PREPRINT

SCIENCE & TECHNOLOGY

Journal homepage: http://www.pertanika.upm.edu.my/

Design, Manufacturing, and Testing a Versatile Test Stand for MP100S Integration

Huu Danh Tran

Department of Mechanical Engineering, Vinh Long University of Technology Education, 73 Nguyen Hue Street, Vinh Long City, 85100 Vinh Long Province, Vietnam

ABSTRACT

The article designs and manufactures an engine mounting test stand with a structure that can not only mount a single test engine but also mount many different types of engines with an engine support structure that can move along the X, Y, Z axes and rotate around the Z axis, making it very flexible and easy to mount and align the engine connected to the MP100S dynamometer system. Manufacturing and assembling a complete engine mounting test stand that can be linked to the MP100S dynamometer system ensures technical requirements, safe operation, and testing to measure the number of revolutions n (rpm), torque Mx (N·m), and power P (kW) of the engine when operating at no load and with load. The results of the paper can be used as reference data in calculating the design and manufacturing of the engine mounting test stand to measure the number of revolutions, torque and power of the engine, Turbocharger blade efficiency, exhaust gas pressure, fuel consumption corresponding to each engine operating mode.

Keywords: Engine, load, MP100S, open power flow, test stand, turbocharger

INTRODUCTION

Diesel engines are the most economical and durable engines in the world, have the longest history and are widely used in machinery and industrial equipment such as automobiles, excavators, forklifts, and construction machinery. There are many research projects in the world on diesel engines to improve engine performance, reduce emissions, reduce noise, and reduce vibration (Calvo et al., 2006; Chen et al., 2022; Huang et al., 2011; Lloyd & Cackette, 2001; Ni et al., 2020; Norouzi et al., 2022; Visan et al., 2022). Research on turbocharger improvements to reduce turbo lag, emissions, and fuel

ARTICLE INFO

Article history:
Received: 15 October 2025
Accepted: 29 December 2025
Published: 01 April 2026

DOI: https://doi.org/10.47836/pjst.34.2.03

E-mail address:
danhth@vlute.edu.vn

e-ISSN: 2231-8526

consumption aims to optimise the turbocharger (Chen et al., 2022; Visan et al., 2022), use advanced algorithms through deep learning to control the engine to reduce NO_x and fuel consumption, keep the load, which reduces the calculation speed (Norouzi et al., 2022), control the engine using advanced algorithms (Norouzi et al., 2022), and reduce environmental impact through biodiesel fuel (Visan et al., 2022) or emission control (Lloyd & Cackette, 2001). From the above research works with those improvements, it is required that the engine mounting test stands must be modern, capable of connecting to the MP100S dynamometer system to collect, and process accurate data, to have a general overview of the research and manufacture of a multi-purpose test stand that can adjust the mounting of many different types of engines, diverse testing requirements, not only testing the main engine performance but also having the ability to flexibly integrate with sensors and MP100S measuring devices. In addition to research works on diesel engines, there are also research works on other types of engines that have been studied such as hybrid engines (Crispi et al., 2022), ammonia-hydrogen fuel engines (Qi et al., 2023), CNG-SI engines (Tomin et al., 2024), and customised internal combustion engines (Altarazi et al., 2020; Yu et al., 2021) to meet the orientation of green and clean energy development in the current period. Combined with the research on auxiliary details such as mufflers in the air intake system (Liu et al., 2019) and exhaust gas thermoelectric generators (Subramaniam et al., 2019) which also greatly affect engine performance, the research, design and manufacture of a test stand for mounting an engine, especially a diesel engine, is an important field with studies focussing on testing and evaluation (Adkine et al., 2017; Alfaiz et al., 2014; Derbiszewski et al., 2023; Izvorean & Stoica, 2022; Lee et al., 1998; Mohammadi et al., 2024; Oliveira et al., 2024; Park, 2023; Santhosh Kumar et al., 2022; Shao, 2011; Singh, 2000; Tatarynow et al., 2022; Wang et al., 2021). These studies use finite element analysis (FEA) to analyse the surface and vibration to optimise the structural design or analyse the stress/load of the engine test stand (Adkine et al., 2017; Mohammadi et al., 2024; Santhosh Kumar et al., 2022).

The studies provide low-cost, efficient options for performing engine performance analysis such as designing a small engine dynamometer using a hydraulic system with a pressure regulator and pressure gauge, measuring power and torque to develop low-cost engine test stands (Alfaiz et al., 2014) and also serve educational or vocational training purposes (Oliveira et al., 2022), or testing with different fuels (Izvorean & Stoica, 2022; Tatarynow et al., 2022).

Through an overview of research projects in the world, it is found that in order to meet the general development trend of the times, especially the localisation of auto parts, mastering the technological capabilities to move towards self-designing and manufacturing diesel engines in Vietnam, it is necessary to have many research projects on engines such as reducing energy consumption, reducing exhaust toxicity, ensuring smooth and unified operation of the equipment without causing noise, improving engine efficiency, especially increasing the Turbocharger efficiency of the engine, to serve the above research well, it is necessary to have experiments in the laboratory similar to the actual operating conditions of the engine. The design of the engine mounting test stand in the experiment is like the engine mounted on the vehicle, the test stand is designed and manufactured with the engine mounted horizontally, like the engine used on front-wheel drive vehicles and some 4-wheel drive vehicles. The test stand is designed to mount a variety of engines and is easily connected to other auxiliary structures. It has a structure that can not only mount a single test engine but also mount many different types of engines with a engine support structure that can move forward along the X, Y, Z axes and rotate around the Z axis, so it is very flexible and easy to mount and align the engine connected to the MP100S system to perform different testing objectives. The engine mount, at the same time, the frame structure must ensure technical requirements for manufacturing and assembly, ensuring durability and anti-vibration ability under the conditions of mounting the engine, operating and testing without load and with load.

Although various engine test stands have been proposed in previous studies, most of them are limited to a fixed configuration and cannot be adjusted in multiple degrees of freedom. None of the published designs provide direct compatibility with the MP100S dynamometer system, nor do they combine structural design, FEA validation, vibration analysis, fabrication, and experimental evaluation in a unified workflow. These limitations form the research gap addressed in this study.

This study focusses on the design, structural evaluation, and experimental implementation of an engine mounting test stand integrated with the MP100S dynamometer system, with the primary aim of providing a practical and flexible laboratory solution rather than a comprehensive performance comparison with commercial engine test benches.

MATERIALS AND METHODS

Approach

Overview of diesel engines, MP100S dynamometer system, related domestic and foreign research projects. Proposing the schematic diagramme of the test stand, analysing and determining a reasonable manufacturing plan, building a 3D model of the test stand, applying finite element analysis (FEA) to evaluate the durability and vibration characteristics, establishing the technological process of processing the parts, selecting materials, processing methods and reasonable processing technological parameters for processing the parts. Manufacture and assemble the complete test stand by connecting the test stand with the MP100S system.

Research Method

Theoretical research method: using the method of collecting documents at the same time as the method of synthesising and processing documents, studying an overview of related domestic and foreign research works, proposing a schematic diagramme of the test stand, analysing and determining a reasonable manufacturing plan, building a 3D model of the test stand, applying the finite element analysis (FEA) to optimise the design.

Experimental Research Method

Manufacturing and assembling a complete test stand connecting multiple engines with the MP100S system, determining the research objective function, building an experimental diagramme, determining a set of experimental parameters, conducting experiments to determine the values corresponding to the experimental modes. Based on the results achieved, comparing them with the measured values from the experiment, it is possible to determine several factors affecting the objective function.

Design and Manufacturing Plan of the Test Stand

From the overview of research topics, it can be seen that there are a number of research projects related to engine test stands, most of the test stands are researched to serve the purpose of testing and applying the achieved results to experimentally verify the results of the achieved goals, however, these projects are all theoretical studies, so the task of the article is to fully research the issues of: test stand, MP100S system and the achieved linkage results to meet the technical requirements and ensure good practical application of the test stand. The test stand is designed according to the open power flow principle: based on the theoretical research on open power flow, the proposed operating principle of the test stand must be flexible to mount many different types of engines, applying design software to draw the principle diagramme and structure of the test stand, designing and assembling 3D models, simulating durability testing and analysing the vibration of the test stand, manufacturing, assembling the complete test stand, checking and testing.

Analysis and Selection of Reasonable Manufacturing Options

The design idea is to design the structural diagramme of the engine test stand from the schematic diagramme of the manufacturing options, analyse the advantages and disadvantages of each option to select a reasonable option, then apply Autodesk inventor software to design 3D, assemble the complete test stand, conduct simulation and durability analysis in Ansys, manufacture, install and test

Select Materials and Manufacturing Methods of the Test Stand

The available equipment and main components of the test stand were identified and selected, including the engine, MP100S dynamometer system, cardan coupling, cooling tank, and fuel tank. The engine support frame works under heavy load conditions, so it is necessary to choose the connecting parts as square steel tubing 75 × 75 × 3 mm made of ASTM A36 steel with the following parameters: Tensile strength: 400-550 MPa; Elongation ≥ 20-23%; Hardness: 119-162 HB; Elastic modulus: 200 GPa; Poisson's ratio: 0.26. According to ASTM A36 standard, the chemical composition of steel usually includes the following elements (percentage by mass) shown in Table 1. The test stand consists of many different parts connected, so the main manufacturing method chosen is welding to connect the parts, combined with bolts and nuts.

Table 1
Chemical composition (percentage) of ASTM A36 standard steel

Steel Grade	C	Si	Mn	P	S	Cu
A36 Steel	0.16	0.22	0.49	0.16	0.08	0.01

Note. C = Carbon; Si = Silicon; Mn = Manganese; P = Phosphorus; S = Sulfur; Cu = Copper

The test stand consists of many different parts connected, so the main manufacturing method chosen is welding to connect the parts, combined with bolts and nuts.

RESULTS AND DISCUSSION

Schematic Diagramme of Engine Mounting Test Stand

Figure 1 shows the schematic layout of the engine mounting test stand. The system consists of the engine (1), the MP100S dynamometer system (2), the cardan coupling (3), the engine support frame (4), the cooling tank (5), the fuel tank (6), and the brake controller (7).

The multi-engine mounting test stand is designed, manufactured and tested according to the open power flow principle, characterised by the input and output power not being connected in a closed loop with the main components including the engine (1), the MP100S unit (2) and the cardan coupling (3). In which, the engine is used for driving, the cardan coupling connects the engine to the MP100S unit, the support frame (4) is used to support the engine, the cooling tank (5) is used to cool the engine, the fuel tank (6) supplies fuel when the engine is running, MP100S dynamometer system manufactured by Weinlich of Germany includes the following main components: the control unit includes the MP computer inside and the control panel; the brake and measuring unit is directly connected to the engine; the brake controller (7) to change the braking force to create load and torque acting on the engine and the support frame to perform the test conditions and requirements.

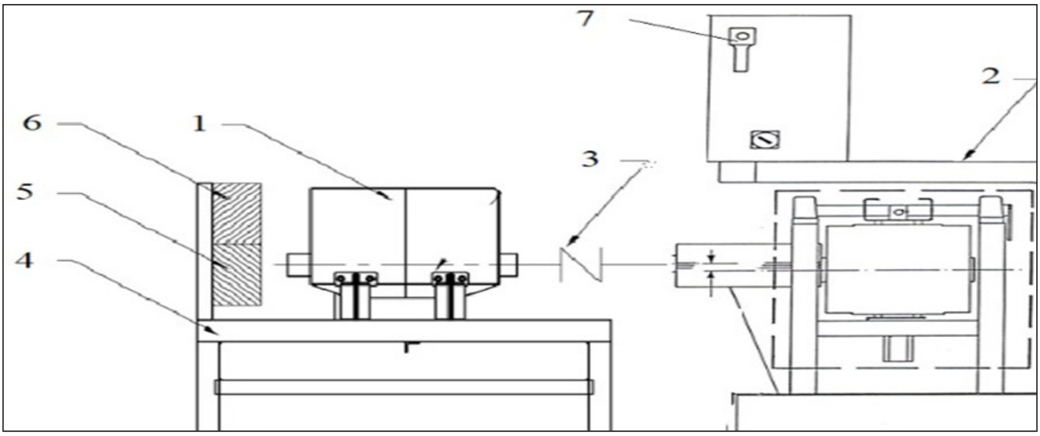

Figure 1. The schematic layout of the engine mounting test stand

Design of the Engine Mounting Test Stand

Figure 2 illustrates the four design alternatives considered for the engine mounting test stand (Alternatives 1-4). Design structural diagrammes of manufacturing options, analyse advantages and disadvantages of each option to choose the appropriate option.

Based on the above design concepts, the four alternatives were compared to identify the most suitable configuration, as shown in Table 2.

Table 2
Comparison of the four design alternatives

Criterion	Alternative 1	Alternative 2	Alternative 3	Alternative 4 (Selected)
Structural rigidity	High	High	Medium	High
Adjustability in X–Y–Z	No	Yes	Yes	Yes
Rotation around Z-axis	No	Yes	Yes	Yes
Safety under load	Medium	Good	Low	Very good
Engine compatibility	Limited	Wide	Limited	Very wide
Ease of fabrication	Medium	Medium	Low	Easy
Shaft alignment accuracy	Poor	Good	Poor	Very good

Note. Alternative 4 offers the most balanced combination of rigidity, adjustability, safety, and compatibility

Alternative 1. Four-point Engine Mounting

The engine is mounted at 4 points at 4 mounting positions at 2 ends of the engine, in which each side is mounted at 2 symmetrical positions across the longitudinal cross-section of the engine. The engine mounting frame consists of a 4-bar support structure, the upper end is welded to the L-shaped engine mounting base to mount to the engine with bolts and nuts, the lower end is fixed to the main frame by welding. The main frame is designed with a rectangular structure; the 4 legs of the main frame are connected to the base by 4 anti-vibration mounts to reduce shock and vibration. In this design, the advantage of the simple structure makes manufacturing easy, the engine is mounted at 4 points, so it has high rigidity. The engine is rigidly mounted to the support, the frame structure and the base must be designed to fit the engine, so it is only possible to permanently connect the engine to the structure with almost minimal deflection, so there is inconvenience in the displacement of the engine mounting system with the support and the ability to withstand tolerance when the test stand is put into operation. With this design, the engine installation also does not allow any adjustment in the vertical (X direction), horizontal (Y direction), and height (Z direction) when such adjustment is very necessary. Therefore, this connection theoretically makes the engine support frame, and the main frame form a unified block, so it only allows the engine to be connected to the MP100S system by moving the entire test stand, so it is very difficult to align the test stand after mounting to ensure the assembly requirements and safety during operation.

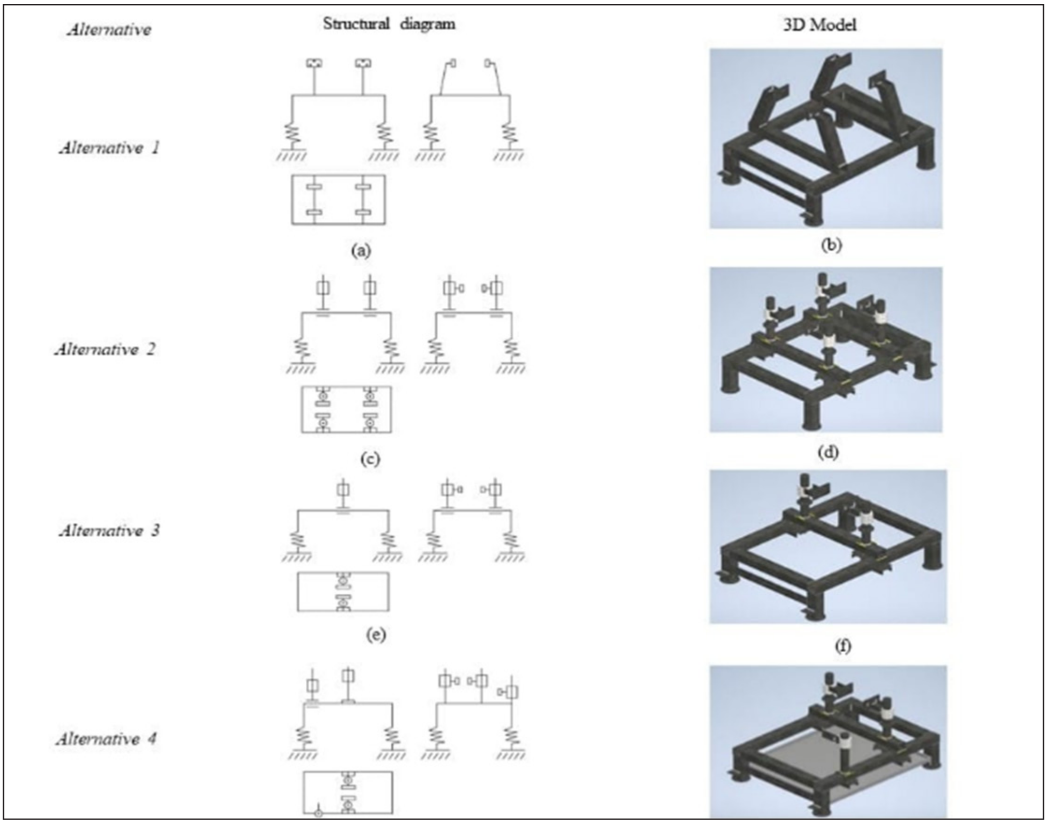

Figure 2. Design alternatives for the engine mounting test stand: (a) Structural diagramme of alternative 1, (b) 3D model of alternative 1, (c) Structural diagramme of alternative 2, (d) 3D model of alternative 2, (e) Structural diagramme of alternative 3, (f) 3D model of alternative 3, (g) Structural diagramme of alternative 4, (h) 3D model of alternative 4

Alternative 2. Adjustable Engine Mounting System

The main frame of the test stand is designed with a rectangular frame structure, the 4 legs of the main frame are connected to the ground by 4 anti-vibration mounts to reduce shock and vibration; The engine support consists of 2 rectangular cross-section bars placed on the upper surface of the main frame, this cross-section bar acts as a horizontal sliding support bar, the cross-section bar has the bottom surface at both ends welded to 02 U-shaped basses to move along the frame (X direction) on the main support bar, each horizontal sliding bar contains 2 sets of round shaft supports + shaft joints, thus 2 horizontal support bars contain 4 sets of round shaft supports + shaft joints, in which the round shaft supports + shaft joints to move up and down (Z direction) and rotate around the centre of the round shaft to the appropriate position are fixed with hexagon socket head locking screws, 04 shaft joints are welded to 04 L-shaped engine mounting basses to mount with the engine with bolts and nuts mounted at 4 points at 4 mounting positions at 2 ends of the engine, in which each side is mounted in 2 symmetrical positions across the longitudinal cross-section plane of the engine, the lower end of the round shaft support is 04 points at 04 mounting positions at 02 ends of the engine, in which each side is mounted in 2 symmetrical positions across the longitudinal cross-section plane of the engine, the lower end of the round shaft support is welded to 04 L-shaped engine mounting bases to mount with the engine. U-shaped bass to connect with the rectangular crossbar on the top of the main frame with bolts + nuts to perform linear movement in the horizontal direction (Y direction). In this design, the advantage is that the engine is mounted at 4 points so it has high rigidity, the engine is rigidly mounted to the engine support mechanism, in which the engine support mechanism can perform translational movement in 3 directions X, Y, Z and rotate around the Z axis, so with this design, the engine will be easily connected to the MP100S performance measuring device by adjusting the dynamic support mechanism vertically (X direction), horizontally (Y direction), and height (Z direction) to the appropriate position, then the fixed connection between the mechanisms and the main frame with bolts + nuts makes it very easy to adjust and mount, expanding the technological capabilities of the fixture, the fixture can mount a variety of different types of engines to ensure assembly requirements and safety during operation. Besides the above advantages, there are also some notes that the mounting structure is too large, so the working space and mounting are limited. The 4 rigid mounting points on the engine create a very high rigidity, so to make the 2 ends of the engine even, the mounting design must be precise. In case the engine rotates around the Y axis, it will be difficult to adjust. However, because the engine is connected to the MP100S by a cardan coupling, the above problem is not significant.

Alternative 3. Centralised Two-point Engine Mounting System

The test stand is designed in terms of main frame structure and engine support mechanism with the same moving principle as option 2, but the engine support mechanism has only

1 rectangular cross-section bar placed on the upper surface of the main frame containing 2 round shaft supports + shaft joints, 02 shaft joints are welded to 02 L-shaped engine mounting basses to mount to the engine with bolts and mounting nuts at 2 points at 2 mounting positions in the middle of the engine. This design has the advantage of overcoming the disadvantages of options 1 and 2. The engine is mounted at 2 points in the middle of the engine, so it bears the entire weight of the engine, making it not very rigid. The engine is connected to the MP100S performance measuring device via a cardan coupling, bearing the load of the joint and the moment when the engine is operating, especially in the case of a load test using the load-inducing and braking mechanism on the MP100S performance measuring device, so it does not ensure safety during operation.

Alternative 4. Three-point Engine Mounting System

The test stand is designed exactly the same as option 3 but has an additional round shaft support + shaft coupling with the lower end of the round shaft support welded with a U-shaped bass to connect to the main frame, the shaft coupling is welded to a fixed bass engine mount with an expansion gap to support the flywheel and the cardan coupling that drives the engine and the MP100S performance measuring device at the engine head. In this design, the engine is mounted at 3 points, including 2 main points in the middle of the engine, so it bears the entire weight of the engine and 1 mounting point at the moving connector of the engine, so it has high rigidity, ensuring safety when operating the test without load and with load on the MP100S performance measuring device. Through analysing the advantages and disadvantages of the 4 design options above, option 04 is the most reasonable, with a simple structure, easy to manufacture, easy to adjust and assemble. The test stand can be assembled with many different types of engines, so option 04 was chosen for design and manufacture.

Complete Assembly of Test Stand and Durability Test Simulation in Inventor Software

Design details and assemble the complete test stand in Autodesk Inventor 3D design software, the results are the scientific basis for the simulation process of analysing and testing the test stand's durability and vibration as shown in Figure 3. Stress analysis in Autodesk Inventor 2025 evaluated structural integrity under a 500 kg engine weight and 100 N·m torque as shown in Figure 4.

Boundary Conditions and Applied Loads

The frame was fixed at the four mounting legs. A distributed load equivalent to the 500 kg engine mass was applied to the mounting brackets, and a torque of 100 N·m was applied through the cardan coupling to represent typical operating conditions. A tetrahedral mesh with refinement in high-stress regions was used. The maximum von-Mises stress obtained (91.79 MPa) remained far below the 250 MPa yield strength of A36 steel.

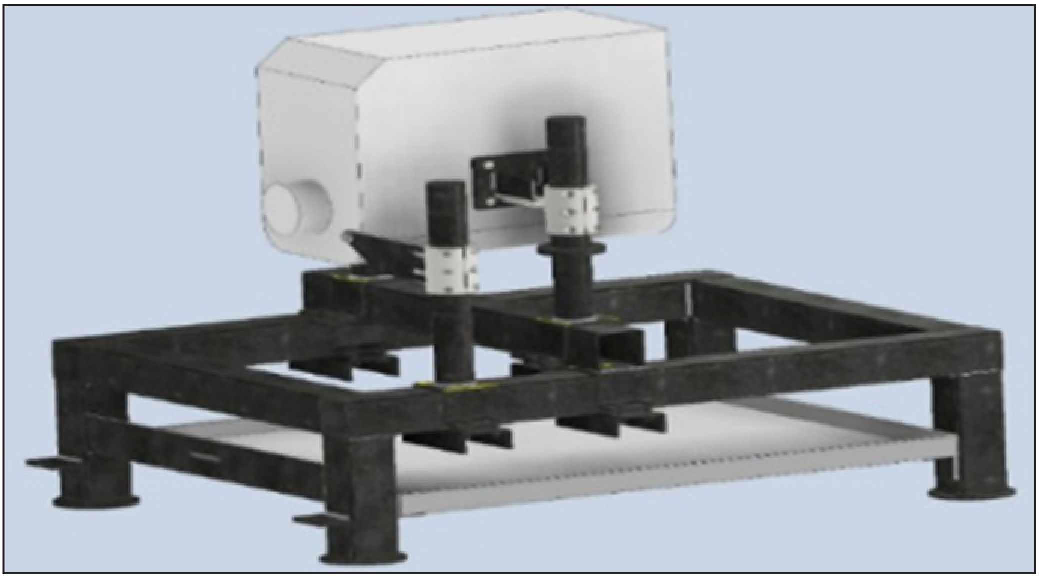

Figure 3. Complete assembly of the design test stand

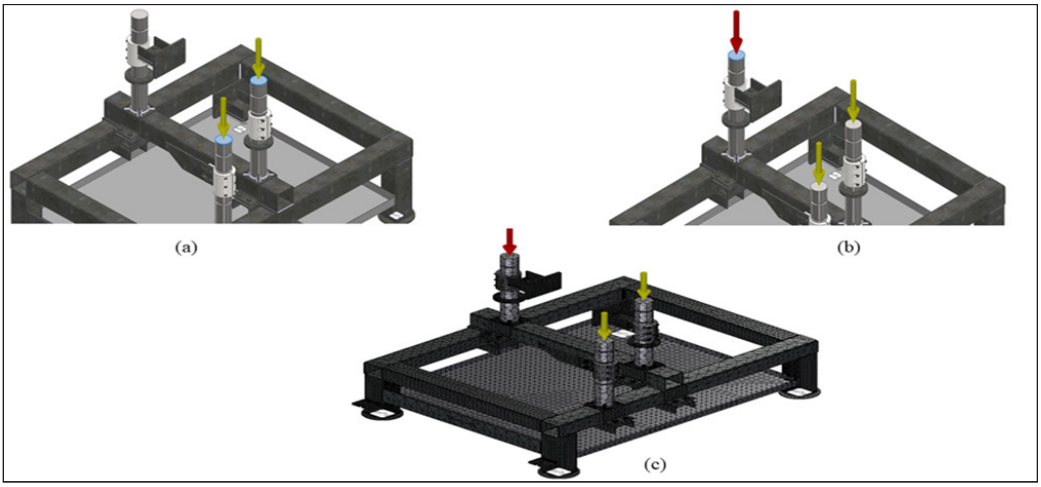

Figure 4. Forces and mesh for stress analysis: (a) F1, F2 (yellow), (b) F3 (red), (c) meshing

Mesh Sensitivity

Several mesh densities were tested. When the element size was refined from 8 mm to 4 mm, the variation in maximum stress decreased from 4.2% to 2.7%, confirming mesh convergence.

Torque Selection

The applied torque of 100 N·m corresponds to the typical mid-load operating range of the Toyota 3C engine as documented in the thesis, ensuring that the simulated loading condition is realistic.This loading condition was selected as a conservative representation of typical mid-load operation to ensure structural safety under normal use as well as slightly unfavourable working conditions.

Material Selection

A36 steel was chosen for its good weldability, wide availability, and adequate yield strength for medium-duty structural applications. This material is suitable for a welded steel frame such as the proposed test stand.

Durability Test of Engine Support Frame

Stress analysis results showed a maximum von Mises stress of 91.79 MPa, well below the A36 steel yield strength of 250 MPa, ensuring safe operation (Figure 5). Maximum displacement was 0.07026 mm, with 0.06657 mm in the Z-axis, indicating high stiffness (Figure 5). The maximum rotation angle of 0.030 radians was within acceptable limits, though flexible couplings could enhance precision in high-vibration environments.

Calculate Input Parameters

The force exerted by the engine acts on the frame due to gravity

$$F_{ĐC} = \frac{(M_{ĐC} \cdot g)}{3} = \frac{210.10}{3} = 700 \ (N) \quad [1]$$

(Divided into three sections because the engine is mounted in three different positions relative to the frame system)
Torque is determined based on the engine parameters

$$M_{Obr} = 216 \text{ (N·m)} \quad [2]$$

Force Exerted:

$$F_{M\,obrY} = \frac{M_{Obr}.x_{max}}{\sum x_i^2} = \frac{216000.360}{(360^2 + 250^2 + 260^2)} = 299(N) \quad [3]$$

Moment of Inertia

Moment of inertia of the flywheel:

$$I_{W1} = \frac{1}{2}.m.(R_x{}^2 - R_w{}^2) = \frac{1}{2}.12.\left(\left(\frac{360}{2}\right)^2 - \left(\frac{86}{2}\right)^2\right) = 183306(kgmm^2) \quad [4]$$

Moment of inertia of steel bushing:

$$I_{W1} = \frac{1}{2}.m.(R_x{}^2 - R_w{}^2) = \frac{1}{2}.0,3.\left(\left(\frac{360}{2}\right)^2 - \left(\frac{86}{2}\right)^2\right) = 694(kgmm^2) \quad [5]$$

Total moment of inertia of flywheel and steel bushing:

$$I_2 = I_W 1 + I_W 2 = 183360 + 694 = 184054(kgm^2) \quad [6]$$

Angular acceleration without the additional flywheel:

$$\varepsilon_1 = 34,90(Rad / s^2) \quad [7]$$

Angular acceleration with the additional flywheel

$$\varepsilon_2 = 23,23(Rad / s^2) \quad [8]$$

Moment of inertia of the crankshaft and piston system in an internal combustion engine:

$$I_1 = (\frac{I_2.\varepsilon_1}{\varepsilon_1.\varepsilon_2}) = \frac{0,184054.23,23}{(34,9 - 23,23)} = 0,3663(kgm^2) \quad [9]$$

Torque of the engine with an additional flywheel:

$$M_T = \left(I_1 + I_2\ \right).\varepsilon_2 = \left(0,3663 + 0,184054\right).23,23 = 12,7\ \left(Nm\right) \quad [10]$$

The force exerted by the load of the crankshaft–piston system on the frame system:

$$F_{(M_T Y)} = 12,7.\frac{360}{360^2 + 250^2 + 260^2} = 18(N) \quad [11]$$

The resultant force acting at a given fixed point:

$$F_{1,2} = F_{ĐC} - F_{MOrY} - F_{M_T Y} = \ 700 - 299 - 18 = 383\ \left(N\right) \quad [12]$$

$$F_3 = F_{ĐC} + F_{MOrY} + F_{M_T\ Y}\ F_3 = F_{ĐC} + F_{MOrY} + F_{M_T\ Y}$$
$$= 700 + 299 + 18 = 1017\ (N) \quad [13]$$

where F denotes the gravitational force acting on the frame (N), m is the engine mass (kg), g represents gravitational acceleration (9.81 m/s²), Mx is the engine torque (N·m), I is the moment of inertia (kg·m²), and α is the angular acceleration (rad/s²).

The von Mises stress distribution of A36 steel reaches a maximum value of 91.79 MPa, which is significantly lower than its yield strength of 250 MPa. This ensures that the structure operates safely within the elastic region, preventing plastic deformation.

The maximum displacement of the frame members in any direction is 0.07026 mm, while the maximum displacement along the Z-axis (vertical direction) is 0.06657 mm. These values indicate that the frame exhibits high stiffness and meets load-bearing requirements under normal operating conditions.

The maximum rotation angle of the structure is 0.030 radians, which may introduce minor misalignments. However, this deviation remains within acceptable limits.

Although this small deviation does not significantly affect structural performance, if higher precision is required or the structure operates in a high-vibration environment, the use of flexible couplings or damping solutions should be considered to enhance stability and minimise eccentricity during operation.

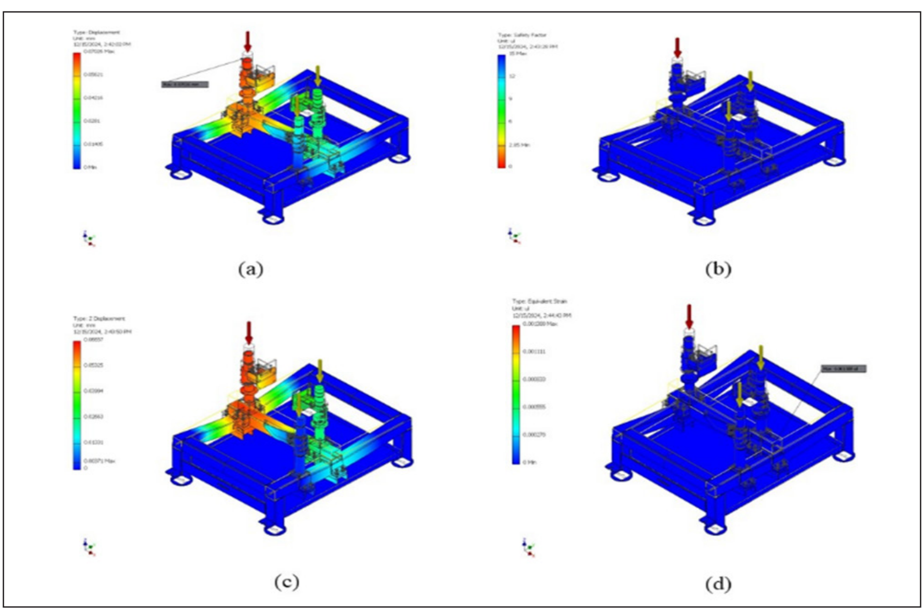

Figure 5. Simulated stress and displacement: (a) total displacement, (b) safety factor, (c) Z-direction displacement, (d) total deformation

Test Stand Vibration Analysis

To conduct a natural frequency analysis for the test stand, follow these steps:

1. Create a natural frequency analysis setup in ANSYS Workbench.
2. Import the designed test stand into the software.
3. Assign material properties to all test stand components.
4. Remove unnecessary details to optimise the simulation.
5. Define contact interactions between components
6. Apply boundary conditions and constraints.
7. Configure simulation parameters.
8. Run the simulation and analyse results.

Vibration analysis in ANSYS Workbench identified 20 natural frequencies, with the lowest at 16.556 Hz, ensuring stability outside typical engine operating ranges (Table 3). The Harmonic Response module showed a peak displacement of 0.2 mm at 38.8 Hz, with minimal impact on measurement accuracy (Figure 6).

Table 3
Natural frequencies of the system

Mode	Frequency [Hz]
1	16.556
2	28.846
3	38.858
4	48.619
5	70.403
6	76.728
7	97.242
8	145.87
9	150.28
10	180.33
11	214.85
12	240.49
13	288.53
14	312.39
15	324.68
16	341.76
17	390.08
18	416.84
19	436.03
20	437.82

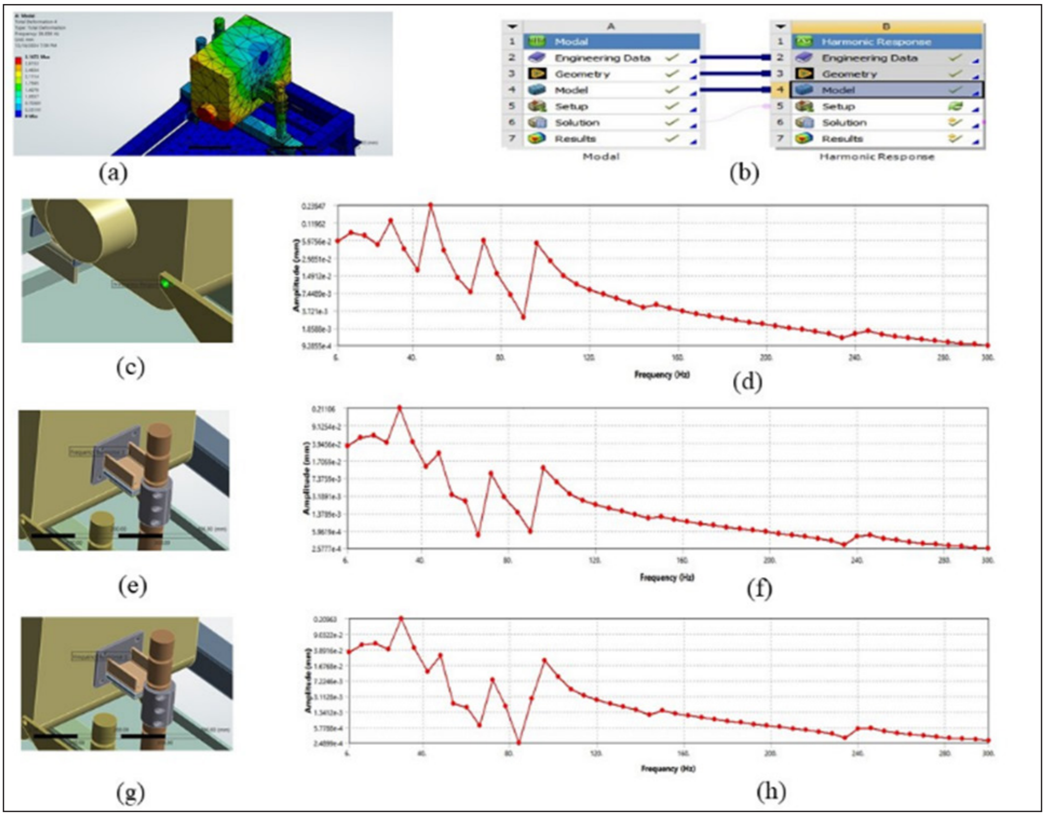

Figure 6. Vibration analysis: (a) ANSYS results, (b) Harmonic response setup, (c) analysis surfaces at Locations 1, (d) total displacement at Locations 1, (e) analysis surfaces at locations 2, (f) total displacement at Locations 2 (g) analysis surfaces at Locations 3, (h) total displacement at Locations 3

Mode Shapes

The first mode exhibited lateral bending of the upper frame, the second mode involved vertical flexing of the mounting platform, and the third mode showed mild torsional deformation. These shapes are typical for lightweight welded steel structures.

Resonance Considerations

The first natural frequency of the test stand was identified as 16.56 Hz (Table 3). This value is slightly higher than the dominant excitation frequency range of the Toyota 3C diesel engine during idle and low-speed operation, which typically lies between 13 and 15 Hz. In practical operation, the test stand is supported by four industrial anti-vibration mounts commonly used for machine tools such as lathes, which are designed to provide effective damping under both static and dynamic loading conditions. In addition, the cardan coupling used to connect the engine to the MP100S unit introduces a certain degree of torsional flexibility and misalignment tolerance, helping to reduce the direct transmission of dynamic forces. The combined effect of these design features contributes to stable operation of the test stand, and resonance is therefore unlikely to occur under normal testing conditions.

Next, to evaluate the influence of these vibrations on the test stand, the analysis results will be used to examine the displacement of critical components in the test stand using the Harmonic Response module.

The Harmonic Response module is configured based on the data obtained from the natural frequency analysis results.

The total displacement amplitude at the specified positions varies with the frequency of the external force, reaching its maximum value at 38.8 Hz. The peak total displacement is approximately 0.2 mm, which is relatively low and has minimal impact on the experimental measurement results

Manufacturing and Complete Installation of The Test Stand Manufacturing and Installation Requirements

The test stand was manufactured using 75 × 75 × 3 mm A36 steel tubing for the main frame and Ø55 mm round steel for the support shafts (Figure 7). Anti-vibration mounts minimised vibrations, and eccentric bushings with adjustment screws ensured precise positioning. The assembly met requirements for secure connection, concentric alignment, and sufficient cardan coupling insertion (minimum 20 mm). Calibration of the MP100S load-inducing mechanism achieved a standard torque of 250 N·m (Figure 7).

After manufacturing, the engine mounting test stand is connected to the MP100S system and must meet the following conditions:

1. The connection between the test stand and the engine support must be secure.
2. The jack-up protection cover must be firmly installed.
3. The engine and brake assembly must be concentric to ensure smooth operation.
4. The exhaust pipe must be securely installed and airtight.
5. The cardan coupling installation into the brake assembly must ensure sufficient insertion depth (minimum 20 mm) and proper alignment with engagement marks.

The installation position of the entire test stand must allow for a reasonable working space, facilitating ease of experimentation when adjusting engine speed (rpm), loads, and operational conditions.

Complete Assembly of the Test Stand and Calibration

The fabricated test stand has been fully assembled, as shown in Figure 7.

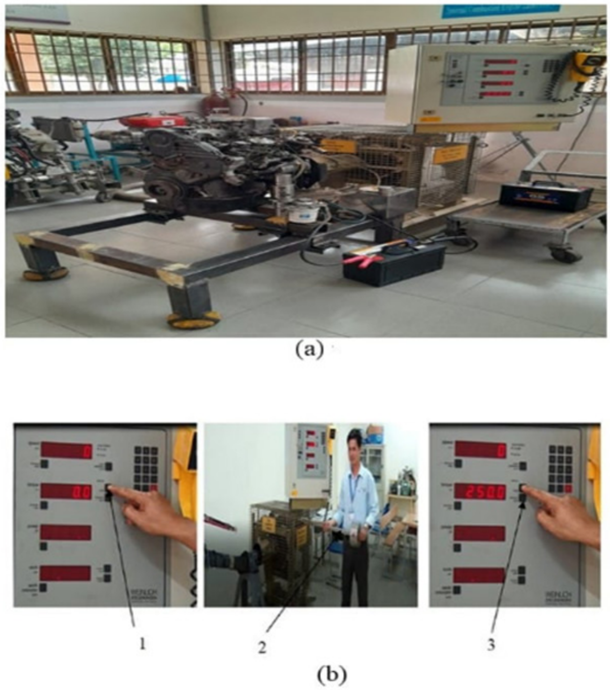

Figure 7. Fabricated test stand and calibration: (a) Fabricated engine test stand, (b) Torque measurement scale

Torque Caliper in the Load-inducing Mechanism

To calibrate the MP100S load-inducing mechanism, follow these steps: Turn on the MP100S load-inducing mechanism and press 0 N·m (Step 1). Insert the calibration tool (Step 2). Select Calibration Value to obtain the standard result of 250 N·m. The standard caliper has a mass of 25 kg, a lever arm length of 1 m, and a resulting torque of 250 N·m, as illustrated in Figure 7.

Experiment

Purpose of the Experiment

The experiment verified the stable connection between the test stand and the MP100S system, measuring engine speed (n, 1000-2400 rpm), torque (Mx), and power (P) (Figure 8).

Test Parameters

Predetermined parameters: Engine speed, n = 1000 to 2400 rpm
Parameters to be measured: Torque, Mx (N·m), engine power, P (kW)

Experimental Setup

The experimental model, as illustrated in Figure 8 (a), used engine speed, n (rpm), as the input parameter, with test modes ranging from 1000 to 2400 rpm. The two output parameters measured were the engine's useful torque, Mx (N·m), and useful power, P (kW). The test stand was fully assembled, and the MP100S dynamometer system was calibrated prior to testing.

Calibration Procedure

Before each test, the MP100S dynamometer was calibrated under no-load conditions to eliminate zero-offset errors, following the manufacturer's recommended procedure

Test Execution

Before operating the engine power tester for the first time, carefully read all instructions for use. Conduct a pre-operation check and ensure compliance with safety principles when using the MP100S device. Pay special attention to preventing the MP100S from exceeding the speed limit specified on the protective cage. Additionally, monitor the load table on the engine tester. Measure the engine power and torque, then record the data using DiaW 1.3 software.

Experimental Results

After fully assembling the test stand, the MP100S performance measuring system was calibrated. The engine was tested under experimental conditions with engine speeds (n) ranging from 1000 to 2400 rpm. The test results determined the useful torque (Mx, N·m) and useful power (P, kW), as shown in Table 4. Additionally, the experimental data were used to generate the corresponding graphs. The power vs. engine speed graph (Figure 8 (b)) indicates that the maximum engine power, Pmax = 11.8 kW, occurs at a speed of 1900 rpm. The torque vs. engine speed graph (Figure 8 (c)) shows that the maximum torque, Mxmax = 66 N·m, is achieved at 1000 rpm, which allows for rapid acceleration, improved heavy-load handling, and fuel efficiency. The power vs. torque graph (Figure 8 (d)) illustrates that maximum power is sustained over a wide range of 1200-2000 rpm, contributing to extended load capacity and enhanced vehicle acceleration. Tests at engine speeds of 1000-2400 rpm yielded a maximum power of 11.8 kW at 1900 rpm and a maximum torque of 66 N·m at 1000 rpm (Table 4; Figure 8). These results align with findings from similar test stands, confirming the system's reliability.

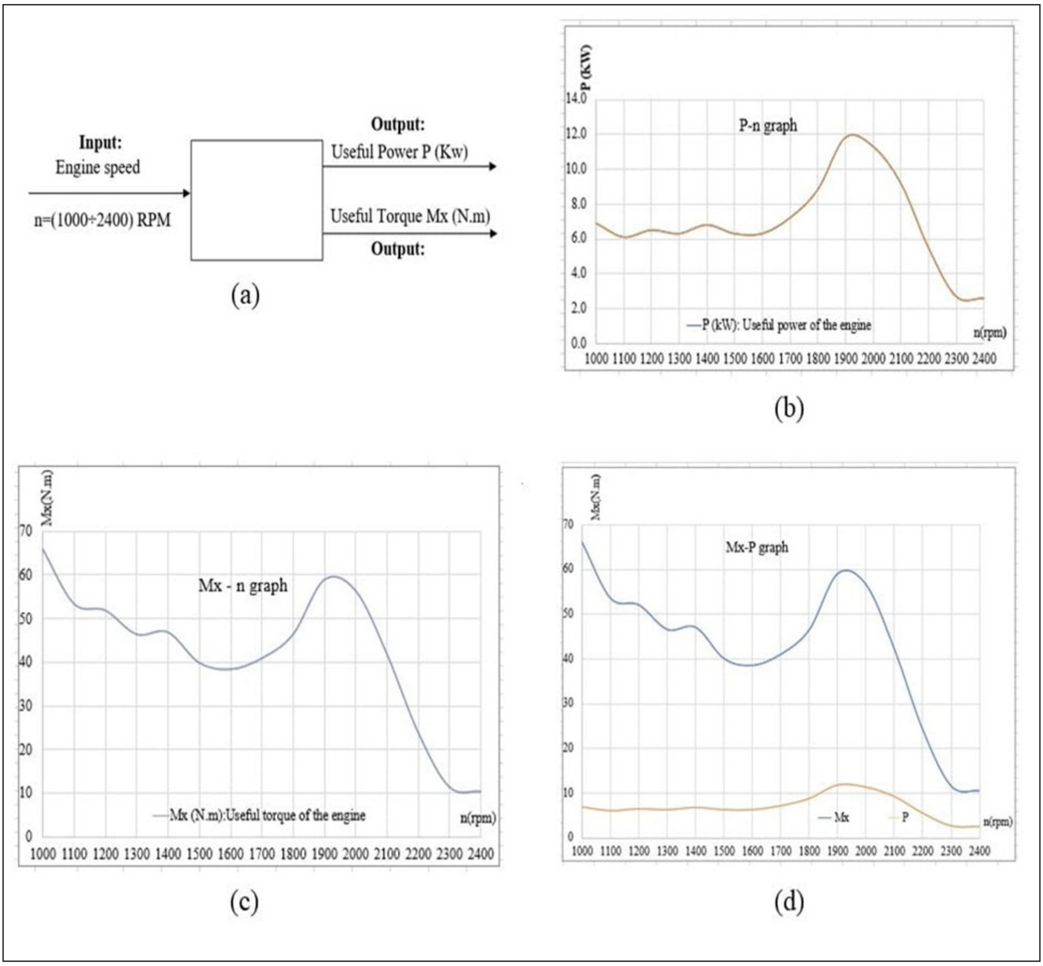

Figure 8. Experimental setup and performance results: (a) Test stand model with input (n = 1000-2400 rpm) and output (P, Mx) via MP100S, (b) Power vs. speed graph with max 11.8 kW at 1900 rpm, (c) Torque vs. speed graph with max 66 N·m at 1000 rpm, (d) Power vs. torque graph (0-11.8 kW, 0-66 N·m)

Table 4
Measured torque (Mx) and power (P) values at engine speeds (n)

n (rpm)	Mx (N·m)	P (kW)
1000	66	6.9
1100	54	6.1
1200	52	6.5
1300	47	6.3
1400	47	6.8
1500	40	6.3
1600	39	6.3

Table 4 (*continued)*

n (rpm)	Mx (N·m)	P (kW)
1700	41	7.2
1800	47	8.8
1900	59	11.8
2000	57	11.3
2100	42	9.2
2200	24	5.5
2300	12	2.7
2400	11	2.6

Measurement Repeatability and Instrument Accuracy

The torque and power values in Table 4 were recorded directly from the MP100S dynamometer system. According to the manufacturer, the MP100S system provides a typical measurement accuracy of ±2%. Although a single measurement was taken at each operating point, this instrument accuracy ensures that the recorded torque and power values remain within the acceptable tolerance range for engine performance evaluation.

It should be noted that the primary purpose of this experiment was to confirm the operational stability of the test stand and its ability to reliably interface with the MP100S measurement system, rather than to conduct a detailed statistical characterisation of engine performance. For this reason, single-point measurements at each operating condition, combined with the certified accuracy of the MP100S system, are considered adequate for the scope of this validation study.

Brake Power Calculation

Brake power was calculated using the relationship:

$$P = \frac{2\pi nM}{60} \qquad [14]$$

where n is the engine speed (rpm) and Mx is the torque (N·m).

Engine Specification

The experiment used a Toyota 3C diesel engine with a rated power of 65-67 kW at 4000 rpm and a displacement of 2.184 liters. The torque and power curves obtained from testing followed the same trend as the manufacturer's specifications, confirming the accuracy of the setup.

Alignment Advantage

Alternative 4 features a symmetric layout that makes it easier to align the engine flywheel with the MP100S shaft. The adjustable bolts allow fine correction of alignment, which helps reduce vibration and transmission losses.

Operational Observation

During testing, the stand ran smoothly with low vibration. The anti-vibration mounts reduced noise and vibration, while the adjustable bolts kept the engine and dynamometer shafts properly aligned throughout the experiment.

Analysis of the Test Results

Design and Manufacturing of a Versatile Engine Test Stand

A test stand has been designed and manufactured to accommodate various engine types and integrate with the MP100S dynamometer system. The test stand ensures proper assembly, operational safety, and the ability to conduct performance tests. It allows measurement of engine speed (n) in rpm, torque (Mx) in N·m, and power (P) in kW across different operating modes (Table 4). Additionally, the data collected enables the generation of power vs. engine speed (Figure 8 (b)) torque vs. engine speed (Figure 8 (c)) and power vs. torque graphs (Figure 8 (d)). Maximum power at 1900 rpm and torque at 1000 rpm indicate robust performance, comparable to results from modular test stands.

The research outcomes extend beyond standard engine testing, enabling various applications such as performance evaluation of turbocharger blades, exhaust pressure analysis, fuel consumption measurement for different operating conditions, emission reduction assessments, ensuring smooth, uniform, and noise-free operation, enhancing efficiency for research, teaching, and practical training.

This test stand provides a valuable tool for universities and technical colleges specialising in automotive technology, supporting both research and education. Furthermore, its application in industrial production contributes to domestic auto parts localisation, improving the industry's capacity for localised manufacturing.

CONCLUSION

The study presents the design and fabrication of a versatile engine test stand that can accommodate different engine types and operate in conjunction with the MP100S dynamometer system. The proposed configuration satisfies assembly requirements and ensures safe operation across various working conditions. The test stand allows reliable measurement of essential engine performance parameters such as rotational speed, torque, and output power. Experimental testing showed a maximum power of 11.8 kW at 1900 rpm and a peak torque of 66 N·m at 1000 rpm, demonstrating stable and consistent system performance. The developed setup can be applied to a wide range of engine testing and evaluation tasks, supporting studies on performance improvement, efficiency enhancement, emission reduction, as well as applications in research, teaching, and practical engineering activities

Beyond its technical performance, the developed test stand is intended to support laboratory-based education and applied research activities at Vinh Long University of Technology Education, particularly for engine testing experiments and powertrain-related courses.

The present study is limited to structural analysis and functional experimental testing; fatigue assessment and repeated experimental trials were not included and are considered as potential directions for future work.

ACKNOWLEDGEMENT

The author gratefully acknowledges the laboratory facilities provided by Vinh Long University of Technology Education for this research.

LIST OF ABBREVIATIONS

ANSYS	Analysis System
ASTM	American Society for Testing and Materials
CAD	Computer-aided Design
CNG-SI	Compressed Natural Gas Spark Ignition
FEA	Finite Element Analysis
MP100S	MP100S Dynamometer system
NO_x	Nitrogen Oxides
RPM	Revolutions per Minute
3D	Three-dimensional

REFERENCES

Adkine, A., Overikar, P., & Surwase, P. (2017). Modal analysis of engine supporting bracket using finite element analysis. *International Journal of Advanced Engineering Research and Science, 4*(3), 50-55. https://doi.org/10.22161/ijaers.4.3.9

Alfaiz, M. Z., Tahir, M. M., Abu Bakar, R., & Ali, M. S. (2014). New design of a low-cost small engine dynamometer for engine testing. *Applied Mechanics and Materials, 699*, 642-647. https://doi.org/10.4028/www.scientific.net/AMM.699.642

Altarazi, Y. S. M., Saadon, S., Yu, J., Gires, E., Ghafir, M. F. A., & Lucas, J. (2020). On-design operation and performance characteristic of custom engine. *Journal of Advanced Research in Fluid Mechanics and Thermal Sciences, 70*(1), 144-154. https://doi.org/10.37934/arfmts.70.1.144154

Calvo, J. A., Diaz, V., & San Román, J. L. (2006). Controlling the turbocharger whistling noise in diesel engines. *International Journal of Vehicle Noise and Vibration, 2*(1), 17-28. https://doi.org/10.1504/IJVNV.2006.008524

Chen, S., Ma, C., & Zhang, H. (2022). Engine performance improvements through turbocharger matching and turbine design. *Energy Science & Engineering, 10*(9), 3384-3396. https://doi.org/10.1002/ese3.1225

Crispi, M., Cervone, D., Arsie, I., Pianese, C., & Polverino, P. (2022). A methodology for the experimental validation at the engine test bed of fuel consumption and NOx emissions reduction in a HEV. *SAE Technical Paper, 2022-24-0006*. https://doi.org/10.4271/2022-24-0006

Derbiszewski, B., Woźniak, M., Józinkiewicz, D., & Zakrzewski, S. (2023). Research of dynamic phenomena in a model engine stand. *Open Engineering, 13*(1), Article 20220436. https://doi.org/10.1515/eng-2022-0436

Huang, J., Lin, L., Wang, Y., Qin, J., Roskilly, A. P., Li, L., Ouyang, T., & Yu, Y. (2011). Experimental study of the performance and emission characteristics of diesel engine using direct and indirect injection systems and different fuels. *Fuel Processing Technology, 92*(7), 1380-1386.https://doi.org/10.1016/j.fuproc.2011.03.001

Izvorean, S., & Stoica, V. (2022). Experimental test bench with diesel engine for the study of multi fuels usage. *IOP Conference Series: Materials Science and Engineering, 1220*(1), Article 012014. https://doi.org/10.1088/1757-899X/1220/1/012014

Lee, N., Lee, M., Kim, H., & Kim, J. (1998). Design of engine mount using finite element method and optimisation technique. *SAE Technical Paper, 980379*. https://doi.org/10.4271/980379

Liu, C., Cao, Y., Liu, Y., & Wenping, Z. (2019). Numerical and experimental analyses of intake silencer and its effects on turbocharger compressor performance. *Advances in Mechanical Engineering, 11*(3), 1-15. https://doi.org/10.1177/1687814019826677

Lloyd, A. C., & Cackette, T. A. (2001). Diesel engines: Environmental impact and control. *Journal of the Air & Waste Management Association, 51*(6), 809-847. https://doi.org/10.1080/10473289.2001.10464315

Mohammadi, M., Nazemosadat, S. M. R., & Afsari, A. (2024). Modelling and analysis of tractor diesel engine test stand structure using the finite element method. *Biomechanism and Bioenergy Research, 3*(2), 75-87. https://doi.org/10.22103/bbr.2024.24161.1090

Ni, S., Guo, Y., Lv, B., Wang, D., Li, W., & Shuai, Z. (2020). Analysis of torsional vibration effect on the diesel engine block. *Mechanics & Industry, 21*(5), Article 522. https://doi.org/10.1051/meca/2020065

Norouzi, A., Shahpouri, S., Gordon, D., & Winkler, A. (2022). Deep learning-based model predictive control for compression ignition engines. *Control Engineering Practice, 127*, Article 105299. https://doi.org/10.1016/j.conengprac.2022.105299

Oliveira, G. L., de Souza, C. M. A., Arcoverde, S. N. S., Venturin, J. C., Armando, E. J., & Donaire, L. O. (2022). Construction of low-cost benches to assist in teaching machine elements and small engine testing. *International Journal for Innovation Education and Research, 10*(12), 113-122. https://doi.org/10.31686/ijier.vol10.iss12.3911

Park, H. (2023). Structural design and numerical analysis of hoisting device of test bed for aircraft engine. *Applied Mechanics, 4*(2), 407-420. https://doi.org/10.3390/applmech4020023

Qi, Y., Liu, W., Liu, S., Wang, W., Peng, Y., & Wang, Z. (2023). A review on ammonia-hydrogen fueled internal combustion engines. *eTransportation, 18*, Article 100288. https://doi.org/10.1016/j.etran.2023.100288

Santhosh Kumar, H. V., Bharadwaj, K. S. P., Rohith, S., Mridhul, S., & Vishnu, T. (2022). Modal analysis of passive engine mount assembly using finite element analysis. *ARAI Journal of Mobility Technology, 2*(1), 158-167. https://doi.org/10.37285/ajmt.1.1.10

Shao, B. W. (2011). Optimum design of engine test bench based on finite element analysis. *Advanced Materials Research, 338*, 255-258. https://doi.org/10.4028/www.scientific.net/AMR.338.255

Singh, R. (2000). Dynamic design of automotive systems: Engine mounts and structural joints. *Sādhanā, 25*(3), 319-330. https://doi.org/10.1007/BF02703548

Subramaniam, H., Duraisamy, S., Raghavan, G., & Govindan, S. (2019). Design and development of a test rig for the performance evaluation of automotive exhaust thermoelectric generator. *AIP Advances, 9*(6), Article 065004. https://doi.org/10.1063/1.5093587

Tatarynow, D., Longwic, R., Sander, P., Zieliński, Ł., Trojgo, M., Lotko, W., & Lonkwic, P. (2022). Test stand for a motor vehicle powered by different fuels. *Applied Sciences, 12*(20), Article 10683. https://doi.org/10.3390/app122010683

Tomin, S., Keller, K., Wagner, U., Lott, P., Koch, T., & Deutschmann, O. (2024). Innovative engine test bench set-up for testing of exhaust gas aftertreatment and detailed gas species analysis for CNG-SI-operation. *Automotive and Engine Technology, 9*(2), 2-22. https://doi.org/10.1007/s41104-024-00140-8

Visan, N. A., Carlanescu, R., Niculescu, D. C., & Chiriac, R. (2022). Study on the cumulative effects of using a high-efficiency turbocharger and biodiesel B20 fuelling on marine diesel engines. *Journal of Marine Science and Engineering, 10*(10), Article 1403. https://doi.org/10.3390/jmse10101403

Wang, Y. M., Xu, K., & Zhang, Q. (2021). Modal analysis and analysis of motor support based on workbench test bench design of motor dynamic shock absorber. *Journal of Physics: Conference Series, 1986*(1), Article 012096. https://doi.org/10.1088/1742-6596/1986/1/012096

Yu, X., Zhu, L., Wang, Y., Filev, D., & Yao, X. (2021). Internal combustion engine calibration using optimisation algorithms. *Applied Energy, 305*, Article 117894. https://doi.org/10.1016/j.apenergy.2021.117894