Design & Development of Nursery Fertilizer Mixer Energized by Human Powered Flywheel Motor

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ABSTRACT

A concept in which a human being spins a flywheel by system similar to bicycle, the rotational kinetic energy is stored in the flywheel. Such energy source is conceptualized as Human Powered Flywheel Motor (HPFM).In this paper an attempt is made to develop and experimentally validate a human powered mixing machine to mix nursery fertilizer in proper proportion . This mixture is then used as a fertilizer for plantation in small size farming. Here this machine performs this mixing operation not by electric power but by human power. The evolved machine system comprises of three subsystems namely (1) Energy Unit : Comprising of a suitable peddling mechanism, speed rise gear pair and Flywheel conceptualized as Human Powered Flywheel Motor (HPFM) (2) Suitable torsionally flexible clutch and torque amplification gear pair and (3) a process unit (Nursery fertilizer mixer). The functional feasibility and economic viability of Human Powered nursery fertilizer mixer to mix nursery fertilizer is established in this paper The machine so developed is economically viable, can be used by unskilled workers and it save time. With the present work design data for low to medium capacity nursery fertilizer mixer energized by human powered fly wheel motor can be established with the help of which the specific unit for a low to medium capacity mixer can be designed.

Keywords: Flywheel, Spiral Jaw Clutch, Nursery Fertilizer Mixer.

1. INTRODUCTION

Dr Modak and his associates [1 to 12] have developed many human powered process machines which can energize process unites needing 3 to 7 hp .This includes such for brick making [1, 6, 7] wood turning [8]. Alge formation machine [9] wood strips cutter and smiths hammer [10] and electricity generation [11]. This machine system comprise of three subsystems (1) energy unit (2) mechanical power transmition system (3) process unit. Energy unit comprise of an arrangement similar to a bicycle, a speed raising gear pair and a flywheel. The flywheel size is one meter rim diameter, 10 cm rim width and 2 cm rim thickness. A flywheel is with 6 armed constructions each arm is with elliptical cross section. Mechanical transmission comprises of spiral jaw clutch or other clutches [4,5] and torque amplification gear pair. A rider through a bicycle mechanism and a speed increasing gear pair G' energizes a flywheel up to 500 r.p.m speed in about a minute time. Peddling is then stopped and the stored kinetic energy in the flywheel is made available to a process unit (PU) (in this case Nursery fertilizer mixer), through a suitable torsionally flexible clutch (TFC) and a torque amplification gear pair G. The stored energy in the flywheel is consumed in overcoming the process resistance of the process unit PU in 15 to 25 seconds depending on the process resistance. This amounts to energizing of a process unit in the range 3 to 12 hp. which could be of intermittent nature.

Dr Modak and his research scholars have also established functional feasibility and economic viability of such human powered machine for many rural based applications. In view of this, fertilizer mixture using human powered flywheel motor as an energy source is developed. It's approximate generalized experimental data based model is evolved which is detailed in this paper. This model is evolved applying methodology of experimentation proposed by H.Schanck, Jr [03].

1.NEED FOR DEVELOPING HUMAN POWERED FERTILIZER MIXER

The main objective to design and develop a machine, which uses the human powered flywheel motor as an energy source

(Modak J and Bapat A, 1987) is to make use of non-conventional energy as source. Developing countries of world like India are India is facing problems of Power storage due to rapid industrialization, non availability of power in rural areas and unemployment among semi-skilled workers. In the context of the present condition in India and the world countries with the Power shortage , exhaustion of coal reserves and unemployment, it is felt that “Manually energized Nursery Fertilizer mixer machine” for mixing nursery fertilizers is very necessary. This machine is environment friendly i.e. non pollutant. Development of such an energy source which has tremendous utility in energizing many rural based process machines in places where reliability of availability of electric energy is much low, will bring innovation & mechanization in agricultural engineering with the use of such machines. Unskilled men/women may also get employment.

2. OPERATION OF THE HUMAN POWERD NURSERY FERTILIZETR MIXER

3.1. Concept

The average work rate of a man working continuously is equivalent to 0.13 h.p. Therefore only continuous manufacturing process requiring less than 0.13 h.p. can be man powered. Any manufacturing process requiring more than 0.13 h.p. and which can be operated intermittently without affecting end product can also be man powered [6,8]. Such man powered manufacturing process can be based on the following concept.Here a flywheel is used as a source of power. Manpower is used to energize the flywheel at an energy input rate, which is convenient for a man. After maximum possible energy is stored in flywheel it is supplied through suitable clutch and gearing system to a shaft, which operates process unit (in this case Nursery Fertilizer mixer) [Modak and Moghe, 1997]; the flywheel will decelerate at a rate dependent on load torque. Larger the resisting torque larger will be the deceleration. Thus theoretical a load torque of even infinite magnitude could be overturn by this man-flywheel system. Manually driven nursery fertilizer mixer machine operates on the basis of above principle.

3.2 Operation

Essentially, the machine consists of three sub-systems: (1) the energy unit (2) transmission mechanism (3) the process unit. The energy unit consists of a conventional bicycle mechanism, the transmission unit consists of a drive train; a chain drive mechanism running over a pair of speed-increasing gears and the process unit. schematic arrangement of a Nursery Fertilizer mixer machine is shown in Figure-1.

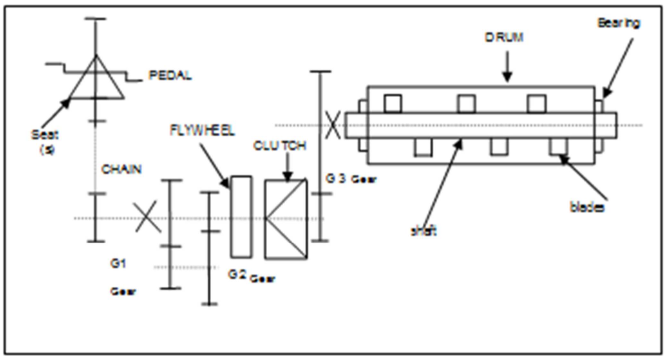

Figure-1: Schematic arrangement of a Nursery Fertilizer mixer machine.

The ingredients of the fertilizer viz Soil, Sand, and Cow dung in required proportion by weight is admitted in the drum through the opening provide in the drum. Then operator seats on the seat(S) and peddles the bicycle mechanism. The rider accelerates the flywheel to a desired speed in about one minute, through a chain and a pair of gears .The chain drive is utilized for first stage transmission because the drive is required to be irreversible, this is achieved by conventional bicycle chain drive with a free wheel . A free wheel is used between pedals and the flywheel to prevent the back flow of energy from flywheel to pedals. Initially the operator has to put in somewhat more driving torque to over come the inertia during initial acceleration phase of the motion. Once the steady speed of the motion is reached, the torque input gets reduced. This torque now just balances all the resistances such as frictional resistance and comparatively smaller inertia resistance time process resistance is offered by the mixing blades with the ingredients of the mixture. When flywheel attains desired speed, pedaling is stopped and it is connected to the process unit though torque amplification gears by engaging a two jaw spiral clutch. A special jaw clutch is used in this machine in place of conventional friction clutch as friction clutch consumes more energy for its own operation.[12].The energy stored in flywheel is supplied at the required rate to nursery fertilizer mixer for mixing ingredients .There is a provision of operating the system at five different speeds by properly choosing the gear ratio of a torque amplification gear pair G_3 provided on the shaft of the drum.

3.PHYSICAL DESIGN OF AN EXPERIMENTAL SETUP

It is necessary to evolve physical design of an experimental set up having provision of setting test points, adjusting test sequence, executing proposed experimental plan, provision for necessary instrumentation for noting down the responses and independent variables. From these provisions one can reduce the dependent and independent pi-terms of the dimensional equation. The experimental set up is designed considering various physical aspects of its elements. For example if it involves a gear, then it has to be designed applying the procedure of the gear design. In this experimentation there is a scope for design as far as fertilizer mixer is concerned from the strength considerations. Actually the fertilizer mixer is designed from the consideration of the dimensions having influence on user's fatigue from ergonomic considerations. The other dimensions of the fertilizer mixture are designed using previous mechanical design experience and practice.

Experimental set up can be designed for the above stated criteria so that the general ranges can be set properly within the test envelope proposed in the experimental plan.

4.1 Dimensional Analysis

Dimensional analysis is the method of dimensions.[14].It is a mathematical technique used in research work for design and for conducting model tests. It deals with the dimensions of the physical quantities involved in the phenomenon. All physical values are measured by comparison, which is made fixed to an arbitrarily fixed value. Dimensional analysis can be used primarily as experimental tool to combine many experimental variables into one. The main purpose of this technique is making experimentation shorter without the loss of control. Applying Buckingham *pai* method the, dimensional equation for response variable time of mixing and resistive torque are formulated.[14]. The various independent and dependent variables of this machine process with their symbols and dimensional formulae are given in Table 1.

Sr. No.	Description of variables	Types of Variables	Symbols	Dimensions
1	Weight of Sand	Independent	Ws	M
2	Weight of Soil	Independent	Wso	M
3	Weight of cow-dung	Independent	Wcd	M
4	Weight of water	Independent	Ww	M
5	Quantity of Mixture	Independent	W	M
6	Diameter of Blade tip	Independent	Dt	L
7	Blade pitch	Independent	P	L
8	Length of drum	Independent	L	L
9	Shaft diameter	Independent	d	L
10	Diameter of Drum	Independent	D	L
11	Input energy to the machine	Independent	E	$ML^2 \theta^{-2}$
12	Acceleration due to gravity	Independent	g	$L\theta^{-2}$
13	Gear ratio of torque amplification	Independent	G	Dimension less
14	Time of mixing	Dependent	tm	θ
15	Instantaneous Torque on shaft	Dependent	Tr	$ML^2 \theta^{-2}$
16	Flywheel speeding up time	Independent	T_f	θ

Table-1: Variables, Symbols, Dimensional formula.

M, L and T are the symbols for mass, length and time respectively. Applying Buckingham *pai* method the, dimensional equation for response variable time of mixing and resistive torque are formulated [14].

Sr. No.	Description of π - term	Equation of π - term
01	π - term relating	$\pi_1 = [w_s/w,\ w_{so}/w,\ w_{cd}/w,$

	to mixing of ingredients	w_w/w]
02	π - term relating to geometric variables of fertilizer mixer	π_2=[D_t/D, d/D, P/D, L/D]
03	π - term relating to initial energy given to Flywheel	π_3=[E / W.g.D]
04	π - term relating to Gear ratio	π_4=[G]
05	π - term relating to time taken for speeding up the flywheel	π_5=[√(g / D)T_f]

Table-2: Reduction of variables (Independent) through dimensional Analysis.

Sr. No.	Description of π - term	Equation of π - term
01	π - term relating to response variable Time of mixing	π_{01}=[√(g / D) t_m]
02	π - term relating to response variable Instantaneous torque on Mixer shaft	π_{02}=[T_r / WgD]

Table-3: Reduction of variables (dependent) through dimensional Analysis

4.2 Dimensional Equation for Response Variable for Time of Mixing & instantaneous torque on mixer shaft (Resistive torque)

4.2.1 Time of Mixing

$$\frac{\sqrt{g}}{D} t_m = f\left[(\tfrac{Ws}{W})(\tfrac{Wso}{W})(\tfrac{Wcd}{W})(\tfrac{Ww}{W})(\tfrac{Dt}{D})(\tfrac{P}{D})(\tfrac{L}{D})(\tfrac{d}{D})(\tfrac{E}{WgD})(G)(\tfrac{\sqrt{g}}{D}Tf) \right]$$

4.2.2 Resistive torque

$$\frac{T_r}{WgD} = f\left[(\tfrac{Ws}{W})(\tfrac{Wso}{W})(\tfrac{Wcd}{W})(\tfrac{Ww}{W})(\tfrac{Dt}{D})(\tfrac{P}{D})(\tfrac{L}{D})(\tfrac{d}{D})(\tfrac{E}{WgD})(G)(\tfrac{\sqrt{g}}{D}Tf) \right]$$

5. RESULT AND DISCUSSIONS

Empirical models to predict the performance of the manually driven nursery fertilizer mixer to mix various ingredients of nursery fertilizer were established and optimum values of various parameters were arrived at on the basis of experiments. A new theory of mixing of nursery fertilizer from the manually driven nursery fertilizer mixer is proposed. This hypothesis states that on engagement of the clutch, the speed of flywheel suddenly falls indicating energy loss. A part of this energy loss is due to developing pressure due to mixing resistance offered by the ingredients when this pressure in the ingredients crosses yield stress, mixing commences. It is further hypothesized that the mixing time is a function of available energy for mixing, resisting torque and average angular speed of the mixer shaft. In designing the Human energized mixer, the main objective was on cost and ergonomic designed, readily-available materials and we proposed a simplistic design that can deliver productive, efficient, and reliable mixer for rural area. This equipment can adequately replace electric motor-driven fertilizer mixer in rural areas where there is no or limited supply of electricity.

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