博士学位論文審査要旨

２０２０年1月２１日

論文題目：　Spray and Combustion Characteristics in Biodiesel Fuels
（バイオディーゼル燃料の噴霧および燃焼特性）

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要　　旨：

車両用パワートレイン分野ではWell to Wheel CO2低減のため電動化へのシフトと同時に，e-fuel（再生可能エネルギー利用の合成燃料）などの低炭素燃料開発が加速されている．この中で現実的な手法としてのバイオ燃料，特に各種のバイオディーゼル燃料(BDF; Biodiesel Fuel)は車両や一般産業用ディーゼル機関での今後の普及が期待されているが，その噴霧燃焼過程とエンジン実機性能の詳細解明は未だ不十分である．

本研究では，Jatropha BDFに着目して，その他のバイオBDF，水素化BDFおよび軽油系の低分点燃料の混合燃料の条件において，その粘性・蒸発性・着火性などの化学的特性を解析した．また容器内実験において雰囲気温度と燃料噴射圧力を変化させて，噴霧蒸発過程のマクロおよびミクロの特性を種々の光学的手法により計測して各種BDFの混合気形成過程を解明した．さらに単気筒小型ディーゼル機関を用いて各負荷条件での燃焼性能と排気特性を測定し，各種のBDFの燃料物性値と含酸素量との関係を考察している．

以上の種々の解析および実験からバイオディーゼル燃料適用時の低エミッションディーゼル燃焼手法を検証しその効果を確認した．

よって，本論文は、博士（工学）（同志社大学）の学位を授与するにふさわしいものであると認められる．

総合試験結果の要旨

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要 旨:

本論文提出者は，2015 年 10 月より本学大学院理工学研究科博士課程（後期課程）に在学している．提出者は，本学在学前および在学中にわたり一貫してバイオ燃料関連の燃焼に関する基礎的研究を行ってきた，

本論文の主たる内容は，International Journal of Mechanical And Mechatronics Engineering, International Review of Mechanical Engineering などの海外のジャーナル論文に５編，国際会議議事録に４編，自動車技術会論文集に４編，同志社大学ハリス理化学研究報告に１編すでに公表され，内外の学会において十分な評価を得ている．

2020 年 1 月 11 日（土）午後３時より約２時間にわたり提出論文に関する学術講演会（博士論文公聴会）が開かれ，種々の質疑応答が行われたが，提出者の説明により十分な理解が得られた．さらに講演終了後，審査委員により学位論文に関連した諸問題につき口頭試問を実施した結果，いずれも十分な学力を有することが確認できた．また，提出者は英語による論文発表を多数行い，十分な語学能力を有すると認められる．

よって，総合試験の結果は合格であると認める．

博 士 学 位 論 文 要 旨

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氏　　名： ANNISA BHIKUNING

要　　旨：

Biodiesel is one of the promising alternative fuel in the future. Biodiesel is made from the trans-esterification process that uses methanol or alcohol and catalyst. The use of biodiesel in the diesel engines have some advantages such as high cetane number, oxidation stability and can reduce the emissions. However, higher viscosity, boiling temperatures and surface tension in biodiesel may affect the spray characteristics compared to diesel oil. To overcome the unbenefited in biodiesel, therefore, the fuels designed to a new method that high-boiling point fuel in jatropha methyl ester is mixed to n-tridecane which is a low-boiling point fuel in order to improve the properties in jatropha methyl ester. Moreover, biodiesel from waste cooking oil, bio hydro-finned diesel oil and biodiesel water emulsions are also investigated.

The first part of the work is concerning to the chemical analysis from all fuels tested. The fuels are jatropha methyl ester (JME) blended to n-tridecane by volume (25:75, 50:50, 75:25 and 0:100), biodiesel fuel 100% (BDF), bio hydro-finned diesel oil (BHD), and biodiesel water emulsions (BWE). It was observed that adding n-tridecane in jatropha methyl ester can affect chemical properties in the fuel. The higher percentage of n-tridecane in jatropha methyl ester can make higher in boiling point, reduce the viscosity and surface tension. Moreover, bio hydro finned diesel oil is a second-generation oil that not using the trans-esterification process but using hydro finning process shows improved the density and viscosity while biodiesel fuel shows higher in viscosity, density and boiling point. This happened because biodiesel fuel (BDF) is the first-generation oil that using methanol and KOH as a catalyst. Furthermore, biodiesel water emulsions are made from waste cooking oil 5%, water 10%, diesel oil 100% and emulsions 18.7% shows higher viscosity, density and lower in caloric value compared to diesel oil.

The second part of the work measurement of non-evaporating spray characteristic including spray tip penetration, spray cone angle and droplet size measurement by using shadowgraph photography for and super spatial resolution photography. Non-evaporating sprays are investigated in vessel chamber under room temperature with different injection pressures (50, 100 and 150 MPa) and the fuels are JME25 (JME 25: tridecane 75), JME 50, JME75, BDF and BHD. The results show that higher percentages of tridecane in JME, the spray tip penetration becomes lower as compared to lower percentages of tridecane. Same results for spray tip penetration of BDF compared to BHD. Spray tip penetration of BDF is larger than BHD and tridecane due to high viscosity, density, poor atomization, and less momentum exchanged between the fuel spray and air. In sauter mean diameter (SMD) results show that the increase of injection pressures makes increase the spray tip penetration, spray cone angle and decreases overall SMD synchronously.

The third part of work is measuring the evaporation spray characteristics in the vessel chamber under injection pressure at 100 MPa and 400, 500 and 600 K. In evaporating spray, lower in ambient temperature (400 K), fuels that have higher boiling point temperature and distillation such ah JME75 and BDF are resulting to have higher spray tip penetration and narrower spray angle as compared to other fuels. As ambient temperature increases at 600 K, the spray characteristics and deployment are improved due to micro-explosion occurred in the fuels. In sauter mean diameter (SMD) results show that at higher ambient temperature, SMD of all fuels is decreased. This happened due to the improved spray characteristics in fuels.

The forth part of the work involved Laser-Induced Scattering (LIS) of non-evaporating spray by using sheet scattered photography. The condition was in the room temperature with an injection pressure of 150 MPa. The results shows that with the percentage of JME increased, the shape of spray cross-section becomes sharp and penetration of spray trend to be longer. This happened due to constant injection pressure, spray tip penetration decrease and spray width increase with the rising of viscosity caused by the percentage of n-tridecane decreases.

The fifth part of the work is regarding the performance and emissions characteristics in BDF and BHD as compared to diesel oil. The experiments were investigated by single cylinder 4 stroke engine, in low and partial load, at EGR 0, 10, and EGR 20%. The results show that BHD has the highest thermal efficiency compared to diesel oil and BDF in low load with EGR zero and 10%. The thermal efficiency can reach to 2.28 to 8.1% as compared to diesel oil and BDF. The using of EGR have several advantages, at low load and EGR 20%, the thermal efficiency of diesel oil and BDF can be raised to 0.84 to 2.83% comparing to EGR zero. Moreover, at low and partial load adding EGR can reduce NOx and THC emissions. Nevertheless, at partial load, the using of EGR can increase the CO and smoke emissions. Therefore, for the emissions control, using EGR is effective in low load than partial load.

The sixth part of the work is concerning the performance and emissions characteristics in biodiesel water emulsions (BDWE). The experiment was conducted in 1500 rpm with low, medium and high load. The results showed that at low load, the thermal efficiency of BDWE is reached up to 8.92% than diesel oil. At medium load, the specific fuel consumption of BDWE is increased to 11.66% compared to diesel oil. Moreover, CO2 emissions in BDWE can be reduced to 12.8% than diesel oil at high load. The opacity of BDWE at middle load can cut up to 84.25% compared to diesel oil. The combustion efficiency is improved when water is emulsified with biodiesel. This is a consequence of the micro-explosions that facilitate atomization of the fuel.