PERFORMANCE EVALUATION OF DIFFERENT TYPES OF CUTTING FLUIDS IN THE MACHINING OF HARDENED STEEL – A REVIEW

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Abstract— This paper presents a review on performance evaluation of different types of cutting fluids in the Machining of various hardened Steel Materials. Knowledge over the performance of vegetable oil based cutting fluids when applied to different work materials and operations is of vital importance in order to improve the efficiency of various conventional machining processes. This Efficiency can be measured, among other parameters, through cutting tool life and surface finish of work piece. In this Review, performances of various vegetable oil based cutting fluids are compared in terms of tool wear, force and surface roughness during various operations of various Hardened steel Material with various cutting tools.

Keywords— Cutting Fluids, Machining, Work Piece material, Tool Material.

I. INTRODUCTION

Cutting fluids are employed in machining to reduce friction, cool the work piece, and wash away the chips. With the application of cutting fluid, the tool wear reduces and machined surface quality improves. Often the cutting fluids also protect the machined surface from corrosion. They also minimize the cutting forces thus saving the energy. These advantages of using cutting fluids in machining are accompanied by a number of drawbacks. Sometimes the cutting fluid costs are more than twice the tool-related costs. Most of the cutting fluids possess the health hazard to the operator. Disposal of the used cutting fluid is also a major challenge.

In the recent past, there has been a general liking for dry machining.On the other hand, several researchers started exploring the application of minimal cutting fluid. In this Paper,a review on performance evaluation of different types of cutting fluids in the machining of hardened steel material is presented.

Cutting fluid (coolant) is any liquid or gas that is applied to the chip and/or cutting tool to improve cutting performance. A very few cutting operations are performed dry, i.e., without the application of cutting fluids. Generally, it is essential that cutting fluids be applied to all machining operations.

Cutting fluids have traditionally been used in machining operations to lubricate the chip-tool and tool-work piece interfaces, remove heat from the work piece and cutting zone, flush away chips from the cutting area, and inhibit corrosion. While each of these four functions can be employed as justification for cutting fluid usage, it is widely believed that the primary functions of a cutting fluid are lubrication and cooling. Seminal contributions to the technical literature in support of this belief are provided below.

II. LITERATURE REVIEW

M. Anthony Xavior, M. Adithan (2008)they determined the influence of cutting fluids on tool wear and surface roughness during turning of AISI 304 austenitic stainless steel. They performed turning operation by using AISI 304 work piece material. They used three different vegetable oil based cutting fluids:1.Coconut Oil 2. Soluble Oil 3. Straight Cutting Oil. They concluded that feed rate affects surface roughness & cutting speed affects tool wear. Coconut oil is better cutting fluid than the conventional mineral oils in reducing the toolwear and surface roughness. [1]

Mohamed HandawiSaadElmunafi, D. Kurniawan& M.Y. Noordin (2015)their study evaluates the performance of MQL using castor oil as cutting fluid & Results are compared with dry cutting. They found that using small amount of lubricant of 50 ml/h during the particular turning process produces better results compared to dry cutting, in terms of longer tool life.They come to know that machining under MQL seems to be limited by cutting temperature, because at high speed the effect of oil mist becomes evaporated. [2]

Patrick AdebisiOlusegunAdegbuyi, GaniyuLawal; OluwatoyinOluseye; GaniyuOdunaiya (2010)they Analysed the effect of cutting fluids on the mechanical properties of mild steel in a turning operation.Turning was done under dry condition and also using 3 coolants. They found that Palm kernel oil performed very well the specific functions of soluble oil as cutting fluid which includes good chip formation, reduction of heat generated and realization of a good surface finish. [3]

A. Hamdan, M. Fadzil, K.A. Abou-El-Hossein, M. Hamdi theypresented the performance evaluation of

three different cutting fluids used in a minimal quantity lubrication (MQL) system. The three cutting fluids chosen were neat oil, soluble oil and semi-synthetic cutting fluids. It was observed that performance of soluble oil does not drastically change with variation to the cutting velocities and feed rates. With proper machining parameter selection, water-mixed cutting fluids (soluble oil and semi synthetic) performed comparatively well to deliver low surface roughnessResults.[4]

R.F. Avila, A.M. abrao (2001)in their work, the performance of three types of cutting fluids were compared to dry cutting when continuous turning hardened AISI 4340 steel using mixed alumina inserts. The parameters they gone through are tool life, surface finish, and chip form. They found that when finish cutting at high cutting speeds, the use of cutting fluid is responsible for reducing the scatter in the surface roughness value. [5]

YahyaIsik (2010)he worked on An Experimental Investigation on Effect of Cutting Fluids in Turning with Coated Carbides Tool.The cutting tool used in this research is CVD coated carbide TiC+AI2O3+TiN insert (ISO P25). The type of inserts is DNMG 150608. The results have been compared with dry and wet-cooled turning. He concluded that CVD coated carbide TiC+AI2O3+TiN cutting tool performed better during wet machining mode. [6]

L.N. L´opez de Lacalle, C. Angulo, A. Lamikiz, J.A. S´anchez (2006)they didExperimental and numerical investigation of the effect of spray cutting fluids in high speed milling. The possibility of minimizing the consumption of cutting oil has also been analyzed. They concluded that Emulsion coolant is inefficient in high speed milling. [7]

R. Deepak Joel Johnson, K. Leo Dev Wins, Anil Raj, B. Anuja Beatrice (2014)they did Optimization of Cutting Parameters and Fluid Application Parameters during Turning of OHNS Steel. The optimized results were compared with dry turning and conventional wet turning under similar cutting conditions. They performed turning operation on lathe machine by using OHNS Steel of hardness 34 HRC work piece material. They concluded that the turning operation with minimum cutting fluid improves the cutting performance and gives the improved surface finish. [8]

Babur Ozcelik, Emelkuram, ErhanDemirbas and Emrah ¸Sik (2013)they showed Effects of vegetable-based cutting fluids on the wear in drilling. They worked on semi-synthetic commercial cutting fluid, sunflower and canola oils. Their Experimental results show that canola based cutting fluid gives the best performance due to its higher lubricant properties with respect to other cutting fluids at the constant cutting conditions. [9]

Yong Huang, Steven Y. Liang (2005)they performed the Effect of Cutting Conditions on ToolPerformance in CBN Hard Turning. They performed turning operation with hardened 52100 bearingsteel (work piece material). They used Cubic boron nitride (CBN) as a tool material. They concluded that the cutting speed plays a dominant role in determining the tool performance in CBN hard turning of hardened 52100 bearing steel, followed by feed and depth of cut. [10]

E. Kuram, B. Ozcelik, E. Demirbas, and E. Şık(2010)they performed the Effects of the Cutting Fluid Types and CuttingParameters on Surface Roughness and Thrust Force. They performed drilling operation with AISI 304 austenitic stainless steel. They took HSSE tool material. They performed experimentation with three vegetable oils that are 1. Refined sunflower oil, 2. Commercial vegetable cutting fluid, 3.Commercial mineral cutting fluid. They concluded that the increase in the spindle speed decreases thethrust force value & thesurface roughness value. An increase in the feed rate increases the thrustforce value & surfaceroughness value.[11]

Y.M. Shashidhara, S.R.Jayaram (2010)they performed a review on Vegetable oils as a potential cutting fluid—An evolution. They did experimentation with three vegetable based cutting fluids that are soya-bean, sunflower and rape seed oil. They remark that Vegetable oils were found to be promising alternative for mineral based oils due to their environmental friendly characteristics. [12]

M. Sokovic, K. Mijanovic (2001)they did an analysis of the ecological parameters of the cutting fluids and its influence on the machinability parameters.Their results help to achieve a prescribed result in terms of tool life, surface finish and accuracy-to-size, and make chip breaking and chip transport easier. [13]

Dragos A. Axinte, Walter Belluco, Leonardo De Chiffre (2001)they proposes a method to obtain reliable measurements of tool life in turning, discussing some aspects related to experimental procedure and measurement accuracy .they taken AISI 316L stainless steel as work piece material and coated carbide tool as tool material.They found that by taking three repetitions the uncertainty calculated with a coverage factor of two was on average three times bigger than the experimental standard deviation. The method was applied to the evaluation of cutting fluid efficiency in turning. [14]

Sachin M. Agrawala, SubhashLahane, N. G. Patil, P. K. Brahmankar (2014)they did Experimental Investigations into Wear Characteristics of M2 Steel Using Cotton Seed Oil. The experiments were carried out on M2 high speed steel under different lubricating conditions. Speed and load have been varied in a wide range to study their combined effect on the wear behavior of this material under dry, wet (SAE 40 oil and cotton seed oil) conditions. The cotton seed oil performed better than dry and wet (SAE 40 oil) condition under varying load; however, no significant difference has been found at higher loading between both wet conditions.

They observed that at initial loading, coefficient of friction at wet conditions by using cotton seed oil is higher or equal to coefficient of friction by using conventional SAE 40 oil but overall performance of cotton seed oil is better as compared to SAE 40 oil and dry condition. [15]

Vamsi Krishna Mamidi and M. Anthony Xaviorthey did a review on selection of cutting fluids. The selection of cutting fluids for machining processes generally provides various benefits such as longer tool life, higher surface finish quality and better dimensional accuracy. These results also offer higher cutting speeds, feed rates and depths of cut. The productivity of machining process will be much higher with combination of selecting higher machining parameters. The material removal rates will be increased. The regeneration methods of used cutting fluids would also provide various advantages such as reducing cutting the fluids cost, disposals cost of used cutting fluids and nearly eliminating environmental pollution. [16]

Matthew Grover, Zulfiqar A Khan (2014)they did The Comparison on Tool Wear, Surface Finish and Geometric Accuracy when Turning EN8 Steel in Wet and Dry Conditions. It can be concluded that although an increased wear rate is present during dry condition; the direct and indirect costs of coolant alone will outweigh the increased frequency for purchasing of new cutting tips. During rough cutting it was noted that a high surface roughness was present with dry conditions, but was still at an acceptable level for non-interfacing surfaces, which would suggest that for pure material removal operations, dry cutting is the most cost effective despite the slight increase in tool ware. [17]

N.R. Dhar, S. Paul, A.B. Chattopadhyay (2002)they didthe influence of cryogenic cooling on tool wear, dimensional accuracy and surface finish in turning AISI 1040 and E4340C steels. They concluded that Dimensional accuracy and surface finish also substantially improved mainly due to significant reduction of wear and damage at the tool tip by the application of liquid nitrogen. Also application of cryogenic cooling by liquid nitrogen jets can provide not only environment friendliness but also substantial technological benefits as has been observed in machining some steels by carbide tools. [18]

M. Kaladhar, K. Venkata, Ch. SrinivasaRao (2012)they did Determination of Optimum Process Parameters during turning of AISI 304 Austenitic Stainless Steels using Taguchi method and ANOVA. And the Analysis Of Variance (ANOVA) is also used to analyze the influence of cutting parameters during machining. In their work, AISI 304 austenitic stainless steel work pieces are turned on computer numerical controlled (CNC) lathe by using Physical Vapour Deposition (PVD) coated cermet insert (TiCN- TiN) of 0.4 and 0.8 mm nose radii. The results revealed that the feed and nose radius is the most significant process parameters on work piece surface roughness. However, the depth of cut and feed are the significant factors on MRR. Optimal range and optimal level of parameters are also predicted for responses. [19]

K.P. Sodavadia and A.H. Makwana (2014)they did Experimental Investigation on the Performance of Coconut oil Based Nano Fluid as Lubricants during Turning of AISI 304 Austenitic Stainless Steel. The Nano fluid lubricants were prepared by suspensions of Nano Boric acid in coconut oil so thermal conductivity and heat transfer coefficient increased and specific heat decreased with percentage increase in Nano boric acid. So cutting temperatures, tool flank wear and surface roughness were decreased significantly with Nano lubricants compared to base oil, due to the better lubricating properties of it. In all the cases, coconut oil with 0.5% Nano Boric acid suspensions showed better performance compared to other Nano fluid in terms of cutting temperatures, tool flank wear and surface roughness. [20]

M. Kaladhar, K. VenkataSubbaiah, Ch. SrinivasaRao and K. NarayanaRao (2010)they did optimization of process parameters in turning of AISI 202 Austenitic Stainless Steel. The experiments have been conducted using full factorial design in the Design of Experiments (DOE) on Computer Numerical Controlled (CNC) lathe. Further, the analysis of variance (ANOVA) was used to analyze the influence of process parameters and their interaction during machining. From the analysis, it is observed that the feed is the most significant factor that influences the surface roughness followed by nose radius. In order to obtain a good surface finish on AISI 202 steel, higher cutting speed, lower feed rate, lower depth of cut and higher nose radius are preferred. [21]

Sobahan Mia and Nobuyoshi Ohno (2010)they did Prospect of Mustard and Coconut Oil as Environment

Friendly Lubricant for Bangladesh. Their study also investigated the high pressure behavior and their phase diagrams are drawn. Results concluded that mustard and coconut oil could be used as base oil for environment friendly lubricant. These vegetable oils can also be used in moderate high pressure application can be replace the mineral oil as like P150N oil to meet the global warming crisis. [22]

Mithun Shah, UmashankarRawat, Prof.V.V.Potdar (2014)they performed A Review on Study of Performance of Vegetable based oils as Cutting Fluid in Machining of Alloys. They concluded from the review of different journal papers that, research has not been done on 'castor oil' as vegetable based cutting fluid. [23]

Arun Nanda, Sanjeev Kumar and Sunil Kumar (2014)they did Investigation of Tool Wear under different Environmental Conditions in Turning of AISI D2 Steel using Taguchi Method. The results indicate that there is a considerable improvement in machining performance under solid lubrication compared to dry and wet machining. Tool wear can also be measured under different environmental like flood lubricants; Minimum quantity of cutting fluids, solid lubricants and gaseous lubricants. [24]

B. Satheesh Kumar, G. Padmanabhan , P. Vamsi Krishna (2015)they did Experimental Investigations of Vegetable Oil Based Cutting Fluids with Extreme Pressure Additive in Machining of AISI 1040 Steel. The results indicated that sesame and coconut oils with EP additive improved machining performance compared to other lubrication conditions.. Further, the performance of SCF and CCF with EP additive are evaluated with varying cutting speed and feed rate. [25]

N.J. Fox, G.W. Stachowiak (2007)they made a review of oxidation on Vegetable oil-based lubricants.This reviewaddresses oxidation as a limitation of vegetable oil-based lubricants. They concluded thatLow oxidation stability hampers the acceptance of vegetable oils as a potential source of environmentally favorablelubricants. Oxidation has an impacton the lubrication performance of vegetable oils and quite possibly plays a role in the lubrication process. [26]

Babur Ozcelik, EmelKuramM.Huseyin Cetin ErhanDemirbs (2011)they performed Experimental investigations of vegetable based cutting fluids with extreme pressure during turning of AISI304L.they performed turning operation b using AISI304L work piece material. They took titanium nitride coated cemented carbide inserts as a tool material. They concluded that the Nose wear of the inserts attributed to the abrasion mechanismwas a dominant wear mode for CFs. [27]

V.T.G.Naves, M.B.Da Silva, F.J.Da Silva (2013)they performed Evaluation of the effect of application of cutting fluid at high pressure ontool wear during turning operation of AISI316 austenitic stainless steel. They performed experimentation with AISI 316 austenitic stainless steel work piece material. Coated cemented carbide tools are used. They concluded with the main findings that the reduction of tool wear and reduced tool-chip contact length with the use of high-pressure coolant. The lowest wear was obtained when the fluid was applied with a concentration of 10%and at a pressure of 10MPa.[28]

Anselmo Eduardo Diniz , Ricardo Micaroni (2007) they performed the Influence of the direction and flow rate of the cutting fluid on tool lifein turning process of AISI 1045 steel. They did turning operation on AISI 1045 steel bars with an averagehardness of 96 HRB. They have taken vegetable oil emulsion with 6%water concentration. They concluded that in dry cutting, tool life is shorter but not excessively so, and thus it can be used in those cases where there is no thermal damage to the work piece. Conventional cooling is not recommended, since it doesnot improve tool life as compared to dry cutting. [29]

A.Shokrani,V.Dhokia,S.T.Newman(2012)they did Environmentally conscious machining of difficult-to-machine materials with regard to cutting fluids. They concluded that thearea ofdifficult-to-machine materials is still vague and requires further research.The major drawbacksare the environmental and health impacts with the costs associated with their use,maintenance and disposal. [30]

W. Belluco, L. De Chiffre (2004)they did Performance evaluation of vegetable-based oilsin drilling austenitic stainless steel. They performed drilling operation on AISI 316L austenitic stainless steel. Conventional HSS-Co tools are used as tool material in experimentation. They used mineral oil, rapeseed oil and ester oil as cutting fluids. They concluded that all vegetable-based oils produced better results than the mineral reference oil, the best performance being 177% tool life increase and 7% reduction in thrust force with respect to the commercial mineral oil. [31]

S.A. LawalI.A.Choudhury ,Y.Nukman(2012)they performed A review on Application of vegetable oil-based metal working fluids in machining ferrous metals. They concluded that Vegetable oil-based metal working fluid's being recognized ashaving superior lubricating properties compared to otherbased-oil. [32]

Marius Wintera, ChristophHerrmanna (2014)they performed theEco-Efficiency of alternative and

conventional cutting fluids in externalcylindrical grinding. They did External cylindrical grinding on hardened carbonalloy steel (62 HRC). They have taken a mineral based emulsion and a grinding oil, and polymer dilution as cutting fluids in their experimentation.They concluded that the cuttingfluid composition has a major influence on the technological,environmental and cost impact and therefore on the eco-efficiencyof the grinding process. [33]

A. Maurotto, D. Tsivoulas, M.G. Burkeb (2014)they performed a parametric study on Surface integrity in dry milling of 304L steel. They did milling operation on 304L steel. They concluded that regarding residual stress generation, although the statistical model predicted a beneficial impact from low depth of cut, low feed per tooth, and high cutting speed, in fact the measured stresses were rather more complicated due to the inter-dependence among all parameters. The most evident trend was the reduction of stresses for lower depth of cut.[34]

Marius Wintera, Ralf Bock, Christoph Herrmann (2012)they performed Investigation of a new ecologically benign metalworking fluid inabrasive machining processes to substitute mineral oil based fluids. They performed grinding operation on hardenable carbon alloy steel by using Cubic boron nitride as a tool material. They used 1.mineral oil 2.water miscible polymer dilution, 3.water misciblemineral oil based emulsionas a cutting fluids. They concluded that the use of cutting oil, even at highspecific material removal rates leads to a good surface roughness, a low wear and a constant cutting power. The use of thepolymer dilution in vitrified aluminum oxide grinding wheels is better than the use of a mineral oil based emulsion, but more disadvantageous than the use of grinding oil.[35]

B. AnujaBeatricea, E. Kirubakaranb, P. RanjitJebaThangaiahc, K. Leo DevWinsd (2014)they performed Surface Roughness Prediction using Artificial Neural Network inHard Turning of AISI H13 Steel with Minimal Cutting FluidApplication. They performed turning operation on AISI H13 Steel work piece material by using insert SNMG 120408(tool material). They concluded that the Minimal cutting fluid application technique promoted green environment in the shop floor, minimized the industrial hazard due to of harmful aerosols and usage of large quantity of cutting fluid. [36]

R. Deepak Joel Johnsona, K. Leo Dev Wins, Anil Raj, B. Anuja Beatrice (2014)they performed Optimization of Cutting Parameters and Fluid Application Parameters during Turning of OHNS Steel.They did turning operation on OHNS Steel of hardness 34 HRC work piece material. They concluded that turning with minimal cutting fluid application improved the cutting performance by giving improved surface finish. It also produced promising results when compared with dry turning and conventional wet turning.[37]

A.Srithara,K.Palanikumar,B.Durgaprasad (2014)they performed Experimental Investigation and Surface roughness Analysis on Hard turning of AISI D2 Steel using Coated Carbide Insert. They did turning operation on AISI D2 Steel work piece material by using Coated Carbide Insert (tool material). They concluded with results which specify that the increase of cutting speed decreases the surface roughness in machining of hardenedSteel.[38]

Literature Outcome–

1. From the literature review, it is observed that less research work has been conducted with the use of ‘castor oil’ as vegetable based cutting oil in machining process.
2. Also less work has been reported for optimization of various turning parameters on Hardened steel material with Castor Oil as a Cutting Fluid.
3. It has been also found that very few work carried out on 904L Stainless Steel as a work piece material.

CONCLUSION

[1] From the review, it is concluded that various vegetable based cutting fluids can be used to optimize cutting parameters and to create healthy environment for machining operators.

[2] Also from the review of different journal papers it is observed that, research has not been done on ‘castor oil’ as vegetable based cutting fluid.

[3] The various review papers concludes that, the vegetable based cutting fluids are better than the conventional cutting oils.

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