INFLUENCE OF COCONUT OIL-BASED BIODIESEL-DIESEL BLENDS ON INJECTION TIMING IN MECHANICAL-INJECTION DIESEL ENGINES

ẢNH HƯỞNG CỦA HỖN HỢP DIESEL-BIODIESEL GỐC DẦU DỪA ĐẾN THỜI ĐIỂM PHUN TRONG ĐỘNG CƠ DIESEL PHUN NHIÊN LIỆU KIỂU CƠ KHÍ

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ABSTRACT

This study investigates the influence of coconut oil-based biodiesel blends on start of injection timing (SOI) in a diesel engine equipped with a mechanically controlled fuel system. Experimental tests were conducted using a four-cylinder diesel engine, with SOI determined from high-pressure line pressure signals. Results show that increasing the biodiesel blending ratio consistently advances SOI due to the higher bulk modulus of biodiesel compared with fossil diesel. For instance, at IMEP = 0.35 MPa, SOI shifted from 14.3° before TDC (Diesel) to 14.6° (B10) and 14.7° (B30). Such shifts may significantly affect combustion characteristics and emissions, warranting careful consideration in biodiesel applications.

Keywords: *Biodiesel; Start of injection; Bulk modulus of compressibility.*

TÓM TẮT

Bài báo khảo sát ảnh hưởng của hỗn hợp biodiesel gốc dầu dừa đến góc phun sớm nhiên liệu (SOI) động cơ diesel trang bị hệ thống nhiên liệu kiểu cơ khí. Các thử nghiệm được tiến hành trên động cơ diesel bốn xi-lanh, với SOI được xác định từ tín hiệu áp suất đường ống cao áp. Kết quả cho thấy việc tăng tỷ lệ pha trộn biodiesel làm tăng SOI do mô đun khối biodiesel cao hơn diesel. Khi IMEP = 0,35 MPa, SOI = 14,3° trước ĐCT đối với diesel trong khi SOI = 14,6° với B10 và 14,7° với B30. Sự thay đổi SOI ảnh hưởng đáng kể đến đặc tính cháy và phát thải, do đó cần cân nhắc kỹ lưỡng khi sử dụng biodiesel.

Từ khóa: *Biodiesel; Góc phun sớm nhiên liệu; Mô đun khối.*

1. INTRODUCTION

Biodiesel (B) is a renewable fuel extracted through the transesterification of vegetable oils or animal fats. It is highly valued for its environmental benefits, such as not contributing carbon dioxide to the atmosphere and reducing emissions compared to traditional diesel [1]. Additionally, B offers technical advantages like good lubricity, a high cetane number, and a high flash point [2, 3]. Due to its physicochemical properties being similar to those of fossil diesel, B is currently considered as an alternate for diesel engine [4].

Among various vegetable oil sources, coconut oil has been identified as a potential source for biodiesel production, especially in tropical regions [5, 6]. However, biodiesel (including coconut oil-based biodiesel) has different physical properties (viscosity, bulk modulus) compared to conventional diesel standards. This poses challenges related to injection timing, especially in engines using mechanical fuel injection systems. Fuel start of injection (SOI) or injection timing is a critical parameter in diesel engines, significantly affecting engine performance, combustion processes, and emissions [2, 3, 7, 8]. Previous studies have shown that biodiesel has a higher bulk modulus of compressibility than fossil diesel, which leads to faster transmission of pressure waves from the fuel pump to the injector, causing the injector to open earlier and thus changing the SOI in mechanical injection systems [9]. This change in SOI is one of the main reasons for increased NO_x emissions when using biodiesel [9].

This paper investigates the influence of coconut oil-based biodiesel-diesel blends on SOI in a diesel engine using a mechanical fuel injection system.

2. EXPERIMENTAL SETUP

The experimental system was set up as shown in Figures 1 and 2.

The engine used in the experimental system is a 4-cylinder diesel engine.

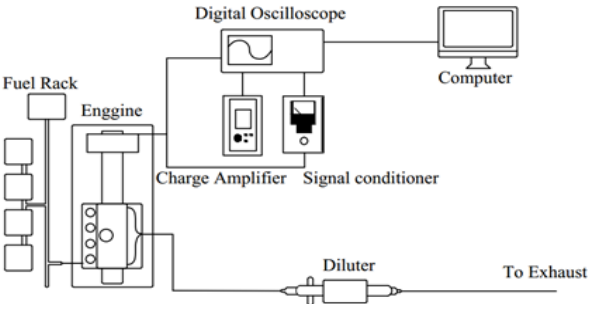

Figure 1. Engine testbed

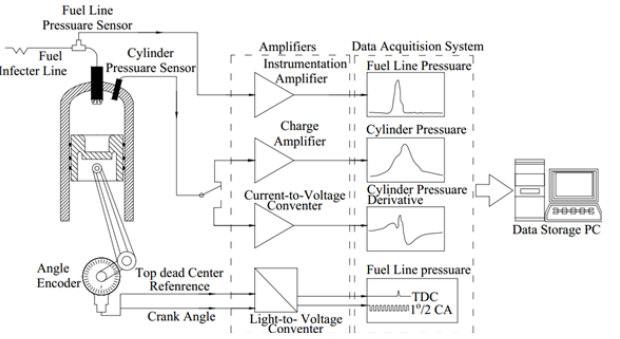

Figure 2. Signal recording and online processing

Crankshaft speed sensors, cylinder pressure sensors, and high-pressure fuel line pressure sensors were installed to collect signals sent to a computer for analysis via amplifiers and a data acquisition system. From the high-pressure line pressure profile, the SOI in mechanical fuel supply systems can be determined.

The physicochemical properties and composition of the tested biodiesel are presented in Table 1.

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Table 1. Coconut-oil based biodiesel properties and constituents

	C1214	Diesel
Stoichiometric air fuel ratio	12.05	14.5
Relative Density [kg/m³]	0.871	0.848
Iodine Number	8	-
Cetane Number	69.8	48.5
Saponification Value	233	-
Boiling Point (°C)	>150	-
Bulk modulus [GPa] at 40°C	1.53	1.4
Viscosity (m²/s) at 40°C	2.40E-06	-
Higher Heating Value (HHV)	38.66	43.4

3. RESULTS AND DISCUSSION

3.1. Data Processing

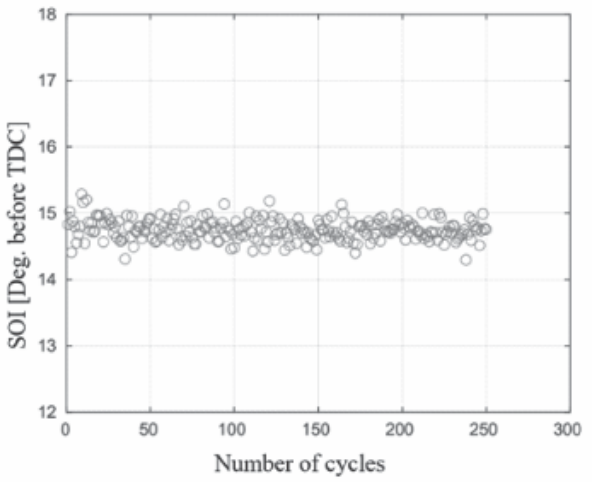

Figure 3. Example of SOI recorded for 250 cycles, D, 1500 rpm, IMEP = 0.38 MPa.

SOI data was recorded for 250 injection events at each test condition. Figure 3 shows the recorded SOI over 250 cycles at an engine speed of 1500 rpm and an indicated mean effective pressure (IMEP) of 0.38 MPa. The results in Figure 3 show the cycle-to-cycle variation of SOI. To determine the reliability of the injection timing results, the Coefficient of Variation of Injection Timing (CoV of InjT) was calculated and is shown in Figure 4. The results show that the CoV of InjT ranges from 1-2%, which is within the permissible range for cycle-to-cycle variation in diesel engines.

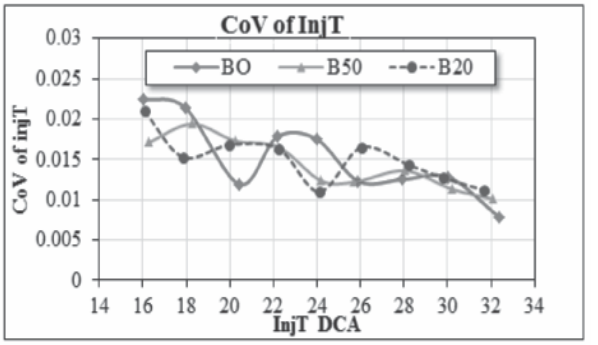

Figure 4. Coefficient of variation of SOI of diesel and biodiesel blends

3.2. Influence of Biodiesel-Diesel Blends on Injection Timing

Figure 5 illustrates the influence of biodiesel-diesel blending ratio on the SOI at different engine operating conditions. The results show that in all cases, increasing the biodiesel ratio leads to earlier SOI. This is because biodiesel has a higher bulk modulus than diesel. When blended, it increases the bulk modulus of the mixture, causing pressure waves to transmit faster from the fuel pump to the injector, and the injector opens earlier. At an IMEP of 0.35 MPa, the SOI for pure diesel is 14.3° before TDC, while for B10 and B30, it is 14.6° and 14.7° before TDC, respectively. Similarly, at an IMEP of 0.3 MPa, the SOI increased from 15.4° for B10 to 16.0° for B50. However, in the IMEP range of 0.3-0.55 MPa, SOI for B10 and B30 showed negligible changes. ☞

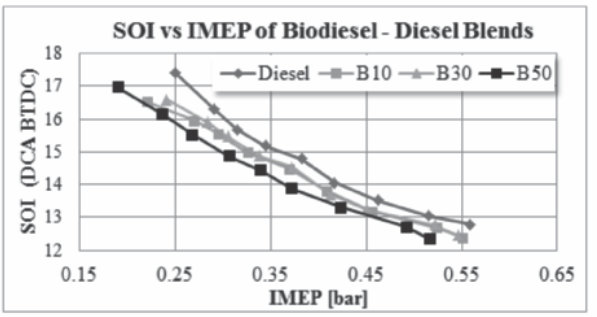

Figure 5. Fuel SOI versus injection timing of biodiesel-diesel blends

4. CONCLUSION

In conclusion, the experiments demonstrate that increasing the proportion of coconut oil-based biodiesel in diesel fuel advances SOI in mechanically controlled diesel engines. For instance, at IMEP = 0.35 MPa, the SOI shifted from 14.3° before TDC for pure diesel to 14.6° and 14.7° for B10 and B30, with a further advance to 16.0° for B50 at IMEP = 0.3 MPa. These shifts in SOI may significantly alter combustion behavior and emissions, highlighting the necessity of careful optimization when employing the blends in diesel engines.❖

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