INTERNSHIP PROJECT REPORT

done at

ASHOK LEYLAND TECHNICAL CENTRE, CHENNAI

PRODUCT DEVELOPMENT DIVISION

From 1 July 2024 to 30 September 2024 (for 3 months)

Under the guidance of **Mr. Ganesh Prasad M.V., DGM (Engines-PD)**

Submitted by

KSL SANJANA

ME21B1015

in partial fulfilment for the award of the degree of

Bachelor of Technology (B. Tech) in Mechanical Engineering and Minor in Product Design

at

Indian Institute of Information Technology,

Design and Manufacturing, Kancheepuram

ABSTRACT

This report provides an overview of my internship at Ashok Leyland Technical Centre, focusing on the development and validation of a 1D engine simulation model for a 6-cylinder, 4-valve engine using GT Suite. The project aimed to transition from traditional physical testbeds to digital simulations, enabling efficient analysis of steady-state and transient engine performance.

Through calibration using empirical testbed data and parametric studies of key variables such as valve lift and compression ratios, the model was optimized to improve fuel efficiency and power output. Additionally, dynamic simulations were conducted to evaluate engine behavior across duty cycles like T90, Sweep, and Lug, offering valuable insights into real-world operational scenarios.

The project integrated product design principles, including systems thinking, to ensure holistic optimization of engine components. Deliverables from this internship provide a foundation for sustainable and high-performance engine design, supporting Ashok Leyland's innovation and sustainability objectives.

CONTENTS

ACKNOWLEDGEMENT

I would like to extend my heartfelt thanks to everyone who played a role in the successful completion of this internship. Their support, expertise, and encouragement were crucial throughout every stage of the process.

A special note of gratitude goes to **Mr. Ganesh Prasad M.V., DGM (Engines-PD)**, my project supervisor, for his exceptional guidance, steadfast support, and insightful feedback. His expert advice was vital in shaping the project and deepening my understanding of the subject matter, and I am thankful for the trust he has shown in me. Further, I would also like to thank **Mr. Raguram M** and **Mrs. Kowcika M** for their guidance and support and, **Dr. Sunil Kumar Pandey** and **Mr. Karthikeyan K R** for their guidance in the installation and learning of the GT Suite software.

I also wish to express my sincere thanks to **Mr. Krishnan Sadagopan, Sr. Vice President**, **and Mr. Mahesh, Vice President**, for taking the time to review my project. It is a great honour to have received a certificate of appreciation for my work from them.

My gratitude extends to **Mr. Rasheed B.** and **Mr. Venkatesh** from the HR department for their crucial role in ensuring a smooth onboarding process and for their constant support throughout this project.

Lastly, I am profoundly grateful to my family, professors and friends for their unwavering support and understanding throughout the course of this project.

INTRODUCTION

The automotive industry is experiencing a paradigm shift, with technological advancements and sustainability taking centre stage in engine design. This transformation focuses on achieving stringent fuel efficiency and emission standards while maintaining high performance, particularly in commercial vehicles. To address these demands, Ashok Leyland, a leader in the Indian automotive sector, is adopting digital simulations to replace traditional physical testbeds. This approach accelerates innovation, reduces costs, and minimizes environmental impact.

My internship at Ashok Leyland Technical Centre was aligned with this vision, centring on the development and validation of a 1D engine simulation model for a 6-cylinder, 4-valve engine using GT Suite. The project involved simulating and analyzing engine performance under both steady-state and transient conditions. Key tasks included building a foundational model, calibrating it against dynamometer data, and conducting parametric studies to optimize design parameters such as valve lift and compression ratios.

One of the major contributions was adapting the model for dynamic simulations, validated across duty cycles like T90 and Sweep, to replicate real-world engine operations. These simulations provided actionable insights for enhancing fuel efficiency and overall performance.

The internship also allowed me to apply academic concepts, such as **Strategic Management of Innovation and Design (SMID)** and **Systems Thinking for Design**, to analyze component interdependencies and streamline workflows. This report details the methodology, deliverables, findings, and challenges encountered during this project, highlighting its contribution to Ashok Leyland's commitment to sustainable and innovative engine design.

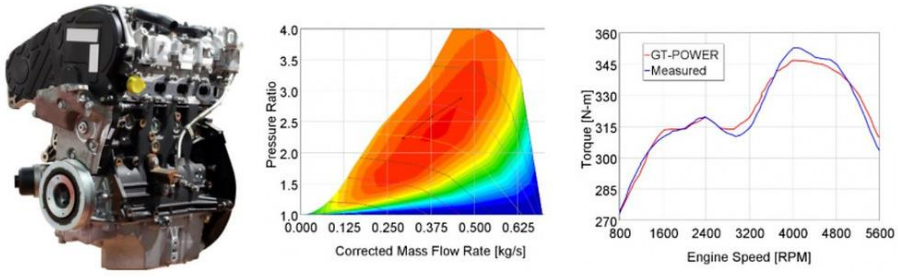


Figure 1: GT Power Engine Simulation Example

MOTIVATION

Ashok Leyland is transforming its approach to engine development by adopting digital simulations. These simulations:

- **Reduce Resource Usage**: Digital models save fuel, time, and manpower compared to physical testing.
- **Contribute to Innovation**: Simulations allow engineers to experiment with configurations without disrupting production lines.
- **Support Sustainability**: By reducing fuel consumption during testing and optimizing engine designs for better fuel economy, simulations contribute to environmental goals.

I was assigned to this project to create validated simulation models that serve as a foundation for future innovation in fuel-efficient and sustainable engines.

OBJECTIVES

1. **Project**: To Develop a 1D engine simulation model of a 6 Cylinder Engine with 4 Valve configuration in both transient and steady-state on GT Suite, validating the model with the data from the test bed and doing a parametric study for different outputs to understand each parameter's impact on the Power and Efficiency of the Engine and studying its dynamics.
2. **Objectives**:
    - Simulate **steady-state performance** (Full-Throttle Position (FTP) and Part-Throttle Position (PTP)).
    - Model **transient conditions** using duty cycles like T90, Sweep, and Lug.
    - Conduct parametric studies on key engine parameters to optimise power and efficiency.
    - Ensure >95% accuracy in simulations compared to testbed data.

Parameter	**Error**
Brake Torque	± 3%
BMEP	± 0.8 bar
Boost Pressure	± 0.2 bar
Boost Temperature	± 3 K
Brake-Specific Fuel Consumption	± 5%

Figure 2: Target Accuracy for Different Parameters

METHODOLOGY

1. Initial Model Development

- I started with a 1-cylinder engine model to familiarise myself with GT Suite functionalities and understand the basics of engine simulation.

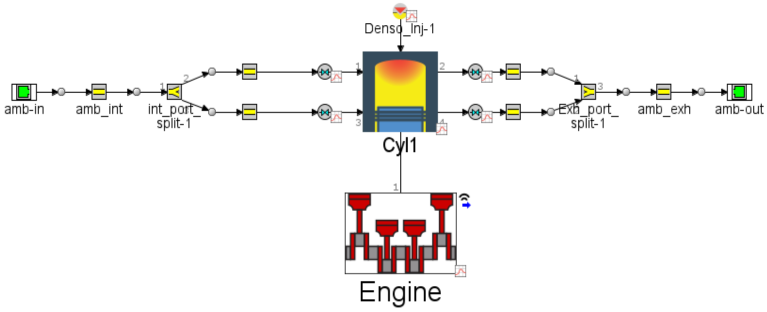


Figure 3: GT-POWER Model of the 1-Cylinder, 4-Valve Engine

- Transitioned to building the 6-cylinder, 4-valve engine model, incorporating specifications from machine drawings and manufacturer data.

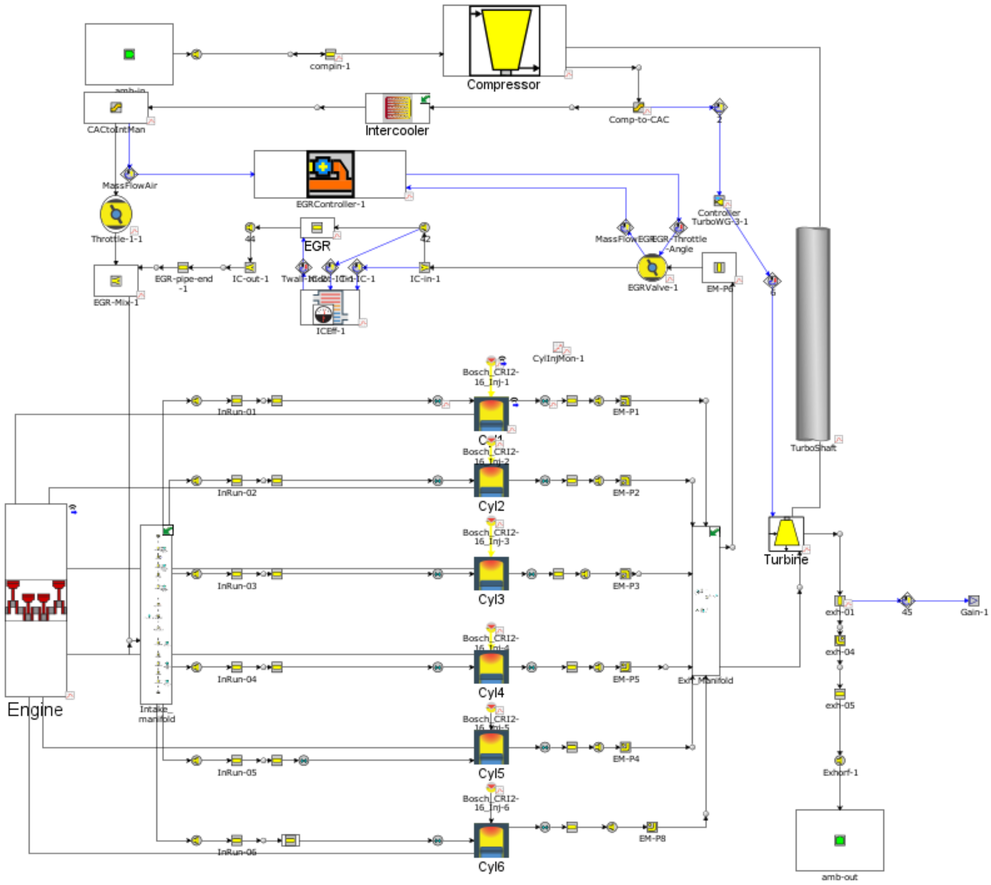


Figure 4: GT-POWER Model of the 6-Cylinder, 2-Valve Engine

- **Components Included**: Turbocharger maps, intake and exhaust manifold geometries, and detailed injection profiles were integrated into the model.

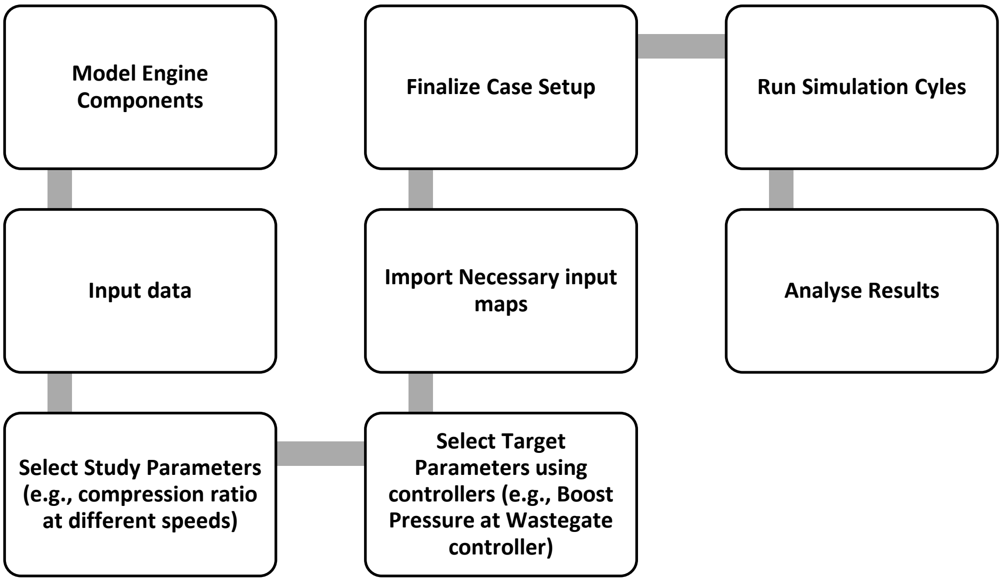
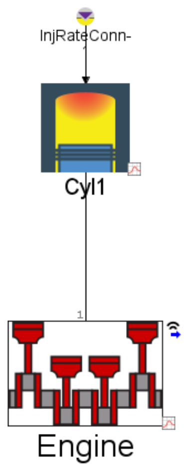


Figure 5: General Steady State Modelling Architecture Flow

2. Calibration and Validation

- **Testbed Data Utilization**:
  - Collected empirical data for Full-Throttle Position (FTP) and Part-Throttle Position (PTP) scenarios from dynamometer testing.
  - Used this data to calibrate critical parameters like boost pressure, injection rates, and friction coefficients.
- **CPOA and M+P Analysis**:
  - Conducted Cylinder Pressure Oscillation Analysis (CPOA) to refine combustion parameters
  - Used M+P (semi-predictive) models to match in-cylinder pressure curves for enhanced accuracy.



- **Error**:
  - Achieved target accuracy with a torque error of ±3% and BSFC (Brake-Specific Fuel Consumption) deviation within ±5%.

Engine Speed (RPM)	Brake Torque (%)	BSFC (%)	BMEP (bar)	Boost Temperature (K)	Boost Pressure (bar)
2600	2.878190812	-4.26803	-0.10457	-0.09064	-0.005382
2400	1.647597651	-2.76044	0.173496	-0.00992	-0.002156
2200	1.844103583	-2.21638	0.299258	0.01372	0.0044238
1600	-1.823750963	-4.89266	0.474012	0.04072	-0.060272
1500	-0.630553298	-3.64465	0.567703	0.07357	-0.0557656
1400	-0.520636308	-4.32271	0.350353	0.10625	-0.0950092
1300	1.692710623	-2.17455	0.172697	0.13868	-0.0673128
1200	2.893108052	-2.46373	0.017535	0.15737	-0.0832213
1000	2.946878253	-0.38763	-0.48023	-0.05666	0.1166471
800	1.230866311	-2.86962	0.183802	-0.04706	0.1186391

Figure 6: % Error of the FTP model

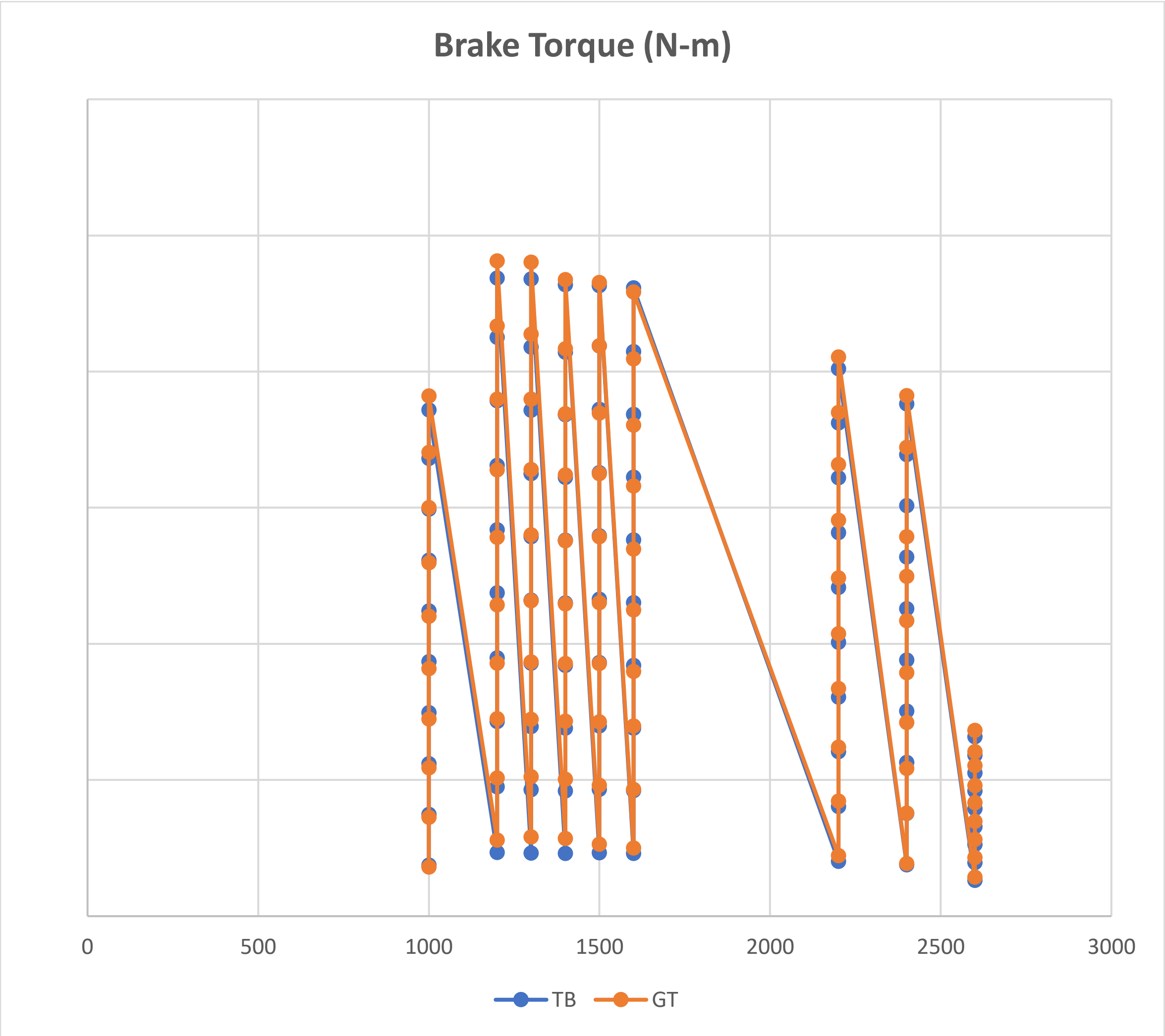


Figure 7: Comparison of Brake Power (kW) between the TB data and the GT power model at PTP

3. Parametric Studies

- **Parameters Analyzed**:
  - **Valve Lift**: Found 6mm lift improved volumetric efficiency compared to 9.5mm due to reduced valve overlap.
  - **Compression Ratios**: Optimized ratios for power output and fuel efficiency.
- **Outcome**: Identified optimal configurations for improved performance and emissions compliance.
- **Findings**: The modified Piston cup design model was tested with this model and the power output increased to 280 hp from 250 hp. This ensured a safe bet to propose the design modifications to be implemented in the test bed. Upon testing in real life, the dynamometer results matched the simulation results with a 95% accuracy.

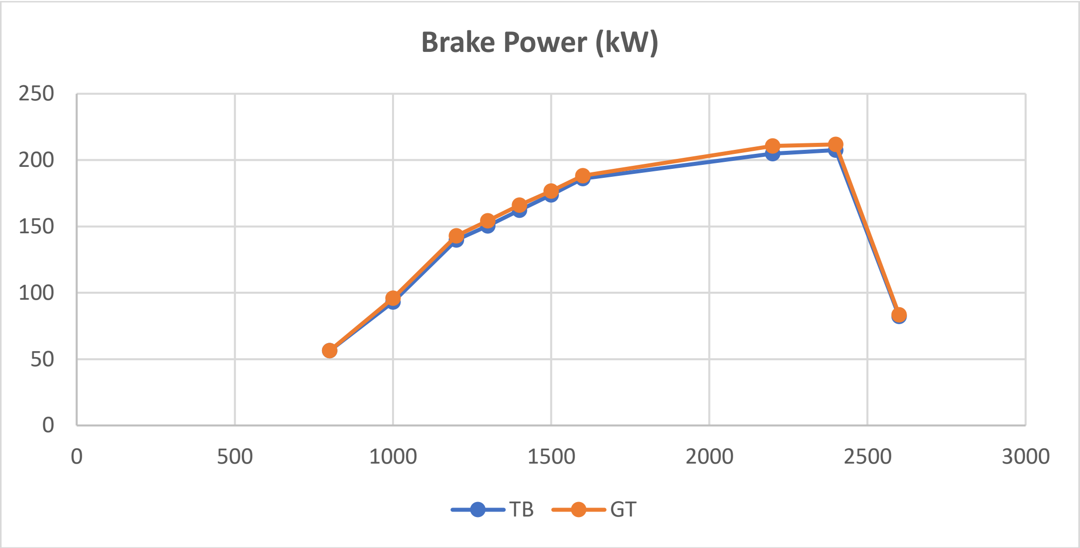


Figure 8: Comparison of Brake Power (kW) between the TB data and the GT power model at FTP

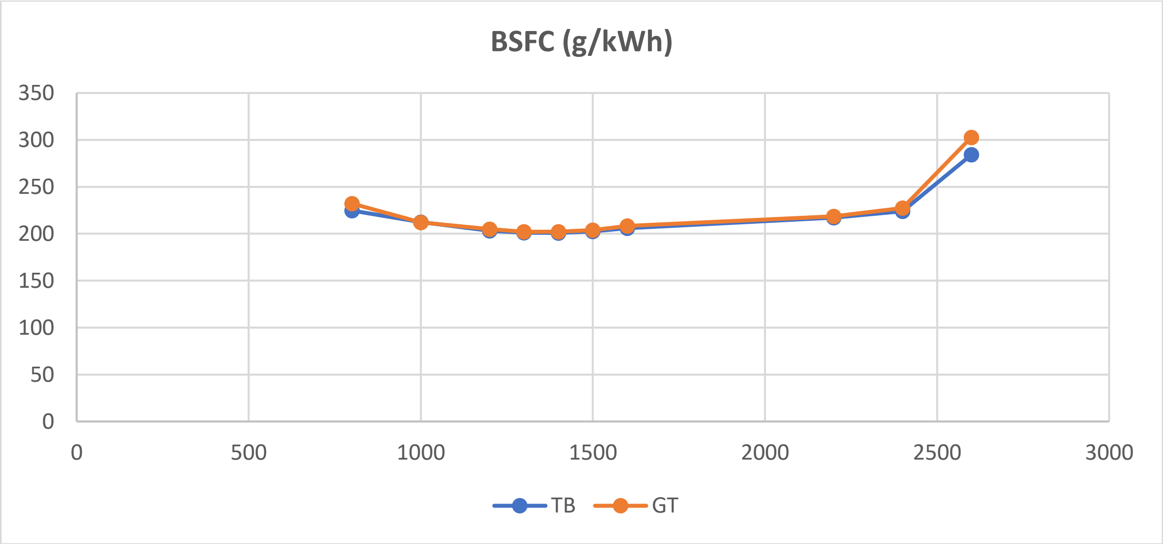


Figure 9: Comparison of BSFC between the TB data and the GT power model at FTP

4. Transient Performance Modelling

- **Dynamic Simulations**:
  - Modelled real-world operating conditions, focusing on duty cycles such as T90 (time to reach 90% of brake torque), Sweep, and Lug.
  - Incorporated transient input variables, including EGR (Exhaust Gas Recirculation) flow rates, injection timings, and turbocharger responses.

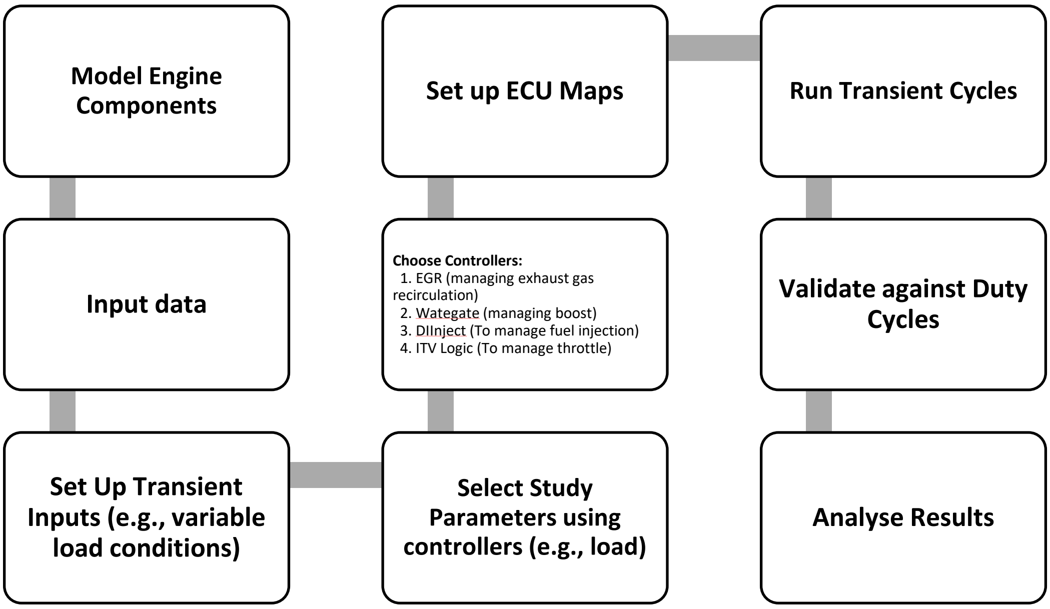


Figure 10: General Transient State Modelling Architecture Flow

- **Validation**:
  - Compared simulation outputs with testbed data to ensure alignment.
  - Observed minimal deviations, demonstrating high accuracy under dynamic conditions.

N	t (TB)	t (GT)
rpm	s	s
2400	1.8	1.6
2200	1.8	1.74
1600	2.8	2.5
1500	2.9	2.8
1400	3.1	2.9
1300	3.3	2.9
1200	4	3
1000	4	4.2

Figure 11: Tabular column comparing the T90 timings of the test bed vs GT model

DELIVERABLES

1. **Validated Simulation Models**:
   - Delivered accurate 1D models for 250 HP and 280 HP engines.
   - Models covered steady-state and transient simulations, serving as a foundation for future innovation.

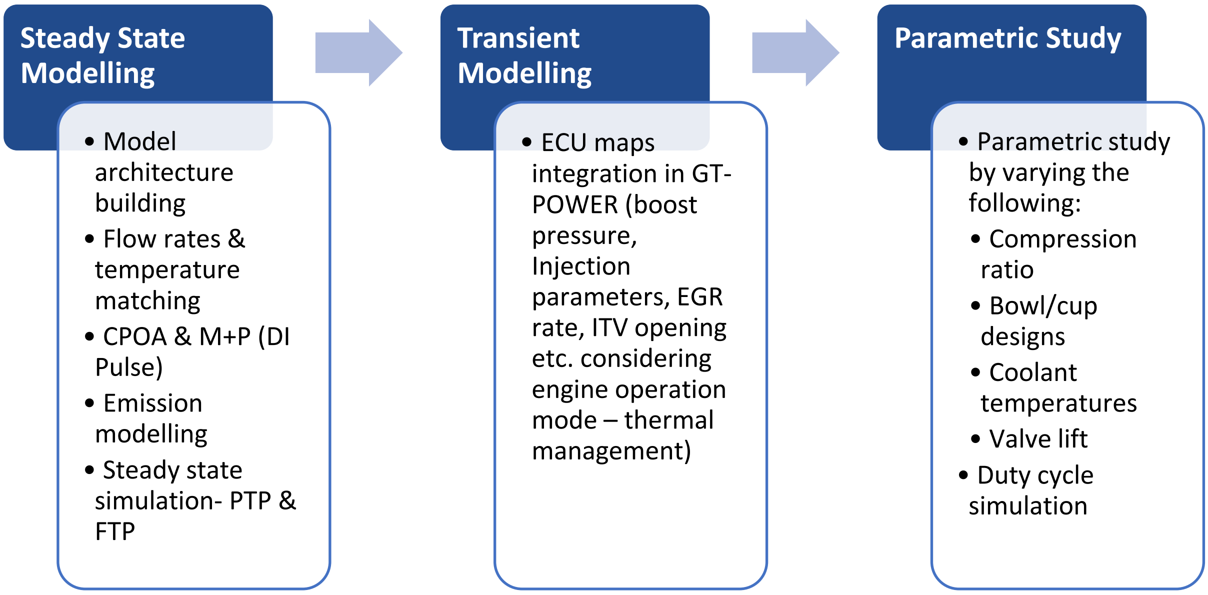


Figure 12: Overall Project Flow

2. **Parametric Study Results**:
   - Found that a **6mm valve lift** provided better volumetric efficiency due to reduced overlap between intake and exhaust valves.
   - Optimized piston cup design for improved performance.
3. **Duty Cycle Simulations**:
   - T90 modelling predicted engine responsiveness during acceleration.
4. **Calibration Outputs**:
   - Created injection rate maps and turbocharger configurations aligned with testbed data due to the unavailability of maps.
5. **Innovation Contributions**:
   - Enabled fuel economy projects by providing models that support Ashok Leyland’s sustainability goals.

KEY FINDINGS

The internship yielded several critical insights into engine performance and optimization through detailed simulation and validation processes. These findings highlight the effectiveness of digital simulations in improving engine design and achieving sustainable performance.

1. Steady-State Performance

- **High Accuracy Achieved**:
  - The simulation model met the target accuracy with a brake torque error of ±3% and BSFC deviation limited to ±5%.
  - Boost pressure and temperature were calibrated to deviate by no more than ±0.2 bar and ±3 K, respectively.
- **Valve Lift Optimization**:
  - A 6mm valve lift provided superior volumetric efficiency compared to a 9.5mm lift.
  - Reduced valve overlaps minimized performance losses, enhancing overall efficiency.
- **Compression Ratio Adjustments**:
  - Optimized ratios significantly improved engine power output and fuel efficiency under steady-state conditions.

2. Transient Performance

- **Duty Cycle Simulations**:
  - **T90 (Time to Reach 90% Torque)**: The model demonstrated high responsiveness, achieving T90 with a maximum error of 0.3 seconds.
- **Turbocharger Dynamics**:
  - Fine-tuning turbocharger maps ensured balanced airflow, boost pressure, and fuel injection across transient conditions.
  - Resolved bottlenecks in low-speed turbocharger response, improving performance consistency.

3. Parametric Study Insights

- The 6mm lift configuration enhanced airflow characteristics, increasing engine power and efficiency.
- Boost pressure configurations were adjusted to achieve ideal air-fuel ratios, improving both power output and emissions.

- Iterative calibration of injection profiles resulted in improved combustion efficiency and reduced fuel consumption.

4. Course Application

- The transition to digital simulations reduced the dependency on resource-intensive physical testbeds, saving fuel and lowering emissions during the development phase. This directly is related to bringing innovation and sustainability in real application.
- Recognized that changes in one component (e.g., valve lift) impacted other parts like airflow, combustion efficiency, and turbocharger performance. Integrated data from various subsystems (e.g., turbocharger, EGR, and injection profiles) into a unified simulation framework. This is an approach learnt from the systems thinking for design.

CHALLENGES AND LEARNINGS

Challenges

1. Missing injection rate maps required calibration using data from similar engines.
2. Complex transient simulations demanded iterative testing and adjustments to achieve accuracy.
3. Limited time necessitated prioritization of key tasks while ensuring quality deliverables.
4. Balancing multiple interdependent parameters required extensive analysis and validation.

Learnings

1. Mastered GT Suite for creating accurate and scalable 1D engine simulation models.
2. Developed expertise in analyzing engine dynamics and identifying performance bottlenecks.
3. Enhanced problem-solving skills by iterating and calibrating models to align with empirical data.
4. Gained hands-on experience in applying systems thinking and innovative design principles to real-world challenges.

FUTURE WORK

1. **Emissions Modelling**: Incorporate NOx and CO2 simulations to evaluate environmental impact.
2. **Enhanced Calibration**: Refine injection maps to improve low-speed accuracy.
3. **System Expansion**: Extend simulations to include after-treatment systems like SCR and DPF.

CONCLUSION

My internship at Ashok Leyland Technical Centre provided an invaluable opportunity to contribute to the development and optimization of engine systems using advanced digital simulation tools. By creating and validating a 1D engine simulation model for a 6-cylinder, 4-valve engine, I supported the organization's transition from physical testbeds to resource-efficient digital simulations, aligning with its goals of sustainability and innovation.

The project enabled a comprehensive analysis of engine performance under both steady-state and transient conditions, revealing critical insights into design parameters like valve lift, compression ratios, and turbocharger configurations. The validated models achieved high accuracy and served as a foundation for future engine design and fuel economy projects.

In addition to technical deliverables, the internship enhanced my understanding of systems thinking and design methodologies, providing a holistic approach to problem-solving in real-world engineering challenges. These experiences have not only deepened my technical expertise but also emphasized the importance of integrating sustainability into product design.

The outcomes of this internship reflect Ashok Leyland's commitment to innovation and efficiency, paving the way for the development of environmentally conscious, high-performance commercial vehicles.