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Comparative Analysis of AISI 1050 Steel Using N5-Soluble Oil and Arachis Oil in Metal Cutting Operation

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ABSTRACT

The use of coolant during cutting processes does not only help in the improvement of surface integrity and increase in tool life, but it also facilitates the conservation of energy due to reduction in power consumed during the process. However, some of these coolants affect human health negatively, hence there is need to consider alternatives. The influence of N5- soluble oil and Arachis oil on machinability of carbon steels is reported in this paper. The performance of the use of soluble oil and Arachis oil using flooded cooling approach was investigated in with interest on their effects on temperature at cutting zone, surface roughness, chip formation and material removal rate. The experimental runs were designed using Taguchi L_{18} orthogonal array using Minitab version 16 and temperature at the cutting zone was monitored using a digital thermometer and a k-type thermocouple wire. Analysis of experimental results was done with focus on percentage contributions of various factors affecting surface roughness and material removal rate and chip profile. It was observed that, the use of Arachis oil as cutting fluid produced a surface finish of 35% improvement compared to soluble oil. Additionally, the chips formed using Arachis oil as coolant is more ductile and continuous than those obtained using N5soluble oil.

***Keywords*:** Flooded cooling; soluble oil; Arachis oil; machining processes; Surface roughness, Chip

1. INTRODUCTION

Machining is the process of cutting a material into a desired shape and size using a controlled material-removal process (Pare*et-al*, 2015).During High Speed Machining (HSM), Computer Numerical Controlled (CNC) machines are employed for fabrication of parts with high surface reliability because it is efficient and has an economical processing nature (Anil *et-al*, 2016).

However, the high cutting temperature generated during HSM may results in the deterioration of surface quality of machined components and wear at the tool tip surface (Salah et-al, 2016). Therefore cutting fluids are used to cool and lubricate the cutting process, improve tool life, improve surface finish and flush away chips from the cutting zone. [Sharma et-al, 2009, Susmitha et-al, 2016]. Currently, several types of conventional cutting fluidsare used such as Straight oils, Soluble oils, Semi synthetic fluids, Synthetic fluids. As reported by Susmitha et-al (2016), viscosity, flash point, fire point and density of a cutting fluid are the major parameters that inform the choice of cutting fluids during machining. However, when inappropriately handled, cutting fluids may result in skin problems and when cutting fluids evaporate they are distributedas vapourand micro-particles and may lead to breathing problems for the operator. (Sokovic and Mijanovic, 2001).To cope with these problems, the necessity of using biodegradable fluids has recently been emphasized (Lawal et-al, 2012, Vamsi et-al, 2010).

Vegetable oil is abiodegradable fluid that also enhancesthe cutting performance, extend tool life and improve the surface finish (Adekunle et-al, 2015). It has high lubricating ability and also possesses a higher flash point than mineral oil-based fluids which reduces smoke formation and fire hazards. A higher flash point allows such cutting fluids to be used in high-temperature conditions (Abdalla et-al, 2007, Shashidhara & Jayaram, 2010).

Various researchers have applied vegetable oil-based cutting fluids during machining operations. Lawal et.al (2011) carried out a review on the applicability of vegetable oil based metal working fluids inmachining of ferrous metal.Kolawale and Odusote (2013) machined mild steel using palm oil and groundnut oil as cutting fluid and evaluated performance compared with that of mineral oil based cutting fluid. They reported that Palm oilgave the highest thickness of 0.27mm due to its better lubricating property.Jitendra and Suhane (2014) studied the prospects of vegetable based oils as metal cutting fluids in manufacturing application; they showed that lubricants provide smooth operation between movable parts of all machines. Fairuz et.al (2015) investigated chip formation and tool wear in drilling process using various types of vegetable-oil based lubricants. Their result showed that coconut oil gave the best machinability and least wear on the drill bit under same condition with others. Shankar et al. (2017) investigated the influence of vegetable based cutting fluids on cutting force during milling of aluminium metal matrix composites. Their result shows that palm oil suits better than the other vegetable based cutting fluids in terms of minimum cutting force requirement and minimum vibration.This work is therefore an approach at investigating the comparative effect of using Arachis oil (a vegetable based cutting fluid) and N5-soluble oil as cutting fluids when machining high carbon steel on a lathe machine.

2. EXPERIMENTAL PROCEDURE

2.1 Cutting Fluids:

The cutting fluids used in this study were Arachis oil and N5-soluble oil. Table 1 shows the physical properties of the cutting fluids used. Arachis oil is a vegetable based (groundnut oil) cutting fluid which contains no destructive material and is environmental friendly. It poses no danger to machine operators and is very biodegradable. Aeroil N5 soluble oil is a mineral-based oil which is soluble in water.

Table 1: Physical properties of cutting fluids used

S/N	Cutting Fluid	Specific Heat (KJ/Kg. K)	Flash Point (°C)	Fire Point (°C)
1.	Arachis oil	1.6418	253	289
2.	Aeroil N5	3.8262	197	236

The densities for Arachis oil and N5-Soluble oil are 725 kg/mm^3 and 980 kg/mm^3. Arachis oil has a flash point of 253^{o}C and a fire point of 289^{o}C while N5-Soluble oil has a flash point of 197^{o}C and a fire point of 236^{o}C.

2.2 Cutting Tool and Work piece material:

The work piece material used for the experimentation was an AISI 1050 carbon steel bar of diameter 30mm and length 200mm. It was acquired from Owode metal market in Ilorin, kwara state, Nigeria. The chemical composition of the work piece is shown in Table 2. The tool used was a HSS (High Speed Steel).

Table 2: Chemical Composition of AISI 1050

Element	**Fe**	**Si**	**Cr**	**S**	**P**	**Mn**	**C**	**Ni**
% C	98.07	0.510	0.054	0.045	0.032	0.65	0.54	0.024
Element	**Sb**	**Nb**	**W**	**V**	**Mo**	**Pb**	**Cu**	**Ti**
% C	0.0008	0.0013	0.0032	0.0007	0.022	0.0016	0.060	0.0009

2.3 Experimental Design:

The experiment was designed using Minitab version 16. Three control factors (Cutting speed, depth of cut and feed rate) were selected based on machine constraints, preliminary experiments and literature (Table 3). Taguchi orthogonal array was used and a L_{18} design matrix was generated for the experiment to design the experimental runs and to determine the optimal control factors for minimizing the SR in lathe machining.

Table 3: Machining Parameters

Factor	**Level**		
	1	**2**	**3**
Speed (rpm)	80	100	120

Feed rate (mm/rev)	0.05	0.06	0.07
Depth of cut (mm)	0.1	0.2	0.3

The machining was done using a Colchester Triumph model 2000 lathe machine with three flutes. A total of 18 turnings were carried out using both cutting fluids and dry each resulting in 54 experimental runs altogether. The experimental setup is as shown in Figure 1.The measurement of surface roughness was done with a 2011 model of TR 210 profilometer which has a precision of 0.005-16 μm.The material removal rate according to Das *et-al*, (2012) was calculated using equation 1:

$$MRR = \frac{\text{Volume Removed}}{\text{Cuttin g Time}} = \frac{\pi l(D-d)}{\frac{4L}{FN}} \text{ mm}^3/\text{min} \quad (1)$$

Where L, F and N are length of piece, Speed and Feed respectively

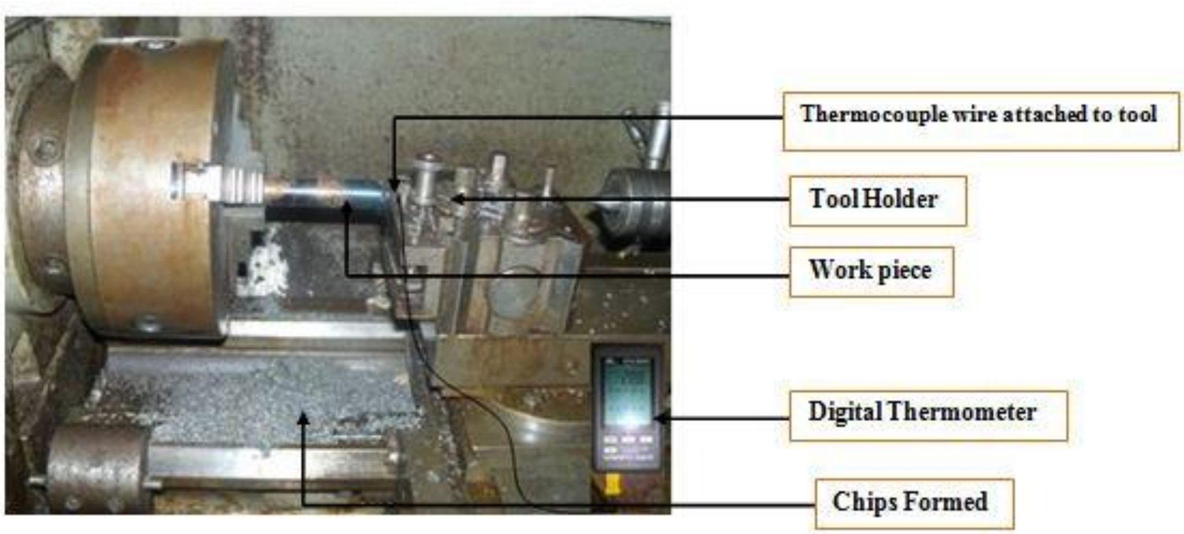

Fig. 1: Experimental setup of tool and work piece

2.4 Temperature Measurement

The measurement of average temperature at the cutting zone was done using a Lutron digital thermometer which has a k-type thermocouple wire. The thermocouple probe was placed at a distance of 5mm from the cutting edge of the tool to effectively capture temperature using the 3 channel SD data logger with a model no *MTM* 380-*SD.*

3 Result

The experimental results from Table 4 were analyzed using signal-to-noise (S/N) ratio. Smaller-is-better S/N ratio was chosen for Surface roughness (SR), and larger-is-better S/N ratio was chosen for material removal rate (MRR), since smaller SR and higher MRR indicates better performance of the process.

Table 4:Results for machining at various conditions

RUN	SPEED (*rpm*)	FEED (*mm/min*)	DOC (*mm*)	**MRR (*mm^3/min*)**	**SR *µm***	**T^{max} ^oC**	**SR *µm***	**T^{max} ^oC**	**SR *µm***	**T^{max} ^oC**
					Dry		**Soluble Oil**		**Arachis Oil**	
1	80	0.05	0.1	129,897.32	3.044	123.0	0.832	54.3	0.309	68.2
2	80	0.06	0.2	134,705.62	3.183	144.1	0.983	62.1	0.422	73.4
3	80	0.07	0.3	137,338.44	2.646	100.2	0.446	35.0	0.145	47.3
4	100	0.05	0.1	170,287.85	3.322	160.2	0.922	76.2	0.408	84.5
5	100	0.06	0.2	190,395.87	3.269	165.8	1.069	75.8	0.483	83.7
6	100	0.07	0.3	210,676.58	3.219	161.2	1.019	76.0	0.497	84.2
7	120	0.05	0.2	465,586.47	3.561	284.3	1.361	91.6	0.421	108.6
8	120	0.06	0.3	465,303.16	3.265	254.3	1.065	92.3	0.432	107.5
9	120	0.07	0.1	488,850.82	3.155	160.4	0.955	74.8	0.322	85.4
10	80	0.05	0.3	135,687.03	2.452	113.2	0.652	41.0	0.212	56.0
11	80	0.06	0.1	131,567.64	2.520	191.2	0.520	80.7	0.194	94.2
12	80	0.07	0.2	134,495.53	2.312	151.0	1.112	66.6	0.181	73.1
13	100	0.05	0.2	172,186.72	3.693	271.1	1.493	89.5	0.456	97.5
14	100	0.06	0.3	193,420.32	2.484	117.2	0.584	45.0	0.193	55.4
15	100	0.07	0.1	199,068.51	2.892	188.1	0.692	80.6	0.213	89.7
16	120	0.05	0.3	446,539.67	3.101	297.1	0.902	93.1	0.415	117.5
17	120	0.06	0.1	428,016.52	3.422	161.8	1.072	75.2	0.318	83.6
18	120	0.07	0.2	522,459.81	3.372	208.2	1.022	88.5	0.311	98.4

During dry machining a maximum surface roughness value of 3.693 µm was gotten which reduced to a maximum of 1.493 µm during machining with N5-soluble oil. However during machining with Arachis oil, the surface roughness reduced to a maximum of 0.497 µm. This is illustrated in Figure 2.

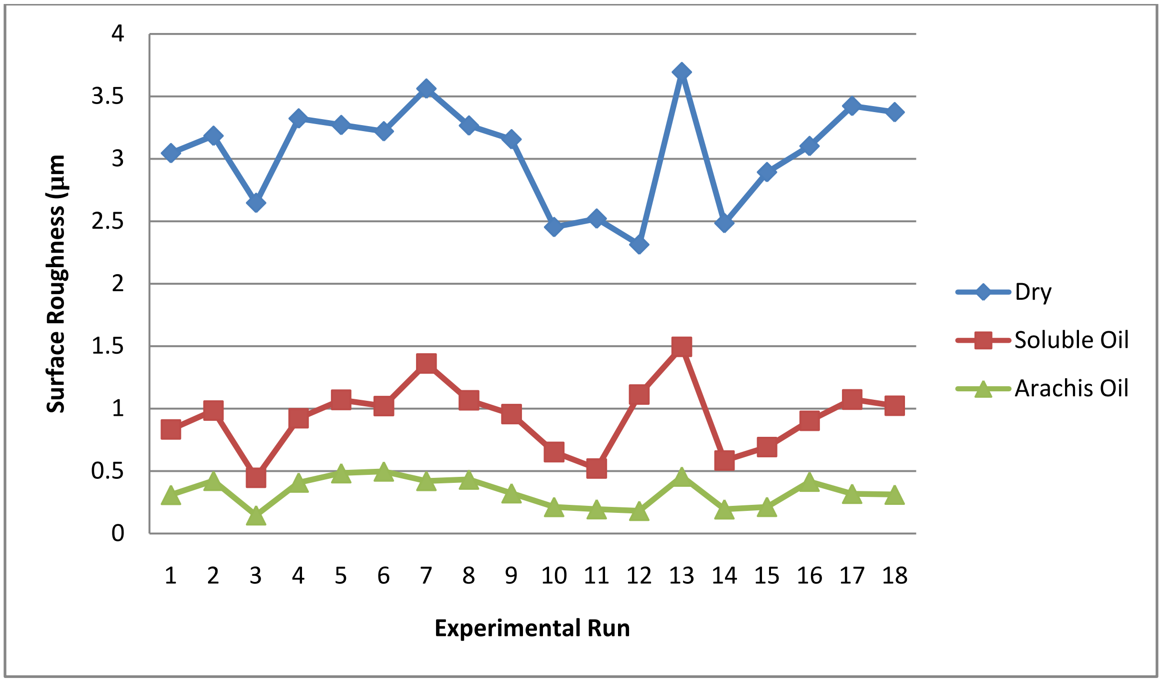

Fig. 2: Surface Roughness measured with cutting fluids and dry condition

This improvement was due to the reduction in maximum temperature at the cutting zone as shown in Figure 3 which ensured a preservation of surface integrity. Arachis oil was therefore a preferred cutting fluid for the reduction of surface roughness during machining of the carbon steel. Its ability to improve surface integrity more than soluble oil was due to the higher lubricating property it posses. N5- Soluble oil was however a better coolant than Arachis oil because it reduced maximum temperature at the cutting zone more effectively than Arachis oil.

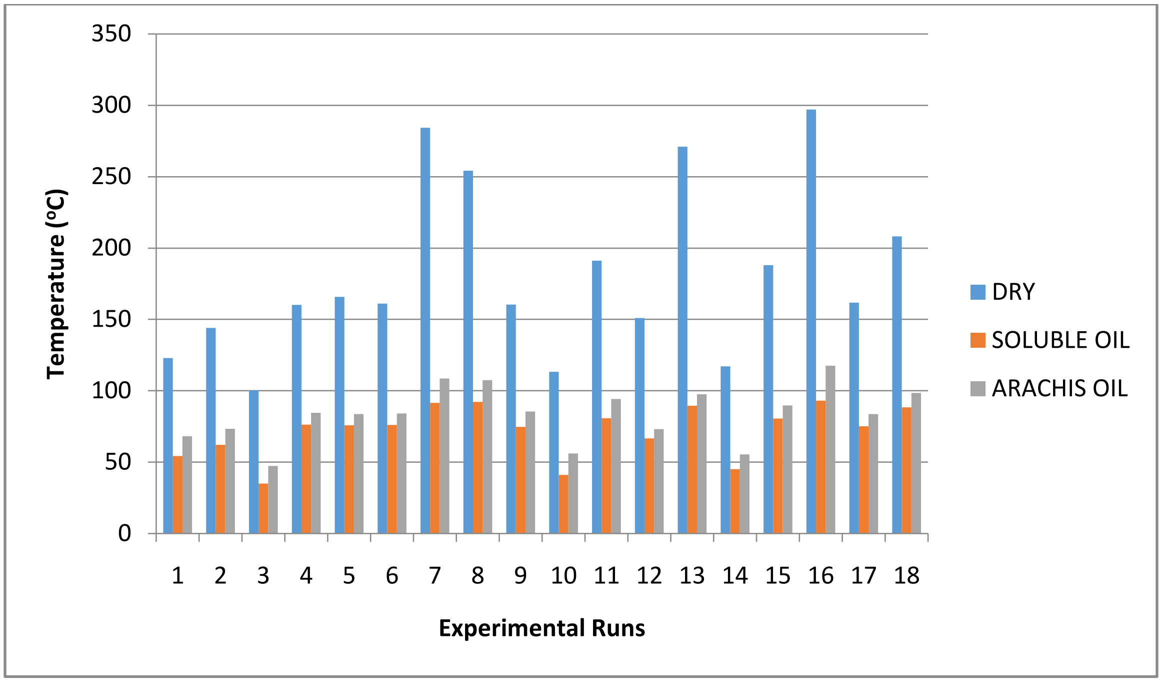

Fig. 3: Maximum Temperature attained during Experimental runs.

As shown in Figure 3, the maximum temperature reduced from 297.1°C recorded during dry machining to 117.5°C during machining with Arachis Oil. The maximum temperature further reduced to 93.1°C N5-Soluble oil. This result shows N5-Soluble oil as a better coolant, able to remove heat more than Arachis oil when used as a cutting fluid.Figure 4 shows the MRR for various experimental runs. High values of MRR were recorded with high cutting speeds and feed rate. The highest MRR was obtained at 120rpm and 0.7mm/rev during experimental run 18. Therefore a reduction in feed rate and cutting speed results in a reduction of MRR.

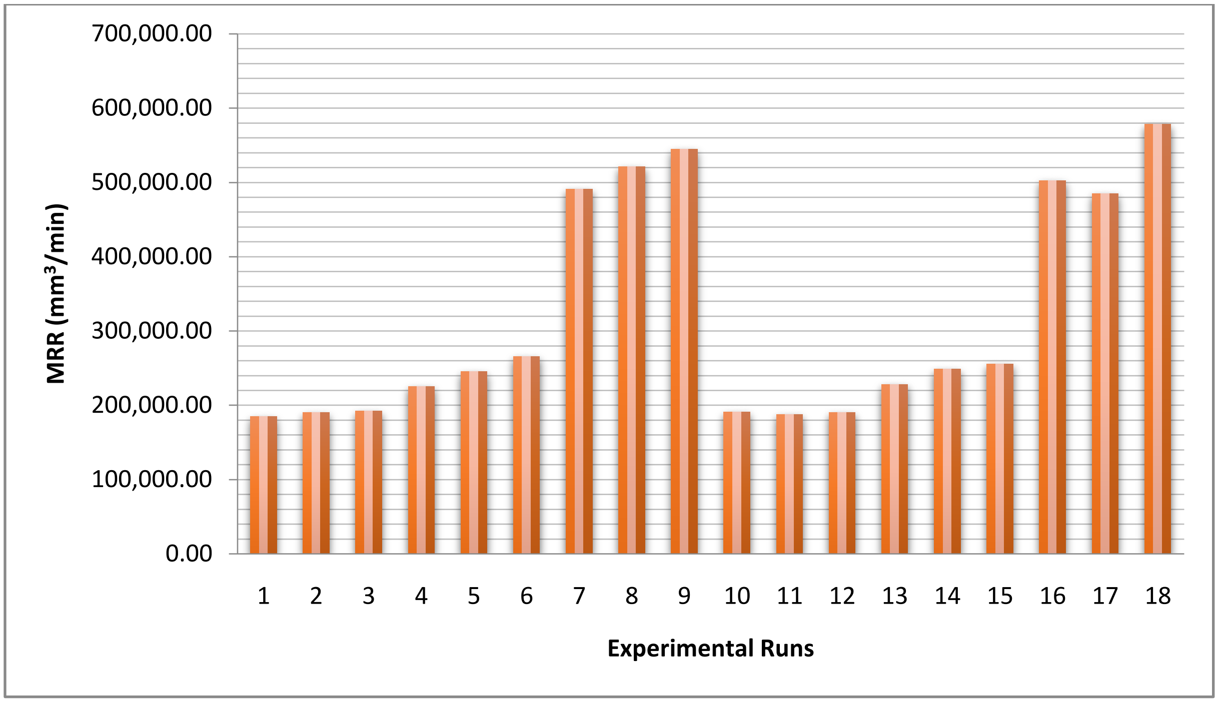

Fig. 4: Material Removal Rate during Experimental runs

(a) (b) (c)

Fig. 5: Chip formation from machining of AISI 1050 steel in various conditions (a) Dry (b) N5-Soluble Oil (c) Arachis Oil

During dry machining, the chips formed from the work piece were discontinuous and burnt. This chip formation (Fig.5a) was as a result of the high temperature generated at the cutting zone during the dry cut which resulted in brittle chip formation. Figure 5b show slightly continuous chips of averagely 35mm in length obtained when machining with N5-Soluble oil. Chips formed from machining with Arachis oil were ductile and continuous with an average length of 140mm. The ductility and continuous nature of the chips formed while machining with Arachis oil was due to the high lubricating ability of Arachis oil.

4 Conclusion

Arachis Oil has a better lubricating performance than N5- Soluble oil. This may be attributed to its higher viscosity as compared to N5-Soluble oil. The surface integrity produced when machining with Arachis oil was better than that produced when machining with N5-Soluble Oil. The surface finish improved by about 36.5% when Arachis oil was used as cutting fluid as compared to when N5-Soluble oil was used. The chips produced during machining with Arachis oil was ductile and continuous as compared to the slightly continuous and brittle chips formed during machining with N5-Soluble oil and dry respectively. N5-Soluble oil performed better in temperature reduction at the cutting zone, however, Arachis oil produce a better surface finish and hence was preferred as a cutting fluid during machining of carbon steel.

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