A Review paper on Dual Mass Flywheel system

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ABSTRACT

During the power stroke vibrations are occurred due to the slight twist in the crankshaft. The combustion cycles of a 4-stroke engine produce torque fluctuations which excite torsional vibration to be passed down the drive train. Hence it is necessary that the vibrations generated by engine be reduced or isolate, so that the operator / driver was feel lesser fatigue.

Dual mass flywheel is a multi-clutch device which is used to dampen. The torsional frequency is defined as the rate at which the torsional vibration occurs. When the torsional frequency of the crankshaft is equal to the transaxles torsional frequency an effect known as the torsional resonance occurs. When the operating speed of the engine is low, vibration occurs due to the torsional resonance and this can be avoided using dual mass flywheel. The resulting noise and vibration, such as gear rattle, body boom and load change vibration, result in poor noise behavior and driving comfort. The objective while developing this concept was to isolate the drive train from the torsional vibrations. This paper includes the development of inertia augmentation mechanism and development of optimized flywheel using this mechanism. The dual mass flywheel comprises primary flywheel and secondary flywheel and two springs.

Keywords: Dual Mass Flywheel, Arc Spring, Torsional Resonance and Torsional Frequency.

I. INTRODUCTION

The clutch system in a vehicle performs two main functions:

• Power interruption and modulation during start up and when shifting

• Reduction of rotational vibrations in the drive train induced by engine irregularities

Rotational vibrations affect durability of the drive train components and create

• Gear rattle

• Body boom

• Tip-in/back-out vibrations

These factors produce considerable noise and a loss in driving comfort. The main cause of these rotational vibrations is variation in torque. This variation results from the discrete piston combustion cycle of the engine as a function of the ignition frequency. These factors produce considerable noise and a loss in driving comfort. The main cause of these rotational vibrations is variation in torque. This variation results from the discrete piston combustion cycle of the engine as a function of the ignition frequency. The vehicle drive train is a vibrating system. Fig. 1 shows a simple model designed to simulate fundamental vibration behavior. The engine, transmission and vehicle are represented as rotating inertias connected by springs. The spring C_3 represents the stiffness of the drive train, while spring C_2, located between engine and transmission, and represents the spring characteristic of the torsion damper. Such a system has two vibrations modes. The first mode, with a natural frequency of between 2 and 10 Hz, is known as the tip-in/back-out reaction. This is generally excited by a driver-induced load change. The second mode, where the transmission inertia vibrates against engine and vehicle, has a natural frequency of 40 - 80 Hz with conventional torsion dampers. This is a typical cause of a gear rattle.

Consequently, the tuning of a conventional automotive torsion damper – a clutch disc with its corresponding spring characteristic - always involves compromise. The upper graph of Fig. 2 shows typical speed fluctuations in a vehicle with a clutch disc. In this case, the friction-damped resonance is located at around 1700 rpm. Further damping of this resonance leads to a worsening of the hypercritical isolation of rotational vibrations (at speeds higher than the **r**esonance). [2]

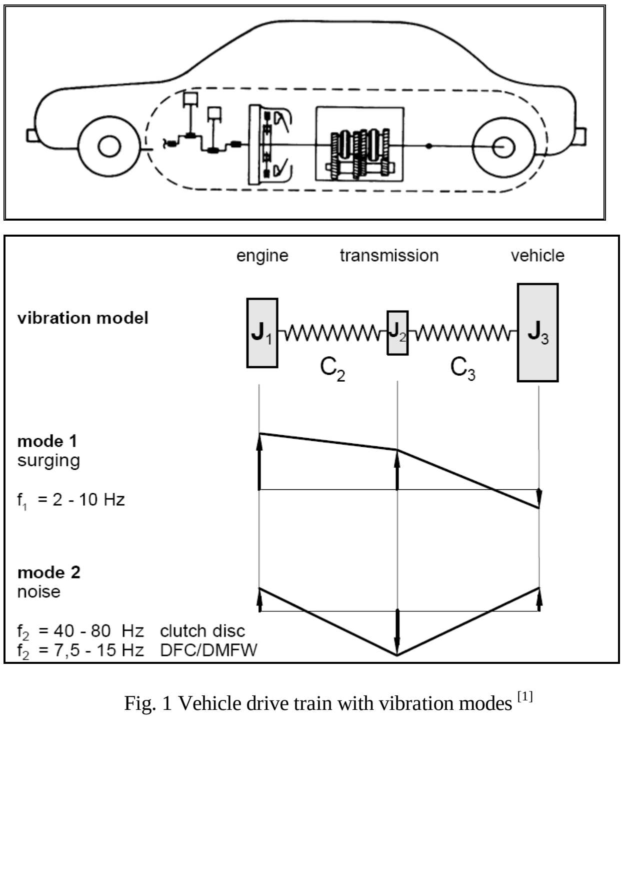

Fig. 1 Vehicle drive train with vibration modes [1]

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The goal of torsion damper development is to keep the torsional vibrations induced by the engine as far as possible from the rest of the drive train. A conventional system only satisfies this requirement at high engine speeds, because the attainable torsion damper spring rates lead to natural frequencies which are always within the normal driving range.

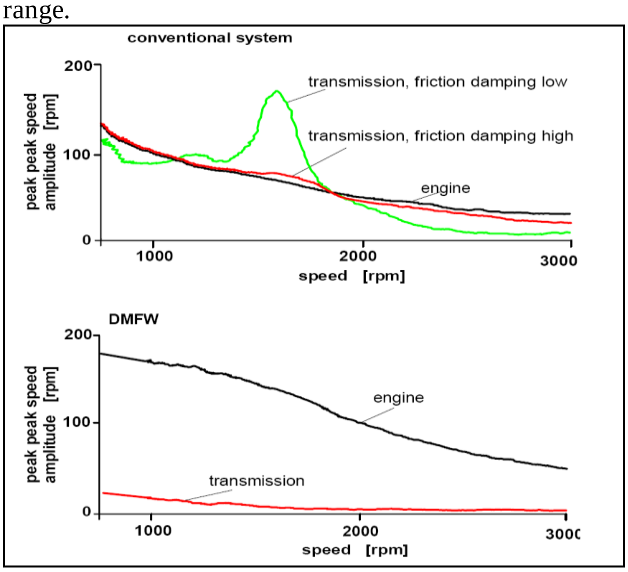

Fig. 2 Torsional vibration isolation with conventional clutch disc and dual mass flywheel [2]

This unsatisfactory situation led to the development of a new torsion damper concept - the dual mass flywheel (DMF). This design shifts part of the flywheel inertia to the transmission input shaft and drastically lowers the torsion damper spring rate by introducing new spring designs (Fig. 3), thus reducing the resonance speed to very low engine speeds. Fig. 2, lower graph, shows the hypercritical isolation of rotational engine vibrations (starting from idle speed).

Improvements in driving comfort achieved by the dual mass flywheel, together with low-cost designs resulting from goal-oriented, value-analyzed development, has led to the increased popularity of this system. Currently the LuK dual mass flywheel is used by ten car manufacturers in approximately 80 different models. [2]

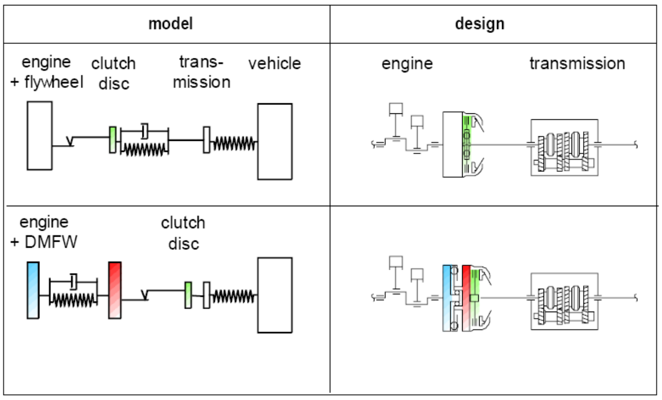

Fig. 3 Principle of the dual mass flywheel [2]

The main function of engine flywheel is to reduced fluctuations in power and produced smooth transmission of power to wheels. There are two schools of thought concerning light flywheels. The first is that they do not contribute to power output. The second is that they do. Which thought is correct? In fact both, in a way, are correct. If we measured the power output of an engine first with light flywheel and then again with the standard part on an engine dyno, no change in power will be seen to occur. At first it appears that the light flywheel has done nothing and was a total waste of cash. This is not the case. A dyno that shows max power at constant revs does not demonstrate what happens to an engine's power output in real life situations - like acceleration. If an engine is accelerated on a dyno (we are talking about a rate of around 2000 rpm a second) it would show a power output of around 20%-25% less than at the constant rev state.

The reason for this is that when accelerating a vehicle the engine not only has to push the total mass of the car but the internal components of the engine need to be accelerated also. This tends to absorb more power as the extra power is used accelerating the internal mass of the engine components and is why a motor accelerating on a dyno will produce less power than at constant revs. Also it must be remembered that the rate of acceleration on the engine internals is much greater that the rest of the car. This would then suggest that by lightening the flywheel, less power would be required to accelerate it and therefore more power would be available to push the car along. Obviously, there’s a certain minimum amount of flywheel inertial that should be resent for several reasons:

1. Idle stability
2. Tolerance of high compression, cam overlap, etc
3. Better clutch operation for low speed and traffic operation
4. Fewer load reversals on the driveline during low speed
5. Better traction
6. The carburetor’s accelerator pump and off-idle circuit settings are closer to “real world”
7. Damps vibration out some
8. Oil pressure is more consistent

Lighter flywheel offers the following advantages

1. Improves acceleration
2. Improves braking
3. Better suspension compliance in non-IRS where flywheel gyro wraps up the springs under brakes
4. Reduced overall weight

On the other hand lighter flywheel leads to following problems;

1. Is harder to kick through
2. Requires slightly higher idle speed screw setting for stable idle
3. Is more likely to stall when cold/out of tune
4. Is easier to shift
5. Has better braking (unless you disconnect the motor by pulling the clutch in while braking)
6. Requires more delicate touch with the clutch in traffic
7. Harder on the primary chain
8. Less tolerant of “walking speed” in gear

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A. Problem statement

In an ordinary conventional flywheel the engines ignition-induced rotational speed irregularity causes torsional vibration in the vehicles driveline also the fluctuations in engines speed. 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 rattle in transmission. Also more mass of flywheel increases the cost of engine.

B. Proposed methodology

The arrangement of the dual mass flywheel is best explained by the mathematical model below. The model is a two spring two mass model graphically represented as below

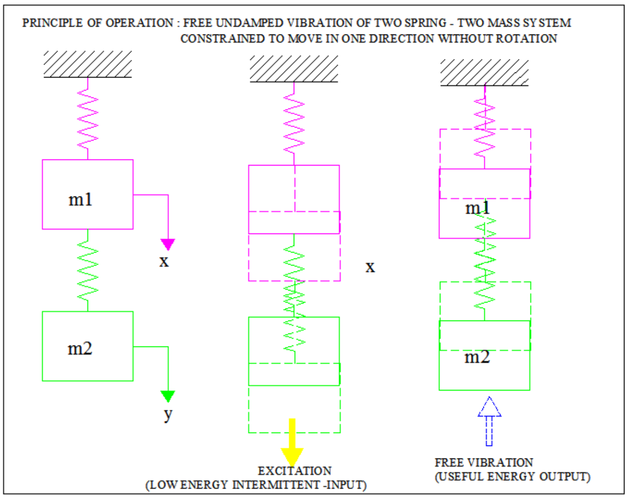

Fig. 4 Graphical Model of spring mass flywheel system

The fig. 4 shows free un-damped vibrations set up of two mass- two spring system. As shown 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 undamped 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 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.

From Fig .5 it is clear that in addition to the mass of the flywheel , the couple owing to the centrifugal and centripetal forces keeps the flywheel into motion for longer time thereby increasing the work done by the system hence the output from the given system increases.

Dual mass flywheel is represented in figure below:

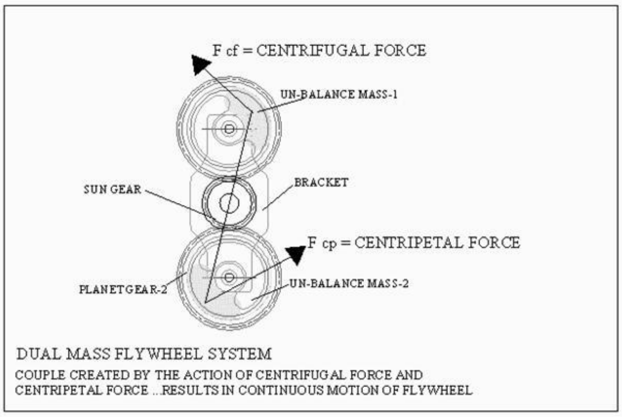

Fig.5. Dual Mass Flywheel System

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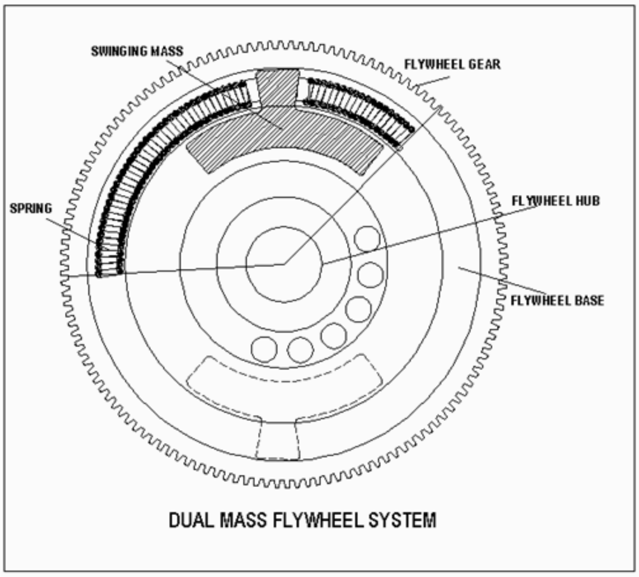

Fig.6.Dual Mass Flywheel System

The dual mass flywheel system is as shown above. The flywheel comprises of the flywheel hub which is keyed to the engine shaft,. Hub carries the flywheel body, on which the flywheel gear ring is mounted. The flywheel body is recessed at the rim inner side to receive the spring. Two springs and two masses are used hence the flywheel has dual masses from which the name of the flywheel originates. As the engine power is delivered to the flywheel, the jerk applied will set the flywheel into motion, so also the jerk is applied to the masses, and as explained in the two spring two mass system the two masses oscillate to generate the free energy as explained earlier. The motion of the masses gives extra impetus to the flywheel body due to which we get extra revolutions from the same jerk as applied to the conventional flywheel. Thus it is able to achieve more inertia

II. Literature Review

There has been a great deal of research on gear analysis, and a large body of literature on energy storage system has been published. The origins and use of flywheel technology for mechanical energy storage began several hundred years ago and developed throughout the Industrial Revolution. One of the first modern dissertations on the theoretical stress limitations of rotational disks is the work by Dr. A. Stodola whose first translation to English was made in 1917. Development of advanced flywheel begins in the 1970s.

Rotating wheels have been used to store and deliver energy since prehistoric times. The potter’s wheel is perhaps the first invention to resemble a flywheel and it has existed for 4,000 years. The first instance of the word flywheel occurred in 1784 during the industrial revolution. At this time flywheels were used on steam engine boats and trains and were often used as energy accumulators in factories. Flywheels became more popular with steep drops in the cost of cast iron and cast steel. In the industrial revolution, flywheels were very large and heavy so that they could store significant energy at low rotational speeds. The first use of flywheels in road vehicles was in the gyrobuses in Switzerland during the 1950’s. The flywheels used on the buses were 1500kg and had a diameter

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of 1.626 meters. When they were fully charged they could store 3.3×107 Joules. Flywheels are now found in many road vehicles as well as space, sea and air vehicles. Flywheels are also used for energy storage in power plants and as voltage controllers. Newly raised concerns about the environment have increased interest in flywheels.

Kevin Ludlum [3] studied a flywheel is an energy storage device that uses its significant moment of inertia to store energy by rotating. Flywheels have long been used to generate or maintain power and are most identified with the industrial age and the steam engine. In one sense it can be thought of as a rechargeable battery that store energy in the form of mechanical energy instead of electrochemical. Flywheels have been gaining popularity as a possible replacement for chemical batteries in vehicles, but until last year there was no record of a flywheels being used to increase the efficiency of a bicycle.

S H Salter [4] discussed here that it is easy to make a device that will respond vigorously to the action of sea waves. Indeed, it is quite hard to make one that will not. However, the conversion of the slow, random, reversing energy flows with very high extreme values into phase-locked synchronous electricity with power quality acceptable to a utility network is very much harder. This paper describes a range of different control strategies of varying degrees of sophistication and then describes possible conversion equipment for high-pressure oil and water and low-pressure air. Like many renewable energy sources, waves would benefit from some form of energy storage, particularly if they are to be used in weak island networks. Flywheels, gas accumulators, submerged oil/vacuum accumulators, thermal stores and reversible fuel cells are discussed, with emphasis on the coupling hardware. This leads on to a description of a new type of hydraulic machine with digital control which has been specially designed for high efficiency and flexible control of multiple erratic sources.

Dr. Robert Hebner, et.al. [5] In the past year, the researchers at the Center for Electro mechanics at The University of Texas at Austin (UT-CEM) and the Nanotech Institute at The University of Texas at Dallas (UTD) began research efforts on improved flywheel designs and flywheel materials to meet energy storage requirements for the grid. UT-CEM's initial effort focused on determining the power and energy requirements for a flywheel energy storage system at various points on the grid. UT-CEM researchers used real-world data from a newly developed community in Austin, TX to analyze the effect of energy storage at the home level, transformer level, and the community distribution level. With requirements defined, an optimization code was developed for sizing a flywheel energy storage system for the grid. Results of this optimization are shown for today's flywheel using conventional materials.

Rudolf Glassner, Kottes [6] A dual mass flywheel for a drive train of motor vehicle includes a primary flywheel mass, a secondary flywheel mass & coupling device. The coupling device includes at least two pivot levers associated with secondary flywheel mass that interact with the controlleled profile formed on the primary mass. The pivot levers are pretension against the controlled profile in radial direction by an elastic element. A control segment of elastic element is disposed radially inside the control profile.

Park, Dong-Hoon Suwan- Si, Kyunggi- Do [7] A dual mass flywheel for a vehicles includes a primary flywheel connected to a crankshaft of an engine, a damper housing integrally formed in a circumferential direction of primary flywheel a secondary flywheel is connected to input shaft of a transmission and rotatably mounted on hub of primary flywheel; driven fingers integrally formed on a second flywheel and inserted vertically into the damper housing to be forced by a damper spring. The damper spring comprises two springs sets symmetrically disposed within the damper housing, one end of each damper springs being driven by the stoppers which are integrally formed on primary flywheel, while the other end of the spring sets drive the driven fingers of the secondary flywheel. The primary & secondary flywheel is integrally provided with projections for preventing the damper spring from being excessively compressed & damaged. The damper spring comprises a plurality of springs, each having different spring coefficients and the damper spring is supported by a plurality of sliding guides or blocks.

Research Gap

From the above discussed literatures, it is concluded that most of the work had been done on study the performance of flywheel, dual mass flywheel act as vibration isolators in engine, energy storage of flywheel etc. Nowadays the requirement of energy storage of flywheel is more in small size, because of the space constraint in engines. This paper describes the improvement of energy storage capability by using dual mass flywheel with same size as compared to conventional flywheel.

III. WORKING STEPS

Typical working steps involved in the proposed work are mentioned as below

Step 1: Literature Review

In this phase literature survey of dual mass flywheel systems, the importance of DMF studied as compared to conventional flywheel. By referring journal like journal, International papers, European patents ,US patents etc.

Step 2: System design & Mechanical design of the DMF for engine of following specifications

Prime mover selection

Make: Crompton Greave Model: IK-35

Engine is Two stroke Spark ignition engine with following specifications:

Bore diameter: 35 mm

Stroke: 35 mm

Capacity: 34 cc

Power out pu : 1.2 BHP at 5500 rpm

Torque: 1.36 N-m @ 5000 rpm

Dry weight: 4.3 kg

Ignition: Magneto ignition

Direction of rotation: Clockwise .looking from driving end

Carburetor: "B" type

Cooling: Air Cooled engine

Step 3: Mathematical model development of system for dual mass flywheel system.

Step 4: Selection of materials of flywheel shaft, flywheel, flywheel mass , arc spring , dyno brake pulleyetc.

Step 5: System design for mechanical component like the coupling for engine connection, flywheel base, flywheel

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shaft, arc springs, flywheel mass, dyno brake pulley, chassis connection for given system of operation. This phase includes the planning of system as per the sketch above .
Step 6: Mechanical design of all components of the set up using theoretical formulae .for mechanical component engine
Step 7: Mechanical design validation using ANSYS for critical components of the system will be designed and validated .
Step 8: Validation of strength calculations of critical components viz, engine connection , engine shaft , mass lever, mass , dyno brake pulley , flywheel base, chassis connection using ANSYS
Step 9: Results and Discussion based on experimentation.
Testing of the developed system with and with Dual mass system & Conventional system by removing spring & masses.

IV. Experimental Setup Of Dual Mass Flywheel

The experimental test rig consist of two stroke petrol engine is paired with the planetary dual mass flywheel mounted on flywheel shaft, by love joy coupling. The flywheel shaft is mounted on base plate with the help of deep groove ball bearing. The torsional vibration damper is incorporated into the flywheel as a two arc spring and two masses on the conventional flywheel. For this purpose the flywheel is divided into a primary and a secondary mass hence the name exists "dual mass flywheel". The unidirectional ball bearing called as unidirectional clutch is mounted on flywheel shaft with bearing mounting to avoid opposite side rotation of dyno brake pulley. The dyno brake pulley is paired with unidirectional clutch. The rope is rapped on dyno brake pulley with one end is tie on base plate, and another end is tie on weighing pan.

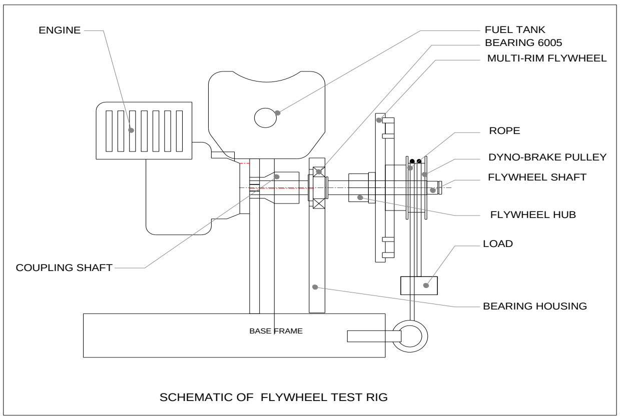

Fig. 7 Schematic of conventional flywheel test rig

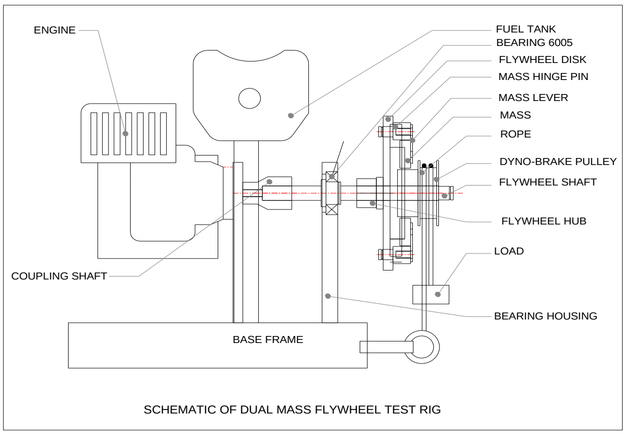

Fig. 8 Schematic of dual mass flywheel test rig

Fig. 9 Actual setup of dual mass flywheel test rig

V. Procedure

1) Start engine by turning
2) Let mechanism run & stabilize at certain speed (say 1300 rpm)
3) Place the pulley cord on dynamo brake pulley and add 500 gm weight into, the pan, note down the output speed for this load by means of tachometer.
4) Add another 500 gm cut & note down the output speed for this load by means of tachometer.
5) Take data of speed up to adding 5 kg weight.
6) Repeat above process with removing weight.
7) Tabulate the readings in the observation table for conventional and dual mass flywheel system.
8) Plot torque Vs speed, Efficiency Vs speed &
Power Vs speed characteristics.

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VI. Expected Outcome of the project-

The expected outcome of the system with dual mass flywheel system & without dual mass flywheel system (conventional system) is effectiveness of dual mass flywheel system with respect to conventional system. Also the improvement in power output as well as efficiency with using dual mass flywheel geometry.

VII. Objective And Scope

A. Objectives of project

1. Development of mathematical model for optimization of flywheel mass to derive stipulated output power.
2. Design and development of inertia augmentation mechanism.
3. Design and development of optimized flywheel using inertia augmentation technique.
4. Test and trial on optimized flywheel using test rig.
5. Plot performance characteristic curves.

B. Scope

1. Lowered weight of flywheel system will reduce system weight thereby leading to better fuel economy of vehicle and also reduce overall material cost.
2. Compact size: The size of the flywheel will lead to better cabin space of vehicle.
3. Engine life increases due to balanced power output.

IV. Conclusion

It is observed that there is approximately 7 to 8 % increase in power output by using the Dual mass flywheel and also observed that the Dual mass flywheel is 5 to 6 % efficient than the conventional flywheel which will also result in increasing fuel economy of the engine.

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