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Vibration Characteristics of Pongamia Pinnata (Karanja) Biodiesel and Its effects on performance of C.I. Engine

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Abstract: -- **Karanja oil is very popular biodiesel used in CI engines in India. Among various biodiesels used, 10% Karanja oil is widely used when compared with rest of other biodiesels like Jatropha, Soybean oil. The combustion experiments were conducted in Mahindra 575DI engine, during experiment combustion vibrations are analyzed at different loads in percentage during ploughing action. It is found that the vibrations are generated due to combustion of biodiesel at different loads. The biodiesels are used in different blends such as B10, B20, B50 and B100. The changes in vibration level were observed during each load for different blends. The changes in vibrations are compared with diesel oil. The vibration result values observed in diesel oil is more than other blends. It is also observed that by increasing the blending rate the change in vibration value is found decreasing. It is concluded that the performance of CI engines from the vibration point of view is improved with biodiesel with diesel.**

Keywords: **Biodiesel, Karanja oil, vibration, performance.**

I. INTRODUCTION

The world presently encounters with the twin crisis of fossil fuel depletion and environmental degradation. Reduction in underground based carbon resources is due to excessive extraction and consumption of fossil fuels. So, significance and action has grown up around the globe to find an alternative to fossil fuels. Rendering to Indian consequence the demand for petroleum product like diesel is rising day by day hence there is a need to find a solution. Biodiesel is one of the most promptly developing fuels that promise to replace diesel in the near future. In recent years, Karanja oil is used as a biodiesel that can be used as a fuel in the CI engines. Under Indian condition, only non-edible oil can be used as biodiesel which is produced in considerable quantity and can be grown in large scale on non-cropped minimal lands and wastelands. Non-edible oils like Jatropa, Karanja and Mahua contain 35% or more oil in their seed, fruit or nut. India has more than 300 species of trees, which produce oil-bearing seeds.

The Karanja oil is the most capable alternative fuels used for CI engines as they are renewable, biodegradable, non-venomous, eco-friendly, a lower emission profile compared to diesel fuel. It is 100% non-edible oil, that can be added to diesel any level to make a biodiesel blend or can be used in its authentic form. Biodiesel, a fuel made up of mono-alkyl esters of long chain fatty acids originated from vegetable oils or animal fats, designated as B100 and meeting the requirements of ASTM D 6751 [1].

During combustion of Diesel as well as Biodiesel in CI engines vibrations are observed. These vibrations are creating dis comfort to vehicle driver at different loads [2]. One of the methods of gaining diagnostic information is monitoring of the vibrations level produced by the sub-assemblies of the engine. In a description of the vibro acoustic signs of the mechanical damages of a CI engine, one should take into account the fact, that a high level of minimal vibrations is generated, causing from the drive unit. The combustion of I C engine is influenced by internal and external inputs such as pressure, temperature and swirling inside the cylinder, type of fuel and injection of fuel inside the cylinder [3]. The vibration characteristics of I C engines are determined by considering four different forces that determine the characteristics of the vibrations. These forces are:

l. The exciting force, such as unbalance or misalignment of pistons.

2. The mass of the vibrating system, denoted by the symbol (M).

3. The stiffness of the vibrating system, denoted by the symbol (K).

4. The damping characteristics of the vibrating system, denoted by the symbol (C).

The exciting force present is trying to cause vibration, whereas the stiffness, mass and damping forces are trying to oppose the exciting force and control or minimize the vibrations. Perhaps the simplest and easiest way to demonstrate and explain vibration and its measurable characteristics is to follow the motion of a weight suspended by a spring. This is a valid analogy since all machines and their components have weight (mass), spring-like properties (stiffness) and damping.

The motion of the mass from top to bottom range and back to the initial starting position in the vertical direction is referred to as one cycle, and it has all the characteristics needed to define the vibration. Continued motion of the spring-mass system will simply be repeating these measurable characteristics. The characteristics needed to define the vibration to include:

• Frequency
• Displacement
• Velocity
• Acceleration
• Phase

Vibrations are generated in the engines, which mainly influenced by combustion pressure, the movement of piston-crank, timing gear system, inputs conveyed from the motor body, cooling mechanism, inlet charge and exhaust gases, fuel through the injector, the inertia of cam unit's parts, impacts of the head's parts [4-5].

Andrew et al. had studied the torsional vibrations in engine systems that demonstrated some unusual occurrences in the vibrations. Vibration produced through Piston crank mechanism geometry and it could be identified by a kinematic and dynamic analysis. In addition, system inertia is varied with crankshaft rotation; the results showed that the produced vibration is affected by the friction between the cylinder and piston too. Piston slap is the rocking of the piston in the cylinder (as opposed to the desired movement of the piston up and down the cylinder). It happens when there is "too much" room for the piston in the cylinder and the skirt of the piston hit the cylinder wall. Piston slap is a common phenomenon in reciprocating engines. This is the main reason for the complex vibration transient response associated with the exited impact in the cylinder [6-7]. Geng and Chen studied the piston slap phenomena in the reciprocating engine dynamic point of view. Therefore, a nonlinear model was recognized to simulate the vibration induced by the shock. Using numerical integration, the vibration responses induced by shock created the impact inside the cylinder were estimated. With the consideration of the results of the simulation and introducing a fast wavelet packet decomposition and analytical algorithm, practical experiments were performed for measurement and extraction of the slap-induced impact message inside the 6190ZLC diesel engine. The obtained results from the simulation were verified with practical results [8]. In a research conducted by Ghobadian, noise was created by the engine vibration due to knocking inside the cylinder. Noise data were measured in a small single-cylinder DI diesel engine (3.68 kW) in a stationary condition. Transmitted noise from the engine, the pressure inside the cylinder, the fuel line pressure and acceleration signals were measured and then analyzed at the time and frequency domains and in different engine angular velocities of 1200, 1350, 1500 and 1650 RPM. A comparison with existing data for multi-cylinder diesel engine showed that the average of obtaining values was 15 dB higher than available data due to its robust structure, however, the results showed severe resonances in frequency bands of 2, 4 and 6.3 kHz [9-11]. Taghizadeh had investigated the effects of vibration on the operator of a power tiller with diesel engine (Mitsubishi, 7.7 HP-2400 RPM). Experiments were conducted at different situations such as stationary state, idling, plowing and transportation states, at six-speed engines: 1300, 1600, 1800, 2000, 2200 and 2400 RPM, and in four locations: chassis, handle, driver arm and chest, and three orthogonal axes: vertical, lateral and longitudinal. It was observed that with increasing engine speed, the RMS (Root Mean Square) of acceleration values was increasing along the vertical, lateral and longitudinal axes. It was also observed that the dominant frequency of vibration in each location and axes are equal to the number of the piston stroke or engine revolution [12].

The literature review showed that the research on the diesel engine vibrations using biodiesel or the blends of diesel-biodiesel fuels has not been reported so far. Therefore, this work was conducted to measure vibration using different blends of diesel and biodiesel fuels in a six-cylinder diesel engine. The main objective was to identify the fuel blends with the minimal vibration. Researchers had examined the vibration characteristic of the engines of biodiesel. How et al. had investigated combustion, vibration characteristics, performance and emissions of diesel engine which run on coconut oil [13]. Gravalos et al. had concluded that vibrational behavior gets affected by the type of biofuel used in the engine although the peak frequencies are determined by the engine structural properties and type of biofuel [14].

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II. EXPERIMENTAL SET-UP

a) Seed Material: The seeds were collected from the Indian Biodiesel Corporation, Baramati, and Maharashtra. The seeds were selected according to their conditions. The damaged seeds were discarded. The good condition seeds were cleaned, de-shelled and dried in the range of temperature 100-105oC for 30 minutes. Seeds were then taken for oil extraction.

b) Extraction of oil: The oil was extracted by mechanical expeller and by soxhlet extraction method. The soxhelt extraction method was selected for good extraction. The methods for extractions are:

i) Mechanical press extraction method (Single chamber and double chamber oil Expeller): This process requires additional time and recovers oil in fewer amounts as compared to other methods.

ii) Cold Percolation Method: During extraction no heat is applied and it is preferred at room temperature. This method is used for the extraction of oil in the laboratory.

iii) Soxhelt Extraction Method: The seeds were grinded into fine particles and 50 gms of grinded was taken and a thimble was made. The soxhelt apparatus set up was prepared. The 300 ml hexane liquid was added to thimble for settling of suspended particles in the oil [19].

c) Percentage yield of oil:
The extraction of oil from Karanja seeds were done by different methods, i.e. mechanical expeller, solvent extraction and cold percolation method using n-hexane as a solvent and their yields are given in Table 2.1:

Table 2.1: Percentage yield of Karanja seed [19]

Extraction Method	Yield in %
Mechanical expeller	24
Soxhelt extraction	31
Cold percolation method	27

The extracted oil cannot be mixed directly in diesel because of the higher viscosity. The high viscosity of Karanja oil would reduce the fuel atomization and the fuel spray penetration, which would be responsible for high engine carbon deposits and thickening of lubricating oil. The use of chemically treated Karanja oil does not require modification in the engine or injection system or fuel lines and is directly possible in any diesel engine. Then the mixture was subjected to trans esterification process. From the oil, water contain was extracted to form pure oil [15-18].

The most important factors that influence trans esterification reaction time and conversion are:

- Reaction temperature
- Ratio of alcohol to oil
- Catalyst type and concentration
- Mixing intensity
- Purity of reactants

Mahindra 575DI tractor was chosen for the present investigation. This tractor is used for agricultural works. The engine testing was conducted for four different speeds and loads. The speed range 1650-2100 RPM was selected for investigation. The vibrometer was used for vibration analysis. Tables 2.2 and 2.3 present the properties of diesel and Karanja oil and specifications of Mahindra 575DI tractor respectively.

Table 2.2: Properties of diesel and Karanja oil

Properties	Diesel	Karanja
Density (Kg/m^3)	840	860
Calorific Value (KJ/Kg)	44000	37700
Viscosity (cSt)	4.2	5.14
Cetane Number	48	49
Stoichiometric A/F Ratio	14.45	12.7

Table 2.3: Specifications of Mahindra 575DI tractor

Brake power	45 HP
Type	Water cooled, four strokes, four cylinders, DI engine
Rated RPM	2300
Engine capacity	2730cc

The tractor engine was operated for plowing work at idle condition of 15–20% the total operating time. When the tractor was mere propelling, the load on the engine was 20–40% of the total power. Nominal load approaches make 80–90% of total power and 60–75% of the total operating time during the actual operation. The engine overloading was occurred for short periods when subjected to plowing. The engine operation period shortens due to the increased load on engine parts, decrease in driving speed and aggregate efficiency drops when working under such operation mode as RPM decrease. Thus, it is irrational to overload the engine [2]. The vibrometer was used to measure the displacement, velocity or acceleration of a vibrating body. Vibrometer is well known as low-frequency transducer and accelerometer as the high-frequency transducer. Vibration diagnosis was carried out by means of a Vibrometer

(Spectrum analyzer Model Type VA-11) with an acceleration measurement range of 0.02-316 m/s2, velocity measurement range of 0.1-1000 mm/s, displacement measurement range of 0.003-22.3mm firmly mounted centrally on the engine head. The various blends of Karanja methyl ester (B10,20,50,100) with diesel used for experimentation at different load conditions on the engine keeping all the independent variables same. The quantities which need to be measured were displayed on a monitor in the form of an electric signal which can be amplified and recorded. The output of an electric signal is directly proportional to the quantity which is to be measured.

III. RESULTS AND DISCUSSION

During the tests, 20 cycles of the accelerations of the engine body vibration were recorded, under different operating conditions of earth surfaces. The vibration acceleration signal of the engine body was observed and measured on the monitor. These signals were recorded for different loads. Similar readings were recorded during test for the operation and the average was calculated. The test results were noted as RMS (root mean square) velocity in mm/Sec. RMS values were obtained for four different loads and speeds. Fig 3.1 shows the overall value of vibrations for different speeds and loads. The RMS values were chosen due to fluctuation in speed at point It is found that the value of engine vibration increases with increase in load. But at full load condition, the vibration reduces. In the diesel engine with diesel oil at zero load, the value of vibration is found as 3.5 mm/sec. The vibration level increases as load on engine increases and reaches to maximum value of vibration 6.1 mm/sec. It is also observed that at 50% load the vibration obtained as 6.1 mm/sec. In the present diesel oil, the 10% biodiesel is added and this is designed as B10. For B10 oil combustion, the level of vibration reduced from 6.1 to 4.7 mm/Sec at 50% load. It is shown that the vibration level reduces from 6.1 to 4.3 mm/sec for B20 biodiesel. It is also observed that vibration level was found similar for B10 and B50. The pure biodiesel is designated as B100 for investigation. It is found that the vibration value is 5.7 mm/sec at 50% load. For further increase in load, values of vibration are reduced. The value of vibration is found 3.98 mm/sec at 100% load. From the results, it is observed that the overall vibration levels at different loads are reducing. This may be due to less turbulence generated during combustion of the fuel inside the cylinder.

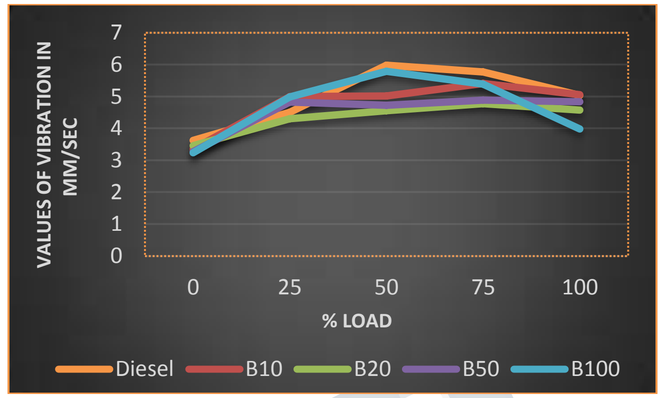

Fig. 3.1: values of vibration vs. load

IV. CONCLUSION

It is concluded from the engine testing that overall performance of the engine found satisfactorily when the biodiesel is used in the engine.

The following conclusions may be made:

1. the more vibrations are obtained due to pure diesel oil.
2. Vibration level is observed as 6.1 mm/sec at 50% load for pure diesel and it is further reduces as load added.
3. It is concluded that for B100, the vibration level drastically reduces.
4. Therefore, it may be concluded that life of the engine may be more by using biodiesel in the engines.

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