Proceedings of the Eighth IASTED International Conference
POWER AND ENERGY SYSTEMS
October 24-26, 2005, Marina del Rey, CA, USA

COMPARATIVE PERFORMANCE STUDY OF MAHUA METHYL ESTER AS DIESEL FUEL SUBSTITUTE ON DI DIESEL ENGINE WITH EMPHASIS ON VIBRATION & NOISE AS POTENTIAL ENGINE PARAMETERS

G Ravi Kiran Sastry, Dr. I N Niranjan Kumar, Dr. S Chandra Prasad, Dr. B V A Rao
Department of Marine Engineering,
Andhra University, Visakhapatnam, AP
INDIA
Neeru9@yahoo.com, neerux@yahoo.com

ABSTRACT
Recently the biomass resources are being used as alternative fuels and effective use of these fuels is gaining prominence as a substitute way to solve the problem of global warming and the energy crisis. In this work conventional laboratory equipment has been used for the transesterification of MAHUA oil to get MME. Various properties of MME have been tested for comparison with diesel fuel, further the investigations are carried out on a laboratory based D.I diesel engine to study it's performance as well as the vibrational aspect. A trail was made to evaluate the feasibility for the possible replacement and it is concluded that the MME is suitable for replacement.

KEY WORDS
MME, C7112, DC11, FFT & time waveform

INTRODUCTION
Among the biomass resources, vegetable oils are observed to be good alternative fuels for use in diesel engines and are also attractive because of renewability. However, there are fundamental problems of engine performance and exhaust emissions due to high viscosity and low volatility of the pure vegetable oil.

Several works have been reported [6-9] to improve the performance of engines fuelled by vegetable oils with property modifications by preheating the oil, use of hot surface ignition, blending with the diesel fuel, emulsions with lighter alcohols and by transesterification [3-5]. Pure vegetable oil blends can be used in lieu of diesel fuel directly without any engine modification. But increase in the percentage of vegetable oil in the blend creates problems like cocking and gum formation[8]. That is the reason why the diesel fuel cannot be replaced by neat vegetable oil without engine modifications. As many of the problems associated with the use of pure vegetable oil in diesel engines is mainly due to high viscosity, reduction of viscosity of the vegetable oil may help in possible replacement. Reduction of viscosity can be effected by any of the processes like transesterification, mineralization, and pyrolysis. Mineralization consumes more time and pyrolysis brings about irregular molecular break down. Hence transesterification is the only method, which reduces the viscosity of the vegetable oil and paves way for possible replacement to diesel fuel in internal combustion engines. Rape seed methyl ester along with alcohol blends to reduce NO_x are tested and performance is evaluated by various authors [9-12]. The present work aims at evaluating the performance of MAHUA METHYL ESTER (MME) (*Botanical Name*: Madhuca Indica, Bassia LatifolaRoxburghi , *Family Name*: Sapotaceae) by measuring and deriving the combustion properties and engine vibration & noise. This duel investigation generates a corroborative method to ascertain the engine combustion quality, as the vibration trend developed by the engine has got bearing on the excitation generated during combustion process.

EXPERIMENTATION
Experimentation is carried out at various loads on a laboratory based single cylinder, DI diesel engine to study the cylinder pressure[Fig.1 - 4] and heat release rate with respect to the crank angle for comparison. Engine cylinder head vibration is monitored at each load simultaneously to compare the cylinder excitation frequencies with the base line frequencies of engine run with diesel fuel which is a tool to detect the knock and detonation if any. A study on the phase of vibration on the cylinder is made along with the noise emanated by the engine is recorded to observe the ignition delay.
The data collected makes three parts.

- Combustion pressure data and the fuel consumed by the engine at various loads for the oil under consideration.
- Vibration of the engine on the cylinder and on the foundation, especially by measuring the acceleration amplitude and phase of vibration.
- Sound pressure levels at one-meter distance from the engine at various loads to record the air borne noise from the engine.

The pressure-crank angle data is collected at various loads (five load points viz. no load, $1/4^{th}$ load, ½ load, $3/4^{th}$ load and full load). Pressure crank angle data is the data collected by the engine recorder, which converts the pressure data into the graphic form by using **C7112** engine software. This data forms a base line acquisition to derive other parameters like pressure–volume, log **p** -log **v**, net heat release rate based on Gatowski Model [2] and cumulative heat release rate. As mentioned above, the vibration data is collected and reported in the form of spectrum averages and overall levels and also presented in the graphic forms (FFT graphs by using Vast-an and On-Time software) for easy comparison and evaluation. Even though the tool of vibration study cannot be directly connected to the engine performance, it can be investigated the effects of knock and detonation during combustion, if any, by the high frequencies generated in the spectrum. The frequency change in the burning rate brings enough variation in the vibration propensity recorded on the cylinder.

Fuel consumption in the case of diesel run is comparatively lower than MME tested on the same engine.[Fig 5 & 6]. Except in the case of mechanical efficiency, diesel excelled in almost all parameters for which graphic evaluation is made [Fig 7]. The reason can be assigned to the lubricity of the MME oil because of which the frictional wastage of power might have been reduced. The brake specific fuel consumption is an important parameter to be taken into consideration whenever engine performance is adjudicated. In our observation diesel fuel BSFC is relatively lower when compared with MME. The reason can be attributed to the inferior calorific values of the ester. There is an increased vibrational severity of the engine with the usage of the diesel fuel at higher loads when compared to the ester tested [Fig 15 & 16]. This may be due to relatively higher power development in the case of diesel fuel. The noise emanation from the engine with the usage of diesel fuel is maximum at all loads when compared to MME [Fig 14]. This trend basically depends on the power generation in the cylinder by the usage of the ester. The aspects of knock and detonation for diesel & MME are conspicuously absent as are assessed from the P-θ plots[Fig3&4]. Vibration phase measurements indicate that there is a phase difference for the first order which exceeds even 10^0 [Fig 25 & 26]. This phase lag can be attributed to the ignition delay in the case of MME oil which is obvious from the P-θ trend in Fig.1.The pressure rise in the premixed combustion period is more in the case of diesel fuel since the ignition delay is more when compared to the MME oil[Fig.12&13].

Comparison of Diesel fuel and MME

S No	Characteristics	Diesel	Mahua	Mahua Methyl Easter
1	Density at 30°C	830	875	860
2	Gross Calorific Value	43000	415000	38250
3	Viscosity at 30°C, Cst.	4.59	4.5	5.2
4	Cetane number	45-55	50	48
5	Rams Bottom Carbon Residue, Wt%	0.1	0.38	0.15
6	Flash Point, ^{0}C	50	172	171
7	Pour Point, ^{0}C	Winter 3 max, summer 15 max	< - 3	< - 3
8	Acid Number, mg KOH/gm	0.2 max	< 0.2	< 0.2

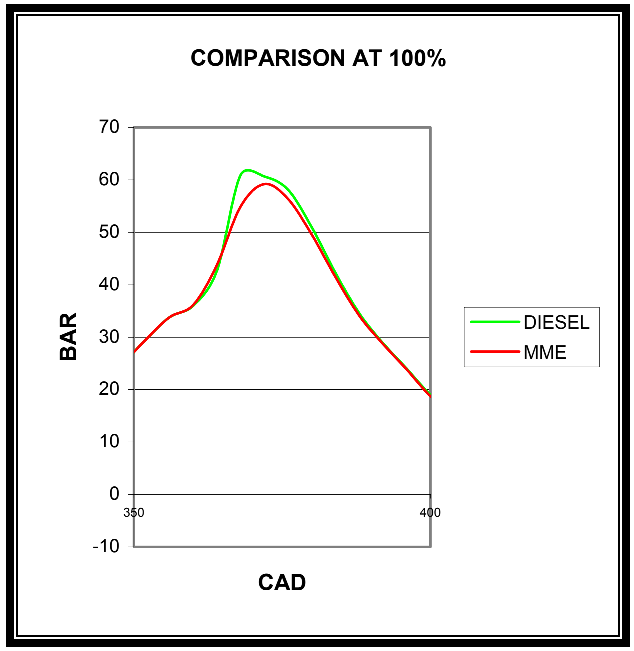

Fig. 1 Comparison of combustion pressures at Full-Load

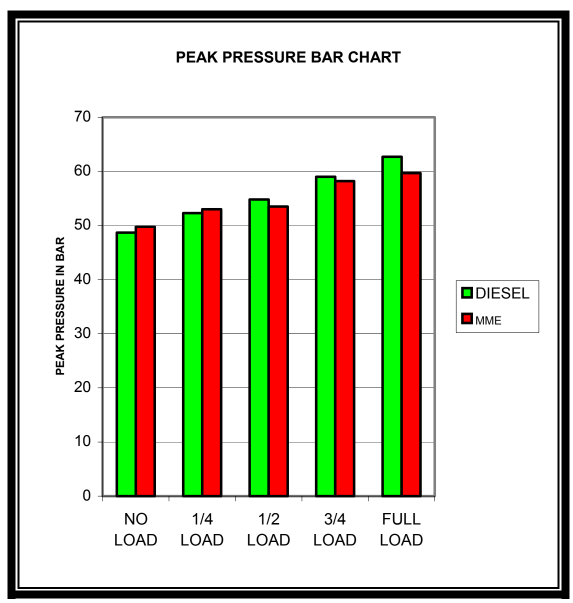

Fig 2. Comparative Peak Pressure bar chart

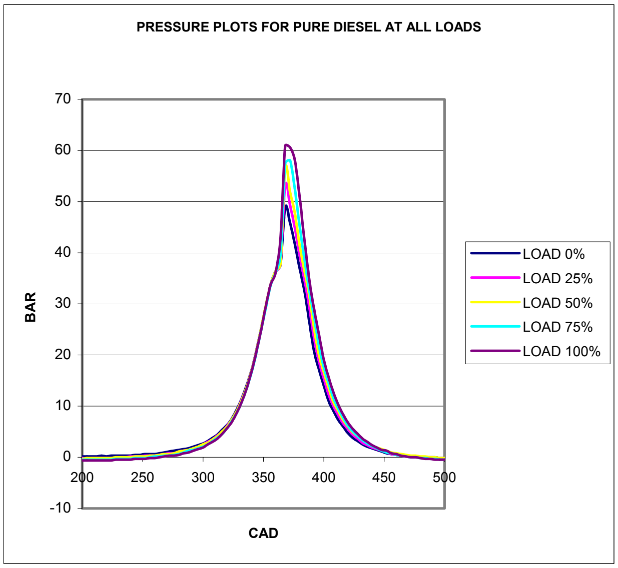

Fig. 3 Comparison of combustion pressures at all loads with pure diesel run.

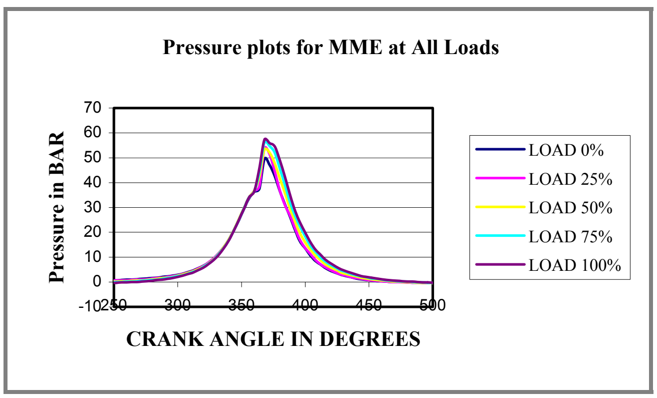

Fig. 4 Comparison of combustion pressures at all loads for MME run.

PERFORMANCE STUDY

The performance curves of the engine are drawn as shown in figures 5-9. MME oil's fuel consumption at all loads is more as per the experimental investigation. The consumption is more by 15-30%and diesel fuel is consumed minimum at all loads. Brake specific fuel consumption follows suit of the absolute fuel consumption. Mechanical efficiency of the engine run with the methyl ester is greater than the diesel by 10-15%. Indicated thermal efficiency and brake thermal efficiency at all loads is more for the diesel where as with the methyl ester the engine is generating lesser thermal efficiency by 5-10%. The cumulative heat release rate is coinciding at higher loads [Fig. 11]. In the case of MME premixed zone is split into three rates and with the diffused combustion zone similar to the pure diesel (figures 12 & 13).The specific gravities and the calorific values of the ester is varying by some degree when compared to the diesel fuel and this aspect stands as the main reason for the above said variation in performance.

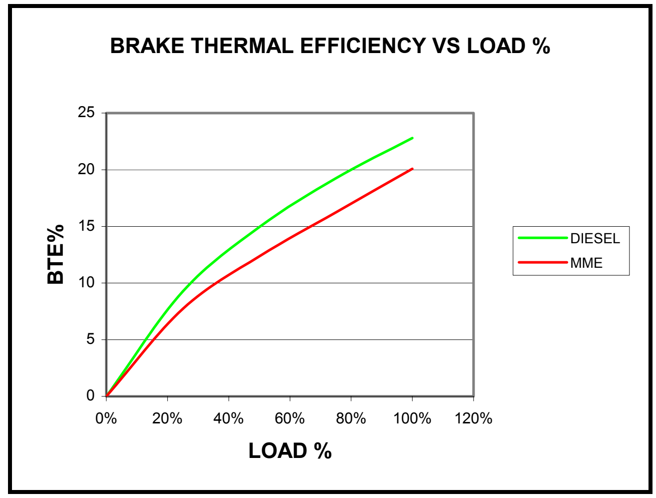

Fig. 5 Comparison of Brake power in KW verses fuel consumption in grams per second

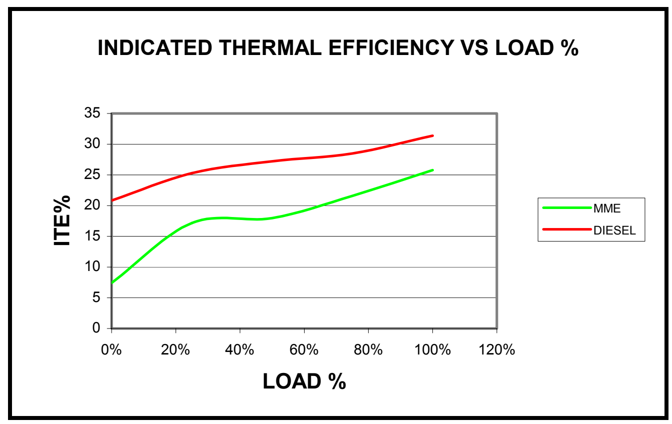

Fig. 6 Comparison of load percent verses Brake specific fuel consumption in kg/kw-hr

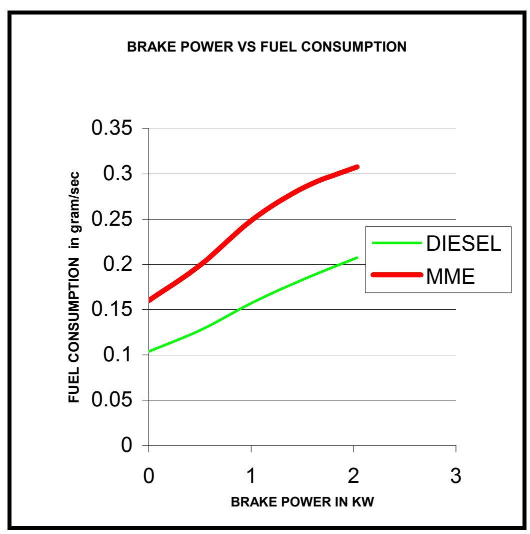

Fig. 7 Comparison of Mechanical efficiency verses load percent

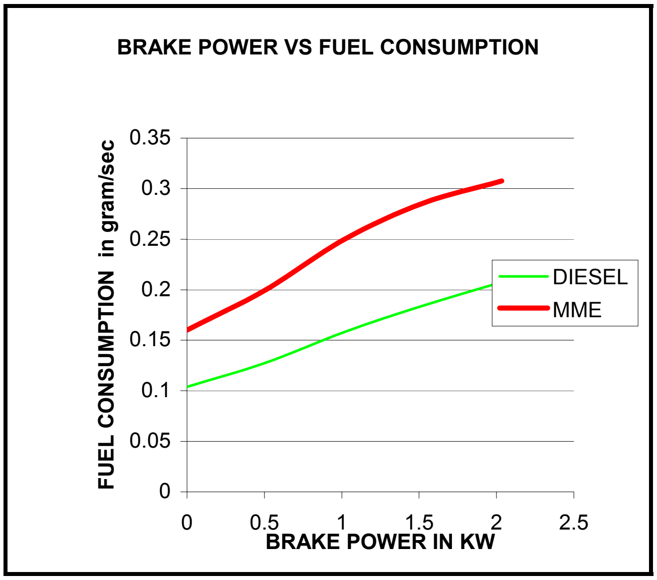

Fig. 8 Comparison of Indicated thermal efficiency verses load percent

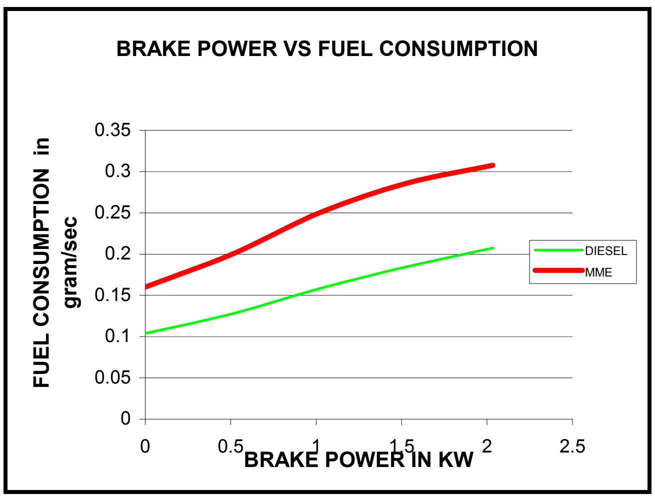

Fig.9 Comparison of Brake thermal efficiency verses load percent

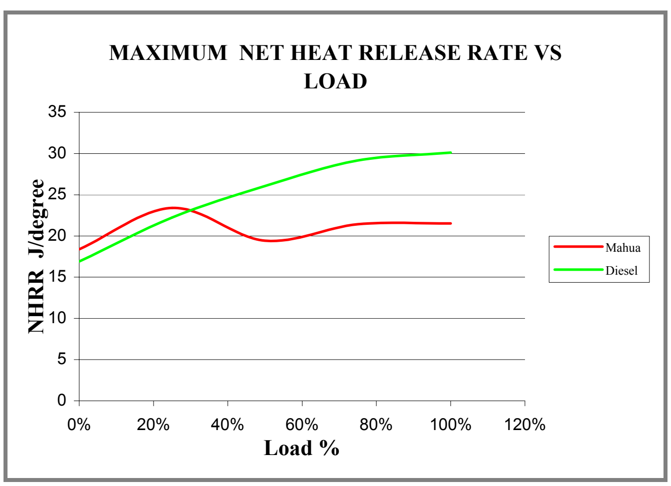

Fig. 10 Comparison of Net heat release rate verses load percentage.

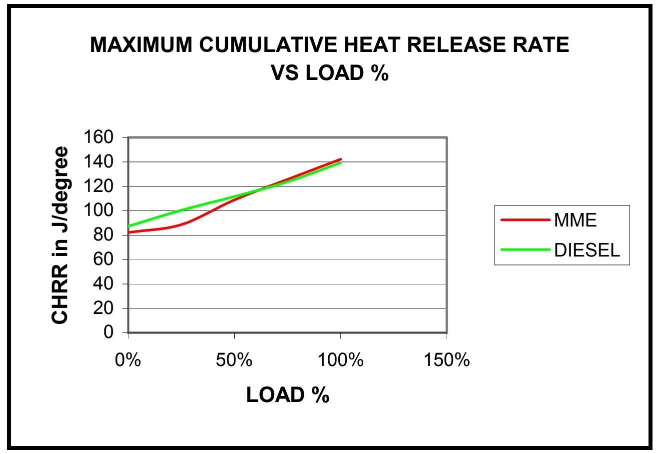

Fig. 11 Comparison of Cumulative heat release rate verses load percentage.

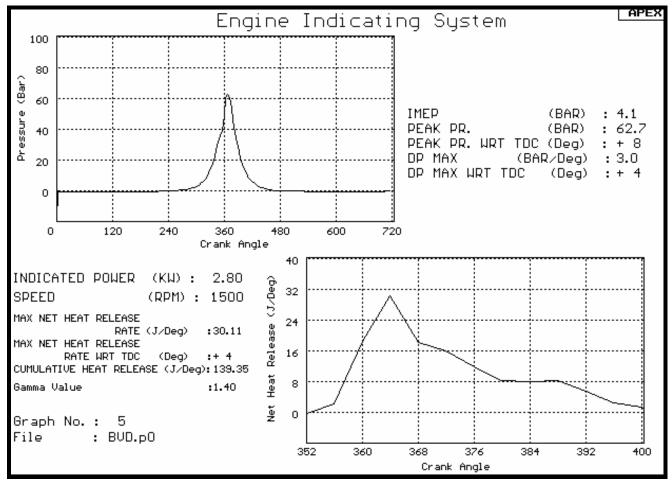

Fig. 12 Diesel heat release rate plot at full load.

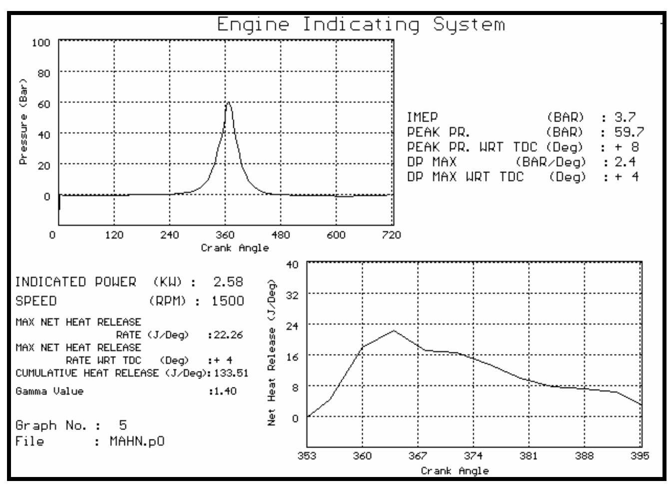

Fig. 13 MME heat release rate plot at full load.

COMPARISON OF THE SOUND PRESSURE LEVELS AT ALL LOADS:

Diesel fuel produces more sound pressure levels than MME at all loads by a maximum increase of 1.5 decibels. The MME generates lesser noise [Fig 14]. It can be attributed that the noise emanation from the cylinder depends on the indicated power developed with particular usage of the oil. Since the power developed by the MME is comparatively low when compared to diesel, the sound pressure levels are also low.

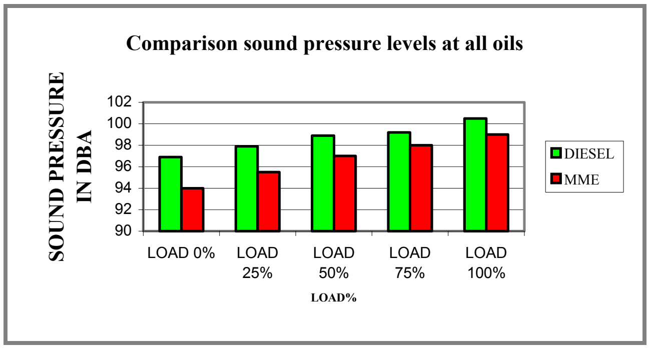

Fig.14 Comparison of Sound pressure levels recorded at various loads and for various oils.

ENGINE VIBRATION COMPARISON

The overall values of vibration on the cylinder in two directions are measured, One in the radial direction perpendicular to the crankshaft and the second on the cylinder head in vertical direction. With MME, the engine generated the minimum overall vibration when compared with diesel. The vibration transmitted to the foundation in the case of diesel fuel run is comparatively more than MME as obtained in the vibration spectrums, [Fig 17 &18]. The spectral densities in these figures also indicate higher vibration transmission to the foundation in the case of diesel. The above said reasons can be assigned to the reduction in overall levels in the case of MME oil. The vibration trend is more in the radial direction of the cylinder as shown in the figures 22 &23 for MME oil and this is also a reason for the reduction of foundation vibration.

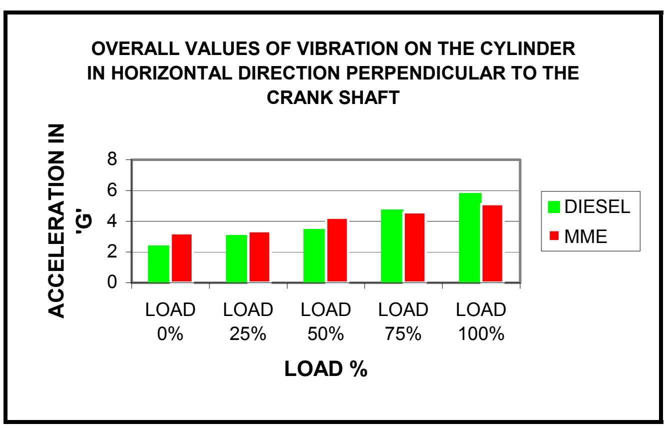

Fig. 15 Overall values of vibration in acceleration amplitude verses the load percentage

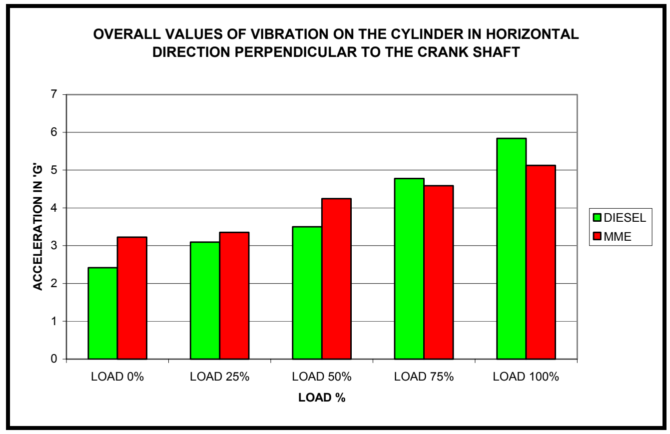

Fig. 16 Overall values of vibration in acceleration amplitude verses the load percentage

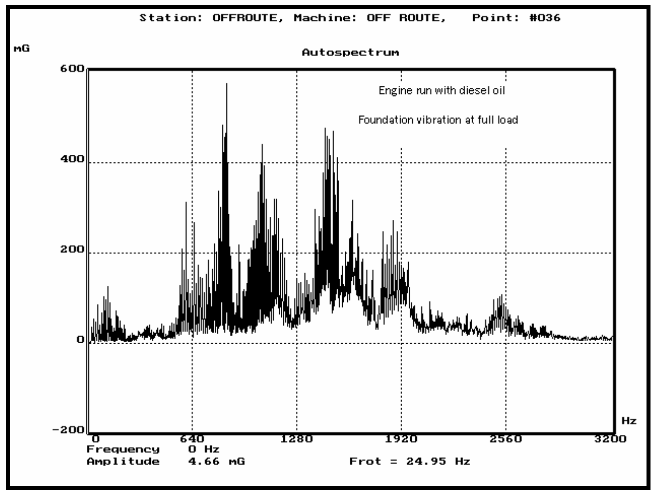

Fig.17 Foundation vibration with the diesel fuel run at full load

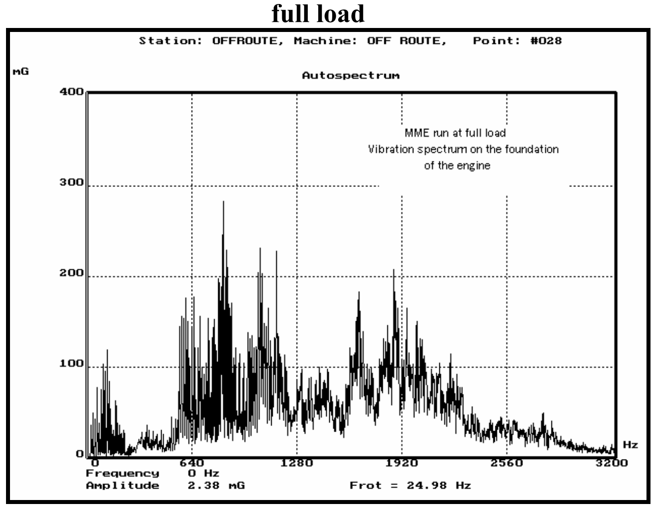

Fig. 18 Foundation vibration with the MME run at full load

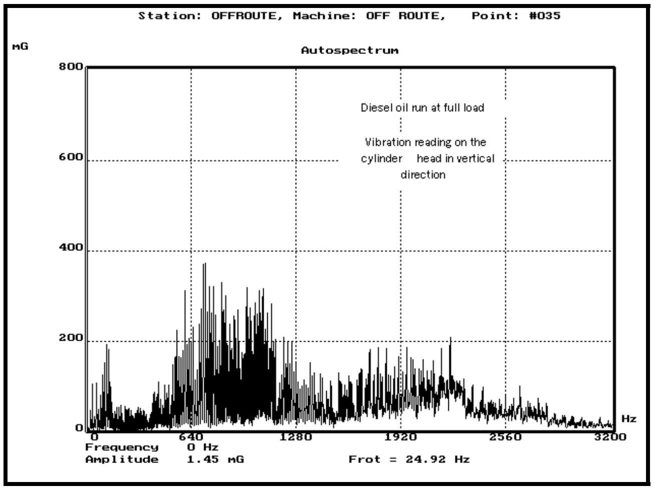

Fig.19 Cylinder vibration in vertical direction with the diesel fuel run at full load

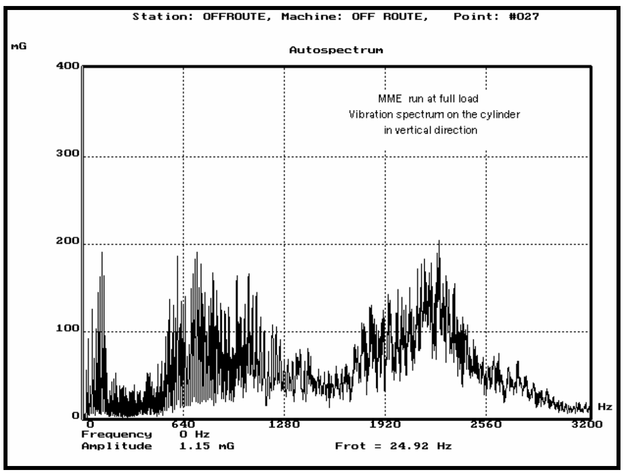

Fig. 20 Cylinder vibration in vertical direction with the MME run at full load

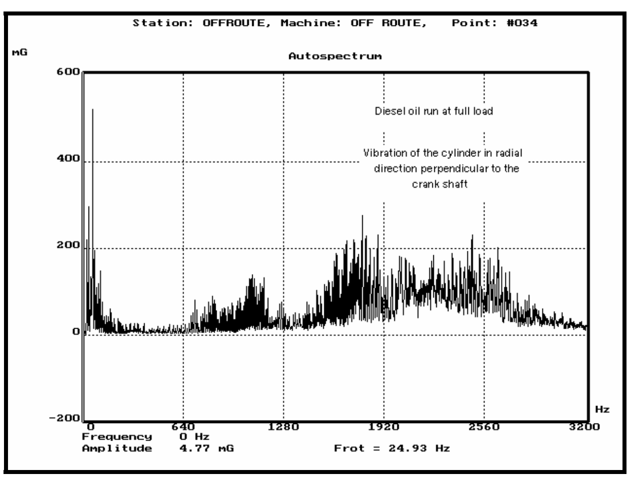

Fig. 21 Cylinder vibration in radial direction perpendicular to the crankshaft with the diesel fuel run at full load

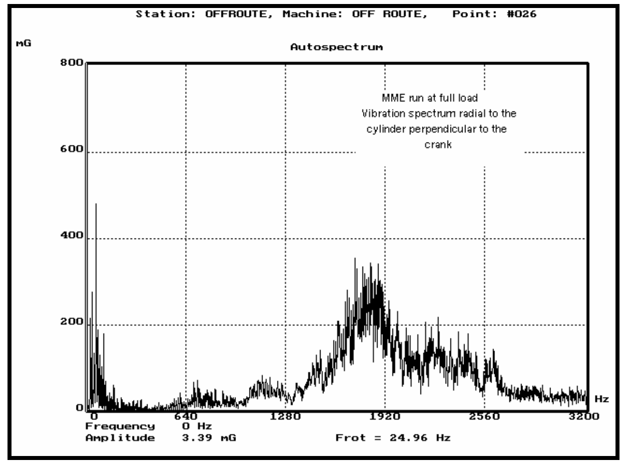

Fig. 22 Cylinder vibration in radial direction perpendicular to the crankshaft with the MME run at full load

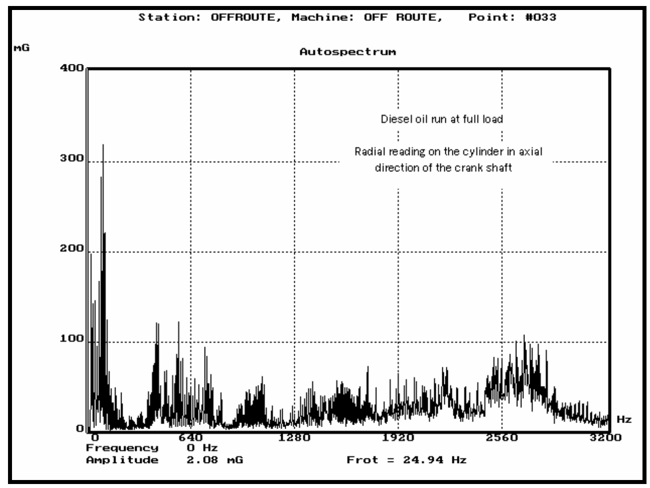

Fig. 23 Cylinder vibration in radial direction axial to the crankshaft with the diesel fuel run at full load

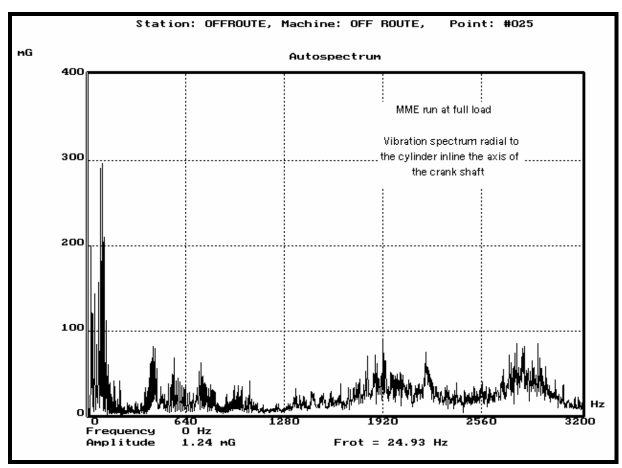

Fig. 24 Cylinder vibration in radial direction axial to the crankshaft with the MME run at full load

PHASE ANALYSIS

The phase of vibration is an important measure to identify the mode of vibration concerning the order. The first order phase measurements are taken at two strategic positions on the cylinder viz. vertical and radial for the engine run with the esters and diesel fuel [Fig 25 & 26]. The phase of vibration for the MME is different in the radial direction to the cylinder as observed in figure 25. The phases measured vertical on the cylinder as shown in figure 26 are different for the ester when compared to the diesel. This indicates change in mode of vibration for the first order. This may cause undue increase in the amplitude of vibration at other non-synchronous frequencies. This phase difference may affect the lower frequencies to generate higher amplitudes of vibration creating an impression that the combustion with the new oils is rough. But the vibration signatures indicate that the ester tested gave reduced vibration levels when compared to the diesel fuel. Hence a conclusion can be drawn that the effect of phase change reflected positively on the performance of the ester starting from the effect on the delay period.

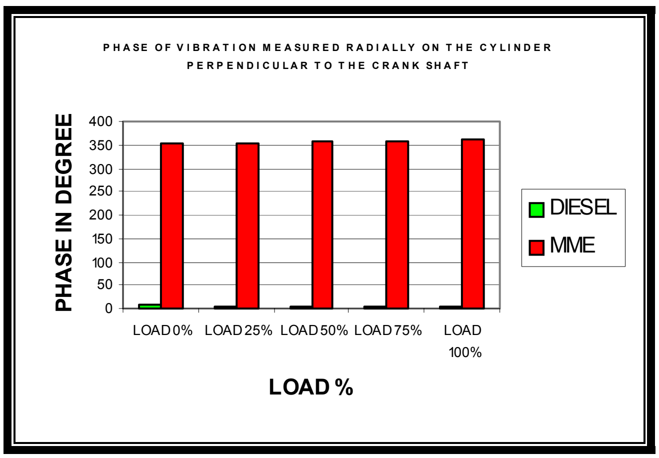

Fig. 25 Comparison of first order Phase of vibration measured radial to the cylinder

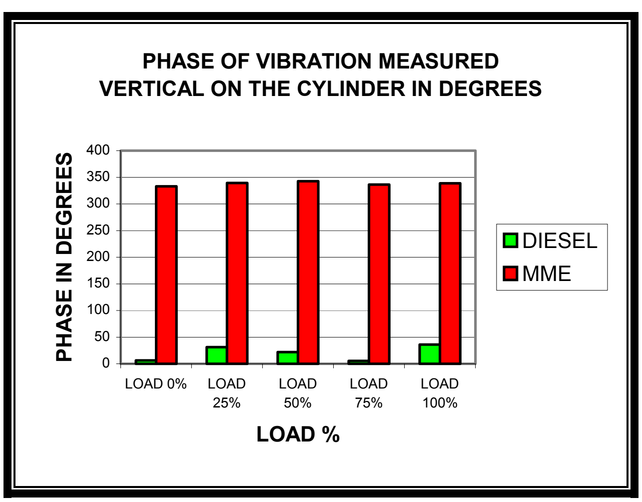

Fig. 26 Comparison of first order Phase of vibration measured vertical on the cylinder

CONCLUSION

The performance variation in the case of MME oil is marginal in the light of above discussions. The lesser calorific value of the oil increased the fuel consumption and the higher lubricity of the ester improved the mechanical efficiency of the engine. The benefit accrued by the reduction in vibration trend can remain as a compensation to the higher fuel consumption.

REFERENCES

1. Tadashi Murayama, Young-taig Oh, Noboru Miyamoto, and Takemi Chikahisa, “Low Carbon Flower Buildup, Low Smoke, and Efficient Diesel Operation with Vegetable Oils by Conversion to Mono-Esters and Blending with Diesel Oil or Alcohols”, SAE 841161.
2. J A Gatowski, E N Balles, K M Chun, F E Nelson, J A Ekchian and J B Heywood. Heat release analysis of engine pressure data. 1984. SAE Technical Paper 841359.
3. L.A. Perkins and C.L. Peterson, “Durability Testing of Transesterified Winter Rape Oil (Brassica Napus L.) as Fuel in Small Bore, Multi-Cylinder, DI, CI Engines”, SAE 911764
4. Jose M. Desantes, Jean Arregle and Santiago “Characterisation of the Injection-Combustion Process in Diesel Engine Running with Rape Oil Methyl Ester” SAE
5. Culshaw F.A.., "The Potential of BioDiesel from Oil-seed Rape”, Journal of Power and Energy, vol.207, No.A3, p.173, 1993.
6. Gunter H., "Rape Oil Methyl Ester (RME) and Used cooking Oil Methyl Ester (UOME) as Alternative Fuels”, SAE Paper 952755, 1995.
7. Andrzejewski J., Sapinski A., “Some Particularities of the Vegetable Oils Combustion in Diesel Engines”, Conference “Engine and Envirioment”, AVL Proceedings, 1991
8. Culshaw F.A.., "The Potential of BioDiesel from Oil-seed Rape”, Journal of Power and Energy, vol.207, No.A3, p.173, 1993
9. Pachter H., Hohl G., "Rapeseed Oil Methyl Ester (RME) as an Alternative Diesel Fuel Fleet Trials in the Austrian Army", Conference "Engine and Environment", AVL Proceedings, 1991.
10. Rickeart D.J., Thompson N.D., "A Review of the Potential for Bio-Fuels as Transportation Fuels", SAE Paper 932778, 1993.
11. Zilman R. "Rape Oil and Rape Methyl Ester - Fuels for the Future?", 4th EAEC International Conference, 1993.
12. Czerwinski, J. 1994. Performance of HD-DI-diesel engine with addition of ethanol and rapeseed oil”,SAE Paper No. 94-0545. Warrendale, PA.