International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 3 Issue 7, July - 2014

Study of Hazards Related To Cutting Fluids and Their Remedies

Pramod Kumar[1],
Department of Mechanical Engineering, Integral University, Lucknow, India.

S. A. H. Jafri[2], P. K. Bharti[3], Mohd Anees Siddiqui[4]
Department of Mechanical Engineering, Integral University, Lucknow, India.

***Abstract*— Cutting fluids are now an integral part of many machining processes of different materials because of their role in reducing friction, lowering temperature in the cutting zone and inhibiting corrosion. Through this review paper an attempt is made to critically analyse different types of cutting fluids on the basis of environmental and operator health related hazards. Further some techniques are reviewed to overcome the problem related to disposal of used cutting fluid, health hazards of operators like minimum quantity lubrication, solid lubricants, high water content cutting fluids and cryogenic cooling.**

Further some of the grey areas of research in this field are discussed.

Keywords—Cutting fluids; Health hazards; environmental problem; cryogenic cooling

I. INTRODUCTION

Cutting fluids are used to remove contaminates, to reduce friction in cutting area, and to inhibit corrosion. Traditionally cutting fluids are selected depending upon the function required and the cost associated. In beginning cutting fluids consists of simple oils applied with brushes to lubricate and cool the machine tool. Today's cutting fluids are special blends of chemical additives, lubricants and water formulated to meet the performance demands of the metal working industry. This paper reviews some of the common as well as some of the obscure environmental and health hazards along with methods been employed in recent years to prevent those. Fig. 1 shows the development of the discussion and how this paper is organized. The review concludes by showing the advanced trends in cutting fluid applications.

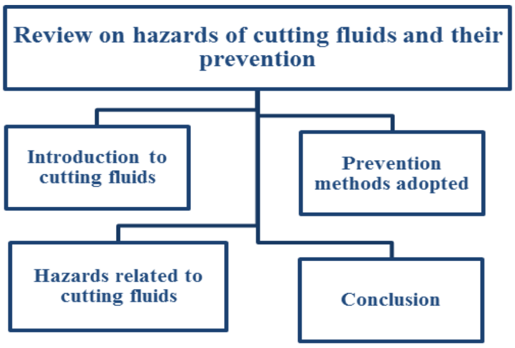

Fig. 1. Outline of discussion

There are several types of cutting fluids, which include oils, oil+water emulsions, pastes, gels, aerosols (mists) and air or other gases. Water based fluids, including soluble oils, synthetics and semi synthetics are now used in approximately 80 to 90% of all applications [1]. According to Blenkowski [2] there are four types of cutting fluids based on their composition: synthetic, semi synthetic, soluble oil and straight oil. Mineral oils or synthetic oils are Napthemic and paraffinic hydrocarbon that are refined from crude oil. Function of above molecules is to serve as a base for other additive molecules to refine & produce specific properties of the fluid. These oils should be hydrogenated so that most of harmful carcinogenic polycyclic aromatics can be destroyed or naturalized [3]. Soluble oil has poor emulsion stability and is prone to the oil separating out of the solution. Semi synthetic oils have good lubrication for both moderate and heavy duty machining operations.

In 1999, Minke [4] had shown comparison between oil & water based cutting fluids for different grinding situations. He ranked cutting fluids according to surface integrity from best to worst i.e. ester oil, oil based coolant and finally water based emulsions have better cooling, but generally lead to higher machining forces and cannot prevent thermal damage to the work piece. R. A. Irani et al. [3] have shown in his study that there occurs thermal damage due to heat generation in grinding process which may lead to fire hazards. Due to increase in the number of laws and directives governing industrial safety and environmental protection, the use of cutting fluids is putting large economic burden on manufacturing companies in the form of fines. Due to poor disposal cutting fluid can become important source of health and environment risks. Environment liability is major problem with cutting fluids disposal due to hazardous metal carry-off, hazardous chemical constituents, oxygen depletion, oil content and nutrient loading. Health hazards are related with exposure to cutting fluids range from irritation of skin, lung, eyes, nose & throat to more severe conditions such as dermatitis, acne, asthma, hypersensitivity, pneumonitis, irritation of the upper respiratory tract, and a variety of cancers. [5-9]

II. HEALTH HAZARDS

Number of health related hazards being reported while cutting fluid is used in different machining operations. Skin exposure is the easiest way of exposure, and it is believed that about 80% of all occupational hazards are caused by skin contact with fluids [10]. Water mixed fluids generally determine irritant contact dermatitis and allergic contact dermatitis when they are in touch with workers skin. Non water miscible fluids may cause skin disorders such as folliculitis, oil acne, keratosis and carcinomas. Besides skin and eye, inhalation is also one of the routes. Mists are aerosols consisting of liquid particles less than 20 µm. During machining vapor produces between solid-liquid interface as a result of heat generation in the machining process. Vapor generated then may condense to form mist. The non-aqueous components of the cutting fluids such as the biocide additives then become a fine aerosol that can enter the work place air. Also the cutting fluids affect machine elements within the machine tool system which leads to mechanical energy being transmitted to the fluid. Thus cutting fluid has higher surface energy and becomes unstable and disintegrates into droplets (atomization). Mists may also be generated by spray from the fluid application. 20 to 30% of health hazards may occur from the combination of evaporation, atomization, splashing and drag out processes [11]. Worker may inhale the vapor suspended and these get deposited in the various regions of respiratory system. The mist droplets can cause throat, pancreas, rectum and prostate cancers, as well as respiratory problems [12]. Several other epidemiological findings have also suggested that exposure to cutting fluid mist may be associated with increased risk of airway irritation, chronic bronchitis, asthma and even laryngeal cancer [13]. By effective selection of cutting fluids good quality and performance can be achieved in a cost effective manner along with healthier and safer environment for workers.

III. ENVIRONMENTAL ISSUES

3.1. Problem of disposal

Cutting fluids have important role in machining processes and impact shop productivity, tool life and quality of work. After number of usage fluids degrade in quality and eventually require disposal once their efficiency is lost. The severity of contaminated cutting fluids disposal after its service period can be better realize through the discussion ahead. It has been observed that the used cutting fluid contains wheel debris and work piece material chips etc. [14]. In 1990's approximately 130,000-250,000 tons per year of cutting fluids was used in Germany. This is one example similar situation exist in all the other developed and developing countries. After consecutive usage of cutting fluids all this fluid must be replaced and disposed of in order to maintain a consistent production level. Environment hazards are greatly due to oils containing alloys of iron. Separation of wheel debris was done by Dahmen et al. [15] who developed a process using supercritical CO_2 originally implemented for glass grinding with high oil and lead content. S. M. A. Suliman [16] et al. isolated twelve species and shown that among them growth of Enterobactersakazakii and Citrobacterdiversus species were mainly due to the cutting fluid system and its environment. Pathogens are also caused by bio deterioration of petroleum based fluids. Thus there is a need for such type of separation mechanism so that contaminations can be separated out that leads to proper dispose of this large quantity of cutting fluid in the most environment friendly manner.

3.2. Microbial contamination

Most of the cutting fluids provide a breading space for bacterial growth which may prove hazardous to the operator [4, 17]. Leached heavy metals in fluid can affect human lungs & stomach [18]. Water based emulsions made from cutting fluid concentrates can easily be affected by microbes under normal operating conditions also. Health Hazards are possible as pathogens produces toxins or catalysts of chemical change [19]. Many pathogenic organism growths are also reported by workers [20-26]. It seems from the findings above that contamination of cutting fluids by microbial organisms is due to some unidentified work force. Some of the serious health related problems like septic infections were caused by Pseudomonas arigenosa, primary allergic are caused due to bronchopulmunary and deratomycosis by Enterobacter sakazakii & Citrobacter diversus [16]. As reported in [16] that aerobic bacteria colonize the cutting fluid and after that it grows rapidly with constant aeration which was well indicated by the microbial count. The most predominant species isolated from these fluids are Pseudomonads and sulphate reducers.

3.3. Issues related to misting of cutting fluids

For high lubrication applications such as hobbing, heavy cutting and broaching water insoluble cutting fluids are preferred. Ease of misting is one of the characteristic of these cutting fluids which can also seen as hazards related to fire, environment pollution and health risks [27].

The water-insoluble fluids used in heavy cutting are usually composed of:

(1) Mineral oils as the base material;

(2) Fatty acid esters as the primary lubricants;

(3) Extreme pressure agents; and

(4) A variety of such additives as oiliness improvers, rust inhibitors, and antioxidants.

As reported by Motohiko Iia [27] extreme pressure agents are used to enhance performance of cutting fluids at different temperatures. Sulphur based extreme pressure agent is used for superior cutting of metals at high temp while phosphor and chlorine based extreme pressure agent gets failed at high temp but can work well at low temp. These kinds of cutting fluids normally are good in lubricity but are flammable and, thus, potential risks of fire hazard. On top of that, the cutting fluid often forms heavy mists during the operation, which not only make the floor oily but also expose the operators to an unhealthy environment. Therefore there is a need for water soluble cutting fluids with high lubricity.

The different problems related to cutting fluids have already been discussed now the further discussion will concentrate on methods that can be used to overcome the above problems.

IV. PREVENTION METHODS ADOPTED

4.1 Dry Machining

For preventing environment and health hazards due to cutting fluids the best approach is to eliminate their usage completely which is known as dry cutting in which excessive tool wear low surface quality is observed [28]. For this minimum quantity lubricant is passed onto the cutting zone to improve machinability. Coolants & Lubricants are reduced due to minimum quantity lubricant; it still uses them in the form of mists and droplets, whose exposure to the operator can be avoided with the proper use of transparent shields.

Thus there is improvement in machinability along with the lesser chances of risks related to health [29]. Fig. 2 shows different hazards along with their prevention methods adopted.

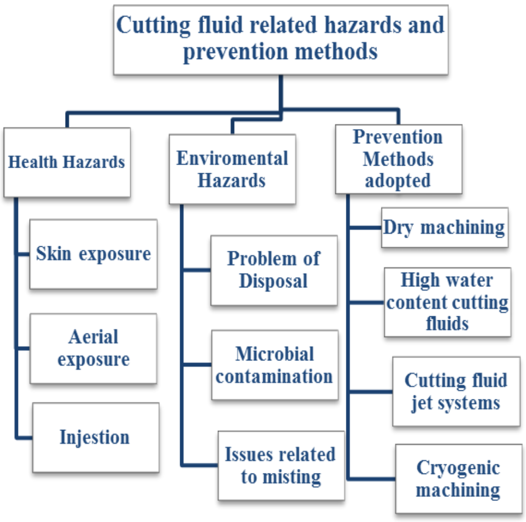

Fig. 2. Illustrates different hazards and prevention method adopted.

Thus dry machining is the most appropriate technique for production shops to eliminate use of cutting fluids, and thereby reducing machining cost and ecological hazards [28, 30]. Many benefits related to dry machining are identified by Weinert et al. [31]. In dry machining frictional force and cutting temperature could be more than that of wet machining. These could affect the tool life, surface quality and cause geometry changes in the machined parts. In view of these problems there is a need of further research in this field.

4.1.1 Solid lubricants

There have been several different researchers that have studied unconventional cutting fluids that reduces mist formation to overcome the problem as discussed earlier. In general graphite is used as solid lubricant because of weakly bonded hexagonal plate like structure [32]. Currently molybdenum disulphide has also been used. It is also known as hard lubricant [33]. Titanium aluminum nitride has been used as a dry lubricant to resist wear on cubic boron nitride wheels [34]. Shaji & Radhakrishna [35] showed with graphite assisted machining the tangential forces, grinding zone temperatures and specific energies are lower with the graphite paste when compared to dry or coolant grinding.

4.2 High water content cutting fluids

High water content cutting fluids provides an anti misting property along with lubricity. Motohiko Ii et al. [27] in his work compared various conventionally used cutting fluids and newly developed water soluble cutting fluids performance in circumference turning with numerically controlled lathe machine. In the high water-content cutting fluid, the surfactants cover up the water droplets to form a micromichelle of about 0.1 mm in size. Fig. 3 shows a model of micromicelles of water solubilized in a mineral oil base. Mineral oil droplets gets attached to water droplet with hydrophilic group pointing inward and lipophilic groups pointing outward resulting into uniformly solubilized water michelles into mineral oil. Thus, it makes the cutting fluid continuous and homogeneous.

With extreme pressure agent of sulphur cutting was improved in ductile materials. Motohiko Ii et al. [27] in his result shown reduction in tool wear and an improvement in surface finish of work piece by using water content cutting fluids.

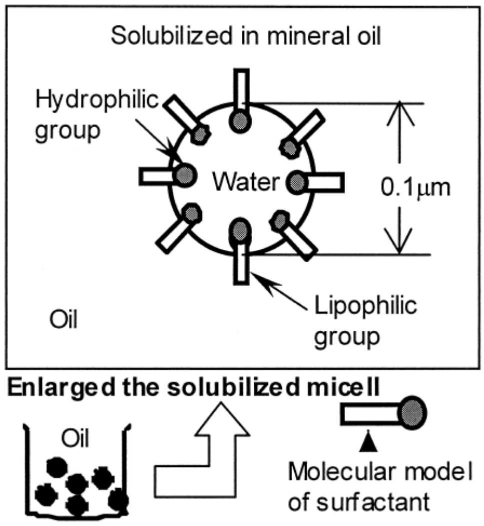

Fig. 3. Model of micromicelles solubilized in mineral oil (high water content cutting fluid) adopted from [27].

Thus by creating high water soluble cutting fluids we can also reduce hazards related to fire and environment pollutions.

4.3 Fluid jet systems

4.3.1 Coherent Jet

Critical specific material removal rate got increased to 30-61 % in case of a coherent jet method depending upon the process parameters [36]. Further there are methods other than this which uses very less cutting fluids, are environment friendly also they do not increase MRR to this level.

4.3.2 Radial Jet

Shoe nozzle and Radial jet systems changes cutting fluid application [37]. These are relatively fragile systems when placed in a production environment. Also they have higher modernizing cost than coherent. With low cost there is improvement in robustness and they can compete with coherent jets in industry where reliability, production rates and costs are a priority. Still there exist a need for research work in the field of development of delivery systems that have both high production rates and low environment impact.

4.4 Cryogenic Cooling

A cryogenic coolant-to dissipate higher heat at cutting zone and enhances machinability through the changes in cutting tool/work material properties. Air cooling employing chilled & compressed air for cooling in machining operations in relatively new technique which has attracted many researchers [38-42]. Air can be the cleanest & most environment friendly method of cooling.

Many findings have indicated longer tool life due to the use of chilled air cooling. It is also cheap alternative to conventional flood cooling but higher than minimum quantity lubricant or emulsion coolant [43-45]. In order to improve cooling effect of minimum quantity lubricant some researchers [42-44] have use chilled air along with minimum quantity lubricant.

V. CONCLUSION

This review paper emphasized on problems related to health and environment caused by different types of cutting fluids. Some of the important conclusions are:

i. Disposal of large quantity of used cutting fluid is a big challenge because it is hazardous for environment in view of fast growth of bacteria and pathogens.

ii. Mist of some of the cutting fluids may cause serious health issues like throat, pancreas, rectum and prostate cancers, as well as respiratory problems.

iii. There are cutting fluids which causes serious skin infections to operator. The use of such cutting fluids should be minimized.

iv. In order to overcome above mentioned problems some of the techniques recently developed like minimum quantity lubricant, solid lubricants, better design of nozzles and cryogenic cooling are reviewed and further research is required for optimizing the use of cutting fluid with required machining performance.

v. It is also worth mentioning here that cryogenic cooling technique is one of the leading techniques because of its several advantages like clean, environment friendly as air is the working fluid.

vi. Further cryogenic cooling technique in combination with minimum quantity lubrication will reduce the mist formation and the quantity of cutting can further be reduced because of better heat removal capacity of chilled air.

vii. Academic research should be done in the direction to achieve best possible material removal rate with the above suggested environment friendly methods.

REFERENCES

[1] Aronson, R.B. “Machine Tool 101: Part 6, Machine Servers,” Manufacturing Engineering (June, 1994), 47-52.

[2] K. Blenkowski, Coolants and lubricants: part 1-the truth, Manufacturing Engineering March (1993) 90–96.

[3] R.A. Irani1, R.J. Bauer*, A. Warkentin2 ,International Journal of Machine Tools & Manufacture 45 (2005) 1696–1705

[4] M.L. Hoff, Cutting fluids: necessary nuisance to productivity tool. Society of Manufacturing Engineers. MR (MR02-302), 2002, pp. 1–6.

[5] Alves S.M., Oliveira J.F. Development of new cutting fluid for grinding process adjusting mechanical performance and environmental impact. Journal of Materials Processing Technology, vol. 179 , no.2 , 2006, pp. 185-189.

[6] Bartz W.J., Ecological and Environmental Aspects of Cutting Fluids. Journal of the Society of Tribologists and Lubrication Engineers, vol.57, no.3, 2001, pp. 13-16.

[7] Dado M. Environmental risks associated with cutting fluids. Journal Strojírenská technologie. vol. 12, 2007, pp. 33-36.

[8] Dado M., Meciarová J. Environmental performance as one of the cutting fluid selection criteria. Proceedings of International conference CO-MAT-TECH 2004, Trnava, pp. 208-214.

[9] Dado M., Hnilica R. Metalworking fluid mist as a risk factor in machining. Proceedings of International conference “Bezpecnost a ochrana zdraví pri práci“, 2009, Ostrava, Czech Republic, pp. 22-28.

[10] Bennett, E. O., Bennett, D. L., Minimizing human exposure to chemicals in metalworking fluids, Lubrication Engineering, 1987, 43(3), 167-175.

[11] Resource Guide for Small Business Air Emission Assistance, Program for Toxic Air Pollutant Studies, Iowa Waste Reduction Center, University of Northern Iowa, January 1996

[12] Low, L.K., J.R. Meeks, and C.R. Mackerer 1989, Health effects of alkyl benzenes II. Xylenes, Toxicol. Ind. Health 5(1):85-105.

[13] Bennett, E.O. and Bennett, D.L., "Occupational Airway Diseases in the Metalworking Industry," Tribology International, 1985, 18/3, pp. 169-176.

[14] E. Brinksmeier, J. Eckebrecht, Possibilities for the disposal of grinding swarf, CIRP Annals-Manufacturing Technology 43 (2)(1994) 593–597.

[15] N. Dahmen, J. Schon, H. Schmieder, K. Ebert, Supercritical Fluid Extraction of Grinding and Metal Cutting Waste Contaminated with Oils, ACS Symposium Series 670 (1997) 270–279.

[16] S. M. A.Suliman, M. I. Abubakr and E. F. Mirghani ,Microbial contamination of cutting fluids and associated hazards Tribology International Vol. 30, No. 10, pp. 753–757, 1997.

[17] C.A. Sluhan, Selecting the right cutting and grinding fluids, Tooling and Production 60 (2) (1994) 7.

[18] H.S.E. Anon, Warnings for grinding coolants, Metalworking Production 147 (5) (2003) 44.

[19] Hill E. C. Microbial aspects of health hazards from Water based metal cutting fluids, Tribology .Int. 1983. 16,3,136.

[20] Hill E. C. Microbial aspects of health hazards from water based metal cutting fluids, Tribology Int. 1983, 16, 3, 136.

[21] Elsmore R. The survival of Legionella pneumophila in dilute metalworking fluids, Tribology Int. 1989, 22, 3, 213.

[22] Hill E. C. and Al-Zubaidy T. S. Some health aspects of infections in oil and emulsions, Tribology Int. 1979, 12, 4, 161.

[23] Kachan V. I. Preventing microbial deterioration of cutting fluids, Soviet Engineering Research 1987, 7, 6, 68.

[24] Lloyd G., Lloyd G. I. and Schofield J. Enteric bacteria in cutting oil emulsion, Tribology Int. 1975, 8, 1, 27.

[25] Pivnick H., Engelhard W. E. and Thompson T. L. The growth of pathogenic bacteria in soluble oil emulsions, Applied Microbiology 1954, 2, 140.

[26] Rossmore H. W. and Williams B. W. Survival of coagulase positive Staphylococci in soluble cutting oils, Health Lab. Sci. 1967, 4, 3, 160.

[27] Motohiko Iia, Hiroshi Edaa, Takaichi Imaib, Masaya Nishimuraa, Takahiko Kawasakia, Jun Shimizua, Takeyuki Yamamotoa, Libo Zhoua, Precision Engineering 24 (2000) 231–236.

[28] F. Klocke, G. Eisenblatter, Dry cutting, CIRP Annals-Manufacturing Technology 46(1997)519–526.

[29] P. Sreejith, B. Ngoi, Dry machining : machining of the future , Journal of Materials Processing Technology 101(2000)287–291.

[30] A.Rivero, G. Aramendi, S. Herranz, L. Lopez de Lacalle, An experimental investigation of the effect of coatings and cutting parameters on the dry drilling performance of aluminium alloys, The International Journal of Advanced Manufacturing Technology 28 (2006)1–11.

[31] K. Weinert, I. Inasaki, J. W. Sutherland, T. Wakabayashi, Dry machining and minimum quantity lubrication, CIRP Annals—Manufacturing Technology 53 (2004) 511–537.

[32] W.D. Callister Jr., Materials Science and Engineering an Introduction, Fifth ed., Wiley, New York, 2000.

[33] S.C. Salmon, The effects of hard lubricant coatings on the performance of electro-plated superabrasive grinding wheels, Key Engineering Materials 238–239 (2003) 283–288.

[34] K. Ramesh, S.H. Yeo, Z.W. Zhong, K.C. Sim, Coolant shoe development for high efficiency grinding, Journal of Materials Processing Technology 114 (2001) 240–245.

[35] Shaji, V. Radhakrishnan, An Investigation on surface grinding using graphite as lubricant, International Journal of Machine Tools and Manufacture 42 (2001) 733–740.

[36] J. Steffen, Application of a coherent Jet Coolant system in Creep Feed Grinding of Inconel 718, MA Sc Thesis, Dalhousie University, 2004.

[37] H.J. Xu, Y.C. Fu, F.H. Sun, Research on enhancing heat transfer in grinding contact zone with radial water jet impinging cooling, Key Engineering Materials 202–203 (2001) 53–56.

[38] L. Brandao, R. Coelho, A. Rodrigues, Experimental and theoretical study of work piece temperature when end milling hardened steels using (TiAl)N-coated and PcBN-tipped tools, Journal of Materials Processing Technology 199 (2008)234–244.

[39] J. Gisip, R. Gazo, H. A. Stewart, Effects of cryogenic treatment and refrigerated air on tool wear when machining medium density fiberboard, Journal of Materials Processing Technology 209(2009)5117–5122.

[40] B. Yalcin, A. Ozgur, M. Koru, The effects of various cooling strategies on surface roughness and tool wear during soft materials milling, Materials & Design 30(2009)896–899.

[41] J. Liu, Y. Kevinchou, On temperature and tool wear in machining hypereutectic Al–Si alloys with vortex tube cooling,International Journal of Machine Tools and Manufacture 47(2007)635–645.

[42] Y. Su, N. He, L. Li, X. Li, An experimental investigation of effects of cooling/ lubrication conditions on tool wear in high-speed end milling of Ti–6Al–4V, Wear 261(2006)760–766.

[43] S. M. Yuan, L. T. Yan, W. D. Liu, Q. Liu, Effects of cooling air temperature on cryogenic machining of Ti–6Al–4V alloy, Journal of Materials Processing Technology 211(2011)356–362.

[44] Y. Su, N. He, L. Li, A. Iqbal, M. Xiao, S. Xu, B. Qiu, Refrigerated cooling air cutting of difficult-to-cut materials, International Journal of Machine Tools and Manufacture 47(2007)927–933.

[45] M. Rahman, A. S. Kumar ,M. U. Salam, M. Ling, Effect of chilled air on machining performance in endmilling, The International Journal of Advanced Manufacturing Technology 21(2003)787–795.