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Measurement of engine vibrations using fuel blends of recycled vegetable oil and diesel – a mathematical and computational analysis

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MEASUREMENT OF ENGINE VIBRATIONS USING FUEL BLENDS OF RECYCLED VEGETABLE OIL AND DIESEL – A MATHEMATICAL AND COMPUTATIONAL ANALYSIS

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ABSTRACT:

Vibrations of the internal combustion engine are an indicator of its stability and mechanical condition. The vibrations of the engine resulting from reciprocating and rotating movement of its parts also depend on quality of combustion process and properties of the fuel. The present research focuses on the effect of the properties and concentration of the fuel blend of diesel and recycled vegetable oil on the vibration level of the engine due to the combustion process. The vibrations of the engine were collected with accelerometers of a mobile communication device, to then determine the resulting vibration level of the engine and its frequency spectrum by means of fast Fourier transforms. In this procedure carried out with each of the tested fuels, the properties such as the cetane number and the flash point were found as those that have influence on the vibration level of the engine. The purpose of the present investigation is to quantify the level of vibration produced by different concentrations of the fuel blend of diesel and recycled vegetable oil, depending on their properties and compared to pure diesel. From this, it is concluded that the stability of the engine in regard to its level of vibration due to the combustion process, can be controlled according to the properties of the fuel.

Keywords:
Diesel, vegetable recycled oil, cetane number, flash point, engine vibrations, vibrations spectrum, fast Fourier transforms.

Introduction

The study of alternative and ecological fuel blends, mainly aims to reduce the pollutant emissions compared with the use of neat diesel. At the same time, for sustainable use of a fuel blend as an energy source for internal combustion engines, it must have properties and characteristics that keep or improve the engine parameters such as performance, fuel consumption, durability and stability. As the quality of the combustion is conditioned by the cetane number and flash point of the fuel, the present research focuses on determining of the effect of these properties on the engine vibration level.

The vibrations on the internal combustion engine are the result of unbalanced forces of the rotational and reciprocating parts; as well as cyclic variations of pressure inside of the engine cylinders, which depend on the rotation velocity, fuel supply and quality of the combustion process [1]. There are identified two types of engines vibrations: torsional and longitudinal. The torsional vibrations have an effect over the engine crankshaft, because of the pressure fluctuation coming from the fuel combustion and engine loads; while the longitudinal ones, have an effect over the engine block and mountings, because of the rotary and alternating components [2]. The present research considers the effect of the fuel properties and the quality of the combustion on the total end engine vibration resulting from the torsional and longitudinal engine vibrations.

The vibrations are mainly understood as mechanical effects, which can be controlled by attenuators [3]; for this reason, another methods and researches are carried out, in order to analyze this phenomenon in a more detailed way. One of the investigations in

special determined that the irregular torque on the engine cylinders are produced by unequal fuel injection in each cylinder. The control of the fuel injection improves the exactitude of the delivered fuel quantity, allowed to reduce the level of vibration up to 92% [4].

One of the applied techniques is non-intrusive, which allows measuring of the engine vibrations without interrupting functionalities of either process [5]. With this technique, the data of the vibrations measurements, can be collected during the combustion process. It allows also distinguishing and analyzing of the effects of different fuel types.

The method to construct the frequencies spectrum and evaluate the vibration level of the engine was performed by means of the fast Fourier Transforms (FFT) [6]. This method consists of discomposing the resulting signal of the acceleration spectrum in individual components of a sinusoidal wave in order to get a frequency spectrum [7]. In this way it is possible to visualize the value of the dominant frequencies corresponding to rotation and ignition process of the engine. The relationship between the frequencies of these two processes is expressed as a function of the engine rotation speed and the number of cylinders [8, 9]. It means that in case of a four-cylinder and four-stroke engine the frequency values corresponding to the ignition are equal to the double of the rotation frequency of the engine. Any additional excitation source, for example the effect of the concentration of the fuel blend, is evidenced with the apparition of addition dominant frequencies in the spectrum.

The studies of engine vibrations with different types and concentrations of biodiesel, beside of valuation of engine stability, show also the capacity of a determined type of biodiesel to be burned, and its ability to keep or improve the engine performance [6, 10]. Engine measurements, regarding engine performance and vibrations using biodiesel based on animal fat [11], show that with increase of biodiesel in the fuel blend there is an increase in the cylinder pressure, with the consequently growing engine vibrations.

Other investigations testing different concentrations of biodiesel based on recycled vegetable palm oil blended with neat diesel, affirm that the engine vibration level decreases when the biodiesel concentration is higher in the blend, because of a higher combustion capacity [10]. While in the investigation, where the fuel blend was preheated [12, 13], the vibrations were reduced, because of the solved issues regarding the higher viscosity, improving the performance of a process like pumping, atomization or combustion.

The biodiesel of the present research, based on recycled vegetable palm oil, was obtained by means of transesterification with methanol and heterogeneous catalysators like calcium oxide (CaO). This kind of catalysators was selected because of their reusability, lower water requirement during the process and easier separation of methyl esters from glycerol [14]. Furthermore, the resulting methyl esters are more volatile compared with the esters resulting from the transesterification with ethanol. The choice of ethanol obeys to the fact that the methanol is more reactive and economic; however, it is more toxic and comes from non-renewable sources, in comparison with ethanol, which comes from starch or sucrose components [15].

The problems to solve in order to produce and implement alternative ecological fuels are not limited to reduce pollutant emissions and fuel consumption; for this reason, in the present research, it is considered that the engine stability can be controlled, by managing the fuel properties, which influence the combustion quality, such as the cetane number and the flash point. A higher cetane number reduces the ignition delay avoiding the combustion in later stages and sudden pressure rises; while a lower flash point allows the combustion process at lower cylinder pressure and temperature. The goal is to determine the effect of these properties of the fuel blend from recycled vegetable palm oil biodiesel for the engine vibration level, compared with neat diesel. In this way it is possible to control engine stability with a more ecological fuel.