

Optimization and Validation for Injector Nozzle Hole Diameter of a Single Cylinder Diesel Engine using GT-Power Simulation Tool

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ABSTRACT

Single cylinder diesel engines are widely used as a power source of gen-sets, three wheelers, agricultural machines in small house-hold applications in Indian automotive sector. Due to its simple structure and mechanism, the operation, maintenance and repairing for this kind of engines is also easily possible. Now, in order to satisfy stringent emission norms there is a need for the development of the above engines [2].

In this paper, Software-predicted performance at different load conditions for a constant speed diesel engine (Gen-set application) are being determined by using GT-Power software. This performance is being validated with the actual Experimented Performance Results. In the above mentioned simulation we basically used 'EngCylCombDIJet Simulation' model. The validated model is used for further work. Critical parameters were listed based on the sensitivity analysis on the base model. Critical parameters were optimized for achieving the desired Fuel injector nozzle hole diameter.

A very close validation with less than 1% difference is achieved at full load. While a less than 10 % difference is achieved at part loads. The simulation model predicts the Power, Torque, BSFC, A/F Ratio, Cylinder pressure, Exhaust Temperature and NO_x with a very good accuracy.

The optimized nozzle hole diameter of the above engine is validating with the experimental results and compared with the base-line model. Thus, an improvement in Performance and Emission results is achieved.

KEY WORDS: Direct injection, Injector nozzle hole diameter, BSFC

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INTRODUCTION

GT-POWER is an industry-standard engine simulation tool used by leading engine and vehicle makers to model the performance of internal combustion engines. The details of the diesel engine design vary significantly over the engine performance and size range. In particular, different combustion chamber geometries and fuel injection characteristics are required to deal effectively with major diesel engine design problem achieving sufficiently rapid fuel-air mixing rates to complete the fuel burning process in the time available.

Most of the single cylinder diesel engines are horizontal reciprocating piston type, providing maximum power output below 15 kW, having maximum crankshaft revolution speed below 2600 r/min, water-cooled / air-cooled engines. Most of the Gen-sets, three wheelers and agricultural machines operate in low to medium speed range (1000~1800 r/min);

As, more and more stringent emission norms are coming for the single cylinder diesel engine. So, there is a need for improvement in the performance of the engine in order to satisfy the stringent norms.

In diesel engine, fuel injection system controls engine emissions and power output. The fuel injection system characteristics such as injector nozzle hole diameter, injected quantity, injection duration, start of dynamic injection and injection pressure with respect to crank angle controls the combustion thus controlling engine emissions. To achieve the desired engine performance a trade-off between various fuel injection system parameters is done. A single cylinder diesel engine with Bore* Stroke of 120*120 with maximum valve lift of 11.5mm is being measured on the test bed and valve lift array with respect to crank angle data is being considered for the construction of the simulation model. The simulation model is constructed using GT-Power software. The model is validated and is further used as a base-line model. The base

model is used for optimization of injector nozzle hole diameter. The pressure data with respect to crank angle require for different nozzle hole diameter is being calculated in "AVL HydSim" software.

NEED OF SIMULATION

As described in the introduction, the target engine emissions and power output are obtained by selecting optimum Injection nozzle hole diameter. During combustion optimization exercise of diesel engine, different nozzle hole size diameters are tested to achieve required performance. Hence, this process of achieving required engine performance by actual testing of engine is costly and time consuming. Hence, a simulation process or a tool is used to optimize the nozzle hole size diameter and predict the optimum size to achieve better performance. This be helpful as it will reduce the cost and time involved. The purpose of this simulation model is base line validation of the single cylinder diesel engine model and further optimization for different nozzle hole size diameters to achieve better performance and emission results.

Engine cycle simulation

The simulation main steps

- Design the model (the model can be designed by placing the elements in the working area by first and then connecting them with the pipes)
- General input data (e.g. engine speed, mixture preparation, fuel, reference conditions, cycle, etc.);
- Element input data (e.g. engine constructive characteristics, combustion model, heat transfer, valve port specifications, etc.);
- Run simulation;
- Post-processing (e.g. engine overall performances)

The model

The [fig.1](#) represents the single cylinder diesel engine DI-Jet combustion model used for the analysis. The model consists of inlet environmental parameters, inlet runner parameters, inlet port parameters, inlet valve parameters, engine and cylinder parameters, Injector parameters Exhaust valve parameters, exhaust port parameters, exhaust runner parameters, Exhaust environment parameters [7].

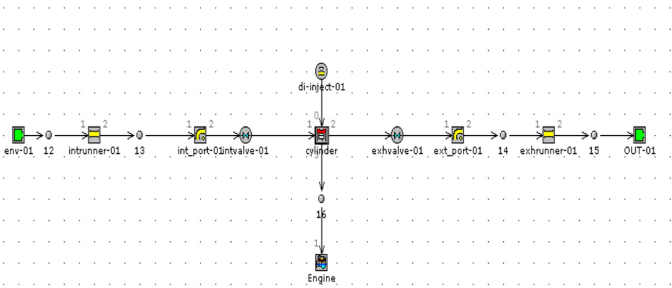


Fig 1. Single Cylinder Diesel Engine GT-Power Model

EXPERIMENTAL SETUP

Testing is carried out at ARAI, Pune on a high dynamic test bed having a maximum torque capacity of 255 Nm and a maximum power capacity of 120kW, and having monitor capabilities. Test bed operation is controlled by interface software. An emission analyser is used to measure exhaust emissions and air flow rate. Provision is made for cylinder pressure data acquisition and analysis. Testing is carried out with intake air conditions of 1000 mbar pressure, 300K temperature and 40% relative humidity.

Table 1. Test apparatus

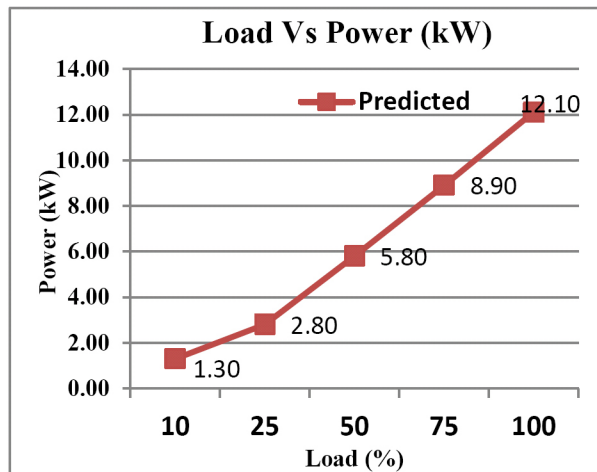
APPARATUS	CAPACITY
Dynamometer	120 kW
Smoke meter	AVL 439
Emission analyzer	Horiba, mexa-9100d
Cond.air system	KS Engg.,cas-03
F.C Meter	KS Engg.,fc-150
Air Flow Meter	ABB, Sensyflow, sfi-03

Table 2. Engine Specifications

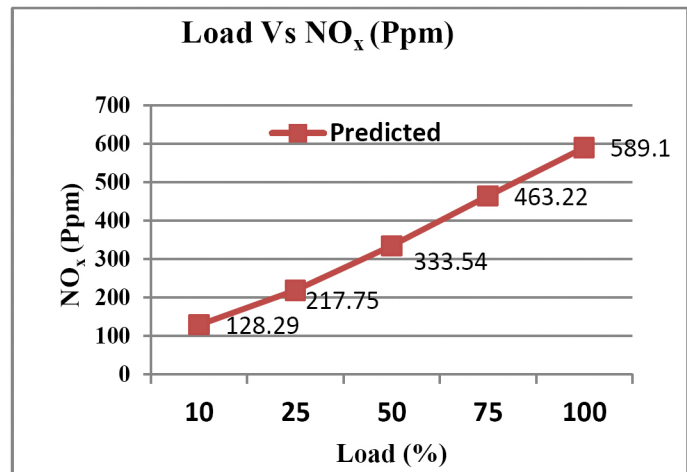
Sr.No	Parameters	Engine Specifications
1	Number of cylinder	1
2	Cylinder bore*stroke	Φ 120 mm*120 mm
3	Compression ratio	18
4	Cubic capacity	1.4 litre
4	Cycle	4
5	Maximum Brake power output	11.88 kW
6	Rated crankshaft speed	1500 r/min
7	Maximum torque@ rpm	75.80 N-m/1500 rpm
8	Cooling System	Water-cooling system with pressurized
9	Combustion type	Naturally aspirated Direct injection
10	Fuel injection system	-2.5° Start of injection with nozzle hole diameter of 0.216 mm.
11	Intake/exhaust valves	1/1
12	Inlet Valve timing angle	230°
13	Exhaust Valve timing angle	128°
14	Application	Gen-set (Constant speed)

ENGINE SIMULATION PREDICTED RESULTS

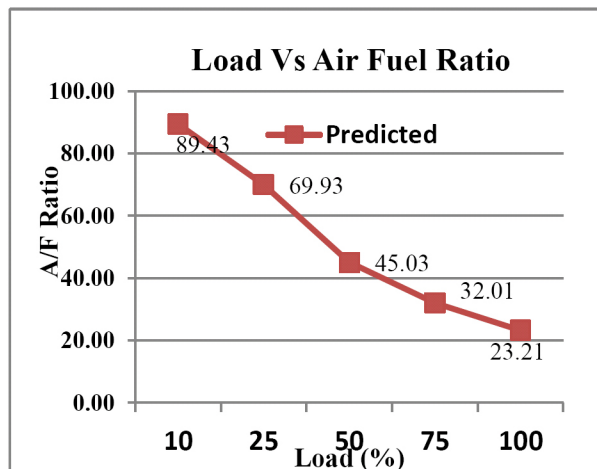
a)



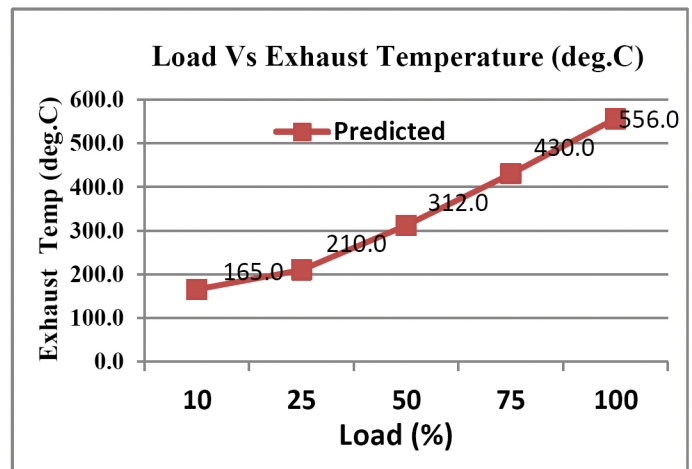
d)



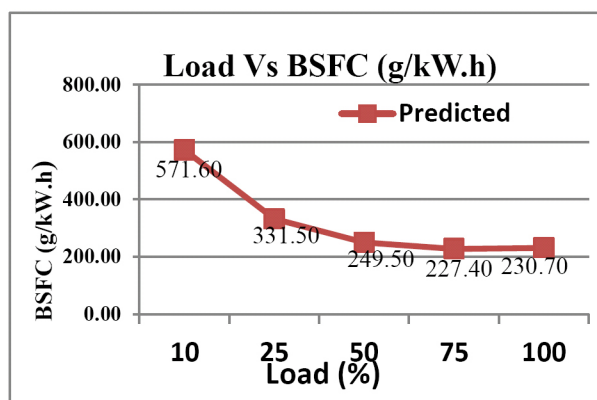
b)



e)



c)



f)

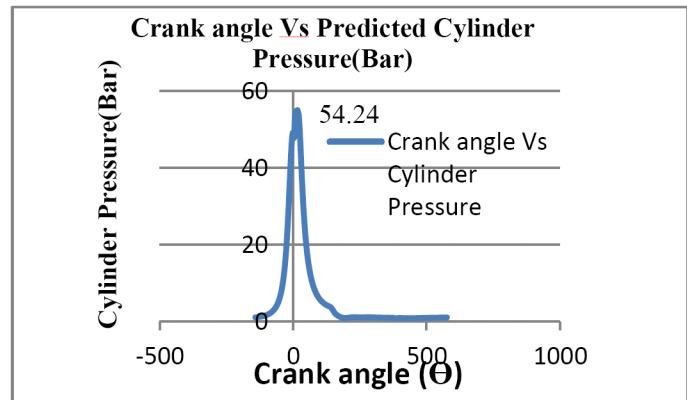


Fig 2. Load Vs Software predicted a) Power, b) A/F Ratio, c) BSFC, d) NO_x, and f) Crank angle Vs Cylinder pressure