Developing An Instrumentation System For Measurement Of Rotational Speed And Slide Mesh Of Spur Gears Of A Novel Gearbox For Human Powered Flywheel Motor (Hpfm)

V. D. Ghuge, J. P. Modak

Abstract: A system similar to bicycle used to spin a flywheel by human power and the energy is stored in the flywheel as rotational kinetic energy. Such an energy source is conceptualized as Human Powered Flywheel Motor (HPFM). It can be substituted for electrical motor for transient processes. As the energy is drained continuously from the flywheel the output speed of Flywheel Motor decreases continuously which in turn runs a process unit. An instrumentation system was designed to measure performance of Novel Gearbox for Human Powered Flywheel Motor which maintain the output speed considerably constant using automatic shifting of cluster pinions by means of flyball governor. An attempt is made to develop instrumentation system for measuring rotational speed of various shafts and know the exact time of engagement and disengagement of sliding gear-pinion pairs of novel gearbox.

Index Terms: Constant Output Speed Transmission, Gearbox, Human Powered Flywheel Motor, Pedal Powered, Instrumentation.

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1 *B*ACKGROUND

Human power, the green power has a great importance in rural areas witnessing large electric power cuts and abundantly available unskilled and semiskilled laborers. A system similar to bicycle used to spin a flywheel of Moment of Inertia of 3.351897 kg.m^2 at about 600 RPM by human power and the energy is stored in the flywheel as rotational kinetic energy. Such an energy source is conceptualized as Human Powered Flywheel Motor (HPFM)[1],[2],[3],[4]. It can be substituted for electrical motor for transient processes *which requires power in the range 3 to 9 hp* even if human energy input rate to flywheel is only 75 watts [7]. As the energy is drained continuously from the flywheel the output speed of Flywheel Motor decreases continuously which in turn runs a process unit. The operator stops pedaling and connects HPFM to a process unit by clutch via an automatic gearbox called 'Novel Gearbox' in which input speed of HPFM even though continuously dropping, the output speed can be maintained reasonably constant by using flyball governor to shift cluster pinions to eliminate the most important limitation i.e. dropping speed of output shaft of HPFM [5]. The Novel Gearbox was designed, fabricated and carried out experimentation with some parametric variations to validate the performance. Rope brake dynamometer was used to simulate process load. An instrumentation system was developed to measure rotational speed of various shafts of Novel Gearbox and to know the exact time of engagement and disengagement of sliding gear-pinion pairs of it.

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2 *E*XPERIMENTAL *S*ETUP

Figure 1 shows experimental setup scheme

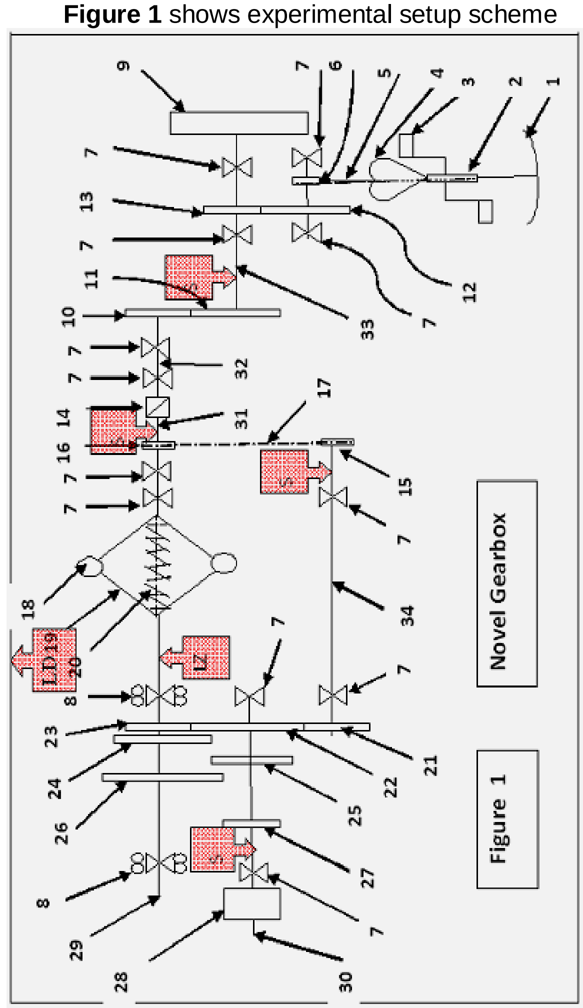

Table 1 Experimental Setup Parts

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	500,650,750,1000 gram
19	Flyball link	25 cm
20	Spring	Stiffness 48.6 & 62.1kg/m
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
S	RPM sensor	Slotted opto-coupler
IZ	Position sensor	Laser torch
LD	Position sensor	LDR(Light Dependent Resistor)

3 WORKING OF MECHANICAL SETUP

Referring to figure 1 The HPFM consists of parts 1-11, Flyball governor 18-19 is at its maximum RPM so that first gear pinion pair-22-23 has got engaged. Due to process load the flywheel speed drops further and hence flyball governor slides down to mesh the second gear pinion pair-25-24, likewise 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 30. During time span between disengagement current gear-pinion pair and engagement of next 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.

4 INSTRUMENTATION SYSTEM

Instrumentation system was designed to measure rotational speed of various shafts and engagement and disengagement time of gear-pairs. In Figure 1. The S shows rotational speed sensor locations and the IZ- laser torch & LD–Light dependent resistor are the gear-pinion engagement-disengagement time position sensors.

Figure 2 Shows Block Diagram Of Instrumentation System

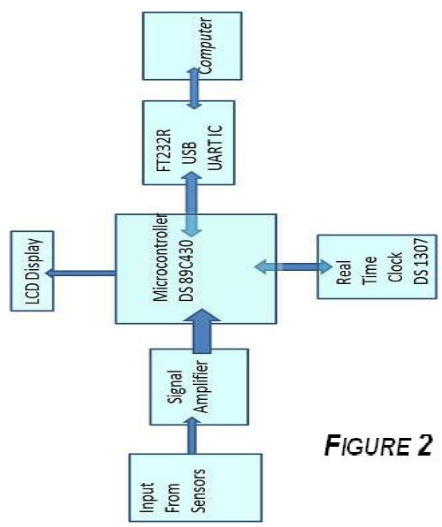

FIGURE 2

4.1 Components of Instrumentation System & Working Principle

Major components of instrumentation system are

a) Mother board or Main board
b) Sensors
c) Input Unit
d) Display Unit
e) Output Storage Unit

Mother board of the system consists of Dallas Semiconductor DS89C430 Microcontroller which is having 64kB Flash memory, 1kB SDRAM, 8051 Pin and Instruction Set Compatible , Four Bidirectional, 8-Bit I/O Ports , Three 16-Bit Timer Counters, 256 Bytes Scratchpad RAM [9]. The microcontroller was programmed by ASCII codes. Sensors used for rotational speed are slotted opto-coupler TCST2103. It is transmissive sensors that include an infrared emitter and phototransistor, located face-to-face on the optical axes in a leaded package which blocks visible light. [10]. It was used as photo interrupter to sense rotational speed then signal was fed to HEF40106 BP (Hex inverting Schmitt trigger). It is used to invert the signal from TCST2103. And the signal ultimately processed to calculate rotational speed by microcontroller. Sensors used to calculate time and position of engagement and disengagement of gear-pinion pairs are LDR (Light Dependent Resistor) in conjunction with a green laser torch as photo switch. The four LDRs were fixed on frame of experimental setup at exactly same distance as that of pinions of cluster and one laser torch was mounted on cluster pinion shaft exactly opposite to LDRs. As cluster pinion shaft is moved by flyball governor to change gear-pinion pairs, in turn laser torch used to scan all the LDRs. The first LDR scan by laser beam is used to give start signal to time counting and full engagement of first gear-pinion pair 22-23. The scan of second LDR gives signal of disengagement first gear-pinion pair and instantaneous engagement second gear-pinion pair 24-25. Similarly the scan of third LDR gives signal of disengagement second gear-pinion pair and instantaneous engagement third gear-pinion pair 26-27. Finally the scan of fourth LDR gives signal of disengagement third gear-pinion pair. All these signals ultimately processed to calculate gear-pinion pairs' engagement-disengagement positions and time by microcontroller. Input unit consists of tactile switch strip which is used to feed various input parameters, variable values, ranges and limiting values. Display unit consists of a LCD onboard display of 16 characters and four lines. It is used to display input parameters and Instantaneous values of output parameters. Output storage unit is laptop or personal computer in which output data was stored in form of log file. The instrumentation setup was connected to laptop by means of windows hyper terminal with FT232R a **Universal Asynchronous Receiver/Transmitter**(**UART)** IC to USB. Real time clock RTC DS1307 keep system time and helps in serial data input/output. The rotational speed readings are recorded for every 500 mili seconds.

5 DISCUSSIONS

The Instrumentation System designed for measuring rotational speed and gear-pinions' engagement-disengagement positions and time is a need based system.

The measurement systems are of two types
1) Direct measurement systems
2) Indirect measurement systems

In experimental setup no direct measurement of parameters was possible so indirect measurements are used, as the electrical voltage signals are used to measure the parameters. Figure 3 shows Designed Instrumentation system.

Figure 4 shows Schematic Measuring System Elements

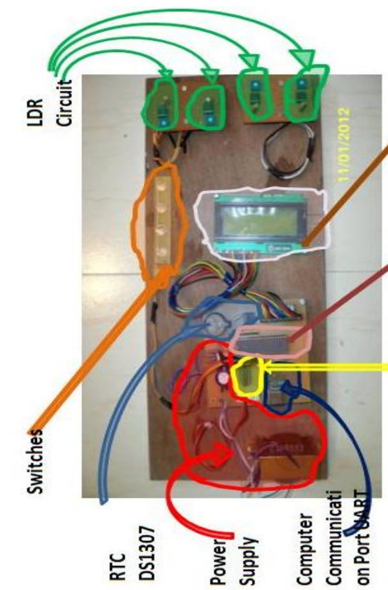

Figure 3

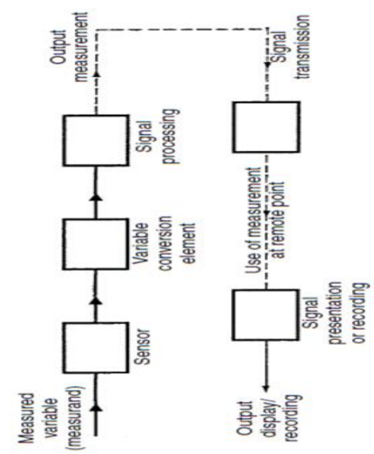

Figure 4
Measuring System Elements
(Reference [8])

The sensor selection in the system is based on
1) System under measurement.
2) The aim of measurement.
3) The result of measurement.
4) The feasibility to use
5) The cost.

The two important sensors in the designed instrumentation system are Slotted opto-coupler TCST2103 and LDR in pair with Green Laser. The opto-coupler has characteristics as shown in figure 5.

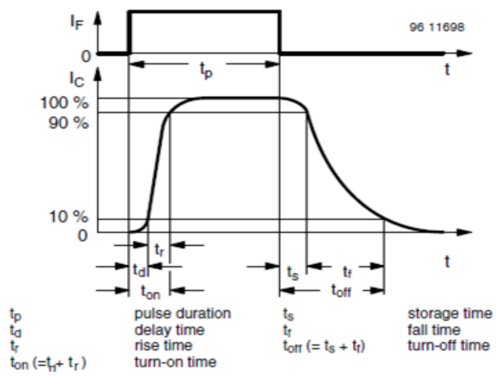

Figure 5 Opto-coupler Pulse Switching times
(Reference [10])

One pulse per revolution is generated by opto-coupler as there was only one interrupt on shaft. And hence frequency of pulses is directly used to give rotational speed. The LDR has spectral response characteristics as shown in figure 6.

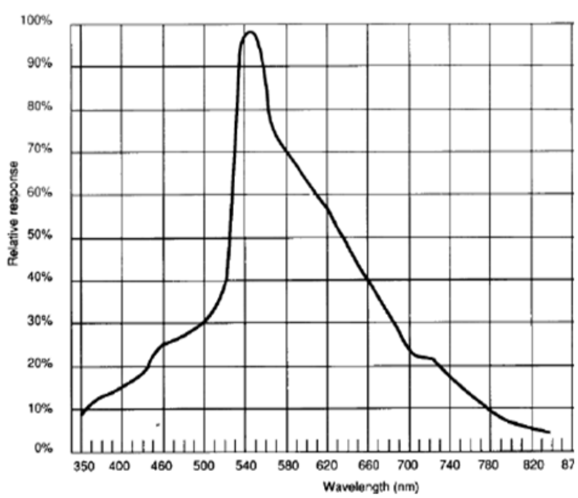

Figure 6 Spectral Response of LDR
(Reference [12])

From the graph (Figure 6) it is found that the LDR has maximum response of about 98% in 550 nm wavelength range and hence a Green Laser of 532 nm wave length and 5 mili watt power is selected. With 532 nm wavelength Green Laser the LDR has got about 95% response. The calibration of designed Instrumentation system was carried out with using measuring instruments in Measurement Laboratory of the institution. The maximum error of 2 rpm is recorded at maximum value of 600 rpm of measurand (rpm as variable).Hence maximum percentage error is 0.3333 in the measurement of rotational speed with this instrumentation system. While the maximum error of 1.5 mm is recorded at maximum value of 134 mm of measurand (gear-pinion position distance as variable). Hence maximum percentage error is 1.119 in the measurement of gear-pinion positions and in terms of time in 62.5 seconds process cycle this error is coming out to be 0.6994 seconds with this instrumentation system.

6 CONCLUSION

The designed instrumentation system is reliable, precise and accurate. It is also a low cost compared to other standard instrumentation systems. The errors in measurement is negligible.

REFERENCES

[1] 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.

[2] 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.

[3] Sohoni V.V et. all., "Manually powered manufacture of keyed Bricks" Building Research and Information , Vol.25 No 6. UK, 1997

[4] 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.

[5] 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.

[6] 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.

[7] 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.

[8] Alan. S. Morris" Measurement and Instrumentation principles" Butterworth Heinemann, Oxford, 2001.

[9] http://datasheets.maximintegrated.com/en/ds/DS89C430-DS89C450.pdf accessed on 10.4.2013 at 9.10 pm

[10] http://www.vishay.com/docs/81147/tcst2103.pdf accessed on 10.4.2013 at 9.30 pm

[11] http://www.nxp.com/documents/data_sheet/HEF40106B.pdf accessed on 10.4.2013 at 9.50 pm

[12] http://www.sunrom.com/files/3190-datasheet.pdf accessed on 10.4.2013 at 4.50 pm