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Performance Optimization of A 4-Stroke Single-Cylinder Engine Through Intake Camshaft Profile Design Using a 1-D Simulation Cycle

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Abstract: An engine camshaft is a rotating shaft that operates an internal combustion engine's intake and exhaust valves. Its main function is to open and close the valves at the correct timing and duration to control the intake of air-fuel mixture and the expulsion of exhaust gases. The project objective is to construct a 1-D engine model to examine various camshafts to improve the performance of the standard engine. The subject of this study is a Yamaha B17 engine that has been used for the Yamaha Y15ZR motorcycle model. The engine is modelled in 1D simulation LOTUS ENGINEERING software in order to assess the torque and power. The model is then correlated with the actual engine performance within the 4% discrepancy limit. The timing, lift, maximum opening point, and length of the intake and exhaust camshaft profiles are all part of the tuning of engine parameters. The second camshaft model, R2, underwent several modifications resulting in an increase of 0.2 Nm in torque and a rise of 0.5 kW in power at the specific engine speed. Engine performance depends on both torque and power, with power controlling sustained high-speed performance and torque impacting low-end performance. To fulfil the unique demands of various applications, ensure optimum performance, and improve the overall driving experience, the proper torque and power balance must be achieved.

Keywords: Camshaft, Engine performance, Optimization

1. Introduction

This project is to develop a 1-D B17 engine Yamaha 15ZR 4-stroke single cylinder liquid cooled 149.9 cc model. Next, the project is carried out using LOTUS ENGINEERING simulation software, which is used to help in the design phase and the entire development program of all engine types. In addition, this project aims to boost power output for better acceleration and top speed while optimizing

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torque delivery for increased high performance by carefully altering engine components and specifications.

A spark-ignition engine (SI engine) is an internal combustion engine that uses a spark from a spark plug to start the combustion process of the air-fuel mixture. In contrast, in compression-ignition engines, such as diesel engines, the heat created by compression combined with the injection of fuel is sufficient to start the combustion process without using an external spark. Spark-ignition engines are commonly referred to as ‘gasoline engines’ in North America, and ‘petrol engines’ in Britain and the rest of the world. An Otto cycle engine is a four-stroke spark-ignition engine, intake stroke, compression stroke, power stroke, and exhaust stroke are the four strokes. Each stroke involves 180° crankshaft rotation, resulting in a four-stroke cycle with 720° of crank rotation.

This project's engine parameters are essential information because it directly deals with the motorcycle engine. The selected benchmark engine was the Yamaha Y15ZR engine. The specification of the engine is outlined in Table 1.1 below.

Table 1.1: Engine specification for YAMAHA B17

Engine Specification	Description
Engine Type	Four-Stroke Gasoline (SI) Engine
Valve Configuration	Single Overhead Camshaft (SOHC)
Valve Per Cylinder	4 Valve
Total Displacement	149.9 cc
Bore x Stroke	57 mm x 58.7 mm
No. of Cylinder	1
Compression Ratio	10.4:1
Maximum Output	11.3kW (8500rpm)
Maximum Torque	13.8Nm(7000rpm)
Fuel System	Fuel injection (FI)
Clutch Type	Wet, Multi Plate
Transmission	Constant Mesh, 5-Speed

2. Materials and Methods

Figure 2 depicts the overall process of this investigation using a flow chart overview. Some basic characteristics for the simulated engine were put up in Lotus Engineering software simulation for the engine modelling process, including main components such as the engine cylinder and intake/exhaust system as shown in figure 2.

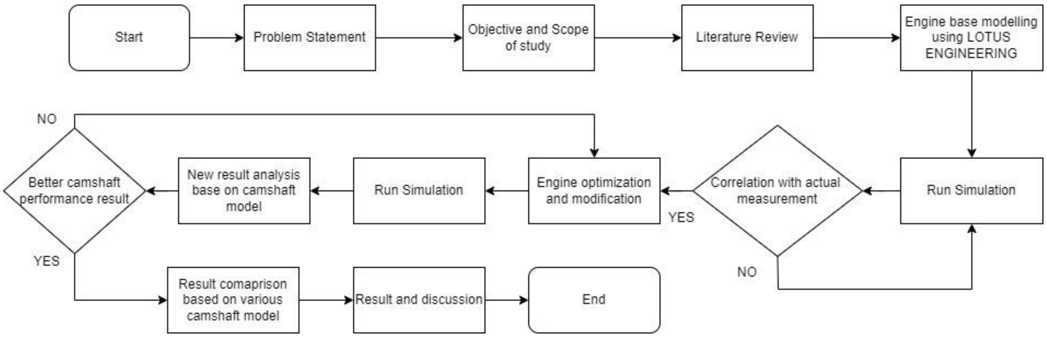


Figure 1: Flow chart overview

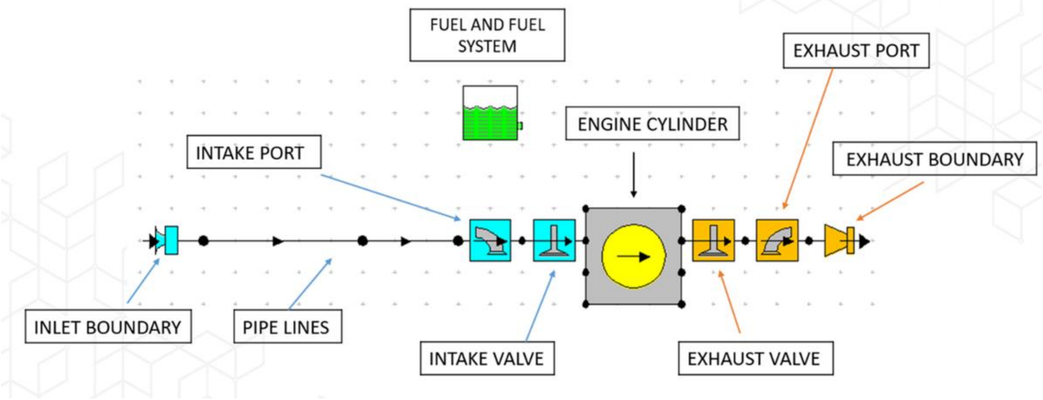


Figure 2: Single-cylinder model with port and inlet runner pipe

LOTUS ENGINE SIMULATION is the software program that was utilized during this investigation to simulate the 1D engine model. The Lotus engineering company is responsible for the creation of this simulation. The LOTUS ENGINE SIMULATION software is a simulation tool that can accurately forecast the overall performance of an engine's parts. Thon can be used to calculate the engine's full- and part-load performance and part-load performance of the engine under steady-state and transient operating conditions; in-cylinder heat transfer data; instantaneous gas property variations within the engine manifolds; and matching conditions for turbochargers and superchargers. As a result, it can assess the performance of an engine.

3. Results and Discussion

This section compares the performance of brake torque and power against engine speed after validation and optimization. Figure 4 depicts a comparison of engine performance between the actual and correlated engine models.

CAMSHAFT DESCRIPTION	BASELINE	R1	R2	R3	R4	R5
IMOP	104	103	103	103	105	105
EMOP	106	104	102	103.5	104	105
DURATION (I)	260	258	261	269	274	280
DURATION (E)	260	261	265	267	272	279
LIFT (I)	6.8	7.71	8.64	9.6	9.32	9.42
LIFT (E)	6.6	7.85	8.82	9.37	9.26	9.38
IVO	27	25	29	31	32.5	34
IVC	53	53	54	56	58.5	65
EVO	56	55	56	56	59.5	65
EVC	24	26	27	33	35.5	35

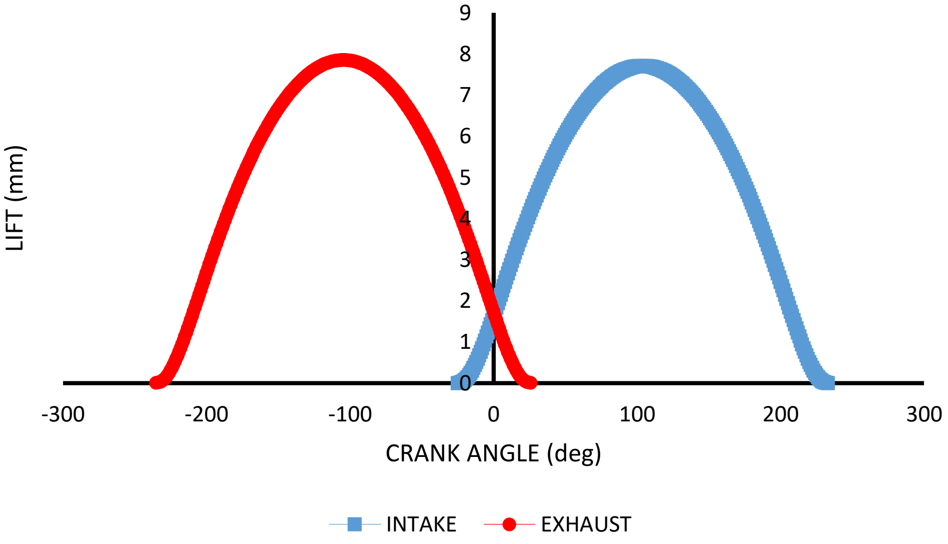
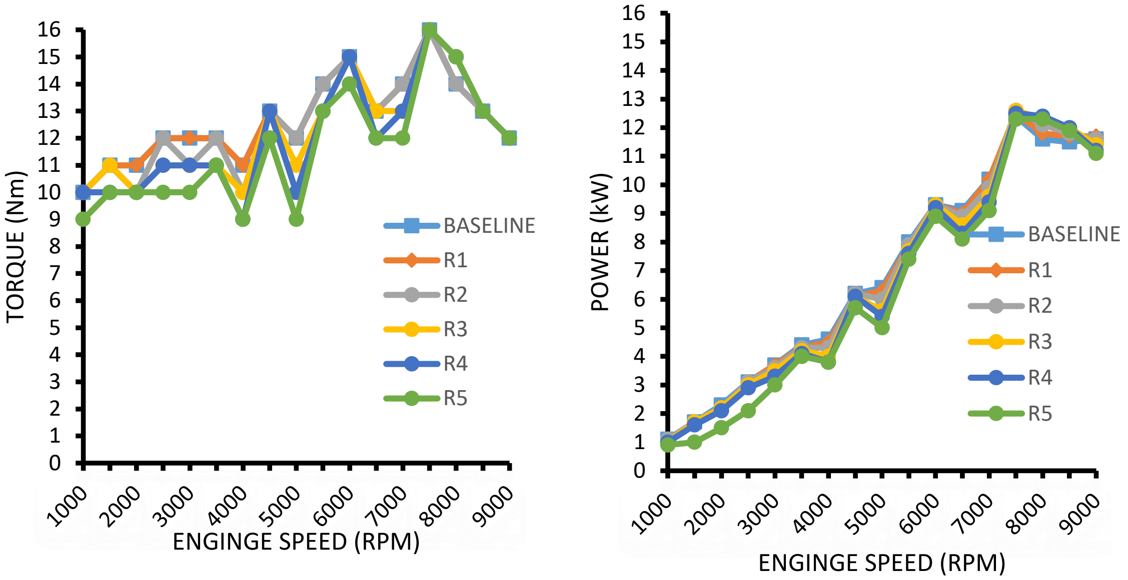


Figure 3: Valve lift diagram

Due to some percentage discrepancies that are greater than the range of 4%, the validation process was completed with 90% success. The values of the percentage differences are 1.4% for torque at the maximum speed (7000 rpm) and 1.8% for power at the highest speed (8500 rpm). The camshaft of intake and exhaust side is the most affect of engine performance that were chosen for the optimization process. The five best parameters from the readings given by Lotus Engineering software for each different camshaft are picked to be studied in terms of torque and power, and the one best parameter among the five that produces the greatest results in performance was chosen as the best camshaft performance. The findings of this analysis were used to determine which camshaft has the better performance in term of torque and power.



(a) **(b)**

Figure 4: Performance result of (a) torque and (b) power of baseline model against various camshaft model

Figure 4 shows five various camshaft in terms of torque and power against engine speed. As a result, in term of torque, the best camshaft that produce more torque is camshaft model R2. With maximum lift is 8.64 mm on the intake side and 8.82 mm on the exhaust side, it can produce more torque than the baseline model which is 14Nm torque at 7000 rpm. in term of the power output, it shows an increment in 2.5% better than correlated engine model. This camshaft model R2 power output is higher than the correlated engine model as 8500 rpm, which is 11.8 kW compared to baseline model which is 11.5 kW. The power output make a new high power level at 8500 rpm as a peak power produced by the improved engine model.

4. Conclusion

In conclusion, engine simulation for motorcycle engine performance has shown to be a beneficial tool for motorcycle engineers and designers. By utilising the capabilities of computational modelling and simulation. However, it is critical to recognise the limitations of engine simulation. Models are simplified representations of complicated realities, and the quality of simulation outcomes is dependent on the accuracy of input data and the assumptions made while modelling. To ensure the accuracy and dependability of the predictions, researchers must confirm simulation results with physical testing. As a result, this research is carried out by applying cutting-edge simulation techniques to build a 1D engine model for performance enhancement over the baseline configuration. The model is then optimised with Lotus Engineering Software to find the best intake and exhaust camshaft configuration. To establish which camshaft variant provides the optimum performance, researchers must uncover the most influential characteristic of each variant that will significantly improve engine performance. The final configuration capable of matching the product's target parameters was chosen after completing engine development, performance validation, and simulation software optimization. By a wide margin, the proposed innovation outperformed the baseline. Finally, the engine optimisation technique and development strategies used in this study can give engine manufacturers and engineers guidance and recommendations for furthering their understanding of the engine design and development process.

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