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Multiple bar Dwell Mechanism actuated Pedal Flywheel Motor for continuous operation

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ABSTRACT: The energy situation in the country demands the generation of requisite gadgets and technologies to harness all the energy resources of the country. Harnessing of fossil fuel based energies is in advanced stage though with foreign technologies. Those of solar and wind are intensively ongoing. The abundant human power apart from the old bicycle and few hand operated machines, is bereft of proper gadgets to extensively harness it. The reliable supply of energy is one of the many important requirements for significant growth in Africa's agricultural productivity. Most of the energy needs in agriculture would be solved if efficient man-machines are developed to handle some farm operations and farm products processing. Human powered machines worked by hands and legs have been developed from ages. The predominant machine is the bicycle and the sewing machines. In India alone, Human Powered Flywheel Motors has been developed and constructed for driving lime-flash sand bricks production machines, wood turning lathes, clothes washing machines, porter's wheels and flour mills among others. These developments are however limited to equipment that offers intermittent operation whereby energy is generated by starting a flywheel till it is speeding, the cranking is stooped, energy tapped till the flywheel stops before cranking again to repeat the cycle. The intermittent operation discourages application and thus lending preference for fossil fuel powered systems at exorbitant costs with the attendant air pollution. This invention introduces a novel mechanism into the existing man-machine system making it possible to harness energy continuously without bringing the flywheel to a stop or near stop.

Keywords: Human Power, Dwell, Mechanism, Flywheel, Continuous, Energy.

I. INTRODUCTION

The industrialized nations, especially America, have given birth to certain assumptions which are rapidly gaining currency around the globe: cars are "better" than bicycles; processed foods are "better" than natural ones; living in a city is "better" than living in a rural area. Ironically, because developing countries must live by the rules of a capital intensive economic order, they are often obliged to accept the above assumptions. The retreat, then, is from the town, from the bicycle, from the land (McCullagh, 1997**).** By perpetrating this philosophy, industrialized countries make permanent slaves of developing and undeveloped nations and intend by so doing to lead them forever. But if technology appropriateness is canvassed, genuine progress would be made; developing countries would be enabled to install appropriate machines and technologies to foster their individual advancement. The roads of appropriate technologies gave China and India the economic positions they occupy in the league of advanced countries. Nigeria's quest to become one of the industrialized countries of the world shall be fast tracked if human powered machines are developed to assuage the energy demand in the domestic, agricultural and industrial areas of the economy.

Energy is considered as the most important resources of any country. It is a well-known fact that high rate of industrial growth of a country is a function of the amount of energy available in that country and the extent to which it is utilized. The present situation in Nigeria is that energy supply does not meet the energy demand. (Osueke and Ezeugwu, 2011). The aspiration of the country to become one the first twenty industrialized countries of the world, would not be met if time, research and funds are not marshaled to harness the abundant energy resources ofthis country. Nigeria, apart from being blessed with large deposits of fossil fuels, is also blessed with abundant solar and wind energy as well as a population estimated at more than 160million people of which more than 50% are energetically endowed to effectively produce muscle power.

Chatiet al., (2013), opines that for the benefit of the third world people and to run a post carbon society with all the comforts of modern life, pedal powered technologies have to be adopted**.** Ever increasing energy crises, increasing fuel crises, busy schedules of load shading, and 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 attendant and consequently make efficient use of human energy. Human powered brick making machine was the first of its kind developed for the manufacturing of bricks 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. 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 (Pitale and Hatwalne, 2012)**.**

Human powered systems have been tremendously developed in India since early 1980s pioneered by the efforts of Professor J. P. Modak and some other engineers. They developed human powered process machines which energized process units needing 3 to 7.5 kW and which have intermittent operation. This machine system comprised of three subsystems; energy unit, mechanical power transmission system and process unit. Energy unit comprised of an arrangement similar to a bicycle, a speed raising gear pair and a flywheel. The flywheel size is 1m diameter, 10 cm width and 2 cm thickness. The flywheel is built with 6 armed constructions and each arm is with elliptical cross section. Mechanical transmission comprises of spiral jaw clutch and torque amplification gear pair. The process units used are for brick making, wood turning, Algae formation machine, wood strips cutter and Smiths hammer and electricity generation. A young operator with a slim stature and 165cm height sped up crusher flywheel to 700 to 800 r/min in a minute. Then pedaling was stopped and clutch was engaged connecting this human powered flywheel through torque amplification gears to a process unit. The stored energy in the flywheel around 28000 joules exhausted within 10 s to 20 s in operating a process unit depending on its process resistance (Dhale and Modak, 2012)**.** Pedaling is started and the process is repeated. The stopping of pedaling to engage the clutch and power a process unit occasioning intermittency as against the continuous and smooth processing achieved by fossil fuel powered engines and electric motors puts the human powered system in disadvantaged position compared to the conventional energy system.

People are reluctant to use equipment of intermittent processing operation no matter the huge energy savings that could be appropriated. Hence they cling to the climate- endangering costly fossil fuel powered systems. This innovation- Human Powered Continuous Flywheel Motor removes the intermittency of earlier human powered flywheel systems by incorporating a Multiple Bar Dwell Mechanism as energy feeder from the flywheel at the rate of flywheel energy conservation to the processing unit. Thus pedaling is continuous and processing is also continuous. This is the importance of this invention.

II. PEDALING

The power output (i.e., the rate of doing work) of a person pedaling a machine depends upon the force he applies on the crank, and on the rate of pedaling measured in the number of revolutions per minute (or RPM for short). As the RPM increases, the power output will increase, provided the applied force does not change. But it does. Repeated trials have shown that this force decreases as the RPM increases. When the pedals are locked, the force applied is a maximum but there is no power delivered (the RPM being zero). There is indeed a value of RPM where the rate of doing work by pedaling is a maximum. This value is between 45 and 60 RPM (Gupta, 2006).

The power levels that a human being can produce through pedaling depend on how strong the pedaling Personnel is and on how long he or she needs to pedal. If the task to be powered will continue for hours at a time, 75 watts mechanical power is generally considered the limit for a larger, healthy non-athletic human. A healthy athletic person of the same build might produce up to twice this amount. A person who is smaller and less well nourished, but not ill, would produce less; the estimate for such a person should probably be 50 watts for the same kind of power production over an extended period (Wilson, 1986). Power levels

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are also directly related to the environment of the person doing the pedaling. To be able to continue pedaling over an extended period, a person must be able to keep cool--whether because the ambient temperature is low enough, or because there is adequate breeze.

Pedaling Rate: How fast should a person pedal? Human beings are very adaptable and can produce power over a wide range of pedaling speeds. However, people can produce more power--or the same amount of power for a longer time--if they pedal at a certain rate. This rate varies from person to person depending on their physical condition, but for each individual there is a pedaling speed somewhere between straining and flailing that is the most comfortable, and the most efficient in terms of power production. For centuries, this fact was apparently not recognized. The predominant method of human power production was to strain with maximum strength against a slowly yielding resistance. This is neither comfortable nor efficient. Neither is the opposite extreme of flailing at full speed against a very small resistance. A simple rule is that most people engaged in delivering power continuously for an hour or more will be most efficient when pedaling in the range of 50 to 70 revolutions per minute (rpm). For simplicity's sake, we will use 60 rpm (Wilson, 1986).

Power Delivery in Pedaling: Following the works of Modak,(1985), it was observed that among the 360^0 revolution of the pedal, only part of it produces the necessary useful torque. Table 1 is a summary of the study showing the relationship between the useful torques developed at the crank as a function of crank position during its revolution. The study further observed that even when both cranks are considered, the useful driving angle is 154^0 (Pitael and Hatwalene, 2012).

Table 1: Relation between Crank Position and Torque Produced

(Source:Pitael and Hatwalene, 2012**).**

SR/No.	Crank position from TDC	Torque
1.	$0\text{-}30^0$	Partially useful
2.	$30\text{-}115^0$	Useful
3.	$115\text{-}162^0$	Partially useful
4.	$162\text{-}360^0$	Idle.

III. FLYWHEEL

The concept of a flywheel is as old as the axe grinder's wheel, but could very well hold the key to tomorrow's problems of efficient energy storage. The flywheel has a bright outlook because of the recent achievement of high specific energy densities. A simple example of a flywheel is a solid, flat rotating disk (Figure 1).A flywheel is an inertial energy-storage device. It absorbs mechanical energy and serves as a reservoir, storing energy during the period when the supply of energy is more than the requirement and releases it during the period when the requirement of energy is more than the supply.

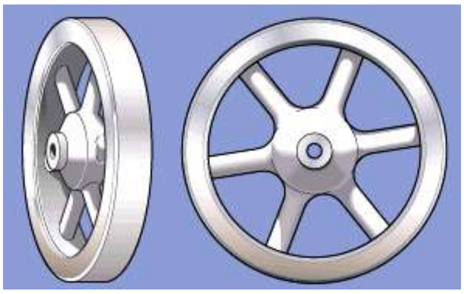

Figure 1: Flywheel

The main function of a flywheel is to smoothen out variations in the speed of a shaft caused by torque fluctuations. If the source of the driving torque or load torque is fluctuating in nature, then a flywheel is usually called for. Many machines have load patterns that cause the torque time function to vary over the cycle. Internal combustion engines with one or two cylinders are a typical example. Piston compressors, punch presses, rock crushers, etc. are the other systems that have flywheels. Due to its high density, low cost and excellent machinability, gray cast iron ASTM 30 is often used to make the flywheel, whose properties are listed in Table 2 (Bawaneet al., 2012).

Table 2: Material and Properties of Conventional Flywheel

(Source: Bawaneet al., 2012)

Material, Class, specification	Gray cast iron, ASTM 30, SAE 111
Ultimate strength	Tension, Sut= 214Mpa; shear sut – 303 MPa
Torsional shear strength	270Mpa
Modulus of elasticity	Tension, E = 101 GPa, shear, G = 41 GPa
Density	7510kg
Poisson's ratio	0.23.

The flywheel can be used as an energy reservoir, with energy being supplied at a slow

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constant rate or when it is available and being withdrawn when desired. A flywheel might, for example, be used to give good acceleration to an automobile that is underpowered by present standards. Regenerative breaking, power storage for peak-demand periods, and mechanical replacements for battery banks are all potential uses for the flywheel. The high charging and discharging rates of a flywheel system give it an advantage over other portable sources of power, such as batteries. The purpose of energy-storage flywheels is to store as much kinetic energy, 0.5Jω2, as possible. In most applications, the flywheel speed does not vary over 50 percent, so that only about 75 percent of this total energy is actually recoverable. The design of the ordinary flywheel is usually dictated by the allowable diameter, governed by the machine size, and the maximum speed, governed by the practicalities of a speed increasing drive and higher bearing speeds (Curtis, 2004).

IV. CONVENTIONAL HUMAN POWERED FLYWHEEL MOTOR

The Human powered Flywheel motor comprises of three sub systems namely (i) Energy supply unit (peddling mechanism to supply power or to store energy in flywheel) (ii) Appropriate clutch and transmission and (iii) a process unit. The complete unit consists of a bicycle mechanism, appropriate clutch and transmission system and a process unit which could be any process device needing power up to 7 hp. Referring to Figure 1 for the case of a hay cutter, the rider sits on the seat and paddles the bicycle mechanism while the clutch is in disengaged position. Thus the load on the legs of the rider is only the inertia load of the flywheel. The flywheel is accelerated to the speed of 600 RPM in minutes time by a young rider of the age group of 20 to 35 physically fit of height about 165 cm. The flywheel size is one meter rim diameter, 10cm rim width and 2cm rim thickness. Such a Flywheel when energized to the speed of 600 rpm, stores energy to the extent of 3200 kgf-m. At the end of one minute, flywheel speed is reached about 600 rpm. Then the peddling is stopped, clutch is engaged and a stored energy in the flywheel is communicated to the process unit through the clutch (Khope and Modak, 2013**).**

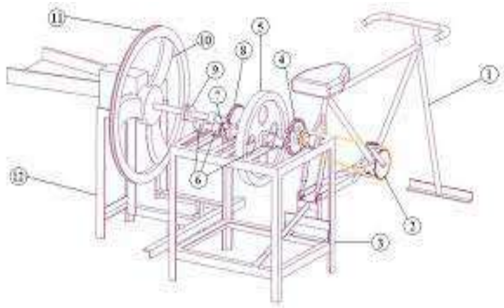

Figure 1: Principles of Human Powered Flywheel Motor depicted for Hay Cutter operation

1). Cycle Stand,2). Sprocket,3).Frame,4).Speed Rising Gear Pair, 5).Flywheel, 6).Bearing, 7).Clutch,8).Torque amplification gear pair, 9). Coupling, 10).Cutter shaft, 11).Cutter blade, 12). Cutter Frame.

This is in tandem with the original conception of J. P. Modak. According to him, on an average, the power produced by a man is approximately 75W (0.10hp), if he works continuously. Therefore human power may be used for a process if the power requirement is maximum of 75W. If process power requirement is more than 75W and if the process can be of an intermittent nature without affecting the end product, a manual machine system can be developed that stores the energy and delivers to the process unit accordingly(Modak and Moghe, 1998). The principal shortcoming of these current Manual flywheel systems is their inherent intermittent operations. Pedaling must be stopped to harness flywheel energy, before pedaling again. This shortcoming is cured by the invention.

V. MULTIPLE BAR DWELL MECHANISM ACTUATED PEDAL FLYWHEEL MOTOR

A dwell mechanism (either a linkage or cam-follower type) is an intermittent motion mechanism that alternates forward and return motion with holding position(s).Single degree of freedom dwell mechanisms are widely required in industrial applications because many production processes include necessary stops in certain cyclical manufacturing operations, after which the movement must continue. The stopping of the mechanical system may be achieved by temporarily stopping the driving motor that powers the kinematic chain, but if the mechanism itself transforms the continuous input movement into intermittent output motion, the motor can work without stopping. Then, the system becomes simpler and more robust, avoiding start/stop

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transient stages (Sanchez-Marin and Roda-Casanova, 2022). Industrial applications of dwell mechanisms include loading and unloading parts, or transporting a part to a machine and holding it in place for a manufacturing process. Other applications include assembly lines, packaging machinery, machine tools, etc.Human Powered Continuous Flywheel Motor is evolved by incorporating a dwell mechanism which feeds the process unit continuously without stopping the pedaling. The lengths of the links comply with the conditions CB = 4.3 AC; BD = 5.85AC; BF = EG; ED = 2.46AC; GF = 8AC and AG = AF = 4.45AC in Figure 2. When point C of crank I travel along the part of the circle indicated by a heavy continuous line, point D of the connecting rod 2 describes a path of which the portion shown by a heavy continuous line approximates a circular arc of radius ED with its Centre at point E. In continuous rotation of crank I, link 3 oscillates about fixed axis G with a dwell during the time that point D travels along the portion of it path indicated by the heavy continuous line. This implies that during the period of dwell, point E is temporarily stationary during four times within one revolution of crank I, with the highest during when the point C is in the right side of its rotation (Artobolevsky, 1986).

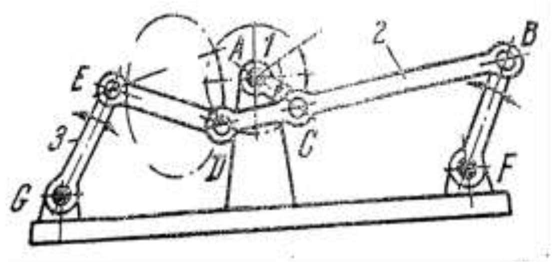

Figure 2: Multiple-Bar Dwell Mechanism

The development of**Multiple bar Dwell Mechanism actuated Pedal Flywheel Motor**is achieved by incorporating the Multiple-Bar Dwell Mechanism shown in Figure 2 into existing human flywheel motor. It is observed that the "to and fro" motion of point **E** can be used to **on** or **off** a motion system if a belt-tensioner is attached and held at **E.** In the new system, motion from the energy supply unit (pedaling unit), is tapped from a point before the flywheel and used to continuously rotate the crank of the Dwell Mechanism.Figure 3 and 4 below, respectively depicts the orthographic and isometric views of the invention. To link EG (of figure 2), at point E is attached an idler pulley or tensioner. The belt-tensioner puts the belt drive in motion and remains for a while during dwell. Thereafter it disengages and remains disengaged until the next dwell period is reached. Thus during the period of "Dwell", the process equipment is energized, while the period "Out of Dwell" is used to store energy in the flywheel. Pulley 8 shown in the drawing tensions during dwells and slacks at other times. Details drawings are as attached hereunder. Position 1 is the Operator's seat while 2 and 3 are the pedal crank and chain which transmit motion to the flywheel through a small gearbox. The motion of the flywheel is then tapped from the shaft and pulley at position 12. While the processing equipment is powered by the shaft (12), the tensioner pulley for engaging and disengaging the transmission is propelled by the Dwell mechanism (10).

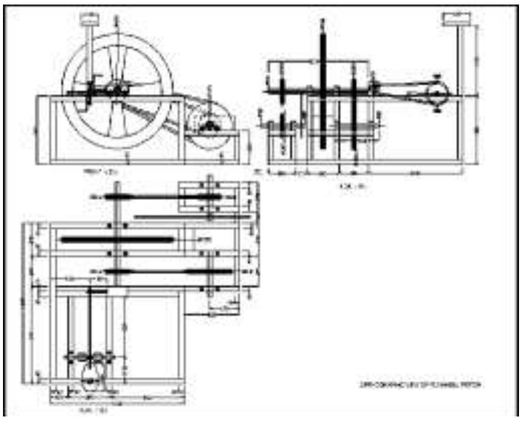

Figure 3: Orthographic View of Multiple bar Dwell Mechanism actuated Pedal Flywheel Motor

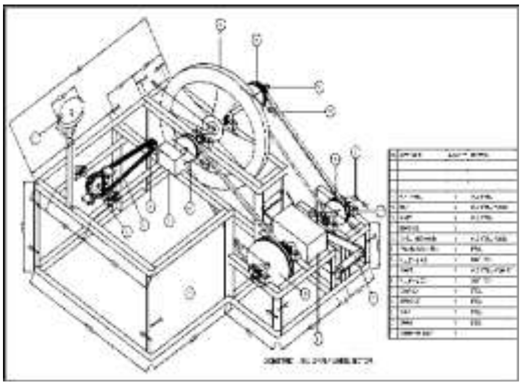

Figure 4: Isometric view of Multiple bar Dwell Mechanism actuated Pedal Flywheel Motor

VI. CONCLUSION

The advancement of the conventional human powered motor by the synchronization of the dwell mechanism actuated tensioner motion in-between the flywheel motion and the process equipment motion avails the opportunity of

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continuous operation of a pedal process machine whether it is for brick-moulding, hay-cutting, threshing etc. It is hoped that this invention is the beginning of the birth of many Man Powered-Machines. The crave for sophistication has led developing countries into importing energy demanding machines and machineries produced by advanced countries at very huge cost and to the detriment of their economy. It is important to look inwards and develop appropriate technologies that can be managed using renewable energies like the human power. The Continuous Human Powered Flywheel Motor finds ready application in remote villages and farms.

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