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DESIGN AND DEVELOPMENT OF CONCRETE MIXER DRIVEN BY HUMAN POWERED FLYWHEEL MOTOR

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ABSTRACT: The energy crisis is a prominent issue faced by today's world. The natural recourses are depleting faster, and many few repositories of natural resources are available by which one could fulfill the future demand of energy. People are on the prowl of finding new repositories of natural resources, but this also has limitations. Therefore, recent research has taken a keen interest in renewable energy sources. There are good renewable energy sources presently available; among them, human power seems to be an eco-friendly and cheaper energy source that is universally available. Human power can be stored in a Flywheel, and it could be used as a motor for driving machines and mechanisms. Several applications have been tried considering HPFM as an energy source. Through this paper, a concrete mixer energized by HPFM is presented. The main focus is given on its design and dynamics, along with its performance analysis.

KEYWORDS: Dynamics, Design, Concrete mixer, HPFM, Human power.

1 INTRODUCTION

Human Power has been used since ancient times for agriculture and household applications [1]-[3]. After industrial revolution main focus was given to evolve the mechanisms for doing the work [4]-[5]. Most of the mechanisms were driven by steam power [6]. Meanwhile, human power was used for various applications using special mechanisms [7]-[10]. In the beginning of the 19th century, the bicycle mechanism has been evolved which was used for traveling purposes [11]-[13]. Over the period, this mechanism used for driving households applications by using human power [14].

The concept of Human Powered Flywheel Motor, which could be considered a novel contribution in Human Power, has abbreviated as HPFM [15]-[16]. By using HPFM concept, one stores the human energy in a flywheel even at a tune of 3 to 5 h.p. The heavy applications were possible to attach with HPFM as a energy source. 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. HPFM concept for concrete mixer is chosen [17]-[23].

2 REVIEW ON CONCRETE MIXERS

The performance or quality of concrete basically depends on following factors (a) its microstructure (b) Its Compositions (c) its Curing conditions (d) Mixing methods (e) Conditions during mixing of the concrete [24]. Most often the quality of mix is governed by the mixing methods. There are two types of mixing methods namely Batch Mixers and Continuous Mixers.

3 TYPES OF MIXERS

3.1.1 Machine operated concrete mixer

The concrete mixer enables the continuous production of fresh concrete keeping appropriate homogeneity. The machine operated concrete mixers are more economical in case of large production of fresh concrete. In fact, concrete mixers fall in two basic types (a) Drum Mixer and (b) Pan Mixer.

3.1.2 Drum mixer

The drum type concrete mixers are generally used for the batch production. These concrete mixers are further classified as (a) Tilting Mixers and (b) Non tilting Mixers.

3.1.3 Pan mixers

The assembly of pan type mixer is simple and is generally used in low production precast companies or laboratories. Generally, it consists of circular pan which rotates about a vertical axis. There are two types of pan mixers available (a) Rotary Pan type (b) Stationary Pan type.

3.2 Concrete mixing process

Mixer of cement, sand and aggregate is designated on the various grades on the basic of proportions of mixing. In olden days mixing were carried out manually which is time consuming and laborious in view of ergonomics. Concrete mixer machine increases the productivity with less human energy consumption. Productivity or mixing efficiency depends upon the various parameters such as drum speed, shape and size of mixing drum, blades, mixing time and many more.

3.3 Need and scope of the present research

The population of the world is increasing day by day and the demands of civil constructional activities are 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 the case of remote or rural areas is considered then the situation seems to be altogether different. This is because of scarcity of the electricity and fossil fuels which are the main resources of energy to run the civil constructional machineries. Even on the flip side, the civil contractor is in a prowl of alternative way to carry out their work. Indeed, Concrete mixer is a prominent and main machine amongst all. Therefore, there is need to use a Concept of HPFM to operate the Concrete Mixer.

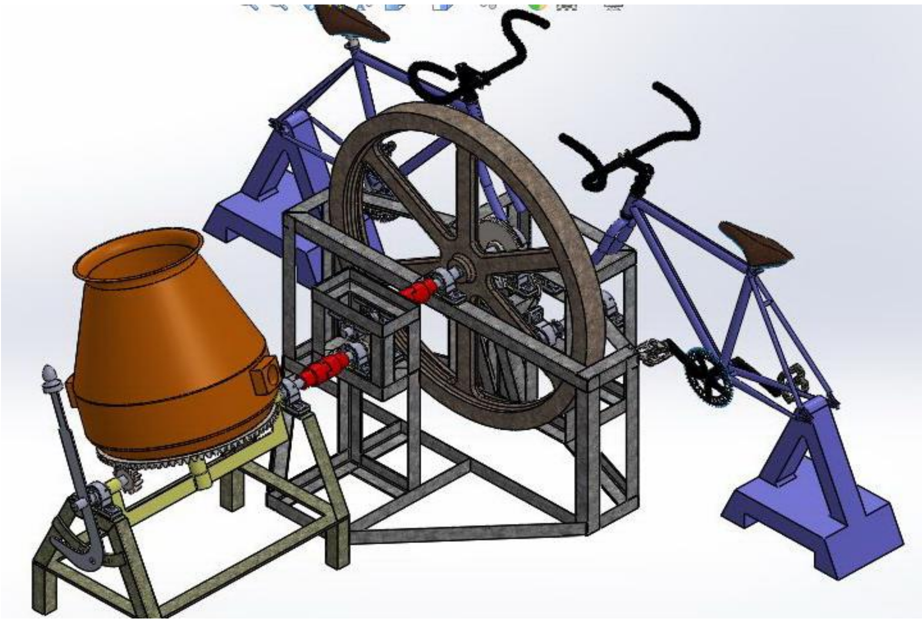

Figure 1. Pictorial view of Concrete Mixer energized by HPFM.

Generation of Design Data for the Proposed Concrete Mixer Energized by Human Powered Flywheel Motor

This is accomplished as follows.

On the basis of the experimentation plan, the medium size concrete mixer energized by Human Powered Flywheel Motor (HPFM) is fabricated.

In the next step, the experimentation for different sets of test points for the desired effects (dependent variables). The sets of reading obtained in the experimentation are useful to form a mathematical relationship amongst causes (independent variable) and effects (dependent variables). This mathematical relationship is commonly known as mathematical modeling.

The design data is generated with the help of obtained mathematical models. As the mathematical models are approximate models, hence to simulate the phenomena in exact manner, the ANN simulation is done.

3.4 Need of mathematical model for concrete mixing phenomenon

Literature indicates that most of the medium duty equipment used for the concrete mixing is designed based on thumb rules. On the other side the concrete mixing is itself complex phenomenon [24]. This concrete mixing equipment is run either by electric motor or diesel engines. The design data related to such concrete mixer are rarely available. If one speaks about the concrete mixer run by Human Powered Flywheel Motor, then it would be perhaps a unique attempt towards development of construction equipment [26]-[27]. As it is tried first time therefore no design data is previously available. If a phenomenon is simple and easy to understand in that case logic-based modeling is possible. But if a phenomenon involves several variables responsible for its occurrence then it becomes difficult to establish the relationship merely on the basis of logic. Then, one has to simulate the phenomenon by experimentation followed by gathering experimental data of variables; it would then be possible to establish a quantitative relationship amongst causes and effects of phenomenon. This relationship is generally known as experimental data-based model. The present phenomenon of concrete mixing is occurred in twofold. The ingredients of concrete mix receive momentum from available energy stored in Flywheel. The energy of flywheel is utilized to give momentum to ingredients of mix, to overcome the inertia of associated parts of machine, friction of bearings and teeth of gears.

The ingredient momentum seems to be a pure energy transformation of kinetic energy into potential energy and vice versa. The moving ingredient imposes the friction on the surface of mixer drum. This effect provides some effect on machine and even on mixing process.

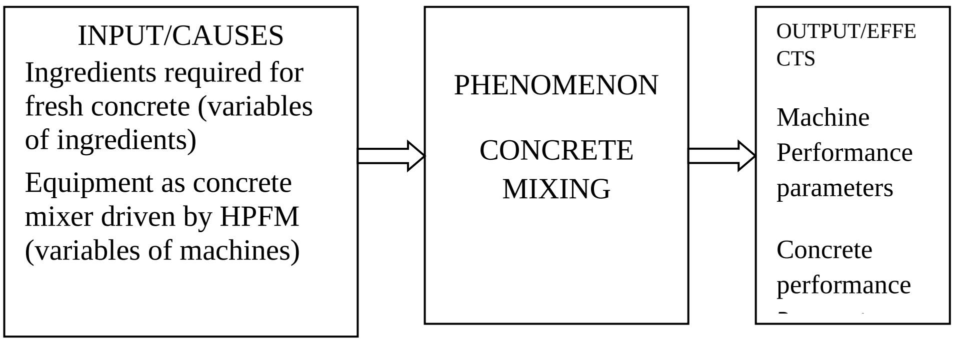

Figure 2. Diagram of concrete mixing phenomenon

4. DESIGN OF CONCRETE MIXER

The design of Concrete mixer energized by Human Powered Flywheel Motor is carried out by deciding the size of flywheel, because the flywheel is main source of Power generation. Therefore, it is inevitable to ascertain the variation of load torque for one complete revolution of concrete drum [24]. Once the size of flywheel is decided, the power developed by a flywheel could be ascertained. This power, decided speed variations and load factors are then useful to design each component placed in proposed Concrete Mixer Energized by Human Power Flywheel Motor.

4.1 Estimation of load torque acting on the drum shaft: Dynamics of drum

The dynamic analysis of concrete mixer is executed for its 3600 travel by considering the oversimplifying assumptions that the concrete mix is moving in a tilted drum as a whole unit. The phase of 0 to 900 travel of drum is quite prominent because, this phase provides actual load torque on the drum shaft [28]-[29].

Initially, the drum is at rest at 00 and it travels to next 900. During this phase, mix material is moving with the surface of drum up to certain limit i.e. below 900. This limit is uncertain because material is adhering to the surface of drum due to the following parameters (a) Skin friction force (b) Centrifugal force acting on material. After certain limits, these parameters have less dominance on the mix material. Therefore, as soon as the concrete material reaches up to 900 or less than that the mix material gets slide back from 900 position of drum to acquire its initial position. This phenomenon is just like oil whirl occurring in a journal bearing.

The dynamics of above cited phenomenon is executed by considering that the mix is moving as a whole unit from rest position to the next 900. The velocity and acceleration of moving concrete mix would be same as that of surface velocity of drum during its upward travel. But it is quite interesting to see the velocity and acceleration of mix when it slides. The acceleration of mix for this phase is evaluated as under.

Consider a bulge of mix having a center of gravity as indicated in figure 3. In fact, through the CG the following forces which encountered are (1) Force due to weight, W (2) Centrifugal force, CF (3) Inertia force, IF (4) shear force between the layers of concrete mix, SF. When the concrete slides from the 900 position it acquires the velocity, V and the bulge of concrete offered a resistance is a shear force between the layers of concrete mix.

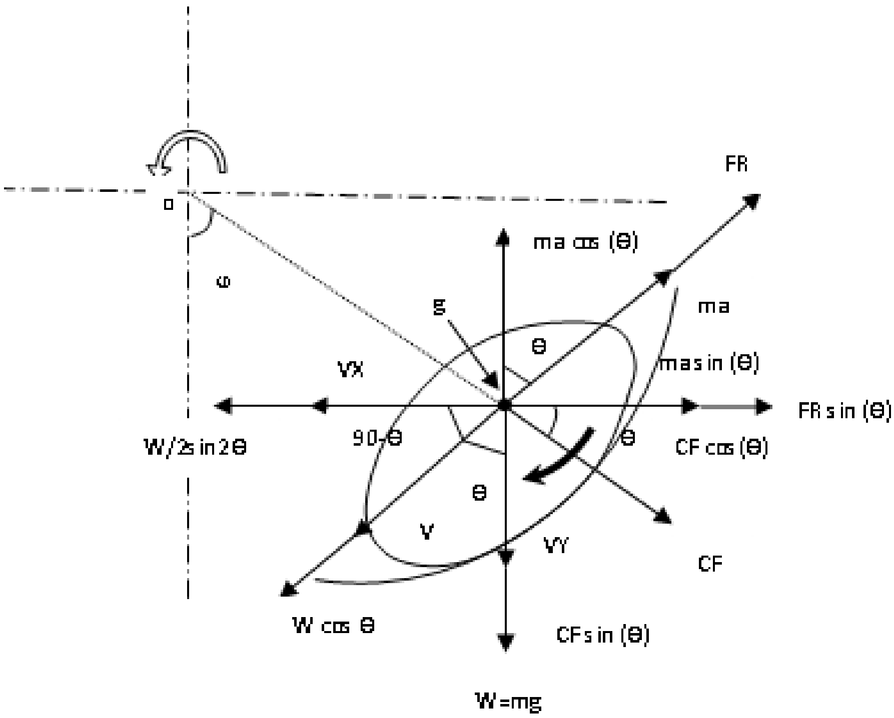

Figure 3. Forces acting on bulge

Thus,
Forces along X axis are

$$ma\sin(\theta) = FR\sin(\theta) - \frac{W}{2}\sin(2\theta) + CF\cos(\theta) \quad (1)$$

As the mass of bulge is sliding downward it means it decelerates in opposite direction. Therefore, one should take the acceleration as deceleration and thus a becomes

$$-ma\sin(\theta) = FR\sin(\theta) - \frac{W}{2}\sin(2\theta) + CF\cos(\theta) \quad (2)$$

The shear force FR can be written as,

$$FR = \mu A \frac{dv}{dy}$$

Here μ is the kinematic viscosity of concrete mix. A is the area of shear, v is the velocity and Y is the distance between the layer to the top most surface. For the simplification the dv and dy have been considered as finite velocity and distance.

$$a = -\frac{\frac{\mu A}{Y}V}{m} - \frac{W}{2m}\cos(\theta) + \frac{CF}{m}\cot(\theta) \qquad (3)$$

as,

$$c = \frac{\mu A}{Y}$$

$$\frac{dvx}{dt} + \frac{cv}{m} = -\frac{W}{m}\cos(\theta) - \frac{CF}{m}\cot(\theta)$$

By integrating

$$Vxe^{\frac{C}{m}t} = \frac{1}{m}\int (W\cos(\theta) - CF\cot(\theta))e^{\frac{C}{m}t}\,\frac{e^{\frac{C}{m}t}}{\frac{C}{m}} + C1$$

$$Vxe^{\frac{C}{m}t} = \int (\frac{W}{m}\cos(\theta) - \frac{CF}{m}\cot(\theta))e^{\frac{C}{m}t} + C1$$

$$C1 = -\frac{1}{c}W\cos(\theta) - CF\cot(\theta)e^{\frac{C}{m}t}$$

$$Vx = \frac{1}{c}(W\cos(\theta) - CF\cot(\theta)(1 - e^{-\frac{C}{m}t}) \qquad (4)$$

Similarly, the forces along the y directions give

$$ma\cos(\theta) = -CF\sin(\theta) - W + Fr\cos(\theta)$$

$$a = \frac{CF}{m}\tan(\theta) + \frac{W}{m}\sec(\theta) - \frac{cv}{m}$$

$$\frac{dVy}{dt} + \frac{cv}{m} = \frac{CF}{m}\tan(\theta) + \frac{W}{m}\sec(\theta)$$

By solving the above equation, one may get

$$Vy = \frac{1}{c}(W\sec(\theta) + CF\tan(\theta))(1 - e^{-\frac{C}{m}t}) \qquad (5)$$

Thus, the resultant velocity of bulge during sliding would be estimated as given below,

$$VR = \frac{1}{c}\sqrt{(W\cos(\theta) - CF\cot(\theta)^2 + (W\sec(\theta) + CF\tan(\theta))^2}\,(1 - e^{-\frac{C}{m}t}) \qquad (6)$$

Again, differentiate with respect to time to get,

$$\frac{dVR}{dt}=\frac{\sqrt{(W\cos(\theta)-CF\cot(\theta)^2+(W\sec(\theta)+CF\tan(\theta))^2}}{m}e^{\frac{-c}{m}t} \tag{7}$$

The above equation represents the equation of sliding acceleration of the concrete bulge at shown in Figure 4. For the present case the sliding acceleration has been graphically plotted shows in Figure 5.

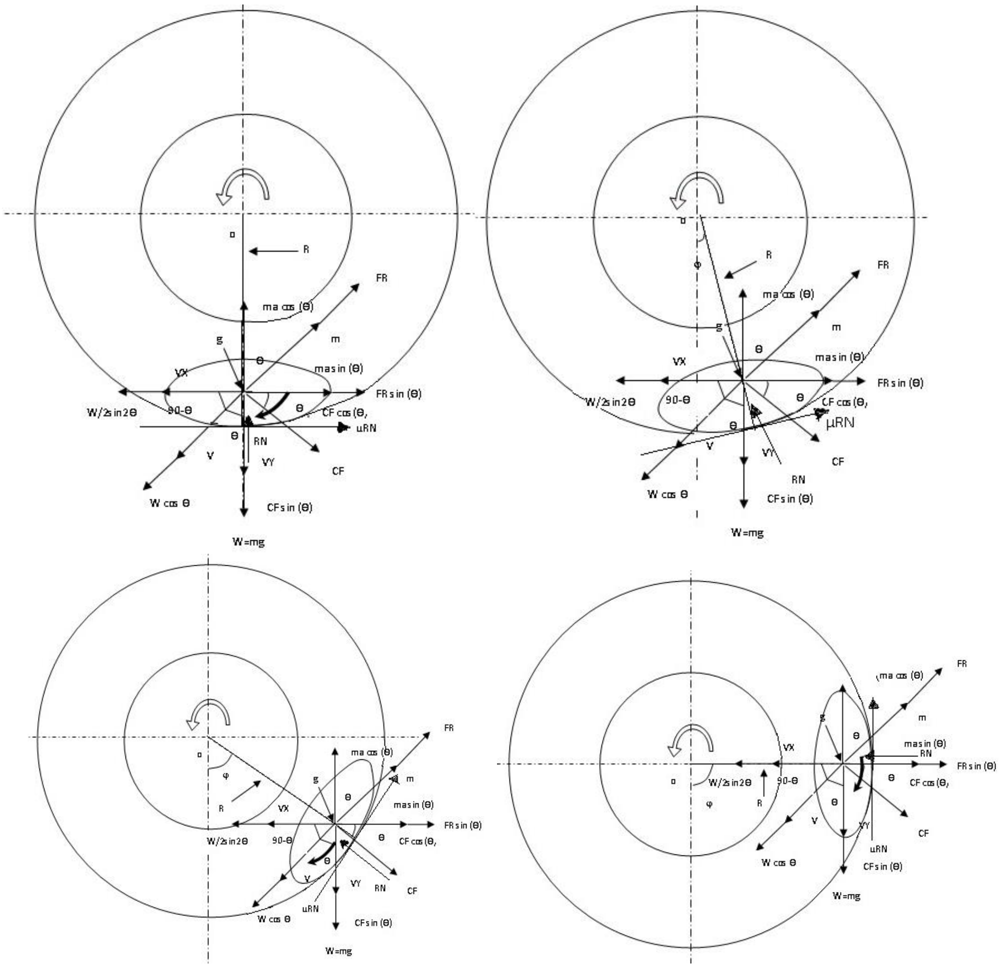

Figure 4. Bulge at different position

The sliding acceleration which is estimated is then used to estimate the inertia force of concrete bulge. Considering the influence of all forces depicted in figure 4 the frictional force μ RN has been estimated for every 100 position of drum by solving below stated equations. Figure 5 is representing some of the position of analysis.

$$Fx = ((-218.73 \times \cos(90-\theta) + m \times a \times \cos(\theta)) \quad (8)$$

$$Fy = ((218.73 \times \sin(90-\theta) + m \times a \times \sin(\theta)) + m \times g \quad (9)$$

The load torque for each 100 position is determined by multiplying (μRN) to the radius of a drum. The graph of load torque verses one rotation of a drum is depicted through figure 7.

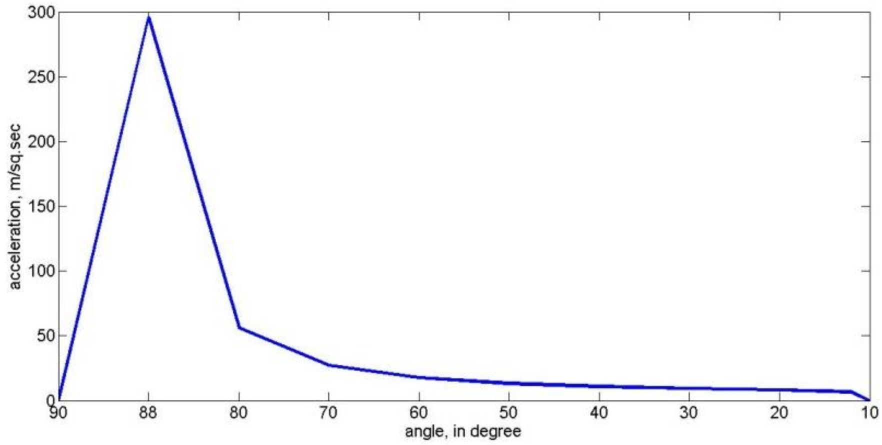

Figure 5. Acceleration of sliding bulge of concrete

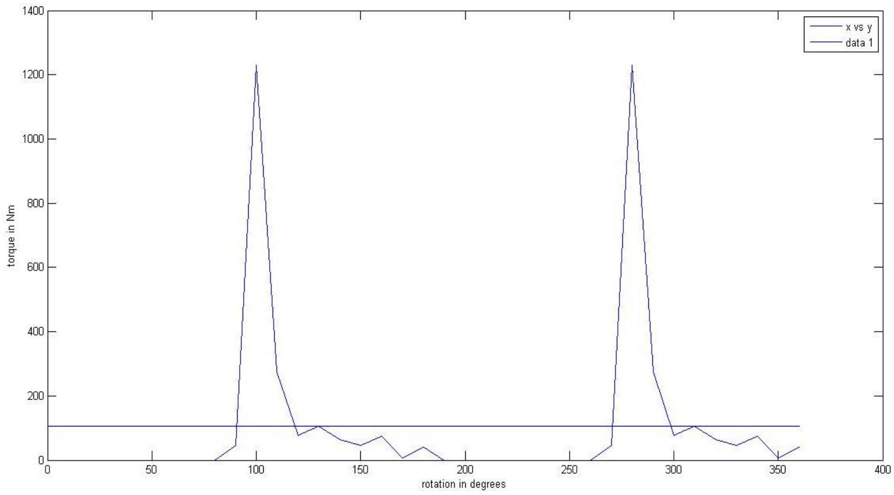

Figure 6. Variation of load torque on drum shaft of Concrete Mixer.

A mean torque is estimated which is helpful to estimate the fluctuation of energy during one rotation. In Figure 6, ΔE represents fluctuation of energy. In the present case the mass of flywheel is estimated from the below stated formula [30]-[31].

$$\Delta E = I\, Cs\, \omega^2 \qquad (10)$$

Where, I- Mass moment of inertia of flywheel,
Cs- Coefficient of fluctuation of speed,
ω- Angular velocity.

From above formula the value of inertia of flywheel is decided. The power stored in the flywheel is estimated as 2 H.P. which is useful to design the complete energy setup.

Table 1. Design Dimensions of Concrete Mixer driven by HPFM

S.N,	**Name of Component**	**Size and Specifications**
	Flywheel Dimensions	
1	Width of flywheel	8.5 cm
2	Thickness of rim	3.5 cm
3	Arm	5 cm
4	Arm Length	35 cm
5	Hub Diameter	9.5 cm
6	Shaft Diameter	4 cm
7	Outer Diameter of flywheel	90 cm
8	Number of arms	6
	Gear Pair 1	
1	Pinion	40 teeth
2	Gear	90 teeth
	Gear Pair 2	
1	Pinion	18 teeth
2	Gear	18 teeth
	Gear Pair 3	
1	Pinion	18 teeth
2	Gear	72 teeth

4.2 Experimentation

The developed concrete mixer driven by HPFM is run for different trials. The trails have been executed for different Grades of cement, no of blades, gear ratios, Space between blade etc (independent variables) as indicated through Table 2. The response or dependent variables are measured adopting following procedure [31].

Table 2. Trials for different independent variables

Grade of cement	**No of Blades**	**Space between drum and blade**	**Blade angle**	**Gear ratio**	**Space between blades**	**Length of blade**
M7.5	2,3,4	0.1 m	15^0	4,6,8	0.03 m	0.4 m
M10	2,3,4	0.1 m	15^0	4,6,8	0.03 m	0.4 m
M15	2,3,4	0.1 m	15^0	4,6,8	0.03 m	0.4 m
M20	2,3,4	0.1 m	15^0	4,6,8	0.03 m	0.4 m

4.3 Estimation of resisting torque

The flywheel is speeded up to a decided speed of 360 rpm for each cycle of trial. As such there are thirty-six cycles are executed. Once the flywheel attended at pertinent speed clutch has been engaged. The stored kinetic energy in the flywheel is exhausted to revolve the already loaded mixer drum. The mixing is carried out till the flywheel gets stopped [32]-[33]. The total duration is one complete cycle. The data of angular speed of the drum shaft is recorded in computer for one complete cycle against every time instant. The estimation of resting torque is done by adopting following procedure.

(a) The data carried out for every cycle is plotted considering angular velocity on ordinate and time on abscissa.

(b) The slope at each section of the graph (the section is considered for every ten seconds duration period) is ascertained by the equation $\frac{d\omega}{dt} = \frac{\omega 2 - \omega 1}{t2 - t1}$. This is known as retardation of the flywheel.

(c) Estimating the value of Equivalent Inertia of the System referring to the drum shaft, the resting torque value could be accomplished by the equation as TR= $I_{eq} \times \frac{\omega 2 - \omega 1}{t2 - t1}$

(d) The values of torque for every ten seconds are calculated and the average value has been considered for the modeling.

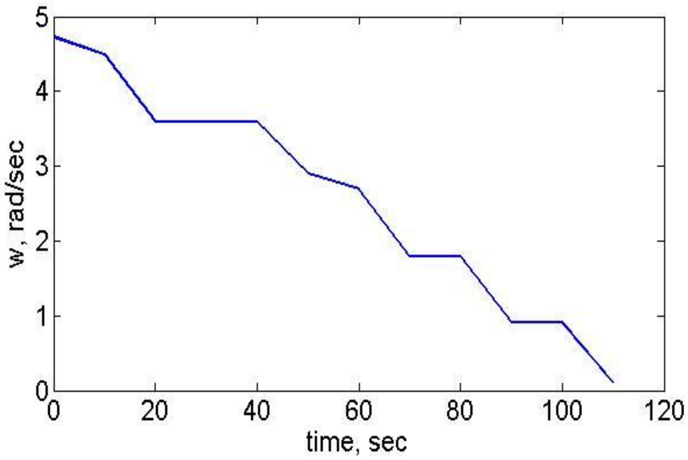

Figure 7. Angular velocity of drum shaft after engagement of clutch

Table 3. Readings for one cycle

Sr.No	wt of cement, Wc, kg	wt of sand, Ws, kg	wt of aggregate, Wa, kg	quantity of water, Ww, kg	dia of drum, Dd,m	depth of drum, Ld, m	no of blades, Nb	inclination of blade, B, degree	length of blade, Lb, m	width of blade, Wb, m
1	5	10	20	2.55	0.7	0.7	4	15^0	0.39	0.09
2	5	10	20	2.55	0.7	0.7	4	15^0	0.39	0.09
3	5	10	20	2.55	0.7	0.7	4	15^0	0.39	0.09
4	5	10	20	2.55	0.7	0.7	4	15^0	0.39	0.09
5	5	10	20	2.55	0.7	0.7	4	15^0	0.39	0.09
6	5	10	20	2.55	0.7	0.7	4	15^0	0.39	0.09
7	5	10	20	2.55	0.72	0.7	4	15^0	0.39	0.09
8	5	10	20	2.55	0.72	0.7	4	15^0	0.39	0.09
9	5	10	20	2.55	0.72	0.7	4	15^0	0.39	0.09
10	5	10	20	2.55	0.72	0.7	4	15^0	0.39	0.09
11	5	10	20	2.55	0.72	0.7	4	15^0	0.39	0.09
12	5	10	20	2.55	0.72	0.7	4	15^0	0.39	0.09

Sr.No	space bet drum and blade, Sdb, m	space bet strips of blade, Ssb, m	flywheel Speed RPM	flywheel energy, Fe, Nm	speed of mixer shaft, Nms	gear ratio, Gr	Mixing Time Tm	Time interval , t	strength	slump height	resisting torque, Tr
1	0.11	0.03	360	8430.313	45.2	8	100	1	15.431	0.05	34.74771
2	0.11	0.03	300	5854.384	42.9	8	100	10	15.431	0.05	34.74771
3	0.11	0.03	300	5854.384	34.3	8	100	20	15.431	0.05	34.74771
4	0.11	0.03	240	3746.806	34.3	8	100	30	15.431	0.05	34.74771
5	0.11	0.03	240	3746.806	34.3	8	100	40	15.431	0.05	34.74771
6	0.11	0.03	180	2107.578	27.7	8	100	50	15.431	0.05	34.74771
7	0.11	0.03	180	2107.578	25.7	8	100	60	15.431	0.05	34.74771
8	0.11	0.03	120	936.7014	17.1	8	100	70	15.431	0.05	34.74771
9	0.11	0.03	120	936.7014	17.1	8	100	80	15.431	0.05	34.74771
10	0.11	0.03	60	234.1754	8.6	8	100	90	15.431	0.05	34.74771
11	0.11	0.03	60	234.1754	8.6	8	100	100	15.431	0.05	34.74771
12	0.11	0.03	1	0.065049	1	8	100	110	15.431	0.05	34.74771

4.4 Estimation of slump height

The fresh concrete is poured in the cone and it was tempered 25 times with the specified size of iron rod. After ascertaining the proper filling of cone then it is lifted carefully so that the slump height could be accomplished. The height may vary because of its proportions of ingredients and mixing quality etc.

Figure 8. Execution of slump test during experimentation

4.5 Estimation of compressive strength

This test is carried out on specimen of specified sizes of cubical. In the present work, test is executed by taking specimen cube of 15×15×15 cm. The fresh concrete is poured into the cube and tampered properly. The mould is removed after 24 hours and the specimen put in water for 28 days for curing. When the curing is completed the specimen is ready for test. Test for each batch is carried out on Universal Testing Machine and the results are recorded. The readings of one cycle are depicted through Table 3.

Figure 9. Cube making for test during experimentation

Figure 10. Execution of Compressive strength Test during

4.6 Derived Mathematical from Experimentations:

Based on the obtained experimental data and by adopting the approach of multiplane regression analysis the mathematical models for 1, Resisting torque 2. Mixing Time 3. Strength 4 Slump Height 5. Drum speed are evolved.

Model of dependent Π term for resisting torque, Tr

$$\Pi d1 = 1.433178 \text{ X } (\pi 1)^{-0.5015} \text{ X } (\pi 2)^{0.3176} \text{ X } (\pi 3)^{-0.009} \text{ X } (\pi 4)^{1.0095} \text{X } (\pi 5)^{-0.6784} \quad (11)$$

Model of dependent Π term for mixing time, Tm

$$\Pi d2 = 769.1304 \text{ X } (\pi 1)^{-0.1582} \text{ X } (\pi 2)^{-0.0148} \text{ X } (\pi 3)^{0.0012} \text{ X} (\pi 4)^{-0.4992} \text{X} (\pi 5)^{-0.022} \quad (12)$$

Model of dependent Π term for strength, S

$$\Pi d3 = 0.802417 \text{ X } (\pi 1)^{-1.0689} \text{ X } (\pi 2)^{0.0332} \text{ X } (\pi 3)^{-0.0002} \text{ X } (\pi 4)^{1.0004} \text{X } (\pi 5)^{-0.0572} \quad (13)$$

Model of dependent Π term for slump height, Sh

$$\Pi d4 = 0.37145 \text{ X } (\pi 1)^{0.0205} \text{X } (\pi 2)^{-0.1376} \text{ X } (\pi 3)^{-0.0006} \text{ X } (\pi 4)^{-0.0004} \text{X } (\pi 5)^{-0.4276} \quad (14)$$

Model of dependent Π term for speed of drum shaft, Nm1

$$\Pi d5 = 4.070052 \text{ X } (\pi 1)^{-0.2474} \text{ X } (\pi 2)^{-0.0722} \text{ X } (\pi 3)^{0.2751} \text{ X } (\pi 4)^{0.0766} \text{X } (\pi 5)^{-0.9442} \quad (15)$$

5 GENERATED DESIGN DATA

The obtained mathematical models are useful to generate the design data for the concrete mixer driven by HPFM. The design data is accomplished by varying drum diameter, angle of blades, space between blades, space between drum and blade and length of blade in each mathematical model. This is done by keeping rest of the variables at their decided magnitude for particular grade of cement and varies only the variable of interest. The ranges for each variable are give in table below.

Table 4. Ranges of variations for decided variables

S.N.	Name of Variable	Range
1	Drum Diameter	0.68m to 0.77m
2	Angle of Blade	0.1047rad to 0.2617rad
3	Space between blade	0.026m to 0.035m
4	Space between drum and blade	0.07m to 0.16m
5	Length of blade	0.09m to 0.99m

6 ARTIFICIAL NEURAL NETWORK SIMULATION

The phenomenon of concrete mixing is already stated that it is quite complex and the mathematical models which are established show considerable complexity. Therefore, it is essential to execute the artificial neural network (ANN) technique for the experimental data-based models [34]-[36].

Procedure for formulation of ANN Simulation:

In the present simulation MATLAB software is being used. The prominent steps are selected which are discussed below [37]-[40],

(1) The gathered data from the experimentation have been discritized into two groups namely (a) independent variables as input data and (b) Dependent variables as output variables. These data have been imported from the program.

(2) The prested function available in matlab software then used to read this data and it is automatically sized.

(3) The preprocessing offers the data to be normalized by estimating mean and standard deviation of the data.

(4) The input and output data then classified into three groups (a) Testing (b) Validation (c) Training. Considering 472 readings the initial 75% of data have been considered for training. Last 75 % of data is decided for validation and middle overlapping 50 % data has been chosen for the testing.

(5) The data is thus stored in structures for training, testing and validation.

(6) By observing the pattern of the data, feed forward back propagation type neural network is chosen.

(7) The network has been trained using training data. The computational error between targeted and actual values are estimated and thus simulation is executed.

7 RESULT AND DISCUSSION

It is observed that resisting torque and strength are decreasing while drum shaft speed, mixing time and slump height are increasing. The reason for decreasing resisting torque is probably due to the added inertia of the blade, because this added inertia helps a drum to store more kinetic energy received from a flywheel. The stored kinetic energy helps drum to spin more. Due to this spinning of a drum at higher rate, resisting torque offered at drum shaft has decreased. The increased speed of a drum induces significant change in centrifugal force which causes the ingredients of mix to move outside from the centre of a drum. This action leads to increase mixing time. However, the prominent role of centrifugal force leads to mitigate the strength of the mix.

When the space between drum and blade have been varied then resisting torque and strength are increased while drum shaft speed, mixing time and slump height are decreased. Logically the resisting torque is increased due to following reasons (a) the more space allowed the material to intact more between the space which gives higher frictional force on the surface of a drum, thus torque has increased and speed has decreased. As speed is less the influence of centrifugal force would be less and thus mixing time will be less due to which proper mixing is allowed to occur which leads to increase in strength.

On the other hand, when the spaces between blade and angle of blade have been varied the resisting torque and strength are decreased while drum shaft speed, mixing time and slump height are increased. Logically when the space between blades is increased the resistance offered by the material to the blade and drum surface will be affected. This results into lowering the resisting torque and increase in drum shaft speed. If the space between the blade increases then the proper mixing cannot be accomplished, this thus adversely affects the strength.

The increased angle of a blade results in low frictional forces at drum surface and blade surface. This significantly affects the resisting torque and strength as well.

When drum diameter has varied it is observed that the resisting torque, mixing time and slump height are increased while drum shaft speed and strength are decreased. As drum diameter increases, a link arm movement of a drum increases which leads to aggrandize the torque value. The point of interest here is that although the value of centrifugal force is less the value of mixing time is more. This is because the increase in drum diameter compels the ingredient of mix to move on surface of a drum larger than the previous case.

8 CONCLUSIONS

Through the present research some important conclusions have been made which are discussed below.

As the natural resource is exhausted rapidly and one another important issue is the global warming. These two aspects instigate the researcher to think over the alternative energy source. However, the Human energy seems to be ecofriendly and pollution free energy source which is universally available and it must be used considering the future goals.

The HPFM concept could be utilized for several applications. Specifically, for interior and rural areas where electricity is a prime issue. This concept not only provides the solution over the energy problem but it also generates the possibility of employment.

Through study, it is revealed that, this concept is applicable to that application which demand torque is fluctuated. Thus, a concrete mixer is the suitable application for such concept because its demand torque fluctuates with respect to time.

The best mixing could be accomplished if the drum speed of concreter mixer should be less than 30 rpm. However, as such a meager literature is available on concrete mixer deign. The literature indicates only about the performance of the concrete mix and very few literatures are available on design of concrete mixer. This is happening because of the transient dynamics of mixing process. It is to be ascertained so that one can fairly estimate the exact optimized parameters of mixing machines. Through the present research an attempt is made to understand its dynamics and attempt to generate the design data of such mixer applying the eco-friendly concept.

CONFLICT OF INTEREST

The authors confirm that there is no conflict of interest to declare for this publication.

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