Effect of Nano Vegetable Cutting Fluids on Surface roughness and Material removal rate in Turning of AISI 1040 steel

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***ABSTRACT*: Machining of tough metals require cutting fluid lubrication to reduce cutting forces, friction which results in good surface finish. Due to the complex compounds present in these cutting fluids there are toxic in nature. Further, the disposal of the cutting fluids adds to the cost due to the required chemical treatment.Further, to make the fluids more harmless, vegetable-based compound fluids are being developed to replace the toxic ingredients. The present work is regarding the development of vegetable based lubricants and addition of Nano particles like graphite, Molybdenum disulphide and mixture of both particles in vegetable oil matrix such as coconut,soya been and rice-bran oil, which are used as lubricants during turning of AISI1040 steel with carbide tool. The results exhibit the drift of the surface roughness and material removal rate (MRR) of the work piece during turning for different weight percentage of Nano particles in different matrix of oils.**

***Keywords*: Vegetable oils, Graphite, Molybdenum disulphide, AISI1040steel, Turning, MRR, Surface Roughness**

1. INTRODUCTION

Machining is a manufacturing process where removal of material is done from a part to give it specific dimensions and a particular surface finish, within a range of given tolerance values. Machining by chip removal can be classified into three main groups. i.e., Turning, this allows rotating parts to be shaped, Milling, this is characterized by the cutting tool's simultaneous rotational movement and feed motion, Axial operations: drilling, tapping, reaming [1]. When the cut is in progress the chip presses heavily on the top face of the tool and continuous shearing takes place across the shear plane and the process of material removal takes place as shown in Fig.1.

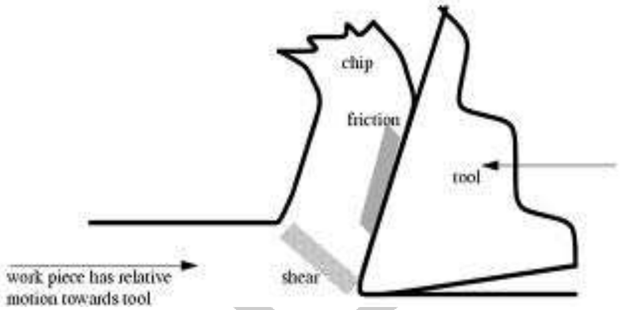

Fig. 1 Mechanism of material removal

The Friction and other machining conditions which are present in between the chip and tool will subject the tool to wear and also effects surface finish. Many techniques were evolved for improving the surface finish and material removal rate of the machining products. One of those techniques is applying lubricant in the form of fluid during the machining process.

Nowadays environmentally adapted lubricants had become more important for industrial applications. The properties of different base fluids vary widely and it is important to understand their effects on the performance of a lubricant in different lubrication regimes [2-4].Because of their biodegradable and non-toxic in nature vegetable oil lubricants acts as potential lubricant in machining sector. Properties required for lubricants, such as high index viscosity, good lubricities etc are excellently controlled by fluid additives [2].Therefore there has been an increasing demand for green lubricants [3].

Nanofluids obtained by dispersing very small quantities of nanoparticlesin base fluids can be applied at machining zone through MQL technique [5]. The usage of new formulations of cutting fluids when appliedthrough MQL technique offers economical and operational advantage. Thus in order to assimilate the positive aspects of vegetableoils, Nanosolid lubricants, and MQL technique, vegetable oil based nanocutting fluids are experimented in the present work.MQL utilizes comparatively very little amount of cutting fluid making it almost dry and clean [6]. As compared to flooding emissions, MQL are low and healthier for the workers. Experimental evidence presented so far indicates that minimum quantity lubrication will be more productive, with an increased tool life and better surface finish.

2. EXPERIMENTAL PROCEDURE

The Turning operation was carried out on mild steel AISI1040 having the chemical composition as shown in Table 2.1[7]. Its physical characteristics are as shown in Table 2.2 respectively.

Table 2.1 Chemical composition of mild steel AISI 1040

MATERIAL	C(%)	Mn(%)	P(%)	S(%)
AISI 1040 STEEL	0.37-0.44	0.60-0.90	0.040	0.050

Table 2.2 Physical properties of mild steel AISI 1040

Physical Properties	Magnitude
Density(g/cm$^{3)}$	7.845
Poisson's Ratios	0.27-0.30
Elastic modulus (G pa)	190
Tensile strength (M pa)	620
Yield strength (M pa)	415
Vickers Hardness(HV)	211
Thermal Conductivity(W/mK)	47

The cutting Fluids used in the current research are the Nano vegetable lubricants. Three different types of vegetable oils are included and they are Coconut oil, Soya bean oil and Rice bran Oil. The Nano particles used are graphite and MoS_2 is procured from Sigma Aldrich(mumbai).Nanofluids are formulated byaddinggraphite and MoS_2 suspensions in Ccoconut, Soya been and Rice Bran oil separately at0.25%, 0.5%, 0.75%and 1%of weight [8].

At firstNano fluids with and without surfactant (triton) are prepared withpre-measured quantity of graphite and MoS_2which are taken in abeakerand the required quantity of vegetable oil (100 ml) is slowly addedwhile manually mixing both to obtain a uniform suspension. The suspensions thus prepared areplaced in a bath type digital ultra-sonic cleaner for 30 mins as shown in Fig 2(a). After the ultrasonic stirring, Nano fluids are kept ideal for one day to get sedimentation of Nano particles. The sedimentation time depends up on the properties of the nano particle, oils and type of surfactant used.

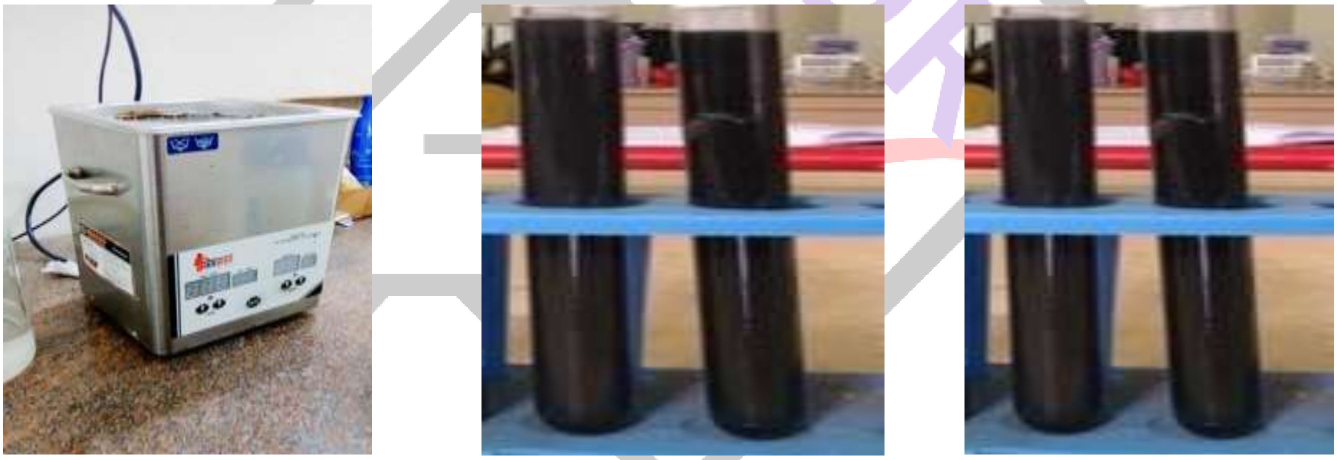

Fig. 2 (a)ultrasonic cleaner (b)Without Surfactant (C)With Surfactant

It is observed that Nano fluids without surfactant have more homogeneous distribution of particles. Hence the Nanofluids thus prepared are vegetable oil without any surfactant as shown in fig 2(b) and fig2 (c).Turning operation with Nano fluids and without Nano fluids is carried out on aCNC Lathe HardingE machine [9].Machining parameters are shown in the Table 3.

Table 3 Machining environment

Machine tool	CNC Lathe Harding E SV150
Machining operation	Turning
Materialofworkpiece	AISI 1040 steel cylindrical bars (Ø25 mm*150 mm Hardness;30±2 HRC, heat treated)
Tool Holder	PSLNR 2020 K12
Cutting tool	CNMG12404PC9030 coated carbide
Cutting speed (m/min)	100
Feed(mm/rev)	0.2
Depth of Cut(mm)	0.3

Lubricant Environment	Dry, Pure oils, CC+NG; SY+NG;RB+NG; CC+nMoS2;SY+nMos2;RB+nMos2; CC+NG+nmoS2;SY+NG+RB+nMoS2 ;RB+NG+nMOS2
Flow Rate	40ml/min
% of Nano particle Inclusions	0.0, 0.25,0.5,0.75,1.00
MQL	40 ml/min

TheTurningoperation set up is as shown in Fig3.Coated carbide tool insert is loaded into a tool holder and the turning operation is done by giving required speed, feed and depth of cut which are programmed in a CNC machine. The Nanofluid is taken in a container, located collinear to theaxis of machining [12]. Due to self-weight and atmospheric pressure the cutting fluid flows in the downward direction.

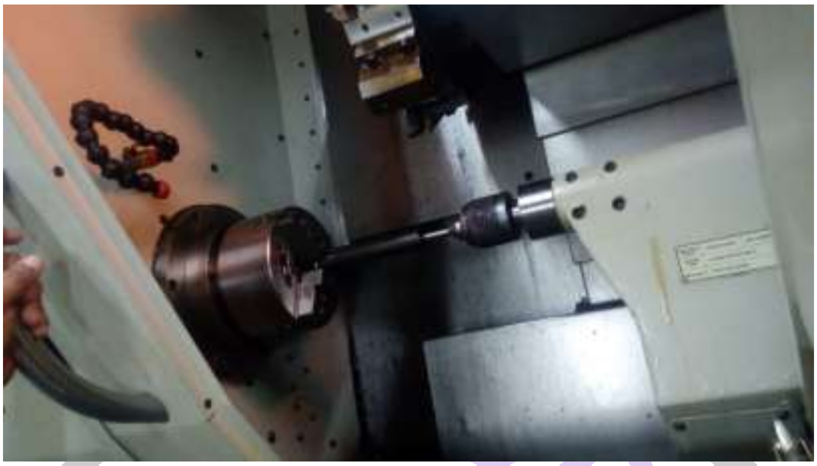

Fig 3Experimental set up in Harding SV150 CNC lathe machine

. The different machining environments selected aredry machining, pure vegetable oil machining, vegetable oil with Nano graphite, vegetable oil withNanoMoS_2 and hybrid vegetable oil environment[10-11]. The experimental plan is as shown in the table 4.

Table 4 Experimental plan for different turning Environments

Sl No	Type Of Oil	Nano Particle	Wt %
1	Coconut OIL	GRAPHITE	0
2	Coconut OIL	GRAPHITE	0.25
3	Coconut OIL	GRAPHITE	0.5
4	Coconut OIL	GRAPHITE	0.75
5	Coconut OIL	GRAPHITE	1
6	Coconut OIL	Mos2	0
7	Coconut OIL	Mos2	0.25
8	Coconut OIL	Mos2	0.5
9	Coconut OIL	Mos2	0.75
10	Coconut OIL	Mos2	1
11	Soya bean Oil	GRAPHITE	0
12	Soya bean Oil	GRAPHITE	0.25
13	Soyabean Oil	GRAPHITE	0.5
14	Soyabean Oil	GRAPHITE	0.75
15	Soyabean Oil	GRAPHITE	1
16	Soyabean Oil	Mos2	0
17	Soyabean Oil	Mos2	0.25
18	Soyabean Oil	Mos2	0.5
19	Soyabean Oil	Mos2	0.75
20	Soyabean Oil	Mos2	1

21	Ricebran Oil	Graphite	0
22	Ricebran Oil	Graphite	0.25
23	Ricebran Oil	Graphite	0.5
24	Ricebran Oil	Graphite	0.75
25	Ricebran Oil	Graphite	1
26	Ricebran Oil	Mos2	0
27	Ricebran Oil	Mos2	0.25
28	Ricebran Oil	Mos2	0.5
29	Ricebran Oil	Mos2	0.75
30	Ricebran Oil	Mos2	1

Machining time is noted for each trail to calculate MRR for each specimen. Surface Roughness[13-14] for each turn is calculated by using Taylor Hobson equipment as shown in Fig 4.

Fig 4 Talysurf tester for surface roughness measurement

2.1MATERIAL REMOVAL RATE (MRR)

The material removal rate can be defined as ratio of volume of the material removed to the machining time.It is measured in mm^3/min. For each revolution of the work piece, a ring shaped layer of material is removed[15]. The equation of MRR in turning is given below in equation (i).

$$MRR = (v.\ f\ .d \times 1000)\ \text{in}\ mm^3 / min \qquad \ldots\ldots\ldots\ldots(i)$$

Where v= cutting velocity(m/min)
f = feed rate (mm/rev)
d =Depth of Cut(mm)

In general, Material Removal Rate (MRR) may also be calculated using the formula in equation(ii) given below

$$MRR = \frac{\text{Material Machined in machining cycle(gm)}}{\text{machining cycle}} \qquad \ldots\ldots\ldots(ii)$$

MRR is determined by weight loss criteria with the help of digital weighing balance as shown in fig.6. The weight difference before and after the experimentation is calculated. The machining time for each operation is noted at the time of machining. Thus MRR is calculated in the turning operation for different experimental conditions.

Fig.6Digital weighing balance

3. RESULTS & DISCUSSIONS

The Turning of AISI 1040 steel is performed with vegetable oils as lubricants containing pure graphite,pure MoS_2 and mixture of graphite and MoS_2 (hybrid oils)carried out at different weight percentage nanoparticle inclusions for three vegetable oils. It can be traced the effect of surface roughness and MRR with respect to the weight percentage inclusions of nanoparticle for the three different oils.

3.1 Effect of Wt % of graphite nanoparticle inclusions with Surface Roughness and MRR

The variation Plots for surface roughness and MRR with weight percentage of graphite nanoparticle inclusions is presented in Fig.7 & Fig.8 and from the plots it is observed that as weight percentage of graphite nanoparticle inclusions increases the surface roughness decreases. It is also obvious that among the three different oil matrix system with varying weight percentage of graphite nanoparticle inclusions, rice bran oil matrix shows better performance at 1.0 wt% of graphite as shown in fig7.

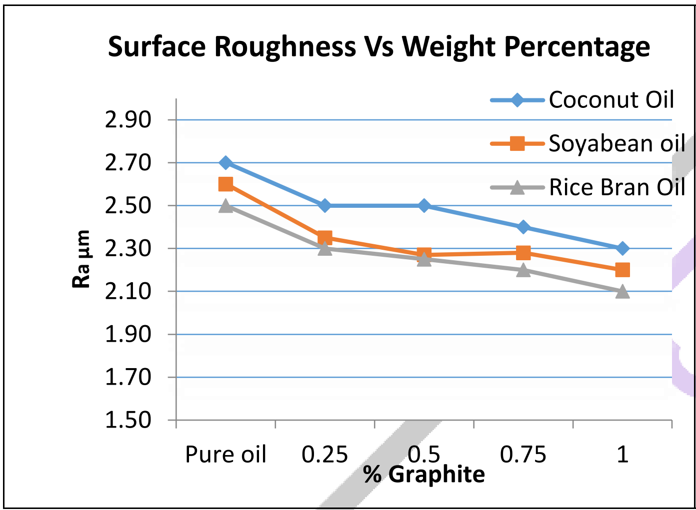

Fig.7 Ra Vs Wt% of Graphite

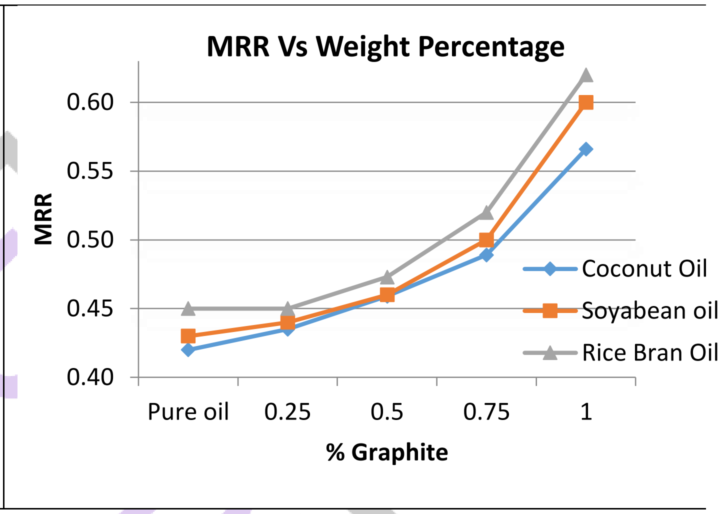

Fig.8 MRR Vs Wt% of Graphite

It is also observed from the Fig.8 that MRR increases with increase weight percentage of graphite nanoparticle inclusions. It is also clear that rice bran oil shows better performance at 1.0 wt% of graphite as shown in fig8.

3.2 Effect of Wt % of MoS_2 nanoparticle inclusions with Surface Roughness and MRR

The variation Plots for surface roughness and MRR with weight percentage of MoS_2nanoparticle inclusions is presented in Fig.9 & Fig.10 and it is observed that as weight percentage of MoS_2nanoparticle inclusions increases the surface roughness decreases. It is also obvious that among the three different oil matrix system with varying weight percentage of MoS_2nanoparticle inclusions, soya bean oil matrix shows better performance at 1.0 wt% of MoS_2 as shown in fig 9.

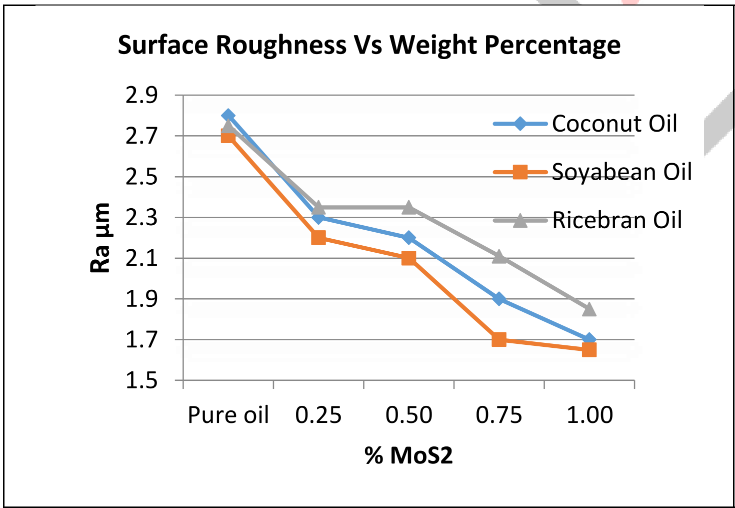

Fig.9 RaVsWt% of MoS_2

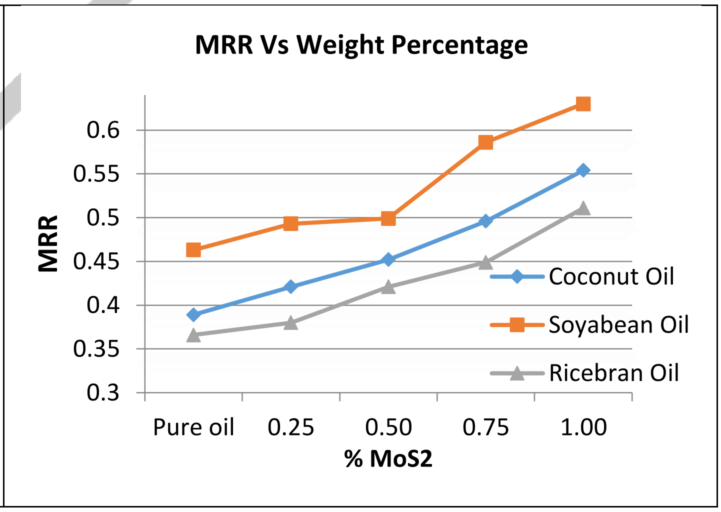

Fig.10 MRRVsWt% of MoS_2

It is obvious from the Fig.10 that MRR increases with increase weight percentage of MoS_2nanoparticle inclusions. It is observed that soya bean oil shows better performance at 1.0 wt% ofMoS_2 as shown in fig10.

3.3Effect of wt% of hybrid mixture on surface roughness and MRR

Surface Roughness is measured for three different matrix of vegetable oils at hybrid mixture weight percentage of graphite and MoS_2nanoparticle inclusions (0.125% GR+0.125% MoS_2 ; 0.25%GR+0.25% MoS_2; 0.1875% GR+0.1875% MoS_2 ; 0.5 % GR+0.5 %MoS_2). It is observed that surface roughness decreases with increase in wt% of hybrid mixture. Among these three base oils, Soya bean oil shows better surface finish at 0.5% of graphite and 0.5% of MoS_2as shown in fig.11.

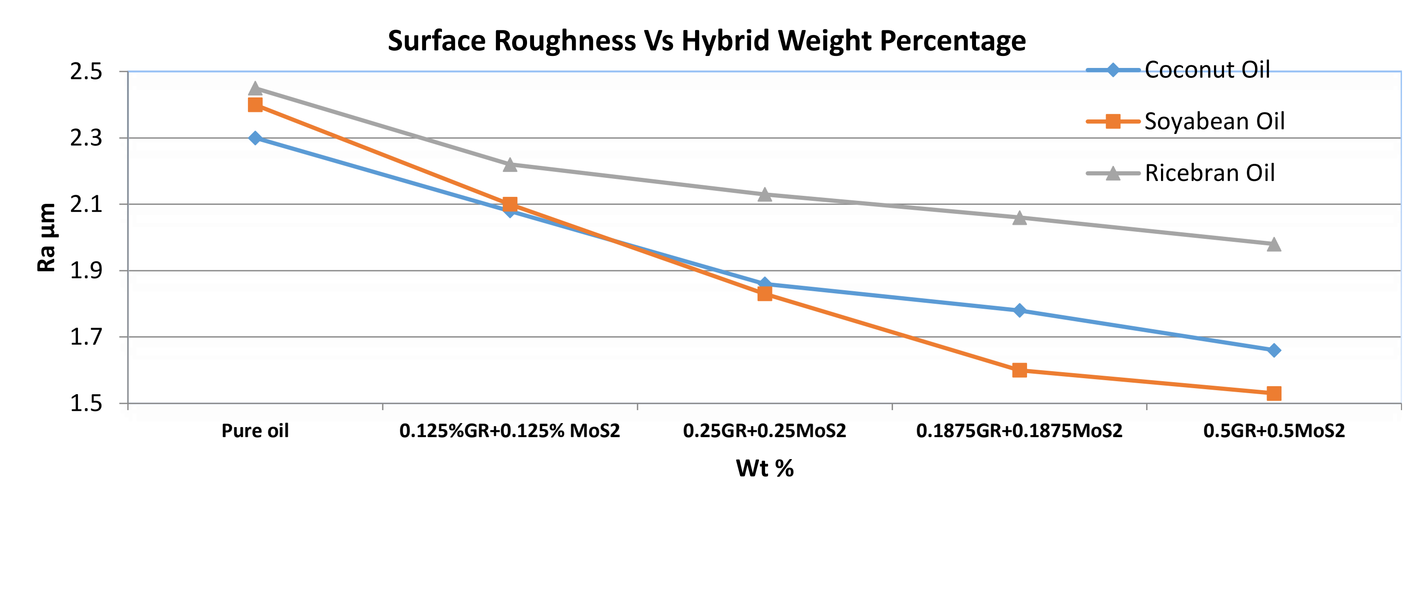

Fig.11 RaVs Wt% of Hybrid mixture

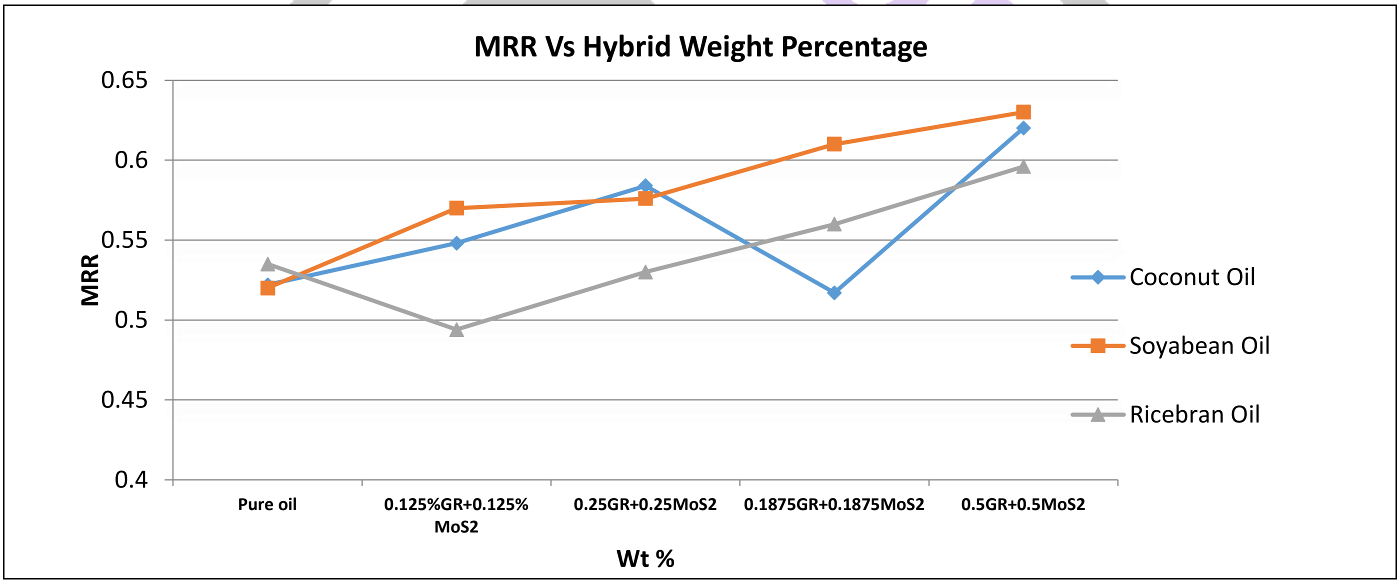

Fig12 RaVsWt% of Hybrid mixture

It is obvious from the Fig.12 that soya bean oil shows better performance at hybrid mixture0.5% of graphite and 0.5% of MoS_2as shown in fig.12. as compared to other two vegetable oils.

4. CONCLUSIONS:

Experimental investigations were performed to examine performance of different vegetable base cutting fluid lubricants for different weight percentage of graphite, $MoS_2$and hybrid mixture both nanoparticle inclusions during turning of AISI 1040 steel. The Conclusions derived from this investigation are as follows:

- Inclusion of Nano particle has greater effect on surface roughness and Material Removal Rate.
- The value of Surface roughness decreases with increase in weight percentage of nano particle inclusions. (i.e. for graphite, MoS_2 and hybrid mixture).
- As compared to Graphite nano particle inclusions and MoS_2nanoparticle inclusions, MoS_2 nano particle inclusions in soya bean oil exhibits good surface finish.

- The Hybrid mixture of nanoparticle inclusions exhibits even better good surface finish than individual MoS_2Nano particle inclusions in soya bean oil.
- On comparing to Graphite nanoparticle inclusions and MoS_2nanoparticle inclusions, both exhibit almost same magnitude of MRR for coconut and soya bean oil respectively.
- There is no much effect of Hybrid mixture of nanoparticle inclusions as compared to individual MoS_2nanoparticle inclusions for best MRR value in soya bean oil as base cutting fluid.

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