International Journal of Pure and Applied Mathematics
Volume 118 No. 20 2018, 19-25
ISSN: 1314-3395 (on-line version)
url: http://www.ijpam.eu
Special Issue

ijpam.eu

PERFORMANCE IMPROVEMENT OF RACING ENGINE USING SIMULATION STUDY AND EXPERIMENTAL VALIDATION

Kishore R[1,*] and *Hari Pragadish S B*[2]

[1]Assistant Professor, Dept. of Automobile Engineering, Kumaraguru College of Technology, Coimbatore - 641048, India
[2]Student - Final Year, B.E. Automobile Engineering, Kumaraguru College of Technology, Coimbatore - 641048, India

Abstract.
Higher airflow rate through the intake port results in higher air-fuel ratio thus increasing the performance of the engine. The airflow can be increased by porting, polishing and honing. The Suzuki G16B engine was selected because this engine is used in the 1.6L rally races where the participants are not permitted to increase the volume of the engine.

The engine specifications were obtained from the OEM, the stock engine's behaviour was simulated in Vannik Developments – Eng Mod 4T Software and its performance was obtained. The same was dynamometer tested to obtain the actual engine performance. The performance characteristics of the racing engine obtained from dynamometer and simulation software are compared and studied in which deviation between the theoretical and actual power were noted down. The difference in horsepower accounted for 6.4% drop in the theoretical value.

The stock engine was then modified by porting, polishing and then the inlet port size of the engine was increased. Increasing the inlet port size increases the airflow and thus performance of the engine shall be improved without altering the capacity of the engine. The inlet port size cannot be increased more than a certain extent which will lead to improper combustion in the engine. The exhaust port size should also be increased in such a way that it does not result in backfiring, which could also lead to drop in performance of the engine. The fuel pressure must be adjusted for proper combustion. The improved engine is again dynamometer tested and simulated to obtain and study the performance curves of the modified engine which resulted in a 5-12 % increase in power. Thus by simulating the errors that can occur during the various iterations shall be avoided and the perfect values for a well ported engine was obtained in a comparatively short duration with more accuracy.

KEYWORDS : racing engines, engine simulation, dynamometer testing, IC engine performance improvement

1 Introduction

Engine tuning is referred as a modification of the internal combustion engine or the Engine Control Unit (ECU). The modifications are made in order to improve the performance or to increase engine's power output or to improve the economy of the engine. The performance of the engine can be improved by remapping the ECU of the vehicle or by modifications made to the engine. The power increase in the engine can be made by 'Boring' or 'Stroking' of the engine which alters the displacement of the engine which is generally not permitted in any stock car racing. The air flow to the engine can be increased which relatively increases the performance of the engine.

1.1 Parameters Influencing Engine Performance

a. Air Fuel Ratio
b. Compression Ratio
c. Valve Timing
d. Ignition Timing
e. Injection Timing and Injection Pressure

The performance of the vehicle needs to be increased motorsport purposes. The engine chosen for this research to improve the power is a Suzuki G16B engine which is used in Indian Rally Championship 1.6 L Class. The engine is modified in order to improve the performance without altering the displacement of the engine, valve timings and quality of the fuel which are few of the important rules of FMSCI – Fedaration of Motor Sports Clubs of India.

2 Technical Specification of Race Car

Engine Displacement	1590 cc
Fuel Type	Petrol

* Mr. Kishore R: kishor.02.03@gmail.com

Fuel System	Electronic MPFI
Engine Type	1.6L 16V SOHC
Max Power	95 BHP @ 6000 rpm
Max Torque	131 Nm @ 3000 rpm
Mileage (ARAI)	11.6 kmpl
No of gears	5 Gears
Transmission Type	Manual
Drivetrain	Front Wheel Drive
Intake port size	27 mm

Table 1. Technical Specifications of Maruthi Baleno

3 Design Calculations

3.1 Mass of air entering the combustion chamber

mass flow rate, $m = \rho\, a\, V$ (1)

where, ρ – Density of air, kg/m^3

a – Area of the duct, m^2

V – Velocity of air, m/s

Intake port diameter of stock engine, when D = 27.5 mm

$m = 1.225 \times 0.00059 \times 40$

$= 0.028$ kg/s

Intake port diameter of modified engine, when D = 29 mm

$m = 1.225 \times 0.00066 \times 40$

$= 0.032$ kg/s

3.2 Quantity of air flowing through the intake port

for stock engine

CFM = HorsePower/VE (2)

= 85.4/0.8

= 107

for modified engine

CFM = HorsePower/VE

= 88.4/VE

= 113

CFM – cubic feet per minute ; VE – volumetric efficiency

This denotes that increase in intake port dia will increase the amount of inlet charge entering the cylinder and so the power of the engine will increase.

4 Engine Simulation

The engine simulation is carried out in the Vannik Developments Eng Mod Software which is specially used for the jet boat engine simulation processes across NewZealand. The engine simulation set of programs consists of three programs:

· Dat4T – the pre-processor where the input data of the engine with intake and exhaust
system is modeled and prepared.

· EngMod4T – the main simulator which takes the data files as prepared by Dat4T as input and then performs the main simulation with specific output files.

· Post4T – the post processor that takes the output files from the simulation and displays it graphically, these can be results that span the rpm range like power or the pressure traces at a specific rpm point.

The required data for simulation is obtained by dismantling the engine and the enigne parameters are measured. These obtained data are given as input in the DAT 4T module and the engine is simulated in the ENG MOD 4T module and the end result is obtained from the POST 4T module of this software.

4.1 Modelling of Stock G16B Engine

The Suzuki G16 B engine is an inline 4 cylinder engine, with the max power at 6000 rpm as 90 hp. Other measured values are given as input in the preprocessor program. Intake Port Dia for Stock Engine is 27.5 mm.

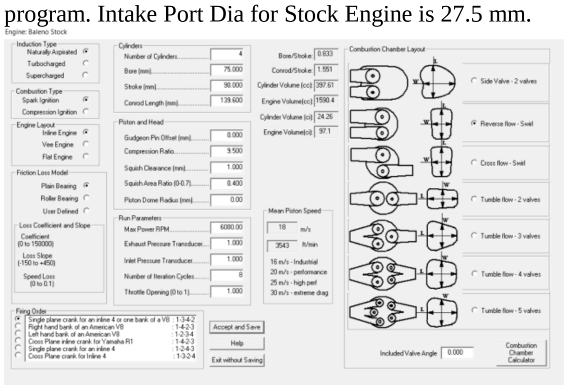

Fig. 1. Engine Parameters Input for the G16 B Engine

Fig. 2. Modelling of Intake Port for G16 B Engine

Fig. 3. Modelling of Exhaust Port for G16 B Engine

4.2 Simulation of Stock G16 B Engine

EngMod4T is the main simulator software used for simulating the previously created G16 B Engine model to predict the performance characteristics and the pressure, flow, temperature and wave action in the ducts, ports and plenums.

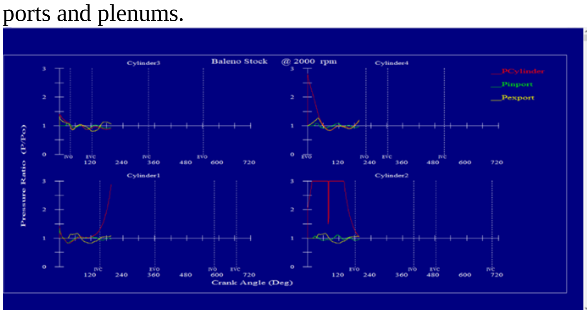

Fig. 4. Generation of RPM Sweep for the Engine Model

As shown in the fig 4, the initial value of the simulation run was given as 1250 rpm and end at 7500 rpm with a constant increase point every 250 rpm.

4.3 Results of G16 B Engine Simulation

To access and display the results of the simulation done in EngMod4T, Post4T – the post processing suite is used to study the pressure traces, temperature traces, mach values, purity values, combustion data etc. at each simulated rpm.

The performance output from the EngMod4T is imported in the Post4T for obtaining the PA-v output and power output. The Horse power of the Stock G16B engine was found to be 90.592 at 6000 RPM, which is exactly the same as the OEM specification.

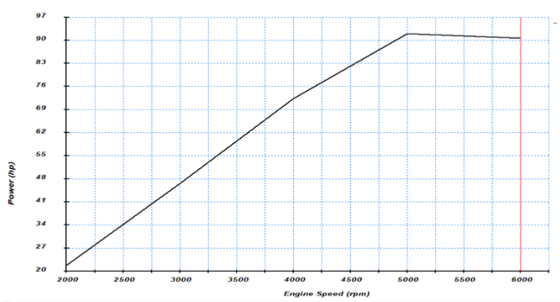

Fig. 5. Performance curve of the stock G16 B Engine

4.4 Modifying the G16 B Engine Model

As per the FMSCI Regulations for ITC Racing, the capacity of the engine needs to be kept constant and also any addition of turbo equipments is prohibited. One technique to increase the power without altering the major engine design could be porting. In order to identify the appropriate value for increasing the port dia, various iterations were carried out with the same simulations procedure and 29 mm diameter was found to be the optimized value for the intake port of G16 B Suzuki Engine.

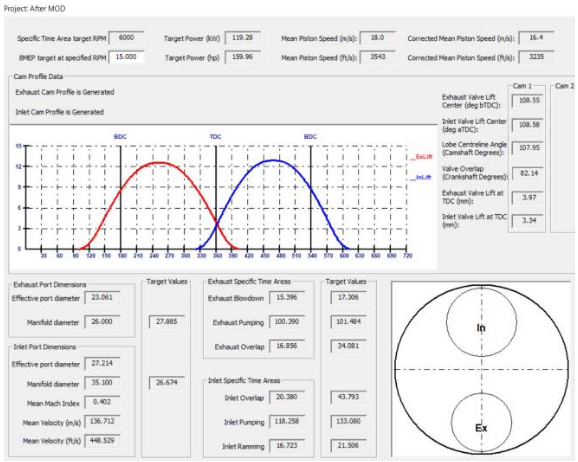

Fig. 6. Intake and Exhaust Cam Profiles

From the fig 6, it was noted that the valve timing remained unaltered and this satisfies the FMSCI regulations.

4.5 Simulation of Modified G16 B Engine Model

The Horse power of the Modified G16B engine was noted as 94.5 BHP at 6000 RPM from the obtained graphical output (fig 7). Here is a view of the resulting graphs for modified G16 B Engine - RPM vs. Power (HP). The curve obtained in blue is set as the optimal value upon considering well ported criteria. Thought the red curve shows the max power, it is an over ported which could affect the flow parameters whereas the curve in black is under ported.

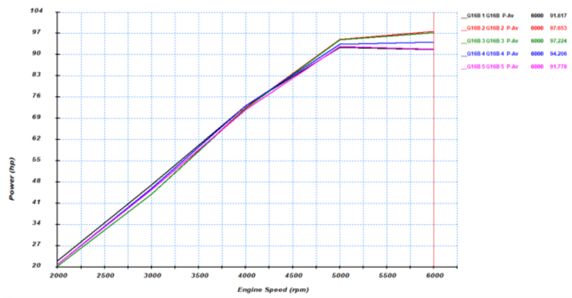

Fig. 7. Performance Curves for various Intake Port Dia

5 Dynamometer Testing

A chassis dynamometer was used to measure the power delivered to the surface of the "drive roller" by the drive wheels. The maruthi baleno vehicle fitted with a stock Suzuki G16 B Engine was parked on the rollers, which the car then turns while ignition is turned on and the output measured thereby.

Fig. 8. Dynamometer Testing of Maruthi Baleno Vehicle

5.1 Chassis Dynamometer Test Result of the Vehicle fitted with Stock Engine

Because of frictional and mechanical losses in the various drive train components, the measured rear wheel brake horsepower is generally 15-20 percent less than the brake horsepower measured at the crankshaft or flywheel on an engine dynamometer. The fig 9 - dyna test report illustrates the trend of engine horsepower, wheel horsepower and torque of the engine at various rpm. It was observed that the engine power and torque characteristics had a 5 HP difference with respect to the simulated results.

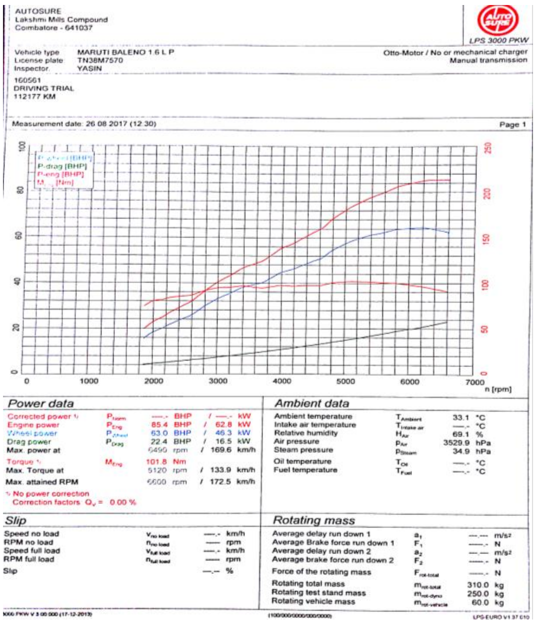

Fig. 9 Dynamometer Test Report of the Stock Engine

5.2 Porting and Polishing of the Racing Engine

Porting is an art of modification by enlarging the intake and exhaust ports to its maximum possible size (in keeping with the highest level of aerodynamic efficiency) but these engines are highly developed where the size of the ports has become the restriction. Porting reduces the flow restriction at the particular area to increase performance of the engine compare with the same engine with same displacement. This porting process to the intake ensures that the flow mixture enters the combustion chamber with the maximum amount of velocity.

With reference to the simulations results, the intake port dia of this racing engine has been ported upto 29mm and then polished. Rough surface can give turbulent flow thus increase the mixture of the fuel and air in combustion chamber. Smooth surface will make those fuel evaporate as the boundary layer for smooth surface is not zero and thus the fuel will touch the surface and increase the mixture of the air and fuel because both is in the same phase and condition. Eventually, polishing gave an extra breathe for the horsepower of this racing engine.

Fig. 10 Well-Ported and Polished Race Engine Intake

5.3 Chassis Dynamometer Test Result of the Vehicle fitted with Modified Engine

Chassis dynamometer test was carried out on the same vehicle fitted with a modified suzuki G16 B engine and the increase in the engine horsepower and the torque was studied. It was observed that the max power at 6250 rpm was approximately 90 BHP.

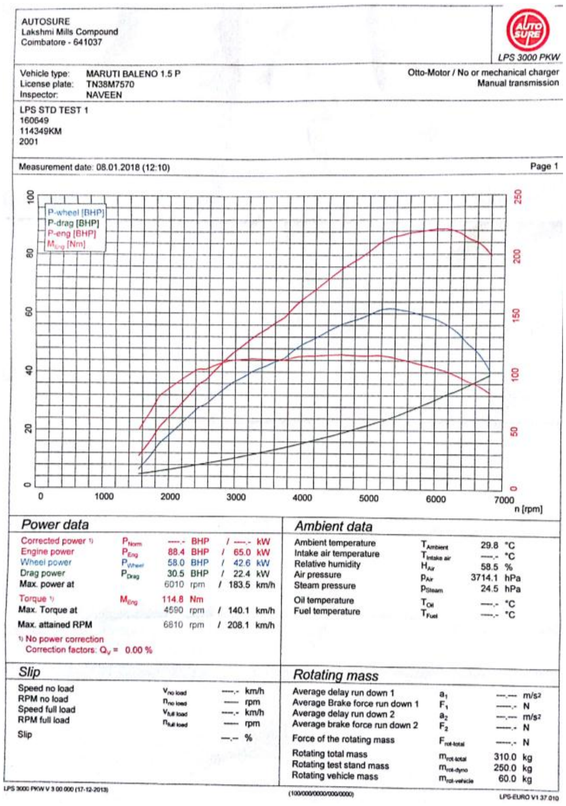

Fig. 10 Dynamometer Test Report of the Modified Engine

6 Results and Discussion

The results obtained from the simulation and the chassis dynamometer test were compared. For the same stock Suzuki G16B race engine, simulation result showed the output power 90 BHP and the chassis dynamometer test gives the power of 85.4 BHP, simulation output is comparatively greater than the dynamometer result. This difference was basically due to the losses occurred during the test because of the ambient temperature, timing chain and other frictional losses.

Testing Method	Engine Power
Simulation	89.8 bhp
Dynamometer Test	85.4 bhp

Table 2. Comparison of the Stock Race Engine Test Results

Also the results of the simulation and the dynamometer test of the modified race engine had almost the same percentile difference with the stock engine and the result obtained was 93.5 BHP from the simulation and 88.4 BHP from the dynamometer test.

Testing Method	Engine Power
Simulation	94.5 bhp
Dynamometer Test	88.4 bhp

Table 3. Comparison of the Modified Race Engine Test Results

The difference in horsepower between the dynamometer and simulation in both the cases were about 5 BHP which accounted for 6.4% drop in the theoretical value. Anyhow, a significant hike in the engine power has been marked which could play a beneficial role in the motorsport arena.

Engine Parameters	Stock Engine	Modified Engine
Intake Port Dia	27.5 mm	29 mm
Engine Power	85.4 BHP @ 6490 rpm	88.4 BHP @ 6010 rpm
Torque	101.8 Nm @ 5120 rpm	114.8 Nm @ 4590 rpm
Maximum RPM	6600 rpm	6810 rpm
Top speed	172.5 km/h	208.1 km/h

Table 4. Comparison of the performance characteristics of the sock and modified race engine

The simulation and the chassis dynamometer test were conducted for the stock G16 B Stock Engine and modified Engine and the validation of the results are done by comparing the performance curves obtained from the simulation and dynamometer test results. The stock horsepower obtained in the chassis dynamometer is 85.4 bhp and the power obtained in the Simulation Software is 90.5 bhp. The modified engine horsepower obtained in the dynamometer test is 88.4 bhp and from the simulation is 94.5 bhp taken as the average bhp from the series of alliterations.

The power on wheels in the chassis dynamometer is 63 bhp for stock engine and 58 bhp for modified engine. The difference between the engine power to the power in wheels is 22.4 bhp which is the drag power of stock engine and 30.54 bhp for modified engine. The difference in engine power to the power on wheels is due to the slip in clutch, transmission and the frictional losses in the engine and wheels. The overall performance of the vehicle is gained by this modification process by increase in bhp and also in the top speed from 172.5 km/h to 208.1 km/h.

7 Conclusion

The overall performance of the vehicle gained with this small modification in the engine by porting and polishing the intake. It is to be considered that the exhaust port size should also be increased in such a way that it does not result in backfiring, which could also lead to drop in performance of the engine. The fuel pressure must be adjusted for proper combustion. The power and torque of the engine can be further increased by mounting velocity stack and turbocharger which can bring the drastic change in the performance of the vehicle and can bring a good output in rally racing and drag racing.

8 References

1. Watson, N., "Turbocharged Spark Ignition Engine Simulation," SAE Technical Paper **845042** (1984)
2. Öberg, P., Nyberg, P., and Nielsen, L., "A New Chassis Dynamometer Laboratory for Vehicle Research," SAE Int. J. Passeng. Cars – Electron. Electr. Syst. **6**, 152-161, (2013).
3. DrAnanthi Sheshasaayee, R. Megala, « A Conceptual Framework For Resource Utilization In Cloud Using Map Reduce Scheduler », International Journal of Innovations in Scientific and Engineering Research (IJISER), Vol.4, No.6, pp.188-190, 2017
4. Shrinath Potul, Rohan Nachnolkar, Sagar Bhave., "Analysis of Change In Intake Manifold Length And Development Of Variable Intake System," IJSTR **3**, 5 (2014)
5. C. Ramesh Kumar and G. Nagarajan, "Investigation of Flow During Intake Stroke of A Single Cylinder Internal Combustion Engine," APRN, **7**, 2 (2012)
6. M Raghu, Pramod S Mehta., "Influence of intake port design on diesel engine air motion characteristics," IJEMS, **6,** 53-58, (1999)
7. V.Ganesan , *Internal Combustion Engines* (Tata McGraw-Hill Education, 2004)
8. A. Graham Bell, *Four Stroke Performance Tuning* (Cambridge University Press, 1998)
9. A. Graham Bell, *Modern Engine Tuning* (Haynes Publishing PLC, 2002)
10. www.vannik.co.za
11. www.torqueperformance.co.nz
12. www.enginebuildermag.com
13. www.research.omicsgroup.org