Design And Cfd Analysis Of Combustion Chamber In IC Engine

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Abstract. Internal combustion engines are applicable in automobile and industrial applications. The main issue in internal combustion engines is lack of enhancement in heat transfer. Primarily heat transfer depends on charge supplied in combustion chamber. Design of combustion chamber done by Creo parametric software as per engine specifications with selective biofuels can improve the heat transfer. Current work investigates Computational fluid dynamic (CFD) analysis on flow of fluids (ethanol, methanol, ethylene, propyl and gasoil) in combustion chamber made with materials steel and cast iron. The analysis helped in study of flow behavior. The flow is properly evaluated into chamber by inlet manifold. From the results heat transfer rate is maximum for propyl fluid. This enhancement is achieved by passing the fluid through inlet manifold considering minimum operating engine specifications and extremely increases the complete combustion. Thermal analysis was performed on combustion chamber made with dissimilar metals steel and cast iron to determine the temperature distribution and heat flux.

Keywords: Combustion chamber, fluids, heat flux, heat transfer, thermal analysis.

1. Introduction
Internal Combustion engines are generally refers to reciprocating, rotary engines. The combustion takes place inside the combustion chamber which generates higher temperature and pressure, this makes expansion of gases due to charge. P. Gurusamy, et al [1] investigated experimentally on internal combustion engine, designed the inlet manifold through CFD. Analysed the flow behavior through inlet manifold. Recommended to make modifications in the flow behavior to enhance heat transfer. Created a tumble flow for efficient combustion at maximum engine speed. Tomas Zadravec, et al [2] used coupled modeling approach in designing the air staged combustion chamber in boiler. CFD simulation is used for validation for modification of energy grate fired boilers to determine the parameters which is processed for fuel conversion model boilers. Concluded the gas temperature inside combustion chamber has accurate forecast by relying on measurements. Arka Ghosh [3] worked on the requirements of combustion chamber in designing for complete combustion. Given essentials on effects of combustion chamber design with innovate technologies in engine. If fuel varies the power should be generated through combustion process only. Even used high technology engine the combustion is meant for combustion of fuel only to generate power. Nagasundaram.S and Nester Ruban.J [4] investigated on emissions and efficiency of CI engine to reduce Nox emissions with the
influence of air swirl combustion process. By using CFD on diesel engine which is 4-stroke unique configuration on pistons. Calculated the performance parameters like turbulent kinetic energy and heat dissipation. Sourabh N Mahandrakar and Chandan K R [5] worked on hybrid engine by compressed air with gasoline. Modified 4 stroke IC engine to 6 strokes, accomplishing this task by UG-NX, Ansys and CFD. First 4 strokes incorporated by combustion process, remaining by compressed air. Revealed that overall efficiency of 60-70% and thermal efficiency of 35-40% has improved by hybridization. Abdul Siddique, et al [6] presented the geometry of combustion chamber which deals with efficiencies in IC engine, investigated on mini patered IC engine for agriculture purpose. Compared the results on mini patered diesel engine with baseline records. Concluded that turbulent impact is more than baseline geometry.Gloria Boafo, et al [7] improved the performance of combustion chamber made with materials like aluminum, ceramic, and mild steel in cook stove. Improved parameters like specific fuel consumption, efficiency individually with three different material combustion chamber. Concluded ceramic made stove is the preferred material and worked on thermal mass reduced by air fuel ratio by providing insulation. P Abhilash, et al [8] done the experimental investigation on solar driven water pump and studied the power- voltage characteristics of solar panel. Increased the efficiency of pump with silicon material panel according to power demand. P. Abhilash and R Nanda kumar [9] numerical investigation on carburetor diameter in variation of size. Done the CFD analysis on flow of fluid for flow behavior and thermal analysis on different materials. P. Abhilash, et al [10] selected hair pin heat exchanger model for thermal analysis on aluminum and titanium carbide nanofluids. Thermal analysis on silver and copper materials. Provided better heat transfer coefficient values on suitable fabricated material with titanium nanofluid as flowing fluid. N Rajashekar Reddy, et al [11] experimental investigation on enhancement of heat transfer in radiator with aluminum nanofluid. Enhanced 13% of heat transfer with nanofluid compared to water as coolants in radiator. Analyzed the size of nano particle with help of X Ray diffraction method. P Abhilash, et al [12] designed the radiator with fixed and helical channels with different types of fluids, done the CFD analysis of each fluid individually in Straight tube and helical tube and properties and fluids are taken as an input for analysis for improvement of better heat transfer rate.

Current article deals with the heat analysis of combustion chamber performance using computational fluid dynamics at different velocities. Present investigation analyzed different types of fluids with two materials, steel and cast-iron. However, no study had been undertaken with materials steel and cast iron with different fluids, which relates to the thermal behavior. So in this research article we had made an attempt with different working fluids in engine to investigate better fluid for heat transfer enhancement. Thermal analysis was performed by CFD used for calculating temperature profile and heat distribution on materials. Results indicate maximum heat flux material is steel compared with cast iron. At 120m/s velocity propyl is the fluid to flow for better heat transfer coefficient.

2. Methodology:
2.1 Materials Used:
Materials used are steel and cast iron for thermal analysis with different fluids to enhance the heat transfer coefficient at suitable flowing fluid.

2.2 Properties of Fluids:
Current study involved fluids like Propyl, Ethanol, Gasoil, Ethylene and Methanol. To proceed with experimentation fluid properties has to be validated for application in CFD. Properties for fluids like density, specific heat, thermal conductivity and viscosity as shown in table.1 in order to analyze the thermal behavior at different materials like steel and cast iron. Property of fluids is analyzed using Ansys.
2.3 CFD Analysis:
CFD technique is used to research the flow of fluid in combustion chamber through Ansys for different fluids. Suitable parameters were focused like pressure, velocity, heat transfer coefficient, heat and mass flow rate on each fluid individually at 120 m/s and 150 m/s velocity as shown in table 2 and table 3.

2.4 Thermal Analysis:
To investigate the thermal stability at different materials steel and cast iron by performing the analysis with temperature distribution at minimum and maximum range along with heat flux. Thermal analysis results on both materials are shown in table 4.

| Fluid   | Thermal conductivity (W/mK) | Specific heat (J/kg-K) | Density (Kg/m$^3$) | Viscosity (Kg m/s) |
|---------|----------------------------|------------------------|--------------------|--------------------|
| Ethanol | 0.0207                     | 1731                   | 1.263              | 0.00000929         |
| Methanol| 0.203                      | 1470                   | 735.5              | 0.98               |
| Ethylene| 0.253                      | 845                    | 729.54             | 0.48               |
| Propyl  | 0.0332                     | 2222                   | 0.6679             | 0.00001087         |
| Gas oil | 0.167                      | 2437.08                | 789.24             | 1.195              |

| Velocity (m/s) | Fluid   | Pressure (Pa) | Velocity (m/s) | Heat transfer coefficient (W/m$^2$K) | Rate of Mass flow (kg/s) | Heat transfer rate (W) |
|----------------|---------|---------------|----------------|-------------------------------------|--------------------------|------------------------|
| 120            | Ethanol | 3.07e+06      | 1.48e+02       | 7.90e+04                            | 3172116.5                | 15.739029              |
|                | Methanol| 2.87e+06      | 1.69e+02       | 8.09e+04                            | 2666271.2                | 11.90834               |
|                | Ethylene| 8.41e+03      | 1.59e+02       | 6.99e+02                            | 1297.443                 | 0.018528               |
|                | Propyl  | 3.71e+06      | 1.76e+02       | 2.09e+05                            | 3400758.7                | 13.964752              |
|                | Gas oil | 1.195e+07     | 1.58e+02       | 3.57e+04                            | 2324893.4                | 13.03038               |

| Velocity (m/s) | Fluid   | Pressure (Pa) | Velocity (m/s) | Heat transfer coefficient (W/m$^2$K) | Rate of Mass flow (kg/s) | Heat transfer rate (W) |
|----------------|---------|---------------|----------------|-------------------------------------|--------------------------|------------------------|
| 150            | Ethanol | 4.6e+06       | 2.0e+02        | 9.780e+04                          | 3634251.9                | 17.86530               |
|                | Methanol| 4.55e+06      | 1.96e+02       | 1.002e+05                          | 3884644.9                | 17.865326              |
|                | Ethylene| 1.42e+04      | 1.90e+02       | 7.462e+02                          | 2815.9748                | 0.022484               |
|                | Propyl  | 5.97e+06      | 1.85e+02       | 2.479e+05                          | 4448207.7                | 19.316803              |
|                | Gas oil | 5.97e+06      | 1.87e+02       | 4.261e+04                          | 3434600.6                | 19.312317              |

| Material     | Temperature | Heat flux (w/m$^2$) |
|--------------|-------------|---------------------|
| Steel        | Minimum 421.07, Maximum 500 | 1.5307              |
| Cast iron    | Minimum 410.52, Maximum 500 | 1.4979              |
3. Results and Discussion:

3.1 Properties of Fluids:
Fluid properties are taken as an input for CFD analysis. Primary parameters like pressure, velocity, heat transfer rate, heat transfer coefficient and heat flux are considered for analysis.

Ethanol
Thermal conductivity of Ethanol = 0.0207 (W/m-K)
Specific heat of Ethanol = 1731 (J/ kg-K)
Density of Ethanol = 1.263 (Kg/ m³)
Viscosity of Ethanol = 0.00000929 (Kg/m-s)

Methanol:
Thermal conductivity of Methanol = 0.203 (W/m-K)
Specific heat of Methanol = 1470 (J/ kg-K)
Density of Methanol = 735.5 (Kg/ m³)
Viscosity of Methanol = 0.98 (Kg/m-s)

Ethylene:
Thermal conductivity of Ethylene = 0.253 (W/m-K)
Specific heat of Ethylene = 845 (J/ kg-K)
Density of Ethylene = 729.54 (Kg/ m³)
Viscosity of Ethylene = 0.48 (Kg/m-s)

Propyl
Thermal conductivity of propyl = 0.0332 (W/m-K)
Specific heat of propyl = 2222 (J/ kg-K)
Density of propyl = 0.6679 (Kg/ m³)
Viscosity of propyl = 0.00001087 (Kg/m-s)

Gasoil:
Thermal conductivity of Gasoil = 0.167 (W/m-K)
Specific heat of Gasoil = 2437.08 (J/ kg-K)
Density of Gasoil = 789.24 (Kg/ m³)
Viscosity of Gasoil = 1.195 (Kg/m-s)

3.2 Thermal Analysis:
Temperature-Material Steel, the analysis is performed through Ansys, considering the boundary at temperature 500°C at steady state thermal condition.
Due to the passing of charge (fluid with air) internal of inlet manifold, there is a maximum temperature distribution inside the tube (manifold) because flowing fluid strikes primarily inside the tube layer with static pressure as shown in figure 1. Above contour plot explains about the temperature variation with material as steel observed that maximum temperature is 500°C and minimum temperature is 421.07°C.

Heat Flux-Material Steel

The maximum flux observed at inside the tubes because of flowing fluid inside the tube of combustion chamber and minimum at casing of combustion chamber as shown in figure 2. Heat transfer rate varies in area with the material from interior to exterior surfaces results the change in heat flux. From above plot observed the maximum value is 1.5307 w/mm² and minimum value is 0.04 w/mm².

Material-Cast iron.
Figure 3 Indicates temperature profile for material cast iron.

Applying the temperature distribution inside the tube and excluding the convection inside the tube, observed that from above contour plot as shown in figure 3. The maximum temperature is inside the tubes and minimum is at casing of combustion chamber.

Heat flux - Material Cast iron

Figure 4 Indicates heat flux for material cast iron

Maximum heat flux at inside the tubes and minimum at combustion chamber casing and outside of the tubes. According to the above contour plot, the maximum heat flux is 1.4979 w/mm² and minimum heat flux is 0.039197 w/mm² as shown in figure 4.
3.3 Graphs:

At velocity 120 m/s, maximum velocity for gas oil compared with 150 m/s. Due to its viscosity of flowing fluid in inlet manifold. But pressure is maximum for ethanol, at 150 m/s velocity in between the tube and internal layer as shown in figure 5 and figure 6.
Figure 7. Heat flux for different materials

From the figure 7, observed that heat flux is increased uniformly for steel material on comparison with cast iron. The maximum heat flux for steel is inside the tube maximum temperature is at inlet manifold. Thermal analysis on both materials is shown in graph 3.

Current investigation deals with fluids which are numerically calculated for the material properties at velocity 120 and 150m/s. From analysis clearly observed that heat transfer rate is maximum for propyl compared with different fluids due to the good conductivity, chemically inert possession and narrow particle distribution at maximum temperature with the steel material for the requirement. These results are in good agreement with previous literature [1]. Compared with previous researcher P.Gurusamy, et al [1] had enhanced heat transfer rate through experimental investigation with modified manifold, improved 1.3% efficiency. Current study has investigated on different fluids with constant manifold to enhance heat transfer rate in combustion chamber. The graphs are mentioned in the article which represents the variation of parameters for desired results. With the improved heat transfer rate automatically, efficiency will increase.

4. Conclusion:
Current investigation, two types of analysis was performed on combustion chamber using different fluids at different velocities. Properties of working fluids in engine are numerically evaluated. Based on results the following points were concluded.

1. The combustion process increases the internal energy of a gas, which translates into an increase in temperature, pressure, or volume depending on the configuration.
2. By observing the CFD analysis the pressure drop, velocities and heat transfer rate values are increasing by increasing the velocity.
3. The thermal analysis is to determine the heat flux of the combustion chamber the heat flux more for steel compare with cast iron material.
4. Heat transfer rate more for Propyl fluid, when heat transfer rate will more, the engine efficiency will increase.
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