A STUDY ON VISCOSITY AND LUBRICITY EFFECTS OF N-BUTANOL AND ITS MIXTURES IN OIL

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ABSTRACT

This paper focuses on the effects of N-Butanol as a lubricity additive in ultra-low sulfur diesel (ULSD). The experimental objective is to determine if, and to what degree, N-Butanol increases the lubricity of ULSD, and whether or not it can be considered as a replacement for Ethanol as the main ULSD. Diesel fuel dilution is one of the many ways that new biofuels are tested for practical usability. The research employed a pin on disk tribometer for friction-force data acquisition, and wear was measured by specimen weight-change. This preliminary testing indicates that the dilutions of ULSD with N-Butanol lead to an increase in lubricity of the mixture. This increase happens at an inflection, meaning that the mixture tested exhibited better lubricity than either ULSD or N-Butanol.

Keywords: Lubricity, Tribology, Fuels, Fuels Testing, N-Butanol, Internal Combustion Engine, ULSD, Diesel, Bio-Diesel, Ultra-Low Sulfur Diesel

1. INTRODUCTION

The most common diesel fuel for passenger vehicles is the so-called ultra-low sulfur diesel (ULSD). Ultra-low sulfur diesel fuel has become mandatory for some typical applications because of its non-contamination advantages, but lowering the amount of sulfur in fuel affects their lubricity, because of sulfur lubricity additive properties [1]. Hazrat [2] discusses the use of biodiesel as an alternative lubricity additive, but acidic biodiesels as additives may cause the crankcase lubricants to gum up in inline fuel filters, and biodiesel compatibility with engine lubricating oils is not well understood, and there is strong evidence that some biodiesel components can significantly increase wear [3,4] (or reduce the effect of anti-wear additives). N-Butanol is a new alternative fuel being researched for either diluting or replacing some of the mineral diesel fuel, because one popular method of replacing diesel fuel, without significantly sacrificing internal-combustion engine efficiency, while no leading to higher friction or increased wear. N-Butanol is a long-chain alcohol has desirable combustion characteristics such as a high calorific value, low water absorption, low-corrosivity in to pipelines, and better miscibility with ULSD as compared to methanol and ethanol [5]. The viscosity of N-butanol tends to be lower than that of mineral diesel alone; but the addition of N-butanol may not significantly lower the mixture viscosity. This preliminary research work studies the tribological properties that can have the biggest impact on determining lubricity of N-butanol-diesel and its mixtures.

2. MATERIALS, METHODS AND RESULTS

A T-11 pin on disk tribometer, shown in Figure 1, is employed with a 1/8 inch-AISI 316 stainless steel ball-on-1 inch-AISI 1018 disk, load of 3kg, and run time of 1,500sec, the choice of materials leads to most wear occurring on the disk instead of on the ball, wear was measured by disk-specimen weight-change. The mixtures are combined by mass and adequately mixed using a magnetic stirrer. The following presented data summarizes the preliminary wear results for the two main fluids (100% N-Butanol in Table 1, and 100% ULSD in Table 2), and for a mixture of 70% ULSD and 30% N-Butanol (in Table 3). Nine specimens were tested for each fluid and mixture.

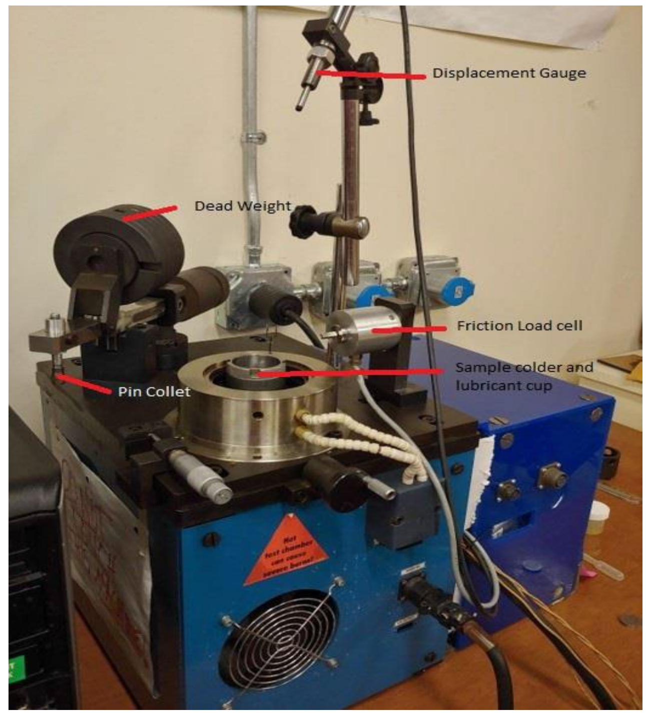

FIGURE 1: Employed T11-Tribometer.

Table 1. Wear results (in grams) for 100% N-Butanol

Test number	Pre-Weight	Post-Weight	Difference	
1	12.53826	12.53773	0.00053	
2	12.54787	12.54724	0.00063	
3	12.53927	12.53589	0.00338	
4	12.53000	12.52945	0.00055	
5	12.51725	12.51658	0.00067	
6	12.54523	12.54416	0.00107	
7	12.51838	12.51765	0.00073	
8	12.58258	12.58179	0.00079	
9	12.32688	12.32598	0.00090	
Average	12.51619	12.51516	0.00103	
	Standard Deviation		0.00090	

Table 2. Wear results (in grams) for 100% ULSD

Test Number	Pre-Weight	Post-Weight	Difference
10	12.52018	12.51970	0.00048
11	12.56336	12.56240	0.00096
12	12.51389	12.51280	0.00109
13	12.54409	12.54319	0.00090
14	12.50647	12.49973	0.00674
15	12.51491	12.51432	0.00059
16	12.56771	12.56646	0.00125
17	12.54963	12.54852	0.00111
18	12.58891	12.58834	0.00057
Average	12.54102	12.53950	0.00152
	Standard Deviation		0.00198

Table 3. Wear (in grams) for 70% ULSD / 30% N-Butanol

Test Number	Pre-Weight	Post-Weight	Difference
19	12.57660	12.57565	0.00095
20	12.55296	12.55178	0.00118
21	12.57759	12.57706	0.00053
22	12.54906	12.54846	0.00060
23	12.51724	12.51658	0.00066
24	12.51688	12.51632	0.00056
25	12.54979	12.54904	0.00075
26	12.55308	12.55248	0.00060
27	12.56325	12.56235	0.00090
28	12.54665	12.54605	0.00060
Average	12.55031	12.54958	0.00073
	Standard Deviation		0.00021

Table 4. Consolidated wear results (in grams)

	100% N-Butanol	100% ULSD	70% ULSD / 30% N-Butanol
Average wear	0.00103	0.00152	0.00073
St. Deviation	0.00090	0.00198	0.00021

The average wear from Tables 1 to 4 shows that wear from the 70/30-ULSD/N-Butanol mixture is about 50% lower than measured wear for the 100% ULSD data set. And significantly lower wear than that of the 100% N-Butanol, The standard deviation of the 70/30 mixture data set is also nearly 10 times smaller than the standard deviation of the 100% ULSD data set.

Typical friction force vs. time for each of the three tested fluids are presented in Figures 2 to 4, they show an initial transient of about 30 sec-length, which leads to a stable friction force for the rest of the test. It is relevant that the 100% N-Butanol friction force in Figure 2 increased during test, but it stayed constant for the 100% ULSD (in Figure 4), while for the 70/30 mixture an increase in time was observed (in Figure 3), starting at the initial friction-value for 100%ULSD, but ending at the relatively higher friction force of N-Butanol; in general the friction force for the mixture was more stable than that of the N-Butanol for the typical tests.

4. CONCLUSION

The preliminary testing and data shows that N-Butanol may be an adequate alternative additive to improve the poor lubricity of ULSD, and they provide useful guidance for future testing. The relevant find that a mixture of N-Butanol in ULSD can lead to lower wear than those of the two pure components suggests that the employed method can be used to explore other percentages mixtures between the two components, which may lead to optimized lower-wear (and improved lubricity). Further fuel research should include the combustion efficiency of such optimum-wear N-Butanol/ULSD mixture [6], and it is under planning in Georgia Southern University's Renewable Energy and Engines Laboratory.

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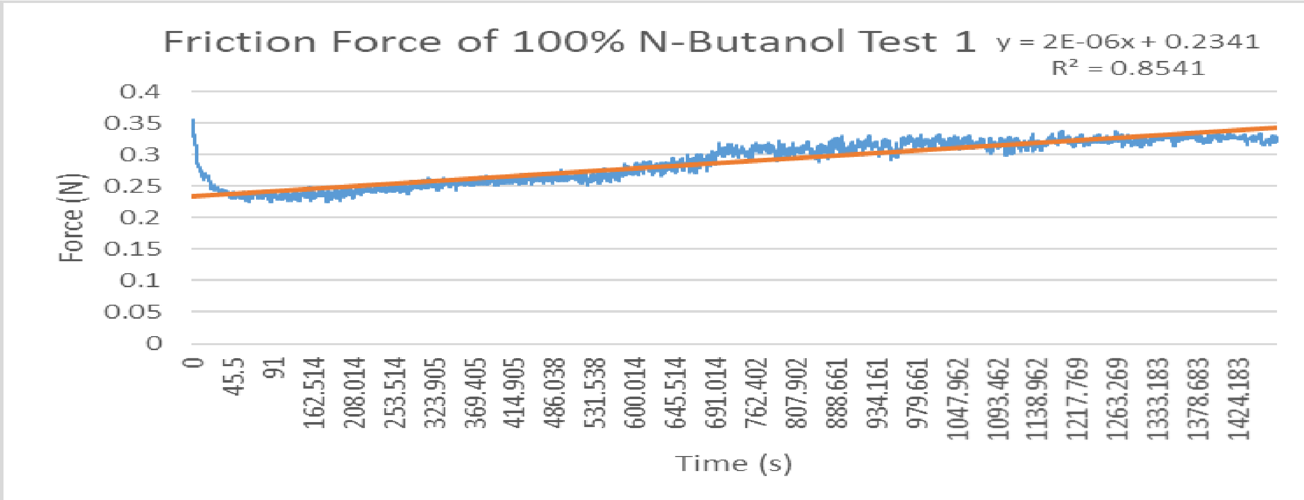

FIGURE 2: Friction force vs. time for 100% N-Butanol.

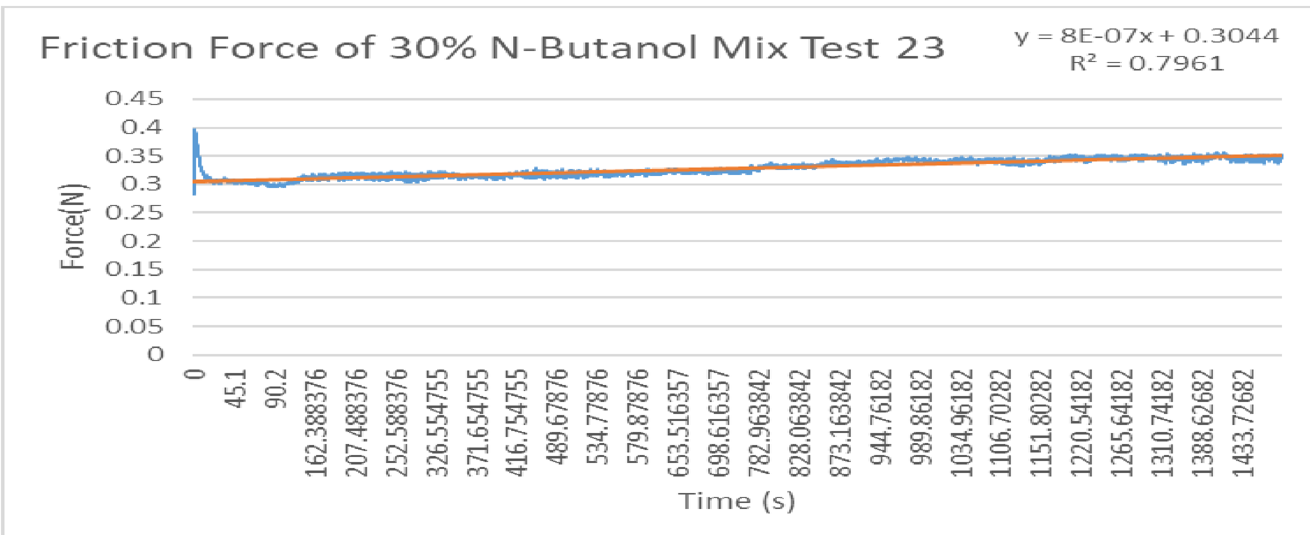

FIGURE 3: Friction force vs. time for 30% N-Butanol / 70% ULSD mixture.

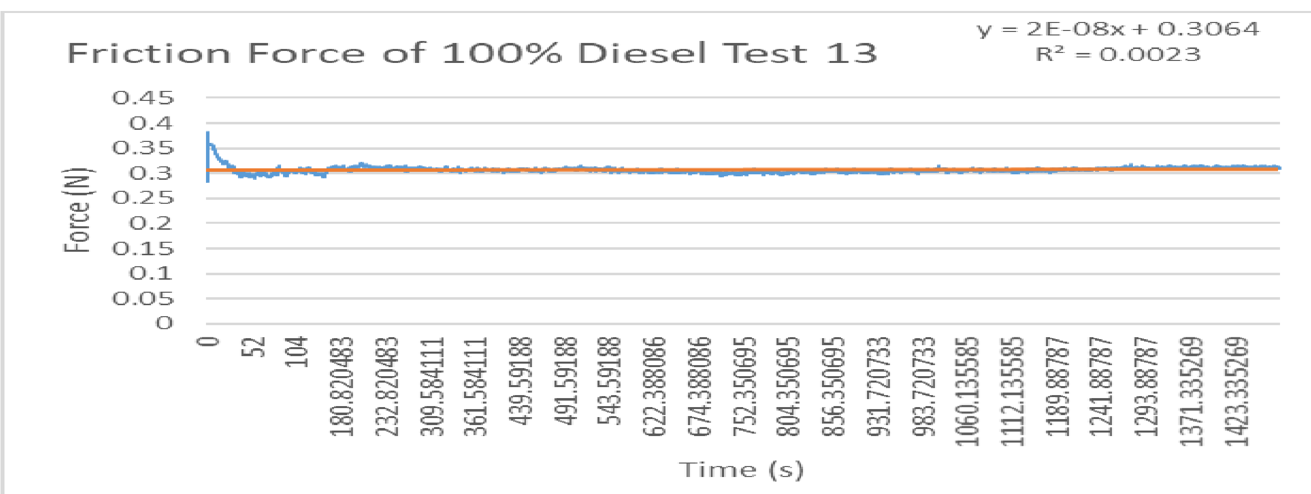

FIGURE 4: Friction force vs. time for 100% ULSD