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Theoretical Modelling and Experimental Validation of Combustion in DI Diesel Engine by using Diesel -RK

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ABSTRACT-*The transportation industrial sectors, the diesel engines are using predominantly. As the diesel engines are known of its compression ratio, which is responsible for self -ignition of heterogeneous mixture. In this, the cylinder motion and combustion chamber geometry leads to effective combustion process. In this work, an attempt is made to simulate the combustion phenomenon using the DIESEL-RK. This simulation* has been carried out with a modified combustion geometry, on which the experiments were conducted and the simulated values have been compared and validated, for which the error analysis also presented. The experiments are conducted on single cylinder, four stroke direct ignition diesel engine. The experiments are conducted by varying the load at constant rated speed of 1500rpm. The results obtained from simulation are compared with experimental investigations. A good agreement between the modelling and experimental data ensures the accuracy of the numerical predictions. From the results, it reveals that the Diesel-RK software can be one of the reliable CFD software for modelling and simulating combustion of diesel engines.

KEYWORDS-DI, CFD, Diesel-RK, Simulation, Experiments, Combustion

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1. INTRODUCTION

Direct injection diesel engines are an important choice as prime mover in applications like on-road, off road, marine and industrial usage. Fuel is injected into the cylinder and mixed with air in diesel engines. The air-fuel mixture burns under compression ignition. Diesel engine processes shows complex feature compared to any other mechanical equipment. The Direct Ignition diesel engine performance is influenced by in-cylinder fluid dynamics because it contributes to the fuel-air mixing and control of the fuel burn rate. Combustion chamber geometry is one of the most important systems in diesel engine shall be reviewed critically to achieve stable combustion. Developing of full scale engine block even for small change every time is costly affair and time consuming. Also, the complicated combustion processes of engine forces the researchers to simulate the entire systems before the engine block cast. This is the main methodology of engineers and producers to create optimum engines. Combustion research is more extensive, diverse and interdisciplinary due to powerful modeling tools [1-3]. The rapid development of computer technology has encouraged the use of complex simulation techniques to quantify the effect of the fundamental processes in the engine systems. The advances achieved by current automotive engines would have been impossible without the simulation models providing these insights [4-6]. In response, several codes were generated as a companion to experimental work in engine design. These codes are capable of modeling transient, three dimensional, compressible, multiphase flows with chemical reactions by solving the mass, momentum, and energy equations [7-8].

In the present study, Computational Fluid Dynamics tool Diesel-RK is used to model the combustion phenomenon in compression ignition diesel engine. The experiments are conducted on 5.2kw single cylinder, four stroke direct ignition diesel engine. The experiments are conducted by varying the load at constant speed of 1500rpm. The results obtained from simulation are compared with experimental investigations.

2. MODELLING AND SIMULATION

Diesel-RK is a modeling and simulation software specifically developed for thermodynamic engine simulation. DIESEL-RK software is developed in 1981-82 in the department of Internal Combustion Engines (Piston Engines), Bauman

Moscow State Technical University. It is mainly designed for simulating and optimizing the working processes of internal combustion engines with all types of boosting. This software is used for torque curves, engine performance predictions, fuel consumption predictions, emission analysis and optimization of fuel injection profile including multiple injection, sprayer design and location as well as piston bowl shape optimization in models of DI Diesel engines [9]. In the present simulation study, Diesel-RK software is used for calculation of performance and emission values for hemispherical piston bowl in which Diesel is used as fuel. In figure 1 shows hemispherical piston bowl modelled with Diesel- RK.

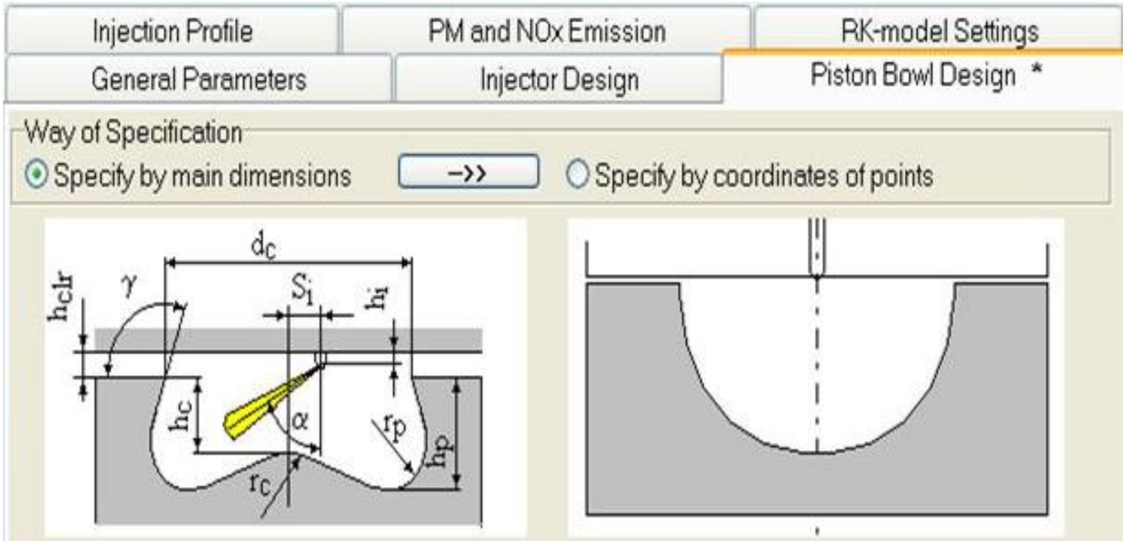

Figure1: Hemispherical Piston Bowl Modelled with Diesel

3. EXPERIMENT

Experimentation is done on a single cylinder, four stroke, vertical, water cooled, direct injection computerized Kirloskar make CI Engine. The specifications of the engine are mentioned in the table 1 and the thermo physical properties of diesel used is shown in table 2. Fig 2 shows the experimental setup of the engine. The engine is attached with a DC electrical dynamometer to measure its output. Smoke measurement is done by using photo electronic smoke detection. Other emissions like Carbon monoxide, Carbon dioxide, Nitrogen oxide and unused oxygen are found in 5 gas emission analyser. The experiments are conducted at different loads like 1,2,3,4 and 5.2kW at constant rated speed of 1500rpm.The engine is warmed up initially and stabilized before taking all the readings. All the readings recorded are replicated thrice to get a reasonable value. The performance parameters such as Brake Thermal Efficiency(ηB.Th.), Brake Specific Fuel Consumption(bsfc), Exhaust Gas Temperature(EGT) and Volumetric efficiency(ηVol.) and emission parameters such as Carbon Monoxide (CO), Carbon Dioxide (CO2) and Nitrogen Oxides (NOx) are evaluated.

Table 1: Engine specifications

Number of cylinders	01
Number of Strokes	04
Fuel	Diesel
Power rating	5.2 KW/7 hp @ 1500 RPM
Cylinder bore & Stroke	87.5 & 110 mm
Compression Ratio	17.5:1
Dynamometer arm length	185 mm
Dynamometer Type	Eddy current
Type of cooling	Water cooled

Figure2: Experimental setup of the test engine

Table 2 Thermo physical properties of Diesel

Property	**Diesel**
Density (gm/cc) at 40^{0}C	0.828
Viscosity (cst)	5.0
Flash point (^{0}C)	57
Fire point (^{0}C)	65
Calorific value (KJ/kg)	42000
Cetane number	50

4. RESULTS AND DISCUSSIONS

The comparison of the results obtained from the experimental investigations and from simulations by DIESEL-RK software are presented in figures from 3 to 10. All the results are analysed by varying the load at rated constant speed of 1500rpm. The simulations are carried out on hemispherical combustion chamber geometry. The simulation results such as specific fuel consumption, mechanical efficiency, exhaust gas temperature, volumetric efficiency, variation of pressure Brake thermal efficiency and exhaust emission CO_2, NOx are showed good agreement with experimental results.

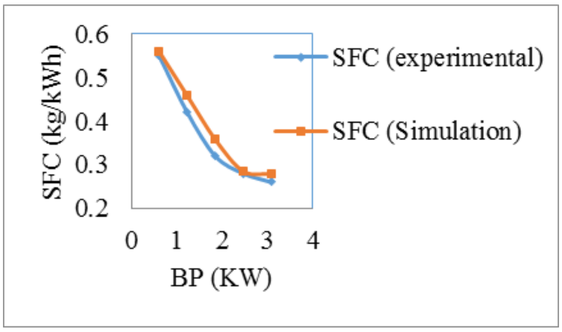

Figure3: Variation of SFC w.r.t BP

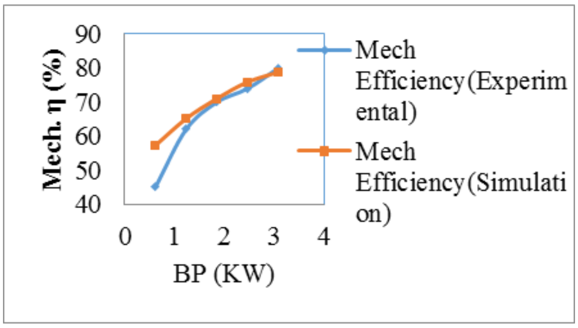

Figure4: Variation of Mechanical Efficiency w.r.t BP

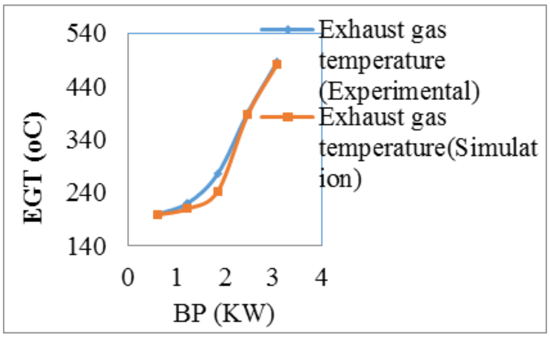

Figure5: Variation of Exhaust Gas temp w.r.t BP

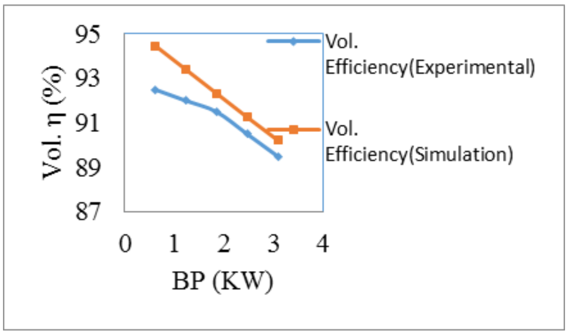

Figure6: Variation of Volumetric Efficiency w.r.t BP

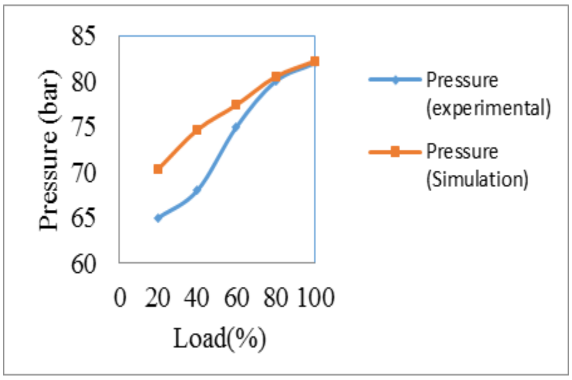

Fig. 7. Variation of Pressure w.r.t % load

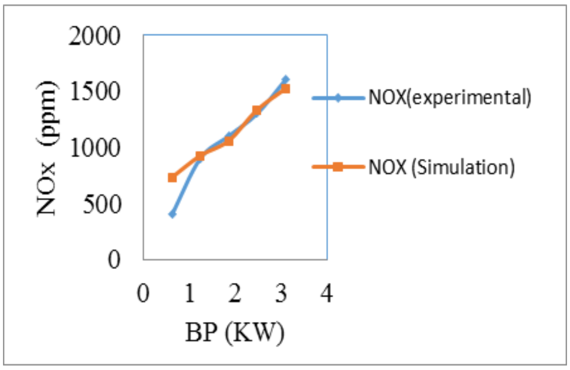

Fig. 8. Variation of NOx w.r.t BP

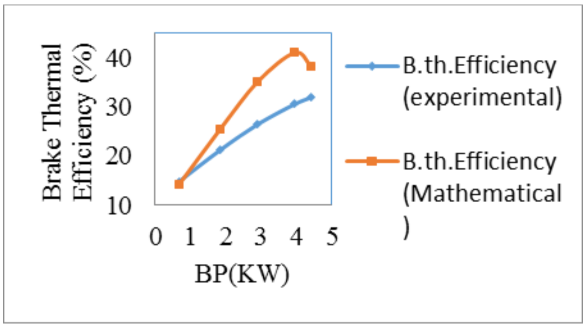

Figure9: Variation of Brake Thermal Efficiency w.r.t Load

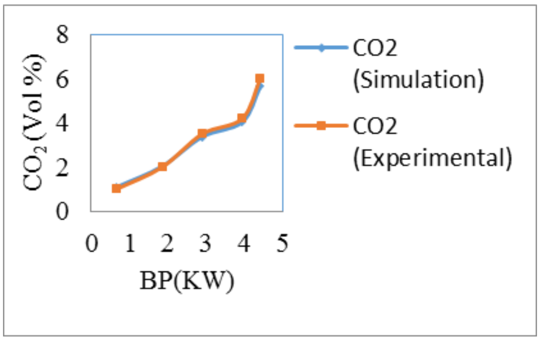

Figure10: Variation of CO_2 w.r.t BP

5. CONCLUSION

The 5.2kW, Kirlosker make single cylinder, four stroke engine is selected for investigation because it can withstand higher pressures and also is used extensively in agriculture and industrial sectors. The DIESEL-RK is used to simulate the combustion characteristics of direct injection diesel engine. The hemispherical bowl combustion chamber geometry is used for model construction. Simulated results including specific fuel consumption, rate of pressure rise, heat release rate, mechanical efficiency, volumetric efficiency and exhaust emission NOx profiles have been analysed. A good agreement between the modelling and experimental data ensures the accuracy of the numerical predictions. The comparison revels that the present model is able to predict the combustion characteristics quire well. From the results, it is concluded that the numerical simulation is one of the powerful and beneficial tool for internal combustion engine development, optimisation and performance analysis instead of developing a new proto type systems and test and evaluate every time which is a cost conscious.

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