International Journal of Advanced Engineering and Nano Technology (IJAENT)
ISSN: 2347-6389, Volume-2 Issue-3, February 2015

Experimental Investigation of Compact Flywheel using Inertia Augmentation Mechanisms

Vishal J. Dhore, E. R. Deore

Abstract— ***Conventional flywheel system uses a single rim flywheel. The performance of the flywheel depends upon its mass, so also it encounters a lot of air friction and leads to more in-efficiency and more occupation. Flywheel releases stored energy by applying torque to a mechanical load, thereby decreasing the flywheels rotational speed. The dissertation work shows the flywheel optimum design model which fulfils minimum criteria of inertia result into safe and efficient working. In this study work on CAD base design and analysis with experimental base model generation in a feasible area of design. For a optimum design consideration of flywheel compare parameters like torque, power, efficiency with respective to speed. The experimental study and analysis shows the feasible area of design with torque Vs speed comparison by showing no changed in a considering design parameter as per the conventional design. The Power and Efficiency Vs Speed characteristics comparison shows that there is approximately in between seven to eight percentage increase in power output and five to six percentage efficient than the conventional flywheel respectively which will also result in increasing fuel economy of the engine efficient.***

Index Terms—***Compact, Conventional, Efficiency, Power, Torque***

I. INTRODUCTION

A flywheel is a rotating mechanical device that is used to stored rotational energy. Flywheels have a significant moment of inertia and thus resist changes in rotational speed. The amount of energy stored in a flywheel is proportional to the square of its rotational speed. Energy is transferred to a flywheel by an applying torque to it, thereby increasing its rotational speed and hence its stored energy. Conversely, a flywheel releases stored energy by applying torque to a mechanical load, thereby decreasing the flywheels rotational speed. Conventional flywheel system uses a single rim flywheel. The performance of the flywheel depends upon its mass, so also it encounters a lot of air friction and leads to more in-efficiency and more occupation. On the other hand lighter flywheel leads to some problem like to get harder to kick through, requires slightly higher idle speed screw setting for stable idle, is more likely to stall when cold out of tune, easier to shift, has better braking (unless you disconnect the motor by pulling the clutch in while braking), requires more delicate touch with the clutch in traffic, harder on the primary chain, less tolerant of walking speed in gear. The engine‘s ignition-induced rotational speed irregularity causes torsional vibration in the vehicle‘s driveline. At a given speed the ignition frequency is equal to the natural frequency of the driveline so that extremely high vibrations amplitudes occur that causes transmission rattle and body boom. Also more mass increases the cost of DMF.

II. METHODOLOGY

According to objectives of project following methods has to be implemented. For further design of compact flywheel using inertia augmentation mechanisms some considerations should be taken in account.

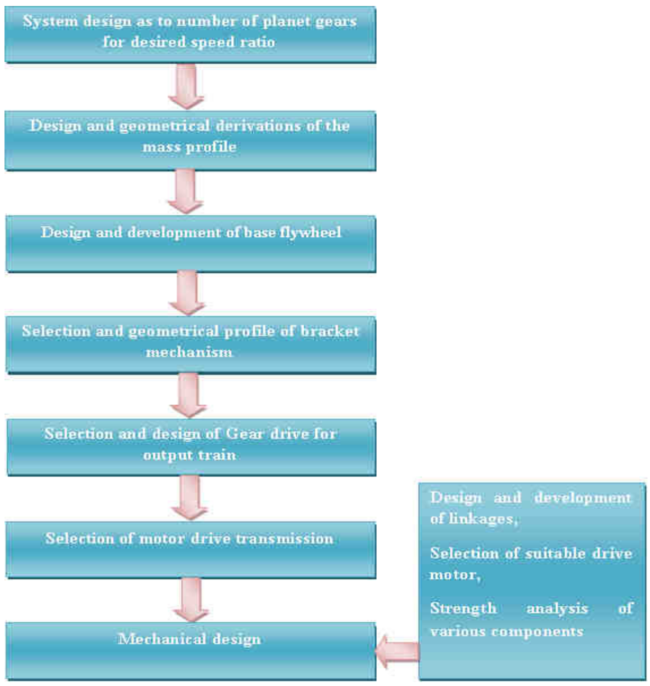

Fig. 1 Design Flow Chart of Compact Flywheel Using Inertia Augmented Mechanisms

In our attempt to design a special purpose device we have adopted a very a very careful approach, the total design work has been divided into two parts mainly;

- System design
- Mechanical design

System design mainly concerns with the various physical constraints and ergonomics, space requirements, arrangement of various components on the main frame of machine no of controls position of these controls ease of maintenance scope of further improvement; height of machine from ground etc.

In Mechanical design the components are categories in two parts.

- Design parts
- Parts to be purchased.

For design parts detail design is done and dimensions thus obtained are compared to next highest dimension which are readily available in market this simplifies the assembly as well

Manuscript Received on February 2015.
Vishal J. Dhore, Department of Mechanical Engineering, S S V P S Bapusaheb Shivajirao Deore College of Engineering, Dhule, India.
Prof. E. R. Deore, Department of Mechanical Engineering, S S V P S Bapusaheb Shivajirao Deore College of Engineering, Dhule, India.

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication Pvt. Ltd.

as post production servicing work. The various tolerances on work pieces are specified in the manufacturing drawings. The process charts are prepared and passed on to the manufacturing stage. The parts are to be purchased directly are specified and selected from standard catalogues. When completing the system design and mechanical design then after all that components CAD drawings are prepared by using the AutoCAD Software and Unigraphics software, then after that send this drawing to production department to manufacture that entire components as per the drawing details. After that all that manufactured components and standard component that we have to purchase from the market, all are assembled together to completing the test rig for trial purpose. In the experimental setup firstly taking trial by mounting the conventional flywheel on the test rig and taking number of reading by applying gradual load (Loading Condition) and removing gradual load (Unloading Condition) to measuring the parameter as speed, then we putting the values of these reading into the mathematical formulae to calculating the torque, power and efficiency of the conventional flywheel. After that plotting the characteristics curves, these characteristics curves are plotted with respect to

a) Torque Vs Speed
b) Power Vs Speed
c) Efficiency Vs Speed

III. WORKING PRINCIPLE

A. Inertia Augmentation Mechanism

All engines have flywheels or weighted crankshafts that balance out compression and power strokes, maintain idle and starting by reducing component wear. If the flywheel is too light the motorcycle requires more effort to start, idles badly, and is prone to stalling. Weight is not the important factor here, but inertia. Inertia is stored energy, and is not directly proportional to flywheel weight. It’s possible to have a light flywheel with much more inertia than a heavier flywheel. Flywheel inertia is stored when you revolve the engine slightly before letting the clutch disengage this small amount of extra power helps in getting the motorcycle underway with minimal effort. By borrowing power for a few seconds, the engine has to develop less to move from a standing start. Once the clutch is completely engaged, inertia can no longer be borrowed from the motorcycle and can only use what it produces in real time. Thus it is safety for the flywheel, inertia plays a major role in vehicle optimized performance and by suitable modifying the flywheel mass of flywheel can be reduces by still maintaining the inertia.

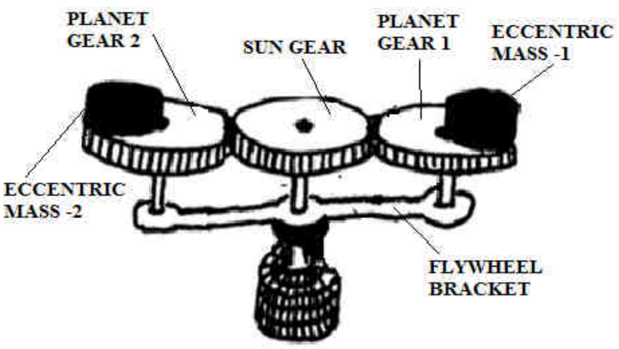

Fig. 2 Inertia Augmentation Mechanism

Two gear wheel rotors are swivelling stored on a main rotor shaft. The main rotor shaft is for his part stored on the tax axle swivelling. The gear wheel rotors reach into the tax gear wheel and unreel around this. On the gear wheel rotors mirror-symmetrically eccentric cam weights are appropriate to the tax axle. During a circulation of the rotors around the tax gear wheel move the eccentric cam weights on a certain course, which runs eccentrically to the tax axle. This course results from two rotations, which are engaged into one another. The eccentric cam weights turn around the axles of the gear wheel rotors and these turn around the tax axle. The inertia augmentation mechanism working can be categorized in to two cases namely, when masses are close to the tax axle and other when they are away from the tax axle.

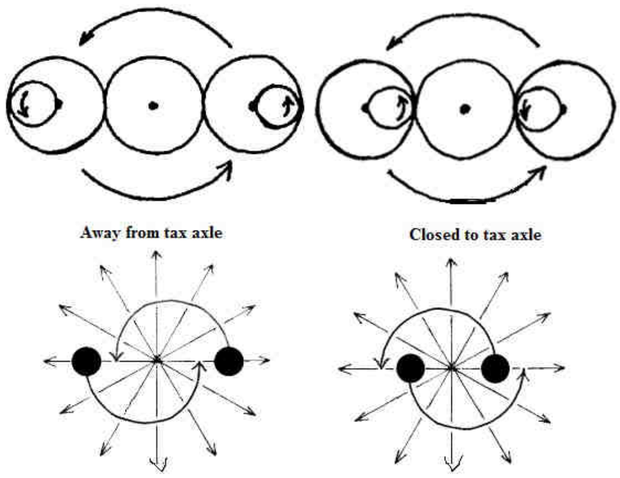

Fig. 3 Effect of Centrifugal Forces on Masses

The arrangement of the dual mass flywheel is a suitable answer to the above problem statement where in the inertia is increased using two set of masses phased opposite to each other. The arrangement of the dual mass flywheel is best explained by the mathematical model as shown in fig. 4.

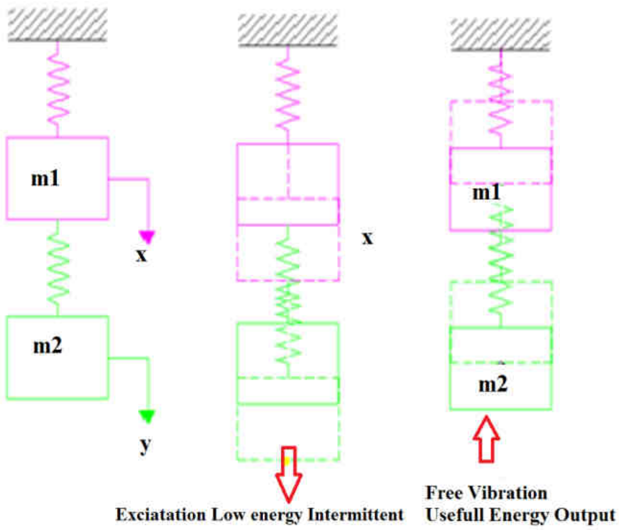

Fig. 4 Principle Operation of Free Undamped Vibration of Two Springs

The fig. 4 shows free un-damped vibrations set up of two mass- two spring system. in the figure the input to the system is in the form of an low energy intermittent input from any power source (excitation), this results in free un-damped vibrations are set up in the system resulting in the free to and fro motion of the mass (m1) & (m2), this motion is assisted by

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication Pvt. Ltd.

gravity and will continue until resonance occurs, i.e., the systems will continue to work long after the input (which is intermittent) has ceased, hence the term free energy is used.

B. Compact Flywheel Using Inertia Augmentation Mechanism

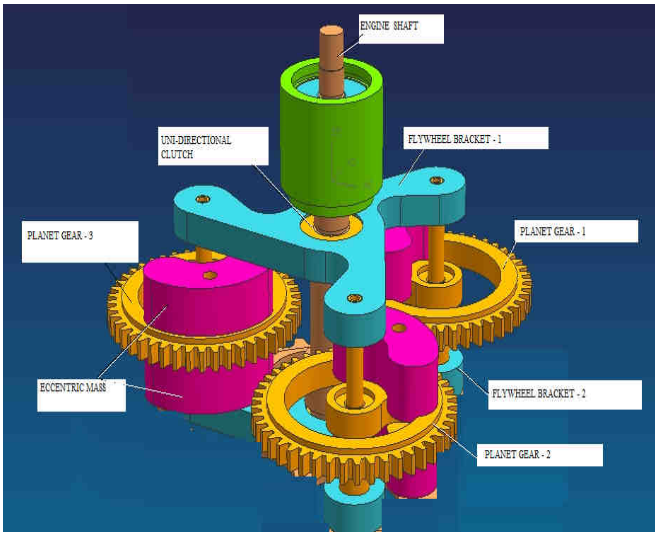

Fig. 5. 3D Model of Compact Flywheel Using Inertia Augmentation Mechanisms

So taking the review about conventional flywheel and dual mass flywheel, its working principle, characteristics of parameters. So think and study of it, to developing the new flywheel by using the three eccentric masses instead of the two masses of dual mass flywheel (DMF). The 3D model of compact flywheel using inertia augmentation mechanism is as shown in fig. 5.

IV. Result and Discussion

Taking the trial on the test rig under the normal condition and environment, firstly take a trial on test rig by mounting the conventional flywheel, and then start the engine at maximum speed, at the same time slowly increasing the load on the engine by externally loading dead weight on it, and measure the speed by using the tachometer, then take some more reading by increasing the dead weight gradually up to 5000 gm and note down the speed of shaft, it is a loading condition. Similarly taking the taking reading of speed by removing the dead weight, it is known as unloading condition. In similar way, taking the reading of newly design compact flywheel using inertia augmentation mechanisms in loading and unloading conditions. After completing the trial on test rig, then plotting the performance characteristic curves as mention follow;

a) Torque Vs Speed
b) Power Vs Speed
c) Efficiency Vs Speed

After that plotting the performance characteristic of separately, then plotting combine performance characteristics of conventional flywheel and compact flywheel using inertia augmentation mechanisms.

A. Trial on Conventional Flywheel and Compact Flywheel

Engine Speed = 1300 rpm
Engine Power = 205 watt
Radius of dyno- brake pulley = 0.032 m

Table 1
Observation Table of Conventional Flywheel

Sr. No	Loading		Unloading		Average
	Load (gm)	Speed (rpm)	Load (gm)	Speed (rpm)	Speed (rpm)
1	1500	1310	1500	1320	1315
2	2000	1270	2000	1280	1275
3	2500	1240	2500	1250	1245
4	3000	1210	3000	1200	1205
5	3500	1180	3500	1190	1185
6	4000	1155	4000	1160	1155
7	4500	1100	4500	1110	1105
8	5000	1070	5000	1080	1075

Table 2
Result Table of Conventional Flywheel

Sr. No.	Load (gm)	Speed (rpm)	Torque (Nm)	Power (watt)	Efficiency (%)
1	1500	1315	0.47088	64.851634	31.634943
2	2000	1275	0.62784	83.83861	40.896885
3	2500	1245	0.7848	102.33242	49.918256
4	3000	1205	0.94176	118.85356	57.977348
5	3500	1185	1.09872	136.36104	66.517580
6	4000	1155	1.25568	151.89584	74.095532
7	4500	1020	1.41264	150.90950	73.614393
8	5000	910	1.5696	149.59439	72.972873

Table 3
Observation Table of Compact Flywheel

Sr. No	Loading		Unloading		Average
	Load (gm)	Speed (rpm)	Load (gm)	Speed (rpm)	Speed (rpm)
1	1500	1430	1500	1420	1425
2	2000	1400	2000	1390	1395
3	2500	1370	2500	1360	1365
4	3000	1320	3000	1310	1315
5	3500	1280	3500	1290	1285
6	4000	1250	4000	1240	1245
7	4500	1210	4500	1210	1210
8	5000	1190	5000	1180	1185

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication Pvt. Ltd.

Table 4
Result Table of Compact Flywheel

Sr. No.	Load (gm)	Speed (rpm)	Torque (Nm)	Power (watt)	Efficiency (%)
1	1500	1425	0.47088	70.27648	34.281212
2	2000	1395	0.62784	91.729307	44.746003
3	2500	1365	0.7848	112.19579	54.729655
4	3000	1315	0.94176	129.70326	63.269886
5	3500	1285	1.09872	147.86830	72.130878
6	4000	1245	1.25568	163.73188	79.869210
7	4500	1080	1.41264	159.78653	77.944651
8	5000	930	1.5696	152.88217	74.576672

B. Performance Characteristics of Conventional Flywheel and Compact Flywheel

Taking trial on both the flywheel and plotting the performance characteristics of both flywheel separately, now checking the performance of both the flywheel, so comparing the both the flywheel by following performance characteristics and plotting the graph of it characteristics.

Fig. 6 Graph of Torque Vs Speed of Conventional Flywheel and Compact Flywheel

By comparing the graph of Torque Vs Speed of conventional flywheel and compact flywheel, it is observed that nature of curve is overlapping to each other, hence no deviation in the curve.

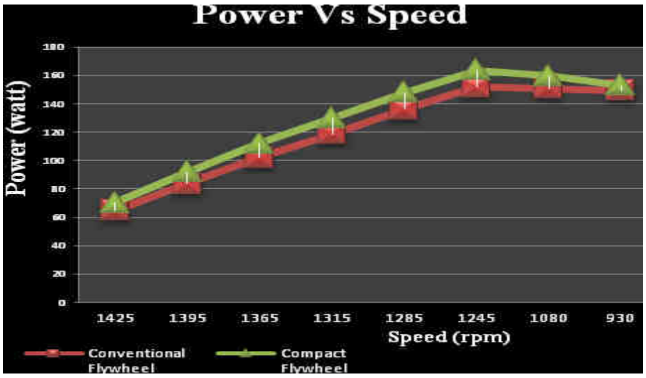

Fig. 7 Graph of Power Vs Speed of Conventional Flywheel and Compact Flywheel

By comparing the Power Vs Speed characteristics of conventional flywheel and compact flywheel, it is observed that there is approximately 7 to 8 % increase in power output by using the Compact flywheel.

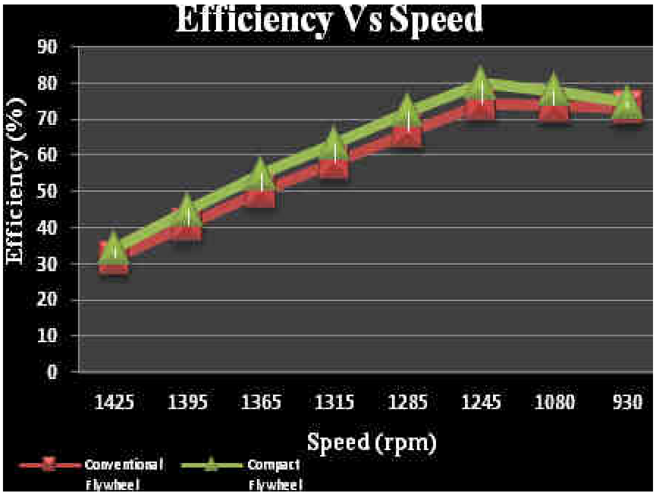

Fig. 8 Graph of Efficiency Vs Speed of Conventional Flywheel and Compact Flywheel

By comparing the Efficiency Vs Speed characteristics of conventional flywheel and compact flywheel, it is observed that the compact flywheel is 5 to 6 % efficient than the conventional flywheel which will also result in increasing fuel economy of the engine.

V. Conclusion

A flywheel is a rotating mechanical device that is used to stored rotational energy. Flywheels have a significant moment of inertia and thus resist changes in rotational speed. Flywheel releases stored energy by applying torque to a mechanical load, thereby decreasing the flywheels rotational speed. This dissertation work shows the flywheel optimum design model which fulfils minimum criteria of inertia with weight result into safe and efficient working. In this study work for a better design considering and compare parameters like torque, power, efficiency with respective to speed to optimize the design of flywheel. Results came from the experimental study and analysis shows the feasible area of design. Torque Vs Speed shows no changed in a considering design parameter as per the conventional design. By comparing the Power Vs Speed characteristics of conventional flywheel and compact flywheel, it is observed that there is approximately in between 7 to 8 % increase in power output by using the Compact flywheel and the Efficiency Vs Speed characteristics of conventional flywheel and compact flywheel, it is observed that the compact flywheel is in between 5 to 6 % efficient than the conventional flywheel which will also result in increasing fuel economy of the engine.

References

[1] Friderícy, Palos Verdes Estates (1980), Multi-Rim Flywheel Attachment, *United States Patent,* and Patent Number: 4,186,623, Application Number 892,587.
[2] R J Haley, J P Kajs, R C Thompson, J H Beno (1998), Design and Testing of a Flywheel Battery for a Transit Bus, *Society of Automobile Engineers,* 1999-01-1159.
[3] Park, Dong-Hoon, Suwon-Si, Kyunggi-Do (KR), (2000), Dual Mass Flywheel for Automobile Vehicle, *European Patent Application,* and Patent Number EP 1 046 834 A2, Application Number: 00105556-5.
[4] Alastair John Young, Kenilworth, (2000), Twin Mass Flywheel,

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication Pvt. Ltd.

United States Patent, Patent Number 6 029 539, Application Number: 09/125 340.

[5] Richard Benito Fradella, San Juan Capistrano (2004), Robust Minimal-Loss Flywheel Systems, *United States Patents,* Patent Number: US 6 794 777 B1, Application Number: 10/739 119.

[6] Christopher W Gbrys, Reno (2004), Axially Free Flywheel System, *United States Patents,* Patent Number: US 6 710 489 B1, Application Number: 10/232 793.

[7] Bjorn Bolund, Hans Bernhoff, Mats Leijon (2005), Flywheel Energy and Power Storage System, *Science Direct,* 11 (2007) 235 – 258.

[8] Ulf Schaper, Oliver Sawodny, Tobias Mahl and Uli Blessing (2009), Modeling and Torque Estimation of an Automotive Dual Mass Flywheel, *American Control Conference, Hyatt Regency Riverfront, st Louis, Mo, USA,* June 10-12, 2009, WeB16.6.

[9] Walter J Ortmann, Saline (2011), Controlling Torque in a Flywheel Power Train, *United States Patent Application Publication,* Publication Number: US 2011/0071000 A1, Application Number: 12/562 187.

[10] John Abranhamsson, Hans Bernhoff (2011), Magnetic Bearing in Kinetic Energy Storage Systems for Vehicular Application, *Journal of Electrical Systems,* 7-2 (2011): 225-236.

[11] Dr. Robert Hebner, (2012), Low-Cost Flywheel Energy Storage for Mitigating the Variability of Renewable Power Generation, *Herber Public Version.*

[12] Rudolf Glassner, Kottes (2013), Dual Mass Flywheel, *United States Patent,* Patent Number: US 8 393 247 B2, Application Number: 13/147 048.

[13] Kishor D Farde, Dr. Dheeraj S Deshmukh (2014), Review: Composite Flywheel for High Speed Application, *International Journal of Innovative Research in Advanced Engineering",* ISSN: 2349-2163, Volume 1 Issue 6.

[14] R. S. Khurmi, J. K. Gupta, "*Machine Design*", Sixth edition, S. Chand Publication, 2005.

[15] V. B. Bhandari, "*Design of Machine Elements*", Third Edition, McGraw-Hill Education Pvt. Ltd. 2007.

[16] Parthiban Delli, Ming Leu (2003), Unigraphics NX-3 for Engineering Design, *Department of Mechanical and Aerospace Engineering, University of Missouri-Rolla.*

Vishal J Dhore, was born in India. He was completed Bachelor of Engineering in Mechanical Engineering from University of Pune, doing the Master of Engineering from North Maharashtra University, Jalgaon, currently Assistant Professor in Guru Gobind Singh College of Engineering and Research Centre, Nashik.

Prof. E. R. Deore, was born in India. He was completed Bachelor of Engineering and Master of Engineering from North Maharashtra University, Jalgaon, Currently he was Head of Department of Mechanical Engineering in S S V P S Bapusaheb Shivajirao Deore College of Engineering, Dhule.

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication Pvt. Ltd.