MACHINING BEHAVIOUR OF USING BIO-OILS AS LUBRICANTS DURING THE TURNING PROCESS

Alam Radhika[1], Shailesh Rao Agari[2]

[1]Department of Mechanical Engineering, KS School of Engineering and Management, Bangalore 64, India
[2]Department of Industrial and Production Engineering, The National Institute of Engineering, Mysuru 8, India

Corresponding author: Shailesh Rao, shaileshra@gmail.com

Abstract: Cutting fluids are commonly used to reduce friction in machines and improve product quality. In the turning process, the use of mineral oil as lubrication raises adverse effects on human health and working environment. Hence, alternative solutions need to be addressed in order to create a safe and healthy working environment. Parametric studies through experimental procedures are carried out to understand the machining process of mild steel using gingelly oil as a lubricant. The experimental results are compared with dry cutting and petroleum-based lubrication to evaluate the effectiveness of using bio-oil as lubricants in the turning process. Using gingelly oil as lubricant, orthogonal cutting shows a reduction in cutting force and formsa smoother surface finish. Coarse grains are formed during dry cutting process and minimal changes in the grain size are observed when using bio-oil. Abrasion and flank wear which are severe in dry cutting, are also reduced after lubrication, as discussed in the final section of this work.

Key words: Bio oils-cutting fluids, chip analysis, Micro structure, Tool wear

1. INTRODUCTION

Cleanliness and safety are crucial in the machining process during turning operations. The formation of heat causes tools to wear, resulting in the formation of inaccuracies on the machined surfaces. In most cases, heat generated needs to be minimized for a better machined surface quality. However, heat generation and transformation become complex when process parameters vary and cutting temperature increases. As such, researchers are working towards minimizing cutting temperature in order to improve the machining process. Cutting fluids are generally used to improve the machining process and achieve better results (Taylor, 2002; Anthony and Adithan, 2009). Cutting fluid minimizes temperature formation by providing lubrication between the workpiece and tool tip junctions. Presently, petroleum-based lubrications (mineral oils) that are used in the manufacturing sector affect the working environment and health of workers. Understanding this concern, researchers are looking into alternative methods of reducing cutting temperature in order to increase manufacturing efficiency.

Conventionally, dry cutting is carried out during the turning process for the removal of small metals from the workpiece. This method is advantageous in improving the machined surface by providing lower depth of cut during turning. However, due to the poor performance of dry cutting machining processes, an alternative method called Minimum Quality Lubrication (MQL) is studied. This method which introduces high velocities of air-lubricating oil impinging to the cutting zone offers more advantages in manufacturing processes due to its reduced oil consumption, minimal space and effective cost (Bruce, et. al., 2011). Munish (2016) conducted a study to understand the optimum process parameters for titanium alloys under the MQL environment where force analysis and wear characteristics were analysed. Using MQL techniques, chip studies, surface roughness and tool wear studies were carried out by several researchers (Globocki, 2012; Hamed, et. al., 2016; Nourredine and Vasim, 2010). Vishal (2015) discussed on challenges of utilizing MQL techniques for the machining process and proposed several improvement ideas. Overall, these methods facilitate poor lubrication even though cutting temperature is reduced.

Recent studies in cutting processes focus on using of bio-oil as lubricant during the machining process (Lawal, et. al., 2012; Sharafaden, 2013). Most of these studies suggest that mineral-based cutting fluids is replaced by bio-oils for better working atmosphere and lesser health issues among workers. Antony (2009) studied the performance of machining operation using coconut oil as lubricant. Comparing the performance of different bio-oils in evaluating the drilling operation, changes in surface morphologies were observed (Sharafaden, 2013). Groundnut oil and palm oil were concluded to be suitable substitutes for mineral oils in the drilling of mild steel. Heat generation on the tool adversely influences its strength, hardness and wear. Heat may also be accumulated on the work material, causing a gradual change in the microstructure of the machined part. This results in poor surface finish on the machined surface.

The machining performances of using bio-oils are evaluated via several methods. Chip formation gives a preliminary understanding of the machining process during turning. Changes in process parameters, coolant used, tool specification and tool sharpness adversely affect the machined surface and surface characteristics. Nakayama (1984) and Jawahir (2000) studied the formation of different types of chips for various tool geometries. Detailed analysis on the chip profile, formation of serration and its influence during the machining of titanium alloy were discussed in the works of Manikanda Kumar (2017). The effects of tool wear and detailed analysis in the turning process were also studied (K Weirnet, 2004). Kayank et. al. (2013) evaluated the relationship between dry cutting and MQL for NiTi shape memory alloys and observed drastic changes in the machining process using MQLtechnique.

Greater heat formation between tool workpiece interface leads to greater tool wear. Studies on the performance of tool rigidity during the machining process are carried out, where drastic changes in the vibration at the tool workpiece junction are observed, when using different coolant for lubrication. Evaluating the relationship between vibration and tool life during the turning process (Siamak et. al., 2018), the tool life depends on the cutting speed (Tarng et. al., 1994), friction coefficient (Kayhan and Burak, 2009) and tool material (Prasad and Babu, 2017). Friction formed during the machining process, which depends on friction coefficient, cutting speed and other related parameters can be controlled through the use of properlubricants.

Table 1. The Physical Properties of gingelly oil used for the machining process

Properties	Oils
Specific gravity at 25^{O}C	0.9188
Iodine value	104
Densityat 30^{O}C	0.915g/ml
Melting Point	-21 to31^{O}C
Flash Point	255^{O}C
Fire Point	280^{O}C
Color	ClearYellow

It is also understood that the use of gingelly oil as lubricant may aid in continuous chip formation and reduction of tool wear as gingelly oil contains some portions of triglycerides. Studies in this field are available in published literatures. Since thermal variation is present when using gingelly oil, detailed study on the process parameter and tool characteristics are required as heat formation may change the metallurgical transformation on the machined surface. The physical properties of the gingelly oil which remain similar as our earlier work (Radhika et. al, 2019) are listed in Table 1. Chip generation for the three processes namely dry cutting, turning using petroleum-based lubricant and turning using bio-oil is studied. Discontinuous chips are formed for dry turning while continuous chips are formed when bio-oil isused as lubricant. Detailed analysis of chip formation and surface characteristics arecarried out for all three processes. Modifications in the microstructure, changes in tool morphology and tool wear in different processes are explained thoroughly.

2. MATERIALS AND METHODS

The machining performances are carried out with a standard medium duty lathe. The AlSI 1014 mild steel (φ20 x150mm length) are placed rigidly in the tailstock and spun at 315rpm with constant feed rate for all the experiments. The machine setup for this study is shown in Figure 1.

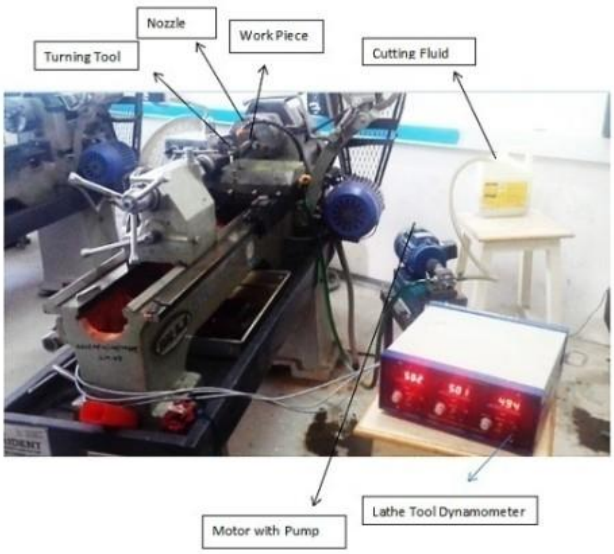


Fig.1. Experimental setup inlathe

The machining parameters are analysed by measuring the cutting force generated during the operation. The précised lathe tool dynamometer (CONTECH make; precision 0.2N) isused for measuring the cutting force formed during cutting. The surface formed on the machined area is characterized in detail. A Talysurf (portable MITUTOYO make) is used to measure the surface roughness, Ra on the machined surface. Formation of chip is evaluated for the different cutting processes. Finally, the images of the tool tip are taken through scanning electron microscope for detailed studies on tool wear characteristics.

In our earlier work, comparison and improvement in the machined process for different workpiece diameter are analysed (Radhika, 2019). In this work, further studies in detailed chip analysis for a larger diameter workpiece and detailed tool wear studies are conducted.

3. RESULTS AND DISCUSSION

3.1 Formation of Chips

The chip pattern formed during the process will give a fair idea on the influence of cutting fluid in the process. The type of chip formed during the turning operation varies, depending on the change in the machining process. The colour and nature of the chip formation allow the behaviour of the process during the machine interface to be interpreted. The chip samples are collected and shown in Figure 2. Some of the measurements that are found during the processes are shown in Table 2. Generally, the temperature during machinability at the chip should be minimized for better cuttingforces.

(a) (b) (c)

Fig. 2. The Chip formation for the three processes: (a) Without Lubricant; (b) With SAE20W40 Lubricant; (c) Gingelly Oil

Table 2. The cutting force, surface roughness and chip reduction coefficient for the different processes

	Dry Cutting Process	Petroleum Based Lubrication	GingellyOil Lubrication
Cutting Force (in N)	301	278	247
Surface Roughness (in µm)	1.18	1.12	0.92
Chip reduction coefficient	3.5	3.22	2.98

In the case of dry cutting operations, the nature of the chip structure indicates the temperature formation at the interface. Primary and secondary deformations of the tool at the machined region produce enormous heat at the junction. The tangible chips that are formed absorb more heat and generate a violet appearance beneath the chip surface. As heat accumulates, the chips brittle and get detached from the workpiece due to machine chattering, creating a poor finish on the machined surface. Heat formation also softens the work material, producing chips with small length. The formation of burnt powdered chips with blue appearance indicates the enormous heat generation at the tool tip interface. Using petroleum-based lubrication and bio-oil, continuous ribbon type chips are formed at specific process parameters. The tubular diameters of the chips are reduced from the second to the third process, which may be due to the reduction in chatter during machining.

Experiments carried out by Khan, et. al. (2009) witnessed a similar smooth back surface on the chip when bio-oils are used as lubricants as there is an appreciable reduction in temperature. Build-up chip formations are not observed for both processes as small chips (burr) that are produced are taken away by the lubricant in motion. In the case of bio-oil (gingelly oil), the oil forms a thin film over the workpiece surface which aids in better lubrication. Improved lubrication allows resistance during the process to be reduced and some of the heat formed to be carried away by the oil, generating uniform continuous chips.

The cutting force during the turning process is studied and surface characterization on the machined area of the workpiece is performed. In the dry cutting operation, more heat is formed and accumulated in the work material which results in poor quality and surface finish. Removal of heat from the interface and material can be done by applying lubrication over the machined surface. In this case, applying gingelly oil as lubricant reduces the heat generated and forms lesser friction between the tool and the workpiece.

In the dry machining process, the tool impinges on the soft workpiece material, which results in increased pitch height on the machined surface. In addition to this, the burrs formed in the interface get collected in the tool tip. A large cutting force and increased temperature causethese burrs to attach on the machined surface, resulting in the formation of micro welds. At larger depth of cut, moremicro weldsare formed due to the increased chatter, creating a rough surface on the machined area. For the petroleum-based lubricating process, the sudden flow of lubricant at the junction carries heat away to effectively improve the surface finish, reduce the cutting force and minimize chatter formation in comparison with the dry turning process. Gingelly oil which adheres on the machined surface by forming a thin film lengthens contact time between the liquid and machined surface. This helps in improving heat transfer from the machined surface to bio-oil. The usage of gingelly oil reduces cutting force by 26% in comparison with dry cutting and around13% compared to mineral-based lubricant. The lubricating film formed over the machined surface aids in the formation of continuous chips. The improved surface finish and reduction in pitch height clearly explain the improvement in the machined process.

Chip reduction coefficient also suggests the change in the quality of machining processes. There is a steady decrease in the coefficient value when switching from dry cutting to using gingelly oil for lubrication. The reduction in chip thickness is due to the shrinkage in the shear zone caused by the decrease in heat generation at the interface. The easy slipping of the tool at the junction helps in heat reduction as lesser friction is generated during the process. For bio-oil, the sticky nature of the oil penetrates the machined surface, eventually softening the material and allowing easy metal removal.

3.2 Formation of Microstructures on the Machined Surface

The formation of microstructures on the machined surface for 20mm diameter workpiece in different processes is shown in Figure 3, while the initial arrangement of the structuresat micro level for the base material is shown in Figure 3(a). The cutting fluid at the interface should have proper lubrication and good heat carrying capacity. In dry machining, larger grain-sized structures are formed with some dent on the machined surface observed. In this case, continuous chatter and repeated penetration lead to rise in temperature, resulting in increased grain size. Dents are formed from the repeated hitting of the tool over the machined surface at high chattering rates, generating greater heat in the machined surface as shown in Figure 3(b). A decrease in heat formation is observed when petroleum-based lubricant flows over the tool tip position. Figure 3(c) shows the microstructure formation when using petroleum-based lubricant where no dent is observed on the workpiece. The sudden impingement of the lubricant over the junction results in poor heat transfer from the machined surface and causes in efficient heat removal from the surface. Hence, an increased grain size is observed. This means that petroleum-based lubricant may be a proper lubricant, but it does not contribute to proper cooling. Gingelly oil is capable of improving the machining process while acting as a good lubricant and coolant. The sticky nature of this coolant helps in easy lubrication and promotes heat transfer from themachined surface. A small increase in grain size is observed when using gingelly oil as shown in Figure 3(d).

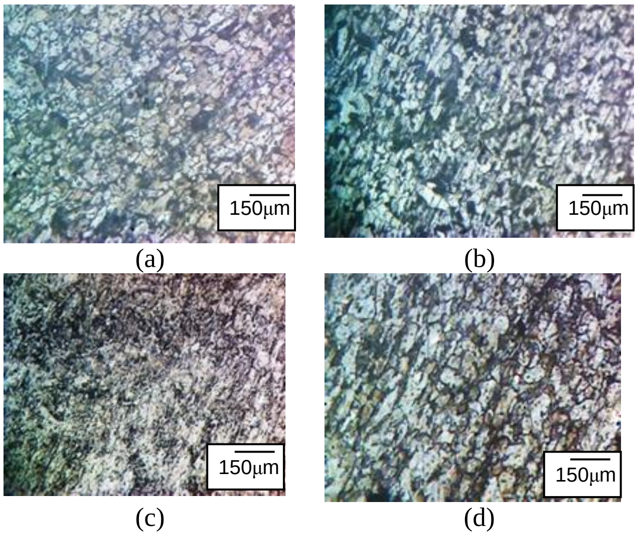


Fig. 3. Microstructure formation on the machined surface for all the processes

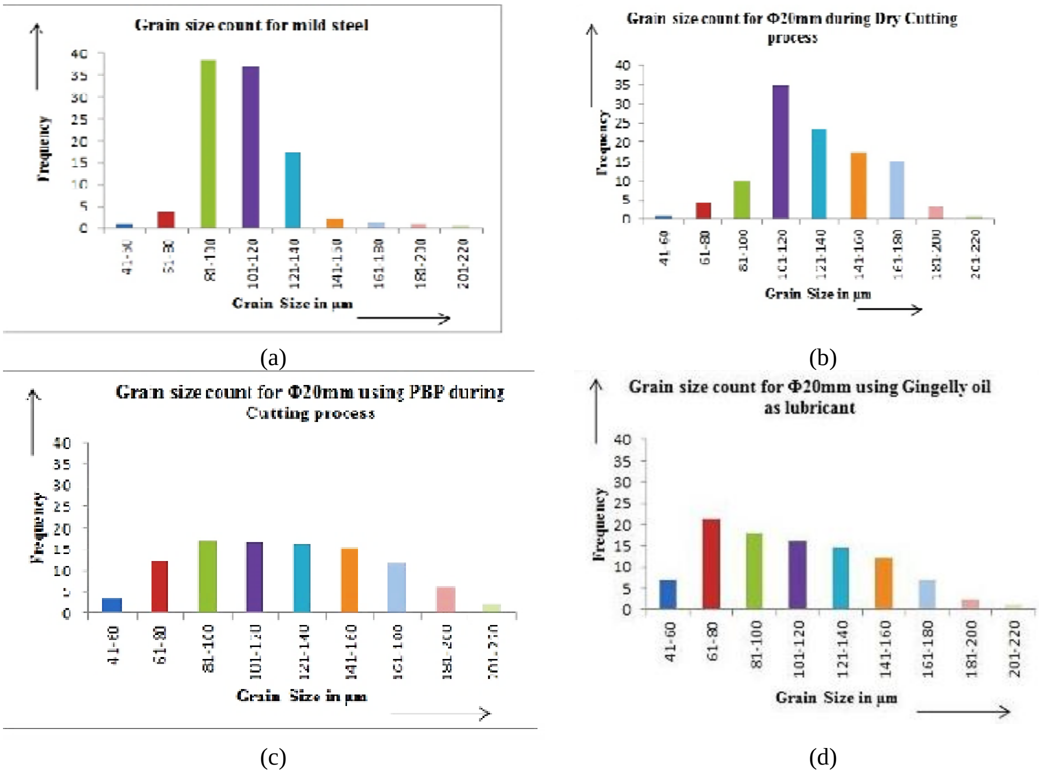
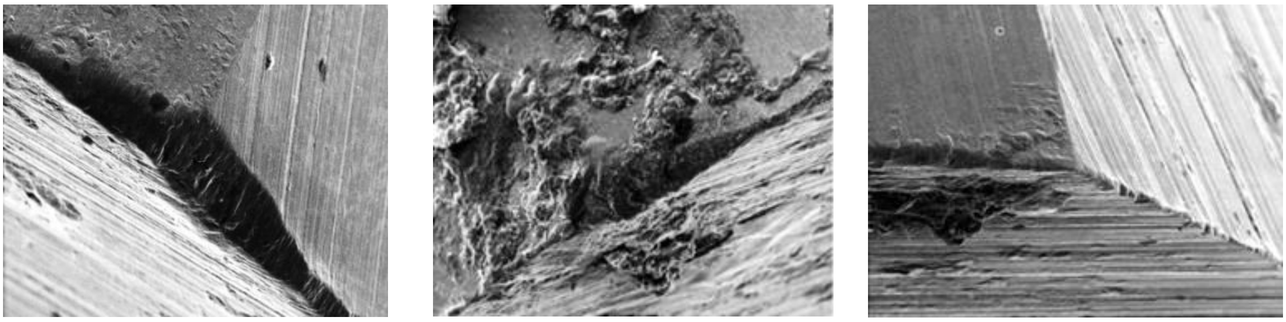


Fig. 4. Grain Count Size for all the process

Grain analysis for the base material is studied using an optical analyser where 80% of the grains are in the range of 80 to 120μmas displayed in Figure 4(a). In dry turning, the formation of large amount of heat at the interface makes a metallurgical conversion on the workpiece surface, causing the grain size to increase from 100 to 180μm as shown in Figure 4(b). The increase in grain size may also be attributed to the dent formed in the machined surface. For mineral-based lubrication, reduced friction does not effectively help in heat removal as the sudden hitting of oil on the junction makes it difficult in transferring heat from the surface. An increase in the grain size is observed during the process, where the grain size ranges from 80 to160μm as shown in Figure 4(c). As for gingelly oil, the lean coating formed helps in the generation of heat. The oil acts as an excellent lubricant on the machined surface, where pitch height reduction and better chip formation are evident in Figure 4(d). Here, the oil butts rigidly over the workpiece circumference which aids in cooling the workpiece. The formation of continuous chips and improved surface finish contribute to the marginal increase in grain size which ranges between 60 to 120 μm.

3.3 Tool Morphology after the Machining Process

The tool wear for the different processes is shown in Figure 5. The dry machining process encounters a severe tool wear with craters and flank wears. Maximum wear is observed at thetool tip and the edge of the nose radius. Due to the enormous heat generation, the formed burr and micro chips accumulate and adhere to the rake surface. With the dynamic loading and greater heat generation during the process, the forces that are exerted remove the tool edge easily, resulting in significant tool wear. When a coolant is added, the flank wear on the cutting tool tip is minimized. The principal flank wear is also gradually reduced and a small wear is noticed on the vertical edge below the nose radius. The coolant reduces the friction during the process and helps in reducing tool wear. Flank wear can be further reduced using fatty contents such as gingelly oils where their high viscosities enable easy liquid flow and minimize heat at the chip toolinterface.



(a) (b) (c)

Fig.5. The Tool wear on the tool tip for (a) dry Cutting, (b) Petroleum based lubrication (c) gingelly oil lubrication processes

4. OVERALL DISCUSSIONS

In present manufacturing processes, mineral-based oils are widely used in the general turning process. The use of gingelly oil in the present work has shown tremendous improvement in the machining process and tool life. Through microstructural studies, minimal change in the microstructure on the machined surface is observed. This indicates that gingelly oil can become a potential candidate as lubricating oil in manufacturing industries. Initially, the chips are collected from all the processes where their sizes, shapes and colours are analysed. Dry cutting produces thick chips. There is a reduction in chip thickness when using mineral oil as lubricant, with the smallest thickness observed when using bio-oil. The reduction in chip thickness helps in lowering the cutting force which is required to slide the chip from the base material (Khan, etal. 2009). The chip colour becomes brighter by using bio-oil as lubricant and the violet burnt appearance cannot be seen below the chip surface. The burrs and powder chips formed in the dry cutting process prove that enormous heat is generated from the tool workpiece friction. The generated heat is then transferred to the chip, making it brittle. As the dynamic movement of the tool causes this chip to break easily, more burrs and shorter chips are formed during the process. The dynamic loading at the tool- workpiece interface should resist fracture toughness. The tool tip generally lacks in strength; thus, wears may be attributed to mechanical breakage. The plastic deformation exerted during the turning process with the excess pressure on the tool tip makes the tip instable. As a result, the tool wears during the process, which leads to poor surface finish on the machined surface. Large numbers of dents are formed and are clearly visible in the microstructure. In the present study, there is a severe wear on the tool tip during the actual machining process as observed from the images. The small number of burrs formed that are welded on the rake tool surface and blunt tool edges on the nose radius are visible. Severe chatter formation causes chipping and fracturing in the primary flank wear. This creates dull edges that are easily removed from the tool. An enormous scratch on the dull edge indicates the severity of the dynamic process during the machining process. There is also indication of abrasive wear on the rake surface. The generated heat aids in micro chipping on the machined surface, an occurrence that is also noticed in similar work from the other researchers (Khan, et. al., 2006). From the workpiece analysis, the microstructure formed on the machined surface increases insize. The great amount of heat generated during the process is transferred through conduction withinthe workpiece. Intense heat can be felt when placing a finger over the rough surface. Here, the grain size changes due to the metallurgical transformation during the process. Grain size ranging between 100 to 150μm with varying proportions is formed during the dry cutting process. This size gradually-based oil is used as lubricant. The chip reduction coefficient gradually lowerswith the use of lubrication. This is due to the reduction of chip shrinkages near the shear plane with lesser friction and lower cutting temperature. Surface roughness also reduces during the process as tabulated in Table 1. The flank wear rate reduces gradually with the use of lubrication and minimum wear is observed whenusing bio-oil in lubrication processes. There is a mixture of burr in petroleum-based lubrication which adheres to the rake surface in large amount as observedfrom the figure. This disrupts the machinability and a small reduction in the surface finish on the machined surface is observed. The adhesiveness of the burr is seen in the flank and rake surface. The cause of reduced flank wear is attributed to the decrease of tool temperature at the flank junction, which minimizes the abrasion wear of the tool. Minimal changes in tool hardness also minimize the tool diffusion in the process. The formation of heat during the process is lowered, hence a small change in the grain size is noticed in the process. Using gingelly oil as lubricant causes lesser friction between the tool junctions, resulting in reduction of tool wear and development on the machined surface quality. Irregular marks are seen on the surface during dry cutting due to chatter formation and improvement of surface finish quality is recorded. Using bio-oil as lubricant, chatter formation is lesser due to easy lubrication and surface finish is gradually reduced in this process. A thin layer of oil is coated over the workpiece during the process, mainly from the fatty acid which helps in coating adhesive content over the machined surface. This thin layer connects the contact surface strongly. Gingelly oil contains triglycerides which help in excellent lubrication due to their molecules which stick to the metal surface (Seyedeh, 2013). This allows proper sliding at the contact surface hence improving machinability. From the tool analysis, a reductionin abrasive wear in the flank surface is identified. A crater wear that is observed near the nose radius during dry cutting process is almost eliminated with distinct reduction in flank and crater wear when using bio-oil as lubrication.

Overall, there is a drastic improvement in the machining operation when using bio-oil as lubricant. Tool life, surface characteristics and microstructure analysis on the machined surface are crucial in understanding the improvement in process parameters during the operation. The value of specific heat has a direct relation with the wettability properties which influence the adherence of lubricant to the workpiece surface (Sharafaden, 2013; Pavani et. al., 2015). The specific heat of gingelly oil at 45°C which is 2.1kJ/kg. Kis higher than that of mineral oil at 1.67 kJ/kg.K. The stickiness of bio-oil on the machined surface increases lubrication and reduces friction at the tool workpiece junction. When used as cutting fluids, bio-oils reduce the generation of heat and improve the tool life without much alteration to the microstructure. From the experiments conducted, it is show cased that gingelly oil has high lubricating ability due to its high viscosity (Alves, Salete, 2008), where uniform and thick chips are formed. Improvement in sliding and reduction in friction between the tool and workpiece due to high oiliness at the junction are also observed. The lower chip thicknesses formed during dry cutting operations are also absent with the usage of gingelly oil. Chatter formation which periodically strikes the tool on the workpiece reduces chip thickness during dry cutting. With reduction of chatter formation using bio-oil, chip thickness increases without tangle. Bio-oil also gives significant improvement in the working temperature, minimizing energy consumption during the machining process. Results show that temperature variation is high in the dry turning process. On the other hand, drastic reduction in temperature variation is observed during lubrication using bio-oil. Turning using bio-oil also produces smoother surface compared to mineral oil. The presence of triglycerides in bio-oil also helps in butting over the workpiece. The thin layer formed from fatty acid chains reduces friction between the tool work piece junctions. The adhering property of bio-oil over machined surface and low friction provide smoother surface finish and reduce cutting force, similar to observations found in other works when bio-oils are used during the drilling operations (Belluco and De Chiffre, 2004). This shows that bio-oil is a capable replacement as lubricating oil where thrust force is reduced by 7% during the machining process, while cutting force is reduced by 16% in turning operations. During the analysis of cutting tool, a severe deformation on the nose radius is observedin dry cutting. The worn tool, when rubbed with the machined surface, results in poor surface finish. Using bio-oil as lubricant, an improved surface finish is recorded. The least primary flank wear is observed when bio-oil is usedfor lubrication, followed by mineral oil and dry cutting. In the case of dry cutting, wearing at the nose radius is mainly due to chipping, indicating unsteady machining. With the use of mineral oil, the principal wear gradually reduces but large quantity of visible burrs and oil particles are deposited on the rake surface. The reduction of temperature using bio-oil is attributed to the decrease in abrasion wear where tool hardness is related to temperature (Seyedeh, 2013). Tool life is improved when lubrication is applied properly. Some wear is also noticed in auxiliary flank in dry cutting operation which results in poor surface finish and inaccurate dimensions. In all turning processes, small pits are seen on the rake surface due to severe adhesive wear in dry cutting process. When gingelly oil is used as lubricant, the reduction in temperature and adhesion of oil over the workpiece help in minimizing tool wear, maintaining tool hardness and increasing toollife.

From the microstructure analysis, white patches representing graphite flakes are seen in a large number for bio-oil. The presence of this graphite is mainly due to hardness, wear and abrasion resistance (Belluco and De Chiffre, 2004). As for dry cutting, a mixture of black and white patches is observed, indicating severe machinability on the machined surface. Here, the material is squeezed between the tool-workpiece interfaces which results in an increase in strain rate during the deformation process. The large cutting force also helps in severe deformation of the tool on the flank and rake surfaces. The thermal cyclic effect and stress formation on the machined surface leadto micro chipping where the removal of material and small pores are clearly visible in the microstructure. The enormous heat generated also results in the change in microstructure and a 20% increase in grain size for the dry cutting process. As for gingelly oil, minimal change in the grain size is recorded, indicating a reduction in repeated heat generation and friction.

5. CONCLUSIONS

Gingelly oil is shown to be a promising replacement as lubricating oil during the machining process. The Bio-oil reduces cutting force, chip reduction coefficient and cutting temperature by about 10 to 25%. The formation of chips from discontinuous to continuous when gingelly oil is instead of dry cutting and petroleum-based oil as lubricant is observed initially. A Violet burnt chips that are formed during dry cutting are not seen when bio-oil is used as lubricant. When the analysis over the machined surface is made, a small change in the microstructure identifies gingelly oil as a promising alternative lubricant during the process. Large grain sizes are seen for the other two processes due to large heat accumulation and chatter formation. The blunt tool edges, high cutting temperature and poor chip tool interaction that are not favourable in dry cutting process are seen during the process. A main reason for the improvement in machining process using bio-oils as lubricant, is the formation of thin coating over the machined surface, which helps in reduced temperature, improved machined surface and sharpened tool edge.

6. REFERENCES

1. Taylor, F, W., (2007). *On the art of cutting metals*, Trans ASME, **28**, pp. 31-58.

2. M, Anthony, Xavior, A. and Adithan, (2009). *Determining the influence of cutting fluids on tool wear and surface roughness during turning of AiSi 304 austenitic Stainless Steel*, Journal of Material Processing Technology, **209**, pp. 900-909.

3. Bruce, L.T., Jean, M.D. and Albert, J.S., (2011). *Evaluation and comparison of lubricant properties in minimum quantity lubrication machining*. Journal of Machining Science and Technology, **15**, pp. 376–391.

4. Munish, Kumar, Gupta., (2016). *Machining Parameters Optimization of Titanium Alloy using Response Surface Methodology and Particle Swarm Optimization under Minimum-Quantity Lubrication Environment*, Journal of Materials and Manufacturing Processes, **31**, pp. 1671- 1682.

5. G. Globocki, (2012). *Experimental Research Using of MQL in Metal Cutting,* Tribology In Industry, **35**, pp. 276-285.

6. Hamed, Hassanpour, Mohammad, H., Sadeghi, Hamed, Rezaei and Amir, Rast I., (2016). *Experimental Study of Cutting Force, Microhardness, Surface Roughness, and BurrSize on Micro milling of Ti6Al4V in Minimum Quantity Lubrication*, Journal of Materials and Manufacturing Processes, **31**, pp. 1654-1662.

7. Nourredine, Boubekri, Vasim, Shaikh, (2010). *A technology enabler for green machining: minimum quantity lubrication (MQL),* Journal of Manufacturing Technology Management, **21**(5), pp. 556-566.

8. Vishal, Sharma, (2015). *A Review on Minimum Quantity Lubrication for Machining Processes*, Journal of Materials and Manufacturing Processes, **30**(8), pp. 935-953.

9. Lawal, S, A., I, A, Choudhury and Nukman, (2012). *Application of vegetable oil-based metal workingfluid in machining ferroud metals- a Review*, International Journal of Machine Tools and Manufacture, **52**, pp. 1-12.
10. Sharafaden, Kinle, (2013). *Performance Evaluation of Vegetable oil-Based Cutting Fluids in Mils Steel Machining*, Chemistry and Materials Research, **3**, pp. 35-45.
11. M, M, A, Khan, M, A, H, Mithu and N, R, Dhar, (2009). *Effects of minimum quantity lubrication on turning AISI 9310 alloy steel using vegetable oil-based cutting fluid*, Journal of Materials Processing Technology, **209**, pp. 5573-5583.
12. Khan, M, M, A. and Dhar, N, R., (2006). *Performance Evaluation of minimum quantity lubrication by vegetable oils in terms of cutting force, cutting zone temperature, tool wear, job dimension and surface finish in turning AISI 1060 steel*, Journal of Zhejiang University Science A, **7**(11), pp. 1790-1799.
13. Seyedeh, Mahdieh, Namayandeh, (2013). *Olive and Sesame Oil Effect on Lipid Profile in Hyper cholesterolemic Patients, Which Better?*, Int. J. Prev. Med., **4**(9), pp. 1059–1062.
14. P, N, L, Pavani, R, Pola, Rao and S, Srikiran, (2015). *Performance evaluation and optimization of nano boric acid powder weight percentage mixed with vegetable oil using the Taguchi approach*, Journal of Mechanical Science and Technology, **29**, pp. 4877-4883.
15. Alves. And Salete Martins, (2008). *Vegetable Based Cutting Fluid: An Environmental Alternative to Grinding Process*, 15th CIRP International Conference on Life Cycle Engineering: Conference Proceedings-2008, pp. 664-668.
16. Belluco, W. and De Chiffre, (2004). *Performance Evaluation of Vegetable-Based Oils in Drilling Austenitic Stainless Steel*, Journal of Material Processing Technology, **148**, pp. 171-176,.
17. K, Nakayama, (1984). *Chip control in metal cutting*, Bull. Japan Soc. Precis. Eng., 18(2), pp. 97–103.
18. I, S, Jawahir, and A, K, Balaji, (2000). *Predictive modeling and optimization of turning operations with complex grooved cutting tools for curled chip formation and chip breaking*, Mach. Sci. Technol., **4**(3), pp. 399–443.
19. Manikanda, Kumar, Shunmugavel, (2017). *Chip formation characteristics of selective laser melted Ti–6Al–4V*, Australian J. of Mechanical Engineering, doi:org/10.1080/14484846.2017.1364833.
20. Kayank, Y., H, E, Karaca, R, D, Noebe and I S Jawahir, (2013). *Tool wear analysis in cryogenic machining of NiTi shape memory alloys: A comparisonoftoolwearperformancewithdryand MQL machining*, Wear, **306**, pp. 51-63.
21. K, Weirnet and V, Petzoldt, (2004). *Machining of NiTi based shape memory alloys*, MaterialScienceand Engineering A, **378**, pp. 180-184.
22. Siamak Ghorbani, Vladimir V. Kopilov, Nikolay I. Polushin, Vladimir A Rogov, (2018). *Experimental and analytical research on relationship between tool life and vibration in cutting process*, Archives of Civil and Mechanical Engineering, **18**(3), pp. 844-862.
23. Y. S.Tarng, H. T. Young, B.Y.Lee, (1994). *An analytical model of chatter vibration in metal cutting*, Int. J. Mach. Tools Manuf., **34**(2), pp.183–197.
24. M. Kayhan, E. Budak, (2009). *An experimental investigation of chatter effects on tool life*, Proc. Inst. Mech. Eng. Part B: J. Eng.Manuf, **223**(11), pp. 1455–1463.
25. B. S. Prasad, M. P. Babu, (2017). *Correlation between vibration amplitude and tool wear in turning: numerical and experimental analysis*, Eng. Sci. Technol. Int. J, **20**, pp. 197–211.
26. Alam Radhika, Shailesh Rao A , Yogesh K B (2019). *Evaluating machining performance of AlSI 1014 steel using gingelly oil as cutting fluid*, Australian Journal of Mechanical Engineering, doi: 10.1080/ 14484846. 2019. 1636517.

Received: February 21, 2021 / Accepted: June 15, 2021 / Paper available online: June 20, 2021 © International Journal of Modern Manufacturing Technologies