International Journal of Advance Research in Science and Engineering
Volume No.06, Special Issue No.(02), December 2017
www.ijarse.com
IJARSE
ISSN: 2319-8354

Numerical Simulation for the Temperature Behavior on Work piece Surface for Different Working Fluids during Grinding Process

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ABSTRACT

This paper described a computational studied of performance of two different types of grinding fluid during abrasive machining, one is water based coolant and other is oil based coolant. The analysis is based on computational fluid dynamics simulation. The analysis is done using both coolants water as water based coolant and kerosene oil as oil based coolant. The results are obtained for different depth of cut. It is observed that cooling capacity of the water based coolant is higher than oil based coolant.

Keywords-*CFD, Grinding process,Heat Transfer, Oil based coolants, Water based coolants*

I. INTRODUCTION

The grinding is an abrasive machining process. It is used as a finishing process to get desired surface finish, correct size and accurate shape of product. Grinding is a process carried out with a grinding wheel made up of abrasive grains for removing very fine quantities of material from the work piece surface. Lapping, honing and abrasive jet machining are a few of the other abrasive machining process. The major difference between the action of an abrasive grain and that of a single-point cutting tool is that in abrasive machining individual abrasive grains have irregular shapes and are spaced randomly along the periphery of the wheel. So, during grinding high energy consumption is necessary to eliminate unit material volume, thus a high amount of heat is generated in the grinding zone. This heat is mostly transferred to grinding wheels and work piece. Grinding heat likely affects the surface quality and usability of work pieces. So to reduce this heat, grinding fluids are used. The main function of grinding fluids is to reduce grinding temperature.Grindingfluids are also used for lubrication, cooling in the contact area, bulk cooling outside the contact area, flushing of the debris away from the contact area and entrapment of abrasive dust and harmful vapors.Malkin and Anderson[1]developed a thermal model and concluded that the almost all of the plowing and sliding energies are conducted as heat to the workpiece, whereas only about 55 percent of the chip formation energy is conducted to the workpiece. Lavine and Jen [2]developed a model that predicts the workpiece temperature as a function of the various parameters. The results were presented in terms of a non-dimensional temperature, which depends on seven non-dimensional parameters.Stefan et al. [3] explain CFD models used to simulate the fluid flow and heat transfer in a grinding process. Simulation of grinding process using CFD by creating 3-D model gives the accurate picture and information regarding distribution of temperatures, pressures, fluid flow pattern in and around the grinding region. Rowe et al. [4]studied the critical factors for the control of thermal damage in grinding at conventional work speeds have been established with reference to experimental and previously published work.Brinksmeier et. al. [5] classified the grinding fluids in two categories, one is oil based coolants and other is water based coolant. Oil based coolant usually consist of 80-95 % basic oil and works by the creation of separation film between grinding wheel and work piece decreases friction, high pressure and temperature during machining process. Oil based coolants further classified as mineral oils, hydrocrack oils, polyalphaolefines, synthetic ester. Water based emulsions or solutions are used if high cooling efficiency and washing away capabilities are neededLavine et al. [6]have discussed a model in which they compare the workpiece temperature rises in grinding, and to explore the effect of the location of heat generation.Morgan et al. [7] addressed the quantity of fluid required for grinding and the method of application in their paper. The results from their research suggest that supply flow rate needs to be 4 times the achievable useful flow rate.Jin and Stephenson[8]studied the convection heat transfer coefficient of the grinding fluids. The experimental measurements to convectional heat transfer coefficient for different grinding fluids have been carried out and they discuss that the heat transfer coefficient depends on the grinding wheel speed and the fluid film thickness within the contact zone. It is also explained that convective heat transfer coefficient of the grinding fluid increases with the increase in grinding wheel velocity.Moulik et al. [9]formulated a finite element model, to calculate the temperature and stresses arising due to moving source of heat. Athanasios and Mamalis[10]have discussed a finite element model for the simulation of grinding of hardened steels with aluminium oxide wheels. For this task the implicit FEM code MARC is used**.** Aurich et al. [11]studied an overview of current simulation methods describing the interaction of grinding process and grinding machine structure, e.g. vibrations, deflections and thermal deformations. Doman and Sudermann[12]have discussed 2-D and 3-Dfinite element models. The scale of modelling approaches either macro or micro scale. Macro scale models consider the overall wheel-workpiece interaction while micro scale models focus on the individual grain workpiece interaction. In the present steady the abrasive machining by grinding is used in presence of two grinding fluids. Thermal performance is predicted by CFD simulation through Ansys Software [13] at different depth of cut. The results are predicted by validation of present model.

II MATHEMATICAL MODELING

2.1 Momentum Equation-

The steady, incompressible, Reynolds Averaged Navier- Stokes equations are employed for the flow calculation. Therefore the momentum equation can be written as [3,13]:

$$S_i = -\left(\frac{\mu}{\alpha}.\boldsymbol{v}_i + C_2.\frac{1}{2}.\rho.|v|.v_i\right) \quad (1)$$

Where, S_i is the source term for the i-th (x,y or z) momentum equation, |v| is the velocity, α is the permeability, C_2 is the inertial resistance factorand μ is the fluid viscosity.

2.2Energy Equation-

The standard energy transport equation [3,13] in contact zone is used with modifications to the conduction flux. In the contact zone, the conduction flux uses an effective conductivity:

$$\nabla.(\vec{\boldsymbol{v}}(\rho_f.E_f+\rho)) = \nabla.[k_{eff}.\nabla.T-(\textstyle\sum_i \boldsymbol{h}_i.J_i)+(\bar{\bar{\boldsymbol{\tau}}}.\bar{\boldsymbol{v}})]+S_f(2)$$

2.3Heat Generation Modeling-

The main sources of heat in grinding are caused due to those grains which are rubbing surfaces of work piece. Therefore, the strength of an elementary heat source Q_{1Z} can be expressed as[3]:

$$Q_{1z} = F_{vz}.v_t.t_z \quad (3)$$

Where

- $F_{vz}= F_{vm}/N_a.A_k$ is the main grinding force (F_{vm} is total main grinding force, N_a is number of active grains per unit of surface of grinding wheel, A_k is the contact surface area between grinding wheel and grinded part),
- v_t is grinding wheel circumferential velocity.

$$t_z = \frac{\sqrt{a.D_t}}{V_t} \quad (4)$$

IJARSE
ISSN: 2319-8354

- t_z is period of time during which grain cuts the workpiece (a is grinding depth, Dt is diameter of grinding wheel).

The final equation for the total heat source strength is obtained by Equation (5) [3];

$$Q' = \frac{v_p}{v_t} . a^{\frac{3}{2}} . D_t^{\frac{1}{2}} . k_{vm} \quad (5)$$

Where v_p is work piece speed and k_{vm} is specific main grinding resistance. Specific main Grinding resistance was calculated using the equation [3];

$$K_{vm} = \frac{C_k}{\epsilon_k \sqrt{A}} \quad (6)$$

2.4. Turbulence Modeling-

In this simulation, the Reynold Stress Model is used as discussed in Stefen et al. [3]

$$\frac{\partial}{\partial t}(\rho.\overline{u}_i.\overline{u}_j) + \frac{\partial}{\partial Xk}(\rho.u_k.\overline{u}_i.\overline{u}_j) = -\frac{\partial}{\partial Xk}[\rho.\overline{u}_i.\overline{u}_j.\overline{u}_k + \overline{\rho}.(\overline{\delta}_{kj}.\overline{u}_i + \overline{\delta}_{kj}.\overline{u}_j)] + \frac{\partial}{\partial Xk}[u.\frac{\partial}{\partial Xk}(\overline{u}_i.\overline{u}_j)]$$

$$-\rho.(\overline{u}_i.\overline{u}_j.\frac{\partial}{\partial Xk}u_j + \overline{u}_j.\overline{u}_i.\frac{\partial}{\partial Xk}u_i) - \rho.\beta.(g_i.\overline{u}_j.\overline{\theta} + g_j.\overline{u}_i.\overline{\theta}) + \rho.(\frac{\partial}{\partial Xj}u_i + \frac{\partial}{\partial Xi}u_j) - 2\mu.\frac{\partial}{\partial Xk}u_i.\frac{\partial}{\partial Xk}u_j$$

$$-2.\rho.£_k.(\overline{u}_j.\overline{u}_m.\epsilon_{ikm} + \overline{u}_i.\overline{u}_m.\epsilon_{jkm}) + S_{user} \quad (7)$$

III NUMERICAL SIMULATION

The flow domain consists of a rotating grinding wheel which is rotating in clockwise direction, the upper layer of workpiece, the grinding zone, a nozzle from where grinding fluid is coming and the shield. The diameter of rotating grinding wheel is 340 mm, the radius of the shield is 180 mm, the area of workpiece is 580mm*150mm, the area of the grinding zone is 50mm *30mm. The grinding depth is 1mm. The size of the nozzle is 5mm.The width of the wheel is 50 mm. The grinding geometry is shown in following Fig.1. The grid size is selected for the number of elements 520473 by grid independent test.The validation of present studied was done with Stefan et al. [3]by comparing maximum change in temperature. The parameters for the simulation are given in Tables 1 and 2.

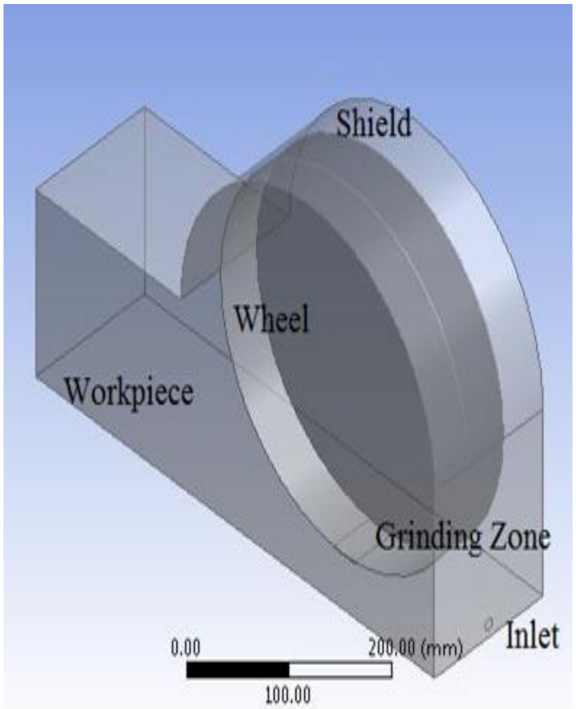


Fig. 1- Geometry of Grinding Process [3]

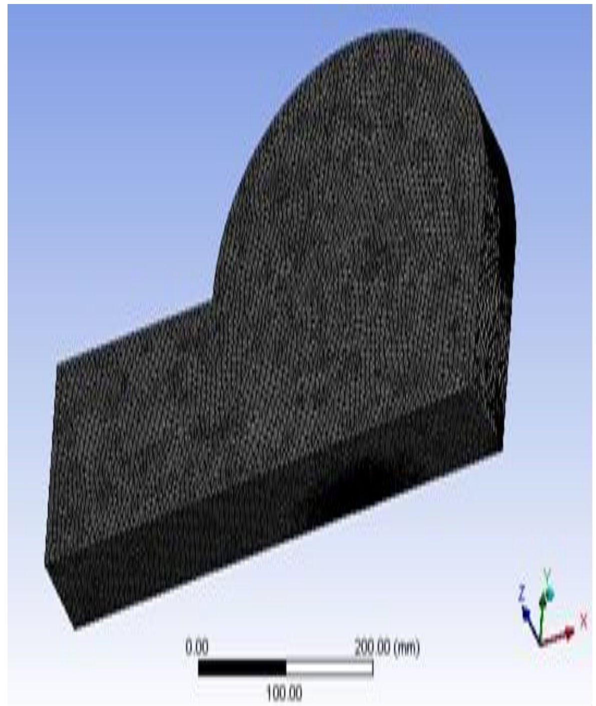


Fig. 2-Meshed Geometry with symmetry

Table 1.Different Properties of Grinding Fluids [3,13]

	Water Based coolant	Kerosene oil
Density(Kg/m^3)	998.2	780
Specific Heat (J/Kg-K)	4182	2090
Conductivity(W/m-K)	0.6	0.149
Viscosity(Kg/m-s)	0.001003	0.0024

IV RESULT AND DISCUSSION

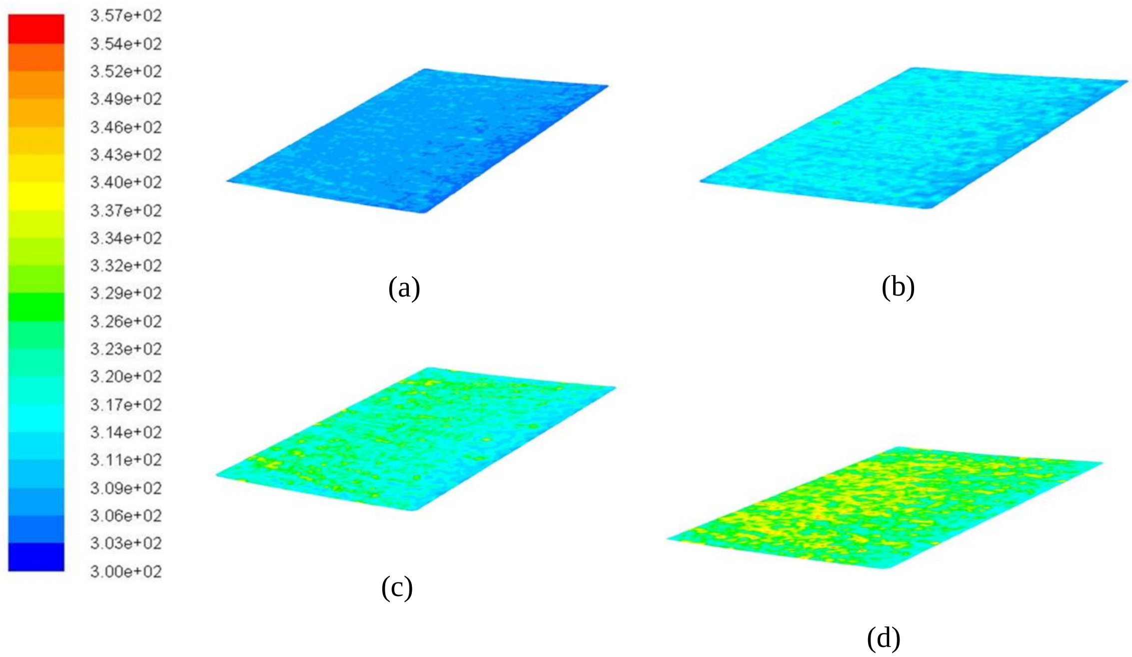
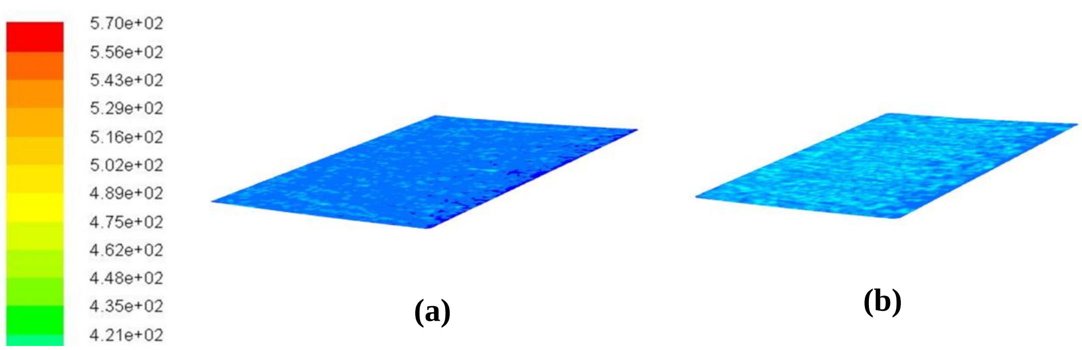
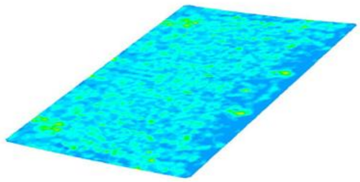
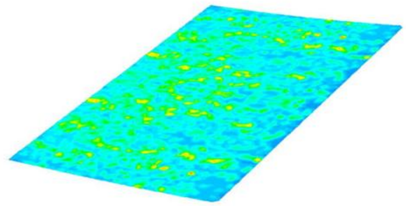


Fig.3-Contour for total temperature in the grinding zone when water based coolant is used as grinding fluid at 68 m/s wheel velocity for the depth of cut(a)0.5 mm (b)0.7 mm(c)0.9 mm (d)1.1 mm





(c)



(d)

Fig.4-Contour for total temperature in the grinding zone when kerosene oil is used as grinding fluid at 68 m/s wheel velocity for the depth of cut(a) 0.5 mm(b)0.7 mm(c) 0.9 mm (d) 1.1 mm

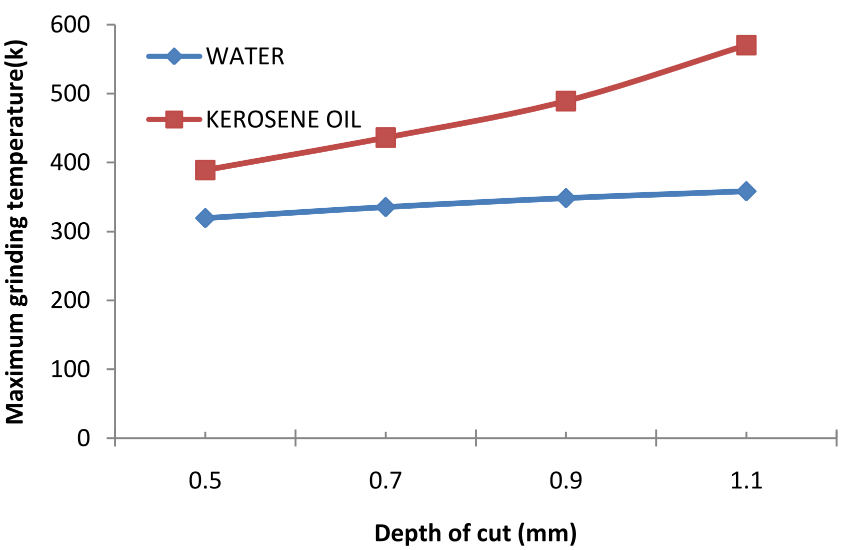


Fig.5- Effect of depth of cut on grinding temperature when the grinding wheel velocity is 68m/s

Figures 3and 4 represent the contour of total temperature in the grinding zone when water and kerosene oil are used as grinding fluid respectively.It is seen that on increasing the depth of cut maximum grinding temperature is increased in case of both fluids. It is also observed that on increasing depth of cut non uniformity of temperature distribution on work piece surface is increased. When the depth of cut increases, the area of heat zone also increases hence maximum grinding temperature is also increased. The maximum grinding temperature in case of water is less than kerosene oil because of its better thermal properties. Water based coolants have high specific heat, high thermal conductivity. Due to these properties water based coolants have higher cooling capacity.

V CONCLUSIONS

The numerical simulation studies in this paper exhibit the thermal performance of abrasive grinding. The water based coolants have higher cooling capacity. The maximum grinding temperature increases with increase in depth of cut due to increase in heat zone area. A good grinding fluid must have higher specific heat, higher conductivity, higher density and lower viscosity. If the necessity of higher cooling required then water based coolants can be used but higher maintenance cost is required in case of using water based coolants. The main advantage of oil based coolants that it can also serve as better lubricant.

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