# Suitability study and analysis of Blended Castor and Madhucaindica oil as an alternative to Traditional Transformer oil

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**Abstract -** *Mineral oil has been used as insulating oil in transformer for the last few decades. However with the increasing consumption of these crude oils, they are going to exhaust one day. These mineral oils because of their high cost, toxicity, and non environment friendly nature need to be replaced with some alternative oil. In this paper work, an approach is made to analyze the suitability of blended Castor and Madhucaindica oil as an alternative to transformer oil. As it is a vegetable oil, it is cheap in cost and also non toxic. The major reason for choosing blended vegetable oil is its environment friendly nature. Unlike the mineral oil, these vegetable oils are biodegradable in nature. So various test are performed in this work, to analyze the properties of Castor and Madhucaindica oil seeing its feasibility whether it can act as an alternative to transformer oil or not. The result obtained is compared with standard mineral oil and previous research work done earlier.*

***Key Words*: Vegetable oil, Mineral oil, Castor oil, Madhucaindica oil, Biodegradable, Environment friendly, Alternative transformer oil.**

## 1. INTRODUCTION

The world's imperativeness essential has been ordered by oil based products for a significant long time in most of the fields like transportation, family, and power. According to Indian essentialness circumstance, the demand of harsh oil is extending well ordered, and therefore there is a need to find a possibility for it. One of the genuine uses of mineral oil is its use as insulating oil in transformer. Mineral oil as an indispensable securing material in transformers has been used for more than 150 years. However, there is a noteworthy opening between the demand, supply and production of these mineral oils.

Remembering the ultimate objective to decrease the usage of this mineral oil as insulating oil in transformer, we can make use of non-attractive oils i.e. vegetable oils like Palm, Madhucaindica, Castor, Karanj and Jatropha and so on. These vegetable oils contain no less than 30% in their seeds, sustenance's developed starting from the earliest stage. In our country, more than 300 extraordinary sorts of plants are found which produces oil bearing seeds. Out of these, around 75 plant species contain no less than 30% oil in their seeds/pieces and are recorded underneath.

One of the real explanations behind focusing on this vegetable oil is a direct result of their condition inviting nature. These vegetable oils are non-toxic. Unlike the mineral oil, which is non-biodegradable; vegetable oils are very biodegradable which guarantees low condition hazard if there should arise an occurrence of oil spillage. They are likewise less expensive in taken a toll contrasted with transformer oil and henceforth are fetched effective. Some vegetable oil meets the specialized detail of ordinary dielectric fluid. So this oil can fill in as another option to regular transformer oil.

### 1.1 Transformer:

A transformer can be described as a static contraption which helps in the change of electric power in one circuit to electric vitality of a comparable repeat in another circuit. The voltage can be brought or acquired down up a circuit, however with a relative augmentation or reducing in the present assessments. The primary rule of operation of a transformer is shared inductance between two circuits which is connected by a typical attractive flux. An essential transformer comprises of two loops that are electrically discrete and inductive, yet are attractively connected through a way of hesitance. The working rule of the transformer can be comprehended from the figure underneath.

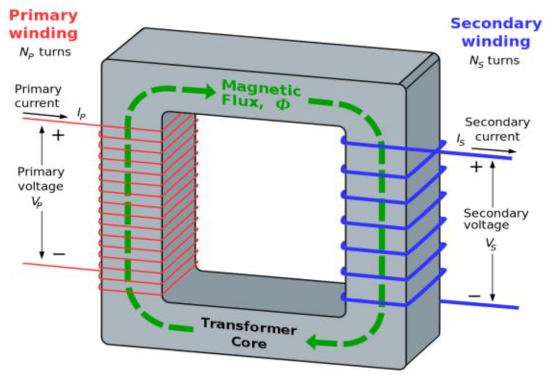


**Fig 1.1 Transformers**

### 1.2 Insulating Oil:

For both the architect and the client of an oil-filled transformer it can be of an incentive to make them comprehend of the creation and the properties of the transformer oil and a valuation for the routes in which these empower it to play out its double elements of giving cooling and insulating inside the transformer. Such a comprehension can incredibly help with acquiring ideal execution from the transformer all through its working life.

Insulating oil in an electrical power transformer is normally known as transformer oil. It is ordinarily obtained by partial refining or fractional distillation and subsequent treatment of unrefined oil. That is the reason this oil is also called mineral Insulating oil.

### 1.3 Types of transformer oil:

By and large, there are two sorts of transformer oil utilized as a part of transformer

1. Paraffin based transformer oil
2. Naphtha based transformer oil

Naphtha oil is more easily oxidized than Paraffin oil. But oxidation product i.e. sludge in the naphtha oil is more soluble than Paraffin oil. Thus sludge of naphtha based oil is not precipitated in bottom of the transformer. Hence it does not obstruct convection circulation of the oil, means it does not disturb the transformer cooling system.

Paraffin oil in spite of the fact that oxidation rate is lower than that of Naphtha oil however the oxidation item or muck is insoluble and hastened at base of the tank and deter the transformer cooling framework. But in our nation it is by and large utilized as a result of its simple accessibility.

### 1.4 Heat dissipation in transformer:

For the most part two sorts of vitality misfortune or losses happen in transformer. The first is the hysteresis misfortune and the second one is the vortex current misfortune or eddy current loss. Therefore, these vitality misfortunes get changed over into warm misfortunes or heat losses.

The heat exchange by offending or insulating oil in the transformer is both through conduction and convection. In any case, the wonder of convection is additionally overwhelming then conduction. Convective heat transfer or exchange fundamentally depend s upon the warm or thermal properties of fluid. Heat transfer happens by two sorts of convection:

1. Free convection
2. Forced convection

Heat transfer by free convection is governed by the equation:

$$Nu = C \times (Gr \times Pr)n$$

Where, Nu – Nusselt number, $Nu = h \times L/k$

Gr – Grashoff number, $Gr = \rho 2 \times g \times \beta \times \Delta T \times L3/\mu 2$

Pr-Prandtl number, $Pr = \mu Cp/k$

C – Constant that depends upon circulation of oil

## 2. LITERATURE SURVEY:

**B. Matharage and Fernando** have led different investigations and tests to check the execution of Coconut oil as an option transformer oil for dielectric insulation Coconut oil in light of its biodegradability and ecofriendly nature is a decent alternative. They discovered that coconut oil has high thermal because of quality of free greasy acids. In their study, three diverse sorts of coconut oil test comprising of refined, bleached and aerated were at first tried by recurrence dielectric spectroscopy estimation to perceive how the conductivity and consistency of oil was improved.

**F.Hijazi and M.H.Abderrazzaq** have performed different tests with olive oil test to contrast the properties of olive oil and ordinary transformer oil. The dielectric properties of this oil are examined and contrasted and that of mineral oil. Several tests are completed on different sorts of olive oils utilizing propelled testing gadgets and treatment hardware in an oil-testing research center. The principle tests, indicated for transformer oil, are connected for new and old examples of olive oil. The consequences of these tests were exhibited for separated and unfiltered oils.

**Norhafiz Azis and Jasronita Jasni** have played out their exploration work to check the plausibility of vegetable palm oil. In this examination work, the physical and chemical properties of palm based oil are contemplated or studied. The principle purpose of center is the viscosity of palm oil, flash purpose of palm oil, and its dielectric quality to fill in as option transformer oil

## 3. Material and Method:

### a) Madhucaindica (Madhucalongifoia):

Madhucaindica is prominently known as mahua oil in our nation. The two noteworthy types of variety Madhuca found in India are Madhucaindica (Latifolia) and Madhucalongifolia (Longifolia). Mahua is generally acknowledged as nearby name, for both these species. This plant is regular in deciduous backwoods. The seed capability of this tree in India is 500,000 tons and oil potential is 180,000 tons.

Mahua seed is likewise called as Bassialatifolia. It is likewise called as spread tree of India as its seeds yield fat called as mahua margarine which is utilized as a part of cooking, corruption of ghee and so forth. Its oil cake is utilized for grub, biofertilizer and excrement. Mahua can be effectively developed in no man's land and dry land. Its oil is non-eatable and very like groundnut oil.

**b) Castor oil:**

Castor oil is a vegetable oil got by squeezing the seeds of the castor oil plant (Ricinus Communis). Castor seed is the wellspring of castor oil. The seeds contain in the vicinity of 40% and 60% oil that is rich in triglycerides, principally ricinolein. The seed additionally contains ricin, a water-solvent poison, which present in lower concentrations throughout the plant.

Castor beans are pressed to separate castor oil which is utilized for various reasons. Ricin a lethal item or toxic product does not parcel into the oil since it is water dissolvable, thusly the castor oil does not contain ricin, gave that no cross pollution happened during its germination.

Castor oil is a colorless to very pale yellow fluid with a particular taste and scent (odor) once first ingested. Its boiling point is 313 °C (595 °F) and its density is 961 kg/m3. It is a triglyceride in which around 90 percent of unsaturated fat or Fatty acid chains are ricinoleates. Oleate and linoleates are the other critical parts.

**Fig 3.1: Castor oil plant**

Worldwide castor seed production is around two million tons for every year. Leading producing areas are ranges are India (with more than seventy five percent of the worldwide yield), China and Mozambique, and it is widely grown as a crop in Ethiopia. As of 2009 India production stands at 1123000 tonnes with an area of 880000 hectare whose yield is 1276 kg/hec. AS of 2013 India production stands at 1,744,000 tonnes.

**3.1 Blend created:**

1. 40% Castor oil + 60% Madhucaindica oil…[SAMPLE 1]
2. 50% Castor oil + 50% Madhucaindica oil…[SAMPLE 2]
3. 60% Castor oil + 40% Madhucaindica oil…[SAMPLE 3]

**3.2 METHODOLOGY**

**3.2.1 Kinematic Viscosity Test:**

This test is performed in Brookfield viscometer. The Brookfield viscometer measures the consistency of oil by measuring the force required to rotate a spindle in the fluid (oil). The viscosity appears in mPa-sec (cP)

**Fig 3.2: Brookfield viscometer**

Apparatus:

1) Brookfield digital viscometer
2) Sample jar
3) Spindle
4) Temperature probe.

**3.2.2 Flash point test (Heating test):**

The test method is ASTM D93. The temperature at which vapours over the oil surface initially lights off, when a little flame is passed over the surface under determined condition. The test is completed with the assistance of infrared thermometer. The detail of infrared thermometer utilized is given underneath:

| | | |
|---|---|---|
| Temperature range | : | -50 to 380°C |
| Power supply | : | 1.5 V batteries |
| Weight | : | 147.5 gm |
| Dimension | : | 53×101×43mm |
| Emissivity | : | 0.95% |
| Type | : | Instant thermometer resolution |
| Display | : | Digital LCD wave length (8-14μm) |


**Fig 3.3: Infrared Thermometer**

The flash point test of oil gives a sign of the combustibility or flammability of oil. They may likewise be utilized to give subjective sign of contamination of more combustible materials.

### 3.2.3 Pour Point Test:

The test method is ASTM D97. It is the least temperature, communicated as multiple of 3°C at which the oil is seen to stream when cooled and inspected under endorsed condition. At the end of the day, the pour purpose of a liquid is the most reduced temperature at which the liquid is fit for perceptible stream.


**Fig 3.4: Measurement of pour point**

### 3.2.4 Density Test:

The test method is ASTM D4052. Density of a fluid is the proportion of the mass of fluid to the volume of liquid. The relative density of mineral oil impacts the heat transfer rate of oil, so it is a critical parameter.

**Fig 3.5: Digital oil Densimeter**

## 4. Experimental results:

This part introduces the appropriateness investigation of Blended Caster oil and madhucaindica (mahua oil) samples as an option for transformer oil (mineral oil) on the premise of result acquired from different trials and tests. The outcomes from tests are contrasted and the standard mineral oil and additionally the vegetable oils on which different tests had been led already to check its attainability to go about as transformer oil

On the basis of various tests performed, the result obtained from it is discussed below:

### 4.1Kinematic Viscosity:

The kinematic viscosity of Blended Caster oil and madhucaindica (mahua oil) samples is determined at varying temperature range from 40˚C to 100˚C at an interval of 10˚C.It is observed that the value of kinematic viscosity for blended sample is maximum at 40˚C.The kinematic viscosity at 40˚C is found out to be 4.83cSt (40% castor +60% mahua), 6.3cSt (50% castor +50% mahua), 7.35cSt (60% castor + 40% mahua). However it is observed to be minimum at 100˚C.The value of kinematic viscosity at 100˚C is 1.82163cSt, 2.376cSt and 2.7720Cst respectively.

It is observed that with rise in temperature the value of kinematic viscosity for blended oil decreases continuously and at very high temperature side it tends to decrease very slowly. But overall, kinematic viscosity decreases linearly with increasing temperature.

The result of kinematic viscosity obtained at varying temperature from 40-100˚C is shown below in the table:

| Temperature(˚C) | Kinematic viscosity (cSt) | | |
|---|---|---|---|
| | Sample 1 | Sample 2 | Sample 3 |
| 40 | 4.83 | 6.3 | 7.35 |
| 50 | 4.1055 | 5.355 | 6.2475 |
| 60 | 3.4896 | 4.5518 | 5.3104 |
| 70 | 2.9662 | 3.868 | 4.5138 |
| 80 | 2.521 | 3.2886 | 3.8367 |
| 90 | 2.1431 | 2.7953 | 3.261 |
| 100 | 1.8216 | 2.376 | 2.7720 |

The effect of temperature on kinematic viscosity of blended sample is shown by graph given below:

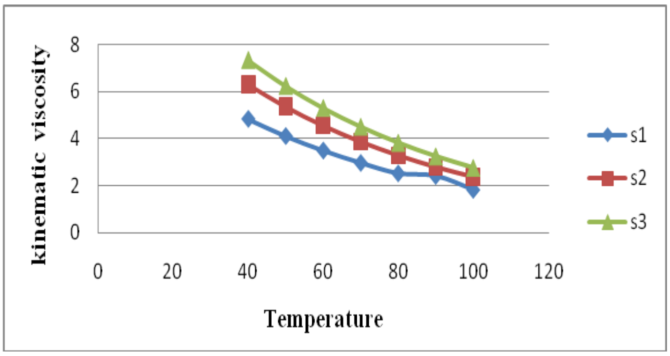


**Fig 4.1: Variation of kinematic viscosity with temperature**

However if we compare the value of kinematic viscosity with that of standard transformer oil, we find that our oil is comparatively less viscous than transformer oil. High value of viscosity is not suitable for insulation purpose as it will increase the resistance to flow of the oil.

The comparison of the kinematic viscosity of blended mixture and transformer oil at 40 and 100˚C is shown below:

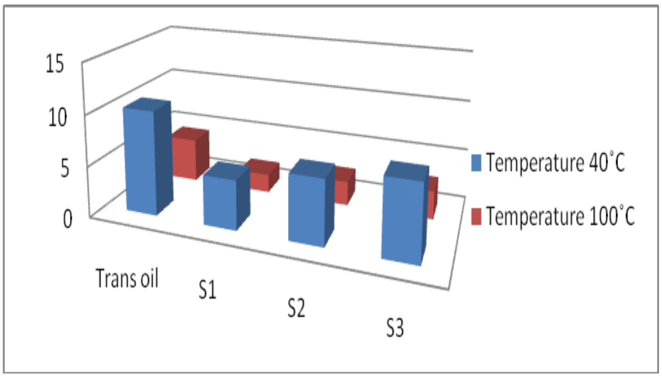


**Fig4.2: Kinematic viscosity of transformer oil vs Different oil samples at 40˚C and 100˚C resp.**

So from the above comparison it is clear that the kinematic viscosity of blends is less than the transformer oil. As high kinematic viscosity affects the speed of moving parts such as in power circuit breakers, switch gears etc. Moreover for better insulation property, the viscosity of oil should be low. So our oil different composition blends of castor and madhucaindica oil is suitable as transformer oil from kinematic viscosity point of view.

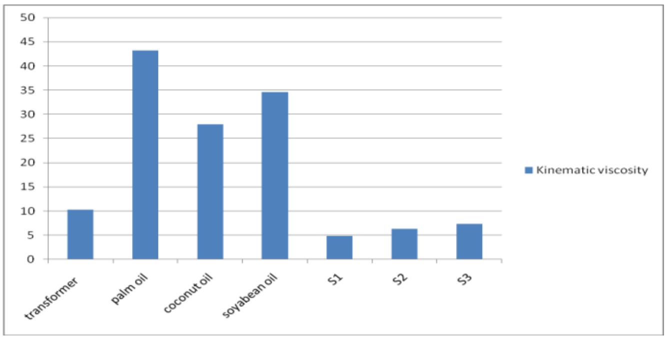


**Fig 4.3: Comparison of kinematic viscosity of different oil samples at 40˚C**

### 4.2 Flash Point:

The flash point of our blended sample are 220˚C (40% castor +60% mahua), 238˚C (50% castor +50% mahua), 270˚C (60% castor + 40% mahua).The flash point of standard transformer oil is 140˚C (minimum). High flash point is very important to ensure high safety during in-service operation. The risk of fire hazard in transformers could also be reduced if the dielectric insulating fluid has a high flash point.

The flash point comparison of blended sample and transformer oil as a function of temperature is shown below:

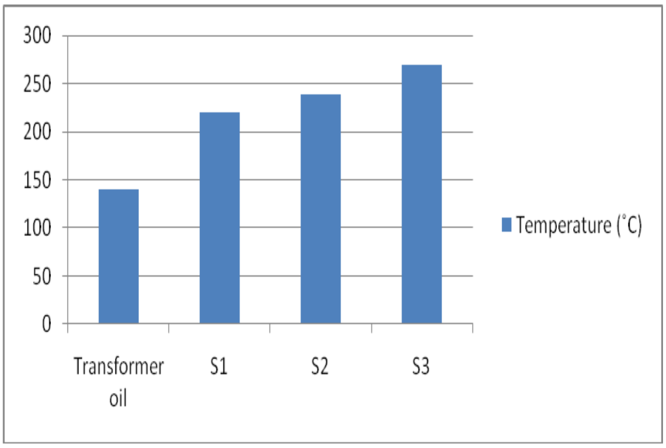


**Fig 4.4: Flash point of transformer oil vs different sample**

So, from the above observation, it is clear that that our sample oils are having much higher flash point than the minimum requirement. Such high flash point is a good indication of our oil to act as insulating oil. So from this prospective it is a good alternative for transformer oil.

Here is the analysis of flash point of different oil samples.

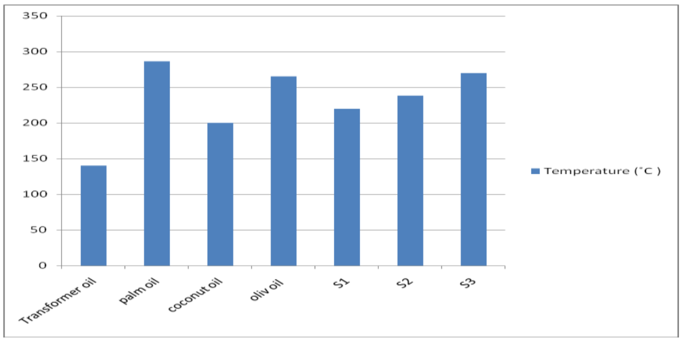


**Fig 4.5: Comparison of flash point of vegetable oils, transformer oils, and blended samples**

### 4.3: Pour Point:

The value of pour point for our blended samples are 4˚C (40% castor +60% mahua), 4.5˚C (50% castor +50% mahua), 5˚C (60% castor + 40% mahua).However for a transformer oil the standard value is −6˚C (maximum).So this value is much greater than the minimum limit. So our oil is a good alternative for transformer oil in prospective to pour point. It is the lowest temperature, expressed as multiple of 3˚C at which the oil is observed to flow when cooled and examined under prescribed condition. In other words, the pour point of a fluid is the lowest temperature at which the fluid is capable of observable flow.

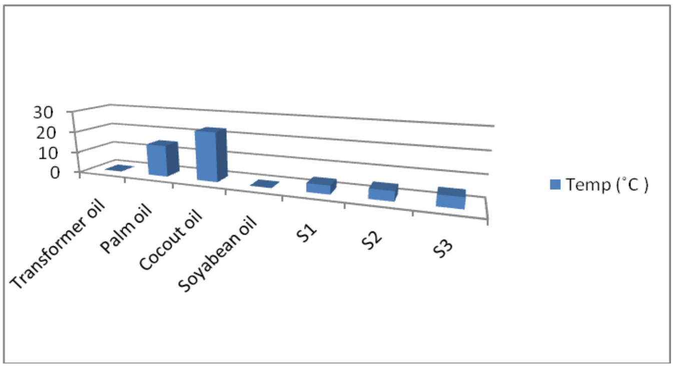


**Fig 4.6: Comparison of pour point of vegetable & transformer oil with mahua oil**

So from the above comparison it is clear that transformer oil shows negative pour point temperature, while in vegetable oil only soyabean shows negative pour point. The pour point of blends lies within the range and is suitable for alternative use on the basis of pour point analysis.

### 4.4: Density:

The density of blended oil comes out to be 0.919 g/cubiccentimeter (40% castor +60% mahua), 0.925 g/cubiccentimeter (50% castor +50% mahua), 0.930 g/cubiccentimeter (60% castor + 40% mahua. In general density property determines the buoyancy and purity. According to the IS code, the density for transformer oil is 0.889g/cubiccentimeter. So as a result of this, our blended sample 1 is good transformer oil.

The density of different vegetable oil in comparison to our different blended sample and transformer oil are as follows:

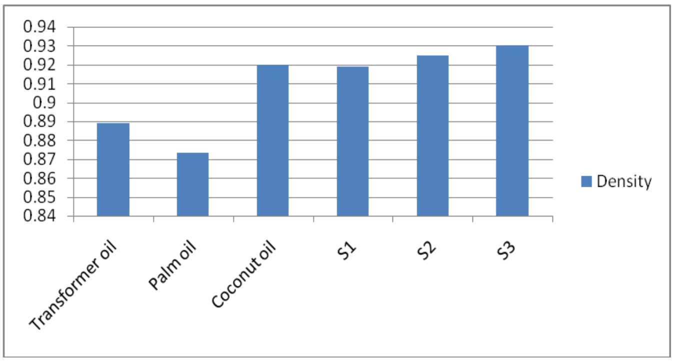


**Fig 4.7: Comparison of density of different oil samples**

So from the above analysis, it is noted that density of Sample 1 and transformer oil are very close. Hence it can act as good transformer oil.

## 5. CONCLUSION

From the various experiments performed, following conclusion can be made:

- The kinematic viscosities of our blended samples are less than the transformer oil. So it can be used as an alternative to transformer oil based on the experiment done.
- The flash points of our blended oil are quite higher than the transformer oil by and large 50°C to 60°C which shows its suitability to be used as an alternative to transformer oil.
- As far as pour point is concern, our blended mixture is suitable as an alternative to transformer oil.
- The density of transformer oil and blended sample 1 are very close to each other, which shows that it is a good alternative to transformer oil.

## 6. Future scope:

From the present work, we have concluded that the blended sample especially sample 1 has the potential to be a substitute for low voltage transformer. However, the oil used in our work is extracted from seeds but not refined so, in future, for improving the property of oil, it can be refined, purified and some different composition mixture or blend may be formed so that it can be used in high voltage transformer as alternative oil.

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