RCES REVIEW OF COMPUTER ENGINEERING STUDIES

ISSN: 2369-0755 (Print), 2369-0763 (Online)
Vol. 3, No. 3, September 2016, pp. 67-71
DOI: 10.18280/rces.030304

A publication of IIETA

IIETA International Information and Engineering Technology Association
Advancing the World of Information and Engineering

http://www.iieta.org/Journals/RCES

Effect of High Injection Pressure on Jatropha oil Fuel-air Mixing Characteristics

Jigang Wang, Xiaorong Wang, Zhangliang Jin and Xun Wang

Institute of Mechanical Engineering, Jiangsu University of Science and Technology, Zhenjiang, 212003, China

Email:wjg_sun@126.com

ABSTRACT

The combustion process of a diesel engine is mainly determined by the fuel-air mixing characteristics. In order to study the effect of injection pressure and ambient pressure on jatropha oil fuel-air mixing characteristics in diesel engine. In this paper, based on the open source finite element software OpenFOAM, a new spray model was established, which considered the effect of fuel evaporation on the spray, and the model has been verified by experimental results. We analyzed the fuel-air mixing characteristics of Jatropha oil spray used this model. The result show, changing injection pressure and ambient pressure can improve jatropha oil fuel-air mixing characteristics, As the injection pressure increases and the ambient pressure decreases, the spray breakup velocity gradually decreased and finally tends to a constant, spray volume increased dramatically, a small increase in spray air entrainment and spray equivalent ratio unchanged at early and late stage, greater reduction in the middle. Therefore, we can award good fuel-air mixing characteristics of jatropha oil by increasing the injection pressure and reduce the back pressure.

Keywords: Fuel-air mixing characteristics, Jatropha oil, Air entrainment, Diesel engine.

1. INTRODUCTION

Jatropha oil is a kind of promising renewable energy sources, it has the very good eco-friendly features, and is easy to be produced with high energy density. On the other hand, when the diesel engine combustion jatropha oil, it can effectively reduce the concentration of particulate matter (PM), unburned hydrocarbon (UHC), carbon monoxide (CO). etc On the other hand, jatropha oil is non-edible oil, it can be more beneficial to improve environment. Many articles have studied the feasibility of replacing diesel oil with the Jatropha oil [1-3]. Pure jatropha oil can be directly applied to diesel engine, by double slot injection method, so that the pure oil and diesel oil mixture and esterification reaction, to produce methyl or ethyl ester [4].Therefore, the research of Jatropha oil is a hot topic in recent years.

The spray characteristics were studied by many scholars. Zan Wang et al. [4] utilized the ultra-high speed imaging technology and Phase Doppler Particle Analyzer (PDPA) techniques to study the macroscopic and microscopic spray characteristics of diesel spray under sub-injection conditions. Balaji Mohan et al. [5] studied the spray characteristics of waste oil and bio-oil in experiment, and they also studied two fuel-air mixing characteristics, such as air entrainment and equivalence ratio. This is the new parameters to describe the fuel-air mixing characteristics in recent years, and this will have a lot of reference value to our further research of fuel spray. Others are introduced in the literature [6-8].

Although scholars at home and abroad have studied the spray characteristics and combustion characteristics of Jatropha oil, but at present, there is less research on Jatropha oil fuel air mixing characteristics. On the other hand, in view of the importance of the injection pressure and ambient pressure to improve the fuel air characteristics, a new spray model was proposed based on the open source finite element software OpenFOAM in this paper. The modified evaporation model was used in this model, and the model has been validated by existing tests [9]. Using the model value to study the characteristics of fuel air mixing jatropha oil spray. In this paper, the influence of the injection pressure and ambient pressure on the four characteristics of the breakup velocity, spray volume, air entrainment and equivalence ratio are studied.

2. CLACULATION MODEL

KH-RT breakup model

The KH-RT model considers that the breakup of droplets is caused by the interaction of the KH instability and RT instability wave. In this paper, the KH-RT model is more applicable to the numerical simulation with high accuracy, regardless of the influence of the pressure range or the influence of the turbulent flow in the spray hole. So the model is used in this paper.

The KH-RT model is described as follows:

In extreme cases, the fluid viscosity can be ignored, the wave number equation is:

$$K_{RT} = \sqrt{\frac{-a(\rho_f - \rho_g)}{3\sigma}} \tag{1}$$

The growth rate equation is:

$$\Omega_{RT} = \sqrt{\frac{2}{3\sqrt{3\sigma}} \frac{[-a(\rho_f - \rho_g)]^{3/2}}{\rho_f + \rho_g}} \tag{2}$$

where a is acceleration and

$$a = -\frac{3}{8} C_D \frac{\rho_g U^2}{\rho_f r} \tag{3}$$

The new liquid droplet radius, which is produced by the large disturbance, is proportional to the large wavelength.

$$r_{stable} = C_4 \frac{\pi}{K} \tag{4}$$

RT breakup time is:

$$\tau = C_5 \frac{1}{\Omega} \tag{5}$$

Collision model

The spray collision occurs between the fuel droplet and the wall, and the behavior of the droplet is interfered with each other. The process of spray collision is very complicated. How to choose the collision model is based on the Weber number of the incident droplet:

$$We = \rho_d \cdot U_{n,in} \cdot D_d / \sigma \tag{6}$$

where ρ_d is the droplet density, $U_{n,in}$ is normal velocity of droplets, D_d is the diameter of the droplet, σ is surface tension of liquid drops. Experience critical numerical value We is 80. When We <80, select reflection model; when We >80, select jet model. This research adopts the jet model.

In this study, the turbulence model used k-epsilon model. The other spray sub-models have been verified by many experimental results, and the spray model used in this paper has been verified by existing experiments [9], so the accuracy of the simulation results can be guaranteed.

2. BOUNDARY CONDITIONS

In this study, the calculation domain using the rectangular chamber (shown in Figure 1), the calculation area size is 20mm×20mm×100mm, the minimum grid size is 0.4mm×0.4mm×1mm, and the total grid number is 250 thousand. The physical and chemical properties of Jatropha oil is shown in Table 1. Table 2 is the condition of spray simulation.

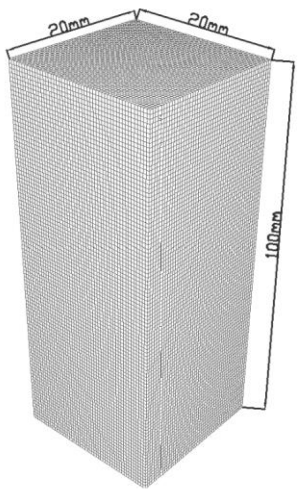


Figure 1. Computational grid

Table 1. Physico-chemical characteristics of jatropha oil [10]

Property	value
Density (kg/m^3)	921
Kinematic Viscosity (mm^2/s)	38
Flash point ($^\circ C$)	235
Sulfur content (m/m)%	0.008
Residual carbon after evaporation (m/m)%	0.15

Table 2. Spray simulation conditions

Property	value
Orifice number	1
orifice diameter (mm)	0.175
Ambient gas	air
Environmental temperature (K)	303
Ambient pressure (MPa)	3, 6
Injection pressure (MPa)	60, 80, 100

3. RESULTS AND DISCUSSION

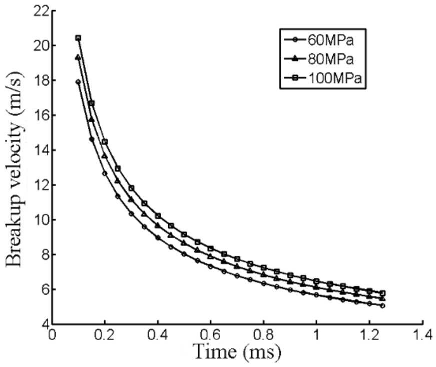
3.1 The effect on spray breakup velocity

Breakup velocity is an important index to evaluate the mixing characteristics of fuel, and the bigger it is, the better the fuel air mixture is. The calculation formula for the breakup velocity is:

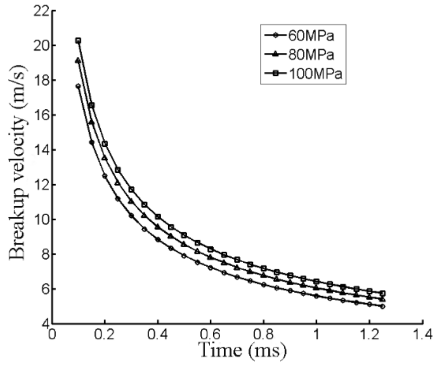
$$u_s(t) = 2.95 \left(\frac{\Delta P}{\rho_g}\right)^{0.25} \left(\frac{d}{t}\right)^{0.5}$$

where ΔP is pressure difference (bar); where ρ_a is ambient air density. (..); $u_s(t)$ is breakup velocity (m/s).

Figure 2 shows the variation curve of different injection pressure (60/80/100MPa)jatropha oil breakup velocity with spray time, as can be seen from the graph, with the spray, the breakup velocity gradually decreases and finally tends to a constant; Under different ambient pressure, the speed had little change, the maximum is 20m/s, the minimum is 5m/s; The greater the injection pressure, the greater the breakup velocity. Thus, improving the diesel engine injection pressure helps to increase the breakup velocity of crushing jatropha oil, to obtain a better fuel air mixing characteristics.



a) ambient pressure 3MPa



b) ambient pressure 6MPa

Figure 2. Breakup velocity under different injection pressure

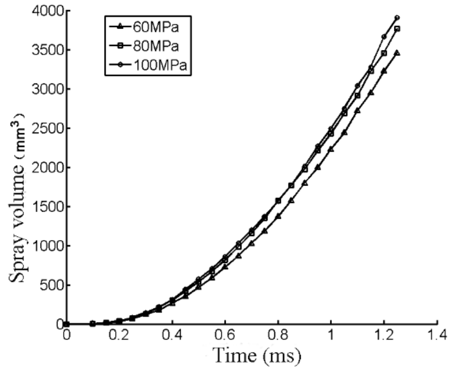
3.2 The effect on spray volume

Spray volume is the volume of atomization, which plays an important role in evaluating the quality of fuel-air mixture, the greater the spray volume, the better the fuel air mixture characteristics. The calculation formula for the spray volume is [5, 11]:

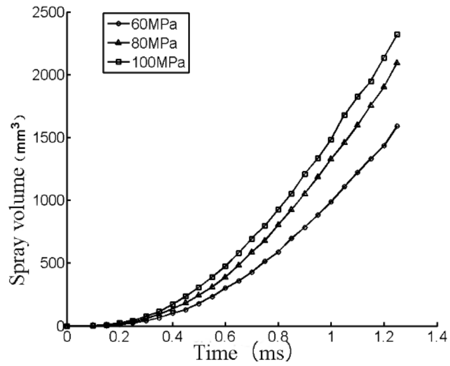
$$V=\frac{\pi}{3}l^3[\tan^2(\frac{\theta}{2})]\frac{1+2\tan(\frac{\theta}{2})}{[1+\tan(\frac{\theta}{2})]^3}$$

where V is spray volume, l is spray penetration, θ is spray angle.

Figure 3 is the change of different injection pressure of jatropha oil spray volume with time. The spray volume increased gradually with the time, and the greater the injection pressure, the greater the spray volume; By a comparison in figure 3 a) and b)we can learn that the smaller the ambient pressure, the greater the spray volume. Therefore, the method can be used by increasing the injection pressure and reducing the ambient pressure to improve the spray volume.



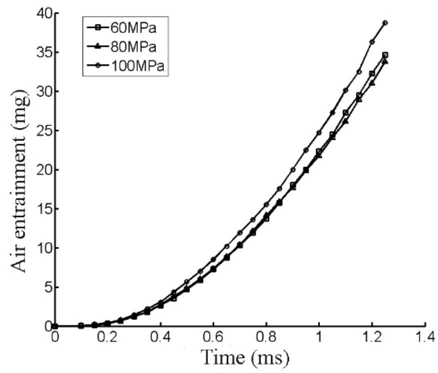
a) ambient pressure 3MPa



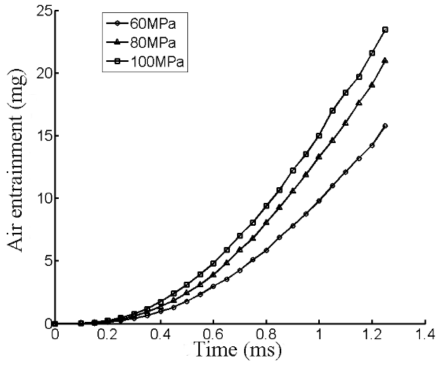
b) ambient pressure 6MPa

Figure 3. Spray volume under different injection pressure

3.3 The effect on spray air entrainment



a) ambient pressure 3MPa



b) ambient pressure 6MPa

Figure 4. Air entrainment under different injection pressure

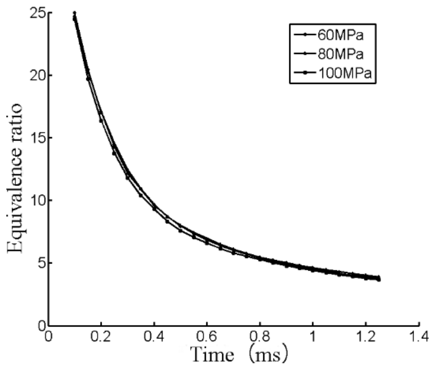
Spray entrainment air quality is a very useful parameter. on one hand, it is an important parameter to describe the fuel-air mixing quality. It is an indispensable parameter to optimize the spray system, and it can also control the formation of soot. Therefore, it is necessary for us to study this parameter. Air entrainment can only be obtained by the calculation method, the calculating formula is [5]:

$$m_a(t) = \frac{\pi}{3}[\tan(\frac{\theta}{2})]^2 l^3 \rho_a$$

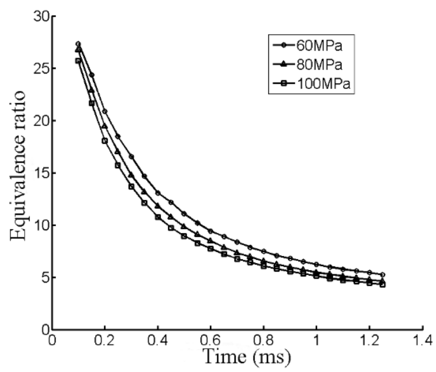
where ρ_a is ambient air density.

Figure 4 is the change of different injection pressure of jatropha oil spray air entrainment with time. It can be seen from the graph, during the spray time of 0-1.2ms, when the ambient pressure is 3MPa, the air entrainment quality can reach the maximum of 40 mg and when the ambient pressure is 6MPa, the air entrainment quality can reach the maximum of 25 mg. The greater the injection pressure, the more the air entrainment quality. By a comparison in graph 4 a) and b)we can learn that the smaller the ambient pressure, the greater the air entrainment quality.

3.4 The effect on spray equivalence ratio



a)ambient pressure3MPa



b)ambient pressure 6MPa

Figure 5. Equivalence ratio under different injection pressure

Spray equivalence ratio is an important parameter to describe the fuel-air mixing quality and the combustion characteristics. The calculation formula for equivalence ratio is [5]:

$$\varphi(x) = \frac{2(A/F)}{\sqrt{1+16(x/x^*)^2} - 1}$$

where $x^* = \sqrt{\rho_f / \rho_a} \frac{\sqrt{C_a} d_0}{a \tan(\theta/2)}$,

A/F is air fuel ratio, ρ_f is Jatropha oil density, ρ_a is ambient air density, a is a constant of 0.8, d_0 is orifice diameter.

Figure 5 is the change of different injection pressure of jatropha oil spray equivalence ratio with time. It can be seen from the graph, The initial spray equivalence ratio value is relatively large, then gradually decreases, and finally tends to a constant. The bigger the injection pressure, the smaller the equivalence ratio. By a comparison in graph 5 a) and b)we can learn that the smaller the ambient pressure, the smaller the equivalence ratio.

4. CONCLUSION

In this paper, the OpenFOAM software is used to study the influence of injection pressure and ambient pressure on jatropha oil fuel air mixing characteristics. It is mainly studied the four characteristics of the breakup velocity, spray volume, air entrainment and equivalence ratio. Thus, this paper obtained the following conclusion:

1) The injection pressure has a great influence on the Jatropha oil spray fuel air mixing characteristics. With the increase of the injection pressure, the spray breakup velocity decreases gradually, the spray volume increased largely, the spray entrainment air quality increased slightly. Spray equivalence ratio is smaller than that of initial and later stage, and greater reduction in the middle. Therefore, the fuel air mixing characteristics of the spray are improved by increasing the incident pressure;

2) Ambient pressure has great influence on the Jatropha oil spray and fuel air mixing characteristics. With the decrease of the ambient pressure, the spray breakup velocity decreases gradually, the spray volume increased largely, the spray entrainment air quality increased slightly in the early stage, but increased more and more in the late stage. Spray equivalence ratio is smaller lightly. Therefore, reduce the ambient pressure can also improve spray fuel air mixing characteristics

3) In the numerical simulation method for the calculation of the bio oil spray process with high-precision, thus it provides a simple and convenient method for the research of Jatropha oil spray.

ACKNOWLEDGMENTS

This work was sponsored by National Natural Science Foundation of China (Grant No. 51306021). The authors would like to acknowledge the teachers and the students of Jiangsu University of Science and Technology for their helpful comments and advice during the preparation of this paper.

REFERENCE

[1] Kjarstad J, Johnsson F. (2008, Nov). Resources and future supply of oil. *Energy Policy* [online]. 37 (2), pp. 441–464. Available: http://www.sciencedirect.com/science/article/pii/S0301421508005259

[2] Moser BR. (2009, Mar). Biodiesel production, properties, and feed-stocks. *In Vitro Cell Dev BioPlant* [online]. 45, pp. 229–266. Available: http://link.springer.com/article/10.1007/s11627-009-9204-z

[3] Leung DYC, Wu X, Leung MKH. (2009, Nov). A review on biodiesel production using catalyzed transesterification. *Applied Energy* [online]. 87 (4), pp. 1083–1095. Available: http://www.sciencedirect.com/science/article/pii/S0306261909004346

[4] Ziman Wang, Hongming Xu, et al. (2016, Feb). Experimental study on microscopic and macroscopic characteristics of diesel spray with split injectio. *Fuel* [online]. 174, pp. 140-152. Available: http://www.sciencedirect.com/science/article/pii/S0016236116001046

[5] Balaji Mohan, Wenming Yang, et al. (2014, Nov). Experimental study of spray characteristics of biodiesel derived from waste cooking oil. *Energy* [online]. 88, pp. 622–632. Available: http://www.sciencedirect.com/science/article/pii/S019689041400805X

[6] Raghu Palani1, Nallusamy Nallusamy, et al. (2015, Oct). Spray characteristics of diesel and derivatives in direct injection diesel engines with varying injection pressures. *Journal of Mechanical Science and Technology* [online]. 29（10）, pp. 4465–4471. Available: http://link.springer.com/article/10.1007/s12206-0150945-9

[7] Xiang Wang, Zhiqiang Han. (2015, Nov). A numerical study of the effects of pressure fluctuations inside injection nozzle on high-pressure and evaporating diesel spray characteristics. *Applied Mathematical Modelling* [online]. 40, pp. 4032–4043. Available: http://www.sciencedirect.com/science/article/pii/S0307904X15007283

[8] Youngsoo Park a, Joonsik Hwang, et al. (2015, Sep). Effects of diesel fuel temperature on fuel flow and spray characteristics. *Fuel* [online]. 162, pp. 1–7. Available: http://www.sciencedirect.com/science/article/pii/S0016236115008984

[9] Donghoon Kim and Kihyun Kim. (2014, Jan). Comparison of Spray Structures of Diesel and Gasoline Using Modified Evaporation Model in Openfoam CFD Package. *SAE paper* [online]. 01-1417. Available: http://papers.sae.org/2014-01-1417

[10] Bhupendra Singh Chauhan, Naveen Kumar, Haeng Muk Cho. (2011, Nov). A study on the performance and emission of a diesel engine fueled with Jatropha biodiesel oil and its blends. *Energy* [online]. 37 (1), pp. 616-622. Available: http://www.sciencedirect.com/science/article/pii/S0360544211007109

[11] Hongzhan Xie, et al. (2015, Jun). An Experimental Study on the Macroscopic Spray Characteristics of Biodiesel and Diesel in a Constant Volume Chamber. Energies [online]. 8, pp. 5952-5972. Available: http://web.b.ebscohost.com/ehost/detail/detail?sid=49c35386-30b2-45c6-8eb8 aa2447431c7a%40sessionmgr105&vid=0&hid=102&bdata=JnNpdGU9ZWhvc3QtbGl2ZQ%3d%3d