Eddy Current Dynamometer for Hydrogen Engine

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Abstract-*Power, speed and torque are the very important parameter when engine is about to be analysed. Thus while developing hydrogen engine test rig the measurement of power and torque by the engine is defined. To carry out this calculation we must possess a device which measures the power, speed and torque of the engine i.e. a dynamometer. This paper includes the different types of dynamometer and their basic information. The comparison has been done based on working principal, output energy form, material, user constraints and the design procedure of a dynamometer. The primary research includes the study of various dynamometers and the selection of suitable dynamometer which is capable for providing outputs in the form of electronic signals which are required in feedback loop to control the input parameter of the hydrogen engine. So by measuring the output parameters, input can be controlled significantly. Thus the eddy current dynamometer is meets the required specification.*

Keywords-Mechanism design, dynamometer, hydrogen engine, eddy current, electromotive force.

I. INTRODUCTION

India is developing country. It need much more fuel for fulfilling its daily requirements. Nowadays we are using diesel, petrol, coal such non-renewable energy sources. This creates much more pollution of the environment, also for that we are depends on UAN countries. So to achieve this demand we are searching for alternative energy source and choose hydrogen energy, which can be produced with the help of aluminium, water and catalyst solution. This can produce required amount of hydrogen for driving engine. Hydrogen fuel is produced from scrap aluminium so its production cost is low and it is directly used in engine without further processing. It is more efficient than conventional energy sources and pollution free energy source. To utilise hydrogen energy design of suitable engine is must. So to design engine we have to maintain the relationship between input and output parameters. To meet this relationship we design a dynamometer, which is highly compactable and fulfil all the requirements for hydrogen engine.

A dynamometer is a device used for measuring Power, Torque or Force of an engine, motor, or any rotating prime mover. There are two major types of Dynamometers: Passive or Absorption Dynamometer and Active or Universal Dynamometer. A dynamometer that is designed to be driven is called an Absorption or Passive Dynamometer. A dynamometer that can either drive or absorb is called a Universal or Active Dynamometer. Other specific types of dynamometers are: Eddy current, Magnetic Powder brake, Electric motor, Fan brake, Hydraulic brake, Prony brake, Water brake.

II. BRAINSTORMING THE IDEAS

The most important constituent of a research-oriented technical initiative is to brainstorm and gather up all the creative ideas and elaborate the working and advantages of different proposals. The best idea is then pursued for the fulfillment of the objective different types of dynamometer are required and suit different conditions.

Therefore, after summing up all the major factors of the different standard types of dynamometers in practice, we came up with the conclusion of opting for a Eddy current Dynamometer due to its error correction ability, output form, and accuracy.

Given Engine Output Parameters

The engine parameters for which we are designing the dynamometer are as follows.

Table 1: Engine specification.

Sr. No.	Parameter	Values
1	Number Of Stroke	4
2	Hydrogen Gas Pressure	2 Bar
3	Power	2 KW
4	Density Of Hydrogen	0.0824 Kg/M^3
5	Speed RANGE	1800 to 4000 Rpm
6	Crank Shaft Speed	2000 Rpm

III. LITERATURE REVIEW

Castro et al. (2006), this paper presents a method for correcting the dynamometer force measurements which significantly improves their accuracy. It allows correcting the force measurements in the studied frequency domain with errors smaller than 20%, in contrast to the measurements without correction that reach 5000% close to the resonance frequency. Fock et al. (2001), studied Magneto elastic dynamometers used in the industry operate under either static or quasistatic circumstances. Magneto elastic transducers belong to the inductive transducers, in which the relative permeability of ferromagnetic materials changes on effect of mechanical loads. The change of relative permeability results in a change of the impedance of the coil located in the transducer. . The value of mechanical impedance is the dependence of the mechanical load on the frequency. Mate et al. (2011), in his study a compact system carrying the eddy current retarder used for the testing of two wheel vehicles is designed. Many performance parameters of the eddy current retarder could be measured in the test bed, and the test bed that was developed was based on design optimization of an eddy current retarder and R&D on a series of products. This test bed is having following benefits Very low inertia, excellent accuracy and repeatability of torque measurements, high reliability for better productivity. Wang et al. (2012), studied Magnetic field distributions in disc magnetic drivers are analyzed by theory of the equivalent magnet charge in present work. An analytical model for magnetic induction is established based on assumption of the equivalent magnet charge. Effect of both dimensions and relative angle of magnets on the magnetic induction is analyzed by the established model to obtain the best ratio between the magnetic induction and magnet volume. In this way the magnetic drivers can be calculated by analyzing the magnetic field from equivalent magnet charge method, and the calculation shows that the components of magnetic flux density distribute periodically. Topolnicki et al. (2011), in his paper, concerns the dynamometer with magneto electric actuator. The dynamometer is designed to measure force parallel to the axis of the measurement rod. However, it is impossible to avoid the presence of parasitic forces which are perpendicular to the rod. . The forces perpendicular to the axis are compensated by the stiffness of suspension system. The proposed construction of the dynamometer with magneto electrical actuator allows achieving very attractive metrological parameters.

IV. SELECTION CRITERIA

At the power measurement is one of the important aspect in the dynamometer from the engine various dynamometers are used to measure output power from the engine. Hydraulic dynamometer is used for measurement of power up to high range i.e.75000kw. These are most suitable for high output power measurement. The eddy current dynamometer is available in large power range. They are available from 5kw to upward these dynamometer are most suitable for small 4 stroke engine. Other dynamometers are cannot be used for the large power output measurement.

Size of the dynamometer is also an important parameter while selecting it. The size of the hydraulic dynamometer is large compared to other dynamometer for measurement of same power output. Hydraulic dynamometer required water as a resisting member. Prony brake and other dynamometer also have the size more than the eddy current dynamometer.

Accuracy of hydraulic dynamometer is high but it affected by the water jerk. Fan brake, Prony brake are outdated types of dynamometers. The value compared by this dynamometer is not much accurate as these dynamometers are controlled by the mechanical load. Eddy current dynamometer is the most precise dynamometer among all of the dynamometers because it is more compact, accurate and reliable than other dynamometers.

The power absorbed by the hydraulic is proportional to the rotational speed and mass of water circulated in the working compartment. In fan brake dynamometer torque absorbed is controlled by changing the gearing or by restricting the air flow though the fan. Due to low viscosity of While eddy current dynamometer it is done by varying the excitation current.

Table 2: Parameter comparison

Type	Power range	compactness	Control	Accuracy	Remark
Hydraulic dyno	5	2	3	3	13
Fan brake	3	4	2	2	11
Eddy current	**3**	**4**	**5**	**4**	**16**
Frictional brake	3	3	3	2	9
Engine dyno	3	3	3	3	12

1=low, 3=moderate, 5=higher

V. RESULT AND DISCUSSION

The eddy current type Dynamometer is one of the most simple, standard, and easy to prototype dynamometer. It has many advantages over other orthodox dynamometers like economical viability, ease of maintenance, compactness, and suitability for higher accuracy.

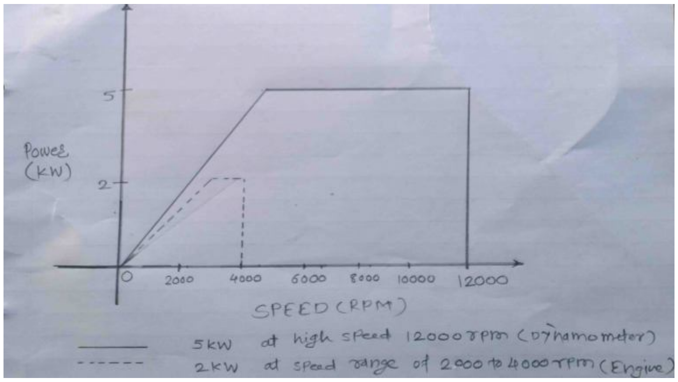

Figure 1 : Characteristic curve

The output power of the engine is 2 kw, the dynamometer with capacity 5 kw is capable for measuring that much power. The engine specification lies within the dynamometer capability as shown in the above graph.

Design procedure of eddy current dynamometer

Eddy current dynamometer consists of following components as discussed and explained below.

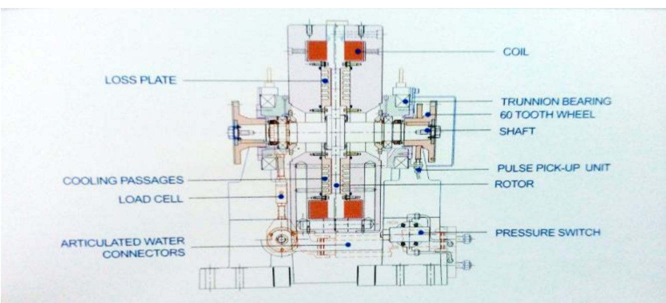

Figure 2: Construction of eddy current dynamometer.

1. Design of input shaft and rotor

Material selection for shaft

For shaft AISI-1020 steel is selected for following properties. Low hardenability and low carbon content. BHN 119-235, Tensile strength 410-790Mpa, high machinability, resistance to corrosion and induction hardening.

1. Diameter of shaft ,

$$d = \left[\frac{16\sqrt{3}\times n\times T}{\pi\times Sy}\right]^{\frac{1}{3}} \qquad (1)$$

2. Angle of twist of the shaft

$$\theta = \frac{584Mt\times L}{G\times d^4} \quad (2)$$

Rotor is manufactured from high magnetic permeability material for maximum performance and is designed for mini inertia.

2. Selection of strain gauge

Choice of strain gauge depends upon the accuracy. Gauge factor is given by the equation.

$$GF= \frac{\frac{\Delta Rg}{Rg}}{\frac{\Delta L}{L}} \quad (3)$$

The specifications of the strain gage selected are as given in the table.

Table 3: Strain Gage Specification

Parameter	Values
Foil measuring grid	Constant foil 5 mm thick
Connection dimension	Solder pads, tinned copper flat wire 30L×0.1D×0.3mm
Resistance	±0.15% to ± 0.5%
Gauge factor	2 to ± 5 %
Reference temp.	23°c

Higher the GF, grater the electrical output for recording purpose in which we can select semi conductor strain gauge having high gauge factor.

GF = ± 2 to ± 5

3. Design of casing

For casing we can generally use cast iron.
It has high strength, High shock absorption capacity and robust structure.

4. Energising coil

These are fully encapsulated two piece coils, used in place of the more common and cheaper single coil arrangement. This configuration ensures optimum distribution of flux throughout the working area for maximum low speed torque and at the same time allows the free flow of the air from the centre of the machine, through the critical air gap between rotor and stator and out of radial ventilation slots. These features ensure both rapid response and reliability under severest loading condition.

5. Cooling passages

The cooling passages and "loss plate" are critical areas in any eddy current dynamometer as thermal loading is high and cyclic loading can cause corresponding temp changes. Associated loss plate distortion may cause catastrophic contact between plate and rotor or loss of coolant. The water passages have been optimised to ensure consistent cooling and these are electro less nickel plated to ensure that corrosion does not detract from performance.

6. Water connections

Water connection is by menace of o'ring sealed articulated pipes, leading to flanges suitable for connection to water supply. This insures that water connection and supply pressure variations have minimum effect or machine accuracy. An integral flow detector monitors flow rates and ensures that a warming signal is given if water flow drops below safe level.

7. Controls

The level of power absorbed is controlled by varying the excitation current at the coil. When used in conjunction with feedback signals for torque from the load cell and speed from the pulse pickup and toothed wheel, closed loop is provided.

8. Selection of coupling

Rigid flexible coupling is selected for joining input shaft to engine. The coupling should be capable for transmitting torque from driving shaft to the driven shaft. The coupling should keep the shaft in proper alignment. The coupling should be easy to assemble and dissemble for purpose of repairs and alteration. The failure of revolving bolt, nuts, key holes and projected parts may causes accidents they should be covered.

9. Bearings

Deep groove – Ball Bearings
High radial and good Axial Loading, less wear and high efficiency. They are extremely rigid and free from resonance problem.

VI. CONCLUSION

The eddy current dynamometer is found out to be most suitable dynamometer for measurement of torque from hydrogen engine. The output obtained from the dynamometer is in the electrical form so dynamometer can be connected in the feedback loop and the output parameters from the engine can be controlled to improve the performance. Eddy current dynamometer is compact, reliable and more accurate for measurement of same power output.

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