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Performance Evaluation of IC Engine Using Dual Mass Flywheel

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ABSTRACT: High efficient IC engines can be reached by applying different possible routes at minimum fuel consumption. We shall focus on development of new flywheel system to achieve better engine performance. Here, Helical springs and multi-mass system shall be used. Conventional flywheel is divided in two parts; Primary and Secondary to form Dual Mass Flywheel (DMF). Inside DMF three springs and three masses system is incorporated to achieve higher engine performance. Comparative study of conventional flywheel and DMF on the basis of engine performance parameters like Power, Thermal Efficiency, Volumetric Efficiency and Specific Fuel Consumption is done. Also the maximum fluctuation of energies of both flywheels is calculated to generate effectiveness.

KEYWORDS: Flywheel, Dual Mass Flywheel, Engine performance, Efficiency, Fuel consumption, Fluctuation, Effectiveness.

I. INTRODUCTION

Work is going on in automobile industry to discover new technology which fulfils stringent regulation without losing performance. These developments enabled to deliver more power. However, this caused an increase in the level of vibration. Any engine that is properly balanced is prone to vibration in a number of ways. These vibrations are almost impossible to minimize because of the repeatative and stringent combustion forces acting on engine components at regular intervals as per the firing order of engine. Torsional vibration is the most damaging of all vibration modes experienced. These torsional vibrations seriously affect torque transmission from engine crankshaft to transmission lines. Thus it indirectly affects the overall performance of engine. Such transmission disability is required to be minimize before transferring it to the further transmission lines. Again the traditional clutch discs are unable to minimize such torque transmission losses. And due to limited space availability in the clutch, torsion dampers are outfitted on the circumference of clutch discs.

A DMF is built-up from two flywheels that are about the same diameter as a single flywheel would be. Each of these flywheels has half of the mass of a single flywheel. The first flywheel is attached to the crankshaft and spigotted into the second flywheel in such a way that the two wheels are able to oscillate with respect to each other. This movement is controlled by circumferential springs mounted on Primary wheel working against stops so that the first flywheel is able to vibrate with the crankshaft while the springs ensure that very little of this vibration gets transferred to the second flywheel. The result is that transmission disability is minimized, resulting in a smooth and silent driving experience.

II. RELATED WORK

Till date the main purpose of using DMF was to minimize the noise and vibration. So that torque dissipation towards the transmission drive line is minimized. Overall engine performance is improved, but no comparative study was done between conventional flywheel and DMF on basis of performance. It becomes interesting and worth to study DMF design and comparison of DMF with conventional flywheel on the basis of speed, power, Efficiencies and BSFC. In this project work as explained in above standard DMF, inside the two decoupled primary and secondary flywheel we are using three springs and three masses. Fig.1 shows spring mass model of the project work.



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Fig.1. Spring mass DMF

Using the principle of free energy, three arc springs with three masses lies in the channel provided inside primary flywheel and supported by the guides. One end of this arc spring is fixed on primary flywheel with the help of stopper while at the other free end mass is attached. These three masses are connected with mass lever with the help of three mass hinge pins. This mass lever is riveted with secondary flywheel. Hence it transfer torque from the primary flywheel via the arc springs and masses to the secondary flywheel. The input to the system is in the form of a low energy intermittent input from power source here from IC engine. These results in free un-damped vibrations are set up in the system. It results in the free to and fro motion of the masses. This motion is assisted by gravity and will continue until resonance occurs, i. e. the systems will continue to work long after the input which is intermittent has decreased. After doing all these mounting in the setup, test and trials are taken by attaching the loads with the help of rope pulley and speed of engine is measured with tachometer. With the help of performance parameters, graphs are drawn. Hence comparison of this spring mass loaded DMF is done with conventional flywheel.

III.METHODOLOGY

For this study testing set up is prepared which consists of base frame, engine, fuel tank, rope pulley and flywheel. After doing all these mounting in the test set up, trials are taken by attaching the loads with the help of rope pulley and speed of engine is measured with tachometer. With the help of speed, engine performance graphs are plotted. Hence comparison of this spring mass loaded DMF is done with conventional flywheel. High Power two stroke Spark ignition engine is lower cc engine which is mainly used in agricultural equipment's such as for commercial lawn cutting, gardening and cultivator purposes. Engine specifications are mentioned below:-

Make	: High Power
Model	: IK-35
Bore /diameter	: 35 mm
Stroke	: 35 mm
Capacity	: 34 cc
Power output	: 1.2 BHP at 5500 rpm
Torque	: 1.36 N-m at 5000 rpm
Dry weight	: 4.3 kg
Ignition	: Electronic Ignition
Direction of rotation	: Clockwise looking from driving end
Cooling	: Air Cooled engine



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Photograph.1 Actual Flywheel Testing Setup

DMF loaded on engine shaft with springs and masses is as shown in above photograph.

Engine Performance Characteristics

Engine performance is measured to indicate effectiveness of the engine in meeting its performance targets like power. Engine performance also becomes the basis for comparing engines. The performance is also an indicator of engine efficiencies. The useful range of engine performance parameters is limited by factors like loading, overheating and knocking.

A. Performance Parameters

For evaluating engine performance, some basic parameters are chosen and effects of these parameters are studied. The basic parameters are as mentioned below:-

1) **Brake Power:** The brake power is the maximum useful power developed by the engine. The engine is connected to a brake or dynamometer which can be loaded in such a way that the torque exerted by the engine can be measured with the help of tachometer. Brake power is given as; $BP = \frac{2\pi nT}{60000} KW$

Where $n = engine \ speed \ in \ rpm$ $T = engine \ torque \ in \ Nm.$

2) **Thermal Efficiency:** Thermal efficiency of the engine is an indicator of how efficiently the engine converts heat energy released by fuel to work. Engines have brake thermal efficiencies in the range of 20-30% $n_{th} = \frac{BP}{mf \times cv}$

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Where
mf = mass of fuel supplied per second
cv = calorific value of fuel.
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- 3) Specific Fuel Consumption: This is defined as the mass of fuel supplied per *kwh* of output from engine. Brake Specific Fuel Consumption decreases as engine speed increases reaches a minimum and then increases at high speeds. Fuel consumption increases at high speed because of greater friction losses. $f = \frac{mf}{BP}$
- 4) Volumetric Efficiency: The volumetric efficiency is a measure of success with which the air supply and the charge is induced into the engine. It is defined as the ratio of the actual mass of air drawn into the engine during a given period of time to the theoretical mass which should have been drawn in during that same period of time, based upon the total piston displacement of the engine and the temperature and pressure of the surrounding atmosphere. Therefore,

Volumetric Efficiency =
$$\frac{\text{Actual mass taken in (kg/unit time)}}{\text{Theoretical mass (kg/unit time)}}$$

B. Measurement of Engine Speed

Speed of engine is the time rate of revolutions of crankshaft measured in rpm. Measurement of speed is essential for calculation of power and torque of engine. Speed can be measured by contact type or non-contact type instrument. Here we are using non-contact type tachometer.

C. Measurement of Fuel Consumption



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The fuel consumption of an engine is measured by determining the volume flow in a given time interval and multiplying it by the specific gravity of fuel which should be measured occasionally to get an accurate value. Volumetric type flow meter includes burette method and we are using this method for fuel measurement. Following photograph .2 shows burette which is used for fuel measurement.



Photograph.2. Fuel Measurements with Burette

D. Measurement of Air Consumption

Measurement of air flow in IC Engine is difficult due to pulsating nature of air flow and compressibility of air. Using only an orifice is not a reliable way of air consumption measurement. Air Box Method is the standard method of air consumption. Other methods include measurement of air flow by viscous flow air meter. Air Box Method for air consumption is discussed in detail as below:-

D.1 Air Box Method for air consumption

This method measures air flow after damping out the flow pulsation. An air box of volume approximate 500 times the engine swept volume is used to dampen the fluctuations. The orifice is placed in the side of the box. The air flow through the orifice is measured by the following formula:-

mass of Air (ma) $= \frac{\pi}{\lambda} \times Coefficient of Discharge(cd) \times orifice diameter^2 \times \sqrt{2gha}$

ma = Mass of air consumed cd = Coefficient of discharge of orifice d = orifice diameterha = Manometer head in cm of water



Photograph.3 Air Box with Manometer



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IV.EXPERIMENT WORK

After making all the arrangement of test set up, experimental work such as various engine parameters like speed, Brake power and Volumetric Efficiency, BSFC and Brake Thermal Efficiency are checked at different loading conditions for conventional flywheel and DMF.

Maximum Loading Condition

Before loading the weights on the rope pulley arrangement, the dynamometer is run at no load condition. After that trial is stared with loads. At the same load the average of speed at loading and unloading condition are calculated. First of all maximum loading condition is checked and which is mentioned as below

$$Power = \frac{2\pi n\tau}{60000}$$

$$895 = \frac{2\pi 5500 (w \times 0.302)}{60000}$$

$$w = 5 ka$$

The maximum loading value is 5 kg hence accordingly partial loading is taken. It means maximum load taking capacity of engine is limited up to 5 kg. Hence load value below it are selected such as 4.5, 4, 3.5, 3 etc. Table.1 shows the maximum loading condition for conventional flywheel

Sr. No.	LOADING		UNLOADING		AVERAGE
	Load	Speed	Load	Speed	Speed
	(Kg)	(rpm)	(Kg)	(rpm)	(rpm)
1	2	5000	2	5200	5100
2	2.5	4990	2.5	5100	5000
3	3	4740	3	4760	4750
4	3.5	4540	3.5	4560	4550
5	4	4390	4	4410	4400
6	4.5	4170	4.5	4190	4180

Table.1.Maximum loading condition for conventional flywheel

For DMF maximum loading condition is checked in same manner as that of conventional flywheel. Below table.2 shows the maximum loading condition for DMF. The sample calculation for other engine parameters is also explained.

Table.2.Maximum loading condition for dual mass flywheel

Sr. No.	LOADING		UNLOADING		AVERAGE
	Load	Speed	Load	Speed	Speed
	(Kg)	(rpm)	(Kg)	(rpm)	(rpm)
1	2	5400	2	5600	5500
2	2.5	5300	2.5	5500	5400
3	3	5240	3	5260	5250
4	3.5	5040	3.5	5060	5050
5	4	4800	4	5000	4900
6	4.5	4770	4.5	4790	4780



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Trial of Conventional Flywheel

During the trail of Conventional Flywheel, (here flywheel is simple disc structured) at partial loaded condition and at fixed time say 4 minutes, the required fuel consumption is checked in burette. Also the corresponding water level in manometer is observed and difference between two levels of manometer is measured with scale. This observed data is tabulated in the following table.3.

Sr.	LOAD	MANOMETER	FUEL	TIME
No.	(Kg)	READING	CONSUMPTON	(Min)
		(Cm)	(CC)	
1.	2	1.5	21	4
2.	2.5	1.55	22	4
3.	3	1.6	22.5	4
4.	3.5	1.65	23.5	4

Table.3 Observation Table of conventional flywheel

On the basis of this observation, the result values such as torque, brake power, volumetric efficiency, BSFC and brake thermal efficiency are calculated which are mentioned in table .4.

1.7

1.6

Sr.No.	LOAD (Kg)	SPEED (Rpm)	TORQUE (Nm)	BRAKE POWER (W)	VOLUMETRIC EFFICIENCY (%)	BSFC (gm/KWh)	BRAKE THERMAL EFFICIENCY (%)
1.	2	5100	0.69	366.7939	70.6018	644.095	12.93806
2.	2.5	5000	0.86	449.5024	73.20981	674.766	15.13476
3.	3	4750	1.03	512.4327	78.29604	690.101	16.87021
4.	3.5	4550	1.20	572.666	83.00495	720.773	18.05094
5.	4	4400	1.37	632.8993	87.12548	766.779	18.75257
6.	4.5	4180	1.55	676.4112	88.97277	797.45	19.27097

Table.4 Result Table of conve	entional flywheel
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4

4

Sample calculation for Conventional Flywheel at 2.5 kg load:

5

6.

4 4.5

a) Torque = Load \times 9.81 \times radius of dyno brake pulley = 2.5 \times 9.81 \times 0.035 = 0.86

b) Brake Power (BP) =
$$\frac{2\pi NT}{60}$$
 = $\frac{2 \times 3.14 \times 5000 \times 0.86}{60}$ = 449.5024

c) Volumetric Efficiency =
$$\frac{Actual mass of Air (kg/unit time)}{Theoretical mass of Air(kg/unit time)}$$

Where,

Actual mass of Air

$$= \frac{\pi}{4} \times Coefficient of Discharge(cd) \times orifice diameter^{2} \times \sqrt{2gha}$$

$$= \frac{\pi}{4} \times 0.6 \times 16.5^{2} \times \sqrt{2gha}$$
And
$$ha = \frac{Manometer Reading}{100} \times \frac{Water Density}{Air Density}$$

$$ha = \frac{1.55}{100} \times \frac{1000}{1.186}$$

$$ha = 13.06$$



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Hence eqⁿ 1 becomes

Actual mass of Air = $\frac{\pi}{4} \times 0.6 \times 16.5^2 \times \sqrt{2 \times 9.81 \times 13.06} = 2054$ And Theorotical mass of Air = $\frac{\pi}{4} \times Bore \ Diameter^2 \times Stroke \ Length \times \frac{RPM}{60}$ $= \frac{\pi}{4} \times 3.5^2 \times 3.5 \times \frac{5000}{60} = 2804.7$ So Volumetric Efficiency = $\frac{2054}{2804.7}$ = 73.20% d) $BSFC = \frac{mf}{BP}$ Where $mf = \frac{Fuel \ Density \times Fuel \ Consumption}{1000 \times min}$ $= \frac{0.75 \times 22}{1000 \times 4}$ $mf = 0.004125 \ kg/min$ So $BSFC = \frac{0.004125 \times 1000 \times 60}{449.50} = 674.76 \ Gm/kwh$ e) $Brake \ Thermal \ Efficiency = \frac{BP}{mf \times CV} = \frac{449.50 \times 100}{0.004125} \times 43200 \times 1000 = 15.134 \ \%$

Trial of DMF

During the trail of DMF, three springs with three masses and mass lever are fitted between primary and secondary flywheel to achieve desired outputs. Further test process is same as that of conventional flywheel. At partial load condition and at fixed time say 4 minutes, the required fuel consumption is checked in burette. Also the corresponding water level in manometer is observed and difference between two levels of manometer is measured with scale. This observed data is tabulated in the following table.5.

Sr.	LOAD	MANOMETER	FUEL	TIME
No.	(Kg)	READING	CONSUMPTON	(Min)
		(Cm)	(CC)	
1.	2	1.95	19	4
2.	2.5	2	17	4
3.	3	2.05	14	4
4.	3.5	2.15	18	4
5.	4	2.25	21	4
6.	4.5	2.3	23	4

Table.5 Observation	Table of	f DMF
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On the basis of this observation, the result values such as torque, brake power, volumetric efficiency, BSFC and brake thermal efficiency are calculated which are mentioned in table .6.



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Table.6 Result Table of DMF

Sr.No.	LOAD (Kg)	SPEED (Rpm)	TORQUE (Nm)	BRAKE POWER (W)	VOLUMETRIC EFFICIENCY (%)	BSFC (gm/Kwh)	BRAKE THERMAL EFFICIENCY (%)
1.	2	5500	0.69	395.5621	74.64969	540.37	15.42152
2.	2.5	5400	0.86	485.4626	77.0007	483.489	21.15305
3.	3	5250	1.03	566.373	80.18461	398.168	29.96683
4.	3.5	5050	1.20	635.5964	85.36921	511.93	26.15623
5.	4	4900	1.37	704.8197	90.00541	597.251	24.86137
6.	4.5	4780	1.55	773.5037	93.28449	654.132	24.91155

Maximum fluctuation of energy

Flywheel is used to control the variations in speed during each cycle of an engine. It helps to make the moment of inertia of rotating parts quite large and thus acts as a reservoir of energy. During the periods when the supply of energy is more than required, it stores energy and during the periods the requirement is more than the supply, it releases energy. Here we are comparing between the maximum fluctuation of energies between conventional flywheel and DMF so that we will get which flywheel is more effective. Hence we will rich towards the conclusion of effectiveness.

Maximum fluctuation of energy of Dual mass flywheel

Let, ΔE_{dmf} = Maximum fluctuation of energy of DMF

$$m = \text{mass of flywheel} = 1.95 \text{ kg}$$

$$R = \text{Mean Radius of rim} = 68 \text{ mm} = 0.068$$

$$\omega_{dmf} = \text{mean angular speed of dual mass Flywheel}$$

$$C_s = \text{Coefficient of fluctuation of Speed}$$

$$\Delta E_{dmf} = mR^2 \omega_{dmf}^2 C_s$$

$$\omega_{dmf} = \frac{2\pi (N_1 + N_2)}{2}$$

$$= \frac{2\pi (5500 + 4780)}{N} = 32295 \text{ rad/sec}$$
And $C_s = \frac{(N_1 - N_2)}{N}$

$$N = \frac{(N_1 + N_2)}{2}$$

$$= 5140$$

$$C_s = \frac{(5500 - 4780)}{5140}$$

$$C_s = 0.14$$
So,
$$\Delta E_{dmf} = mR^2 \omega_{dmf}^2 C_s$$

$$= 1.95 \times 0.0682^2 \times 7414^2 \times 0.14$$

$$= 1317.323 \text{ KJ}$$

Maximum fluctuation of energy of Conventional flywheel

 $\Delta E_{cnv} = mR^2 \omega_{cnv}^2 C_s$ Where, ΔE_{cnv} = Maximum fluctuation of energy of conventional flywheel m = mass of flywheel = 1.9 kgR = Mean Radius of rim = 68 mm = 0.068 ω_{cnv} = mean angular speed of conventional Flywheel $\omega_{cnv} = \frac{2\pi (N_1 + N_2)}{2}$ $= \frac{2\pi (5100 + 4180)}{2}$ 2 = 29153 rad/sec



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 $C_{s} = \text{Coefficient of fluctuation of Speed}$ $C_{s} = \frac{(N_{1} - N_{2})}{N}$ $N = \frac{(N_{1} + N_{2})}{2}$ = 4640 rpm $C_{s} = \frac{(5100 - 4180)}{4640}$ $C_{s} = 0.1982$ $\Delta E_{cnv} = mR^{2}\omega_{cnv}^{2}C_{s}$ $= 1.9 \times 0.0682^{2} \times 29153^{2} \times 0.19$ = 1489.219 KJ $\Delta E_{cnv} = MR^{2}\omega_{cnv}^{2}C_{s}$

$$Effectiveness (\varepsilon) = \frac{\Delta E_{dmf}}{\Delta E_{cnv}}$$
$$= 1.30$$

Thus the Dual mass flywheel is 1.3 times effective than the Conventional flywheel.

V. RESULTS AND DISCUSSION

In this chapter performance parameter curves are plotted with the help of performance parameters to represent the comparative study in graphical manner more effectively.

Performance Characteristics Curves

Where

Performance characteristics curves are the graphical presentation of engine performance. These curves are constructed from data obtained during actual engine testing and are useful for comparison of two flywheels. Here we are plotting engine performance parameters verses load.

1. Effect of Load on Engine Speed

As load on engine is increased, the speed of engine goes on decreasing. It means there is inverse relation between load and speed.



Graph1. Comparison Graph of Speed

2. Effect of Load on Brake Power

As load on engine is increased, the brake power of engine goes on increasing. It means there is direct proportion between load and speed.



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Graph2. Comparison Graph of Brake Power

3. Effect of Load on Volumetric Efficiency

Volumetric efficiency of engine goes on increasing as load on engine is increased due to increase in charge density.



Graph.3 Comparison Graph of Volumetric Efficiency

4. Effect of Load on BSFC

As load on engine is increased, the suction pressure becomes high causing efficient combustion and thereby BSFC reduces a minimum. If load is further increased the BSFC again increased due to high frictional losses as shown in below graph.



Graph.4 Comparison Graph of BSFC



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5. Effect of Load on Brake Thermal Efficiency

Thermal efficiency of the engine is an indicator of how efficiently the engine converts heat energy released by fuel to work. Following graphs shows that brake thermal efficiency increases with increase in load.



Graph.5.Comparison Graph of Brake Thermal Efficiency

VI. CONCLUSION

It is observed that there is approximately 7 to 8 % increase in all performance parameters of DMF as compared to conventional flywheel except BSFC as decrease in BSFC indicates better performance of DMF over Conventional Flywheel. It means that the Dual mass flywheel is 12 to 15 % efficient than the conventional flywheel which will also result in increasing fuel economy of the engine.

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