ISSN 2394-3777 (Print)
ISSN 2394-3785 (Online)
Available online at www.ijartet.com
International Journal of Advanced Research Trends in Engineering and Technology (IJARTET)
Vol. 3, Special Issue 5, February 2016 in association with
HEERA COLLEGE OF ENGINEERING AND TECHNOLOGY, THIRUVANANTHAPURAM
Organizes
NATIONAL CONFERENCE ON ENGINEERING FOR LIFE (NCEL – 2016)
(12th -13th February 2016)

Experimental analysis of direct injection diesel engine fuelled with used transformer oil blends.

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***Abstract*—Now a days fossil fuels are widely used and theincreasing number of vehicles cause lots of problems in the environment. So we have to develop alternative fuels to replace the fossil fuels. Transformer oil is widely used in electrical transformers, welding transformers for cooling purpose. After long period the transformer oil becomes waste and it will through out. The disposal of waste transformer oil becomes a major issue because lots of transformers are used in industries and other places. We have to reuse or recycle the waste oil otherwise it causes pollution. The waste transformer oil posseses properties and heating value similar to diesel fuel. So we can use the UTO as an alternative fuel in diesel engine. In the present study use single cylinder, four stroke, water cooled,direct injection, variable compression ratio diesel engine developing a power of 5.7KW at a rated speed of 1500rpm. The UTO have higher viscosity than the diesel, so for reducing the viscosity UTO- diesel blends are used. Initially, the engine run with normal diesel fuel and performance parameters are calculated. Then UTO-diesel blends on varying the UTO concentration from 10% to 50%, at a regular interval of 10% by volume basis was used. The performance parameters obtained from the UTO- blends operation compared with normal diesel fuel operation. The thermal efficiency and indicated thermal efficiency of UTO blends increases than the diesel operation. The brake specific fuel consumption reduces and brake power almost equal to the diesel operation.**

I. INTRODUCTION

Fossil fuels are fuels formed by natural processes such as anaerobic decomposition of buried dead organisms. The age of the organisms and their resulting fossil fuels is typically millions of years, and sometimes exceeds 650 million years. Fossil fuels contain high percentages of carbon and include coal, petroleum and natural gas. Other more commonly used derivatives of fossil fuels include kerosene and propane. They range from volatile materials with low carbon: hydrogen ratios like methane, to liquid petroleum to non-volatile materials composed of almost pure carbon, like anthracite coal. Methane can be found in hydrocarbon fields, alone, associated with oil, or in the form of methane clathrates. The theory that fossil fuels formed from the fossilized remains of dead plants by exposure to heat and pressure in the Earth's crust over millions of years (see biogenic theory) was first introduced by Georg Agricola in 1556 and later by Mikhail Lomonosov in the 18th century.

The Energy Information Administration estimates that in 2007 the primary sources of energy consisted of petroleum 36.0%, coal 27.4%, and natural gas 23.0%, amounting to an 86.4% share for fossil fuels in primary energy consumption in the world. Non-fossil sources in 2006 included hydroelectric 6.3%, nuclear 8.5%, and others (geothermal, solar, tidal, wind, wood, waste) amounting to 0.9%.The use of fossil fuels raises serious environmental concerns.

The burning of fossil fuels produces around 21.3 billion tonnes (21.3 giga tonnes) of carbon dioxide (CO2) per year, but it is estimated that natural processes can only absorb about half of that amount, so there is a net increase of 10.65 billion tonnes of atmospheric carbon dioxide per year (one tonne of atmospheric carbon is equivalent to 44/12 or 3.7 tonnes of carbon dioxide).Carbon dioxide is one of the greenhouse gases that enhances radiative forcing and contributes to global warming, causing the average surface temperature of the Earth to rise in response, which the vast majority of climate scientists agree will cause major adverse effects.

Middle-east countries have huge reserves of oil and natural gas and many other countries are dependent on them for constant supply of these fuels. Organization of the Petroleum Exporting Countries (OPEC) is a group of 13 countries including Iran, Iraq, Kuwait, Qatar, Saudi Arabia and UAE.

They are responsible for 40 percent of the world’s oil production and hold the majority of the world’s oil reserves,

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according to the Energy Information Administration (EIA).

However, it may also be used as a fuel, most often in combination with gasoline. For the most part, it is used in a 9:1 ratio of gasoline to ethanol to reduce the negative environmental effects of gasoline. There is increasing interest in the use of a blend of 85% fuel ethanol blended with 15% gasoline

Alcohols, both ethanol and methanol, have been moderately successful as mixtures of alcohols and diesel fuel. But ethanol resource materials are inadequate to have an impact on the probable future requirements. Methanol, owing it its potential availability as a product of coal conversion, continues to gnition engines. Hydrogen is almost in exhaustible natural source present in water. Also hydrogen on combustion produces only water and NOx whose toxic effects are very less compared to other fuels.

Generally two types of transformer oil

(1) Paraffin based transformer oil

(2) Naphtha based transformer oil

Transformer oil or insulating oil is oil that is stable at high temperatures and has excellent electrical insulating properties. It is used in oil-filled transformers, some types of high-voltage capacitors, fluorescent lamp ballasts, and some types of high-voltage switches and circuit breakers. Its functions are to insulate, suppress corona and arcing, and to serve as a coolant. Oil transformer with air convection cooled heat exchangers in the front and at the side. The oil helps cool the transformer. Because it also provides part of the electrical insulation between internal live parts, transformer oil remains stable at high temperatures for an extended period. To improve cooling of large power transformers, the oil-filled tank may have external radiators through which the oil circulates by natural convection. Very large or high-power transformers (with capacities of thousands of kVA) may also have cooling fans, oil pumps, and even oil-to-water heat exchangers.

The main objective of the investigation is to find an alternative fuel for the diesel engines.for this purpose used transformer oil (UTO) is used. The UTO posses properties and heating values similar to diesel fuel. So we have to find the possibilities for using UTO as an alternative fuel in direct injection diesel engine. In the present work different fuel blends are prepared. That means UTO mixes with normal diesel fuel at different ratios.. Then the diiderent blends used in the diesel engine and performance paramaters are calculated and compared with normal diesel fuel operation.

In the present investigation different methods are following for finding an alternative fuel for the diesel engine. They are

•Select one alternative fuel (UTO) and find the properties of the same.

•Compare the properties of the UTO with diesel fuel.

•Then prepare different UTO- diesel blends at different ratios.

•Initially run the engine with normal diesel fuel.

•Then run the engine with different UTO- diesel blends.

•Compare the performance parameters of the UTO operations with diesel fuel operation.

Among the industrial wastes, disposed tyres, plastics and oils, and refrigerants are the main contributors of GHG emissions. The used oil, a contributor to industrial waste includes brake fluids, and hydraulic, transmission, motor, crank case, gear box, synthetic and transformer oils. Such oils can be recycled and used in various ways. The first way is to change the original properties of the oil. The second way is to recover the heat energy available in it. Some of the researchers have converted such waste organic substances into useful energy for IC engine applications.

D Balajee, G Sankaranarayanan [12] investigates the utilization of jatropha and Pongamia Pinnata Methyl Ester (PPME) blends with diesel in Variable Compression Ratio (VCR) CI engine.

Leenus Jesu Martin, Edwin Geo [13] investigated Vegetable oil based fuels are biodegradable, non-toxic and significantly reduce pollution. Cottonseed oil, which is considered, is not suitable as a fuel for diesel engines straight because of its high viscosity.

Sagar Pramodrao Kadu, Rajendra H. Sarda [14] investigated the performance of a four stroke, single cylinder C.I. engine by preheated neat Karanja oil is done from 30oC to 100oC.

Orhan Arpa [3] investigated the diesel fuel produced from waste engine lubrication oil purified from dust, heavy carbon soot, metal particles, gum-type materials and other impurities.

M. Mani, G. Nagarajan [2] properties of the oil derived from waste plastics were analyzed and found that it has properties similar to that of diesel. Waste plastic oil (WPO) was tested as a fuel in a D.I diesel engine.

II. .USED TRANSFORMER OIL

A. Transformer Oil

Transformer oil or insulating oil is oil that is stable at high temperatures and has excellent electrical insulating properties. It is used in oil-filled transformers, some types of high-voltage capacitors, fluorescent lamp ballasts, and some types of high-voltage switches and circuit breakers. Its functions are to insulate, suppress corona and arcing, and to serve as a coolant. The oil helps cool the transformer. Because it also provides part of the electrical insulation between internal live parts, transformer oil remains stable at high temperatures for an extended period. To improve cooling of large power transformers, the oil-filled tank may have external radiators through which the oil circulates by natural convection.

Large, high voltage transformers undergo prolonged drying

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processes, using electrical self-heating, the application of a vacuum, or both to ensure that the transformer is completely free of water vapour before the cooling oil is introduced. This helps prevent corona formation and subsequent electrical breakdown under load. The pure transformer oil is shown in Fig.3.1

B. Used Transformer Oil

After long use, the transformer oil becomes unusable and is disposed off. It possesses considerable heating value and properties similar to diesel fue. We can use UTO as an alternative fuel in diesel engine.. The used transformer oil looks like dark brown in colour and its colour shown in Fig.3.2. The oils in transformers are used for cooling purposes and after use it is waste and found that the properties of UTO are similar to diesel fuel. So it can be used as alternative fuel in diesel engine. The waste transformer oils are collected from the power transformers and it is allowed for settling and filtering. Due to high viscosity the UTO blended with normal diesel fuel and used in engine.

The transformer oil will deteriorate rapidly at high temperatures and moisture acts as a catalyst for its aging. Christo Ananth et al. [16] proposed a system, this fully automatic vehicle is equipped by micro controller, motor driving mechanism and battery. The power stored in the battery is used to drive the DC motor that causes the movement to AGV. The speed of rotation of DC motor i.e., velocity of AGV is controlled by the microprocessor controller.This is an era of automation where it is broadly defined as replacement of manual effort by mechanical power in all degrees of automation. The operation remains an essential part of the system although with changing demands on physical input as the degree of mechanization is increased. There are also other substances and metals present in a transformer that are responsible for oil degradation.

C. Properties Of UTO And Diesel Fuel

The different properties like viscosity, flash point and fire point of UTO and diesel are measured by using different apparatus. The table no.1 shows values. It is found that the viscosity

UTO is much more than the diesel fuel. Flash and fire point are also very much more for UTO than the diesel fuel. So these values are very important for using UTO as an alternative fuel. Table3.3 properties of UTO and diesel

Property	UTO	Diesel
Kinematic viscosity, CP at 29°C	10.18	2.54
Flash point, °C	156	70
Fire point, °C`	162	76
Density kg/m^3 [4]	890	860
Lower calorific value (kJ/kg)[4]	39270	44800
Sulfur content (%)[4]	0.02	0.05
Cetane number[4]	43.6	40-55

D. Viscosity Measurement

The viscosity of UTO and Diesel were measured by using Rotational viscometer (Brookfield viscometer DV2T).The spindle used is CP40 Z. The Fig.3.4 shows rotational viscometer. The viscosity of diesel was found to be 2.54 and that of used transformer oil is 10.18. The viscosity of UTO is very higher than the diesel fuel. So we have to reduce the viscosity. For that purpose two methods are used. They are increase the oil temperature and the next one is fuel blends that mean mixing the UTO with diesel at different ratios.

E. Flash And Fire Point Measurement.

All fuels have specific flash and fire points. These properties are needed for using the fuel in IC engines. The flash and fire point of UTO and diesel fuels were measured by using flash and fire point apparatus. The Fig.3.5 shows the flash and fire point apparatus.

F. Chemical Composition

The chemical composition of UTO and diesel are shown in the Table 3.6. The chemical composition of the UTO indicates that the fuel has carbon equal to that of diesel fuel. The hydrogen present in the UTO is 1.5 times less than that of diesel. It is also clear from the table that the UTO has considerable oxygen present.

Fig.3.4 Rotational viscometer.

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Fig.3.5 Flash and fire point apparatus.

Table3.6 Chemical composition of UTO and diesel [4]

Description	UTO	Diesel
C (%)	89.95	86.5
H (%)	9.19	13.2
N (%)	0.03	0.18
S (%)	0.35	0.3
C/H ratio	19.302	5.437
Carbon residue (%)	0.02	0.02

III. EXPERIMENTAL INVESTIGATION

A. Experimental Preparation.

Initially the required UTO was collected from the electrical transformer and the foreign particles were removed by the settling and filtering process. After that the properties of UTO found out and compared with diesel fuel. The results indicated that the viscosity of UTO is higher than the diesel fuel. So inorder to use UTO as an alternative fuel in diesel engine, the viscosity of the UTO must be reduced. For that the diesel-UTO blends were prepared.

B. Preparation Of UTO-Diesel Blends.

Blending is the simplest method of using a high viscous fuel as an alternative fuel in a CI engine by mixing it with a diesel fuel or low viscous fuel. For the experimental investigation, the UTO was blended with diesel in different proportions on a volume from 10% to 60% in regular steps of 10%. The blend was denoted as the UTO, followed by the numerical value, which represents the percentage of the UTO in the blend. For example, the numerical value in the blend UTO10 indicates 10% of UTO. Similarly, other blends were denoted as UTO20, UTO30, UTO40, UTO50.The samples of UTO- diesel blends are shown in the figures.(Fig.4.2.1 to 4.2.5).

B. Properties Of UTO-Diesel Fuel Blends

The properties like viscosity, flash point and fire point of fuel blends are shown in the Table 4.3. The table shows that the viscosity of blends almost nearer to the normal diesel fuel.

Table 4.3 Properties of UTO - diesel fuel blends

Property	UTO 10	UTO 20	UTO 30	UTO 40
Viscosity, CP at 29°C	2.80	3.07	3.60	4.12
Flash point, °C	79	82	92	94
Fire point, °C	84	86	94	99

D. Experimental Setup

The experimental setup used for this investigation is Kirloskar TV1 variable compression ratio diesel engine**.** The engine is single cylinder, four stroke, water cooled, constant speed, direct injection diesel engine. The engine has electrical loading system. A dynamometer is connected with the engine. The compression ratio can be changed with a lever mechanism. The engine speed is constant at 1600 rpm. And the governor system will adjust the speed when load varies. The engine specifications are shown in the table 4.4.

Table 4.4 Engine specifications

Make	Kirloskar TV1
Type of engine	Single cylinder, 4 stroke, water cooled, diesel engine
Output power	5.7KW(7HP)
Rated speed	1500 rpm
Displacement	661CC
Bore	87.5mm
Stroke	110mm

E.Experimental Work

The engine used for the investigation is four stroke single cylinder diesel engine. The engine is water cooled. So before starting the engine the coolant pump should be switched on. Then the apparatus electrical connections are switched on. The system consists of a fuel tank and filled with diesel fuel. Then the engine operated with diesel fuel initially. The compression ratio of the engine was set to 16:1. Then the engine operated for some time to get stable. After that the readings are taken. Initially the engine was at no load condition and gradually the load was varied. At each load different readings like time for fuel consumption for 10 ml volume, speed, load and different temperature are measured and noted. The different temperatures include T1 (inlet to engine and calorimeter), T2 (outlet water from engine), T3 (inlet air to engine), T4 (exhaust gas from engine), T5 (outlet water from calorimeter), T6 (exhaust gas from calorimeter). After collecting all the datas at different load the performance parameters were calculated. Again the

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experiment was repeated and readings were taken and performance parameters were calculated. The average values were used for the plotting performance parameters curve.

Fig.4.4 Test engine setup

The next step of investigation was UTO fuel operation. The UTO fuel blends were prepared before starting the engine. Initially UTO10 was prepared. That means 10% of UTO and 90% of diesel. Before using UTO as fuel we have to drain the diesel. Then the UTO 10 was applied. The corresponding readings were taken. Then the next blends UTO 20 was applied and corresponding readings were taken. This process continued up to UTO 50. All the readings were taken and calculated the performance parameters. The performance parameters curve was drawn. When the engine operation was finished we have to continue the coolant water flow to the engine for balancing the temperature. If it is not followed the engine parts may damage.

After finishing the UTO operation we have to drain the UTO fuels blends from the engine and fuel pump and use the diesel fuel for the normal diesel engine operation. The fuel mixing is the process in which we have to mix both the diesel fuel and UTO at different proportions. When mixed the fuels the viscosity of the fuel blends was almost nearer to the diesel fuel. So we can use UTO blends as an alternative fuel in diesel engine.

IV. RESULT AND DISCUSSIONS

In the present work used transformer oil is used for diesel engine. The used transformer oil was used at different percentage that is UTO10, UTO20, UTO30, UTO40, and UTO50. In this section the results of the performance parameters of the engine fueled with UTO and its diesel blends are analyzed, compared with those of diesel operation of the same engine and presented. The numerical value after UTO refers to the percentage of UTO in the blend. For example, UTO10 is composed of 10% UTO and 90% diesel.

A. Performance Parameters

The performance parameters of UTO- diesel fuel blends operation compared with normal diesel fuel operation.

a.Brake power

The brake power of the engine operated with UTO blends compared with diesel operation shown in the Fig.5.1.1 When graph plotted the brake power of UTO blends operation almost equal to the normal diesel fuel operation. The BP of diesel operation at maximum load (8Kg) was 2.22 KW and that of UTO 40 was 2.23 KW.

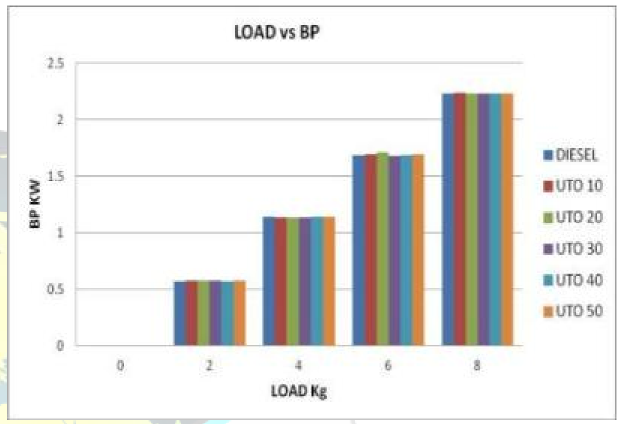

Fig.5.1.1 Load VS Brake power

b.Brake specific fuel consumption.

The brake specific fuel consumption comparison of UTO blends operation and diesel operations are shown in the fig5.1.2. The bsfc of the engine at maximum load decreases when UTO 40 was used as compared to diesel operation. The value of bsfc when diesel operation is 0.435 Kg/KW hr and that of UTO40 is 0.413Kg/KW hr. When the UTO50 was used, the bsfc slightly increases, because the spray formation for the combustion was very poor due to high viscosity of UTO fuel blends.

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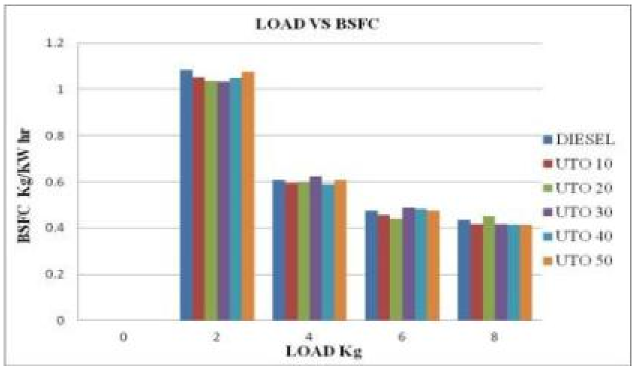

Fig.5.1.2 Load VS Bsfc

c. Brake thermal efficiency

The brake thermal efficiency of UTO blends and diesel operation are shown in the fig.5.1.3.The BTE of UTO40 blends slightly increases than the diesel operation. The BTE value of diesel at maximum load is 18.46% and that of UTO40 is 19.99%. When the concentration of UTO increases from UTO40, the efficiency slightly starts to decrease. So the better fuel blend may be UTO40.

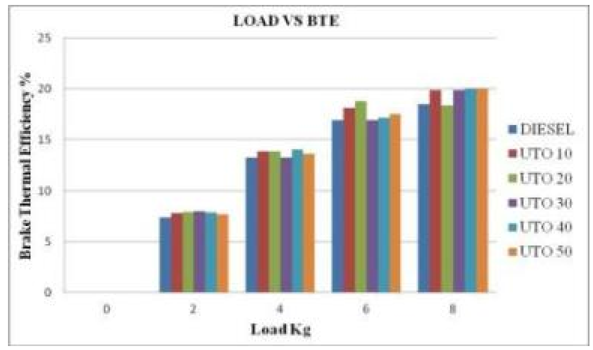

Fig.5.1.3 Load VS Brake thermal efficiency

d. Exhaust gas temperature

The variation of exhaust gas temperature with load is shown in the fig.5.1.4. The exhaust gas temperature of UTO blends are more than the baseline diesel fuel operation. The exhaust gas temperature of engine when diesel used is 332°C at full load while the exhaust gas temperature of engine when UTO50 is 350°C. This shows that, when the UTO concentration increases the exhaust gas temperature of the engine increases.The exhaust gas temperature of the engine increases with increase in brake power for diesel and UTO blends. And the exhaust gas temperature for UTO blends is higher than the diesel, because of higher density and viscosity.

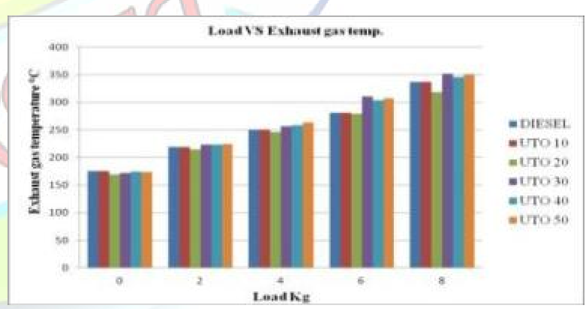

Fig.5.1.4 Load VS Exhaust gas temperature

e. Indicated thermal efficiency

The comparison of indicated thermal efficiency of the engine shown in the fig.5.1.5.The graph shows that, the indicated thermal efficiency UTO operation slightly more than the normal diesel operation. The ITE of diesel operation at maximum load is 23.08% and that of UTO40 at maximum load is 24.99%.

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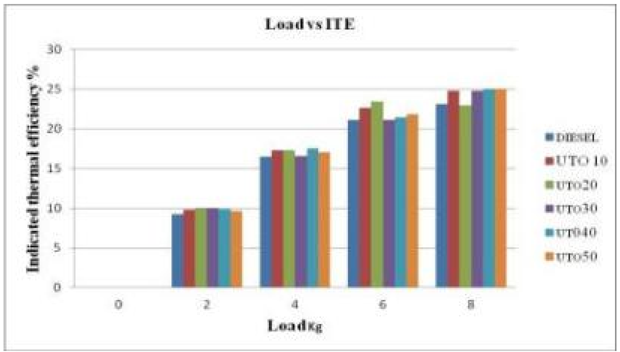

Fig.5.1.2 Load VS ITE

V. CONCLUSION

This investigation concluded that, a single cylinder, direct injection, four stroke, water cooled, VCR diesel engine was operated successfully with both diesel and used transformer oil blends. The different blends are UTO10, UTO20, UTO30, UTO40, and UTO50. The performance parameters obtained from UTO blends were compared with normal diesel fuel operation. The following conclusions are drawn.

- The used transformer oil can be used as an alternative fuel in the compression ignition engine.
- Different UTO blends are used for the working of the diesel engine.
- From the different UTO blends, the UTO40 shows some good performance.
- The result shows that the brake power of diesel operation and UTO blends operation.
- The brake specific fuel consumption of the UTO blends operation was found to be better than the diesel operation.
- The brake thermal efficiency of the UTO blends operation better than the diesel operation.UTO40 blends shows better performance than the other blends. The BTE of diesel operation at full load was found to be 18.46% while the BTE of UTO40 was found to be 19.99%.
- The indicated thermal efficiency of the UTO operation was also be found better than the normal diesel operation. The ITE of diesel operation at full load was found to be 23.08% and that of UTO40 operation is 24.99%.
- The exhaust gas temperature of the engine was found to be increased when the UTO blends concentration increases. The exhaust gas temperature of diesel operation at full load is 332°C and that of UTO50 is 350°C.

Acknowledgment

This work was carried out in Thermal engineering Lab, Department of Mechanical Engineering, College of Engineering, Adoor, Kerala, India and is supported by TEQIP phase II.

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