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NUMERICAL INVESTIGATION OF THE USE OF SOME PISTON CROWN GEOMETRY ON CI ENGINE PERFORMANCE

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Abstract: Performance enhancement of internal combustion engines is basically achieved through process type, fuel use, injection mode and, combustion chamber geometry modification. Extensive studies are being undertaken to optimize the performance of compression ignition engines by combustion chamber geometry modification, however, this is largely executed with experiments. Numerical results on the effect of piston crown geometry as a means of combustion chamber modification on the performance characteristics of a compression ignition engine are presented in this short paper. The impact of in-cylinder fluid flow velocity was used to evaluate the performance of the engine. The in-cylinder motion of the fluid was positively impacted using the conical, hemispherical and dual hemisphere indented piston crowns which is in agreement with previous experimental studies.
Keywords: Combustion Chamber Geometry, Engine Performance, In-Cylinder fluid motion, Piston crown

1. INTRODUCTION

The enhancement of the performance of internal combustion engines is being usually achieved through the following means; fuels, process types, injection mode, and combustion chamber geometry type. The importance of the internal combustion engines in the transportation sector is unquantifiable, as it is basically the driving force in the sector.

Better fuel efficiency and reduced emission of engines have been proven to be a reality from results of studies on combustion chamber geometry which ultimately determine the fuel mixture formation, in-cylinder flow, and the combustion process achieved using different piston crown geometries [1, 2, 3]. The use of dual fuels in engines results in improved engine performance and reduced emissions [4, 5, 6, 7]. Improved performance of these engines is essential for the reduction of the much talked about global warming resulting from the emission of CO_2 gas [8, 9, 10].

More of the studies reported in literature have been based on experimental studies, and it is imperative to develop models to make further studies easier, faster and less costly. This study is therefore concerned about the numerical studies of the performance enhancement of the compression ignition engine. The next section discusses the methodology employed, third section is a presentation of the results and discussion, while the last section is the conclusion.

2. METHODOLOGY

The different piston crown geometries investigated in this numerical studies are cylindrical, conical, hemispherical, dual cone, and dual hemisphere indented piston crowns as shown in figure 1. All the pistons were dimensioned towards the kirloskar TV1 compression ignition engine with a bore D of 0.0875 m, stroke S of 0.11 m, and compression ratio CR of 17.5:1. The connecting rod length L_c was 0.238 m, crank arm length L_a was 0.055 m and the utilized initial pressure and temperature for the simulation were 1e5 N/m^2 and 313 K respectively. The engine performance was simulated using COMSOL Multiphysics 5.0 software which employs the finite element solution method. The turbulence in the engine cylinder was modelled using the Reynolds Average Naiver Stokes (RANS) equation with the kinetic energy-eddy dissipation (k-**ε**) model because of its ease of convergence to simplify the Naiver Stokes equation.

The RANS equation;

K equation;

$$\rho \frac{\partial u}{\partial t} + \rho\, u.\nabla u = \nabla.\left[-\rho 2I + (\mu + \mu_T)\left(\nabla u + (\nabla u)^T\right) - \frac{2}{3}(\mu + \mu_T)\nabla(\nabla . u)I - \frac{2}{3}\rho k I\right] + F \quad (1)$$

$$\rho \frac{\partial k}{\partial t} + \rho(u.\nabla)k = \nabla.\left[(\mu + \frac{\mu_T}{\sigma_k})\nabla k\right] + p_k - p_\varepsilon \quad (2)$$

ε equation;

$$\rho \frac{\partial \varepsilon}{\partial t} + \rho(u.\nabla)\varepsilon = \nabla.\left[(\mu + \frac{\mu_T}{\sigma_\varepsilon})\nabla \varepsilon\right] + C_{\varepsilon 1}\frac{\varepsilon}{k}P_k - C_{\varepsilon 2}\rho\frac{\varepsilon^2}{k} \quad (3)$$

The performance criteria; thermal efficiency, brake power and, brake specific fuel consumption were calculated using equations 4, 5 and, 6 respectively.

$$\eta_{Th} = \frac{W_{net}}{Q_{in}} \quad (4)$$

$$P = \frac{P_m LAN}{n_c} \tag{5}$$

$$BSFC = \frac{\rho_f q}{P} \tag{6}$$

W_{net} is the net work output from the engine, and Q_{in} is the heat energy generated by the combustion of the fuel-air mixture, both obtained from the simulation results.

A is the area of the engine cylinder; N is the number of revolutions per minute; n_c is the number of cycles required to make a complete revolution; P_m is the mean effective pressure ; ρ_f is the fuel density.

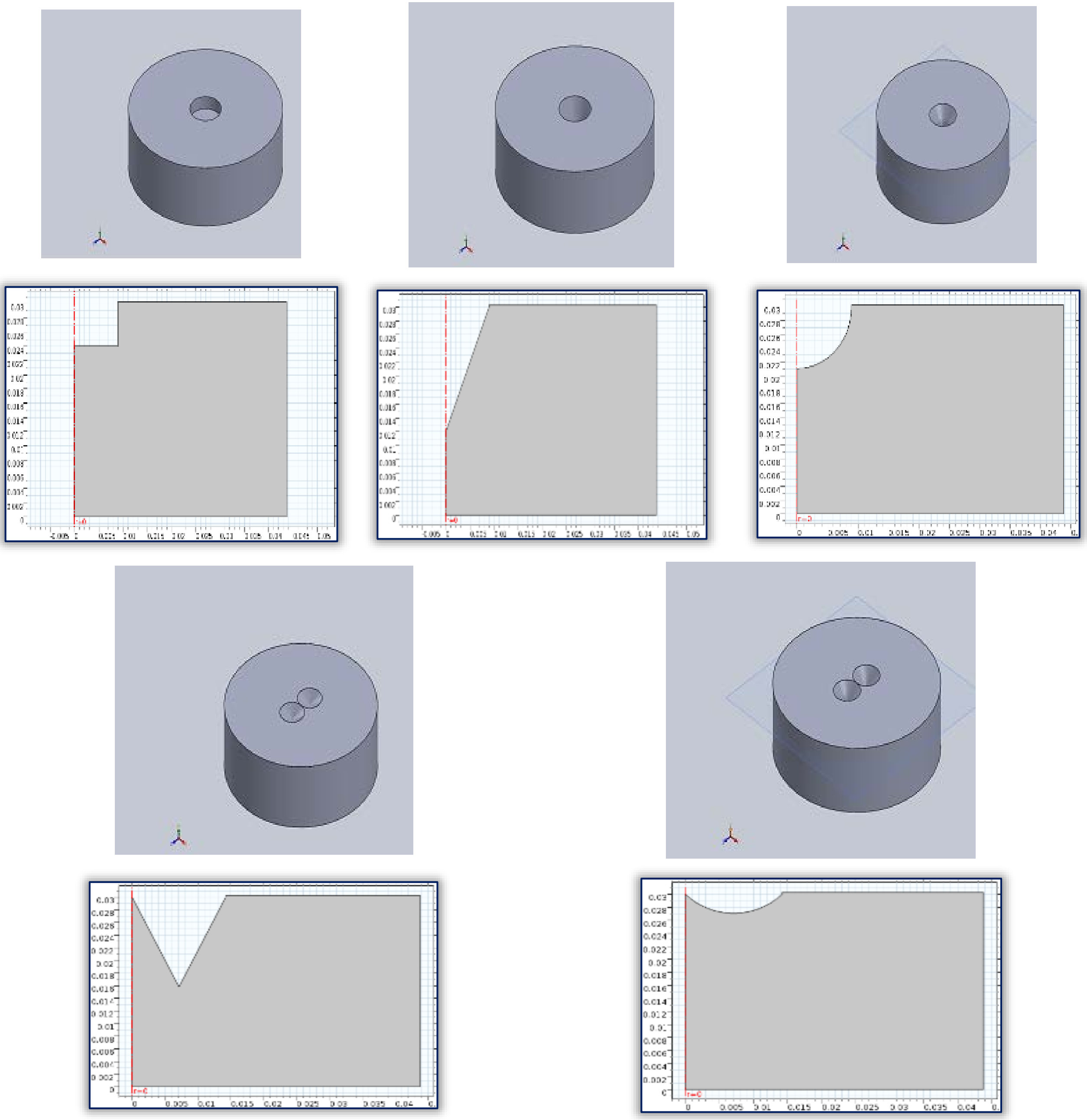

Figure 1. Geometry of the Investigated Cases in 3D and 2D Axisymmetric Views

3. RESULTS AND DISCUSSION

The in-cylinder fluid motion is dependent on the combustion chamber geometry which for this study was effected with the use of different piston crown shapes. The velocity distribution for the studied cases are depicted in figure 2. The piston crown geometry did have notable impact on the simulated engine performance. The performance of the engine was negatively affected with the use of the cylindrical indented and the dual cone indented piston crown signaling that the in-cylinder motion of the fluid was negatively impacted using these dimensioned combustion chamber and this is evident in their lower fluid velocity in figure 2.

The more mobile the fluid particles, the greater the generated pressure which is available for doing work. The effect of the use of the different piston crowns on the engine performance; thermal efficiency, brake power, and the brake specific fuel consumption in comparison to that of an ideal flat piston crown is tabulated in figure 3, as derived with the use of equations 4, 5 and 6 in each of the considered case.

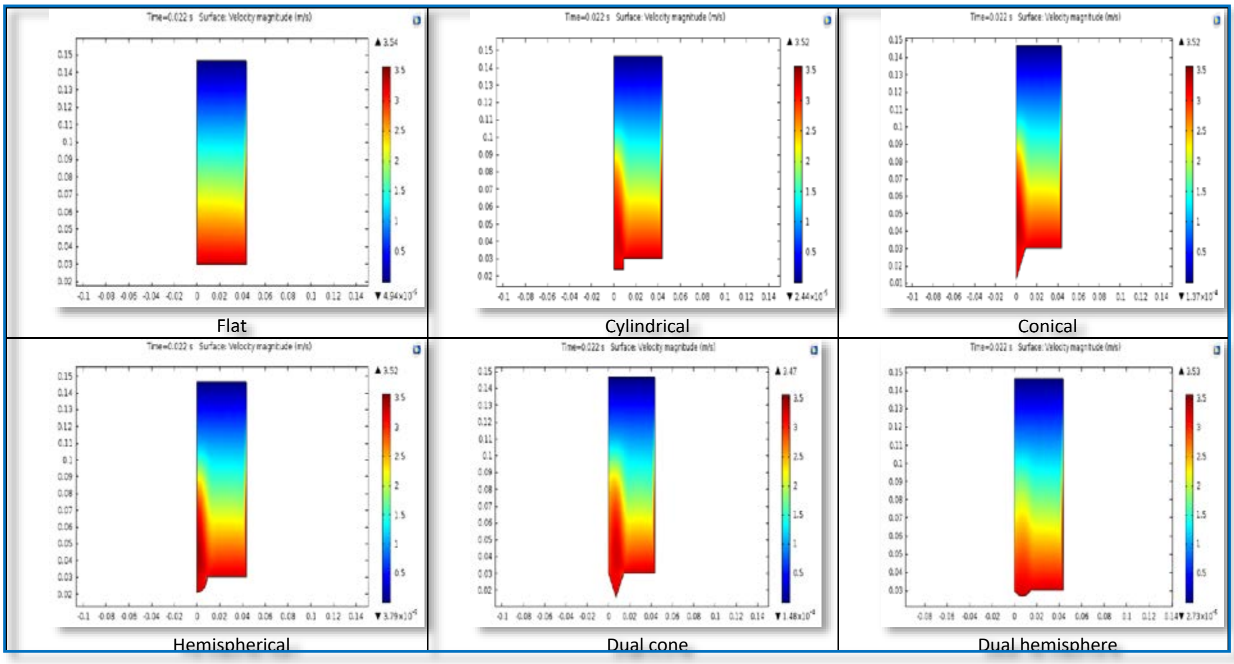

Figure 2. Velocity Distribution of the In-cylinder Fluid

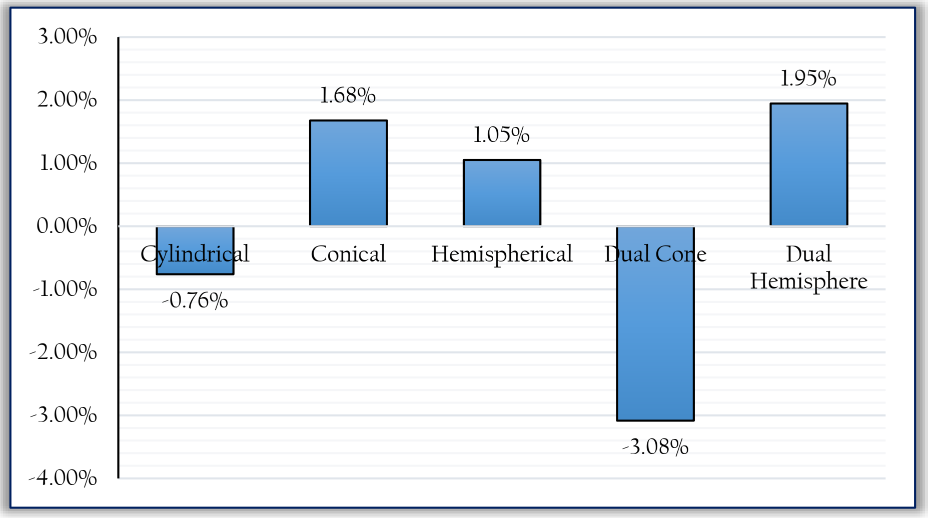

Figure 3. Percentage Difference in Engine Performance in Comparison with Flat Face Piston Crown

4. CONCLUSIONS

The performance of a compression ignition engine equipped with different piston crown geometry was numerically determined and compared vis-à-vis that of a flat faced piston crown. The piston crown geometry did have notable impact on the simulated engine performance.

- The performance of the engine was negatively affected with the use of the cylindrical indented and the dual cone indented piston crown
- The in-cylinder motion of the fluid was negatively impacted using the cylindrical and dual cone indented piston crowns
- The in-cylinder motion of the fluid was positively impacted using the conical, hemispherical and dual hemisphere indented piston crowns

The results showed an agreement with previous experimental studies where the use of hemispherical indented piston crown and cone shaped piston crown led to an improvement in the engine performance.

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