

Effect of Intake Valve Mode and Spray Cone Angle on Wall Fuel Film and Air Fuel Mixture Formation of PFI Gasoline Engine

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ABSTRACT: The air-fuel mixture formation process affects the performance and pollutant emissions of PFI gasoline engine. Hence it becomes necessary to consolidate the numerical methods which are able to describe such a complex physical process. The impacts of intake valve mode and spray cone angle on wall fuel film and equivalence ratio were investigated using Computational Fluid Dynamics (CFD) PFI engine simulation. The results showed that, the wall fuel film with use of open valve injection mode (OVI) was lower compared with the closed valve injection mode (CVI). It was also observed that the air-fuel mixture when applied OVI mode was richer compared with CVI mode. In addition, increasing the spray cone angle is better for decreasing the oil film.

KEYWORDS: Intake valve mode; spray cone angle; wall fuel film; mixture formation; PFI gasoline engine.

I. INTRODUCTION

An engine with a port fuel injection has been occupied for numerous years, spray features and air-fuel formation are still the matter of investigation. The adjustment of the fuel-air mixture formation performs a significant character in order to improve the combustion procedure and decrease the total emissions from an SI engine. The fuel vaporization configurations, the droplet size distribution, the temperature of intake port and valve, affected by the fuel properties, spray cone angle, injection timing, valve and port and the manifold absolute pressure [1]. The liquid fuel that is injected will be atomized and evaporates shaping fuel vapor. In addition, the fuel droplets formed through atomization relating to their size are also reliable for wall film. Finer atomization decreases the air-fuel mixing time and reduces wall-wetting, consequent in a further uniform air-fuel mixture [2].

A number of researchers [3-6] have studied the impact of diverse operating conditions on evaporation and spray of air fuel mixture. Brenn et al. [3] reported that the air flow velocity was a significant factor for spray dynamic performance. Oliveira [4], who noticed that the closed valve injection ensued in better derivability of the engine equated to open valve injection. Dementhon and Vannobel [7] examined the spray behavior in the intake manifold, and the outcomes revealed that the injection timing had a main impact on spray characteristics.

Due to the continuous restrictions on engine pollutants, many experimental reports have applied multi strategies to reduce emissions from PFI engines [8-10]. The combustion characteristics and emissions produced from PFI engines are affected by air-fuel mixing, it is controlled by the fuel-injection processes and gas flow. Hence, to explore the wall film and equivalence ratio of air fuel mixture, the CFD PFI engine simulation was applied to simulate the gasoline formation. The fuel applied alternatively of gasoline was iso-octane, since its boiling point is 99°C, which close to the fifty percent evaporation point of gasoline [11].

In this simulation work, the engine was run on speed of 1200 rev/min, the effects of intake valve mode (closed and open) and spray cone angle on air-fuel mixing and wall wetting were studied.

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II. METHODOLOGY

Engine model

The engine studied was a single-cylinder, two intake valves, four-stroke PFI engine. It has a 75 mm bore, 84.4 mm stroke and 10.5 compression ratio. However, to simulate the intake stroke and compression stroke the simulation mesh includes of intake port, exhaust port and cylinder, which is shown in Fig. 1. The basic grid scale of 4mm is used with adaptive grid encryption technology (Adaptive Mesh Refinement, AMR) to enhance the calculation precision. Grid encoding level is 3; the local encryption grid size is 0.5mm.

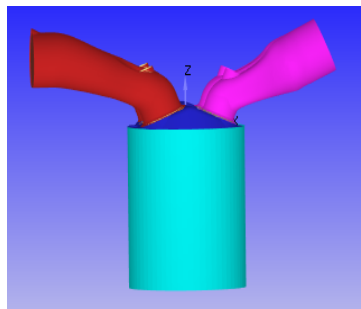


Fig. 1: Engine single cylinder model

Spray and evaporation models

KH-RT spray breakup model [12-14] was applied. The model supposes that at exit of the nozzle, the liquid core is formed, and the core fractures down due to the unsteadiness getting up over liquid core surface providing bigger droplets. These greater droplets from the core are controlled by the KH-RT model. The droplet evaporation is controlled by heat transfer equations and mass conservation [12]. The droplet collisions are depended on the No Time Counter (NTC) model [15]. In addition, Frossling Model used for the droplet evaporation [16]. Reynolds-Averaged Navier-Stokes (RANS) established on the subject of the group (RNG) $k-\epsilon$ model is applied to simulate turbulence for an air-fuel mixture inside the combustion chamber.

Boundary conditions

The start time of calculation is -460°CA and end at 0°CA . Assume that the last cycle is completely burned, the residual gas in the inside cylinder and exhaust pipes is N_2 , CO_2 and H_2O , and only air is present in the inlet of intake port. The fuel injection starts at -440°CA , the total fuel mass injected is 2.5×10^{-5} , the intake port temperature is 310K and inflow pressure is 0.56 bar, the total number of droplets is 50000, the nozzle diameter is 0.25 mm.

III. RESULTS AND DISCUSSION

Intake valve mode

A comparison was made between two intake valve modes; the first mode is the closed valve injection (CVI), and the second mode is the open valve injection (OVI) to explain the wall wetting and air fuel formation under identical engine speed and same fuel mass injected. The total mass has been calculated to make the equivalence ratio at the end of compression ratio equal 1 for the CVI mode. For OVI mode, CFD PFI engine examination was controlled under states where the intake valve is opened exact before the fuel spray contacts the intake valve. The relationship of wall-film for CVI mode and OVI mode can be viewed in Fig. 2. It can be observed that, the wall wetting distribution were highly difference between these two modes, the film concentration of fuel in CVI mode stick on the wall has been larger than OVI mode. At the compression stroke (crank angle -145°), there is very little oil film stick on the intake port for the OVI mode. Fig. 3 shows the oil film versus crank angle, it can be seen that, the oil film for both modes have been evaporated at same crank angle, the oil film at OVI significantly evaporated compared with CVI.

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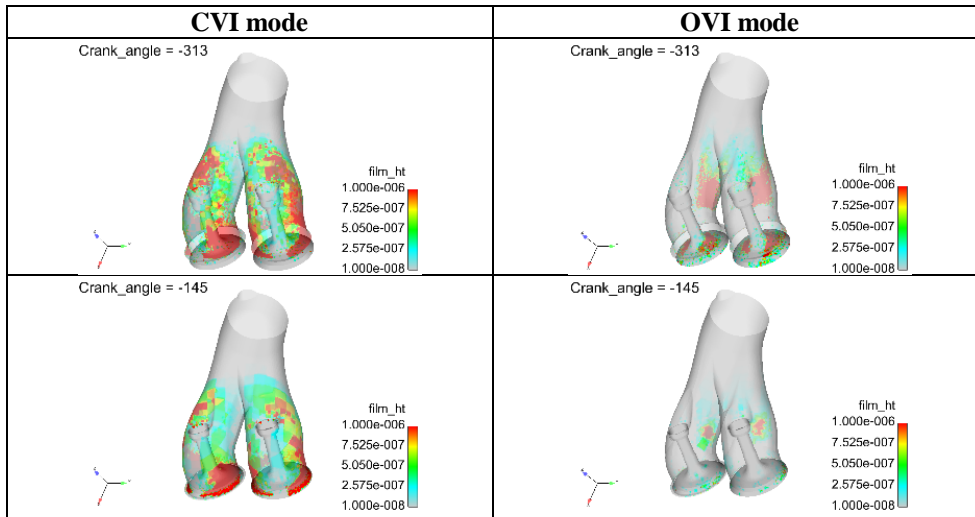


Fig. 2: Comparison of wall film on intake port for CVI mode and OVI mode

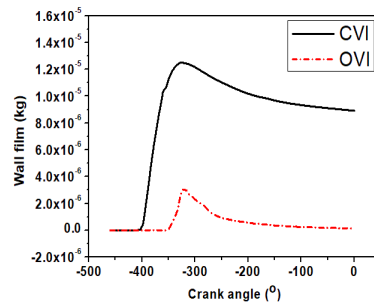
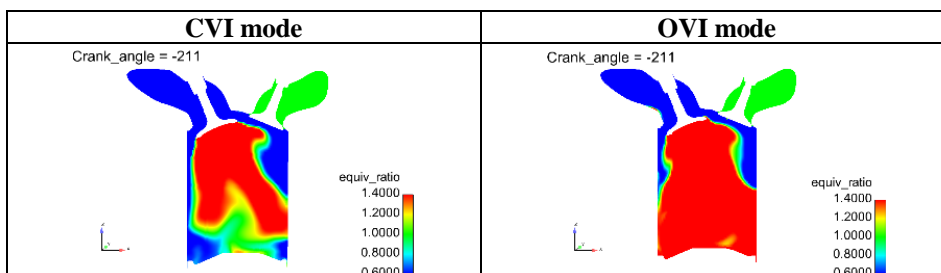


Fig. 3: Wall film mass for CVI mode and OVI mode.

Fig. 4 displays the in-cylinder equivalent ratio distribution for the intake and compression strokes through two intake port modes. From the above results, we found that the oil film stick on the intake port for CVI is higher than OVI, these results mean that the amount of fuel enter the engine cylinder is higher for OVI compared with CVI, and that will effect on equivalence ratio distribution. It observed from Fig. 4 the air-fuel mixture when applied OVI mode was richer compared with CVI. On the other hand, at the compression stroke, the air-fuel mixture is getting more and more uniforms compared with intake stroke. In general, the homogeneity of air fuel mixture for OVI is better than CVI mode. The combustible air fuel mixture at the time of spark was richer for OVI, these result may suggest that, the amount of fuel used for these two modes should be difference and that mean reduces the fuel consumption when OVI mode has been applied. Fig. 5 shows the equivalence ratio versus crank angle, it can be seen that, the equivalence ratio for air fuel mixture at the time of spark for CVI mode and OVI mode equal 1 and 1.7, respectively.



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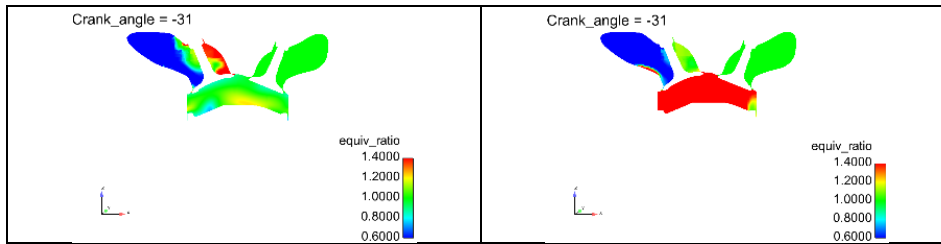


Fig. 4: Comparison of equivalence ratio distribution for CVI mode and OVI mode.

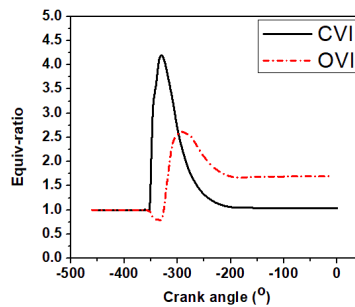


Fig. 5: Equivalence ratio distribution versus crank angle

Spray cone angle

The spray characteristics are impacted by fuel pressure, fuel temperature, fuel properties, and injector geometry, etc. In this part we have tested to decline the wall wetting and explore the impacts of spray cone angle on wall film and equivalence ratio. The contrast of wall-film for various spray cone angle 10° and 15° can be seen in Fig. 6 and Fig. 7. It observed that, the increase spray cone angle from 10° to 15° leads to decrease the wall film. At the beginning of injection, the wall film was smaller and increased with the raise the crank angle until reach the maximum value, and after that the oil film decreased due to evaporation process.

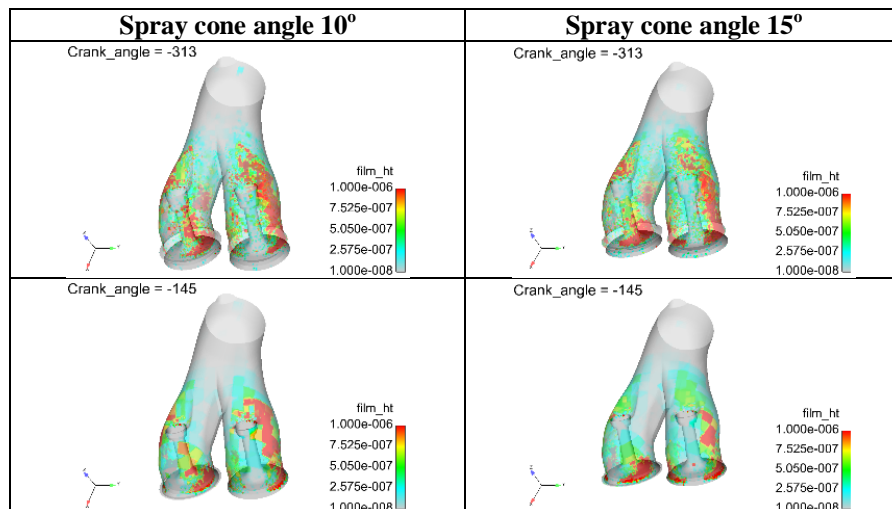


Fig. 6: Comparison of oil film on intake port for different spray cone angle.

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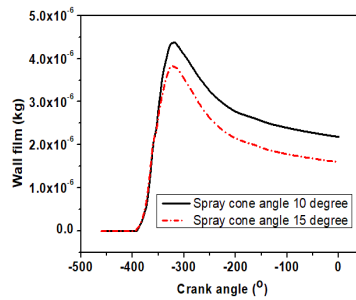


Fig. 7: Oil film mass for spray cone angle 10 and 15 degree.

Fig. 8 and Fig. 9 displays the equivalent ratio distribution inside cylinder for the intake stroke and compression stroke. It can be seen that, the top centre part of the cylinder has more concentrated with air fuel, increase the spray cone angle leads to a higher equivalence ratio compared with narrow spray cone angle, this also attributed to the more wall wetting stick on intake port when a narrow spray cone angle applied. On the other hand, at the compression stroke, the air fuel is getting more and more uniforms compared with intake stroke.

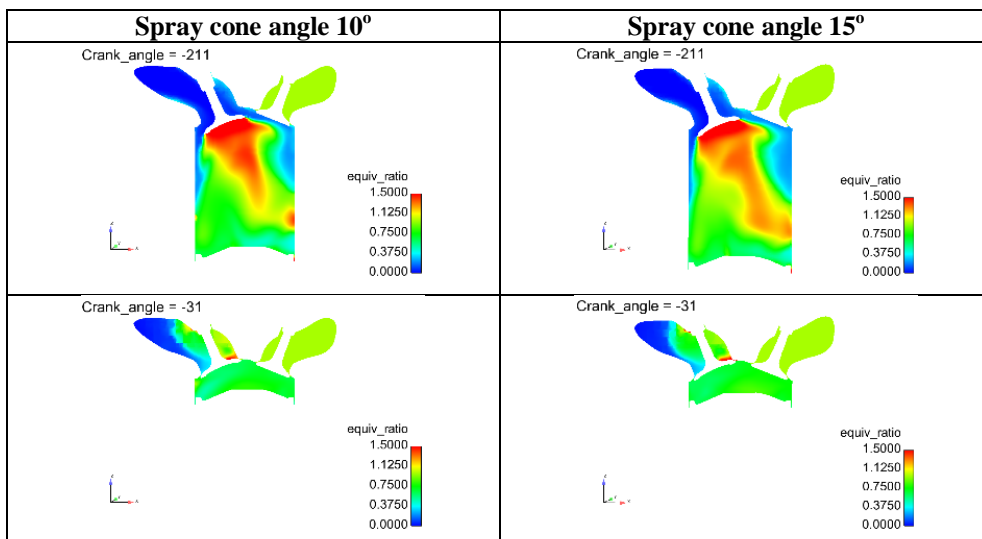


Fig. 8: comparison of equivalence ratio distribution for different spray cone angle.

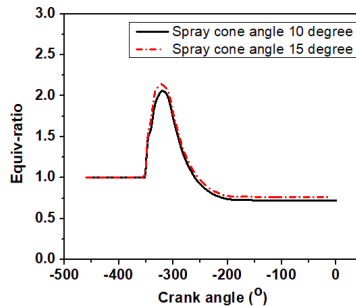


Fig. 9: Equivalence ratio distribution versus crank angle

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IV. CONCLUSION

- Open valve injection mode showed a significant decrease in wall film compared with closed valve injection mode. While, the air-fuel mixture at the time of spark ignition was richer for open valve injection.
- Wide spray cone angle is good for decrease the wall film but the narrow spray cone angle is better for increasing the level of turbulent and enhance the combustion characteristics.

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