Study on the compatibility of rubber materials in biodiesel derived from cottonseed oil

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Abstract

This paper studies the compatibility of nitrile rubber (NBR) and fluorine rubber (FKM) in cottonseed oil methyl ester (CSME) by static immersion method. Two approaches for reducing swelling of NBR and FKM in CSME are investigated: blending with petrodiesel and treating with antioxidant additives. The study shows that CSME has unfavorable material compatibility of NBR and FKM compared to that of 0PD. And NBR has stronger swelling characteristics in CSME than that of FKM. Blending with 0 petrodiesel (0PD) and treating with tertiary butyl hydroquinone (TBHQ) antioxidant additive, the swelling of NBR and FKM in CSME is reduced significantly.

Keywords

Biodiesel, Rubber, Swelling corrosion, Cottonseed oil.

1. Introduction

Biodiesel is an alternative compression-ignition (diesel) engine fuel comprised of alkyl esters of fatty acids derived from renewable feed stock such as vegetable oil and animal fat. [1] However, the high costs of these feedstocks and their competition with food sources are the major bottlenecks for the commercialization of biodiesel especially in developing countries such as China with limited arable land per capita. China is one of the main cotton producing countries in the world. The total production of cotton is up to 5.343 million tons in 2016. It has certain risks of eating cotton oil since the presence of toxic gossypol in it. It is a new way to use cottonseed for the preparation of biodiesel just because of its low price and rich resources [2]. A further assertion is that the supplement problem of raw material for preparation biodiesel is also relieved.

However, a number of practical problems have been caused by using biodiesel in diesel engines. Material compatibility with biodiesel is one of major concerns. Many of materials used in a diesel engine, such as those using in the fuel system, might not be compatible with biodiesel [3,4].Biodiesel produced from different feedstocks has difference in molecular structure, such as difference in carbon chain length, degree of unsaturation, and branching of carbon chain, which will influence the physical and chemical properties of the biodiesel and hence its material compatibility.[5] Thus, the aim of this study is to compare mass change of nitrile butandiene rubber (NBR) and fluorine rubber (FKM) material in cottonseed oil methyl ester (CSME) and 0 petrodiesel (0PD), in order to investigate the effects of feedstock of biodiesel on its compatibility with fluorine rubber material.

2. Experimental

2.1 Materials

Homemade cottonseed oil methyl ester (CSME) is prepared from commercial cottonseed oil using an alkali-catalyzed transesterification procedure, in line with GB/T 20828-2007 requirements. 0 petrodiesel (0PD) is purchased from China Petroleum & Chemical Corporation. Tertiary butyl hydroquinone (TBHQ) is purchased form Guangzhou YOURUI Biotechnology Co., Ltd.

2.2 Static immersion test method

The compatibility of nitrile rubber and fluorine rubber with CSME and 0PD is assessed by conducting the static immersion test. For each fuel, the immersion test is carried out at 55°C for 60 days. Before measuring the degradation behavior, the fluorine rubber rings are dried by blotting with lint-free cloth followed by air-drying at room temperature for 30 min. The mass, inner, outer and cross sectional diameters of rubber are measured before and after the immersion test to obtain the changes. Change in mass is measured by an electronic balance with Eq.(1). Change rate in inner, outer and cross sectional diameters are calculated with Eq.(2), respectively.

$$\Delta m = \frac{m_i - m_0}{m_0} \times 100\% \quad (1)$$

$$\Delta D = \frac{D_i - D_0}{D_0} \times 100\% \quad (2)$$

3. Results and discussion

3.1 The effect on the mass of the nitrile and fluorine rubber rings

(1) CSME and 0PD

Fig.1 and Fig.2 show a comparison of the changes in mass of the nitrile rubber and fluorine rubber rings immersed in CSME and 0PD at 55°C for 60 days.According to Fig.1 and Fig.2, the swelling (increase in mass) NBR and FKM in CSME and 0PD can be seen. The biodiesel results in an increase in mass of the CSME sample compared with 0PD. And it is obvious that CSME causes larger increase in mass of NBR samples compared with FKM.

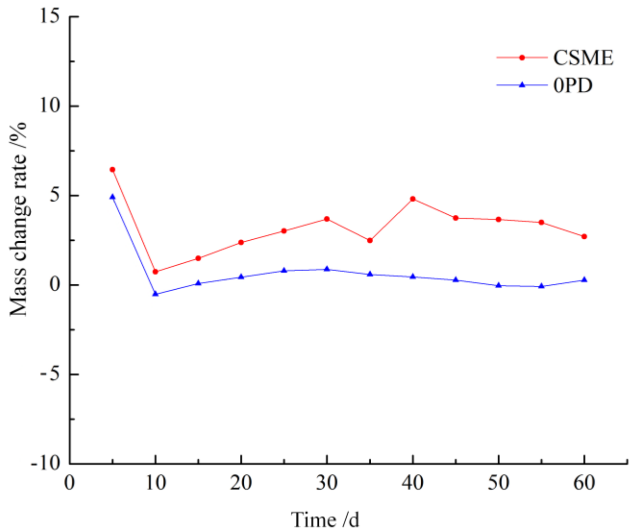

Fig.1 Mass change rate for NBR in CSME and 0PD

(2) CSME blending with 0PD

Fig.3 and Fig.4 show respectively a comparison of the mass change rate of the nitrile rubber and fluorine rubber rings immersed in CSME/0PD at 55°C for 60 days.

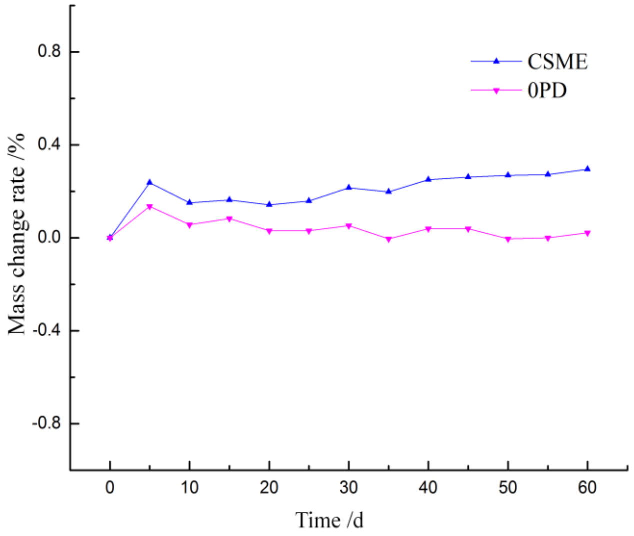

Fig.2 Mass change rate for FKM in CSME and 0PD

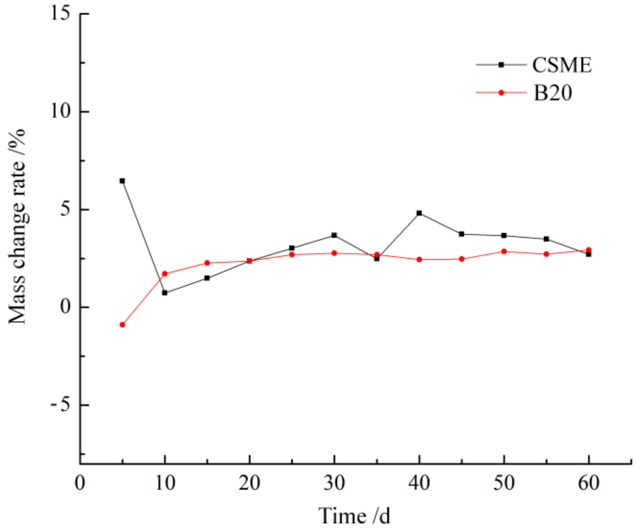

Fig.3 Mass change rate for NBR in CSME/0PD

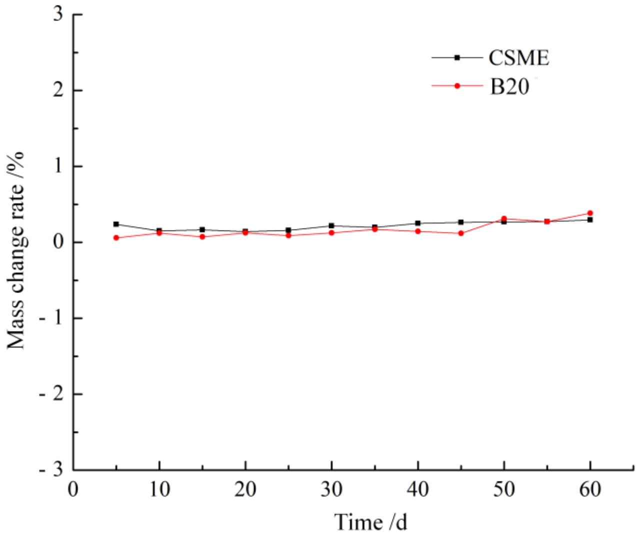

Fig.4 Mass change rate for FKM in CSME/0PD

From Fig.3 and Fig.4, the swelling (increase in mass) NBR and FKM in CSME/0PD can also be seen, and biodiesel blending with 0PD can reduce the swelling rubber.

(3) CSME treating with TBHQ

Fig.5 and Fig.6 show respectively a comparison of the mass change mass of the nitrile rubber and fluorine rubber rings immersed in CSME treating with TBHQ at 55°C for 60days.

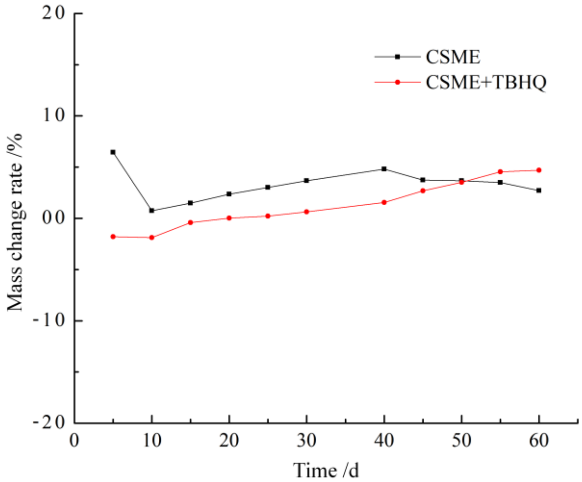

Fig.5 Mass change rate for NBR in CSME without/with TBHQ

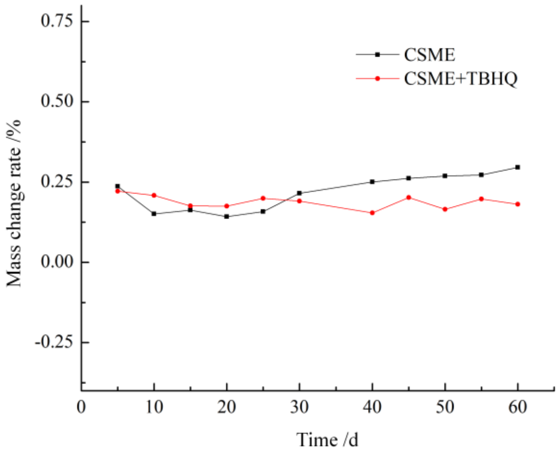

Fig.6 Mass change rate for FKM in CSME without/with TBHQ

From Fig.5 and Fig.6, the swelling (increase in mass) NBR and FKM in CSME treating with antioxidant can also be seen, and biodiesel and its blending with adding antioxidant can reduce the swelling rubber.

3.2 Viscosity-Temperature Characteristics of RME, 0PD and -10PD

The outer and inner change rates of NBR and FKM immersed in CSME, 0PD, B20 and CSME + TBHQ at 55°C for 60days are showed in Table 1.

Table 1 The change rates of NBR and FKM

Swelling Index		Outer change rate /%	Inner change rate /%
NBR	CSME	17.65	18.90
	0PD	1.69	3.51
	B20	10.42	11.05
	CSME + TBHQ	6.24	7.97
FKM	CSME	0.84	1.11
	0PD	0.61	0.24
	B20	0.04	1.02
	CSME + TBHQ	0.58	1.71

The swelling (increase in outer and inner) NBR and FKM can also be seen, and biodiesel and its blending with 0PD and treating with antioxidant can reduce the swelling rubber.

4. Conclusion

The effects of biodiesel on the nitrile rubber and fluorine rubber rings of automotive materials are investigated in this study through the immersion tests. The changes in mass, the inner and outer diameter of the fluorine rubber ring samples indicate that biodiesel fuel is less compatible with rubber than diesel fuel. The sequence of compatibility of CSME with rubber is found to be in the order of FKM and NBR. Blending with diesel fuel and treating with antioxidant additive can reduce the swelling of the rubber.

Acknowledgements

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