Experimental Investigation of MQL and Nano Fluids (CuO) on the Machining of Nicrofer C263

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Abstract—Minimum amount Lubrication (MQL) may be a superb tradeoff between over-use of cutting fluids and poor surface integrity obtained by dry machining. MQL provides eco-friendly machining atmosphere and improves machinability characteristics. Nanofluids have novel properties that create them doubtless helpful in heat transfer medium in cutting zone. This paper presents the result of MQL and Nanofluids with one hundred and twenty fifth volume of CuO and 4WD volume CuO on the machinability characteristics of Nicrofer C263 principally with relevance Surface Roughness, Cutting Forces and Temperature dissipation. Experimental analysis for three completely different conditions—dry, MQL and MQL + CuO Nanoparticles square measure dispensed. It had been found that use of combination of Nanofluids and MQL offers higher surface end with smart thermal dissipation in cutting zone when put next with different conditions. it’s conjointly discovered that there’s a decrease in cutting forces and which can result in reduced tool wear.

Key words: CNC Milling, Nicrofer C263, CuO (Nano Fluid), Finite Difference Method, Literature

I. INTRODUCTION

Nanofluid could be a new category of fluids designed by dispersing nanometer-size solid particles in base fluids to extend heat transfer and tribological properties. This analysis studied the synthesis, characterization of nano fluids, and its application in minimum amount lubrication (MQL) Metal Cutting. MQL is to produce a second amount of cooling stuff medium to the tool-work piece interface, which may hugely scale back the applied quantity of cutting fluid. The goal of this analysis is to develop a production possible and environmentally benign Metal Cutting method. Cutting fluids, Metal Cutting wheels, and comprehensive understanding of the thermal aspects in Metal Cutting ar 3 key technical areas which will modify the success of MQL Metal Cutting.

II. HEAT GENERATION IN METAL CUTTING

The Metal Cutting method generates a particularly high input of energy per unit volume of fabric removed. just about all this energy is born-again to heat, which might cause high temperatures and thermal harm to the work piece like work piece burn, part transformations, undesirable residual tensile stresses, cracks, reduced fatigue strength, and thermal distortion and inaccuracies (Malkin, 1989). various studies are according on each the theoretical and experimental aspects of warmth transfer in Metal Cutting. Early analysis targeting predicting work piece surface temperatures in dry Metal Cutting within the absence of serious convective heat transfer (Outwater and Shaw, 1952; Hahn, 1956; Takazawa, 1966; Malkin and Anderson, 1974). Thermal models are developed to estimate the piece of work surface temperature, heat flux distribution within the Metal Cutting zone, fraction of energy getting into the piece of work, and convective heat transfer constant for cooling on the piece of work surface. Experimental investigations of warmth transfer in Metal Cutting need correct temperature measurements. strategies for temperature measuring in Metal Cutting embrace thermal imaging.

III. NANOFLIUID FOR COOLING APPLICATIONS

Heat transfer fluids play a very important role for cooling applications in several industries as well as producing, transportation, energy, and natural philosophy, etc. Developments in new technologies like extremely integrated electronics devices, higher power output engines, and reduction in applied cutting fluids endlessly increase the thermal load, which needs advances in cooling capability. Therefore, there's associate degree pressing want for brand new and innovative heat transfer fluids to attain higher cooling performance. Generally, standard heat transfer fluids have poor heat transfer properties compared to solids. Most solids have orders of magnitude larger thermal conductivities than those of standard heat transfer fluids. Therefore, fluids containing suspended solid particles area unit expected to show vital sweetening in thermal conductivities relative to standard heat transfer fluids. various theoretical and experimental studies of the effective thermal conduction of fluids containing particles are conducted since Maxwell's theoretical work was revealed over a hundred years ago. However, these studies were confined to dispersions containing millimeter- or micrometer-sized particles. In developing advanced fluids for industrial applications, it absolutely was known that metric linear unit or micrometer-sized sized particles have severe preventive and abrasive issues. With the event of nanopowder synthesizing techniques, it absolutely was planned that millimicron sized solid particles will be uniformly and stably suspended in industrial heat transfer fluids like water, antifreeze, or engine oil to supply a replacement category of built fluids with high thermal conduction. Choi (1995) coined the term “nanofluids” for this new category of built heat transfer fluids. Since nanoparticles area unit sufficiently little that they're expected to behave like molecules of liquid, nanofluids won't clog flow passages, however will improve the thermal properties.

IV. NANOFLIUID FOR LUBRICATION APPLICATION

On the opposite hand, as we know, solid lubricants square measure helpful for conditions once standard liquid lubricants square measure inadequate like hot temperature and extreme contact pressures. Their lubricating properties square measure attributed to a stratified structure on the molecular level with weak bonding between layers. Such
layers square measure ready to slide relative to every alternative with borderline applied force, so giving them their low friction properties. black lead and atomic number 42 disulfide (MoS2) square measure the predominant materials used as solid lubricating substance. alternative helpful solid lubricants embody element compound, atomic number 74 disulfide, poly characin fish fluorescent ethylene (PTFE), etc, to boost the tribological properties of lubricating oils by dispersing nano particles, particularly nano particulate solid lubricants, becomes of interest to folks. Recent analysis has shown that lubricating oils with nano particle additives exhibit improved load-carrying capability, anti-wear and friction-reduction properties. Xu et al. (1996) investigated tribological properties of the two-phase lubricating substance of coal oil and diamond nano particles, and also the results showed that, beneath boundary lubricating conditions, this sort of two-phase lubricating substance possesses wonderful load-carrying capability, anti-wear and friction-reduction properties. in step with Verma et al. (2007), MoS2 in its nano particulate type has exceptional tribological properties, which might scale back friction beneath extreme pressure conditions. Wu et al. (2006) examined the tribological properties of lubricating oils with CuO, TiO2, and diamond nano particles additives. The experimental results show that nano particles, particularly CuO, else to plain oils exhibit smart friction-reduction and anti-wear properties.

V. LITERATURE SURVEY
Murshed et al. (2005) showed that the measured thermal physical phenomenon for water primarily based TiO2 nanofluids (average diameter of fifteen nm) encompasses a most improvement half-hour for five pathology of particles. nanotube nanofluids, is of special interests to researchers owing to the novel properties of carbon nanotubes - extraordinary strength, distinctive electrical properties, and economical conductors of warmth. Carbon nanotubes (CNTs) square measure fullerene-related structures that accommodates either a graphic symbol cylinder (the alleged single-wall carbon nanotubes, SWCNTs) or variety of coaxal cylinders (the alleged multiwalled carbon nanotubes, MWCNTs) (Wen and peal, 2004b).

In this paper measured the effective thermal physical phenomenon of MWCNTs distributed in artificial (poly-α-olefin) oil and reportable the improvement up to a a hundred and fiftieth in physical phenomenon at just about one pathology CNT, that is out and away the very best thermal physical phenomenon improvement ever achieved in an exceedingly liquid (Lockwood et al., 2005).

However, this immense improvement wasn't discovered by Xie et al. (2003) for water/olefine glycol/decene primarily based MWCNTs nanofluids, nor by Assael et al. (2004) for water primarily based MWCNTs nanofluids.

The maximum thermal physical phenomenon enhancements discovered square measure nineteen.6%, 12.7%, and 7.0% for MWCNTs suspension at one.0 pathology in decene, ethanediol, and water, severally, which discovered was thirty eighth for MWCNTs suspension at zero.6 pathology in water. The reportable mensuration results aren’t terribly consistent. Assael et al. (2006)

This is most likely as a result of totally different researchers might have different procedure and there’s uncertainty within the thermal physical phenomenon mensuration exploitation hot wire methodology, a substantial effort has dedicated to each theoretical and experimental aspects of warmth transfer in grinding. The classic thermal analysis of moving heat supply and also the temperature at slippery contacts was studied by coastal diving bird (2006).

The application of Jaeger’s moving heat supply solutions to heat transfer issues in grinding was 1st projected by Outwater and Shaw (1952), whereby the grinding zone is approximated as a band supply of warmth moving on the surface of the piece of work.

Outwater and Shaw (1952) assumed that grinding heat is especially generated at the shear plane, and so the grinding temperature is calculated by matching the common temperatures on the shear plane.

Hahn (1956) thought of the resistance rubbing forces on the clearance surface and neglected the cutting forces on the rake surface within the grinding thermal model.

Snoeys et al. (1979) and Malkin (1984) conferred a comprehensive literature review of early analysis work on the prediction of piece of work surface temperatures in dry grinding while not vital convective heat transfer.

Takazawa (1972) thought of the partitioning of energy over the grinding contact zone supported emery wheel bulk thermal properties.

Similar contact zone thermal model was additionally projected by Rowe et al. (1988). Shaw (1990) thought of each real and apparent contact areas, and used a vicinity quantitative relation issue to...correlate grain properties with such a model. Grain analysis considers the energy partitioning at the grain-workpiece interface, instead of the wheel-workpiece interface (the whole contact zone). it absolutely was 1st projected by Hahn (1956, 1962, 1966).

Later, several grain analysis heat transfer models are develop. The grain ANalysis models tend to grant higher results across a large vary of grinding conditions developed an energy partition model, which mixes each the micro- and macro-scale thermal analysis. The wheel and grinding fluid square measure thought of to be a composite solid moving at the wheel speed. It predicts the convective heat transfer constant on the piece of work surface, the fraction of energy getting into the piece of work, and also the piece of work surface temperature. (Liao et al., 2000; Maksoud, 2005).

The model was additional extended to account for the variation of the warmth fluxes on the grinding zone in down grinding with giant Peclet variety thought about each the scales of the wheel work and grain-workpiece contact length and developed an entire thermal analysis that may handle each up and down surface grinding while not the idea of huge Peclet variety. Temperature measurements within the work submerged throughout grinding indicated that the triangular heat supply is additional correct than the oblong one (Kohli et al., 1999). Analytical investigations by Guo and Malkin (1995a) indicated that energy, partition is more or less constant on the grinding zone for normal down grinding, however varies greatly on the grinding zone for normal up grinding and each up and down creep-feed grinding. The inverse heat transfer technique was conjointly
applied to grinding thermal modeling. First developed associated inverse heat transfer technique to estimate the
warmth flux distribution within the work for normal grinding and also the native convective heat transfer
constant on the work surface from the measured temperature distributions within the work. Inverse heat transfer models
are studied extensively in grinding processes (Hong and Lo, 2000; Wang and Chen, 2002; Kim and Kwak, 2006). These
models are just like Guo and Malkin (2000), except that
Wang and Chen (2002) generalized the inverse heat transfer
model to the 3D case. Most of those ancient grinding thermal models have assumptions like the steady-state
condition, semi-infinite work size, and adiabatic stipulation
on the work surface. The numerical technique is associate
approach to beat these constraints. The finite component
technique (FEM) and finite distinction technique (FDM) are
tax-toward to model the warmth transfer issues in
grinding. In this paper has developed the FDM based
mostly grinding thermal model for the transient temperature
distribution and shown that work temperature rises chop-
chop throughout the initial wheel work engagement,
afterward reaches a quasi-steady state worth if the work is
sufficiently long and additional will increase throughout the
ultimate wheel-workpiece disengagement. The FEM has
been wide used to simulate the work grinding temperature for each second and 3D cases and additional developed to
investigate the section transformation and thermal stress on
ground surface (Mahdi and Zhang, 2003; Biermann et al.,
2008; Wang et al., 2003; Mamalis et al., 2003; Lefebvre et al.,
2006). FDM applies the distinct analog of the by-
product and is easy to formulate, simple to use and easy to
increase to 2 or 3 dimensional issues. During this study, a
FDM based mostly grinding thermal model is developed to
check the warmth transfer in grinding. This model is
comparable to it developed by Guo and Malkin (2009),
additionally to the transient heat transfer drawback, this
study conjointly investigated the work with finite dimension
and numerous boundary conditions. In this paper alloy AL-
2017-T4 ar used for part applications, type] sorts of the
merchandise cause completely different difficult shapes
form to be developed. the pc numerical management miller
facilities provides, the answer is to boost the effectiveness
of existing lubrication systems within the machining method,
introducing the nano lubrication system may cut back the
cutting force .In this study, carbon onion has been used as
nano particle mixed at completely different concentrate to
analyze the cutting force decrease and also the surface
quality improvement of CNC end-milling machined alloy
AL-2017-T4. Finally the results, with exploitation of carbon
onion nano material, the forces of cutting and roughness
values of surface ar reduced by twenty one.99 and 46.32 %,
severally, compared with the case of exploitation standard
lubrication systems. M. Sayuti &amp; Ahmed A. D. Sarhan
et. al, (2012) This paper study the use of the minimum
amount lubrication technique in finish edge employing a
coated inorganic compound tool. work items composition ar
chrome steel and metal alloy, the results of MQL were
principally lacate by temperature of tool flank, forces of
cutting and surface roughness. In MQL cutting speed v=26
m/min, the tool flank temperature down by fifty approx,
compared with dry cutting. Finally result The surface
roughness was greatly improved by activity associate oil
mist in low-speed cutting of chrome steel. Masato Okada
&amp; Akira Hososokawa &amp; Naoki Asakawa &amp;
Takashi Ueda (2014) during this paper cut back the adverse
effects on atmosphere and avoid health issues caused by the
overly used cutting fluids, a inexperienced machining
technology, MQL, is drawing additional and additional
attention. The refrigerant minimum amount lubrication
technique which mixes the benefits of refrigerant air and
MQL will improve cooling and lubricating performances.
Internal cooling cutters are giant used to feed the cutting
medium to the cutting zone directly. In work, cutting forces
and power wear were analysis throughout facet edge H13
steel with 3 forms of internal cooling edge cutters below the
CMQL condition. The experimental results showed that the
dge cutter with double straight channel (DSC) performed
best in tool life and reducing the cutting forces. within the
perspective of economy and environmental protection,
internal cooling cutter with DSC is advocate in cutting of
H13 steel below CMQL condition. Chengliang Zhang
&amp; Song Zhang &amp; Xufan Yan &amp; Qing dynasty
Zhang (2015) during this paper, nature of various cutting
fluids has been investigated. This paper conjointly give a
detail review of the cooling strage with reference to their
environmental impact on human’s health and developments
in eradicating the utilization of standard cutting fluids has
conjointly been review. Moreover, completely different
atmosphere friendly cooling methods, principally (MQL),
and refrigerant arrangement are reviewed within the
literature, and it's found that there's a large scope of analysis
to optimize cooling strate so as to create them functionally
applicable. Muhammed Nadeem Sharif &amp; Salman
Pervaiz &amp; patriach Deiab (2016) This paper investigates the MQL technique in finish edge of Al alloy
AA6061 with minimum amount lubrication (MQL)
conditions exploitation nano fluid. Wear mechanisms for
the water-based TiO2 nano fluid with a nano particle
volume fraction of one.5 {you ar|you're} compared with
standard oil-based MQL associated flooded cooling
conditions exploitation an uncoated atomic number 74
inorganic compound (WC)insert and Wear mechanisms are
characterised. Results show adhesion of the work material
because the major tool injury method, determined along side
adhesion Abrasion wear is additionally find, the foremost
exploit the water-based nanoFluid MQL is shown within the
intact edge pure mathematics, this is often conclude to the
cooling result created by the most heat of vaporization of
water, end in lower of temperature within the cutting zone.
M. S. Najihah &amp; M. M. Rahman (2016)

VI. OBJECTIVES OF THE PRESENT INVESTIGATION

1) Investigation of the working range and levels of the
nano fluids machining process parameters using CuO
working fluid design of experiment
2) Experimental determination of the effects of the
various process parameters viz. machining time,
temperature, metal removal effect, friction effects
performance and measures.
3) Optimization of the performance measures using Finite
Difference Method.
4) Machining performance measures using CuO as a nano
fluid used in CNC machining process.
5) Optimization of the process parameters of the Al₂O₃ as a nano fluid using CuO.

VII. FINITE DIFFERENCE METHOD

A grinding thermal model has been developed based on the finite difference method (FDM) in order to estimate the energy partition and the convection heat transfer coefficient in grinding. It also can be used to study the transient heat transfer and temperature distributions in workpiece with finite dimension and various boundary conditions. The model is first validated by comparing with the traditional grinding thermal model assuming semi-infinite workpiece. Effects of workpiece size, feed rate, and various cooling conditions are further investigated using the FDM model. When the workpiece is short or the feed rate is low, transient heat transfer becomes more dominant during grinding. Investigation of cooling effects revealed that the free convection and cooling in the leading edge have negligible effect, cooling in the trailing edge only has influence in the trailing edge region and cooling in the grinding zone has a significant effect on the reduction of workpiece temperature. The model is further applied to investigate convective cooling in the grinding experiment. The energy required to remove a unit volume of work-material for grinding is very high. Virtually all this energy is converted to heat, which can cause high temperatures and thermal damage to the workpiece such as grinding burn, phase transformations, undesirable tensile residual tensile stresses, cracks, reduced fatigue strength, thermal distortion and inaccuracies. To apply the finite difference method, the first step is to subdivide the computational domain into small regions and assigning each region a reference point. Now that the computation domain is characterized in terms of a nodal network, the governing equation and the boundary conditions need to be transformed into the finite difference form to compute the nodal temperatures. In the finite difference method, either full grid or half grid can be used at the boundary. The half grid has the advantage of direct expression of the nodal temperature at the boundary, while the full grid requires much less computation time and is more accuracy because of the uniform mesh. Therefore, in this study the full grid was adopted at the boundary.

VIII. EXPERIMENTAL SET UP & PROCESS PARAMETER SELECTION

The Experiments were carried out on a CNC Milling machine installed at Tool Room Department, Indo German Tool Room, Ranchi. The machine has been shown in the figure the CNC Milling machine Tool has the following specifications.

| Work Piece | NiCrofer C263 (40x253) of 6 Rod |
| Cutting Tool | 10x1/8" carbide Flute Nose END Mill CNC Router Bits double Flute Spiral Set Kit |
| Feed Rate (f) | 0.075-0.23 mm/rev |
| Cutting Speed | 35-50 m/min |

X. EXPERIMENTATION

The experiments were accomplished on an electronic control panel following steps were followed in the cutting operation:

1) The code is applied on control panel for positioning of chuck.
2) The work piece was mounted and clamped on the work table.
3) A reference point on the work piece was set for setting work co-ordinate system (WCS). The programming was done with the reference to the WCS. The reference point was defined by the ground edges of the work piece.
4) The program was made for machining operation of the work piece and a profile of 5mmx10mm rectangle was machined.
5) To reduce error due to experimental set up, each experiment was repeated three times in each of the trial conditions.
6) Each set of experiments was performed at room temperature and machining time, nano fluid temperature is measured.

<table>
<thead>
<tr>
<th>Condition</th>
<th>Run No.</th>
<th>Speed m/min</th>
<th>Feed m/m/rev</th>
<th>Depth of cut</th>
<th>Ra₁</th>
<th>Ra₂</th>
<th>Ra₃</th>
<th>Avg. Ra micron</th>
<th>Force Newton</th>
<th>Temp. °C</th>
</tr>
</thead>
<tbody>
<tr>
<td>NanoFluid + MQL (4% CuO)</td>
<td>1</td>
<td>43.00</td>
<td>0.13</td>
<td>0.76</td>
<td>0.39</td>
<td>0.40</td>
<td>0.38</td>
<td>0.39</td>
<td>148</td>
<td>54.8</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>56.00</td>
<td>0.089</td>
<td>0.87</td>
<td>0.38</td>
<td>0.39</td>
<td>0.38</td>
<td>0.38</td>
<td>145</td>
<td>56</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>38.00</td>
<td>0.089</td>
<td>0.878</td>
<td>0.8</td>
<td>0.34</td>
<td>0.35</td>
<td>0.35</td>
<td>160</td>
<td>58</td>
</tr>
</tbody>
</table>

Table 1: specifications

Fig. 1: Figure shows controls on control panel in CNC Milling
Table 2: Experimental values of surface roughness, cutting forces and cutting Temperature of Nicrofer C263 under dry, MQL and Nano fluid conditions

<table>
<thead>
<tr>
<th>Condition</th>
<th>Run</th>
<th>Surface Roughness</th>
<th>Cutting Forces</th>
<th>Cutting Temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) Nanofluid+MQL L (1% CuO)</td>
<td>1</td>
<td>43.00</td>
<td>0.13</td>
<td>0.76</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>56.00</td>
<td>0.089</td>
<td>0.87</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>38.00</td>
<td>0.089</td>
<td>0.878</td>
</tr>
<tr>
<td>2) Mix coolant+MQL</td>
<td>1</td>
<td>43.00</td>
<td>0.13</td>
<td>0.76</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>56.00</td>
<td>0.089</td>
<td>0.87</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>38.00</td>
<td>0.089</td>
<td>0.87</td>
</tr>
<tr>
<td>3) Dry condition</td>
<td>1</td>
<td>43</td>
<td>0.13</td>
<td>0.76</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>56</td>
<td>0.089</td>
<td>0.87</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>38</td>
<td>0.089</td>
<td>0.875</td>
</tr>
</tbody>
</table>

Fig. 2: Variation of temperature with different nanofluid and dry condition with respect to number of runs during machining.

Fig. 3: Variation of average roughness (microns) with different nanofluid and dry condition with respect to number of runs during machining.

Fig. 4: Variation of Force (N) with different nanofluid and dry condition with respect to number of runs during machining.

Fig. 5: Variation of depth of cut with different nanofluid and dry condition with respect to number of runs during machining.

X. CONCLUSIONS

This research advances the fundamental research of nanofluids and the state-of-the-art MQL Milling. The formulation and characterization of nanofluids and MQL Milling of cast iron using nanofluids were investigated. A new Infrared Thermometer fixating method for Milling temperature measurement was proposed, thermal analysis of MQL Milling was conducted, and a Milling thermal model based on the Finite Difference Method has been developed.

The major contributions made in this research include:

1) The fundamental research of nanofluids was conducted. The suspension of nanoparticles has been proved to be able to enhance the thermal conductivity, especially with the high volume fraction of nanoparticles.

2) The application of nanofluids in MQL Milling was evaluated for the first time. It is concluded that nanofluids are not able to provide superior cooling capacity in MQL Milling process. However, the suspension of nanoparticles can improve the tribological properties of the base fluids, which can help lubricate the Milling zone. Therefore, the research of application of nanofluids in MQL Milling should focus on the advanced lubrication properties.

3) It is shown for the first time that lubricant oils with novel CuO nanoparticles significantly reduces the tangential Milling force and friction between the wear flats and the workpiece.

4) A new Infrared Thermometer fixating method was developed for Milling temperature measurement which is easy to install, and can provide a direct measurement of the surface temperature.
REFERENCES


[20] Chengliang Zhang & Song Zhang & Xufan Yan & Qing Zhang, Effects of internal cooling channel structures on cutting forces and tool life inside milling of H13 steel under cryogenic minimum quantity lubrication condition (2015)
