ISSN: 2319-5967
ISO 9001:2008 Certified
International Journal of Engineering Science and Innovative Technology (IJESIT)
Volume 1, Issue 2, November 2012

A Review on- Flywheel Motor

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***Abstract*— Since invention Flywheel motor is being extensively used in various application which are energized by the human energy. Such application includes brick making machine, flour mill, forge hammer, chaff cutter etc. Because of increasing range of application flywheel motor is being the subject of interest of the researchers for the optimum use of human energy. In an attempt this paper presents the exhaustive literature survey on the flywheel motor focusing on the work done so far.**

Index Terms— **Flywheel Motor, Brick Making Machine, Chaff Cutter, Forge Hammer, Pedal Operated Flour Mill.**

I. INTRODUCTION

Human powered brick making machine was first of its kind developed for the manufacturing of bricks (Modak J.P. J.P.1982, 1994, 1997, 1998) [**1**]. and since then various processes are energized by the human power such as chaff cutter, wood turning, cloth washing, potter's wheel, flour mill etc [**2**]. All these machines are operated by the human power. Human pedals the system with rate suitable to it, this energy is supplied to the processing unit through intermediate flywheel. Essentially The Machine consists of flywheel motor , driven bicycle mechanism with speed increasing gearing , which drives the shaft of process of process unit through clutch and torque amplification unit (Gupta 1977)[**1**].Ever increasing energy crises , increasing fuel crises, , busy schedules of load shading, unemployment in rural side of developing countries like India justify the need of human powered machines. Various parameters of these machines are optimized for easy operation by the operator and consequently make efficient use of human energy. In an attempt, this paper presents the exhaustive literature survey on the flywheel motor focusing on the numerous experimentation done on flywheel motor for optimizing its performance.

II. DETAILS OF FLYWHEEL MOTOR

Alexandrove 1981 stated that to power any machine by human energy, its driving power should be less than 75 watts but if any machine or process requiring more than 75 Watts and if process is intermittent without affecting and product, it can also be operated by human energy with the provision of intermittent energy storing unit such as flywheel [**3**]. This stored energy is supplied periodically at required rate to process unit. This necessitates the use of flywheel in human energized machines and called as flywheel motor. From 1977 Modak J.P. and his associates are working on flywheel motor. A manually driven brick making machine was first of its kind in which manually energized flywheel motor is used for first time [**4**]. Essentially the flywheel motor consists of a simple bicycle mechanism, which drives flywheel by a human energy through pedaling and pair of speed increasing gears and clutch. [**3**]. the schematic of flywheel motor is as shown in fig1.

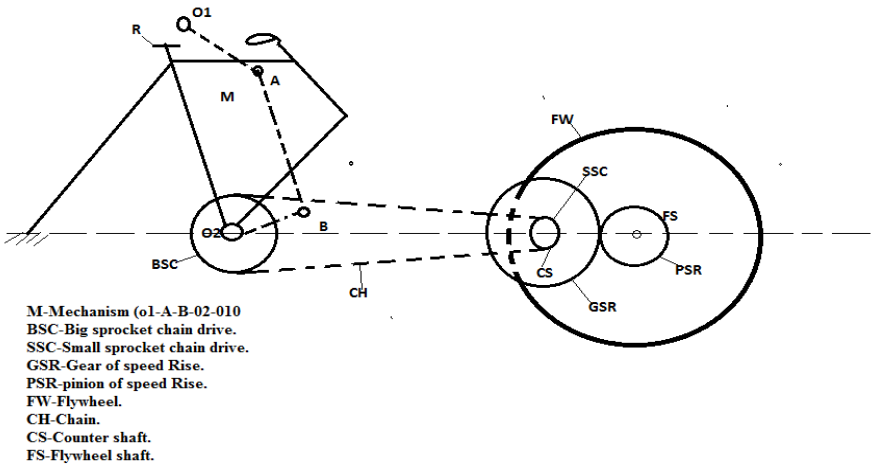

Fig1: Schematics of Flywheel Motor

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As shown in figure1 the mechanism 'M' is energized by the rider by pedaling at big sprocket chain drive 'BSC' there by converting the oscillatory motion of thighs into rotational motion of counter shaft 'Cs'. The pair of speed increasing gears connects the counter shaft 'Cs' with the flywheel shaft 'Fs' [**4**].Driver pumps the energy in flywheel at energy rate convenient to him [**4**]. In this way, the muscular energy of human is converted into kinetic energy and stored into flywheel by this man machine system and for its efficient use it is necessary to optimize its parameters [**4**].

III. PERFROMANCE PARAMETERS

Initially, the flywheel motor was developed only on the intitution of human, not based on any design data; rather it was built [**4**]. But later with the numerous experimentation the design data is made available which is discussed below.

A. *Flywheel size and Moment of Inertia*

The size of the flywheel and its moment of inertia also plays the vital role in the terminal velocity of flywheel. Modak J.P (1987) during the experimentation has observed that for the average person of 165 cm stature from age group 20-22 years maximum thigh oscillation is 40. [**5**]. Therefore with the available chain drive for existing 22" bicycle frame the flywheel speed of 240 rpm was found appropriate enough from point of total speed rise from pedals to flywheel shaft [**5**]. In order to store the maximum energy in flywheel irrespective of speed fluctuation, Modak J.P.(1987) has determined the size of flywheel (180-240 rpm)[**5**]. During his research the Flywheel rim diameter is found to 82 cm which gives the weight of flywheel as 150Kg and 266 Kg for 240 rpm and 180 rpm respectively. Hence Modak J.P.(1987) suggested the flywheel with 150 Kg @240 rpm[**5**]. Further Modak J.P. (1987) has also found that Moment of inertia has no effects on required driving torque at pedal and stores same energy for same frequency of thigh oscillation [**5**].

B. *Gear Ratio*

In order to provide the ease to operator it is necessary to reduce the harness effect of vibration and jerk at the process unit shaft. Hence Modak J.P. (1987) suggested the value of gear ratio as 4:1 so as to reduce the effect of jerk induced at process unit shaft as result of energy or momentum exchange during the clutch engagement. If lower value of gear ratio is to be used then flywheel speed should be maintained higher than 240 rpm [**5**].

C. Improvement in Existing Bicycle Mechanism

For the efficient use of the system it is necessary to make maximum use of the human energy. But Modak J.P. has observed that among the 360° revolution of pedal only part of it produces the necessary useful torque. This is because of the limitation of existing bicycle drive .Modak J.P (1985) has established the relationship between the useful torque developed at the crank as function of crank position during its revolution [**7**]. The observations made by Modak J.P. are tabulated below.

Table 1: Relation between crank position and torque produced.

Sr no	Crank position from TDC	Torque
1	0°-30°	Partially useful
2	30°-115°	Useful
3	115°-162	Partially useful
4	162°-360°	Idle.

Even when both the cranks are considered the useful driving angle is found to be 154°. [**7**].Consequently for improvement in maximum utilization of operators energy Modak J.P. suggested three modified mechanisms namely Quick return ratio one, Double lever inversion and Elliptical sprocket[**7**].Based on his mathematical modeling he concluded improvement of 18%,17%, and 38% in human energy utilization for Elliptical sprocket, Quick return ratio one, Double lever inversion and respectively. This performance of various bicycle drives then was experimentally verified by Modak J.P., Chandurkar K.C. (1987) and found almost matching with theoretical values [**6**].

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IV. OPTIMISATION OF VARIOUS PARAMETERS

Because of the wide range of applications the flywheel motor is being the constant subject of researchers for the performance improvement of the system through parameter optimization. For this various experimentation is done on the flywheel motor. To determine the various dynamic responses ,Modak J.P. and Bapat A.R.(determine the various dynamic response such as force exerted on pedal/crank, measuring crank angle w.r.t. frame, measuring angle between pedal w.r.t. ground, Human input energy measurement (R). Modak J.P. and Bapat A.R. (1994) formulated generalized experimental model for flywheel motor [**8**]. They established the functional relation between the terminal angular velocity (W) and other dependent variable such as moment inertia (I), Gear ratio (G), Human input energy (R), Effectiveness of mechanism (E_M). From this functional relation, for a particular time period of oscillation (T), the terminal velocity at the end of pedaling can be determined. [**8**]

Further during experimentation Modak J.P. and Bapat A.R. (1994) also find the variation of terminal velocity (W) with G, I, and E_M. Determined the valued of G, I, and E_M depending upon the objective of study which are shown in table number2. [**8**]

Table 2: Optimized Value

Obj. Funct.	I(Kg/m^2)	E_M	G
Max WT	0.255	1	4
Max Energy	0.255	1	4
Max. Effectiveness	0.255-1.061	1	2-4

Modak J.P. and Bapat A.R. [**1**] conducted experiments for various combination of moment of inertia (I) & (G) and determined the variation of pedal force (F_t) with position of crank angle. Modak J.P. and Bapat A.R. [**1**] also found that of moment of inertia (I) of flywheel should not between 1.4 to 2.4 Kg/m^2 because during this variation pedal force (F_t) and load torque to overcome has a maximum value. Furthermore in order to minimize frictional losses the gear ratio (G) should be taken 3.8 and moment of inertia (I) should 1.06 Kg/m^2.

V. CONCLUSION

Thus the exhaustive literature survey on flywheel motor is carried out. Firstly it was developed for the manufacturing of lime fly ash bricks later on various applications is developed such as chaff cutter, potters wheel; forge hammers etc.Because of its numerous advantages flywheel motor is finding the importance in the rural side of developing countries like India. And hence it is necessary to optimize its performance parameters. In an attempt lots of experimental and numerical models are developed which are already discussed. The effect of multiple operators with alteration in the mechanisms such as gear ratio can also be analyzed as future work for the flywheel motor.

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ISSN: 2319-5967
ISO 9001:2008 Certified
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