Modeling of Temperature Distribution in Metalcutting using Finite Element Method

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Abstract - This work simulation of the effect of the temperature distribution in tool life and wear using finite element method. By modeling the heat intensity at the cutting zone and shear zone as non uniform. This work tries to obtain temperature distribution in deformation zones. In this work to consider the temperature increases on the chip side and tool side along the interface. X,Y,Z dimensional(3D) study heat transfer FEA problem was given boundary conditions that specified temperature, insulated and active conditions. The numerical methodology used here is solid works simulation. Finite element method was used to model the effect of base insulated and base not insulated Cemented carbide cutting tool. From the simulation analytical results; Titanium carbide cutting tool when air cooled maintain constant temperature of 30 C, but cutting tool is insulated the temperature rapidly increases. The Solid works Simulation results show that the tools when its base is convecting has the maximum temperature 130 C and 115 C respectively.

Keywords: Solid works simulation software, contact phenomena, cemented carbide tools, Finite element method (FEM)

I. INTRODUCTION

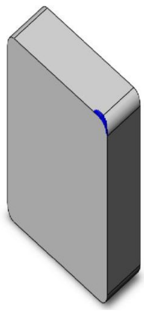
A very interesting method was developed to measure the temperature in the flank face of the tool using wire of a different from that of the work piece and the tool [2]. The wire is inserted into the work piece into a hole of a small diameter and is insulated. When the material is being cut, the wire will also be machined, and when this happens a thermocouple is formed between the wire and the tool. With regard to the results obtained, the temperature of the tool flank face is affected little by the cutting speed, feed rate and depth of cut. Major disadvantage of this method is that the duration of contact is very short. A method was developed by Kato et al.[3],Cutting temperature: prediction and measurement methods-a review, MarcioBacci de Silva*,James Wallbank, to measure tool temperature distribution within the tool by means of fine powders that have a constant melting point. The tool was divided into two symmetrical parts parallel to the chip flow direction and fine powders were scattered on the side of the divided surfaces. The tools were then put together and used to cut. The temperature distribution is obtained using different powders and observations were made of the melted areas. Some results observed that using this method temperature tends to be absorbed gradually at a point away from the cutting edge, but very rapidly at the cutting edge ,the time required being about 1-2 min. The temperature gradient obtained was little different from that obtained using other methods. The technique of measuring temperature by the method of radiation is sometimes very useful in obtaining the temperature of the surface of work piece. This method gives information only about the temperature on exposed surfaces, although some experimental techniques attempted to measure the temperature distribution on the flank or the rake face of the tool through small holes in the work piece. The radiation methods are very complicated and are suitable for laboratory studies. Extreme care is required assembling and using radiation pyrometer and the minimum temperature detectable is a limiting factor for the use of these set -ups. According to cutting forces value, the rate of energy (Wc) consumed in metal cutting was found to be Wc = Fv*V, Where, Fv –cutting force (N) V-cutting speed (m/s) Considering, all the mechanical work done in machining process at primary deformation zone was converted into Heat. Then the amount of heat generated (Qs) was given to be, Qs=Wc = Fc*V

Material	Model type	Thermal Conductivity	Specific heat	Mass Density
WC-CO	LineaElastic Isotropic	84.02 W/m K	150 J/kg K	14200 Kg/m^3

According to first law of thermodynamics.
The finite element method has gained importance for simulating metal cutting processes [4-6]. Finite element models are widely used for calculating the stress, strain, strain-rate and temperature distributions in the primary, secondary and tertiary zones.

II. PROBLEM DESCRIPTION

A insert of SNUN 120408 specification was taken 12 here indicated the length of cutting edge to be 12mm,04 indicates the thickness of the insert to be 4mm and 08 represents the nose radius to be 0.8mm.The main objective is to analyze the thermal influence of heat flux in both coated and uncoated tool during cutting operation using solid works Software. The heat diffusion equation is subject to two types of boundary conditions: imposed heat flux and constant convection in the remaining regions of the cutting tool.



Mass:0.008148 kg
Volume:5.73802e-007 m^3
Density:14200 kg/m^3
Weight:0.0798504 N

Study name	Study 1
Analysis type	Thermal(Transient state)
Mesh type	Solid Mesh
Solver type	FFEPlus
Solution type	Transients state
Contact resistance defined?	No
Result folder	SolidWorks document (H:\toolbit)

Modelling of Tool Insert and Type of analysis

Fig1 shows the finite element discretization of the cutting tool where heat is dissipated at the tip of the cutting tool. In this work, triangular sections are taken to allow for the application of the triangular elements in the modelling of the cutting tool. It is assumed that triangular element results with approximate 3-D element results. Hence existing 3-D software is used to solve the model of the cutting tool.The following Methodology were considered in the present analysis: 3D geometrical domain; study regime; no radiation models; constant thermal properties; perfect thermal contact and no thermal resistance contact between the coating layer and the substrate body; uniform and time-dependent boundary conditions of the heat flux q''(t).

Thermal Loads:

Inlet Temperature	Convection coefficient	Bulk Temperature
400 C	25W/m^2	25 C

III. FNINITE ELEMENT METHOD:

The main objective is to analyze the thermal influence of heat flux in both coated and uncoated tool during cutting operation using Solid works Software.
Tool insert of 12×12×04 mm3 volume was made with value of Thermal conductivity (k)= 84 WmK-1, Density (ρ)= 14100 kg/m3, Specific heat capacity (cp)=150 Jkg-1K-1 then meshing of insert was done and the area where the contact between work piece and tool is going to take place is made much denser to obtain better view of temperature profile. In this case tetrahedral meshing was done along the volume. The numerical meshing(FEM) was done using Solidworks simulation. software generated a three-dimensional structure mesh.
In this paper, a Lagrangian finite element code solidworks simulation in orthogonal metal cutting with continuous chip formation produced by plane-faced uncoated and differently coated carbide tools. The entire cutting process is simulated, i.e. from the initial to the unsteady-state phase. A unsteady state 3-D analytical model to determine the average temperature in metal cutting. They calculated the average temperature rise in chip based on the existence of two heat sources, shear plane and tool-chip interface.

IV. RESULTS &NUMERICAL VALIDATION

A study about the influence of mesh refinement on the temperature results was carried out. The analysis of the numerical mesh convergence was done by using the following thermal properties of Thermal conductivity (k)= 84 Wm-1K-1, Density (ρ)= 14100 kgm-3, Specific heat capacity (cp)=150 Jkg-1K-1
Heat transfer that are governed by partial differential equation which are inadequate to give analytical solutions, except for very simple cases. Therefore to analyze the thermal simulation, domains are required to be split into smaller sub domains (triangles in 3D) as shown in figure 1.

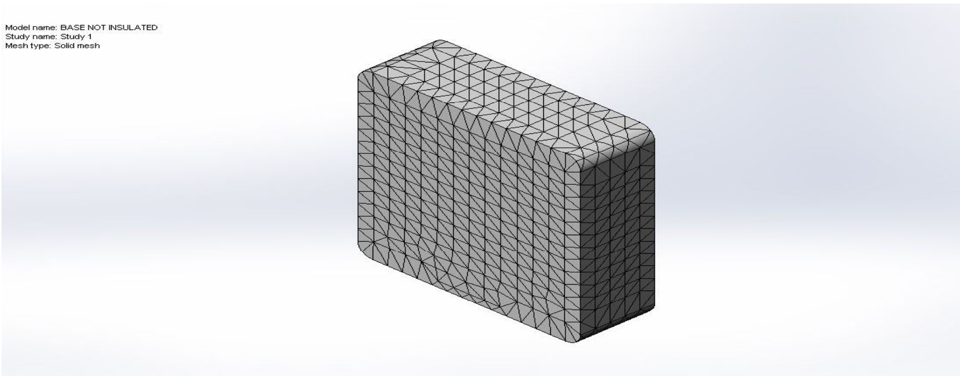


Fig 1 Discretization elements of the cutting tool

Meshing information:

Mesh type	Total Nodes	Total Elements	% of elements with aspect ratio<3	Mesh quality
Solid mesh	**10080**	**6495**	**99.8**	**High**

Meshing of insert was done and the area where the contact between work piece and tool is going to take place is made much denser to obtain better view of temperature profile. In this case tetrahedral meshing was done along the volume. The numerical meshing was done using Solidworks simulation . The software generated a three-dimensional structure mesh.After generation of mesh the value of heat flux (Φ) was inserted which was found to be 1.36×107 Wm-2 . During operation the time duration of machining was taken to be 110 seconds with equal time interval of 0.22 seconds was maintained for analysis i.e, after every 04 seconds it gets analyzed for better result and room temperature was maintained at 20°C, and a constant and equal heat transfer coefficient of 25 Wm-2K-1 was taken.

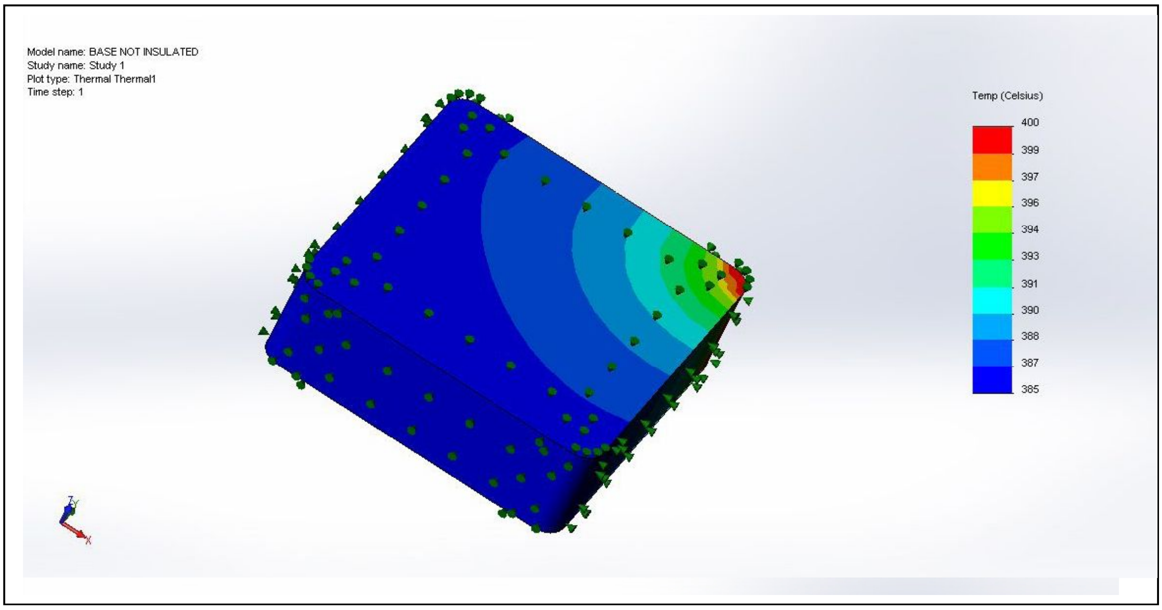


Fig.2 Temperature distribution of cutting tool when base is convecting

From the results obtained in FEM analysis as shown in Fig. 2, it was observed that the maximum temperature is 400ºC and the minimum temperature is 385ºC. The temperature at any point can be deducted from the results above. Therefore, the temperature at the tip of the cutting tool is higher than that far away from the cutting tool. when the carbide cutting tool was air-cooled, it maintained constant temperature of 30 ºC.

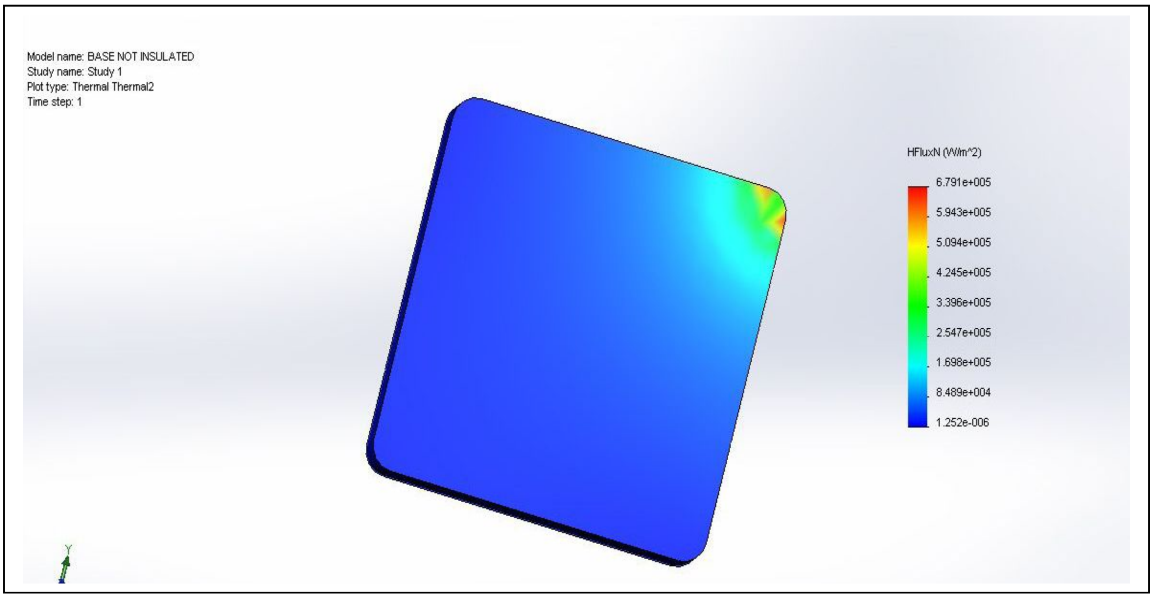


Fig.3 Heat flux distribution of cutting tool when base convecting

Fig.2&3 when carbide cutting tool was not convecting, the temperature & heat flux increases rapidly

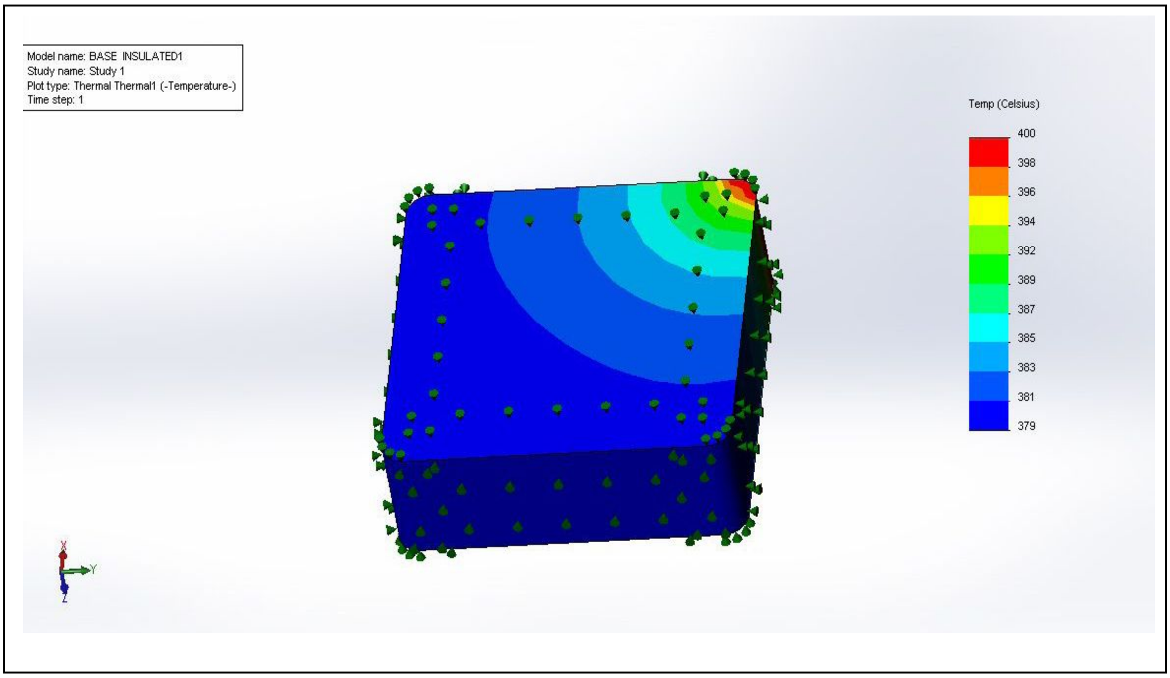


Fig.4 Temperature distribution of cutting tool when base not convecting

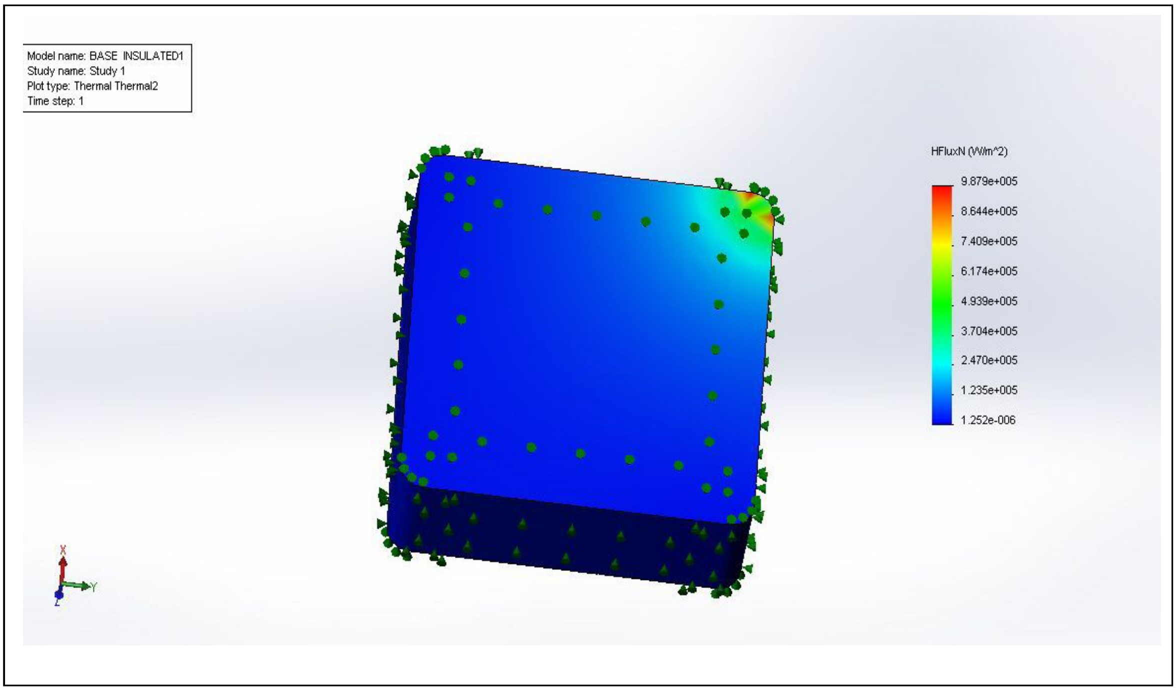


Fig.5 Heat flux distribution of cutting tool when base not convecting

Compare Fig2,3 temperature & heat flux increases rapidly when base in convecting. If base not convecting temperature and heat flux normally increases

V. CONCLUSIONS

A more detailed investigation is necessary in order to include other types of coating materials, their thickness, considering the influence of temperature variation on the thermal conductivity k and specific heat capacity Cp.Future FEM research should concentrate on understanding the tool-chip interaction zone,especially from a friction and plastic flow standpoint. Additionally, the effects of temperature on tool wear should be investigated. The models can be used to investigate the effects of the major parameters on the cooling efficiency. Without involving intensive computation for chip formation analysis, this study used the derived heat-source characteristics as the input of temperature simulations.

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