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Developing a Constant Output Speed Transmission For Human Powered Flywheel Motor (Hpfm) with Variable Input Speed- a Novel Gearbox

KEYWORDS Human Powered Flywheel Motor, Pedal Powered Bicycle system, Constant Output Speed

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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 an energy source is conceptualized as Human Powered Flywheel Motor (HPFM). It caters the need of electrical motor for processes which require power in the range 3 to 9 hp for very short duration of time. As the kinetic energy is drained continuously from the flywheel the output speed of Flywheel Motor decreases continuously which in turn runs a process unit.*

In this paper an attempt is made to develop and experimentally validate a Novel Gearbox for Human Powered Flywheel Motor which maintains the output speed considerably constant using automatic shifting of gear pinions using flyball governor.

Background of the present research
Machines operated using human power has a great applicability in areas witnessing large electric power cut and abundantly available unskilled and semiskilled laborers especially in rural areas. Human Powered Flywheel Motor (HPFM) is a concept in which a human being spins a flywheel of Moment of Inertia of 3.351897 kg.m^2 at about 600 RPM by a system similar to bicycle. The rotational kinetic energy is stored in flywheel. Such an energy source is conceptualized as HPFM [1-5]. It caters the need of electric motor for processes which requires power in the range 3 to 9 hp for very short durations of time even if human energy input rate to flywheel is only 75 watts[8]. Upon engagement of the clutch the operator stops pedaling and connects HPFM to a process unit through a torque amplification gear pairs, the process unit input shaft thus is subjected to sudden rise in its speed on account of instantaneous momentum transfer and it is followed by continuous dropping speed because of energy extraction from flywheel to overcome the process resistance. Hence this is a rather important limitation of such a HPFM energized process machines where in only such applications should be tried in which product quality doesn't get affected because of continual variations of the speed of process unit.

An automatic gearbox called 'Novel Gearbox ' in which input speed even though continuously variable, the output speed can be maintained reasonably constant by using flyball governor to shift torque amplifying gears to eliminate the most important limitation i.e. dropping speed of output shaft of HPFM [6]. The Novel Gearbox was designed and carried out experimentation with some parametric variations to validate the performance. Rope brake dynamometer was used to give load to simulate process load. The experimentally obtained results were analyzed to validate the performance of Novel Gearbox for HPFM.

Experimental Setup
Schematic Experimental Setup is shown in Figure 1 and Figure 2 Shows the actual Fabricated Setup photo.

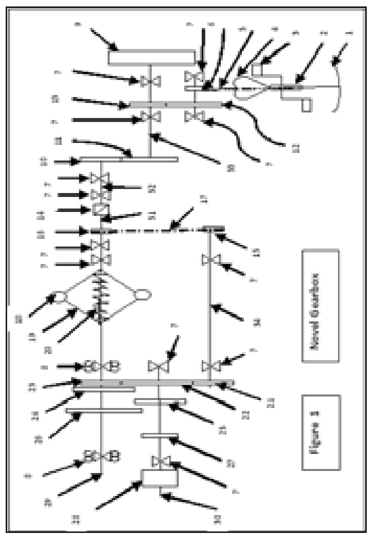

Figure 1

Table-- SETUP PARTS

Part No.	Setup Part Name	Setup Part Specification
1	Handle Bar	--
2	Front sprocket	44 teeth
3	Pedal	--
4	Rider Seat	--
5	Chain	--
6	Freewheel	18 teeth
7	Ball Bearing	6206,6204,6210
8	Bearing	Rolling-sliding bearing
9	Flywheel	M.I.= 3.351897 kgm^2
10	Pinion	25 teeth, module 3.175mm
11	Gear	75 teeth, module 3.175mm
12	Gear	85 teeth, module 3.175mm
13	Pinion	16 teeth, module 3.175mm
14	Dog Clutch	---
15	Freewheel	24 teeth
16	Sprocket	24 teeth
17	Chain	---
18	Flyball	500gm,650gm,750gm, 1000gm
19	Flyball link	25 cm
20	Spring	Stiffness 48.6kg/m,62.1kg/m

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21	Pinion	25 teeth, module 3.175mm
22	Gear	75 teeth, module 3.175mm
23	Pinion	25 teeth, module 3.175mm
24	Pinion	30 teeth, module 3.175mm
25	Gear	70 teeth, module 3.175mm
26	Pinion	35 teeth, module 3.175mm
27	Gear	65 teeth, module 3.175mm
28	Brake Drum	300 mm Diameter
29	Shaft	30 mm Diameter
30	Shaft	30 mm Diameter
31	Shaft	30mm Diameter
32	Shaft	30mm Diameter
33	Shaft	50mm Diameter
34	Shaft	30mm Diameter

Experimental setup consists following important subsystems:

1) Human Powered Flywheel Motor (HPFM)

a) Bicycle Mechanism --- Part No. 1 to 7
b) Energy Unit --- Part No 9 to 13

2) Transmission Unit
c) Dog clutch (Manual) --- Part No. 14
d) Partial Synchronization & Automatic Clutching Assembly --- Part No. 15 to 17 & 21
e) Flyball Governor --- Part No. 18 to 20
f) Sliding Cluster Pinions --- Part No. 23, 24, & 26
g) Speed Maintaining Gears --- Part No. 22, 25 & 27

3) Simulated Process Unit (Rope Brake Dynamometer) --- Part No. 28

Operation Principle of Setup
When Flywheel attain 600 RPM the rider stops pedaling and engages clutch-14 which in turn spins flyball governor its maximum RPM so that first gear pinion pair-22-23 get engaged ,as due to process load at rope brake drum-28 the flywheel seed goes on continuously dropping and hence flyball governor slides to mesh the second gear pinion pair-25-24, as flywheel speed drops further similarly third gear pinion -27-26 get engaged. Thus changing gear ratios from 3, 2.33 & 1.86 in first, second & third gear-pinion pairs respectively , which ultimately results in maintaining output speed fairly constant at rope brake drum shaft.

During time span between disengagement of first gear-pinion pair and engagement of second gear-pinion pair (similarly for second pair & third gear-pinion pair) the power is transmitted through sprocket-16 to chain-17 to freewheel-15 to pinion-21 and finally to gear-22.

Partial speed synchronization for gear mesh and automatic clutching and declutching of freewheel-is achieved due to the difference of RPM between cluster pinions shaft-29 & freewheel shaft-34.

Data Acquisition
Customized Data acquisition system was designed to generate RPM data of flywheel shaft and output shaft at interval of 500 mili seconds and generated data was saved on laptop.

The components used to design data acquisition were microprocessor DS89C430, Logic IC HEF40106BP, Slotted Optocoupler TCST2103 , Real time Clock DS1307 , LDR, IC NE555N and USB communicating IC UART FT232RQ & FT232RL. The HEX codes (ASCII) were used to program microprocessor DS89C430.

Figure 2

Trial Test Performance
All the test trials were carried out in ambient air temperature of 25-35 ° C with relative humidity of 40- 60% . For conducting trials the riders were of age, height & weight ranges 25-38 years ,165- 175 cm & 55-70 kg respectively.

Tests are carried out at 200, 300,400,500 & 600 RPM of flywheel with variation of following

1) Governor springs with stiffness 48.6 kg/m & 62.1 kg/m
2) Flyball Mass 500,650,750,1000 grams
3) Lub. Oil Viscosity in sliding Gears and sliding Bearings 59cSt (2t oil at40° C) & 225cSt (SAE 250 at 40° C)
4) Brake load of 5,8,10 kg
5) Gear ratio of gear-pinion pair I, II & III is 3,2.33 & 1.86 respectively.

Total 240 readings are taken.

Table 1 Typical Reading

Time Sec	Flywheel RPM	Output RPM with Novel Gearbox	Output RPM without Novel Gearbox
0	600	113	113
2	582	110	110
4	566	106	107
6	540	102	102
8	521	109	108
10	500	94	94
12	483	91	91
14	461	87	87
15	454	111	85
16	441	108	83
18	419	100	79
20	397	95	75
22	372	89	70
24	350	86	66
26	326	78	61
28	306	76	58
30	285	71	54
32	260	64	49
34	239	59	45
36	215	53	40
37	204	68	38
38	191	60	36
40	165	51	31
42	139	46	27
44	115	41	22

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46	93	35	18
48	64	27	12
50	51	27	10
52	31	16	06
Sample Reading with Brake load 10kg, Flyball mass 750 gram, Spring 48.6 kg/m, Lub oil 225 cSt. at 600 RPM of Flywheel.			

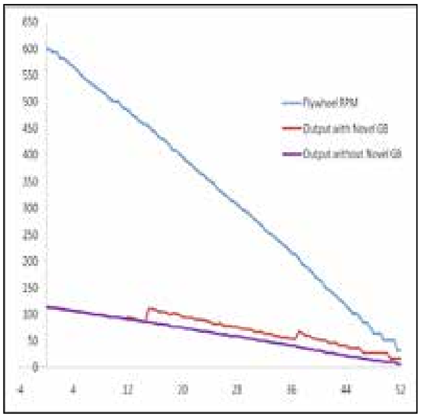
Results and Discussions

Evaluation of trial results for brake load of 10 kg shows that total process time is 52 seconds from engagement of clutch to energy unit of HPFM , the

I st Gear-pinion pair remains in mesh for 26.92% of total process time where as IInd Gear-pinion pair remains in mesh for 40.38% of total process time and III rd Pair Gear-Pinion remains in mesh for 28.8% of total process time.

No Gear-Pinion pair is in mesh for 3.9% of total process time but during this 3.9 % of time the power is transmitted to process unit (Brake Drum) through Partial Synchronization & Automatic Clutching Assembly hence no power loss other than loss of transmission efficiency .

The average output RPM is 21.71% higher with Novel Gearbox compared to output RPM without Novel Gearbox for Human Powered Flywheel Motor.



Conclusions

1) Higher and fairly constant output RPM by introduction of Novel Gearbox .
2) Higher and fairly constant output RPM by Novel Gearbox results in better product output efficiency of process unit coupled to human powered flywheel motor.
3) Addition of Partial Synchronization & Automatic Clutching Assembly to Novel Gearbox increases transmission efficiency and ensures no damage to in motion sliding mesh of gears and pinions.

REFERENCE [1] J. P. Modak & A. R Bapat. " Manually driven flywheel motor operates wood turning process" Proceedings of International Ergonomics Society Annual Convention, April 1993, UK. | | [2] R. D. Askhedkar & J. P. Modak " Hypothesis for the extrusion of Lime-Flyash-Sand bricks using a manually driven brick making machine" Building Research and Information , Vol.22 Nov.1 pp 54 . UK, 1994. | | [3] A.G. Katpatal , et. all " Design of Manually Energized Centrifugal Drum type Algae Formation Process Unit" Proceedings International ASME conference, ' System Analysis, Control & Design' Lyon, France vol. 3, 4-6 pp227-232, July 1994. | | [4] Sohoni V.V et. all., "Manually powered manufacture of keyed Bricks" Building Research and Information , Vol.25 No 6. UK, 1997 | | [5] S.D. Moghe & J. P. Modak " Design & Development of a Human Powered machine for manufacture of Lime-Flyash-Sand bricks", Human Power , Vol 13, PP 3-8, 1998. | | [6] V. D. Ghuge & V.V. Sohoni ," Design and analysis of transmission for a production process unit powered by manually Energized Flywheel Motor", IPROMM ,Nagpur, 19-20th . Jan 2001. | | [7] J. P. Modak , " Design & Development of Manually Energized process machines having Relevance to Village/ Agriculture & other productive operations" Human Power – A Journal of International Human powered Vehicle Association (IHPVA) , USA Issue No.57 8th Sept.2008. | | [8] 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 Volume 2, Issue 3, March 2013. | | [9] Hilbert Schenk Jr. "Theories of Engineering Experimentation" McGraw Hill Book Co., New York. 1961. |