CFD Simulation in Direct Diesel Engine with Different Combustion Chamber for NOX Reduction

G. Shiva Kumar[1] R. Hanuma Naik[2] S. Amith Kumar[3]
[1,2,3]Department of Mechanical Engineering
[1,2,3]St.Martin's Engineering College, Secunderabad, India

Abstract— Direct Injection (DI) diesel engines have taken a prominent place in public and private transport. Emissions of the diesel engine emissions Carbon monoxide (CO), Hydro Carbon (HC) have been effectively controlled with improvement in engine design. However Nitrogen Oxides (NOX) and soot are still a matter of concern for the engineers. The main objective of the present work is to reduce NOX emission in DI diesel engines. In this work, an attempt is made to the influence of engine operating parameters on Nitric Oxide (NO) emissions using a Computational Fluid Dynamic (CFD) code. STAR-CD, a 3-dimensional (3-D) CFD code based on finite volume method has been used for this purpose, which is capable of solving 3-D unsteady turbulent flows, sprays and combustion of IC engines. A four-stroke single cylinder Compression Ignition (CI) engine fitted with spherical bowl-in-piston for which CFD analysis carried. Though CFD code has the capability to solve complex in-cylinder fluid problems it is always necessary to validate output results of the code. Finally simulation analysis is extended to various engine parameters that influence on NO formations. In this sequence, first the effect of piston bowl configurations on in-cylinder fluid dynamics and pollutant formations are studied.

Keywords: Combustion, NOX, CFD, Diesel-Engine, emissions

I. Introduction

Diesel engine has better efficiency as compared to petrol engines due to the higher compression ratio. Diesel fuel is better lubricant than gasoline, so, is less harmful to the oil film on piston rings and cylinder. Diesel engine produces very little excess carbon dioxide as it burns the fuel in excess air even at full load. In general diesel engines are low speed engines. Hence, it runs cooler than petrol engines do and less maintenance. Its use in applications of the transport sector is firmly established. Increase in automotive exhaust pollution and fuel prices have driven the nation to impose stringent emission norms for automotive industry. This has prompted the researchers to improve power densities, which simultaneously minimize the exhaust emissions of diesel engines. Nowadays, the magnitude of pollution is increasing in such way that it is not only threatening the health and wellbeing of the world population in urban areas but also affecting global scale ecology. The phenomenal growth of energy consumption in the world, especially in the advanced and developing countries has considerably increased the problem of air pollution. The automotive vehicles and industrial power units using IC engines are major contributors to this problem.

If the combustion is complete and perfect inside the cylinder, the exhaust will be a mixture of carbon dioxide CO_2, water Vapour H_2O, nitrogen and oxygen (due to excess air). None of these products are toxic in nature. Also when combustion is complete (usually with excess air) no smoke or particulate matters are produced. But combustion process that takes place in IC engine is never perfect or complete as a result, products that are formed have undesirable properties. These products are considered to be pollutants when they come out during exhaust process.

II. Literature Review

There is a great deal of literature available on engine studies. The literature on this work is summarized in the following pages. In the DI diesel engine, the effect of combustion was greatly influenced by the inductive web and piston bowl configuration. As the combustion control mechanism in a diesel engine is heterogeneous in nature, its performance and contaminant formation increase significantly. Better knowledge of fluid dynamics, combustion and fuel sprays can help to address difficult problems such as the fuel economy and the creation of pollutants. In the past there have been accounts of several experimental, CFD plays. Criticism of the literature available The following section covers the shapes of the piston tank, the in-cylinder flows, the spray of fuel and the EGR effect. Because of their highly efficient transient actions and the ability to develop modular systems, large engines become more critical for grid stabilisation with greater use of renewable energy sources (solar or wind). [1]. According to a recent study[2], big motors will also play an significant role in the transport market, which is three times as long as 2050. While electricity production will mainly be assisted by gas motors[3], diesel motors will continue to dominate the transport (maritime, rail) market. Representing 80% of transportation administrations around the world, the marine division specifically is going under expanded weight and needs to make up for lost time to land-based applications as far as discharge limits [4,5]. Low outflow gas motors are supported as an answer for meet the exceptionally tough discharge prerequisites for marine applications. This requires further development of the gas foundation; as of late a lot of examination into liquefied flammable gas has been attempted [6]. Other than standard gas and diesel ignition ideas, completely flexible double fuel ignition ideas that can consume diesel and gas all the while have likewise gotten set up in the enormous motor segment as of late. Versatile applications, for example, marine or rail footing just as fixed applications, for example, generator sets for power age are accessible with double fuel burning frameworks [7–9]. Be that as it may, today double fuel innovation is utilized essentially in the marine segment as an outcome of the at present ominous advancement in the cost of petroleum gas contrasted with the cost of unrefined petroleum [10].

III. EXPERIMENTAL WORK AND ANALYSIS

The presentation of a diesel motor depends to an enormous degree on the state of the burning chamber. It is commonly acknowledged that the most productive ignition chamber configuration would give in any event, consuming every which way. Ignition chamber geometry essentially impacts the in-chamber liquid elements, fuel-air blending and resulting burning procedures and fumes discharge arrangements. Consequently, it is essential to contemplate the impact of cylinder bowl design on these attributes. Computational liquid powerful investigation is completed, at first, to show up at the most appropriate bowl arrangement among the chose three well known cylinder bowls. Three-cylinder bowl-arrangements considered are (I) Hemi-round Bowl (HSB), (it is an ordinary model which has precisely 50% of the circular depression at the center of the cylinder). (ii) Toroidal Bowl (TB), (it has a sharp cone at the center of the cylinder bowl, it makes the toroidal shape depression in the cylinder bowl) (iii) Central Squish-lip Bowl (CSLB), (state of the CSLB is chosen in such manner that the crunch lip is set at the center of the sidewalls of the bowl which is relied upon to upgrade crush impact in the in-chamber liquids). The geometry highlights of the three dishes viable are talked about in the accompanying segment.

The dimensional details and its 3-D computational mesh of the three piston bowl configurations considered Line diagram and 450 Sector 3-D Computational Mesh for HSB at TDC.

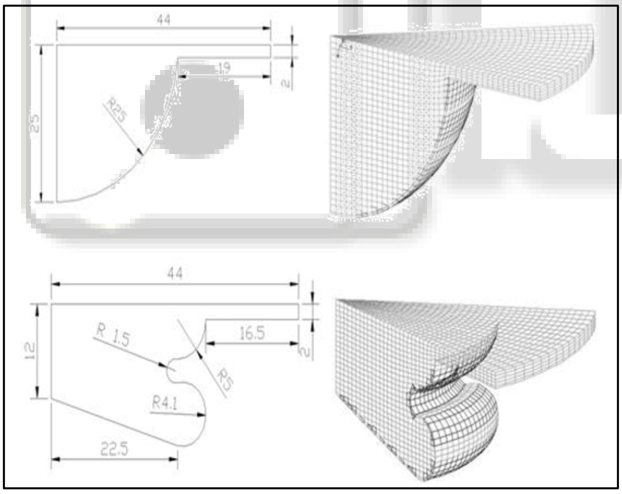

Fig 1: Line diagram and 450 Sector 3-D Computational Mesh for CSLB at TDC

A. Effect of Piston Bowl Configuration on Heat Release Rates

In diesel motors, the burning procedure continues in three discernable stages, after the underlying start postpone period. In the principal stage, the pace of consuming is commonly exceptionally high and goes on for just a couple of wrench point degrees. It compares to the time of fast chamber pressure rise, and this stage is named as "premixed or quick burning stage". The subsequent stage compares to a time of bit by bit diminishing warmth discharge rate. The third stage compares to the "tail" of the warmth discharge, with a little yet Distinguishable pace of warmth discharge perseveres in the extension stroke, and this is named as "late ignition stage".

IV. RESULTS

The implementation schedule of European Union emission standards in India is summarized in table I, II & III.

Emission Norms for Passenger Cars

Norms	CO (g/km)	HC+NOx (g/km)
1991 Norms	14.3 – 27.1	2.0 (only HC)
1996 Norms	8.68 – 12.40	3.00 – 4.36
1998 Norms	4.34 – 6.20	1.50 – 2.18
India Stage 2000 Norms	2.72	0.97
Bharat Stage – II	2.2	0.5
Bharat Stage – III	2.3	0.35(combined)
Bharat Stage – IV	1.0	0.18(combined)
Source: www.cpcb.nic.in (Central Pollution Control Board)		

Emission Norms for Heavy Diesel Vehicles

Norms	CO (g/km)	HC (g/km)	NOx (g/km)	PM (g/km)
1991 Norms	14	3.5	18	-
1996 Norms	11.2	2.4	14.4	-
India Stage 2000 Norms	4.5	1.1	8.0	0.36
Bharat Stage – II	4.0	1.1	7.0	0.10
Bharat Stage – III	2.1	1.6	5.0	0.10
Bharat Stage – IV	1.5	0.96	3.5	0.02
Source: www.cpcb.nic.in (Central Pollution Control Board)				

Emission Norms for 2/3 Wheeler

Norms	CO (g/km)	HC + NOx (g/km)
1991 Norms	12.30	8 – 12 (only HC)
1996 Norms	4.5	3.6
India Stage 2000 Norms	2.0	2.0
Bharat Stage – II	1.6	1.5
Bharat Stage – III	1.0	1.0
Source: www.cpcb.nic.in (Central Pollution Control Board)		

V. CONCLUSIONS

The techniques that are employed in reduction of exhaust gas emissions are use of catalytic converters, modifications in the engine designs that include piston bowl shape, fuel injection strategies, and inert gas circulation Reduces NOx from a CI engine, the chemical composition of the exhaust gas must first be changed. Two main techniques used to reduce NOx emissions are (i) Selective catalytic reduction (ii) NOx traps. Selective catalytic reduction is a means of converting nitrogen-oxides, also referred to as NOx with the aid to a catalyst into diatomic nitrogen and water.

– optimized gas motion within the engine cylinder that controls the fuel-air mixing and combustion process
– dilutions of in-cylinder fluids with exhaust gas recirculation that minimize the NOx engines.

– Engine researchers are attracted towards modeling techniques to predict the in-cylinder fluid dynamics

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