Investigation into the effect of Nano lubrication in machining environment

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Abstract

The challenge associated with machining operation is the generation of large amount of heat. The heat generated raises the temperature of machining zone which adversely affect the machining performance in terms of failure of the tool , deterioration of surface finish, more power consumption, change in microstructure, low production rate. The reason behind high temperature is friction along the tool- chip interface and interaction between tool flank-machined surfaces. The effective and appropriate application of cooling can drastically reduces the temperature of machining zone which consequent into better machining performance. Therefore, the aim of this paper is to study the effect of nanolubrication in machining environment and how nanoparticles improve the machining performance.

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Keywords: Nanolubrication, types of lubrication, nanoparticles

1. Introduction

Conservation of energy is an important aspect in current scenario. In Indian context, the industry sectors contributing around 27% of share in gross domestic product (GDP). Machining plays a vital role to achieve close tolerance, dimensionally stable, accaurate and burr free components as well as act as an important process essentially required to finish components from other shaping processes such as casting, deformation etc. the cost of machining components highly depends on selection of tool, process parameters, lubricating system etc. The main problem associated with metal cutting is the large amount of heat is generated owing to plastic deformation along shear plane, interaction of chip-tool interface and interaction between flank face and the already machined surface. This heat energy consequent into temperature rise of machining zone which adversely affect the tool life and spoil the surface integrity of machined component. It is evident almost 30% of heat is lost in wear and friction [1]. Existing lubricating system effectively carry away the heat from machining zone such as flooded cooling, minimum quantity lubrication(MQL)[2], cryogenic cooling[3]etc. In the recent studies, it is being observed that the researcher's constantly putting effort to improve the existing lubrication system so that the consumption of lubricant and its adverse effect on ecology of the system can be suppresses. Recently in machining, nanolubrication is extensively being used to analyze its performance of efficiency of machining [4].In the literature, use of nanolubrication effectively reduced the cutting force required for machining, tool wear rate, chip thickness and surface roughness[5].the effectiveness of nanolubrication is highly depends upon the size, crystallographic arrangement and morphology. Also, the considerable investigation is required for appropriate selection and implementation of these nanolubricants in machining environment [6]. There are three main compositions of nanolubrication A) base oil B) nanolubricants/additives and C) surfactant. Nano lubrication consist of nanoparticle dispersed in based oil such as Mineral oils, Synthetic oils and Vegetable oils and surfactants help to improve the stability of nanofluids during the operations. In this paper, the role of nano particles and nanolubrication concoction in existing lubricating system has been investigated and how the concept of nanolubrication improves the machining performance through the response parameters is presented.

2. Concept of nanolubrication

Lubrication is defined as the mechanism to reduce and control the friction and wear of interacting surfaces during their relative motion [7]. Lubrication is applied when the surfaces are in contact and have relative motion such as journal bearing, brakes; pumps chain drives, piston and cylinder and so on. Recently use of lubrication is extended in Micro electromechanical systems (MEMS), micro pump, and magnetic storage devices etc. various types of lubrication available in different form such solid, liquid and gaseous are applicable depends of application. In order to protect the surface, the surface energy needs to be maintained and control. In application such as journal bearing, the parts are completed separated by fluid under pressure but challenges arises when asperities comes in contact owing to high application of load. Here the fluid film breaks and an asperity deform and breaks in the form of tiny wear of surface. Therefore, to protect the surface, nanoparticles are being added in base oil to form a thin film to protect the surfaces are in contact [8].the Fig 1 shows the methodology to prepare the nanolubricants [9].

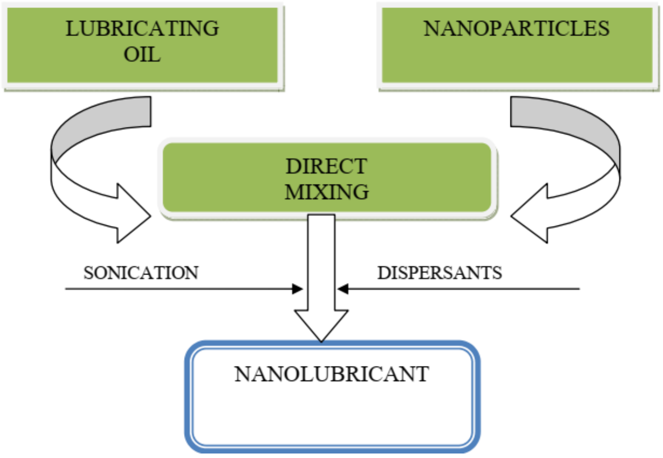

Fig 1: Method to prepared nanolubricants [9]

3. Types of lubrication and boundary lubrication in machining

Depending on loading condition exist between the interacting surfaces and at contact geometries, lubrication are classified as hydrodynamic, hydrostatic, Elasto hydrodynamic lubrication (EHL) and boundary lubrication as shown in Fig2. Hydrodynamic, Hydrodynamic lubrication occur when the interacting surfaces are completely separated by film thicknesses near or more than 1 µm. Owing to the nature of hydrodynamic lubrication, frictional losses under this condition is minimum. The hydrodynamic pressure is generated in lubricating film and interacting surfaces are completely separated by using pressurized lubricating film. The principle of which is based on Reynolds equation and continuum mechanics. In the hydrostatic lubrication, the interacting surfaces are separated by liquid fluid film generated by externally applied pump instead of self forming film like hydrodynamic lubrication. The elasto hydrodynamic lubrication (EHL) condition exists at high load and where the hydrodynamic and hydrostatic conditions are may not be efficient to keep interacting surfaces apart. In this situation, metal to metal contact occurs depending of asperities property, fluid film thickness and load acting and asperities deform elastically. When the load increased beyond EHL, metal to metal contact occurs and asperities at interacting surfaces deformed elastically and then plastically. The load is mainly supported by asperities are in contact. The interaction of interacting surface in boundary lubrication results in formation of debris, loss of material, abrasion, adhesion, plowing results [7]. Therefore, use of nanolubrication helps to minime the adverse effect of boundary condition that exists in metal cutting.

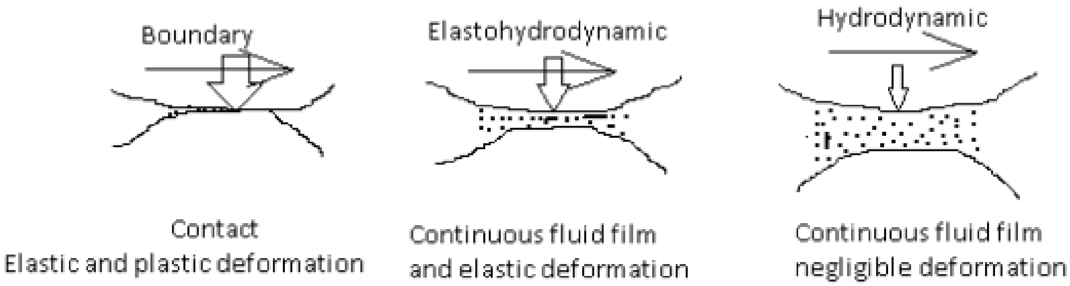

Fig 2: Various lubricating condition exist at different load [7]

4. Effect of nanolubrication in machining environment

Prabhu.S and Vinayagam B.k [10] investigated the effect of carbon nanotube dispersed in mineral oil in grinding of AISI D2 tool steel on surface characteristics. Result shows the improvement in surface characteristics of AISI tool steel.

Kalita, P. A et al.[11]investigated the effect of nanolubricants in MQL grinding on tribological properties. It is observed during tribological testing, coefficient of friction and wear in nanolubricant based MQL is lowers amongst dry, flooded and MQL based lubricating system.

D.Nageswara Rao [12] investigated the effect of Cuo nanoparticles dispersed in base oil on properties of cutting fluid. FEM approach is implemented to determine heat transfer coefficient and temperature profile and result of which is compared with experiments. The result shows that inclusion of CuO as nano particles in base oil improve the property of cutting fluid. It is also reported that CuO upto 6% in base oil is significant to show better result beyond which results are not beneficial.

Krishna, P. V et al[13] investigated the effect of nano boric powder suspended in two base oil SAE40 and coconut oil on surface roughness, cutting temperature and tool flank wear during turning of AISI 1040 steel.

The results shows that cutting temperature, flank wear, and surface roughness are lowest when 0.5% of boric powder is added in coconut oil,

Lee, P. H et al [14] investigated the effect of nano diamond particles dispersed in paraffin oil on grinding force and surface roughness during machining of tool steel using minimum quantity lubrication system. The result shows that thrust and tangential force were reduced by 33.2% and 30.3% when using nanofluid. With the use of 30nm diamond nano particles the surface finish improved by 64% as compared to dry grinding.

Sarhan, A. A et al [15] studied the effect of 0.2% of SiO2 nanoparticles suspended in mineral oil on cutting force and coefficient of friction at chip tool interface during milling of aluminium (AA6061-T6). The result shows that the uses of nanoparticles in base fluid improve the response parameters as cutting force and hence the specific power consumption as compared to use of base fluid alone.

Sayuti, M et al [16] investigated post machining surface quality of Aluminium 6061-T6 with different concentration of SiO2 nano lubricant using morphological analysis. It is evident from the study that the concentration of nanoparticles upto 0.2% increases the growth of thin film. This growth in thin film ensures the reduction of cutting force, cutting temperature and improves the surface finish of the machined components.

Sayuti, M et al[17] investigated effect of carbon onion nanolubricants on machining performance such as cutting force and surface quality in machining of duralumin AL-2017-T4.The result shows that the concentration of carbon onion 1.5% weight gives lower value of cutting force and reduce the surface roughness by 21.99 and 46.32 % Respectively.

Khalil, A. N. M et al[18] studied the effect of aluminium oxide(Al2O3)with SDBS surfactant on tool wear in turning of AISI 1050.The three lubricating system have been taken for the study namely dry, MQL and MQL with nano particles. The results show that dry machining causes highest tool wear. Uses of Al_2O_3 effectively flush the away the heat ans uses of Al_2O_3 with surfactant provide effective cooling of machining zone.

Li, M et al[2018] investigated the effect of grapheme nanoparticles suspended in vegetable oil on milling force, milling temperature, tool wear, and surface integrity in milling of Titanium alloy TC4 using MQL cooling system. The results shows that addition of graphene nanoparticles reduces the milling force because they enhance anti-friction and load-bearing capacity of the oil film, surface temperature in the work part is drastically reduced under the graphene MQL condition and tool life is enhanced in grapheme based MQL system.

Table 1: Use of nano particles in machining environment

Author	**Base lubricant**	**Types of additive**	**Workpiece**	**Benefits**
Prabhu, S., & Vinayagam, B. K[2010]	Mineral oil(SAE20W40)	Carbon Nano tubes	AISI D2 tool steel	Improvement in surface characteristics of AISI tool steel
Kalita, P. A et al[2010]	soybean oil	Molybdenum disulphide (MoS2)	Ductile Iron	Coefficient of friction and amount of wear is reduced in nano MQL based lubrication.
D.Nageswara Rao[2008]	Base oil	Copper oxide(CuO)	AISI 1040 (EN 8) steel	1. Thermal conductivity of base oil increases. 2. Viscosity is increases.
Krishna, P. V et al[2010]	SAE40 and coconut oil	Boric powder(50nm)	AISI 1040 steel	Improvement in machining performance when 0.5% of boric powder is added in base oil.
Lee, P. H et al[2010]	Paraffin oil	nano diamond particles	Tool steel	1. Thrust and tangential force were reduced by 33.2% and 30.3%. 2. Surface finish improved by 64% as compared to dry grinding.
Sarhan, A. A et al[2012]	Mineral oil	SiO2	Aluminium (AA6061-T6).	Reduction in value of cutting force, power and specific power consumption.
Sayuti, M et al[2014]	Mineral oil	SiO2	Aluminium 6061-T6	Concentration of nanoparticles upto 0.2% increases the growth of thin film
Sayuti, M et al[2013]	Alumicut oil	Carbon onion nanolubrication	duralumin AL-2017-T4.	1. Cutting force and surface roughness decreases by 21.99 and 46.32 %. 2. Nano particles provide rolling effect at chip tool interface.
Khalil, A. N. M et	soluble cutting oil (SolCut)	Aluminium Oxide(Al_2O_3)	AISI 1050	Use of Al_2O_3 with surfactant provide effective cooling of machining zone

al[2015]				
Li, M et al[2018]	Vegetable oil	Graphene	Titanium alloy TC4	1. addition of graphene nanoparticles reduces the milling force because they enhance anti-friction and load-bearing capacity of the oil film. 2.improvement in tool life

Discussion and conclusion

The available cooling systems are essential to carry the heat away from the machining zone such as flooded cooling, minimum quantity lubrication, cryogenics etc.but there is requirement to improve the performance of existing cooling system and hence the use of nano particles plays a vital role to achieve the goal. In literatures, various researchers utilizes various nanoparticles such as boric acid, aluminium oxide, copper oxide, carbon nanotube,graphene,silicon oxide dispersed in base oil to improve the capability of base oil and reduced the overall consumption of base oil. It is evident from the various research work that the appropriate and controlled use of nanoparticles enhanced the machining performance through improving various response parameters such as cutting force, temperature, surface finish, power require men etc. therefore, the nanolubricants is the promising candidate to minimise the cutting fluid consumption and indeed step to achieve sustainable machining.

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