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Effect of Temperature Distribution onTool Life in Turning Process: a Review

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ABSTRACT: Temperature on the chip-tool interface is important parameters in the analysis and control of machining process. Due to thehigh shear and friction energies dissipated during a machining operation the temperature in the primary and secondary shear zones areusually very high, hence affect the shear deformation and tool wear. This paper is a review of research work in last decade ontemperature distribution in turning process. Research is going on to investigate the level of maximum temperature generated at tool rakefaceandtocontrolthistemperaturetherebyimprovingthetoollifeandqualityofworkpiece.Inthisstudy,thetemperatat uregeneratedon rake face of cutting tool and experimental methods for measurement of temperature are reviewed. Out of number of interfacetemperature measuring methods, the special attention has been paid to the tool work thermocouple as it is easy to apply and inexpensiveas compared to other techniques. The procedure for the working of tool work thermocouple and the method of calibration is described inthis paper. The calibration set up establishes the relationship between emf developed and the cutting temperature. To compare andvalidate the experimental results, the FEA model is the best way and also it helps to locate the highly temperature affected area on thetoolinsert.
Keywords: Temperaturedistribution,Tool-workthermocouple,FEA

I. INTRODUCTION

The importance of knowledge on the temperature gradientand its distribution within the cutting zone resulting fromchanges in the cutting conditions is well recognized due tosevereeffectsonthetoolandworkpiecematerialspro perties and a considerable influence on the tool wear [1],3]. In general, three regions of intensive heat generation aredistinguished, namely the primary shear zone, the tool–chipinterface or the secondary deformation zone and the tool–workpieceinterface.

Heat is removed from the primary, secondary and tertiaryzonesbythechip,thetoolandtheworkpiece.Fig .1schematicallyshowsthisdissipationofheat.Thetem peratureriseinthecuttingtoolismainlyduetothesecond aryheatsource,buttheprimaryheatsourcealsocontribu tes towards the temperature rise of the cutting tooland indirectly affects the temperature distribution on the toolrakeface[11,14]

During the process, part of the heat generated at the shearplane flows by convection into the chip and then through theinterfacezoneintothecuttingtool.Therefore,thehea tgeneratedattheshearzoneaffectsthetemperaturedistr ibutions of both the tool and the chip sides of the tool–chip interface, and the temperature rise on the tool rake faceis due to the combined effect of the heat generated in theprimaryandsecondaryzones[14].

1.1. EstimationofHeatGenerationinMetalCutting

The rate of energy consumption in metal cutting is given by:$W_C= F_V V$

Where, Fv is the cutting force and V (m/sec) is the cuttingspeed.

Assumingthatallthemechanicalworkdoneinthemachi ningprocessisconvertedintoheat[5,6],heatgeneration intheprimarydeformationzonemaybecalculatedfrom theworkdoneandthecuttingforceFv,as:

$Qr = FvV$

The amount of heat generated due to the work done in thesecondarydeformationzonealongthetoolrakefacei scalculated from the friction energy given by the followingequation:

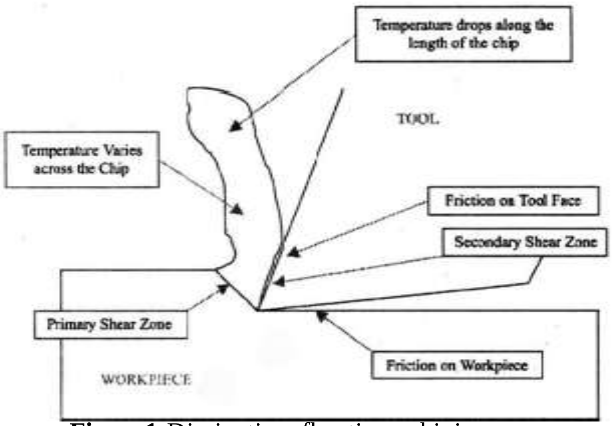

Figure1: Dissipationofheatinmachining

$Q_S = F_{Fr} V / \mu$

Where, F_{fr} is the total shear force acting on the rake face (N),Visthecuttingspeed(m/s)andμisthechipthickness ratio.

TheforceF$_{Fr}$canbecalculatedbyusingthefollowingequation:

$F_{fr} = F_V \sin\alpha + Fs\cos\alpha$

Where, Fv is the cutting force, Fs is the feed force and α istherake angle.

1.2 ToolWorkThermocouple

Thetool-workthermocoupleisworkontheprincipleofseebeck effect which states that if there is a temperaturedifference between any two junctions then there will be adevelopment of emf in between the two junctions [13, 14].Theprincipleofthis methodis showninfig.2

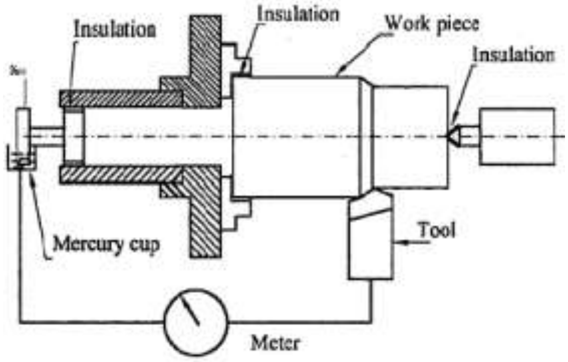

Figure2: SetupofTool-WorkThermocouple

In a thermocouple two dissimilar but electrically conductivemetals are connected at two junctions. Whenever one of thejunctions is heated, the difference in temperature at the hotand cold junctions produces a proportional current which isdetected and measured by a milli-voltmeter. In machininglike turning, the tool and the job constitute the two dissimilarmetals and the cutting zone functions as the hot junction.Then the average cutting temperature is evaluated from themVafterthoroughcalibrationforestablishingtheexactrelation between mVand the cutting temperature [13, 14,and 16]. Fig. 3 typically shows a method of calibration formeasuringaverage cuttingtemperature in turningsteel rodbyuncoated carbide tool.

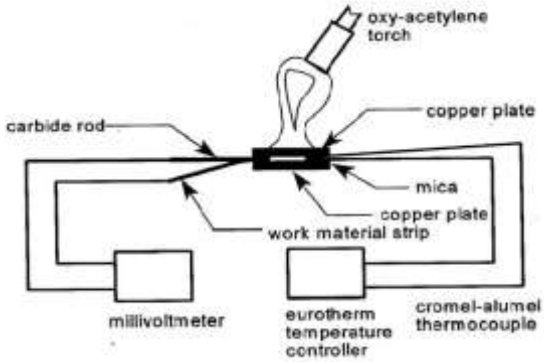

Figure3: Calibrationsetupoftool-workthermocouple

Inthisworktool-workthermocouplejunctionwasconstructedusingalongcontinuouschipofthework-material and a tungsten carbide inserts to be used in actualcutting and clamped to the copper plate. A standard Alumel-chromel thermocouple is mounted at the site of tool-work(junctionofchipandinsert)junction.Theoxyacetylenetorch heated the copper plate and it simulated the thermalperformancephenomenainmachiningandraisedthetemperatureatthechip-toolinterface.Standardthermocouples directly monitored the junction temperature(Alumel-chromel thermocouple) while the emf generated bythe hot junction of the chip-tool was monitored by a digitalmilivoltmeter[14].

1.3 Finite Element Analysis

A commercial finite element analysis system ANSYS 14 isusedtosolvetheproblemofthermaldistributioninthe cutting tool insert. The analysis is based on the experimentalvalues of the temperature at the tool work interface, cuttingforcesinducedinmachining,mechanicalpropertiesofmaterialusedandthecuttingconditionsapplied[5,6,7,16].

II. LITERATURE REVIEW

X. L. Liu et al. investigated the performance of PCBN toolin the finish turning of GCr15 bearing steel with differenthardness between HRC30and 64. A natural thermocouplewas used to measure the cutting temperature, and tool lifeandcuttingtemperaturewereinvestigatedandcompared[1].

W.Grzesiketal.obtainedsomeresultsofextensiveexperimentalinvestigationsofthethermalinteractionsbetween the coating/substrate and the moving surface of thechip.Semiorthogonalcuttingwhenbarturningmediumcarbon steel and an austenitic stainless steel was carried out.Bothflat-facedandgroovedinsertscoatedwithTiC,TiC/TiN, and TiC/Al_2O_3/TiN was tested. A standard K-typethermocoupleembeddedintheworkpiecewasusedtoconvert measured emf's to the interfacial temperatures. Inaddition, the chip rake contact length and the area of contactwere determined by using computer processing of scannedcontactimages.Theminimum steady-statetemperatureattheinterfacebetweenthemovingchipandthecoatingsubstrate system was explained in terms of the heat fluxintensity and the thermal properties of both components of auniqueclosed tribo-system[3].

JosefMayretal.performedsomeexperimentsonmeasurement of temperatures and displacements, especiallydisplacementsatthetoolcentrepoint,computationsofthermal errors of machine tools, and reduction of thermalerrors.Computingthethermalerrorsofmachinetoolsincludeboth,temperaturedistributionanddisplacements.Shortlyaddressedisalsotoavoidthermalerrorswithtemperaturecontrol,theinfluenceoffluidsandashortlinktoenergy efficiencyof machine tools[4].

PradipMujumdaret al. developed a finite element basedcomputationalmodeltodeterminethetemperaturedistributioninametalcuttingprocess.Themodelisbasedon multi dimensional steady state heat diffusion equationalong with heat losses by convection film coefficients at thesurfaces.The modelsfor heatgenerations withinprimaryand secondary zones, and in the rake face due to friction atthe tool–chip interface are discussed and incorporated in theFEMmodel.Resultsarepresentedforthemachining ofhigh-speed carbon steel and for a range of cutting conditions[5].

W. Grzesiket al. investigated the

applicability of varioussimulationmodelstoobtainfiniteelementsolutionsofcuttingforces,specificcuttingenergyandadequatetemperatures for a range of coated tool materials and definedcutting conditions. The various thermal simulation resultswerecomparedwiththemeasuredcuttingtemperature[6].

SaratBabuSingamneniintroducedanewmethodofsolving the thermal fields of metal cutting tools combiningcertain classical techniques suggested in the past with somerelativelynewmethodsofthecontinuumapproach.Themovingworkpieceandthechipareconsideredas onedomain and the stationary cutting tool as another domain tosimulate the material flow conditions. The iterative solutionsufficiently takes care of the distribution of the primary andsecondaryheatsourcesandtheneedtoassumeaheat partition coefficient is eliminated. A mixed finite elementand boundary element method finally enables the estimationofthe cutting temperatures[8].

N. A. Abukshinet al. presented the results of temperaturemeasurementsonthetoolrakefaceduringorthogonalcuttingatcuttingspeedsrangingbetween200 and1200m/min.Thesemeasuredtemperaturesarecomparedwithtemperature fields in the cutting tool obtained from a finiteelement transient thermal analysis and showed the tool–chipcontact area, and hence the proportion of the secondary heatsource conducting into the tool, changes significantly withcuttingspeed[11].

AbhijeetAmritkaretal.designedanddevelopedacalibration set-up in order to establish a relationship betweenobtained emf during machining and the cutting temperature.Also,themostsimplestandeconomicaltechniqueoftemperaturemeasurementi.e.tool-work thermocouple set-upwasdevelopedforthemeasurementofthecuttingtemperatureinmachining[13].

L.B.Abhangmeasuredexperimentallythetool-chipinterfacetemperatureduringturningusingatool-workthermocoupletechnique.Firstandsecondordermathematical models are developed in terms of machiningparametersbyusingtheresponsesurfacemethodologyonthebasisoftheexperimentalresults.Theresultsareanalyzedstatisticallyandgraphically.Themetalcuttingparameters considered are cutting speed, feed rate, depth ofcutand toolnose radius[14].

III. CONCLUSION

In the literature review, there have been many experimentsandreportsabouttemperaturemeasurementduringmetalcutting.Inthiswork,thetool-chiptemperaturehasbeenstudiedbyusingtool-workthermocoupletechnique.Thetool-work thermocouple technique is the bestmethod formeasuringtheaveragechip-toolinterfacetemperatureduring metal cutting. The benefits of using the tool-workthermocouple are its ease of implementation and its low costas compared to other thermocouples. The tool-chip contactareadecreaseswithcuttingspeedandcontacttimeinconventional cutting region. As the amount of heat removedby the chip increases, the fraction of heat flowing into thecutting tool decreases. The temperature of the tool rake faceincreases with the cutting speed. FEA results determines thatthemaximumtemperature,atthetool-chipcontactisincreasingwithcuttingspeed but notlinearlyduetothefashion of the heat flowing into the tool. A force has beenfound to be an important variable in generation of surfacetemperature.

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