Analysis of Temperature in Orthogonal Cutting

Dinesh Singh, Department of Electrical Engineering
Galgotias University, Yamuna Expressway Greater Noida, Uttar Pradesh
E-mail id - dineshsingh@Galgotiasuniversity.edu.in

Abstract: In this paper, a study based on the finite difference method is presented to anticipate tool and chip temperature fields in continuous as well as interrupted machining. Continuous machining operations like orthogonal cutting are considered for study the heat transfer between the tool and chip at the tool rake face contact surface. For temperature variation, primary heat zone is considered where number of parameter come into analysis i.e. shear energy created in primary zone, friction energy produced at chip tool interface. Later, model is extended to to milling where cutting is interrupted. it is discovered that increasingly steady expectations of rake face temperatures can be made. From this work data has been gotten on the state of the zones of plastic distortion in metal cutting and on the appropriation of heat age inside these zones.

Keywords: Orthogonal Cutting, Machining, Temperature, Tool Rake Face, Accuracy, Precision, Measurement.

INTRODUCTION

The analysis of temperature generation at primary zone in machining processes has been well recognised in the field of researchers for machining. Temperature is the one of the main factor that is considered in calculation of the tool life [1]. Hence, it is one of the main criteria to calculate the overall productivity [2] . Temperature consideration, such as cutting speed and feed rate, is the key factor in the selection of process parameters. In the material that was processed by the machining process, apart from the mechanical stress, other thermal stresses were applied because of the material's conductivity. The thermal stresses are directly related to fatigue of the instrument and loss due to fracture, wear or chipping. If thermal stresses are not properly managed, the risk of tool failure will increase and the life of the tool will also decrease.. The tool chip interface temperature can be divided in two parts, firstly temperature generated due to plastic deformation at shear zone, secondly, temperature also generated due to friction between the chip and tool face contact region [3].

Figure1 shows acting of the forces in the orthogonal cutting. Work consumption W in the orthogonal cutting is the function of the cutting force Fc and cutting velocity V_c, thus

$$W = F_c \times V_c \qquad \text{eq. (1)}$$

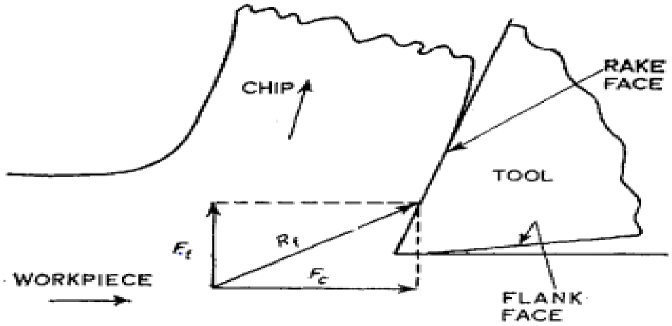
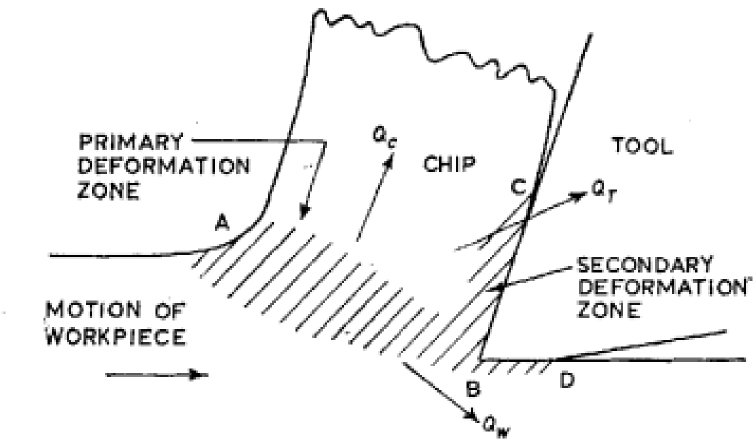


Fig.1 Forces acting in machining

As we know that this work consumption converted in to heat in the region of plastic deformation [4][5]. In the chip tool interface, there are two plastic deformation regions ,The first region of plastic deformation which is also known as the primary deformation zone as well as shear zone and secondary deformation zone i.e. friction forces is acting between the tool and chip [6]. As shown in fig. 2, AB is the region where the work material undergoes shear action, this is the shear zone, and BC is the region where a large amount of friction force acted which causes severe deformation in the chip material .this region BC is the secondary deformation region[7][8]



Where, Q_c = heat carried by chip
Q_T = heat carried by tool
Q_w = heat carried by work piece

Fig. 2 Distribution of Generated Heat in Machining

METHODOLOGY

As explained in the previous analytical description of the cutting temperature, it was believed that work material undergoes shear action on the plane (known as shear plane) and produces uniform intensity of heat due to shearing [9]. It was also considered that the heat produced was also of uniform strength due to friction between the instrument and chip. Fig. 3 illustrated the idealized model of the chip tool interface during the machining process [10].

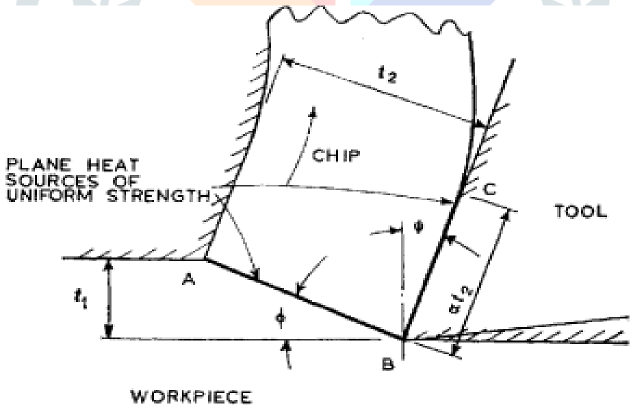


Fig. 3 Idealized Model of Chip Tool Interface

Where, t_1 = uncut thickness of chip
t_2 = cut thickness of chip
ϕ = Shear angle
ψ = Rake angle of used tool
$\alpha\, t_2$ = contact length of tool chip

When the some work piece of material is undergone the machining process, the variation of the plastic deformation in primary shear zone [11].

Temperature in the primary shear zone

Assumption is made that within practical cutting speed, flow of heat due to conduction in the work material is neglected. Basic equation of heat transfer in material moving in x direction relative to stationary heat source

$$\frac{\delta^2\theta}{\delta y^2}+\frac{\delta^2\theta}{\delta x^2}-\frac{\mathrm{R}}{t1}\frac{\delta\theta}{\delta x}=0$$

Where θ = temperature
t1 = uncut thickness
R = thermal number = $\frac{\rho cvt1}{k}$
ρ = density
c = specific heat
k = heat conductivity
v = velocity

Temperature in the chip and along the tool chip interface

Again refer fig.6; Rapier solved the conduction equation within the boundary condition. Rapier given his results for temperature distribution as follow

$$\frac{\alpha\theta}{R\theta_f^2}\simeq 1.15\sqrt{\frac{x}{Rt_2}}$$

Where t_2 = cut thickness of chip
αt_2 = length of contact between chip and tool
R =thermal number = $\frac{\rho cvt1}{k}$
x = distance along the heat source from end of shear plane
θ = increase in the temperature of the chip
θ_f = average increase of the temperature

Analysis of Experimental result

As a will to find out the more accurate result, a heat balance sheet was drawn on the basis of the heat carried by the work piece, tool and chip. The heat carried by the different element of the chip tool interface is studied and observation is used to drawn the graph as shown in figure 7.

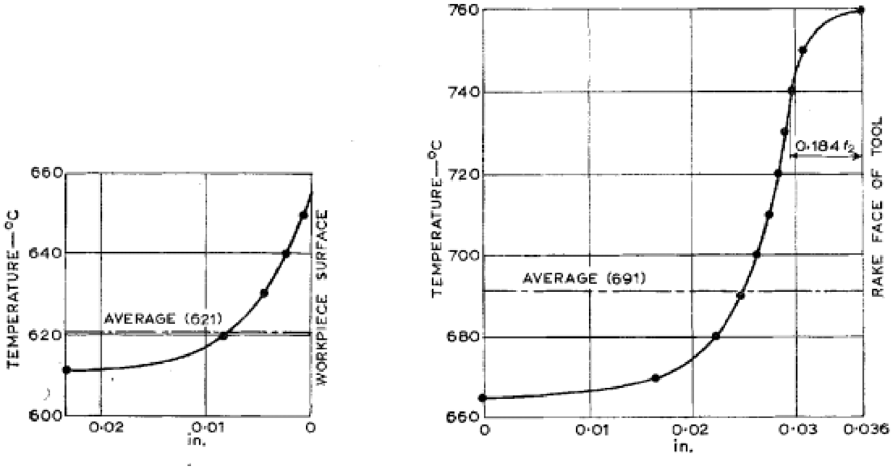


Fig. 4. Experimentally Determined Temperature Distribution [2]

DISCUSSION

Compared to the estimation of the experimental findings with the prediction of prior hypotheses, it is incredible. The distribution of temperature in the work piece and chip is indicated by this study. For the experimental end results, this often utilises the boundary condition of the Rapier. A qualitative comparison between these theoretical findings and the experimental results potentially indicates that errors have occurred in the theoretical predictions since the heat sources are believed to be flat.

CONCLUSION

The results of this work indicate that the distribution of heat generation rate within the plastic zones is an important factor in the determination of the temperatures in metal. It has been shown that the rise of temperature in the chip is very sensitive to small changes in the width of the distributed frictional heat source. It is further visible that the temperature along the rake face of the device had been substantially over envisioned. Thus, earlier than a correct prediction of the temperature distribution within the reducing procedure can be made. Because plane heat sources have been assumed in all previous work on reducing temperatures, an indication of the shape of the plastic deformation zones and the distribution of heat generation within them is relevant in the present discussion.

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