A Review on Nanofluid used in Machining

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Abstract - *Nanofluids are produced by dispersing nanometer scale solid particles in to base liquid with low thermal conductivity such as water, ethylene glycol, oil, etc. These fluids are dissolving by colloidal suspensions of Nanoparticles in a base fluid. In the nanofluid different types of Nanoparticles are used such as and they are typically made of metals, oxides, carbides, or carbon nanotube. Machining is one of the most widely used methods of producing different in industries. In the different machining process cutting fluids play an important role in minimize the production time, cost and energy. This paper present summery of some important published research works on the application of nanofluid in different machining processes: milling, drilling, grinding, and turning.*

Key Words: Nanofluid, Machining, Machine Parameters, cutting fluid, Manufacturing

1. INTRODUCTION

The different machining process has an important role in the production industry. Cost saving in the all machining processes has been eagerly investigated. This is mainly affected by selection of suitable machining parameters like cutting speed, feed rate and depth of cut cutting fluid. The selection of optimum machining parameters will result in longer better surface finish, tool life and higher material removal rate. In the machining process, the cutting fluid functions in three ways: minimize the heat from workpiece, removes the chips from the cutting zone, surface and the cutting tool and lubricates the tool workpiece interface. Most of the cutting fluids negatively affects on environment and human health both through their use and their disposal. Also, the cutting fluid occupies 15% to 20% of the cost of production in the manufacturing industry. Therefore unnecessary use of these fluids should be avoided. [1] In metalworking operations, the frictional resistance reduced by adding a lubricant between the surfaces. Lubricants separate the sliding surfaces by create a film, and thereby reduce the frictional resistance and wearing [2]. Cooling ability of a fluid helps to control undesirable temperature of tool, workpiece and chip. Furthermore, during the process, cutting fluids can wash and remove generated chip [3]. Cutting fluids used to prevent re-welding, corrosion protection, reducing the energy consumption of the machine, and increasing tool life [4].

A Nanofluid is a fluid containing solid nanoparticles with a dimension measured in nanometers, 1/1000 of a micron or roughly one ten thousandth of the width of a human hair. These particles are carried by the fluid in a suspension, typically called a colloidal dispersion. Nanofluids have been shown to have higher heat transfer rates and thermal conductivity, even at very low solid concentrations (<1%). The nanoparticles can also affect viscosity, particularly at higher concentrations.

The Present study focuses on the utilizing of nanofluids as cutting fluid of various machining processes. Also, a brief review has been done on a number of papers published by different researchers.

1.1 Function of Cutting Fluid

The primary function of cutting fluid is control the temperature through cooling and lubrication. Cutting fluid also improves the quality of the workpiece by removing metal fines and cuttings from the tool and cutting zone. As cutting fluid is applied during machining operations, it removes heat by carrying it away from the cutting tool/workpiece interface. The cooling effect by coolant prevents tools from exceeding their critical temperature range beyond which the tool softens and wears rapidly. Application of cutting fluid also reduces the occurrence of built-up edge. Built-up edge refers to metal particulates which adhere to the edge of a tool during machining of some metals. In some operations, fluid transparency or clarity may be a desired characteristic for a cutting fluid.

1.2 Coolant System

In a machining center, coolant is supplied to the spindle nose and to the tool either externally or internally through the spindle. Coolant is supplied externally using swilling jets mounted on a plate at the top of the spindle, or move more effectively around the spindle housing on the machine unit or on the machine top cover. These nozzles are freely adjustable to different distance between spindle and workpiece so that they are effective over the entire workpiece. External coolant also is supplied through permanent nozzle located on the face of spindle housing. This is especially effective for ram type spindle since the nozzle travel with the spindle with the Z direction. In this type the coolant supplied through the spindle housing.

2. LITERATURE REVIEW

The use of metal working fluid as cooling and lubricating medium is integral to the machining processes since the inception of machining processes and these fluids are commonly considered necessary for higher quality of products along with higher machining productivity. It is generally believed the cutting fluids are used for decreasing the friction at the work tool interface, for minimizing the wear by reducing galling, adhesion and welding thus improving the surface characteristics, for minimizing the heat generated at the mated surfaces and for flushing away the chips, debris and residues. According to Najiha et.al.[5] reviewed of advances use of lubrication techniques during machining operations as well as the application of state of the art nano fluids in machining is presented also role of cutting fluids in machining, economic as well as occupational impacts of these fluids, current technological advances in the sustainable systems and the review of the role of minimum quantity lubrication (MQL) technique as a sustainable manufacturing method replacing the conventional flooded coolant machining. He emphasized the use of MQL as a substitute to conventional flooded machining. Mohammadreza Shabgard et.al.[6] researched to produce graphite nanofluid by submerged electro discharge process and evaluate the features of synthesized nanofluid, including particle size, thermal conductivity, and stability of suspension. He concluded that the composition of base fluid has significant effects on the size of nanoparticles and thermal conductivity enhancement of nanofluid. Yu Su et.al.[7] studied the effect of nanofluid MQL with vegetable-based oil and ester oil as base fluids on cutting force and temperature in cylindrical turning of AISI 1045 medium carbon steel. He concluded that Graphite oil-based nanofluid MQL obviously reduced cutting force and temperature when compared with dry cutting and MQL with the corresponding base oil. S. Khandekaret.et.al.[8] mentioned that the cutting force, workpiece surface roughness, tool wear, and chip thickness are reduced by the using nano-cutting fluid compared to dry machining and machining with conventional cutting fluid. In this study he developed the special type of nano-cutting fluid by mixing self-synthesized Al_2O_3 nano particles into the conventional cutting fluid. He founded that by adding 1% Al_2O_3 nanoparticles to the conventional cutting fluid greatly enhances its wettability characteristics compared to conventional cutting fluid also great reduction of crater and flank wear is attributed to enhanced improvement in wettability, thermal properties, and lubricating characteristics of the nano-cutting fluid. Emel Kuramet.al.[9] focused on the performances of VBCFs with respect to CMCF in terms of cutting forces and tool wear during turning of aluminum alloy and he concluded that there was improvement in performances with respect to percentage increment of EP additive in these cutting fluids reducing cutting, feed and radial forces in the turning of aluminum alloy. Bin Shen et. al.[10] studied the wheel wear and tribological characteristics in wet, dry, and MQL grinding of cast iron. Water-based Al_2O_3 and diamond nanofluid were applied in the MQL grinding process he demonstrated that the flow rate was very important in MQL grinding and it was possible to achieve the desired cooling effects by increasing the amount of fluids applied in MQL grinding. A. K. Singh.[11] provided a review of research in this field with focus on thermal conductivity studies of nanofluids he concluded that the miniaturization of mechanical and electrical components creates a need for heat transfer fluids with improved thermal characteristics over those of conventional coolants similarly spreading behavior of nanofluids containing surfactant micells has implications for soil remediation, oily soil removal, lubrication and enhanced soil recovery. R.K. Sahu et.al.[12] investigated the dispersion stability and thermal conductivity of copper based nanofluids obtained by generating copper nanoparticles using micro electrical discharge machining (micro-EDM) process in both, de-ionized (DI) water and de-ionized water with polyethylene glycol (PEG) stabilizing agent. The experimental results show that the dispersion stability of PEG based copper nanofluid as compared to DI water-based copper nanofluid is improved as discussed in the following sections of the paper. It was also found that the thermal conductivity of copper-water nanofluid and copper-water with PEG nanofluid are higher than that of pure DI water. Sleman Rasul et.al.[13] presented on a review of published research works on the use of nano fluids in machining processes and as per the study he concluded that utilizing nano cutting fluid application in machining as coolant and lubricant lead to lower tool temperature, tool wear, high surface quality, cutting force, specific energy, surface roughness in drilling and less environmental dangers. Ming-Hui Chang et. al.[14] researched on synthesize copper oxide nanoparticles, which were then applied to prepare CuO–water nanofluid, using a spinning disk reactor (SDR) and he concluded that The thermal conductivity of nanofluid prepared from the produced copper oxide using NaHMP as surfactant increased with increasing CuO content up to 0.40 vol.%, at which the thermal conductivity increased by 10.8%. R. Manimaran et.al.[15] studied that copper oxide nanofluids was synthesized with a wet chemical method, and the characterization has been carried out using XRD, EDXA, SEM, and TGA it & concluded that the copper oxide nanofluid can be used for heat transfer applications due to their enhancement in thermal conductivity. Sharma et.al.[16] studied a nanofluid with superior thermal and tribological properties are developed by mixing TiO_2 nanoparticles in vegetable oil water emulsion in different concentrations he concluded that by using nano-cutting fluid machining performance improved by reducing tool wear up to 58.1% and 35.85% w.r.t. dry and conventional mist machining. Nano-cutting fluid reduced cutting force up to 62.67%, 34.88% and 35.38% compared to dry, conventional mist and wet machining. Also density of nanofluids, thermal conductivity and viscosity are improved with increasing of nanoparticle concentration. Bizhan Rahmati et. al.[17] researched on the optimum MoS_2 Nano lubrication parameters in Al6061-T6 milling to achieve the lowest cutting force, cutting temperature and surface roughness and he concluded that Cutting force can be minimized by applying 1 wt.% nanoparticle & The minimum cutting temperature is achieved with 0.5 wt.% nanoparticle concentration in the mineral oil, higher air stream pressure (4 bars) and 30° nozzle orientation angle. Yanbin Zhang et.al.[18] Studied to determine whether hybrid nanoparticles have better lubrication performance than pure nanoparticle and he concluded that MoS2 nanofluids in MQL grinding achieves lower grinding forces and surface roughness and better ground surface and also better lubrication effect is mainly due to the physical synergistic effect of MoS2/CNTs hybrid nanoparticles in MQL grinding fluids.

Table -1: Report of various articles about nanofluids as metalworking fluid

Sr.No.	Auther of the Paper	Workpiece Material	Tool Material	Base Fluid	Nano Particle	Machine Tool	With MQl/Without MQL	Input Parameters	O/P Parameters
1	Yu Su Et. Al.[7]	Annealed carbon steel bar of AISI 1045	CNMG 120408 - QM5015 type uncoated carbide insert (Sandwik)	Vegetable-based oil and Ester oil (Biodegradable)	Graphite oil based nano fluid	Cylindrical turning (CA6140 lathe.)	With MQL	1. Feed Rate (mm/rev) : 0.1 2. Cutting Speed(m/min) : 55, 96 3. Depth of cut(mm) : 1.0 4. Cooling : Vegetable oil, Dry & MQL	1. Cutting Force 2. Cutting Temperature
2	S. Khandekar Et.Al.[8]	AISI 4340	Uncoated cemented carbide insert	Water & Emulsion type cutting fluid & Additives	Al2O3	LB=17 Lathe (HMT, India)	Without MQL	Cutting time (t) 50, 100, 150, 200, 250, 300, 350 (sec) Feed (f) 0.1 (mm=rev) Cutting velocity (V) 350 (m=min) Depth of cut (d) 1.0 (mm) (radially) Machining environments (i) dry machining (ii) Machining with conventional cutting fluid (iii) Machining with nano-cutting fluid	Output Parameter 1. Tool Wear 2. Cutting Force 3. Chip Thickness 4. Surface Roughness
3	R.K. Sahu Et. Al.[12]	Copper (300 μm thickness),	Copper (900 μm diameter)	De-ionized water & polyethylene glycol	Copper nanoparticle	Micro Electrical discharge machining	Without MQL	Table 1. Process parameters for experimentation Process parameters Values Pulsed dc voltage 30 V Input current 2 A Frequency	a. Stability of & Size of copper particles b. Thermal Conductivity

								5 kHz Duty cycle 30 % Pulse width 60 µs	
4	Emel Kuram Et. Al.[9]	Al 7075-T6 aluminium alloy	Titanium nitride-coated cemented carbide inserts	sunflower oil, and canola oil, & Blended of these two of 8% & 12%	Blended fluid	Longitudinal turning (Universal lathe)	Without MQL	Cutting fluid, Cutting speed, Feed rate and depth of cut (175mmin-1 for cutting speed, 0.24mmrev-1 for feed rate and 2mm for depth of cut)	1. Turning forces (Fc, Ff and Fr) 2. Tool wears (VBB and VBC)
5	Anuj kumar Sharma Et. Al.[16]	AISI 1040 steel	Uncoated cemented carbide insert	vegetable oil water emulsion	TiO2 (Titanium dioxide)	HMT lathe machine	With MQL	flow rate 50 mL/min Air supply pressure 4 bar feed (f) 0.1 mm/rev, cutting velocity (v) 96.7 m / min and depth of cut (d) 1.0 mm	surface roughness, tool wear, cutting force and chip morphology
6	Bizhan Rahmati Et. Al.[17]	AL6061-T6 aluminum alloy	tungsten carbide (AE302100) tool	The ECOCUT HSG 905S from FUCHS served as the base oil in both modes of lubrication. This oil is free from phenol, chlorine and other additives.	molybdenum disulfide (MoS2) with the mineral oil followed by sonication	End milling machining (Vertical)	With MQL	The cutting speed, feed and depth of cut were 5000 min 1, 100 mm/min and 5 mm respectively, oil-air lubrication system having maximum rotational speed of 20,000 min 1 and 15 kW power.	Surface roughness FESEM analysis (Field Emission Scanning Electron Microscopy) XRD analysis (X-ray Powder Diffraction)
7	M M S Prasad Et. Al.[19]	AISI 1040 steel	Cutting tool (insert): Carbide, CNMG 120408(H-13A, ISO specification) & HSS tool	soluble oil	nano graphite	Lathe machine: turning operation	With MQL	Process Parameters: Cutting speed: 105 m/min Feed: 0.14 mm/rev Depth of cut: 1 mm Environment : Solid	surface roughness, tool flank wear, temperatures and cutting forces

								lubricant (Graphite) Lubricating oil: soluble oil Solid lubricant particle size: <80 nm Flow rate of the lubricant: 10 ml/min	
8	BIN SHEN Et . Al.[10]	Dura-Bar 100-70-02 ductile iron.	vitreous bond grey aluminum oxide grinding wheel (508-μmaverage abrasive size)	Ethylene glycol Deionized water Cimtech 500 synthetic fluid (5%)	Al2O3 & Diamond nanofluid	surface grinding machine. (vitreous bond grey aluminum oxide grinding wheel)	With MQL	The surface speed of the wheel and the down feed were set to be 30 m/s and 10 μm, respectively. The grinding was conducted by traversing the wheel across the workpiece at 2400 mm/min table speed in one direction. The grinding wheel was dressed at 10 μm down feed, 500 mm/min traverse speed, and a −0.4 speed ratio using a rotary diamond disk.	1. Fluid Thermal Conductivity 2. Grinding Forces 3. G-ratio 4. Surface Roughness 5. Grinding Temperature
9	Mohammadreza Shabgard Et. Al.[6]		Cylindrical rods of copper and graphite materials with diameter of Ø5 mm were prepared and used as electrodes	distilled water (DW) and ethylene glycol (EG)	Graphite nanofluid	electro discharge Machine	**	Pulse current (A) 5 and 10 Pulse on-time (μs) 2 and 4 Open voltage (V) 200 Pulse off-time (μs) 20 Dielectric temperature (°C) 2 Process period (min) 5 Copper electrode polarity	1. Particle size and concentration in base fluid, 2. Thermal conductivity enhancement of synthesized nanofluid 3. Effect of temperature control

								Positive Base fluid: DW/EG vol% 70/30; 50/50; 30/70 with and without GA	system on the size of nanoparticle 4. Effect of process variables on the size of synthesized nanoparticle
10	Yanbin Zhang Et.Al.[18]	Ni-based alloy material	conventional white corundum abrasive grinding wheel	synthetic liquids	MoS2(molybdenum disulfide)/ CNT(carbon nanotube) nanofluid	Grinding Machine	With MQL	grinding speed,30m/s; tables peed,3m/min; depth of cut,10 μm; and number of passes,15	on grinding force, coefficient of friction, and workpiece surface quality
11	P. Vamsi Krishna Et.Al.[19]	AISI1040 steel	cemented carbide tool inserts, SNMG120408	SAE-40 and coconut oil	boric acid solid lubricant of 50nm particle size	Lathe machine: turning operation	Without MQL	Cutting velocity V¼60, 80and100m/min Feed rate S¼0.14, 0.16,0.2mm/rev Depth of cut t¼1.0 mm Environment Solid lubricant(boricacid) Lubricating oilSAE-40,coconutoil Solid lubricant particle size 50nm Flow rate of lubricant oil 10ml/min	Cutting temperatures, Tool flank wear, Surface roughness
12	C. Mohanraj Et. Al.[20]	copper flat plate heat pipe	**	DI water	CuO Nano fluid	Evaporator	**	FPHP Dimension Parameters Dimension in mm Length: 100 Width: 85 Height: 40 Wick thickness : 0.25 Wall Thickness: 2	Temperature

13	Pil-Ho Lee Et. Al.[21]	tool steel, SK-41C	vitrified CBN tool grinding wheel 320-grain size aluminum oxide block	Water	diamond particles	Grinding Machine	With MQL	the grinding speed, feed rate and depth of cut were fixed at 80,000RPM, 120mm/min and 5μm.	Grinding Force & Surface Roughnes s
14	V Vasu Et. Al.[22]	Incone l 600 alloy.(nickel-chromi um)	coated carbide cutting tools	Coolube 2210 (Vegetable Oil)	Al2O3 nanofluid	Lathe Machine	With MQL	Cutting velocity, Vc 40, 50, and 60 m/min Feed rate, f 0.08, 0.12, and 0.16 mm/rev Depth of cut, t 0.4, 0.8, and 1.2mm MQL supply Air: 5 bar, lubricant: 100 ml/h	Taguchi's approach surface roughness , tool tip temperatu re, cutting forces, and tool wear
15	Patole P. B Et. al [23]	AISI 4340	tungsten coated carbide insert	ethylene glycol as a base fluid	Multiwall Carbon Nano Tube	Lathe machine: (CNC) turning operation	With MQL	Factor Level 1 Cutting speed (m/min.) 75 90 2 Feed rate (mm/rev.) 0.04 0.06 0.08 0.1 0.12 3 Depth of cut (mm) 0.5 1 1.5 4 Tool nose radius (mm) 0.4 0.8 5 Air pressure (bar) 5 6 Fluid flow rate (ml/hr.) 140	surface roughness and cutting force.
16	D.V. Lohar Et. Al.[24]	AISI43 40 steel	CBN Tool insert	Commercia lly used fluid	**	A high speed precision CNC Lathe	With MQL	Feed rate (mm/rev) 0.05,0.075,0. 10 Cutting speed (m/min) 40,80,120 Depth Of Cut (mm) 0.5,1.0 Cutting fluid condition Dry, Wet, MQL	cutting force, cutting temperatu re surface finish

17	C.Y.Chan Et. Al.[25]	6061-T651 aluminum rod, Brass & Copper	CBN cutting tool	Pure water Diluted treated water-miscible cutting fluid (JAEGERS W-105) & soluble oil	Nano Droplets Cutting Fluid	ultra-precision turning	Without MQL	**	Waviness and roughness of the machined surfaces & Chip morphology, Cutting Force & Thrust force
18	Farzad Pashmforoush Et. Al.[26]	Inconel 738 super alloy	Vitrified CBN270N125V. Grinding Wheel	conventional grinding fluid (mixture of water and soap	copper nanofluid	Grinding Machine	Without MQL	Depth of cut (μm) 10 20 30 Feed velocity (mm/s) 50 100 150 Nanoparticle concentration (ppm) 50 100 150	Wheel loading and surface roughness measurement

3. CONCLUSIONS

This paper presents an overview of important published experimental investigations on nano-enhanced cutting fluids and its application in different machining processes. It also covers a brief description of the experimental setups and procedures adopted by researchers for their investigation in a systematic manner. According to literature review the inclusion of nano particles in cutting fluids showed a significant reduction in cutting force, surface roughness, power consumption, specific energy, nodal temperature, torque in machining Also tool wear (flank and crater), and friction coefficient during machining. Nano fluids employed in experimental research have to be well characterized with respect to particle size, size distribution, shape and clustering so as to render the results most widely applicable. Once the science and engineering of nano fluids are fully understood and their full potential researched, they can be reproduced on a large scale and used in many applications.

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