechanism. Indeed the use of this mechanism was helpful to supply the human energy to end application with different speed ratios. Thus man could get an idea to use human energy for several applications, like (a) Agricultural equipments (b) House hold equipment 3.Industrial based medium horse power equipment.[10] Amongst this Agricultural based applications was considered at prime importance. However, this mechanisms were useful for limited applications these demanded horse power requirement less than 0.1 hp. Prof Modak,[5] has developed a concept of Human Powered Flywheel Motor, which seems a novel contribution in the area of Human power, because, now, one can store the human energy in the flywheel even at a tune of 3 to 5 h.p. The heavy application is now possible to attach with this mechanism and can be considered as one of the alternative energy source and became one possible substitute for conventional energies. In fact Prof Modak and his associates have developed various applications treating HPFM as an epic centre such as 1. Chaff cutter, 2.Brick making machine 3.Rice husking 4.Kadba cutting 4.Flour mill, 5.Sugar Cane crusher etc It is thought that the HPFM concept could further be used for several applications; therefore to add one more assignment for research concrete mixer is taken as one possible application applying the concept of HPFM

Need of Concrete Mixer Energized By HPFM

The population of the world is increasing day by day and the demand of civil constructional activities is at their culmination point. If one considers the case of civil constructional activities pertaining to the urban areas, the automation related to civil construction machineries facilitate the worker to work efficiently. But when one considers the case of remote or rural areas, then the situation seems to be altogether different. This is because of scarcity of the electricity and fossil fuels which are the main sources of energy to run the civil constructional machineries. Even on other side of the flip, the civil contractor is in the prowl of alternative way to carry out their work. Indeed, Concrete mixture is a prominent and main machine amongst all. Therefore there is need to use a Concept of HPFM to run the Concrete Mixture.

A Concept of Concrete Mixer Energized By HPFM

The medium duty concrete mixer driven by HPFM is depicted in Figure1. In this machine, four shafts S1, S2, S3 and S4 are used. On shaft S1, two components Gear (G1) and small chain sprocket (CH2) is placed. On shaft S2, two mechanical elements are placed, such as, Pinion (P1), Flywheel (FW). Pinion (P2) is placed on shaft S3 while shaft S4 is a process unit shaft on which Gear (G2) is placed. Clutch (TFC) is used to connect the shafts S2 & S3. Initially, the torsionally flexible clutch is in disengaged position. A human does the process of pedaling. The energy is transmitted to the flywheel for storing this energy through speed amplification elements P1 and G1. After certain duration the sufficient amount of energy is stored in the flywheel. This stored energy in the flywheel is now useful to energize any process machine. Hence, a clutch is now engaged and available stored energy in the flywheel is fed to medium duty concrete mixer through gear pair P2 G2.



1. Pedal, P1; 2. Seat, S1; 3. Big chain sprocket, BCS1; 4. Pedal, P2; 5.Seat, S2; 6.Big chain sprocket, BCS2, 7.Small chain sprocket, SCS2, 8.Small chain sprocket, SCS1; Shaft, S1, 10.Bearing, B1; 11.Flywheel, FW; 12.Bearing, B2; 13.Clutch; 14.Bearing, B3; 15.Pinion, P1; 16.Gear, G1; 17.Bearing, B4; 18.Shaft, S3; 19.Bearing, B5; 20.Pinion, P2; 21.Gear, G2, 22.Bearing, B6; 23.Shaft, S4; 24.Bearing, B7; 25.Pinion, P3; 26.Gear, G3; 27.Shaft, S5.

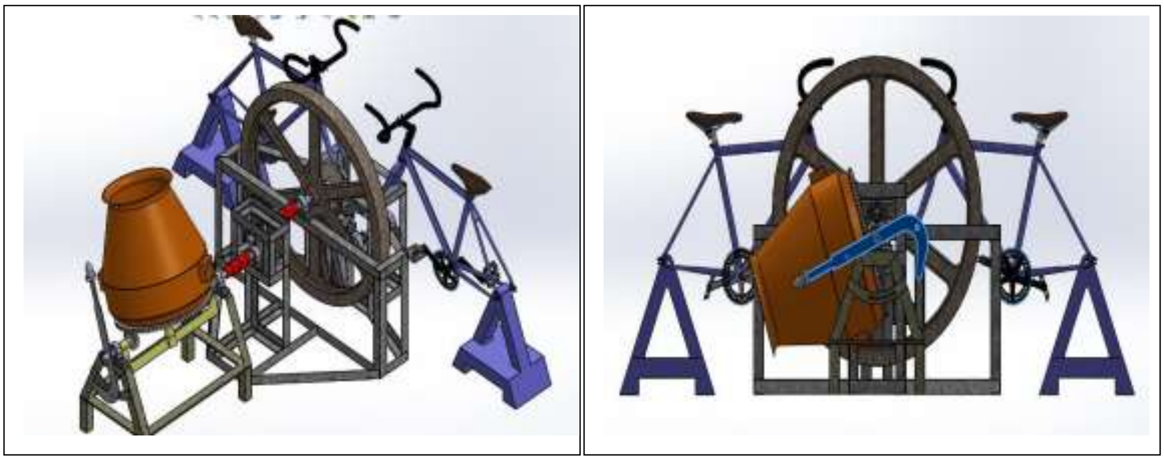


Figure 1: Schematic diagram of a HPFM energized process machine.

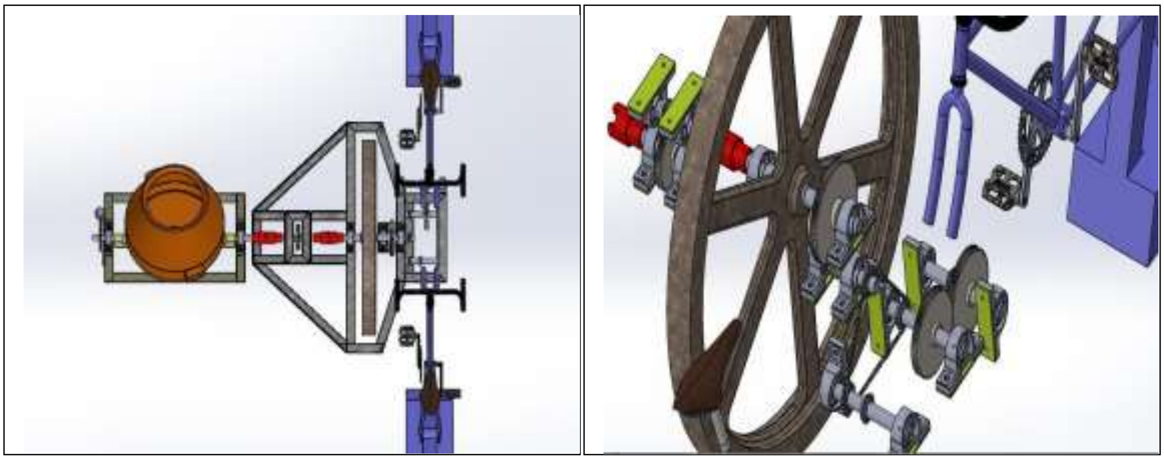


Figure 2: CAD model of concrete mixer.

Process Of Establishment Of Empirical Relationship[1]

The process of establishment of empirical relationship involves following prominent steps

1. Identification of Variables
2. Reduction of Variables
3. Design of Concrete mixture energized by HPFM
4. Development of Concrete mixture energized by HPFM
5. Plan of experimentation
6. Procedure of Experimentation
7. Establishment of empirical relationship.

Identification of Variables

The first step of model formulation is an identification of variables. Generally, there are three types of variables which are used to establish the model. These variables are namely (a) Independent Variables (b) Dependent Variables (c) Extraneous Variables. The independent variables are those variables, which are varying as per the choice of designer or experimenter, whereas the dependent variables are those variables which may only be varied if there is certain variation in any of the independent variables. The random variables are those, which may vary as per it own natural behavior, it means an experimenter does not have any control on the variation of random variables. Intact for the present work the table 1 shows the list of Dependent and independent variables.

Reduction of Variables

The reduction of variables is process of obtaining a group of pie terms from several independent variables into one. Each pie term shows the effect of all variables included within its domain in totality. This is an effective method by which one can obtain the model as per his desire. Two methods are available for the reduction of variables, which are namely (a) Buckingham Pi method (b) Religh's Method. In the present work for the reduction of variables a Religh's method is used and it is detailed out as below.

Dimensional analysis for Resistive torque

$$TL = P[Ws^a, WA^b, Wc^c, Ww^d, Dd^e, Ld^f, Lb^g, Wb^h, Sdb^i, Ssb^j, fe^k, g^l t^m]$$

The MLT form of the above equation is,

$$M^1L^2T^{-2} = f[(M)^a, (M)^b, (M)^c, (M)^d, (c)^e, (L)^f, (L)^g, (L)^l, (L)^i, (L)^j, (ML^2T^{-2})^k, (LT^{-2})^l, T^m]$$

The solution for the above MLT equation is,

For M

1 = a +b +c + d + k ⇒ b =1 -a –c –d –k

For L

2 = e + f +g + h + i + j + 2k + l ⇒ e =2 - f - g - h - i - j - 2k - L

For T

-2 = -2k -2L +m

⇒ m =-2+2k+2L

Resultant equation is putting the values in general equation one find,

$$Tr = f\left[\begin{array}{c} Ws^a, WA^{(1-a-c-d-k)}Wc^c, Ww^d, Dd^{(2-f-g-h-i-j-2k-l)}, Ld^f, Lb^g, Wb^h, Sdb^i, Ssb^j, \\ fe^k, g^l, t^{-2+2k+2l} \end{array}\right]$$

$$\frac{Tr}{WAD_d^2 t^{-2}} = \left[\frac{Ws}{WA}\right]^a \left[\frac{Wc}{WA}\right]^c \left[\frac{Ww}{WA}\right]^d \left[\frac{Fet^2}{WADd^2}\right]^k \left[\frac{Ld}{Dd}\right]^f \left[\frac{Lb}{Dd}\right]^g \left[\frac{Wb}{Dd}\right]^h \left[\frac{Sdb}{Dd}\right]^i \left[\frac{Ssb}{Dd}\right]^j \left[\frac{gt^2}{Dd}\right]^l$$

After rearranging the terms in the above equation one can get the model for resisting torque as,

$$\frac{Tr}{WAD_d^2 t^{-2}} = \left[\frac{Ws}{Ww}\frac{Wc}{WA}\right]^a \left[\frac{Ld}{Lb}\frac{Wb}{Dd}\frac{Sdb}{Ssb}\frac{Nb}{D}\right]^b \left[\frac{Fet^2}{WADd^3}\right]^c \left[\frac{gt^2}{D_d}\right]^d [Gr]^e \text{------------------------------------} \quad (1)$$

$$\Pi1 = \left[\frac{Ws}{Ww}\frac{Wc}{WA}\right]^a \quad \Pi2 = \left[\frac{Ld}{Lb}\frac{Wb}{Dd}\frac{Sdb}{Ssb}\frac{Nb}{D}\right]^b \quad \Pi3 = \left[\frac{Fet^2}{WADd^3}\right]^c \quad \Pi4 = \left[\frac{gt^2}{D_d}\right]^d \quad \Pi5 = [Gr]^e$$

Likewise following the same procedure, one can get the model for respective pie terms which can be given as:

Model for Mixing Time, $\frac{Tm}{t} = \left[\frac{Ws}{Ww}\frac{Wc}{WA}\right]^a \left[\frac{Ld}{Lb}\frac{Wb}{Dd}\frac{Sdb}{Ssb}\frac{Nb}{D}\right]^b \left[\frac{Fet^2}{WADd^3}\right]^c \left[\frac{gt^2}{D_d}\right]^d$ ------------------ (2)

Model for Compressive strength, $\frac{SD_d t^2}{Wa} = \left[\frac{Ws}{Ww}\frac{Wc}{WA}\right]^a \left[\frac{Ld}{Lb}\frac{Wb}{Dd}\frac{Sdb}{Ssb}\frac{Nb}{D}\right]^b \left[\frac{Fet^2}{WADd^3}\right]^c \left[\frac{gt^2}{D_d}\right]^d [Gr]^e$--- (3)

Model for Slump Height, $\frac{Hs}{Dd} = \left[\frac{Ws}{Ww}\frac{Wc}{WA}\right]^a \left[\frac{Ld}{Lb}\frac{Wb}{Dd}\frac{Sdb}{Ssb}\frac{Nb}{D}\right]^b \left[\frac{Fet^2}{WADd^3}\right]^c \left[\frac{gt^2}{D_d}\right]^d [Gr]^e$--------- (4)

Model for speed of drum shaft, $N_{ms}t = \left[\frac{Ws}{Ww}\frac{Wc}{WA}\right]^a \left[\frac{Ld}{Lb}\frac{Wb}{Dd}\frac{Sdb}{Ssb}\frac{Nb}{D}\right]^b \left[\frac{Fet^2}{WADd^3}\right]^c \left[\frac{gt^2}{D_d}\right]^d [Gr]^e$--- (5)

Test planning

The basic aim of test planning is to utilize the obtained experimental data with minimum error and keeping control over the outside influence. It contains below stated points.

1. Test envelope: The range over which, one could vary the values of independent variables.
2. Test points: Are the discrete values of independent variables in the test envelope.
3. Test sequence: reversible or irreversible.

Procedure of Experimentations

The procedure for experimentation is followed which is discussed as below

1. As per the grade of concrete and decided experimentation plan the ingredients are poured in the mixer. Numbers of Settings have been done for first decided gear ratio.
2. Two persons then speed up the flywheel to desired speed. Once the desired speed is achieved then pedaling is stopped.
3. Immediately, the clutch is engaged the stored power in the flywheel is utilized to mix the concrete
4. At the same time instant, the computer stores the data with the help of the sensors until the mixer comes to state of rest.
5. This procedure is continuous for several settings for each concrete grade like M20, M15, M10, and M7.5.

The readings of experimentations are shown graphically as below

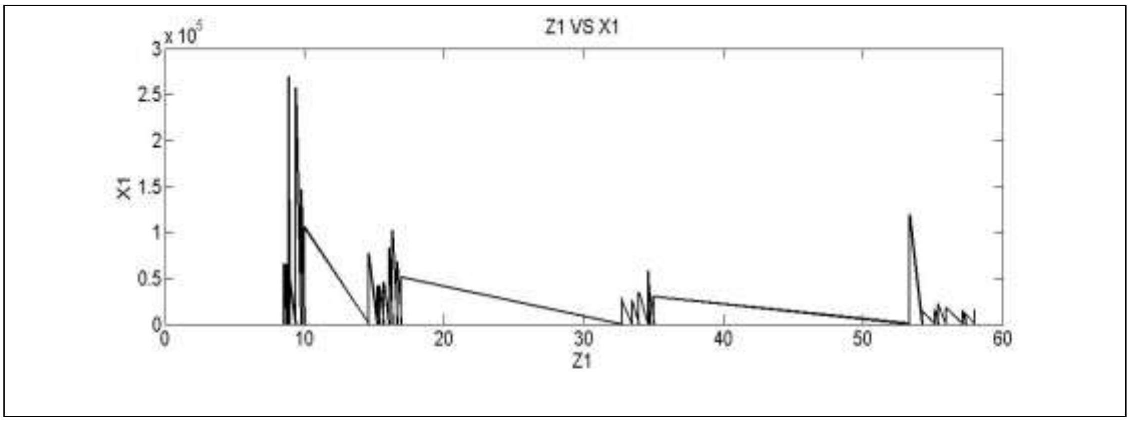


Figure 3: Variation of dependent π1 (X1) vs independent πd1 (Z1).

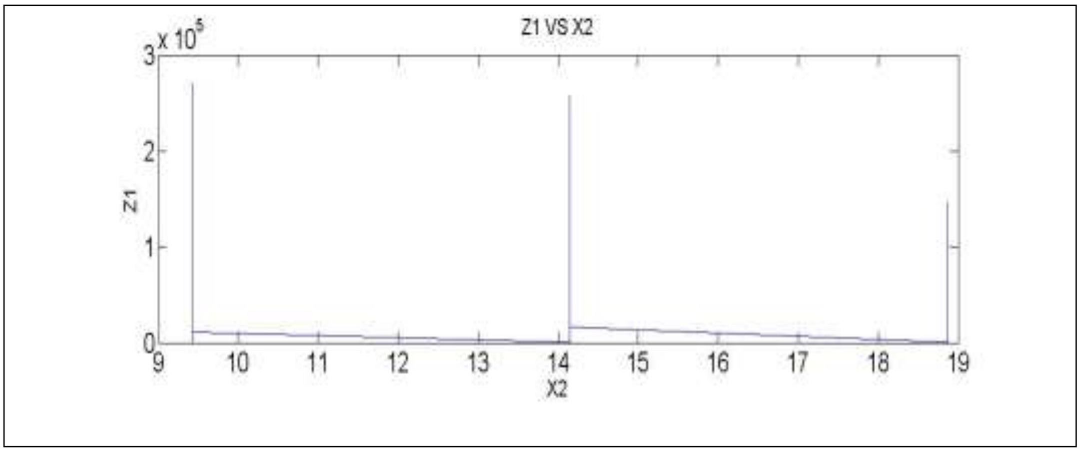


Figure 4: Variation of dependent π2 (X2) vs independent πd1 (Z1).

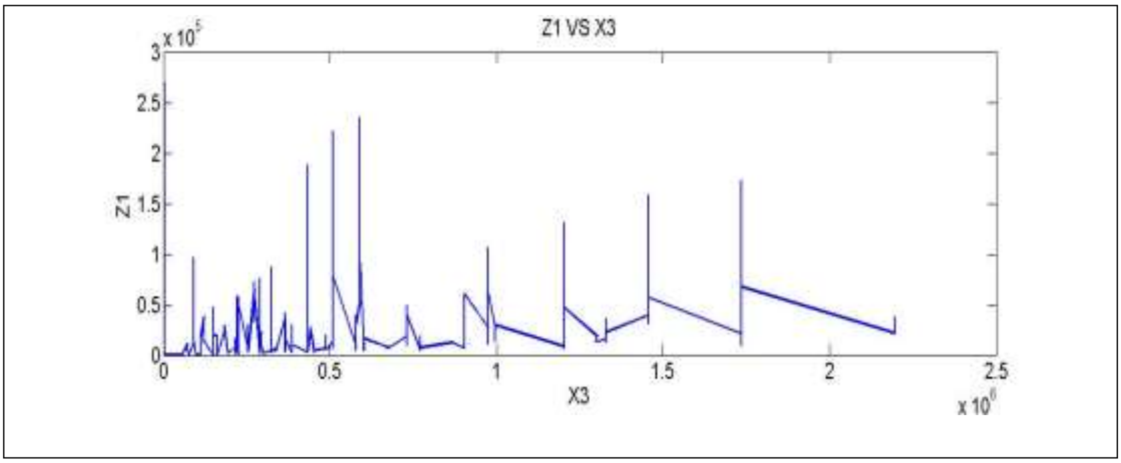


Figure 5: Variation of dependent π3 (X3) vs independent πd1 (Z1).

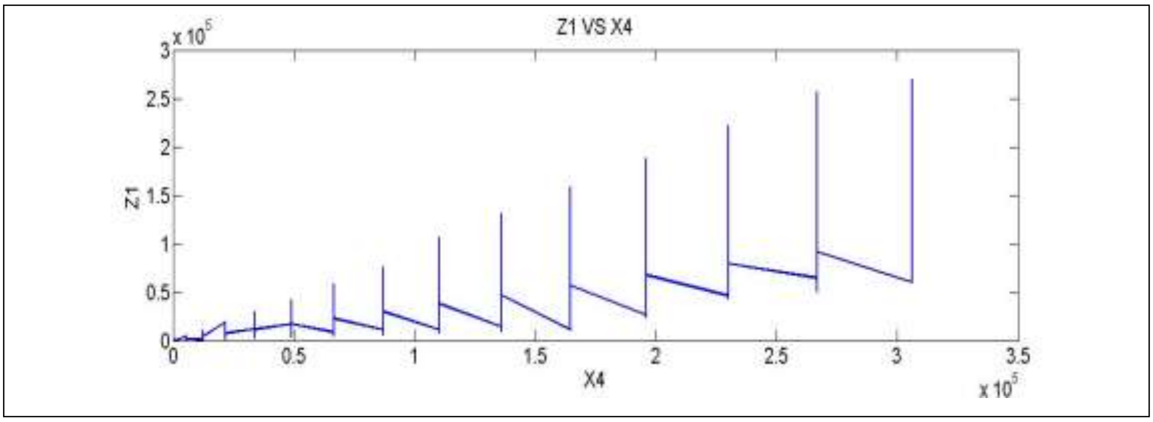


Figure 6: Variation of dependent π4 (X4) vs independent πd1 (Z1).

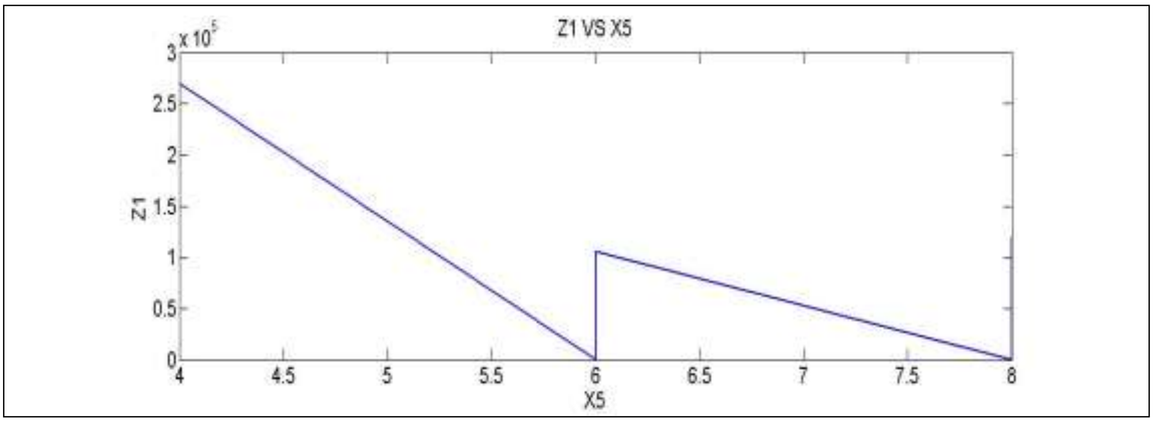


Figure 7: Variation of dependent π5 (X5) vs independent πd1 (Z1).

Model formulation by identifying the constant and various indices of pi terms

The indices of different pi terms aimed at model can be identified by using multiple regression analysis. By considering five independent pi terms and one dependent pi term, Let model aimed at be of the form,

$(\pi) = K*((\pi_1)^a*(\pi_2)^b*(\pi_3)^c*(\pi_4)^d*(\pi_5)^e$

The regression equations become as under.

∑Y = n K1 + a∑A + b∑B + c∑C + d∑D+e∑E

∑YA = K1∑A + a∑A^2 + b∑AB + c∑AC +d∑AD+e∑AE

∑YB = K1∑B + a∑AB + b∑B^2 + c∑BC + d∑BD+e∑BE

∑YC = K1∑C + a∑AC + b∑BC + c∑C^2 + d∑CD+e∑CE

∑YD = K1∑D + a∑AD + b∑BD + c∑CD+ d∑D^2+e∑DE

∑YE = K1∑E + a∑AE + b∑BE + c∑CE+ d∑ED+e∑E^2 ----------------------------------(6)

In the above equations, n is the number of sets of readings, A,B,C, D depicts the independent pi terms π1,π2,π3,π4 and π5 whilst Y represents dependent pi term. Afterwards, estimate the values of independent pi terms for corresponding dependent pi term, which helps to form the equations in matrix form.

The following matrix represents the equations, which is used for programming.

[Y]=[X] x[a]

By solving the above matrix one would get the mathematical model of dependent Π term as shown below.

Model of dependent Π term of resisting torque, Tr

$$\Pi d1 = \frac{Tr}{WaD_d^2 t^{-2}}$$

$$= 1.433178 \left[\frac{Ws}{Ww}\frac{Wc}{WA}\right]^{-0.5015} \left[\frac{Ld}{Lb}\frac{Wb}{Dd}\frac{Sdb}{Ssb}\frac{Nb}{D}\right]^{0.3176} \left[\frac{Fet^2}{WADd^3}\right]^{-0.009} \left[\frac{gt^2}{D_a}\right]^{1.0095} [Gr]^{-0.6784}$$

$$Tr = 1.433178 \left(\frac{WaD_d^2}{t^2}\right) \left[\frac{Ws}{Ww}\frac{Wc}{WA}\right]^{-0.5015} \left[\frac{Ld}{Lb}\frac{Wb}{Dd}\frac{Sdb}{Ssb}\frac{Nb}{D}\right]^{0.3176} \left[\frac{Fet^2}{WADd^3}\right]^{-0.009} \left[\frac{gt^2}{D_a}\right]^{1.0095} [Gr]^{-0.6784}$$

$\Pi d1 = 1.433178 \times (\pi 1)^{-0.5015} \times (\pi 2)^{0.3176} \times (\pi 3)^{-0.009} \times (\pi 4)^{1.0095} \times (\pi 5)^{-0.6784}$ -------------(7)

Model of dependent Π term for mixing time, Tm

$$\Pi d2 = \frac{Tm}{t}$$

$$= 769.1304 \left[\frac{Ws}{Ww}\frac{Wc}{WA}\right]^{-0.1582} \left[\frac{Ld}{Lb}\frac{Wb}{Dd}\frac{Sdb}{Ssb}\frac{Nb}{D}\right]^{-0.0148} \left[\frac{Fet^2}{WADd^3}\right]^{0.0012} \left[\frac{gt^2}{D_a}\right]^{-0.4992} [Gr]^{-0.022}$$

$$Tm = 769.1304\, t \left[\frac{Ws}{Ww}\frac{Wc}{WA}\right]^{-0.1582} \left[\frac{Ld}{Lb}\frac{Wb}{Dd}\frac{Sdb}{Ssb}\frac{Nb}{D}\right]^{-0.0148} \left[\frac{Fet^2}{WADd^3}\right]^{0.0012} \left[\frac{gt^2}{D_a}\right]^{-0.4992} [Gr]^{-0.022}$$

Πd2= 769.1304 X $(\pi 1)^{-0.1582}$ X $(\pi 2)^{-0.0148}$ X $(\pi 3)^{0.0012}$ X $(\pi 4)^{-0.4992}$ X $(\pi 5)^{-0.022}$--------------(8)

Model of dependent Π term for strength, S

$$\Pi d3 = \frac{SD_a t^2}{Wa} = 0.80247 \left(\frac{Wa}{D_a t^2}\right) \left[\frac{Ws}{Ww}\frac{Wc}{WA}\right]^{-1.0689} \left[\frac{Ld}{Lb}\frac{Wb}{Dd}\frac{Sdb}{Ssb}\frac{Nb}{D}\right]^{0.0332} \left[\frac{Fet^2}{WADd^3}\right]^{-0.0002} \left[\frac{gt^2}{D_a}\right]^{1.0004} [Gr]^{-0.0572}$$

$$S = 0.80247 \left(\frac{Wa}{D_a t^2}\right) \left[\frac{Ws}{Ww}\frac{Wc}{WA}\right]^{-1.0689} \left[\frac{Ld}{Lb}\frac{Wb}{Dd}\frac{Sdb}{Ssb}\frac{Nb}{D}\right]^{0.0332} \left[\frac{Fet^2}{WADd^3}\right]^{-0.0002} \left[\frac{gt^2}{D_a}\right]^{1.0004} [Gr]^{-0.0572}$$

Πd3 =0.802417 X $(\pi 1)^{-1.0689}$ X $(\pi 2)^{0.0332}$ X $(\pi 3)^{-0.0002}$ X $(\pi 4)^{1.0004}$ X $(\pi 5)^{-0.0572}$-------------(9)

Model of dependent Π term for slump height, Sh

$$\Pi d4 = \frac{Sh}{Dd} = 0.37145 \left[\frac{Ws}{Ww}\frac{Wc}{WA}\right]^{0.0205} \left[\frac{Ld}{Lb}\frac{Wb}{Dd}\frac{Sdb}{Ssb}\frac{Nb}{D}\right]^{-0.1376} \left[\frac{Fet^2}{WADd^3}\right]^{-0.0006} \left[\frac{gt^2}{D_a}\right]^{-0.0004} [Gr]^{-0.4276}$$

$$Sh = 0.37145\, Dd \left[\frac{Ws}{Ww}\frac{Wc}{WA}\right]^{0.0205} \left[\frac{Ld}{Lb}\frac{Wb}{Dd}\frac{Sdb}{Ssb}\frac{Nb}{D}\right]^{-0.1376} \left[\frac{Fet^2}{WADd^3}\right]^{-0.0006} \left[\frac{gt^2}{D_a}\right]^{-0.0004} [Gr]^{-0.4276}$$

Πd4=0.37145 X $(\pi 1)^{0.0205}$ X $(\pi 2)^{-0.1376}$ X $(\pi 3)^{-0.0006}$ X $(\pi 4)^{-0.0004}$ X $(\pi 5)^{-0.4276}$ -----------------(10)

Model of dependent Π term for speed of drum shaft, Nms

$$\Pi d5 = N_{ms} t = 4.070052 \left[\frac{Ws}{Ww}\frac{Wc}{WA}\right]^{-0.2474} \left[\frac{Ld}{Lb}\frac{Wb}{Dd}\frac{Sdb}{Ssb}\frac{Nb}{D}\right]^{-0.0722} \left[\frac{Fet^2}{WADd^3}\right]^{0.2751} \left[\frac{gt^2}{D_a}\right]^{0.0766} [Gr]^{-0.9442}$$

$$N_{ms} = \frac{4.070052}{t} \left[\frac{Ws}{Ww}\frac{Wc}{WA}\right]^{-0.2474} \left[\frac{Ld}{Lb}\frac{Wb}{Dd}\frac{Sdb}{Ssb}\frac{Nb}{D}\right]^{-0.0722} \left[\frac{Fet^2}{WADd^3}\right]^{0.2751} \left[\frac{gt^2}{D_a}\right]^{0.0766} [Gr]^{-0.9442}$$

Πd5 =4.070052 X $(\pi 1)^{-0.2474}$ X $(\pi 2)^{-0.0722}$ X $(\pi 3)^{0.2751}$ X $(\pi 4)^{0.0766}$ X $(\pi 5)^{-0.9442}$---------------(11)

Qualitative Discussion of Mathematical Model (Interpretation of Model)

The mathematical models need to be interpreted therefore interpretation of above models are notified in terms of certain aspects namely (1) order of influence of various inputs (causes) on outputs (effects) (2) Interpretation of curve fitting constant K.

Table 1: List of Dependent and Independent Variables.

Sr. no.	Name of variable	Variable	Symbol	MLT Form
1	Resisting Torque	Dependent	Tr	$ML^{-1} T^{-2}$
2	Mixing Time	Dependent	Tm	T
3	Compressive Strength	Dependent	S	$ML^{-1} T^{-2}$
4	Slump Height	Dependent	Sh	L
5	Speed of mixer shaft	Dependent	Nms	T^{-1}
6	Weight of sand	Independent	Ws	M
7	Weight of Aggregate	Independent	Wa	M
8	Weight of Cement	Independent	Wc	M
9	Quantity of water	Independent	Qw	M
10	Diameter of Drum	Independent	Dd	L
11	Depth of Drum	Independent	Ld	L
12	No. of Blades	Independent	Nb	
13	Inclination of Blade	Independent	β	
14	Length of blade	Independent	Lb	L
15	Width of blade	Independent	Wb	L
16	Space between Drum and blade	Independent	Sdb	L
17	Space between strips of blade	Independent	Ssb	L
18	Speed of mixer shaft	Independent	Nms	T^{-1}
19	Flywheel Energy	Dependent	Fe	$ML^{2}T^{-2}$
20	Gear ratio	Independent	Gr	
21	Acceleration due to gravity	Independent	g	LT^{-2}
22	Time	Independent	T	T

Table: 2 Test envelope, Test Point for Human Powered energized Concrete Mixer

Pi Term Equation	Test Envelope	Test Point	Independent Variable in its own range
Π1=Term for the ingredients Π1= $\left[\frac{Ws}{Ww}\frac{Wc}{WA}\right]^{a}$	57.97, 8.55	57.97,34.6,15.4,8.55	WA = 15,20,30,40 kg Ws = 7.5,10,15,20 Kg Ww = 2.3,2.5,2.6,3 Kg Wc = 5 Kg
Π2=Term for geometric variable of mixer Π2=$\left[\frac{Ld}{Lb}\frac{Wb}{Dd}\frac{Sdb}{Ssb}\frac{Nb}{\beta}\right]^{b}$	18.86, 9.43	18.9, 14.2, 9.4	Ld = 0.7 m, Lb = 0.39 m, Dd = 0.72 m, Wb= 9 m, Sdb = 0.11 m, Ssb = 0.03 m, Nb = 2,3,4, β = 0.17
Π3=Term for energy in flywheel Π3=$\left[\frac{Fet^{2}}{WADd^{2}}\right]^{c}$	2195393, 31.36	2195393, 31.36	Inertia ,If = 11.87 kg-m^2 Angular Velocity, ω = 6.28, 12.56, 18.84. 25.12, 31.4, 37.68 rad/s Fe = 237.17, 936.7, 2107.57, 3746.8, 5854.38, 8430.31, Nm , WA = 15,20,30,40 kg
Π4=Time interval Π4=$\left[\frac{gt^{2}}{Dd}\right]^{d}$	306250, 13.61	306250, 13.61	t = 10 Sec, g = 9.8 m/s, , Dd = 0.72 m
Π5=Gear Ratio Π5=$[Gr]^{e}$	8,4	8,6,4	8, 6, 4

Table 3: Optimized value for different values.

Pie Terms	For model ∏d1	For model ∏d2	For model ∏d3	For model ∏d4	For model ∏d5
∏d	1.139	0.678356	25341.39	0.163356	0.533487
∏1	57.97	57.97101	8.555133	57.97101	57.97101
∏2	9.434	18.86811	18.86811	9.434055	18.86811
∏3	2195394	31.36994	31.36994	31.36994	31.36994
∏4	13.61111	306250	306250	13.61111	13.61111
∏5	8	8	4	4	8

Order of Influence of Various Inputs on dependent Variable

Model of Resting Torque (Tr)

The equation (7) is formulated based on experimental data obtained during experimentation. In this model, the highest influencing pie term is considered as a π4.This pie term is related to time interval. Whereas, the least influence is observed for π3 as -0.009, this pie term relates to stored flywheel energy. The π1, π2, π5 relate to weight of ingredients, Geometrical parameters, Gear ratio have moderate influence as -0.5015, 0.3176, and -0.6784 respectively.

Interpretation of curve fitting constant (K)

The value for curve fitting constant for the model is 1.4443. This value shows the combined effect of extraneous variables. Similarly, the value is positive; which indicates that, there are good numbers of causes, which have influence on increasing effect.

The Quantitative Analysis of Mathematical Model

The basic aim of this section is to obtain quantitative analysis of mathematical model. This analysis comprises of (1) Sensitivity analysis (2) Optimization of model (3) Reliability of the model.

Sensitivity analysis

This analysis is executed to see the sensitiveness of each independent pi term of mathematical model. The detailed procedure is explained as below.

A perceptible change in dependent pie term could be accomplished by making percentage change in independent pie terms. Therefore, in the present work, the change of +10 % and -10% is introduced in each pie term and it is done one at a time. Thus, total rate of introduced change is 20%. This analysis is executed for all mathematical models. The result of analysis for mathematical model referred to the equation (7) is given below.

Effect of introduced change on the dependent pie term

Model of Resting Torque Referring to the model (Equation7), the maximum change of 20.19 % in dependent pie term (Πd1) (estimated from Model) is observed due to 20% change introduced in π4, On the other side, the meager change of 0.18% is observed in dependent pie term (Πd1) due to change introduced in π3, Subsequently the changes of 10%,6%,13& in dependent variable (Πd1) have been observed for changes in π1, π2, π5.

If one carefully analyses the former observations, then it is cleared from the logic that the most sensitive term will be chosen where perceptible and maximum change has occurred. It means π4 term is the most sensitive term and the least change is observed for π3, it is considered as the least sensitive pie term. The sequence of the various pi terms in descending order of sensitivity is π4, π5, π1, π2, π3.

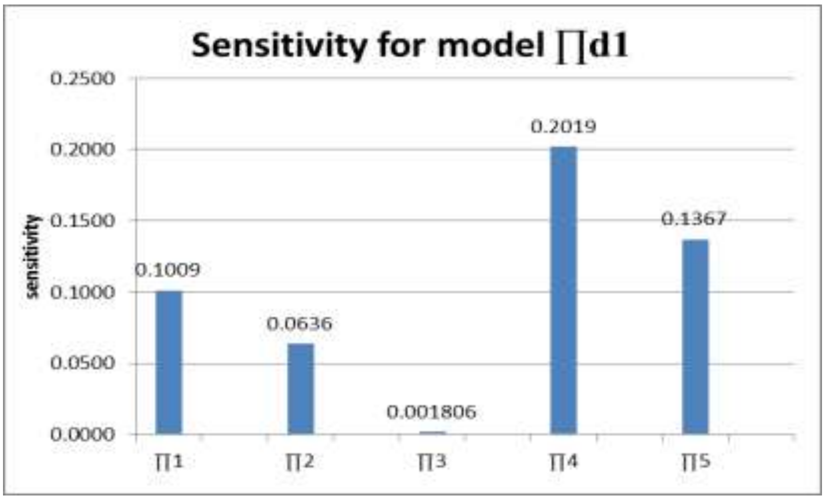


Figure 8: Sensitivity Graph of independent pi terms for model πd1.

Optimization of model

The main intention of the present work is not merely to come out with a mathematical model but to provide the best set of independent variables. This in turn will help us to find out the maximum or minimum value of dependent pi term aiming with objective function. As far as the present case is concerned, the objective is to minimize the vibration amplitude. The present model depicted in a nonlinear form and for the optimization of this model, it is to be converted into linear form. It is carried out by taking log on both the sides. For the minimization of linear function one may use linear programming technique as detailed below. For the dependent π term, we have.

$$\pi_d = k \times \pi_1^a \times \pi_2^b \times \pi_3^c \times \pi_4^d \times \pi_5^e$$

$$\log \pi_d = \log k + a\, log\pi_1 + b\, log\pi_2 + c\, log\pi_3 + d\, log\pi_4 + e\, log\pi_5$$

$$\text{let}, \log \pi_d = Z; \log k = K;\ log\pi_1 = X1;\ log\pi_2 = X2;\ log\pi_3 = X3;\ log\pi_4 = X4;\ log\pi_5 = X5$$

Then the linear model in the form of first degree of polynomial can be written as,

$$Z = K + a\,X1 + b\,X2 + c\,X3 + d\,X4 + e\,X5$$

In this case there are five different models corresponding to resisting torque (Tr), mixing time (Tm), compressive strength (S), slump height (Sh), and speed of drum shaft (Nms) in the phenomenon of mixing of concrete mix ingredients hence five objective functions corresponding to this models. The objective functions of resisting torque, mixing time and speed of the drum shaft of human powered energized mixing operation need to be minimized whereas compressive strength and slump height need to be maximized. Secondly, it is required to apply the constraints to the problem .During gathering of data certain range of independent pi terms is achieved. In fact this range has a minimum and maximum value. Therefore, this range can be taken as constrains for this problem. Thus, there are two constraints for each independent variable.

If one consider greatest and least estimations of value of dependent pie term πd by πdmax and πdmin then first two constraints for the problem will be acquired by taking log of these quantities and putting the values of multiplier of other variable except the one under thought as zero. Consider that the log of the limits be characterized as C1 and C2 (i.e. C1= log (πdmax) and C2= log (πdmin)). So now the equations of the constraints can be as under

1*X1 + 0*X2 +0*X3+0*X4+0*X5 ≤ C1

1*X1 + 0*X2 +0*X3+0*X4+0*X5 ≥ C2

The other constraints are also found to be.

0*X1 + 1*X2 +0*X3+0*X4+0*X5 ≤ C3

0*X1 + 1*X2 +0*X3+0*X4+0*X5 ≥ C4

0*X1 + 0*X2 +1*X3+0*X4+0*X5 ≤ C5

0*X1 + 0*X2 +1*X3+0*X4+0*X5 ≥ C6

0*X1 + 0*X2 +0*X3+1*X4+0*X5 ≤ C7

0*X1 + 0*X2 +0*X3+1*X4+0*X5 ≥ C8

0*X1 + 0*X2 +0*X3+0*X4+1*X5 ≤ C9

$$0*X1 + 0*X2 + 0*X3 + 0*X4 + 1*X5 \geq C10 \quad \text{--------------------------------------} \quad (12)$$

By solving the above linear programming one can get minimum or maximum value of Z, and the best set of values of independent pi terms to acquire this minimum value. However, the values of dependent pi term and independent pi terms could be acquired by taking antilog of Z, X1, X2, X3, X4 and X5. The present linear programming problem is solved by MS Solver. This function is available with Microsoft Excel office. By solving, the above problem with MS solver, one would get value as represented in tabular form below.

Reliability of model

The reliability term is pertaining to the chance of failure. Indeed reliability is an indicator to show the performance of model. For the present case the reliability of model is evaluated as under.

With reference to model, the known values of independent pi terms have been submitted in the model and thus obtained the required dependent pie terms; generally it is called as calculated values of dependent pie terms. Now, one could find the error by subtracting the calculated values from observed values of dependent pie terms. Once the error is estimated, then reliability can be estimated by calculating the mean error.

This can be done by using following formula,

Reliability= 1- Mean error --- (13)

Where, Mean error= $\Sigma XIFI / \Sigma FI$

Where, $\Sigma XIFI$= Summation of the product for percentage of error and frequency of error occurrence and ΣFI= Summation of frequency of error occurrence. Hence reliabilities obtained for five models in percentage are 78.59, 94.62, 87.06, 79.70, and 78.69 respectively.

CONCLUSIONS

From the present work, following are some important conclusions have been made

1. It is possible to execute the concrete mixing process with the help of concrete mixer energized by Human Powered Flywheel Motor.
2. The concrete mixing phenomenon seems to be complex as it is quite difficult to provide exact simulations by logic based model.
3. Through experimentations it is evident that the pattern of data obtained is nonlinear. The exponential form of models is possible to establish and the models are fairly reliable.

REFERENCES

1. H. Schenk Jr. "Test Sequence and Experimental Plans, "Theories of Engineering Experimentation" McGraw Hill Book Co., New York.
2. H S Bhatkulkar, J P Modak, "Design & Development of Nursery Fertilizer Mixer Energized by Human Powered Flywheel Motor.' International journal for Research in Emerging Science and Technology, Vol-1, issue-5, October-2014
3. Dhale A. and Modak, J. P., "Formulation of the approximate generalized data based model for oilseed presser using human powered flywheel motor as an energy source" International Journal of Agricultural Engineering.
4. Modak J.P, Moghe S.D "Design and development of human powered machine for the manufacture of lime fly ash sand bricks" Human power, 1998; 13(2): 3-7.
5. Modak J. P. "Design and development of manually energized process machines having relevance to village / agriculture and other productive operations" Human Power, USA International Human Power Vehicle Association, 2004; 58: 16-22.
6. Modak, J. P. and Katpatal A.A., "Design of Manually Energized Centrifugal Drum Type Algae Formation Unit" Proceedings International AMSE Conference on System, Analysis, Control and Design, Layon (France), 1994; 3(4-6): 227-232.
7. Deshpande S. B., Modak, J. P. and Tarnekar S. B., "Confirming Application of human powered flywheel motor as an energy source for rural generation of electrical energy for rural applications, and computer aided analysis of battery charging process.", Human Power, USA International Human Power Vehicle Association, 2009; 58: 10-16.
8. Modak J. P. et all, "Manufacturing of Lime- fly ash-sand bricks Using Manually Driven Bricks Making Machine" a project sponsored by Maharashtra Housing & Area Development Authority, (MAHDA), Mumbai, India.
9. Modak J. P. and Bapat A. R. "Various efficiency of a Human Power Flywheel motor" Human Power, USA International Human Power Vehicle Association, 2003; 54: 21-23.
10. David Gordon Wilson VITA volunteer: Understanding the pedal power. ISBN: 0-86619-268-9.
11. Modak, J.P. and Bapat, A.R. Manually driven flywheel motor operates wood turning process. Contemporary Ergonomics, Proc. Ergonomics Society Annual Convention 13-16 April, Edinburgh, Scotland, 1993; 352-357.
12. Modak, J.P. and Bapat, A.R. Formulation of Generalized Experimental Model for a Manually Driven Flywheel Motor and its Optimization, Applied Ergonomics, U.K., 1994; 25(2): 119-122.

13. Modak, J.P. "Influence of development and human powered process machine and its impact on energy management of rural and interior sector", Proceeding of National Conference on Energy Management in Changing Business Scenario, (EMCBS 2005), BITS Pilani, 2005.
14. Sohoni, V.V., H.P. Aware and Modak J.P. Manually Powered Manufacture of Keyed Bricks, Building Research & Information, U.K., 1997; 25(6): 354-364.
15. P. B. Khope, J.P. Modak, "Development And Performance Evaluation Of A Human Powered Flywheel Motor Operated Forge Cutter", International Journal of Scientific & Technology Research, 2013; 2(3): 146-149.
16. Ferraris, C.F., "Concrete Mixing Methods and Concrete Mixers: State of the Art", Journal of Research of the National Institute of Standards and Technology, 2001; 106(2): 391-399.
17. Thompson Aguheva, Design and Fabrication of an Industrial Mixer: International Journal of Practices and Technologies ISSN 1583-1078, 2012; 20.
18. Bhandari V.B. Design of Machine Elements, Tata McGraw Hill Publication, India, 2005.
19. Shiwalkar, B.D. Design Data for Machine Elements, Denett & Co., India, 2004.