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CFD Studies of Split Injection on the Combustion and Emission Characteristics in DI Diesel Engine

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ABSTRACT
In this study, the effect of split injection on the combustion and emissions in DI diesel engine is investigated using CFD tool .One of the important problems in reducing pollutant emission from diesel engines is trade-off between soot and NOx. Split injection is one of the most powerful tools that decrease soot and NOx emissions simultaneously. Split injection is defined as splitting the main single injection profile in two or more injection pulses with definite delay dwell between the injections. A four-stroke, single cylinder, diesel engine was taken into consideration at constant speed conditions . A model was developed for comprehensive predictions and assessments for variations in combustion phenomenon for DI diesel engines . By using the finite volume method the design and analysis of combustion chamber,emission characteristics were studied. The results of the split injection were compared with single injection and the optimum case of split injection was observed.
***Keywords*–**SplitInjection,CFDtool,DIdieselengine,Emission,Optimumsplitinjection

I. INTRODUCTION

One of the important problems in reducing pollutant emission from diesel engines is trade-off between soot and NOx. Split injection is one of the most powerful tools that decrease soot and NOx emissions simultaneously. Stringent exhaust emission standards require the simultaneous reduction of soot and NOx. However it seems to be very difficult to reduce NOx emission without increasing soot emission.. The aim is to model and analyse the combustion and emission in an internal combustion engine using CFD tool (Fluent, ANSYS 14.5 package) .The split injection effect on the combustion process and emissions of a DI engine is investigated by the CFD Fluent tool..By using the finite volume method the design and analysis of combustion chamber, emission characteristic study is done for 6 different cases of split injection and comparing the results with the single injection case .

II. PROCEDURE IN COMPUTATION

The combustion simulation of compression ignition engine was developed using Fluent software (ANSYS 14.5 package) and the various equations of the multi-dimensional model were solved by the software automatically . The main inputs include engine speed, injection details of single injection, bore, stroke, connecting rod length, initial pressure and temperature[1]. Then the same procedure is repeated for 6 different split injection cases .The program concerning the simulation model predicts the cylinder pressure, cylinder temperature, emission etc. The results including graphs and various contours (NOx,Soot etc) were generated by Fluent software .

III. DEFINITION OF MODEL

A 3D cylinder geometry with centrally located injector was considered .The mesh was created using ANSYS Workbench.The engine geometry details and specification details are given below. . A hexadominent mesh was created uniformly throughout the area and analysed using FLUENT, ANSYS 14.5 package. The complete meshed geometry contains 19722 faces and 48432 nodes.
Fig.1 Shows the meshed geometry of the cylinder.

Connecting rod length :140 mm
Bore :80 mm
Crank radius :55 mm
Crank shaft speed :1500 rpm

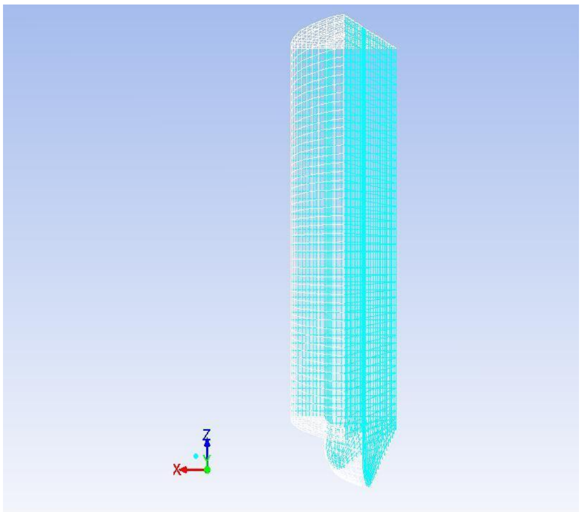


Fig.1 Meshed Geometry of the cylinder.

IV. MODELING TURBULENCE

Turbulent flows are characterized by fluctuating velocity fields. These fluctuations mix transported quantities such as momentum, energy, and species concentration, and cause the transported quantities to fluctuate as well. Since these fluctuations can be of small scale and high frequency, they are too computationally expensive to simulate directly in practical engineering calculations. Instead, the instantaneous (exact) governing equations can be time-averaged or otherwise manipulated to remove the small scales, resulting in a modified set of equations that are computationally less expensive to solve. However, the modified equations contain additional unknown variables, and turbulence models are needed to determine these variables in terms of known quantities. In this analysis standard k-ε model[1] is used.

V. BOUNDARY CONDITIONS

The boundary conditions should be given after modeling the geometry .In the analysis viscous standard k-e model is enabled for considering eddy dissipation,ie species transport model. The injection parameters and specifications are given below

X-position :0.50038 mm
Y- velocity :468 m/s
Diameter :0.287 mm
Temperature :341 K
Flow rate :0.001044 kg/S
Start crank angle :355 deg
Stop crank angle :377deg

Mainly 6 types of split injection cases are considered. They are 85%,5-15%,90%-5-10%,95%-5-5%,85%-10-15%,90%-10-105,95%-10-5%.In the 85%-5-15% split injection case ,85% of the total fuel is injected at first and remaining 15% of the fuel injected at a crank angle difference of 5 deg. All the other properties will be the same as in the single injection case.

VI. RESULTS AND DISCUSSIONS

1.**Combustion Characteristics** .

The combustion characteristics for the single injection and for all the 6 split injection cases were done.And the values of peak pressure and the temperature was approximately equal to the theoretical values.

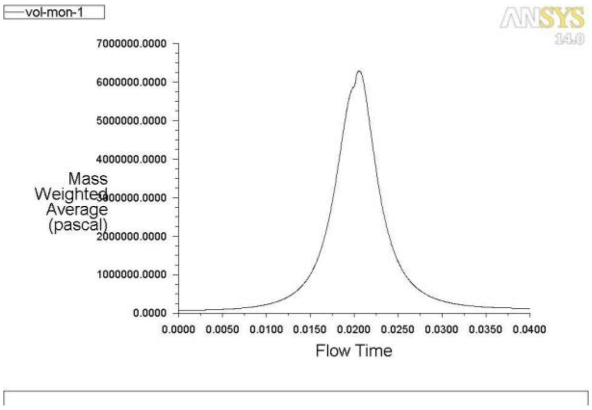


Fig. 2. Pressure v/s Flow time

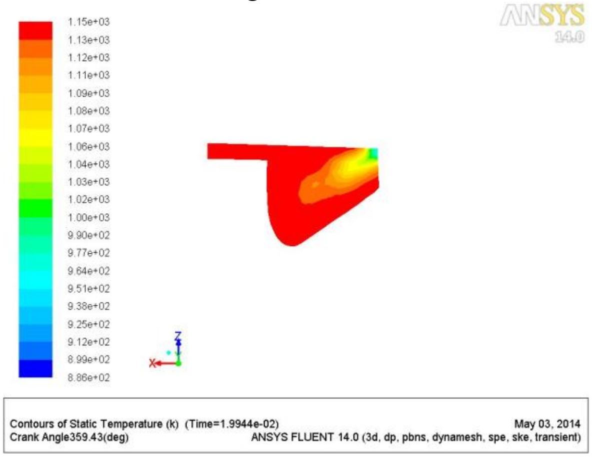


Fig. 3. Temperature contour

2.EMMISION CHARACTERISTICS

NOx and soot emission characteristics were obtained for the split injection cases .The obtained results were compared with the single injection case.The NOx and soot emission for the single injection contours are shown in the Fig.4.

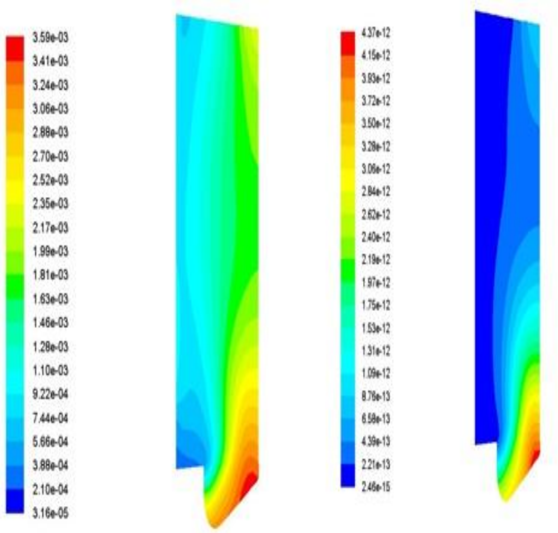


Fig. 4. NOx and soot contour-single injection

The reduction in NOx and soot emission was found less in the 85%-5-15% and in 90%-10-10% respectively. Fig 5 shows the contours of both the cases. The NOx and soot emission were plotted against the Crank angle and compared it with the single injection which is shown in the Fig.6..Then the optimum split injection case,ie the highest average reduction is calculated from all the split injection cases which is tabulated in the Fig .6.

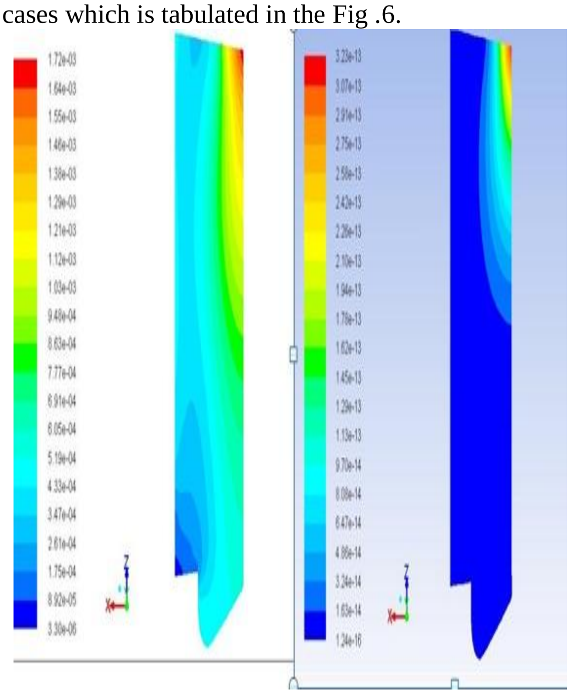
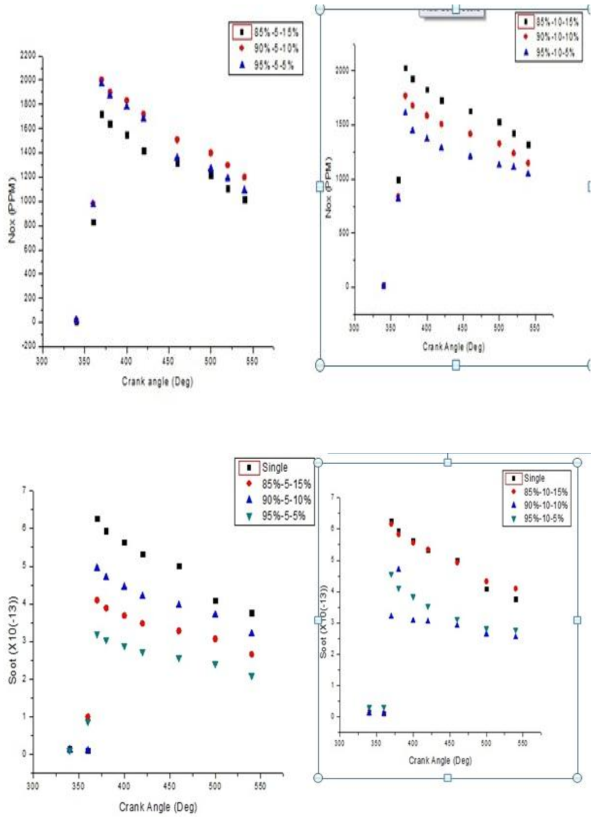


Fig. 5. NOx (85%-5-15%) Soot(90%-10-10%)contour



Details	Nox(PPM)	SOOT(e-13)	Nox reduction	Soot Reduction	Average Reduction(%)
Single Injection	2170	6.27	0	0	0
85%-5-15%	1720	4.1	0.207	0.346	27.67
90%-5-10%	2000	4.95	0.078	0.210	14.45
95%-5-5%	1970	3.21	0.092	0.488	29.01
85%-10-15%	2030	6.16	0.064	0.017	4.1
90%-10-10%	1770	3.2	0.184	0.489	33.69
95%-10-5%	1610	4.56	0.258	0.273	26.53

FIG. 6. COMPARISSION OF EMISSION CHARACTERISTICS

VII. CONCLUSION

At the present work, the effect of the split injection on combustion and pollution of DI diesel engines was studied by the CFD tool. The target was to obtain the optimum split injection cases for these engine in which the total exhaust NOx and soot concentrations are the lowest .Three different split injection schemes, in which 5, 10 and 15% of total fuel injected in the second pulse, was considered. The delay dwell between injections pulses is varied from 5°CA to 10° Crank angle. Use of CFD tool has shown reliable results by saving cost, time and material.

The results are as follows.

- The calculated combustion and performance parameters, exhaust NOx and soot emissions for the single injection case showed a good agreement with the corresponding theoretical value.

- The lowest NOx and Soot emissions are related to the 85%-5-15% and 90%-10-10%cases respectively. Finally, optimum case was 90%-10-10% regarding the highest average of NOx and soot reduction

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