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論　文　内　容　要　旨

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| 学位論文題目 | Optical Analysis of Characteristics of Rape-seed Oil Diesel Spray Applied to Direct Injection Diesel Engine<br>光学解析による直噴ディーゼル機関用菜種油噴霧特性に関する研究 | | |

内容要旨


It has become very important to study the alternative sources of fuel because of the concern over the availability and the price of petroleum based fuels.

Biomass fuel are mainly derived from biomass or bio waste such as a vegetable oil or animal fat-based diesel fuel. Besides being renewable and biodegradable, they have characteristics quite similar to those of a common diesel fuel. They contain no sulphur elements and are regarded as no contribution to the accumulation of CO2 in the atmosphere. However, actual practice in the biomass as fuel for diesel engines is subjected to transesterification process. This is because carbon deposit, for instance, are produced by direct use of biomass fuel in DI (direct injection) diesel engines. The carbon deposit causes harmful damage to engines and unfavorable effects on engine durability. Blending biomass with practical fuel can partly solve the problem. On the other hand, it is still desirable to use neat biomass fuel to DI diesel engine without transesterification or blending.

As for fuel characteristics, biomass fuel has high level of kinematic viscosity and high distillation temperature, and it is oxygenated fuel. When using biomass fuel, particulate emissions decreases at heavy load due to oxygenated nature; in contrast, SOF (soluble organic fraction) emissions increases at light load operation. High viscosity of biomass fuel results in resistance of fuel flow during fuel injection, affecting the spray development and, in the end, affects the atomization process. SOF emissions is caused partly by poor atomization and SOF emissions is supposed to be one of source of carbon deposit.

The objective of this study is to make clear characteristics of diesel engine spray fueled with rapeseed oil (as a biomass fuel) and find potential method to improve its atomization. First, the characteristics of rapeseed oil spray are compared to diesel spray. This is important as rapeseed oil has very high kinematic viscosity that negatively impacts spray development, and detail understanding on this topic is necessary. Next, this study explores the effect of nozzle geometry in multi-hole nozzle on rapeseed oil spray. It has be observed from many studies that smaller nozzle hole diameter improve atomization, while nozzle scaling and nozzle sac-volume affect spray development. The use of wall impingement technique as a possible method to improve atomization also has been considered in this study especially as rapeseed oil has very high distillation temperature. Impingement to piston wall forces the fuel liquid to disintegrate and this help to atomize the spray more quickly. Furthermore, piston geometry (piston wall shape) could also affects diesel engine emission which in rapeseed oil case, by providing the wall spray an optimum penetration condition for larger spray boundary region that could help atomization. These strategies are used to promote diesel spray atomization and also should apply to direct use

of rapeseed oil. Lastly, air movement affect on the rapeseed oil spray was also investigated. Although high speed swirl (air movement) strategy is usually used in IDI engine, it would be interesting to study this effect to rapeseed oil spray for both IDI and DI nozzle. The result would be very beneficial for future study.

This study uses model equipment to observe spray development optically using constant volume spray chamber. A rapid compression machine was utilized to simulate the high pressure and high ambient temperature in actual diesel engine. Diesel (also referred as gas oil or GO) and Rapeseed oil (also referred as RO) were used as test oil. Shadowgraphy that utilize nano-spark light source (to freeze movement) in a dark room was used to capture still picture capture that provide very high image resolution for study of spray characteristics. The same apparatus can also be configured for taking dual exposure of the same spray (referred as dual nano-spark) to measure other parameters such as high density liquid and vapor phase progression, and also droplet dynamic behavior. Study on the effect of nozzle geometry and wall configuration on the wall impingement spray also utilized high-speed camera direct photography. Analysis of still picture is done by using image analysis software coupled with custom made algorithm that has been initially calibrated. This is especially important for precise measurement of the fuel droplet.

Experiment parameter was chosen to reflect the actual condition in a small diesel engine. The injection pressure was set to 40MPa (low injection pressure) and 70MPa (high injection pressure). The spray chamber ambient temperature were 298K (room temperature) and 700K (high temperature). Some image was also taken at 500K and 850K (very high temperature). The ambient gas density was kept constant at 15kg/$m^3$ for all condition. The injection duration was set to suitable duration.

In conclusion, result shows that RO spray has poor atomization when compared to GO and needs high temperature and high pressure to help atomization. The use of suitable nozzle geometry, in particular nozzle with mini-sac design and narrow outlet nozzle diameter can help atomization process especially at the initial stage. Wall impingement strategy, with suitable wall configuration (shape) and injection nozzle angle also can help atomization process of RO spray as it can promote longer wall spray jet (path) and create a wider spray boundary for droplet formation. Lastly, the effect of high speed swirl (air movement) was studied and proven to be beneficial in improving RO spray atomization.

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論文審査の結果の要旨

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学位論文題目

Optical Analysis of Characteristics of Rape-seed Oil Diesel Spray Applied to Direct Injection Diesel Engine

（光学解析による直噴ディーゼル機関用菜種油噴霧特性に関する研究）

審査結果の要旨

本論文は，菜種油ディーゼル噴霧の解析に関するものである。

ディーゼル機関は耐久性があることに加えて，熱効率が高く $CO_2$ 排出量が少ないことから，主要な動力源になっている。一方で，カーボンニュートラルの特性から，菜種油をディーゼル機関に適用することが期待される。しかし，菜種油は粘性が高く，蒸発特性も悪いことから，生燃料で直接噴射式ディーゼル機関に用いることは，機関内に堆積物を生じる問題を生じ，このため菜種油を燃料として適用するにはエステル化などの処理が行われている。

本論文は，菜種油を燃料として直噴ディーゼル機関に直接適用する際の問題点を菜種油ディーゼル噴霧の噴霧特性の観点から明らかにしている。とくに，これまで解析が困難であったディーゼル燃焼雰囲気場に高圧噴射される菜種油噴霧の挙動を光学解析したところに創意と工夫が認められる。

解析では，菜種油ディーゼル噴霧の巨視的および微視的特徴を軽油噴霧と比較して明らかにしており，菜種油の燃料特性が噴霧の微粒化特性，蒸発特性に及ぼす影響が明確になっている。また，菜種油の噴霧特性を向上させる手段として，燃料噴射ノズルの噴孔形状，あるいは噴霧の壁面衝突状況，空気流動を変化させた場合に，これらが菜種油噴霧の微粒化，蒸発特性の改善に及ぼす効果を示すことにも成功しているなど，研究成果は評価できる。

この論文の内容については，博士論文公聴会で，発表，質疑応答で検討された。また，論文審査委員において査読を行い，記述，内容共に十分であることを認めた。

以上，本論文は，菜種油ディーゼル噴霧の解析として学術的価値の高い成果を収めており，博士（工学）の学位授与に値するものと判定した。