Feasibilty of The Use of Zirconia Based Nanocoolant For Machining

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Abstract-Nanocoolants have been used for some time now due to their excellent thermal properties. In this work, Zirconia based nanocoolants of 4 different concentrations have been manufactured. Volume fraction of 0.4% was found to have maximum thermal conductivity among the 4 manufactured. This volume fraction was used to find surface roughness of machined specimen. Coolant with nanoparttcles exhibited lower surface roughness values on all 4 of the roughness parameters measured.
Keywords-Nanocoolant, Zirconia ,Sonication, Machining

I. INTRODUCTION

Nanoparticles have been used for a variety of purposes. Automobile heavy-duty engine cooling rates have been increased by increasing the efficiency, lowering the weight, and reducing the complexity of thermal management systems. The heat rejection requirements of automobiles can also be met in the same way.[1] . Other potential uses include advanced nanoparticles as a filler in car tyres, anti-reflective coatings for displays and mirrors, nanoparticle-reinforced polymers and metals, modified adhesive technologies and adhesive primers, improved fuel cell technology and hydrogen storage, catalytic nanoparticles as a fuel additive,[2]

II. LITERATURE SURVEY

Synthesis of zirconia based nanopowder has been done by precipitation and ageing. Addition of ammonium solution to the aqueous solution of zirconium chloride at room temperature was used for precipitation. The precipitate formed in the mother liquor was left undisturbed in the glass beaker for 48 hours at ambient temperatures. [3]
Another hydrothermal synthesis method has been used to synthesize Zirconia Nanopartlces from Commercial Zirconia.[4]
zirconia-based nanopowders have been prepared using the sol-gel method. gelatin as structure directing agent and Cerium as dopant have been utilized,. This combination creates nanostructures with an active surface.[5]
The cooling capabilities of an ethylene glycol (EG)-based nanofluid containing three different types of nanoparticles: copper oxide (CuO), aluminium oxide (Al_2O_3), and titanium dioxide (TiO_2) are investigatedEthylene Glycol based Nanofliuds with CuO, $Al_2O_3$and TiO_2 been invrestigated by Winfred Mutuku and it has been established that CuO based Nanofluids have a great effect on reduction in temperature of boundary layer.[6]

III. EXPERIMENTAL WORK

In our work, we have bought Zirconia powder ,mixed with waterand prepared different volume fraction mixtures. These mixtures were used as coolant to cool mild steel while machining.

3.1 Methodology

The samples of various concentration of the nano-fluid is prepared by varying the volume fraction (ϕ) from 0.1 to 0.5. These samples are tested using the instrument KD2 Pro Analyser in order to determine the thermal conductivity of these samples. According to the test result coolant is prepared in large volume and used for machining (step- turning operation). Finally, the surface roughness was measured for, before and after use of the coolant.
The nanopowders were weighed and mixed. They were subjected to sonication in an ultrasonic bath. Thermal Conductivity of the different mixes were determined. Coolant was prepared in a large volume Using the prepared coolant, machining was done using CNC lathe. Surface Roughness was determined.

3.2 Materials Used

The structure and properties of Zirconia nanopartilces have been calculated theretically by Antonio Ruiz et al.[8]Zirconium oxide is the nanopowder used with base fluid distilled water.Base metal for machining is mild steel. The Table 1 shown below gives properties of the Nanopowder.

Table 1 showing properties of Zirconia Nanopowder

Particle Size(nm)	Density(kg/m^3)	Purity(%)
45	5680	99.5

3.2.1 Weighing and Mixing of the nano-powder with the base fluid.

By varying the volume fraction (ϕ), various samples of the nono-fluid is prepared. Required amount of the nano- powder (zirconium oxide) is weighed and mixed with the base fluid (distilled water) with the help of magnetic stirrer.

Calculation of the amount of nano-powder to be added to the base fluid by varying the volume fraction (ϕ).

- To prepare 100 ml of nano-fluid, ZrO_2 with base fluid as water.
- We know that the density of ZrO_2 is 5680 kg/m^3 and density of water is 1000 kg/m^3
- Therefore, % volume concentration,

$$\phi = \left[\frac{\left(\frac{W_{ZrO2}}{\rho_{CuO}}\right)}{\left(\frac{W_{ZrO2}}{\rho_{ZrO2}}+\frac{W_{bf}}{\rho_{bf}}\right)}\right] \times 100 = \left[\frac{\left(\frac{W_{ZrO2}}{5680}\right)}{\left(\frac{W_{ZrO2}}{5680}+\frac{100}{1000}\right)}\right] \times 100$$

- If the volume fraction (ϕ), is fixed as 0.1%, then W□ZrO_2 = 0.56 gm
- Hence $WZrO_2$ = 0.56 gm is to be mixed in the base fluid to obtain 100 ml ZrO_2 /water nano-fluid with 0.1% volume fraction.
- Similarly, by varying the volume fraction various samples are prepared.

3.3 .Sonication Using Ultra-Sonic Bath Or The Probe

Sonication is the act of applying sound (usually ultrasound) energy to agitate the particles in the sample. this process is done to disperse the nano-particle uniformly through-out the sample. In the laboratory it is applied using an ultra-sonic bath or the ultrasonic probe.

Fig 1 showing sonication

3.4. Measuring The Thermal Conductivity Using Kd2 Pro Analyser

The KD2 Pro is a handheld device used to measure thermal properties. The base KD-2 Pro package consists of a handheld controller and one sensor kit of your choice. There are several sensors available for purchase that operators can insert into almost any material. The single needle sensors measure thermal conductivity and resistivity; while the dual-needle sensor measures thermal conductivity, resistivity, volumetric specific heat capacity and diffusivity.

Fig 2 showing measurement of Thermal Conductivity

3.5. Preparation Of The Coolant In Large Volume

Depending on the results obtained from the thermal conductivity test, the nano-fluid is prepared in large volume by undergoing the previously mentioned procedure for the preparation of the nano-fluid. Approximately 3- 4 litres of the coolant is prepared,

3.6.Using The Prepared Coolant Machining Is Done In The Cnc Lathe

Coolant prepared is poured into the coolant circulating tank and machining is done, step turning. And the work piece is tested by using surftest sj-210 to determine the surface roughness of that work piece before and after using the coolant.

Figure 3 shows machined specimen

3.7. Determination Of The Surface Roughness

The surface roughness of the machined work piece is determined using the surftest sj-210 contact type surface roughness tester. It has a small stylus which is moved over the work piece for which the surface roughness is to be determined, Corresponding Ra and Rz are displayed in the digital output screen. the stylus is moved over the work piece at a rate of 0.5mm/s. The stylus movement is controlled using a drive unit.

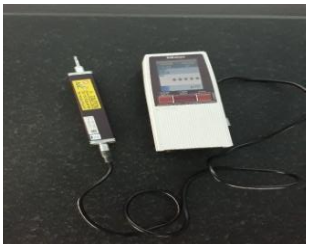

Figure 4showing Surface Roughness tester

3.8. Thermal Conductivity Test

The thermal conductivity of the different concentraton of the nano-fluid is measured using the KD2 pro analyser. The KD2 Pro is a handheld device used to measure thermal properties. The base KD-2 Pro package consists of a handheld controller and one sensor kit .

KS-1 sensor used to measure thermal conductivity and resistivity of liquid samples. However, measuring thermal properties of liquids is difficult and great care must be taken to obtain accurate and repeatable results.

For an accurate measurement of thermal properties of a liquid sample, the sample must be absolutely still in relation to the KS-1 sensor. Convection, or bulk movement of the sample, causes errors in the thermal properties measurement. Error from convective heat exchange is often very large, rendering the thermal properties measurement useless

Thus the sensor is dipped into the fluid sample and kept for a minute and it displays the value of the thermal conductivity

IV. RESULTS AND DISCUSSION

The results obtained from the different concentration of the sample are listed below:

- Sample 1:
  Volume fraction (ϕ) = 0.1 and $WZrO_2$ = 0.568 gm
  Thermal conductivity – 0.675 W/mk
- Sample 2:
  Volume fraction (ϕ) = 0.2 and $WZrO_2$ = 1.13 gm
  Thermal conductivity – 0.728 W/mk
- Sample 3:
  Volume fraction (ϕ) = 0.3 and $WZrO_2$ = 1.70 gm
  Thermal conductivity – 0.812 W/mk
- Sample 4:
  Volume fraction (ϕ) = 0.4 and $WZrO_2$ = 2.28 gm
  Thermal conductivity – 0.917 W/Mk

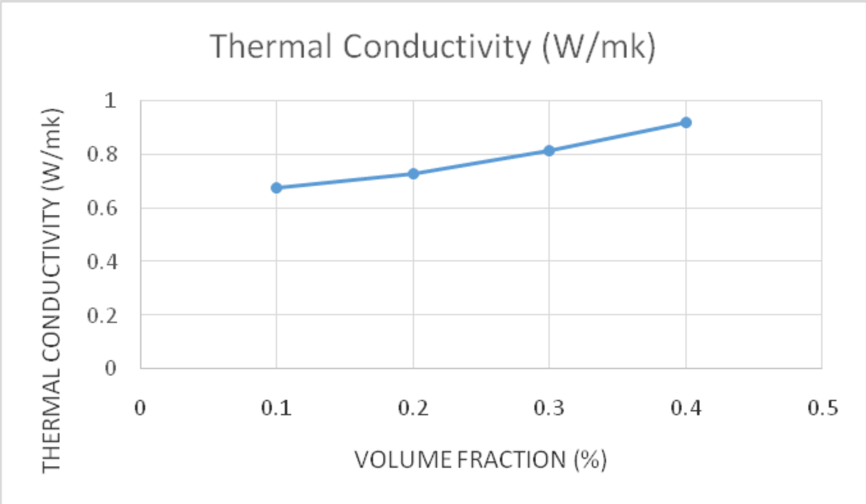

Figure 5 showing variation of Thermal Conductivity with Volume Fraction of Zirconia

Thus it can be concluded that, the thermal conductivity of the nano-fluid increases with the increase in the volume fraction (ϕ),

Table 2 shows surface roughnesss values before suing coolant.

Parameter	Reading value (μm)
Ra	4.380
Rq	4.577
Rz	29.706
Rt	36.868

Table 3 shows surface roughness values with coolant

Parameter	Reading value (μm)
Ra	3.048
Rq	3.960
Rz	17.886
Rt	22.765

From the above results we can conclude that after using the coolant the surface roughness has reduced. Hence the surface finish has improved after the use of the nano-fluid as the coolant.

V. CONCLUSIONS

Zirconia based Nanofuid has been successfully prepared
Thermal Conductivity of Nanofluids increases with increase in Volume %age of Zirconia.
All the surface roughness parameters unifromly show a decrease in value and hence surfcae has become smoother when machined using nanofluids.

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