Modeling and Experimental Validation of Combustion in DI Diesel Engine through CFD Simulation

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Abstract: *This paper describes the combustion analysis in direct injection (DI) diesel engine. In the present study the Computational Fluid dynamics (CFD) code STAR-CD is used to model complex combustion phenomenon in compression ignition (CI) engine [1]. The experiments were accomplished on single cylinder and DI engine, with full load condition at constant speed of 1600 rpm. Combustion parameters such as cylinder pressure, heat release rate and mass of NO emission with crank angle were obtained from experiment [2]. The results obtained from modeling were compared with experimental investigation. Consequences in terms of pressure, heat release rate and mass of NO are presented. The modeling outcome is discussed in detail with combustion parameters. The results presented in this paper demonstrate that, the CFD modeling can be the reliable tool for modeling combustion of internal combustion engine.*

Keywords: *CFD, DI, combustion modeling, pressure, heat release rate, NO, simulation.*

1. Validation of CFD Code

The purpose of the validation of the CFD code is being used in this work. It is proposed to compare the results predicted through CFD simulation with experimental results.

Since, the experimental facilities available are not enough to measure in-cylinder fluid parameters, the experimental results available in literature has been used. The experimental results of a four stroke single cylinder DI diesel engine with Mexican Hat Bowl piston is being used for validation of the predicted capability of the CFD code [3]. CFD simulations were performed for the same engine and injection details are compared with experimental engine. And the injection details used in the simulation study are given in table 1 Fuel and Injection details are given in table 2

Comparisons are drawn between the experimental and predicted results based on the global parameters such as Pressure vs. Crank angle, Heat Release Rate vs. Crank Angle, and Mass of NO vs. Crank Angle formations.

TABLE: 1 Engine Details

Bore	137.19 mm
Stroke	165.10 mm
Connecting rod length	261.62 mm
Piston bowl	Mexican Hat Bowl(MHB)
Engine speed	1600 rpm

TABLE: 2 Fuel And Injection Details

Fuel	Diesel
Number of nozzle holes	6
Nozzle hole diameter	0.259 mm
Fuel injected (g/cycle)	0.1622
Injection duration (CA)	21.5
Start of injection (CA)	9 bTDC

2. Presentation of Results

It is important to study the in-cylinder fluid dynamics during the later part of combustion and initial part of expansion strokes in a diesel engine as the fuel injection, fuel-air mixing, combustion and pollutant formation takes place during this period only. Hence the present analysis is considered from 40^0 before TDC during compression stroke to 80^0 after TDC during the expansion stroke so as to include fuel injection, combustion and subsequent emission formation stages, as these are the crucial stages of DI diesel engine operation [5].

3. Comparison between Experimental and Predicted In-Cylinder Pressure with Crank Angle

The comparison of experimental and predicted pressure as shown in figure.6.1.The variation of in-cylinder pressure with crank angle is presented during compression stroke and expansion strokes. Pressure variation may be due to the greater ignition delay during combustion. The increase in ignition delay causes the combustion to continue even after the piston crosses TDC towards expansion stroke, resulting in lower difference in peak pressures, may be by blow-by and crevice flows. The pressure variation is studied from 40° before TDC in compression stroke to 80° after TDC in expansion stroke. In predicted curve a smooth rise is due to compression is noticed from 40° before TDC to 30° before TDC during compression stroke [6].

Figure: 1 shows the pressure rise with experimental model is noticed to be almost same 20 bar to be 38 bar. A rapid pressure rise in the predicted curve after TDC for a short span is noticed. The experimental peak pressure is slightly lower than that of a predicted model.

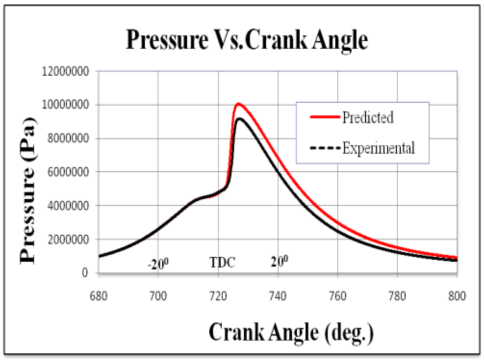

Fig: 1 Comparison of experimental and Predicted In-Cylinder Pressures

However they are comparable to the peak pressures which are noticed 99.7 bar in the case of predicted and 90 bar in the case of experimental. 20° after TDC in the expansion stroke the peak pressures are noticed. In both predicted and experimental the peak pressures are gradually decreased, but they are not following in the same path. The predictions made with this model are found to be closer to the experimental values [7].

4. Comparison between Experimental Predicted Heat Release Rate Variations with Crank Angle

Variation of heat release rate with crank angle predicted with experimental results are shown in figure: 2

The heat release in the combustion chamber is due to the combustion of fuel. Heat releases are noticed to be similar between 35° before TDC to 20° before TDC. And it is also observed that in the case of predicted model it is 47.9 J/Ca at about 5° after TDC [8]. Whereas in the experimental heat release rate 39 J/Ca is noticed. From the above discussions it is concluded that the predicted model is better than the experimental values in the case of experimental heat release rates are almost 20% lower than that of predicted model [9].

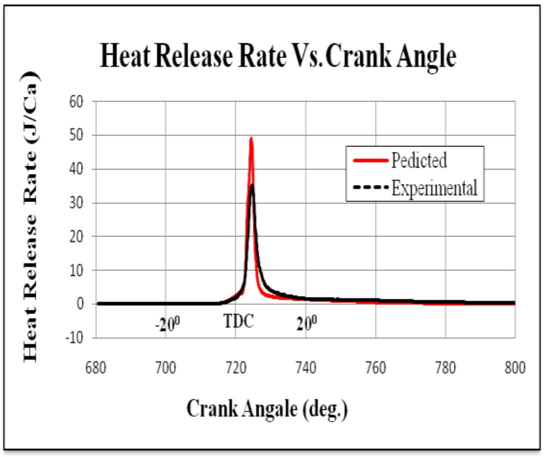

Fig: 2 Comparison of Predicted and Experimental Heat Release Rate

Accordingly it can be concluded that rapid-combustion phase is suppressed and mixing-controlled combustion phase is enhanced [10].

5. Comparison between Experimental and Predicted Model No Emissions

Figure: 3 present the predicted model and experimental Mass of NO emission vs. crank angle.

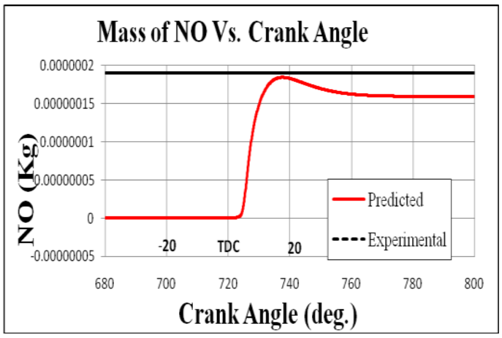

Fig: 3 Comparison of Predicted and Experimental NO Emission

The experimental value of mass of NO emission is 1.85 mg and the predicted value of mass of NO emission is 1.72mg. It is clear that the predicted results are comparable to the experimental results [11]. There is higher experimental value of NO emission may be due to the oxidation of nitrogen which is present in the fuel. This is used for future predictions.

6. Conclusion

To simulate Diesel injection and combustion the CFD code STAR-CD has been used for diesel spray. The model implemented in STAR-CD code for spray orientation was validated by comparison to publish experimental data. A good agreement between the predicted and experimental values ensures the accuracy of the numerical predictions collected with the present work. The results reported in this paper illustrate that the numerical simulation can be one of the most powerful and beneficial tools for the internal combustion engine design, optimization and performance analysis.

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