International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 15 Issue 06 , June - 2026

Development of a MATLAB/Simulink Model with Graphical User Interface for Prediction of Engine Forces in a Single-Cylinder Four-Stroke Engine

Manav Matwankar, Om Pardeshi, Ankit Lande, Om Abnave
Department of Mechanical Engineering
AISSMS College of Engineering
Savitribai Phule Pune University
Pune, India

C. S. Dharankar
Department of Mechanical Engineering
AISSMS College of Engineering
Savitribai Phule Pune University Pune, India
(Project Guide)

Abstract — This paper describes the development of a MATLAB/Simulink model, supported by a custom graphical user interface (GUI), for estimating the principal forces and the crankshaft torque produced during the operation of a single-cylinder, four-stroke internal combustion engine. Following a Model-Based Design (MBD) workflow, the gas pressure force is obtained from the brake mean effective pressure, the reciprocating inertia force is derived from crank kinematics, and the crankshaft torque is taken from the manufacturer-rated engine output; these are combined with a longitudinal vehicle-dynamics block that accounts for gear ratio, drivetrain efficiency, rolling resistance and aerodynamic drag. A Yamaha FZ-X 150 motorcycle (149 cc, bore 57.3 mm, stroke 57.9 mm, compression ratio 9.6:1) served as the reference test vehicle, and selected geometric inputs were cross-checked through physical measurement on the machine itself. The computed mean gas pressure force is close to 2893 N, while the reciprocating inertia force rises from about 2401 N at 5500 rpm to 6429 N at 9000 rpm, consistent with the expected speed-squared growth of inertia loading. The App Designer-based GUI lets a user vary reciprocating mass, crank radius and reference torque, select a gear and a road gradient, and view the simulated 0-60 km/h time and top speed together with the underlying force values. The resulting tool offers a fast, low-cost route to early-stage force estimates that would otherwise require either hand calculation or dedicated bench testing.

Keywords — Engine force prediction; MATLAB/Simulink; Model-Based Design; graphical user interface; gas pressure force; reciprocating inertia force; crankshaft torque; vehicle dynamics simulation

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 15 Issue 06 , June - 2026

I. INTRODUCTION

Predicting engine forces like gas pressure, inertia, and crank torque is easily one of the most tedious parts of designing a powertrain. If you want to check bearing loads, flywheel sizes, or vibration, you have to run calculations for tons of different operating scenarios. Doing that by hand takes forever and it is incredibly easy to mess up the math. Model-Based Design (MBD) makes this whole process less painful. Instead of old-school methods, it relies on software blocks that link together. The best part is that you can mess with individual subsystems, test them on their own, and reuse the blocks later on. It speeds up the design work and cuts down on mistakes.

We focused on a basic four-stroke, single-cylinder petrol engine—the usual kind found in commuter bikes. Inside MATLAB/Simulink, we calculated the mean gas pressure, inertia, and crankshaft torque using the engine's rated power, brake mean effective pressure (BMEP), and crank kinematics. But just looking at raw internal forces isn't very helpful. To get data that makes sense for real-world driving, we threw the engine model into a longitudinal vehicle dynamics simulation. That way, we could link those internal forces directly to obvious things like vehicle speed and gear selection.

We also wanted a tool that didn't require digging through messy Simulink block diagrams. So, we used MATLAB App Designer to build a simple GUI. Now, you can just change the engine or vehicle specs on the screen and instantly see the results—like top speed, acceleration curves, and how long it takes to max out.

To make sure the model actually worked, we bench-marked it against a Yamaha FZ-X 150. The standard factory specs gave us the bore, stroke, compression ratio, power, and torque.

But for the finer details like the exact crank geometry and drivetrain setup, we went into the lab and measured the physical parts ourselves using a dial gauge and a hand tachometer. We had to get those real dimensions to make sure the simulation actually matched the behavior of a real engine.

II. LITERATURE REVIEW

This research can be categorized into three sections: Simulink modeling of the internal combustion (IC) engine, Simulink modeling of pneumatic piston-cylinder mechanisms, and the force and torque relations frequently discussed in kinematics and their studies.

Thompson and Yoon [1] advanced engine modeling by creating a one-dimensional gas dynamics model in MATLAB/Simulink. They constructed a gas engine model by employing gas engine components (e.g., pipes, restrictions, and boundary conditions) and connecting them in a block diagram as gas engine components would be assembled in a physical model. They showed that the mass flow characteristics of the gas engine model were comparable to those obtained using GT-Power, a popular gas engine simulation software. Although Thompson and Yoon's study mainly focused on the solution of unsteady gas flow equations and the mass flows through the components of an engine model, it also showed that Simulink is a good framework for building engine models. This study is an example of simplified gas dynamics, and in this study, the gas forces were estimated using the brake mean effective pressure (BMEP) approach. Research on pneumatic systems has also provided valuable insights. Szakács [3] created a Simulink model of a double acting pneumatic cylinder. This model includes pneumatic supply, pressure regulation, and control elements. This model was validated by comparing the motion and response time of the cylinder with the actual measurements. Quazi and Baskar [2] created a model of a three-cylinder pneumatic engine using MATLAB/Simulink and an Automotive Studio and accurately predicted the piston motion, pressure, and pneumatic consumption without empirical adjustment factors. Although these papers did not focus on combustion engines, they showed the relationships between the piston cylinder and the force displacement, which can be modelled and simulated in Simulink. This supports the methodology of the project, where the gas and inertia forces are calculated. Another area that can be mentioned here is the modelling of free-piston engines. Ye et al. [4] studied the dynamics of a free-piston Stirling engine, including nonlinear thermodynamics and the motion of the piston and displacer. He considered the effects of spring stiffness and damping, as well as some nonlinear pressure effects on the operation of the engine. Unlike conventional engines, free-piston engines do not have a crankshaft that controls the piston motion. This complicates the force and dynamics balance in free-piston engines. Although the work presented here is on a conventional crank-slider mechanism, this study shows the significance of force dynamics with respect to engine systems.

The methodology used in this study to compute the gas pressure force, inertia force, and crankshaft torque is based on the procedures that are generally used and described in standard books on machines. One of these is the book by Khurmi and Gupta [5]. It continues to be one of the most cited books in mechanical engineering and frame-based courses, and the book has provided the author with the formulations used in this paper. Overall, the literature reviewed validated the use of MATLAB/Simulink for engine system modelling and force calculations. Although there is a significant gap in the literature, as most studies emphasize detailed gas dynamics and pneumatic actuator systems rather than force estimation for practical combustion engines, and few studies have been conducted on integration.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 15 Issue 06 , June - 2026

III. EXPERIMENTAL METHODOLOGY

A. Model-Based Design Approach
MATLAB/Simulink was used to develop the system by employing a Model-Based Design (MBD) approach. Instead of developing a single large code, the design was partitioned into several independent subsystems. Each subsystem was constructed to capture discrete physical phenomena such as reciprocating inertia, gas pressure, drivetrain losses, rolling resistance, and aerodynamic drag. The modular approach to the design of the system makes the design easy to understand, maintain, and update. Subsystems of the design can be altered and/or replaced without affecting the design of the system as a whole. For example, a simplified gas model used in the design can easily be advanced to a crank-angle-based gas pressure model, and so on, with minimal impact on the rest of the design. To enhance the usability of the design, a graphical user interface (GUI) was developed that is external to the Simulink Model. The communication between the GUI and the Simulink Model is performed using preset input and output parameters. This allows for a user-friendly interface while keeping the Simulink Model extensible for future additions.

B. Mathematical Formulation of Engine Forces
Standard reciprocating engine kinematics and machine theory were applied to calculate the engine forces. The cross-sectional area of the piston (Ap) is expressed in terms of the cylinder bore diameter (D) as follows:

$$Ap = (\pi/4)\ D2 \qquad (1)$$

The force due to the gas pressure acting on the piston is expressed as

$$Fg = P \times Ap \qquad (2)$$

where (P) is the piston pressure,and In the current work, the Brake Mean Effective Pressure (BMEP) is considered. For a four-stroke engine, the BMEP is given by

$$BMEP = 4\pi T / Vd \qquad (3)$$

where:
- T = engine torque (N·m)
- Vd = engine displacement volume

This equation is obtained by equating the two expressions for the work done in one complete engine cycle, which is equal to the work done by the crankshaft in two complete engine cycles. The BMEP was estimated from the rated engine torque and engine displacement, and the mean gas pressure was estimated.The reciprocating inertia force owing to the piston acceleration is expressed as follows:

$$Fi = mr\ r\ \omega 2\ [\cos\theta + (r/l)\cos 2\theta] \qquad (4)$$

where:
- mr= reciprocating mass
- r = crank radius
- ω = angular velocity
- θ = crank angle
- l = connecting rod length

To ease the calculations, the model considers the maximum inertia force at the top dead center (TDC) and ignores the small (r/l) correction. Therefore, the inertia force is approximated as follows:

$$Fi,max \approx mr\ r\ \omega^2 \qquad (5)$$

This was sufficient for the model purposes and was implemented in the Simulink model.
The torque generated on the crankshaft is expressed as

$$T = F_t\ r \qquad (6)$$

where F_t is the tangential force on the
the crank, and instead of calculating F_t directly, the model relies on the rated torque data supplied by the manufacturers. When only power data are accessible, the torque is given by the following equation:

$$T=9549P/N \qquad (7)$$

where:
- P = power (kW)
- N = engine speed (rpm)

C. Simulink Model Architecture
Fig. 1 shows the top level of the resulting Simulink model, named FZ_model_v2 in the working files.

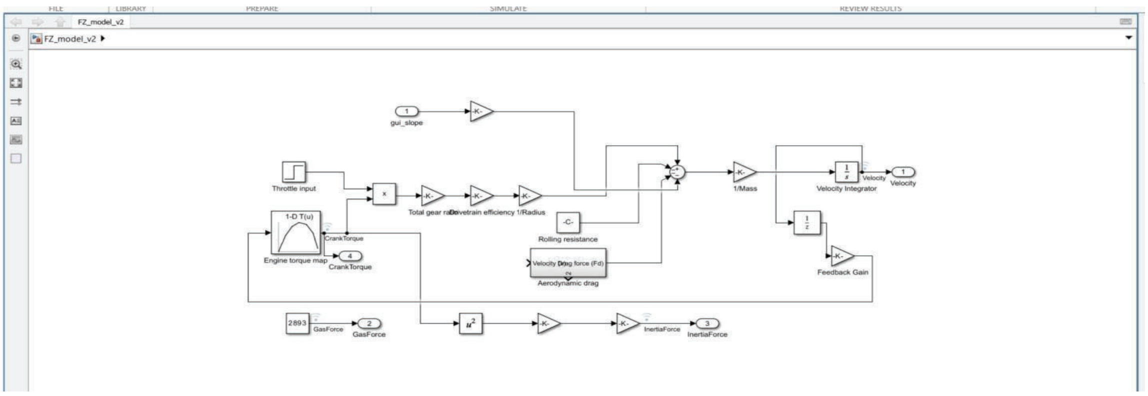

Fig. 1. Top-level Simulink architecture (FZ_model_v2) showing the vehicle-dynamics loop and the parallel gas-force, inertia-force and crank-torque calculation paths.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 15 Issue 06 , June - 2026

The constructed Simulink model consists of two primary components.
1.Force and torque prediction subsystem
2.Longitudinal vehicle dynamics subsystem
Vehicle Dynamics Subsystem
The vehicle dynamics model was initiated using a throttle input represented as a step function. This function was applied to the engine schedule to retrieve the torque values as a function of the engine speed. The torque produced was transformed into an accelerating force at the wheels by multiplying the gear ratio, efficiency of the drive train, and radius of the wheels. This force was then combined with the road gradient and opposed by two resistive forces:
- Rolling resistance
- Aerodynamic drag
The sum of the resistive forces was then set equal to the mass of the vehicle to estimate its acceleration. The acceleration was then integrated to determine the vehicle velocity. To stabilize the response, a feedback loop with a small delay was implemented, which also helped reduce the effect of unwanted oscillations at the start of the simulation.
Force Prediction Subsystem
Although the vehicle dynamics models are separate from the force calculation subsystem, the model simulates the gas pressure force as a constant value derived from the BMEP. For the given engine and its operating parameters, the gas force was approximately 2893 N. The inertia force is calculated using the approximate relation:
$F_i = m_r \cdot r \cdot \omega^2$
The engine speed signal used to develop the torque map was also used to estimate the inertia force. The torque of the crank was obtained from an engine torque map.
The model has four main outputs.
- Gas Pressure Force
- Inertia Force
- Crankshaft Torque
- Vehicle Velocity
These outputs can be viewed in the Simulink scopes, logged for the data, and displayed in the GUI.

D. Graphical User Interface Design
The MATLAB App Designer was used to develop a graphical interface to make interactions with the model more user-friendly and to prevent users from having to open Simulink. The GUI comprises three main sections:
- Input Parameters. The reciprocating mass, crank radius, and engine torque can be entered as inputs. These inputs are used to calculate force and torque.
- Test Conditions. Users can set the gear and slope which control the performance of the vehicle in the simulation.
When the Run Simulator button is pressed, the GUI executes the Simulink model and displays the velocity–time graph along with the 0–60 km/h time, top speed, and the force and torque of the vehicle. The design of the interface separates the inputs from the outputs of the simulation which assists users with limited knowledge of vehicle dynamics to increase their understanding of the model.

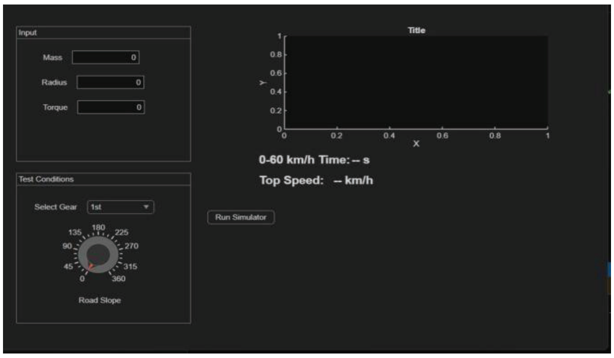

Fig. 2. MATLAB App Designer GUI: input panel (mass, radius, torque), test-condition controls (gear, road slope) and simulated 0-60 km/h time / top-speed read-outs.

E. Tes Vehicle and Practical Verification
The Yamaha FZ-X 150 motorcycle was the focus of this verification activity. The parameters used for the simulation are tabulated below.

Parameter	Value
Bore × Stroke	57.3 mm × 57.9 mm
Compression ratio	9.6 : 1
Displacement	149 cc
Max power	12.2 bhp @ 7250 rpm
Max torque	13.3 N·m @ 5500 rpm
Kerb weight	139 kg
Gearbox	5-speed, constant mesh

The simulation model used the manufacturer specifications as input. Practical verification of the parameters was carried out by direct measurement of the test vehicle. Engine speed verification was accomplished using a handheld contact tachometer. Measurement of the drivetrain and wheels was accomplished using a dial gauge. These methods were the basis for most of the verification of the parameters for the simulation.

Due to the lack of high precision measurement equipment such as an engine dynamometer or a chassis dynamometer, extensive verification of the measured parameters was carried out. It, however, was a cost effective method. The measured parameters were found to be in close agreement with those of the test vehicle.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 15 Issue 06 , June - 2026

In a future work, a chassis dynamometer could be used to verify the model with high precision. Testing the motorcycle in such a manner would provide the opportunity to assess the performance of the motorcycle in a controlled setting and measure power, fuel, and emissions and allow comparison of the simulated and measured results to enhance verification of the model.

Fig. 3. Practical verification on the test vehicle: hand-held contact tachometer (left) and dial-gauge check of drivetrain geometry (right).

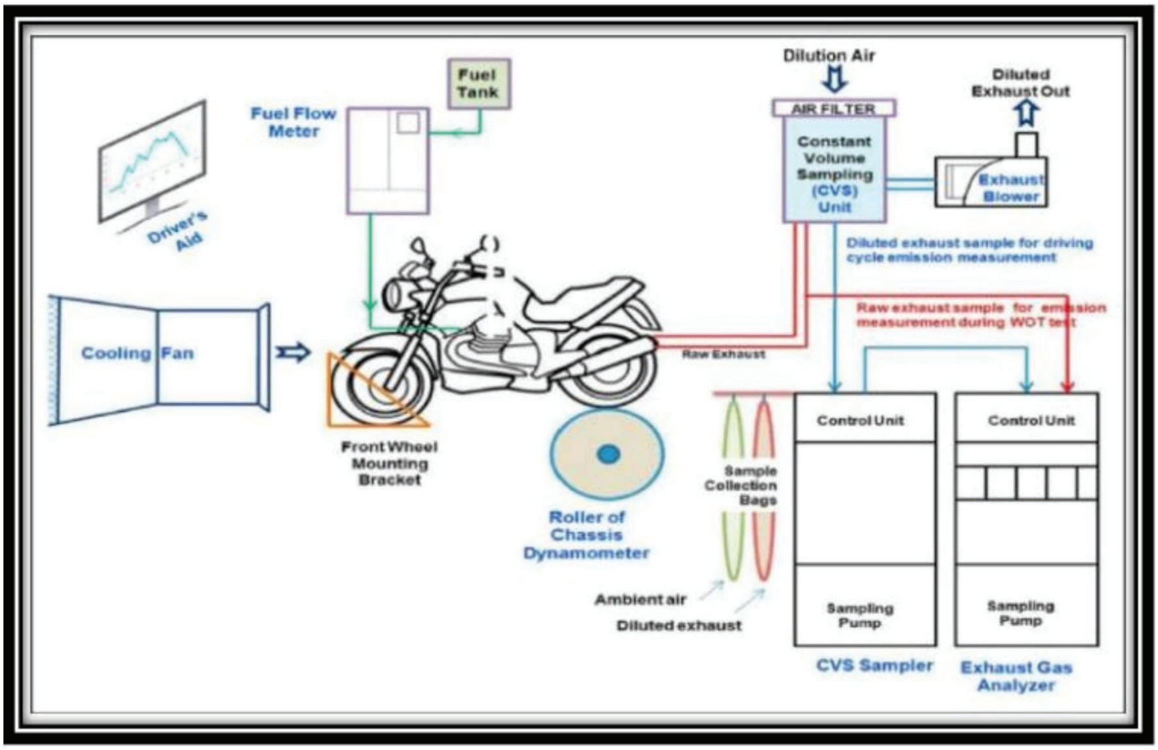

Fig. 4. Schematic of a constant-volume-sampling (CVS) based two-wheeler chassis dynamometer test setup, representative of the validation level beyond the scope of the present work.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 15 Issue 06 , June - 2026

IV. ULTS AND DISCUSSION

The piston area, using Equation (1) and an engine bore diameter of 57.3 mm, was approximately 2.58×10^{-3} m^2 (2580 mm^2). The rated torque of 13.3 N·m and engine displacement of 149×10^{-6} m^3 gave a Brake Mean Effective Pressure (BMEP) of 1121 kPa (11.2 bar) when substituted into Equation (3). This pressure, when substituted into Equation (2), gave a mean gas pressure force of 2893 N. This force was treated as constant gas force in the Simulink model.

TABLE II. SUMMARY OF COMPUTED ENGINE FORCES

Quantity	Value
Piston area, Ap	2.58×10^{-3} m²
Brake mean effective pressure	≈ 1121 kPa
Mean gas pressure force, Fg	≈ 2893 N
Inertia force at 5500 rpm	≈ 2401 N
Inertia force at 7250 rpm	≈ 4172 N
Inertia force at 9000 rpm	≈ 6429 N
Crankshaft torque (rated)	13.3 N·m @ 5500 rpm

The inertia force is calculated using Eq. (5) with r = 28.95 mm and an estimated value of the reciprocating mass (m r = 0.25 kg).

Results for the engine speed and reciprocating inertia forces from Table II show the engine speed effects on reciprocating inertia force. For engine speed at the rated torque speed of 5500 rpm, inertia forces were 2401 N. At 9000 rpm, inertia forces were approximately at 6429 N. This was expected as inertia forces are proportional to the angular velocity ω^2; even though engine speed increased by only about 1.64 times from 5500 rpm to 9000 rpm, inertia force almost increased by 2.7 times. The effect of this behavior is significant mechanical stress on engine components like bearings, connecting rod and crankshaft, at high operating speeds. Therefore, this effect is extended to high speed operations. A comparison between gas pressure and inertia forces is important. The calculated gas pressure force is about 2893 N and remains constant, whereas the inertia force is related to the engine speed. In the 6000 – 6500 rpm region, both forces are almost equal. Beyond the 6500 rpm region, the inertia force becomes the larger force. This is a true representation of the behavior of an engine, as at high engine speed the magnitude of vibration, noise and bearing loads are high. When data are limited to engine power only, torque can be estimated using Equation
(7). Two examples demonstrating the relationship between power, speed and Torque are presented in Table III.

TABLE III. ILLUSTRATIVE TORQUE FROM POWER–SPEED RELATIONSHIP, EQ. (7)

Case	Power	Speed	Torque
1	0.5 kW	1000 rpm	4.77 N.m
2	0.8 kW	1000 rpm	7.63 N.m

Assumptions: air density = 1.2 kg/m³, stoichiometric AFR = 14.7:1, gasoline density = 0.745 kg/L, and intake events per second = rpm/120

Fuel consumption increased with increased throttle, as anticipated. At 25% throttle, the fuel consumption was 0.94 L/h; at full throttle, the consumption was 2.42 L/h. Though the fuel consumption values presented are not validated against manufacturer fuel economy data, these values do indicate that with little extra effort, the current framework for this type of modeling can be modified to include fuel consumption. The simulation results were consistent with each other and with the expected behavior. The gas pressure force derived from the BMEP was equal to the force used in the Simulink model. The inertia force values exhibited the square-law relation with the engine speed. However, the scope of this study was limited to the verification of the geometric and kinematic parameters. Engine forces and torque were not measured directly. Thus, although the model shows the proposed approach, the predicted force values were neither theoretically nor practically verified against the actual engine. This constraint is addressed in the following section.

V. SCOPE FOR FUTURE WORK

The model is supposed to undergo further changes in the future. One improvement that can be implemented is testing the model on an actual engine or chassis dynamometer. This would allow us to collect real data and compare it with our predicted outcomes, which will further optimize the model.This would verify the correctness of our model. Currently, we make use of an assumed value for the pressure inside the engine. We can further improve the model by assuming values from a high fidelity map which dynamically calculates the pressure inside the engine while it is in operation. This model can then be applied to complicated engines with multiple gears along with drivetrain behavior of the vehicle. We can implement Hardware- In- the-Loop(HIL) Testing. By doing so we can test the model on real engine parts. Moreover we can incorporate more features into the model such as fuel utilized by the engine and emissions produced. We can use the actual value of the weights of the engine components instead of assuming them. These improvements will allow the model to be implemented on engineering scenarios and allow us to get actual results. We can implement HIL testing to analyze how various components in the engine affect it.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 15 Issue 06 , June - 2026

VI. CONCLUSION

A model was created to predict gas pressure force, inertia force and torque, as well as simulate the behavior of a single-cylinder, four-stroke petrol engine. Using MATLAB/ Simulink, a GUI was constructed using MATLAB App Designer. The engine inputs for the simulation were taken from the specifications of a Yamaha FZ-X 150 motorcycle. Based on the rated torque and displacement of the engine, the model predicted a Brake Mean Effective Pressure (BMEP) of approximately 1121 kPa that would result in an average gas pressure force of 28 93 N acting on the piston. Using the same parameters, calculations showed that an inertia force value of approximately 24 01 N would be present at an engine speed of 55 00 rpm, and that the inertia force value would increase to around 64 29 N at 9000 rpm. These results confirm the previously predicted relationship between inertia force and engine speed and demonstrate that model is capable of realistically representing the engine. Because this force prediction model is integrated with the previously developed longitudinal vehicle dynamics model, simulation outputs can now be correlated to vehicle speed and acceleration. MATLAB App Designer GUI was built so users can interact with the model by editing parameters and reviewing key outputs such as 0-60 km/h acceleration time, maximum vehicle speed, and force values all while only using a simple GUI and without having to directly interact with the Simulink model. The model's results closely follow predicted theory, but were only validated through ensuring that motorcycle geometry and operating parameters matched up with those of an actual motorcycle. No dynamometer testing was able to be conducted to confirm model validity. As such, the results should only be considered as initial estimates of motorcycle performance. The finished system demonstrates that Model Based Design could be used to estimate engine forces and vehicle performance parameters while requiring very little input data.

ACKNOWLEDGMENT

The authors thank Dr. C. S. Dharankar for his guidance throughout this project. The authors also acknowledge the training on Noise, Vibration and Harshness (NVH) received at Flora Institute, Kusgaon, Bhor, in September 2025, which informed parts of the discussion in this paper.

REFERENCES

[1] *B. Thompson and H.-S. Yoon, "Internal combustion engine modeling framework in Simulink: Gas dynamics modeling," Modelling and Simulation in Engineering, vol. 2020, Art. ID 6787408, pp. 1–16, 2020.*

[2] *M. A. Quazi and P. Baskar, "Computer simulation of pneumatic engine operation," International Journal of Engineering Research & Technology (IJERT), vol. 1, no. 5, July 2012.*

[3] *T. Szakács, "A MATLAB/Simulink dynamic model of a pneumatic piston and system for industrial application," in Proc. 2020 4th Int. Symp. Multidisciplinary Studies and Innovative Technologies (ISMSIT), 2020, pp. 1–6.*

[4] *W. Ye, W. Wang, Y. Yan, L. Kong, and Y. Liu, "Influences of nonlinear parameters on the performance of a free-piston Stirlingengine," Energy Science & Engineering, vol. 11, no. 11, pp. 4019–4038, 2023.*

[5] *R. S. Khurmi and J. K. Gupta, Theory of Machines, 14th ed. New Delhi, India: S. Chand Publishing, 2005.*

[6] *MathWorks, MATLAB and Simulink, Release R2025b. Natick, MA, USA: The MathWorks, Inc., 2025.*