The Fundamental Study of Impingement Behavior in Direct Injection Gasoline Spray

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1. Background

In general, the combustion phenomena in a direct injection gasoline engine can be characterized with the stratification burning under the lean burn condition for partial load. As a result fuel consumption is considerably improved especially for the partial load. In addition, overall responsibility with respect to engine performance is also improved due to direct injection into the combustion chamber compared to conventional port injection system. However, there is a problem that HC occurs with adhesion fuel to the wall, and so on. The purpose of this study is to clarify the mixture formation process including the spray-wall interaction for the solution of these problems and further high efficiency.

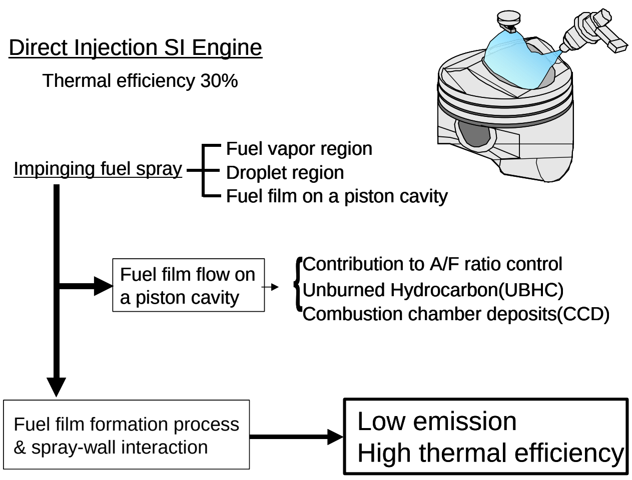


Fig.1 Background

2. Concept

In the case of direct injection gasoline engine (Wall-guide), after the fuel injected into the combution chamber is atomizing and impinging on piston wall, they adhere to wall as a wall film or break up as a droplet. Therefore, it is important for mixture formation process include spray-wall interaction that adhesion fuel formation on the wall at the impingement, and breakup behavior of droplet impinging on the wall. And wall temprature change with a ever-changing driving condition of engine. Consequently, it has need construct new model which include film formation process and characteristics breakup behavior in detail.

In this study, small non-dispersed droplets that simplify fuel spray impinge on the wall for constructing the new model. Here, Weber number, viscosity and wall temprature take account of the behavior of impinged liquid droplet. For the next, the behavior of droplet images and the film formation process in the impinging spray is observed. The variables of the spray experiment were the fuel injection pressure, the impingement angle, wall temprature and the atmospheric pressure. Then, we made new submodel based on droplets experimental results. This new model is incorporated into KIVA-3 code. And the results calculated by this model are compared with spray experimental result and oiginal code.

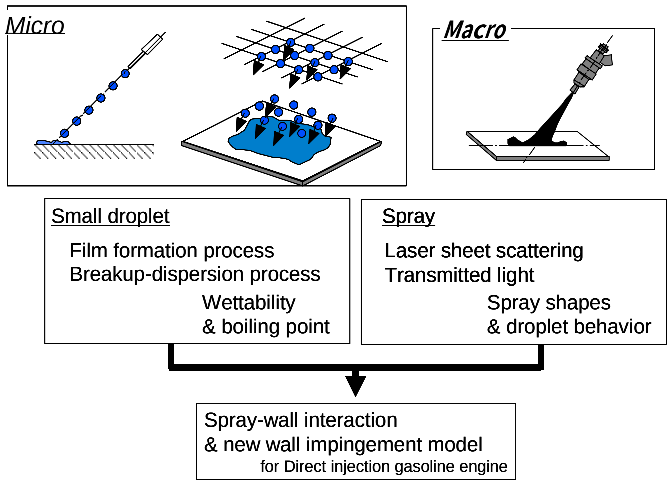


Fig.2 Concept

3. Experimental rig

The schematic diagram of droplets experimental apparatus is shown in fig.3. It uses a vibration minute atomization method for the formation of droplets and falling droplets are divided with using electrification. The photographs of the wall impingement behaviors were taken by high speed video camera and a halogen lamp is used as the light source. Droplets number n, Weber number We, wall temperature T_w, impinge angle α_w are taken as the parameter. And it is observed about the wall impingement behaviors, the lifetime, the process of the liquid film formation and so on.

Fig.4 shows high pressure injection system. It uses high-pressure injector for direct injection gasoline as the

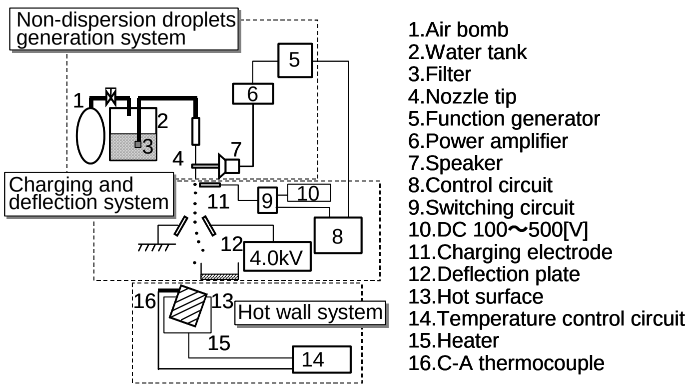


Fig.3 Schematic diagram of experimental apparatus

fuel jet valve, an aluminum alloy piston for the gasoline organization (f=85[mm], 1.6a of surface roughness) for the wall, iso-octane (the boiling point: 372.35 [K]) for liquid. The behavior of droplet images is taken by a laser sheet scattering. In addition, the film formation process in the impinging spray is observed by a high-speed video camera.

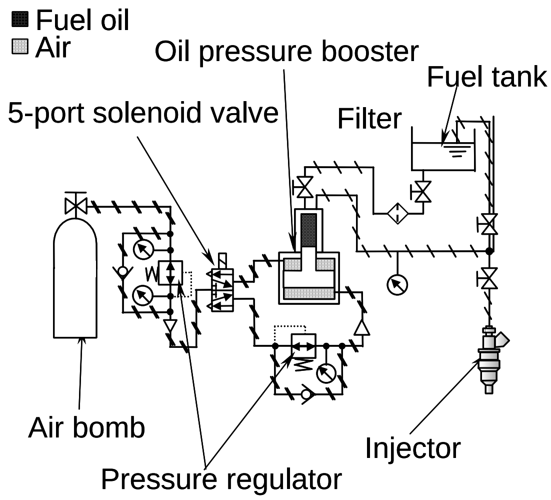


Fig.4 Flow sheet of high pressure injection system

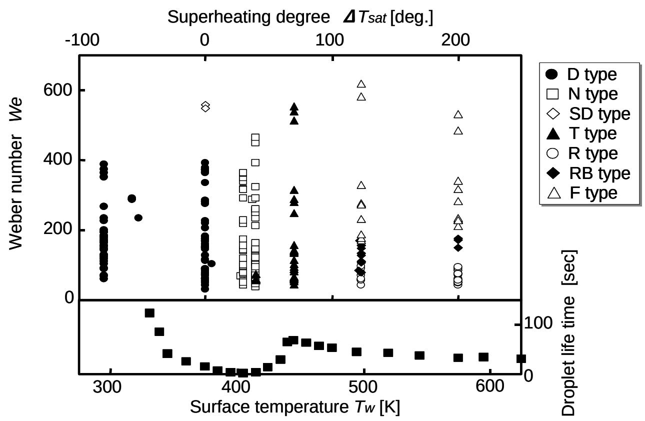
3. Result and discussion

・droplets

Fig.5 shows a distribution figure that 7 typical breakup forms which were observed this time. It ordered a split form in Weber number $We=\rho dV^2/\sigma$ (ρ : density, d : droplet diameter, V : droplet velocity, σ : surface tension) and surface superheat $\Delta Tsat = Tw - Tsat$ (Tw : Surface temperature, $Tsat$: Saturation temperature). In the non-boiling region and the nuclear boiling region, the droplet spreads on the wall and adheres as the liquid film. In the transitional boiling region and film boiling region, the droplets bounce off hot surface.

The other results are written as follows

- The breakup pattern of the impinging droplet can be classified into 7 types. They are mapped by Weber number of the impinging droplet and the superheating degree of the wall.
- For the single component fuel case, it is able to predict the diameter of adhered film by Weber number and the superheating degree.
- In the non-boiling region at the liquid-solid interface, it is capable of estimating the diameter of adhered film by Weber number and Ohnesorge number.
- For the array of droplets, the normalized diameter of the spreading film is increased with higher Weber number and higher number of the impinging droplets, regardless of their frequency related to the number of the incident droplets per unit time impacting the surface.



・spray

It is shown in fig.6 that the result of the photography of the laser-induced scattering when changing a degree of the wall. In ΔT_{sat} =-80, 0[deg.], there is not a difference in spray radius and height. As for this, in both, it formed a liquid film and spread to the direction of the radius as the jet, after spray impinged on the wall. In $\Delta Tsat$=70[deg.], it spreads from the early stage of injection period to the direction of the height compared with the other degree. This tendency agrees with the tendency of the split form of the T type in the droplets experiment. In Δ Tsat=127[deg.], it doesn't very spread to the direction of the height compared with the other wall temperature and spreads to the direction of the radius. This agrees with the R type, RB type, F type tendency.

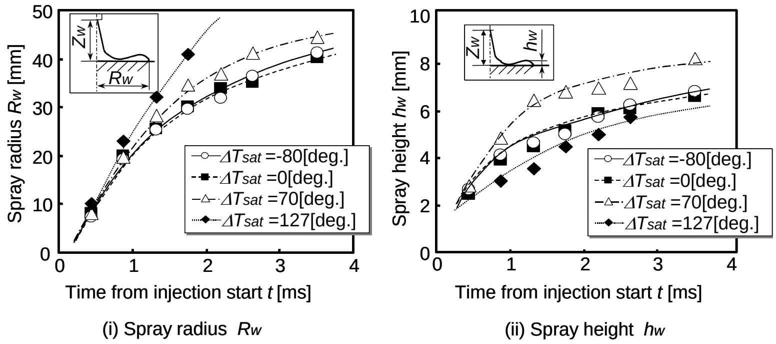


Fig.6 Temporal change in spray radius *Rw* and spray height *hw* as a function of superheating degree of wall (*pinj*=10[MPa],*tinj*=1.76[ms],*pa*=0.1[MPa],*Ta*=293[K], *Zw*=30[mm])

The other results are written as follows

- As the impinging angle is decreased, the spray radius and the film diameter in the spray direction are increased, however, the adhered fuel area is decreased.
- The higher superheating degree, the larger spray radius and the smaller film diameter.

4. The schedule in the future

It plans to do the observation of the impinging behavior of spray in the high-pressure place, using constant volume vessel, the building of a spray/wall model by KIVA3 and so on.*