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Assessment on the consequences of injection timing and injection pressure on combustion characteristics of sustainable biodiesel fuelled engine

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ABSTRACT

In the rapidly growing global energy consumption, diesel engines play the key role. Usage of diesel fuel contributes to harmful air pollution exhausted from combustion chamber. To overcome these serious issues, the biodiesel extracted from many feedstocks have been studied and implemented for the past few decades. The combustion characteristics of diesel are not same as the biodiesel blends due to the discrepancy in physio-chemical properties of biodiesel. Enormous studies have been focused on inadequate combustion profiles of biodiesel in compression ignition engines. This review paper analyzes the previous researches concerning the consequences of proposed effective strategies including the variation in engine operating parameters like fuel injection timing and injection pressure for enhancing combustion characteristics of biodiesel implementation. This study focuses its light on the advancement and retardation methods of injection timing and injection pressure to treat the engine combustion indicators such as in-cylinder pressure, peak cylinder pressure, heat release rate, ignition delay period and combustion duration, finally a comparative evaluation has been developed and the relevant reasons for the variation of combustion characteristics have been conversed. The review concludes that the advancement in injection timing and higher injection pressure are best in amplifying the combustion phenomena of biodiesel fuelling.

1. Introduction

Studies concerning the practice of renewable energy sources especially oxygenated biodiesel as the substitute for diesel fuel have been escalated in a high rate due to the exaggerating demand and diminishing supply of fossil fuels caused by rapid rate of industrialization and increasing vehicle population in the recent decades. In the year 2011, it was reported that India was ranked fourth in energy consumption in the world [1]. To meet this growing energy needs, alternative fuels are receiving more consideration. Biodiesel derived from vegetable oils, used cooking oils, animal fats, plastic oils, etc., are used as alternative fuels in diesel engines [2]. Biodiesel have been recommended as a vehicular fuel because of their similar physio-chemical properties when compared to diesel fuel. Due to the benefits like renewability, feasibility, availability, higher combustion efficiency and lower emission; biodiesel has been suggested as the superior renewable source [3]. Over the past few decades, various biodiesel for diesel engines have been explored and studied on the performance, emission and combustion characteristics by many researchers. They investigated that the effect of operating parameters like injection timing and injection pressure on the engine combustion characteristic is quite significant. Injection timing and injection pressure influences major impacts on the performance characteristics of biodiesel fuelled engines [4,5]. Injection timing plays an important role in the emission characteristics of biodiesel fuelled diesel engine [6]. Variation in fuel injection timing and fuel injection pressure leads to the divergence in combustion distinctiveness that concerns deviation in the emission characteristics of biodiesel fuelled diesel engine, which have been evaluated in our previous review paper [3]. No previous authors have done the survey on the consequences of variation of both injection timing and injection pressure on biodiesel powered engines. A substantial number of research studies from highly rated journals in the scientific indexes were selected and surveyed preferentially since the year 1999–2017, on the basis of effects of operating parameters variation on diesel engine combustion characteristics literatures. Therefore it is important to review the effect of injection timing and injection pressure on the combustion characteristics of a variety of biodiesels for the effective combustion in modern Compression Ignition Direct Injection (CIDI) engines.

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Nomenclature

IT	Injection Timing
IP	Injection Pressure
BTDC	Before Top Dead Centre
CAD	Crank Angle Degree
ATDC	After Top Dead Centre
ICP	In-cylinder Pressure
PCP	Peak Cylinder Pressure
ID	Ignition Delay
HRR	Heat Release Rate
CD	Combustion Duration
SOC	Start of Combustion
SOI	Start of Injection
NA	Not Analyzed
NM	Not Mentioned
NC	No Change
Std IT	Standard Injection Timing
Std IP	Standard Injection Pressure
Adv IT	Advanced Injection Timing
Ret IT	Retarded Injection Timing
Mod IP	Modified Injection Pressure
ASTM	American Society for Testing and Materials

2. History and background of biodiesel in global fuel market

Rudolf Diesel developed the diesel engine (internal combustion engine) that depends on the fuel self-ignition at higher temperature and pressure, which is termed as compression-ignition engine. In the book *Die Entstehung des Dieselmotors*, he described about numerous fuels tested in the engine. In Paris on the year 1900, the vegetable oil was initially used as the fuel in diesel engine at World Exposition. Due to the African colonies energy independence, the French Government involved in developing fuels for diesel engines. At the World Exposition, among the five diesel engine models, a small engine ran smoothly by using groundnut (peanut) oil [7]. Approximately during the end of World War II (1920); due to energy independence, many literatures insisted the usage of vegetable oils for fuelling diesel engine. Numerous researchers found that the vegetable oils displayed poor operational performance while powering the diesel engine due to its higher viscosity. In 1937, the Belgian patent 422,877 [8] was issued concerning the procedure for transesterification of palm oil with ethanol as ethyl esters with reduced viscosity, which was tested in an urban bus in the year 1938 [9]. After the World War II, the research on alternative fuels was dormant until the augmentation of energy crises during the year 1970s. In the year 1980, the research on methyl ester derived from sunflower oil has been elevated in South Africa, with the penalties of engine performance degradation and higher viscosity even after the transesterification process [10]. For the elevated viscosity distinctiveness, three other solutions were aroused by the later researchers as petrodiesel dilution, micro emulsification and pyrolysis. Among these processes, the transesterification was proposed as the effective method to higher yield of methyl or ethyl esters. The research on the renewable biodiesel using various feedstocks was escalated in a gigantic sum after the year 1980s, which highlighted biodiesel as one of the most-researched alternative fuels.

The outcomes of the numerous researches insisted that the biodiesel is an effective alternative fuel that replaces the diesel consumption in compression-ignition engines and also act as an eco-friendly fuel with lower scale of emissions except oxides of nitrogen (NOx). Although biodiesel possess the above said optimistic aspects, some issues like feedstock availability, lower cold flow property (at lower temperature), substandard combustion uniqueness, inferior resistance to oxidation (oxidation stability and storage stability) during storage and higher NOx emission level have impaired its global commercialization in fuel market. Many researchers have concerned the variation of combustion individuality of various biodiesel feedstocks as an important issue and studied its discrepancies over the modification of engine operating parameters like fuel injection timing, fuel injection pressure and compression ratio. This review article focuses on the technical issue concerning combustion characteristics distinctions with varying injection timing and injection pressure for various biodiesel.

3. Global energy consumption

The prolonged use of hydrocarbon based fossil fuels tends to make an alarm for the need of eco-friendly renewable resources, which

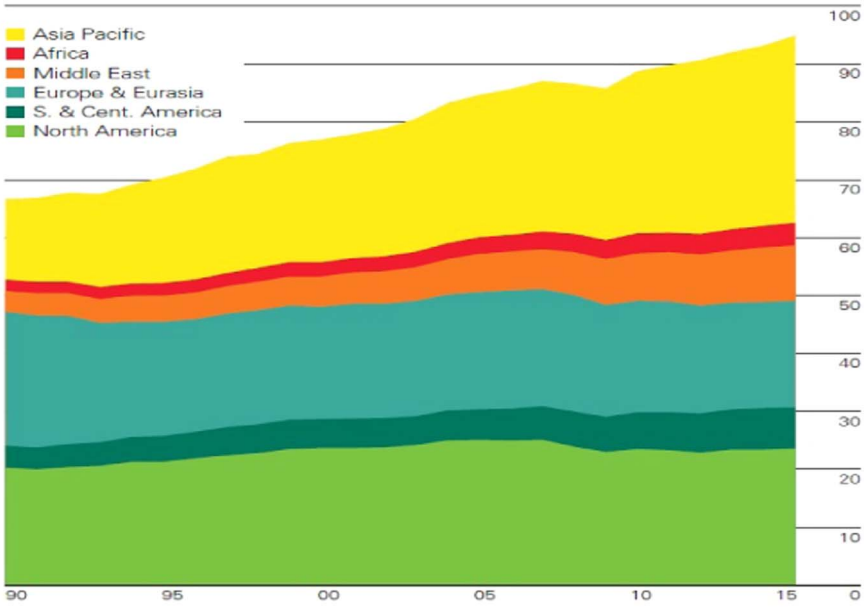

Fig. 1. Global oil consumption (%) from year 1990 to 2015 (Ref [15]).