

Development of a Simplified Gearbox System for Engine Dynamometer Test Cells

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Abstract: Engine dynamometer test cells are widely used in automotive research laboratories to evaluate the performance characteristics of internal combustion engines. Parameters such as torque, power output, fuel consumption, and emissions can be measured accurately under controlled operating conditions using these systems. In many test facilities, a conventional automotive gearbox is placed between the engine and the dynamometer to support engine mounting and transmit torque. However, traditional gearboxes are designed for vehicle applications and contain several components such as gear sets, synchronizers, and shifting mechanisms that are unnecessary for stationary testing systems.

This study presents the design and development of a simplified gearbox system intended specifically for engine dynamometer test cells. The proposed design eliminates internal gear mechanisms and instead uses a direct transmission shaft supported by high-precision bearings within a rigid housing structure. The objective of the system is to transmit torque reliably while maintaining proper alignment between the engine and dynamometer shafts.

The gearbox was designed to operate at a maximum torque of 60 Nm and a rotational speed of 4500 rpm. Mechanical design calculations were carried out to determine the appropriate shaft diameter based on torsional stress criteria. Deep groove ball bearings were selected to support the rotating shaft and reduce frictional losses. The system was manufactured using conventional machining processes and installed in an engine test cell for performance evaluation.

Experimental results showed that the simplified gearbox achieved an average torque transmission efficiency of approximately 98%, while vibration levels remained within acceptable limits for rotating machinery. The developed system significantly reduces mechanical complexity, manufacturing cost, and maintenance requirements compared with conventional gearbox arrangements. The proposed design therefore provides a practical solution for torque transmission in stationary engine dynamometer applications..

Keywords: Engine dynamometer, simplified gearbox, torque transmission, test cell, mechanical design

I. INTRODUCTION

Engine performance testing is an essential part of automotive research and development. Engineers rely on controlled laboratory experiments to evaluate parameters such as engine torque, power output, fuel consumption, efficiency, and exhaust emissions. One of the most widely used tools for this purpose is the engine dynamometer, which allows the engine to operate under controlled load conditions while performance data are recorded.

In a typical dynamometer test setup, the crankshaft of the engine is connected directly to a dynamometer that absorbs the mechanical power produced by the engine. By measuring the torque and rotational speed simultaneously, the power output of the engine can be calculated accurately.



In some laboratory test cells, a conventional automotive gearbox is installed between the engine and the dynamometer. This arrangement is sometimes used because it simplifies mounting and allows compatibility with existing vehicle powertrain components. However, gearboxes designed for vehicle applications contain multiple gear ratios and several internal mechanisms that are not required when the engine operates in a stationary testing environment.

Automotive gearboxes generally include components such as gear pairs, synchronizer mechanisms, shift forks, selector systems, and countershafts. These elements are necessary for changing gear ratios during vehicle operation but do not contribute to torque transmission in a fixed-speed test environment. The presence of these components increases system weight, mechanical complexity, friction losses, and maintenance requirements.

To address these issues, it is beneficial to develop a simplified transmission system specifically intended for engine dynamometer test cells. Such a system should focus primarily on transmitting torque efficiently while ensuring accurate alignment between rotating shafts.

The main objective of this research is therefore to design, fabricate, and experimentally evaluate a simplified gearbox system that eliminates unnecessary gear mechanisms and provides a reliable connection between the engine and the dynamometer

II. DESIGN METHODOLOGY

2.1 System Configuration

The simplified gearbox system developed in this research consists of the following main components:

- Transmission shaft
- Bearing assembly
- Gearbox housing
- Engine coupling interface
- Dynamometer coupling interface

Unlike conventional automotive gearboxes, the proposed design does not include gear sets or shifting mechanisms. Instead, torque is transmitted directly through a solid shaft supported by bearings within a rigid housing.

This configuration offers several advantages:

- Reduced mechanical complexity
- Lower frictional losses
- Improved reliability
- Easier maintenance

2.2 Shaft Design

The transmission shaft must be capable of safely transmitting the maximum engine torque without exceeding the allowable shear stress of the shaft material.

The torsion equation used in shaft design is:

$$T = (\pi/16) \tau d^3$$

Where:

T = transmitted torque

τ = allowable shear stress

d = shaft diameter

For the proposed system:

Maximum torque = 60 Nm

Allowable shear stress for steel \approx 55 MPa

Using the torsion equation, the calculated shaft diameter was approximately 20 mm. To ensure adequate strength and provide a suitable factor of safety, the final shaft diameter selected for fabrication was 30 mm.



The shaft material chosen for the system was medium carbon steel (AISI 1045) because it offers good mechanical strength, fatigue resistance, and machinability.

2.3 Bearing Selection

Bearings were incorporated to support the rotating shaft and minimize friction during operation. Deep groove ball bearings were selected because of their ability to handle radial loads while operating efficiently at high rotational speeds.

Selected bearing:

- SKF 6007-2Z Deep Groove Ball Bearing
- Advantages of this bearing include:
 - Low friction characteristics
 - High speed capability
 - Compact design
 - Long operational life

2.4 Fabrication and Assembly

The gearbox components were manufactured using conventional machining processes. The transmission shaft was produced through precision turning operations to achieve the required dimensional accuracy and surface finish. Special attention was given to the bearing seat regions to ensure proper fitting and alignment.

The gearbox housing was fabricated from steel plates and machined to accommodate the bearing assembly. After machining, the bearings were installed into the housing, and the transmission shaft was positioned through the bearing supports.

III. EXPERIMENTAL TESTING

3.1 Torque Transmission test:

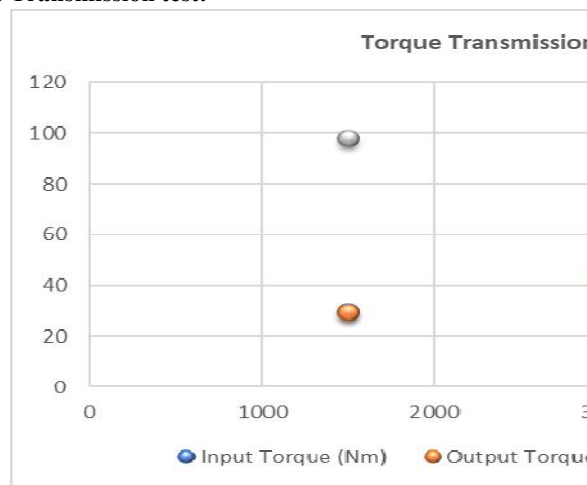


Figure: 3.1 Torque Transmission Test

Figure 3.1 shows the torque transmission performance of the dummy gearbox at different operating conditions. The input torque increases with operating speed, and the output torque closely follows the input values, indicating effective torque transfer. The slight difference between input and output torque represents minimal transmission losses. The efficiency remains consistently high at around 98% across all test points. This demonstrates that the Manual gummy gearbox transmits torque with very low losses



The results indicate that the simplified gearbox maintains high torque transmission efficiency throughout the tested operating range.

Vibration Measurement :

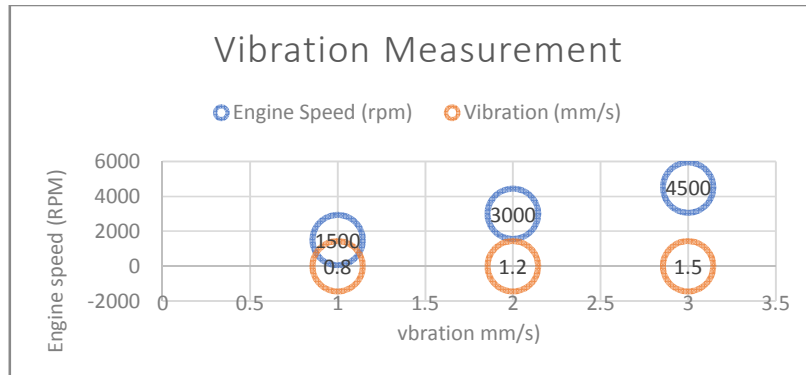


Figure3.2 illustrates the variation of vibration amplitude with engine speed,

Figure3.2 illustrates the variation of vibration amplitude with engine speed, showing a consistent increasing trend. As the engine speed increases from 1500 rpm to 4500 rpm, the vibration level rises from 0.8 mm/s to 1.5 mm/s. This indicates that higher rotational speeds result in increased dynamic forces and possible imbalance within the engine system. The rise in vibration is smooth and gradual, suggesting stable engine operation without any abrupt peaks or resonance effects. Such behavior is commonly observed in durability testing, where vibration response is used as an indicator of mechanical condition.

The vibration level increased gradually with engine speed but remained within acceptable limits for rotating mechanical equipment.

IV. RESULTS AND DISCUSSION

The experimental evaluation demonstrated that the simplified gearbox system provides efficient and reliable torque transmission. The elimination of internal gear meshes significantly reduces friction losses within the system. As a result, the mechanical efficiency remained close to 98% across the tested operating conditions.

4.1 Test cell Engine Durability cycle:

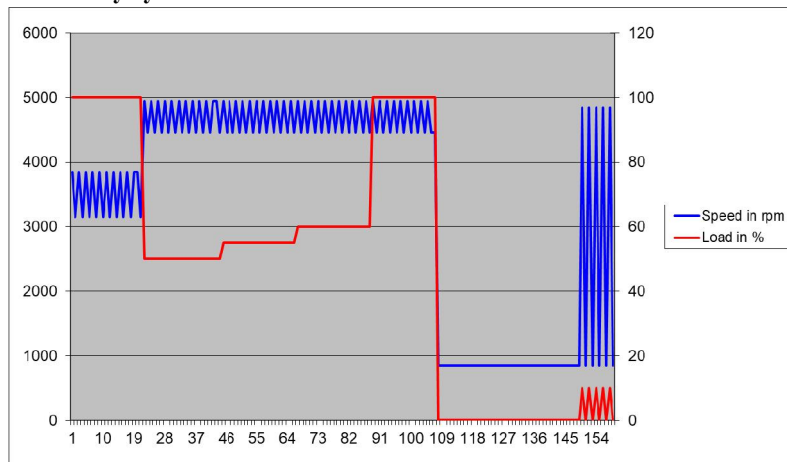


Fig4.1 Test cell engine Durability cycle



Figure 4.1 shows the variation of engine torque (load %), speed (rpm), and time during a durability test cycle. Such cycles are used to simulate real operating conditions for engine validation. Initially, the engine runs at high torque with moderate speed fluctuations. As torque reduces, the speed increases and stabilizes at higher rpm. The system responds well to sudden torque changes without instability. At low torque, the engine returns to idle conditions. Overall, the results confirm stable operation and suitability of the simplified gearbox system for durability testing.

Another advantage of the proposed design is the reduction in mechanical vibration and noise, since gear meshing and shifting mechanisms are not present. The simplified structure also lowers manufacturing costs and simplifies maintenance procedures.

Compared with conventional gearbox systems used in vehicle applications, the simplified gearbox offers the following benefits:

- Lower mechanical complexity
- Reduced friction losses
- Lower maintenance requirements
- Improved reliability for stationary applications

The compact structure also makes installation and alignment within the engine test cell easier.

V. CONCLUSION

This study presented the design, fabrication, and experimental evaluation of a simplified gearbox system intended for engine dynamometer test cells. The proposed design eliminates conventional gear mechanisms and replaces them with a direct transmission shaft supported by bearings.

Experimental testing showed that the system achieved approximately 98% torque transmission efficiency while maintaining acceptable vibration levels across the tested speed range.

The simplified gearbox design reduces mechanical complexity, manufacturing cost, and maintenance requirements compared with traditional gearbox systems. The results suggest that the developed system can serve as an efficient and practical solution for torque transmission in stationary engine testing facilities.

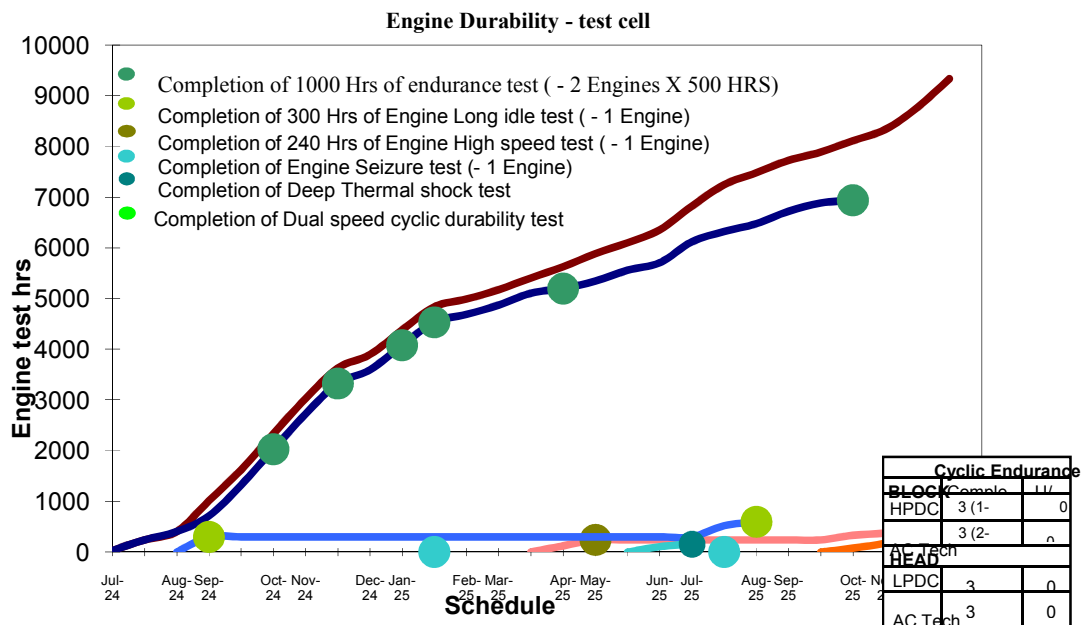


Figure 5 cumulative engine durability test hours and cyclic endurance



Figure 5 shows the cumulative engine durability test hours and cyclic endurance progression using the simplified gearbox system (SGS) in the test cell. A steady, near-linear increase in cumulative hours indicates stable and uninterrupted operation. The cyclic endurance trend aligns closely, confirming effective integration of cyclic loading within the durability program. Test events across multiple conditions (high-speed, long idle, seizure, DTS, and dual-speed) demonstrate comprehensive operating coverage. The high completion rate and absence of irregularities validate the reliability of the SGS for controlled engine durability testing.

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