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Development and modification of a single overhead camshaft 4-valve 4-stroke 135 cc formula varsity race car engine

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Abstract. The engine that was chosen to be developed and modified is Yamaha LC 135 Single Overhead Camshaft (SOHC) 4-valve 4-stroke 135cc liquid-cooled engine. The engine selection is based on the specification, rule and regulation in UTeM Formula Varsity 2012 (FV 2012). The engine performance is determined by engine operating characteristics. The engine air flow affects the filtration, intake and exhaust systems. The heat from the engine rejected to the surrounding through the active cooling system which has radiator and fan. The selection of the engine is based on weighted decision matrix which consists of reliability, operating and maintenance cost, fuel consumption and weight. The score of the matrix is formulated based on relative weighted factor among the selections. It been compared between Yamaha LC 135 Single Overhead Camshaft (SOHC) 4-valve 4-stroke 135cc liquid-cooled engine, Honda Wave 125 X Air Cooled, 4 Cycle Engine Overhead Camshaft (OHC) and Suzuki Shogun RR 4 stroke air cooled Single Overhead Camshaft (SOHC). The modification is applied to the engine through the simulation and tuning of Capacitor Discharge Ignition (CDI).

1. Introduction

In the previous researches, the development and modification of engine part were not presented [1][2]. Original and standard engine was used to drive the race car. In this research, the chassis is designed and developed [3-4] and in addition the engine is modified to increase its capability. The development and modification of Formula Varsity (FV) race car are performed in proper manner so that it will not harm the driver. The development and modification are performed with consideration of rake angle, gear ratios, carburettor type, vehicle weight, the number of cylinders and the brake and suspension systems [5-9]. Motorcycle that manufactured by manufacturer produced different power output based on displacement volume and engine setting whereby it is not always produce optimum performance due to improper design and manufactures error. However, in order to produce optimum engine performance, the engine needed to be analyzed via simulation. Lotus Single Engine simulation software is suitable for the engine performance analysis. Investigation on which parameters will produce optimum engine performance is carried out by modification of the engine specifications. Comparison is also performed for engine performance between actual and simulation by using parameters from manufacturer sources. The specifications of the engine are shown by table 1 [10].



Table 1. Yamaha LC 135 engine specifications.

	Specification
Engine type	Liquid-cooled 4-stroke, SOHC, 4-valve
Cylinder arrangement	Single cylinder
Displacement	134.4 cm ³
Bore x stroke	54.0 mm x 58.7 mm
Connecting rod length	125 mm
Intake valve size	2 x 23.19 mm
Exhaust valve size	2 x 20.13 mm
Compression ratio	10.9:1
Maximum output	8.93 kW @ 8500 rpm
Maximum torque	11.79 Nm @ 5500 rpm
Starter	Electric starter and kick starter
Lubrication	Wet sump
Engine oil capacity	0.9 l
Fuel tank volume	4.0 l
Carburetion	Mikuni BS25 x 1
Ignition	DC-CDI

2. Methodology

Lotus Single Engine Simulation is used to analyze by changing parameter such as bore size of piston to get the result which can sustain the engine for 30 Laps in Melaka International Motorsport Circuit (MIMC) for 48 km. The analyses of the engine include engine fuel consumption, engine heat rejection, and factor of safety. Through this theoretical proof modification is made on the engine precisely and accurately. The modifications are:

- i. Substitution of current Ignition Capacitor Discharge Ignition (CDI) to Capacitor Discharge Ignition (CDI) of Racing Rextor and unlimited Rotation per Minute (RPM).
- ii. Engine overhaul and increment of bore size of piston to 57 mm with new connecting rod.
- iii. Improvement of Carburetor with Throttle Position Sensor (TPS) and accelerator pump to UMA Racing Carburetor with Throttle Position Sensor (TPS) and accelerator pump (Main Jet size 142 - Pilot Jet size 45).

The modification follows the specification, rule and regulation that been fixed in UTeM Formula Varsity 2012 [9]. The engine is shown in figure 1. Figure 2 shows the software program (capacitor discharge ignition (CDI) of Racing Rextor Tuning Program) used to in the development and modification of the engine for Formula Varsity race car.



Figure 1. Yamaha LC135 engine [10].

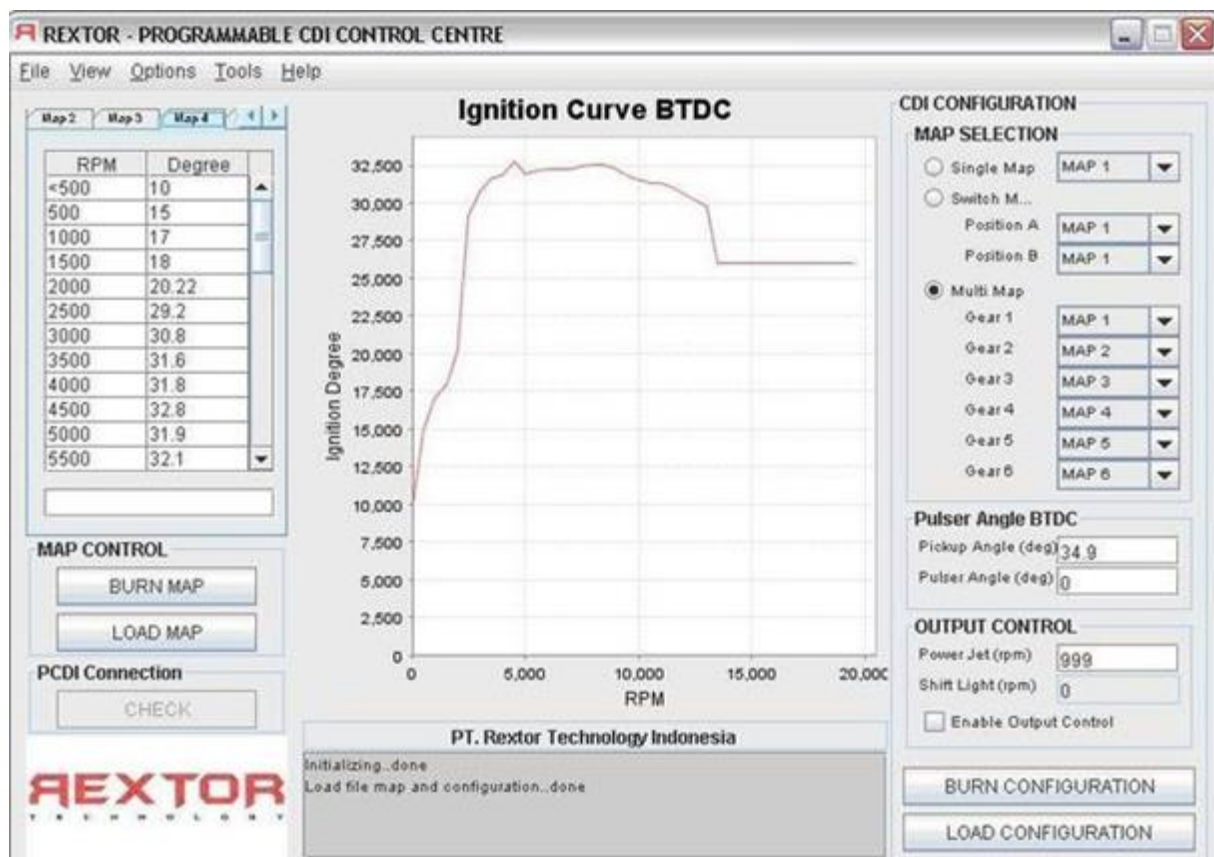


Figure 2. Concept design No. 2.

3. Analysis

The Lotus Single Engine simulation program is used to simulate the performance of the engine by 3 basic steps:

- i. Construction of simulation model and engine specifications.
- ii. Data and test conditions are defined for the cycle simulation.
- iii. Calculation results for cycle-averaged data (volumetric efficiencies, brake specific fuel consumption (BSFC), torque, power), and intra-cycle data (pressure, temperature, mass flow rate) [11-13] in the form of report quality summary sheet and through quick-to-use graph plotting.

The engine performance is calculated theoretically with the new modified specifications from the simulation results (table 2) using Rextor tuning program.

Table 2. Yamaha LC 135 engine modifications.

	Specification
Bore, B x stroke, S	65.0 mm x 58.7 mm
Compression ratio, r_c	12.2:1
Maximum output power, P	8.45 kW @ 8500 rpm
Maximum torque, T	11.65 Nm @ 5500 rpm

The volume displacement is [13],

$$V_d = \frac{\pi B^2 S}{4} \quad (1)$$

The engine torque is calculated at max power [14].

$$P = \frac{2\pi NT}{60} \quad (2)$$

The average piston speed at max power is [15],

$$U_p = N_s \quad (3)$$

The volumetric efficiency is [16],

$$\eta_{ve} = \frac{ma}{pa} \quad (4)$$

The thermal efficiency is calculated by [14],

$$\eta_{thermal} = 1 - \left[\frac{T_4 - T_1}{T_3 - T_2} \right] \quad (5)$$

The results of the calculation and data gathering from engine trial are tabulated in Table 3. Throughout the modification process, the engine components are machined and amended according to the standard procedures of workshop and machining practices [17-21]. The engine trial is performed on the Melaka International Motorsport Circuit (MIMC).

Table 3. Results and data of the modified engine.

Engine Specification	Value
Engine Capacity	194.78 cc
Engine Torque at maximum Power	29.8235 N.m
Average piston speed@ max power	16.63 m/s
Bore-Stroke ratio (B/S)	1.1073
Volumetric Efficiency	0.878 @ 87.8%
Engine Power at maximum Torque	26.55 kW @ 35.6 hp
Thermal Efficiency	0.567 @ 56.7%

Fuel flow rate	8.0952 ml/s
Fuel per millage	0.2125 ml/m

4. Results and Discussion

Through the simulation results obtained for original engine condition, the maximum torque is 10.23 Nm @ 5500 rpm and the maximum power is 8.80 kW @ 8,500 rpm. The compression ratio is 10.9 : 1. The comparison of performance summary between the original and modified engine is shown in figure 4. The simulation analysis result for the modification engine has established approving outcome in term of 194.78 cc of engine capacity, compression ratio 12.2:1, bore size of piston 65 mm, engine power at maximum torque 26.55kW @ 35.6hp, engine torque at maximum power 29.8235 Nm, and thermal efficiency of 56.7%. It is validated that the theoretical data calculated and the results are precise. With the modification of the engine, the performance is improved for endurance and racing.

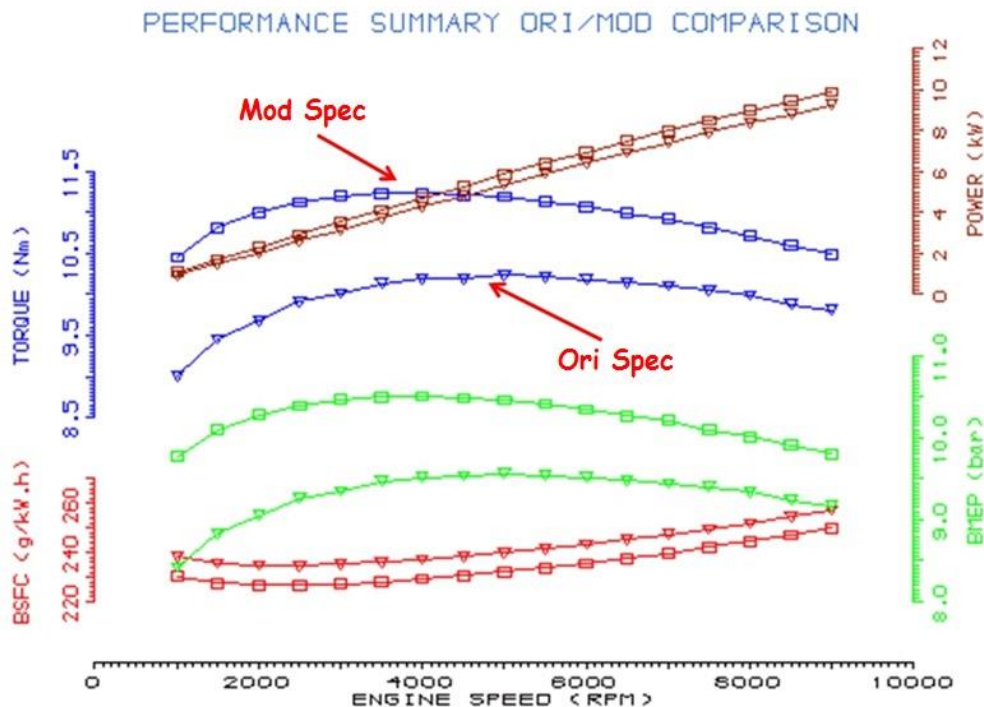


Figure 4. Performance summary comparison of original and modification.

5. Conclusion

Through the research, development and modification of FV race car engine is successfully performed. The parameters such as bore size, stroke length, compression ratio, valve timing give significant impact to the engine performance when modified. The simulation analysis result has established approving outcome in term of engine capacity, compression ratio, engine power at maximum torque, engine torque at maximum power and thermal efficiency. The engine is later assembled with power train and chassis for the FV racing competition. The validation of the results between simulation and theoretical calculation shows the availability and practicality of engine modification.

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