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Study of Natural Gas Engine using non-premixed combustion model

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Abstract

Direct injection natural gas engines are used in many heavy duty vehicles. Similar to diesel engines, high thermal efficiency and power density is maintained in such direct injection natural gas engines. In such engines, natural gas is injected directly into the combustion chamber. Then the gas mixes with the high pressure air in the combustion chamber and combustion occurs. The main objective is to simulate a cycle, from the end of the compression stroke to 50° after TDC. Simulation would be done keeping methane as fuel. A 30 degree sector of a 4-stroke engine which corresponds to one fuel injector hole is modeled. Since combustion simulation is to be studied, the simulation starts at 20 degree crank angle (CA) before the start of injection (SOI) and ends at 50 degree CA after top dead center (TDC). A simplified model of the engine with no valves is modeled since during the entire combustion process, both the valves remain closed.

1. Geometry and Mesh Generation

Dynamic meshing method is used for meshing the combustion chamber. For efficient meshing the combustion chamber is decomposed in several zones. The principle of decomposition is to divide the complicated combustion chamber into several different zones with either simpler geometry or less mesh movement. That is, in some zones, the geometry is complicated, but the mesh will not move much during the computation process. The mesh in those zones is much easier to handle. Once the mesh is generated with fair quality, the mesh will stay in such way though out the entire computational process. For zones with moving boundaries, the geometry is made to be simple such as between two parallel surfaces. The mesh in those zones is not only easy to generate but also the mesh is easy to manage during the piston and valve moving process. The makes the re-meshing process much more robust, efficient, and reliable. With the division, the complex geometry of the entire chamber is broken down into four much simpler geometry, the ports, the head zone, the cylinder zone, and the bowl-in-piston zone. [1] Because of large movement of piston, must use a kind of mesh that able to be swept when piston moves up and again generate when piston moves down. For this part hexahedral elements are used while for part where valves move tetrahedral elements are used. [2]
There are three methods to update the meshes of a moving boundary:

- Smoothing
- Layering
- Re meshing

In the present work a 30° sector of a combustion chamber having bore of 120mm and stroke of 220mm with one injector is modeled. Since combustion simulation is to be studied, the simulation starts at 20° crank angle before injection and 50° crank angle after top dead centre. A simplified model of combustion chamber with no valves is modeled since during the entire combustion process, both the valves remain closed. This way the geometrical complexity of piston head is simplified and is thus easier to mesh. Four dynamic mesh zones are defined namely

- fluid-outer
- bowl
- bowl:019
- wall top outer

Layering methods is used for dynamic meshing of the moving piston boundary. Height based layering method is used with split factor of 0.4 and collapse factor of 0.1. To define an initial volume and to describe the motion of moving zones In-Cylinder motion is described with table 1 parameters.

Table 1 Input parameters

Parameter	Value
Crank Shaft Speed (rpm)	2000
Starting Crank Angle (deg)	360
Crank Period (deg)	720
Crank Angle Step Size (deg)	0.25
Piston Stroke (mm)	120
Connecting Rod Length (mm)	220
Piston Stroke Cutoff (mm)	0
Minimum Valve Lift (mm)	0

2. Result and Discussion

An IC engine performance was characterized by measuring the profiles of in-cylinder CH_4 mole fraction and temperature variations during engine cycle. During the measurements, significant variations in the selected parameters were observed within the combustion chamber. This comparison provided the baseline information for the selection of an appropriate kinetic model (mechanism) of oxidation of natural gas in IC engine. The mesh generated is

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as shown in figure 2. The simulation was done with the following fuel charge mixture as described Table 2.

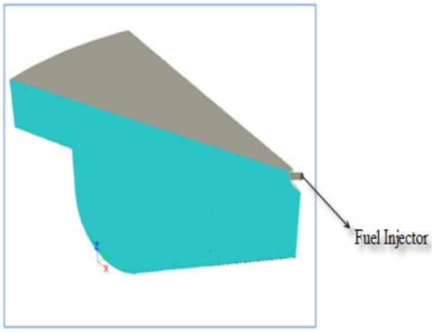

Fig. 1: Sector Geometry of a Direct Injection Natural Gas Engine

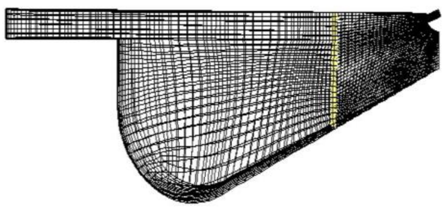

Fig.2 Mesh

Table 2 Fuel composition

Species	Fuel	Oxid
ch4	1	0
n2	0	0.78992
o2	0	0.21008

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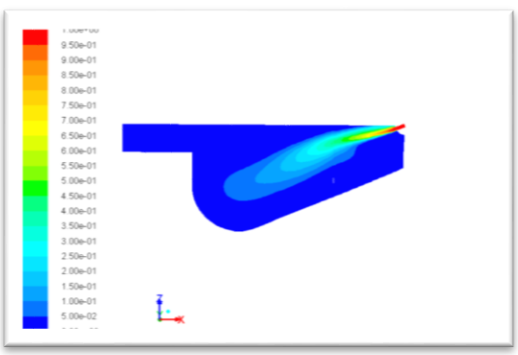

Fig. 3 Contours of CH4 mass fraction (10° after SOI)

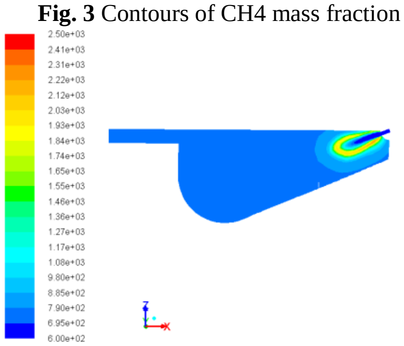

Fig. 4 Static Temperature (1.25° after ignition)

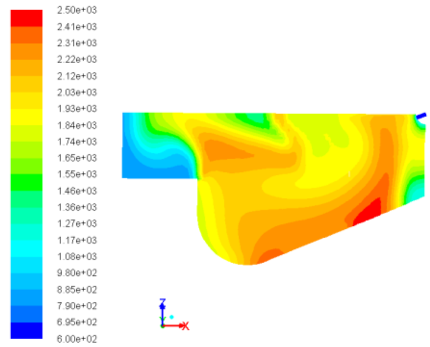

Fig. 5 Static Temperature (30° after ignition)

The simulation is started from 20° before the start of injection and ends at 50° after top dead center. No valves are modeled because the valves are closed between these crank angle periods.

3. Conclusions

The combustion characteristics of a natural gas engine was completed and the presented CFD based computational approaches can strongly contribute to improve the performance, efficiency and emissions of the combustion chambers beside allowing possibilities for investigating the effect of alternative fuels concerning the expected goals and taking care for the requirements and standards.

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