Design and Validation of Air-cooled Eddy Current Dynamometer Test Rig

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Abstract—Dynamometers are generally not portable devices, since these cannot be used in more than one operation station. Another factor that is the cooling system used in dynamometers is complex. The dynamometers are generally liquid cooled, which prone the design towards more complicated and sturdier. This makes the device costlier and more complicated in design. In this project, the dynamometer used is air cooled type eddy current dynamometer. Hence the conventional liquid cooling system is replaced by air cooling. Another main factor which is advantageous is that air cooled dynamometer is lighter than any others. This makes it a portable device. Therefore, the design is simpler and device is portable, hence it can serve the purpose of working on multiple work stations. The construction of the system and interaction of component of the dynamometer was also considered which were done using CAD drawings.

Keywords—Eddy Current Dynamometer, Cardan Shaft, Engine testing, Portable Test Rig.

I. INTRODUCTION

A dynamometer is a device used for measuring force, torque, or power. The power produced by an engine, motor or other rotating prime mover can be calculated by simultaneously measuring torque and rotational speed (RPM). In addition to being used to determine the torque or power characteristics of a machine under performance and endurance test, dynamometers are employed in a number of other roles such as test of modern devices, transmission testing, test of chains, belts etc.

II. OBJECTIVE

The project is aimed at designing and fabricating a prime mover (engine/motor) testing rig using an air-cooled eddy current dynamometer. The various objectives of this project are as follows: To make a portable test rig for testing small range of engines or motors. To make the system automated by using a controller panel, which would ease changing the speed of prime mover and the eddy current load on it in order to obtain the desired test points. To make the system lightweight robust, thereby making the frame out of aluminum extrusions which would significantly reduce the weight. To select appropriate cardan shaft, couplings, bearings, swivel casters etc. Validation of prime mover by obtaining various characteristic graphs and comparing it with manufacturer’s specified performance graphs. To construct a reliable system and keeping it cost effective.

METHODOLOGY

Step 1: Engine Selection

Selection of the type of engine which we have to test with their power and torque produce capacity. This information is collected from specifications given by manufacturer. As per our requirement such as net torque available, output power, weight of engine, size as well as market cost, we choose GX25, GX35, GX80, GXH50, GX100, GXR120, GX120, GX240 among this available engine we follow weighted point method for selection of engine as per our requirement. As per data available from engine manufacturer (Honda) are given below.

![Honda GX80 Engine](image)

Fig1. Honda GX80 Engine
Table 1: Specifications of Honda GX80 four Stroke

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Engine type</th>
<th>Bore x stroke</th>
<th>Displacement</th>
<th>Compression ratio</th>
<th>Net power</th>
<th>Cont. rated power</th>
<th>Max. net torque</th>
<th>Ignition system</th>
<th>Starting system</th>
<th>Fuel tank capacity</th>
<th>Fuel cons. at cont. rated power</th>
<th>Engine oil capacity</th>
<th>Dimensions</th>
<th>Dry weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Air cooled 4-stroke OHC petrol engine, horizontal shaft, cast iron sleeve</td>
<td>46 x 48 mm</td>
<td>79.7 cm³</td>
<td>9:1</td>
<td>1.5 kW</td>
<td>1.2 kW</td>
<td>4.5Nm</td>
<td>Transistorized</td>
<td>Recoil starter</td>
<td>1.5 l</td>
<td>0.65 L/hr - 3 600 rpm</td>
<td>0.36 l</td>
<td>(L x W x H) 275 x 342 x 323 mm</td>
<td>10.6 kg</td>
</tr>
</tbody>
</table>

Step 2: Selection of Dynamometer
The type of retarder is selected according to our purpose as many choices are available such as air-cooled Eddy Current dynamometer, water cooled Eddy Current dynamometer, Hydraulic dynamometer etc. In this project air cooled eddy current retarder is selected. Selection of power absorption unit is based on the torque/power requirement.

![Fig. 2 Exploded View of Dynamometer K10](image)

Table 2: Electrical Specification

<table>
<thead>
<tr>
<th>Voltage</th>
<th>Resistance per coil (Ω) ±5% (20°C)</th>
<th>Resistance (Ω) ±5% (20°C)</th>
<th>Consumption (A) ±5% (20°C)</th>
<th>Insulation resistance (MΩ)</th>
</tr>
</thead>
<tbody>
<tr>
<td>72V</td>
<td>1</td>
<td>4</td>
<td>18</td>
<td>1</td>
</tr>
<tr>
<td>96V</td>
<td>1</td>
<td>4</td>
<td>24</td>
<td>1</td>
</tr>
</tbody>
</table>

Table 3: Specifications

<table>
<thead>
<tr>
<th>Maximum braking torque</th>
<th>Complete Weight</th>
<th>Stator Weight</th>
<th>Rotors Weight</th>
<th>Rotor’s Inertia</th>
<th>Maximum transmissible torque</th>
<th>Max. admissible R.P.M. (min-1) Constant Periodic</th>
<th>Air-gap regulation (±0.1 mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>27Nm / 19.1 Lb.Ft</td>
<td>17.2 Kg / 37.9 Lb</td>
<td>14.4 Kg / 31.73 Lb</td>
<td>2.8 Kg / 6.17 Lb</td>
<td>0.01 Kgm2 / 0.237 Lb-Ft2</td>
<td>800 Nm / 590 Lb Ft</td>
<td>11000 /13000</td>
<td>0.6 mm / 0.0236 inch</td>
</tr>
</tbody>
</table>
Step 3: Selection of Cardan Shaft
Also known as propeller shaft or cardan shaft & used for mechanical power transmission from engine to dynamometer. Data required for calculation to select a suitable shaft is: Speed range & torque characteristic of engine to be test, Rotational inertia of engine, Load factor with reference to nominal rating of shaft. Maximum engine torque, Whirling of shaft, Degree of misalignment of engine & dynamometer, Selection of coupling with minimum backlash as per our Cardan shaft diameter.

![Cardan Shaft Diagram](image)

**Fig. 4: XLO 1140 Cardan Shaft**

<table>
<thead>
<tr>
<th>Series</th>
<th>1140</th>
<th>1260</th>
<th>1350</th>
<th>1410</th>
<th>1510</th>
<th>1550</th>
<th>1600</th>
</tr>
</thead>
<tbody>
<tr>
<td>Short Duration Torque</td>
<td>570</td>
<td>770</td>
<td>1600</td>
<td>2040</td>
<td>3120</td>
<td>3300</td>
<td>4050</td>
</tr>
<tr>
<td>Flange OD</td>
<td>87.3</td>
<td>96.8</td>
<td>RECT FLANGE</td>
<td>RECT FLANGE</td>
<td>146</td>
<td>RECT FLANGE</td>
<td>174</td>
</tr>
<tr>
<td>Flange Spigot Dia.</td>
<td>57,150</td>
<td>60,325</td>
<td>69,850</td>
<td>95,250</td>
<td>95,250</td>
<td>95,250</td>
<td>168,250</td>
</tr>
<tr>
<td>Flange Thickness</td>
<td>5.2</td>
<td>6.8</td>
<td>7.5</td>
<td>7.5</td>
<td>9.1</td>
<td>10.4</td>
<td>9.5</td>
</tr>
<tr>
<td>PCD of bolt Hole</td>
<td>69,875</td>
<td>79,375</td>
<td>95.25</td>
<td>95.25</td>
<td>120,625</td>
<td>120,625</td>
<td>155.5</td>
</tr>
<tr>
<td>Flange Height</td>
<td>1.6</td>
<td>1.6</td>
<td>3.0</td>
<td>1.6</td>
<td>2.0</td>
<td>1.85</td>
<td>1.8</td>
</tr>
<tr>
<td>C.I of joint to flange face</td>
<td>30.2</td>
<td>30.2</td>
<td>39.7</td>
<td>42.7</td>
<td>63.5</td>
<td>50</td>
<td>69.9</td>
</tr>
<tr>
<td>Rotating Dia.</td>
<td>76.2</td>
<td>76.2</td>
<td>107</td>
<td>121.4</td>
<td>136.6</td>
<td>146</td>
<td>173</td>
</tr>
<tr>
<td>Tube Dia.</td>
<td>63.5</td>
<td>63.5</td>
<td>76</td>
<td>76</td>
<td>76</td>
<td>88</td>
<td>88</td>
</tr>
<tr>
<td>Slip Movement</td>
<td>42.9</td>
<td>42.9</td>
<td>57.2</td>
<td>57.2</td>
<td>57.2</td>
<td>60.3</td>
<td>69.3</td>
</tr>
<tr>
<td>Angular Movement</td>
<td>14</td>
<td>20</td>
<td>18</td>
<td>20</td>
<td>18</td>
<td>20</td>
<td>18</td>
</tr>
<tr>
<td>Max. Compressed Length</td>
<td>260</td>
<td>321</td>
<td>356</td>
<td>363</td>
<td>455</td>
<td>415</td>
<td>533</td>
</tr>
</tbody>
</table>

Step 4: Design of Bed Plate

Bed plate is made of cast iron for all models. It is accurately machined at trunnion mounting faces & on foundation areas. Provision is also made on bed plate for mounting stop screws. Pre-load tension spring for load cell is attached to bed plate. Terminal box, pressure switch / flow switch is mounted on bed plate.
Bed Plate Dimensions -1200*800, Material- Mild Steel

Table 5. Selected Tslot Specifications

<table>
<thead>
<tr>
<th></th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>M12 (bolt)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Depth min (C1)</td>
<td>9mm</td>
<td>11mm</td>
</tr>
<tr>
<td>Width (B1)</td>
<td>23mm</td>
<td>25mm</td>
</tr>
<tr>
<td>Width of Throat (A1)</td>
<td>14mm</td>
<td>-</td>
</tr>
</tbody>
</table>

![Fig 5: Basic Dimensional Design](image)

Step 5: Selection of Accessories:

A. Pulse Pickup Bracket- A Magnetic pickups (MPUs) are speed sensors that detect the speed of a prime mover, typically an engine or turbine. The MPU is installed next to a drive shaft gear made of a material that reacts to a magnetic field. A Magnetic pulse pickup consists of a permanent magnet, a pole-piece and a sensing coil all encapsulated in a cylindrical case. An object(target) of iron, steel or other ferromagnetic material, passing closely by its pole piece causes distortion of magnetic flux field passing through a sensing coil and pole piece which in turns a single voltage.

The magnitude of single voltage depends on the relative size of the magnetic target, its speed of approach, and how close it approaches. The polarity of signal depends on whether the target is moving towards or away from pole piece. Magnetic pickups are most frequently used to sense passing teeth on a gear, sprocket, timing belt wheel, to bolt-heads, keyway or other moving machine mounted targets. The magnetic field of the target body distorts the magnetic field of the sensor. This change in the sensor's magnetic field triggers its output voltage, which is a speed signal and hence rpm of target is known.

![Fig 6: Bed Plate with T-slots](image)

B. Load Cell- A load cell is a transducer that is used to create an electrical signal whose magnitude is directly proportional to the force being measured. The various load cell types include hydraulic, pneumatic, and strain gauge. Strain gauge load cells enables us to measure tension compression which is required for our application. It works on the principle that the strain gauge (a planar resistor) deforms when the material of the load cells deforms appropriately. Deformation of the strain gauge changes its electrical resistance, by an amount that is proportional to the strain. The change in resistance of the strain gauge provides an electrical value change that is calibrated to the load placed on the load cell.

Load cell selected is Sensortronics Model 60001, which is a tension-compression load cell with a humidity-resistant coating and shielded cables, which enable use in harsh environments while maintaining operating performance. It is ideally suited for lever conversions, hanging scales, force measurement and a wide range of other industrial applications. It has Nickel-plated coating for outstanding corrosion resistance.

![Fig 7: Pulse Pickup Bracket](image)
C. Swivel Castors- A castor is a wheeled device typically mounted to a larger object that enables relatively easy rolling movement of the object. Casters are essentially housings, that include a wheel and a mounting to install the caster to objects (equipment, apparatus and more). Swivel castor allows movement in all directions. They can have one or two sets of raceways that allow the caster to swivel 360-degrees under a load. Because of displacement of wheel axis from steering axis, in spite of their zero-caster angle, the point at which the wheel touches the floor trails behind the steering axis, keeping the wheel oriented in the direction of travel. Several devices that can be added to casters to prevent the wheel from rotating or the swivel assembly from turning. Brakes (locks) types are wheel-brakes, total lock, central locking, or add-on butterfly brake. Selection Criteria – It is normally observed that 80% of the castor failures are due to improper selection of castor wheels, hence, while selecting any wheel or castor for any purpose or application, one should keep following points in his mind. Load Carrying Capacity, Pushing pulling Efforts, Floor Surface, Noise Level.

Medium Duty (MD Series) castors are designed to carry moderate loads and are suitable for various types of trolleys and equipment’s used in industries, warehouses, godowns, stores, railway platform and so on. These castors are suitable where load carrying capacity required is higher & the light duty castors need frequent replacement.

D. Plummer Block- A Plummer block usually refers to a housing with an included anti-friction bearing. A Plummer block refers to any mounted bearing wherein the mounted shaft is in a parallel plane to the mounting surface, and perpendicular to the centre line of the mounting holes, as contrasted with various types of flange blocks or flange units. A Plummer block may contain a bearing with one of several types of rolling elements, including ball, cylindrical roller, spherical roller, tapered roller or metallic or synthetic bushing.
CONCLUSION

After the laborious work of Designing & Developing a Test Rig, measuring Torque and Power. Using these values, conclusions could be drawn upon various performance parameters such as Power produced by the engines, Engine speed (Rev/min), Fuel consumption. Total financial aid required to form this test rig was approximately Rs 2,00,000/-. A very paltry amount when compared to the market price of the machine.

ACKNOWLEDGMENT

The authors would like to acknowledge for their support and cooperation of Mechanical Department, Project Guide Prof. P.H. Lokhande. They would also like to thank all members of Mechanical Department for their work and their support.

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