Preparation and analysis of the thermal properties of non-toxic eco-friendly vegetable based oils

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Abstract. Cutting fluids play an important role in increasing the efficiency of the production system. Vegetable based cutting fluids produce less harmful effects to the environment thereby leading to the cleaner production system. In the present study, vegetable oils such as Neem and Karanja oils are blended in three different proportions which are used to improve the thermal performance of the vegetable based cutting fluids. Density, viscosity, flash point and fire point are the quality parameters used to analyze the thermal properties of vegetable oils were also studied. Triple Necked Round Bottom flask setup is used for mixing the two vegetable oils in different proportions. The experimental results reveal that the combination of 25% Neem and 75% Karanja proves to be the efficient vegetable oil for sustainable production in the modern industries.

Keywords: Cutting fluid, Karanja oil, Neem oil, Vegetable oil, Viscosity.

1. Introduction
Li et al. [1] made an investigation to study the effect of adding graphene Nanoparticles into the vegetable-oil-based cutting fluid to enhance the machinability characteristics of TC4 alloy by using MQL technique. They have found that chosen cutting fluid meets the cleaner manufacturing demands. Gaurav et al. [2] have presented a feasibility study on jojoba vegetable oil as base oil mixed with and without MoS₂ Nanoparticles during hard turning of Ti-6Al-4V alloy with MQL technique. The results reveal that jojoba oil chosen presents as a sustainable replacement for mineral oil during MQL turning. Lawal et al. [3] have formulated oil-in-water emulsion by using palm kernel and cottonseed oils for turning operation of AISI 4340 steel with coated carbide inserts. They have found that vegetable oils have enhanced the machining characteristics when compared to conventional mineral oil-in-water emulsion cutting fluid. Gajrani et al. [4] in their present investigation have synthesized and characterized vegetable-based green cutting fluid for turning of hardened AISI H-13 steel. They have found that MQL technique using vegetable oil has improved the machining characteristics when compared to flood cooling and dry turning. Shokoohi et al. [5] have developed eco-friendly cutting fluid by using water mixed vegetable oil with anti-bacterial agent for turning operation of hardened AISI 1045 steel. They have found that the newly formulated vegetable oils are able to prevent the spread of infections caused during bacterial growth when compared to straight oil. Zhang et al. [6] have studied the effect of adding 50nm MoS₂ Nanoparticle in vegetable based oils during MQL
grinding of 45 steel work piece. The results reveal that palm oil-based Nano fluids have produced the best lubrication properties when compared to conventional grinding processes. Desari and Davoodi [7] have developed vegetable oil-based Nano-lubricants by dispersing CuO and SiO₂ Nano particles in soybean and rapeseed oils in diverse concentrations for metal forming processes. They have found that 0.5-0.7 wt. % of Nano particle concentration has reduced the friction factor by 21-31%. Sen et al. [8] have developed Nano-green lubricant by reinforcing Nano-silica into palm oil for MQL milling of Inconel 690. The experimental results reveal that 1% silica deposited palm oil cutting fluid have improved the machining responses when compared to conventional machining conditions. Talib et al. [9] have formulated modified jatropha oil by mixing hexagonal boron nitride Nano particles with it. The results reveal that MJO5 base mixed with 0.5 wt. % of hBN Nano particle has provided the best physicochemical properties thereby meeting the demands of cleaner production. Silva et al. [10] have studied the effect of vegetable oil for MQL grinding process of hardened AISI 4340 steel. They have found that MQL system can enhance the machinability characteristics of grinding process thereby leading to an environmentally friendly manufacturing. Wang et al. [11] have made an experimental investigation to study the effect of water as grinding fluid during grinding process with AISI 1045 steel. They have found that small quantity lubrication system has enhanced the machining characteristics thereby leading to economic, healthy and environmental benefits. Huang et al. [12] have studied the grinding performance by using multi-walled carbon Nanotubes dispersed in vegetable oil through ultrasonic-assisted oscillator during MQL grinding of NAK80 mold steel. The results reveal that the oscillator can reduce the agglomeration of Nano particles thereby improve the machining characteristics of the MQL grinding process. Najiha et al. [13] have studied the effect of machining parameters on the wear mechanisms during end milling of aluminum alloy AA6061 by employing water based TiO₂ Nano fluids under MQL conditions. The results reveal that the volume fraction of 2.5% TiO₂ Nano particles has produced better results in terms of tool damage. Sani et al. [14] have introduced a refined modified Jatropha-based TMP ester (MJO) containing oil-miscible ionic liquids as vegetable-based cutting fluids during orthogonal cutting of AISI 1045 steel. The results reveal that the use of MQL vegetable based cutting fluids have reduced the enormous wastage of cutting fluids thereby leading to cleaner production. Susmitha et al. [15] have studied the effect of different non-edible vegetable oils on machining characteristics during drilling of mild steel work piece. The results reveal that the combination of 50% Neem and 50% Karanja proves to be the best cutting fluids in enhancing the machinability characteristics during the drilling process. Therefore, the present work deals with the preparation of non-edible vegetable oil in three different proportions and the analysis of the thermal properties of the blended vegetable oils.

2. Experimental procedure
2.1. Materials used
2.1.1. Neem oil
Neem oil comes from the seed of the tropical Neem tree, also known as Indian lilac. It has been used to treat many conditions. Figure 1 shows the photograph of the Neem oil.
2.1.2. Karanja oil
Pongamia Pinnata is one of the few nitrogen fixing trees (NFTS) to produce seeds containing 30-40% oil. This species is commonly called Pongam, Karanja. Figure 2 shows the photograph of the Karanja oil.

Fig. 1. Neem oil

Fig. 2. Karanja oil
2.2 Preparation of Bio lubricants
The bio lubricants were prepared by mixing Neem oil into the Karanja oil in three different proportions of 25% Neem-75% Karanja, 50% Neem-50% Karanja and 75% Neem-25% Karanja. The mixing was performed by using Three Necked Round Bottom Flask setup. The setup consists of flask, support base and a stirrer. The mixing was done for 3 hours. The stirrer speed was set at 300rpm. The experimental setup is shown in figure 3. The mixing process is done at Delta Laboratory, Chennai.

![Experimental setup](image)

Fig. 3. Experimental setup

2.3 Testing the characteristics of vegetable oils
The properties of vegetable oils are tested in Delta laboratory, Chennai, India. The density of vegetable based oil samples is measured on the basis standard of ASTM D 1298. The thermal properties of the vegetable oil samples are calculated on the basis of established standards ASTM D 93 respectively. The properties of vegetable oils are shown in Table 1.

| Characteristic Test | Observation | Protocol |
|---------------------|-------------|----------|
| Density (g/cm³)     | 0.907       | Sample 1 | ASTM D 1298 |
|                     | 0.914       | Sample 2 |         |
|                     | 0.916       | Sample 3 |         |
| Kinematic viscosity @ 23°C (cSt) | 30.98 | Sample 1 | ASTM D 445 |
|                     | 34.25       | Sample 2 |         |
|                     | 39.42       | Sample 3 |         |
| Flash Point (°C)    | 185         | Sample 1 | ASTM D 93 |
|                     | 165         | Sample 2 |         |
|                     | 158         | Sample 3 |         |
| Fire Point (°C)     | 214         | Sample 1 | ASTM D 93 |
|                     | 201         | Sample 2 |         |
|                     | 196         | Sample 3 |         |

Sample 1 – 25% Neem oil + 75% Karanja oil
Sample 2 - 75% Neem oil + 25% Karanja oil
Sample 3 – 50% Neem oil + 50% Karanja oil
3. Results and Discussions
3.1. Analysis of thermal properties of vegetable oil
3.1.1. Density

![Chart of Density(g/cm3)](image)

**Fig. 4.** Density of vegetable oils

The results of density measurements of Neem and Karanja oils mixed in different proportions are shown in figure 4. The experimental results reveal that the density of 50% Neem-50% Karanja oil sample is more when it is compared to the other two samples.

3.1.2. Viscosity

![Chart of Kinematic Viscosity(cSt)](image)

**Fig. 5.** Kinematic viscosity at 23°C
The results of Kinematic viscosity measurements of Neem and Karanja oils mixed in different proportions are shown in figure 5. The viscosity of the cutting fluid has its ability to reduce frictional forces between sliding surfaces in motion. It is known that the more force is required for the less viscous oil to cause motion between sliding surfaces apart. A high viscous oil requires higher energy to cause movement between sliding surfaces apart. The experimental results reveal that the amount of viscosity is optimum for 25% Neem and 75% Karanja oil which improves the machining conditions.

3.1.3 Flash point

![Chart of Flash point(oC)](image)

**Fig. 6.** Flash point of vegetable oils

Flash point is the temperature of the oil, at which its vapor ignites. The flash point of a vegetable oil should be high so that it cannot burn at elevated temperatures. The comparison of vegetable oils like Neem and Karanja mixed in different proportions in terms of flash point is shown in figure 6. The experimental values from the tables reveal that the combination of 25% Neem and 75% Karanja had its best amount of flash point of 185oC.

3.1.4 Fire point

![Chart of Fire point(oC)](image)

**Fig. 7.** Fire point of vegetable oils
The fire point is the temperature at which lubricant combustion will be sustained. The results of fire point measurements of Neem and Karanja oils mixed in different proportions are shown in figure 7. The experimental values from the tables reveal that the combination of 25% Neem and 75% Karanja had its best amount of fire point of 214°C.

3.2. Summary
In this research work, the effects of mixing Neem and Karanja oils in different proportions are analyzed. The results reveal that the 25% Neem - 75% Karanja oil sample has a significant improvement in the thermal properties when compared to that of the other samples. It indicates that the heat harvesting capability of 25% Neem-75% Karanja oil is increased.

4. Conclusion
In this research work, the effects of mixing Neem and Karanja oils at three different proportions was analyzed. The results reveal that the blend of 25% Neem and 75% Karanja had its best amount of its properties when compared to that of the other samples. It is eco-friendly, bio-degradable, non-toxic and economical.

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