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Review Study on Finite Element Analysis of Single Point Cutting Tool

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Abstract:- In this report, we analytically predict and examine temperatures in tool-chip interface used in high speed orthogonal machining operations. Specifically, three different analysis was compared to an experimental measurement of temperature in a machining process at slow speed, medium speed and at high speed. In addition, three analyses were done of a High Speed Steel and also of a Carbide Tip Tool machining process at three different cutting speeds, in order to compare to experimental results produced as part of this study. An investigation of heat generation in cutting tool was performed by varying cutting parameters at the suitable cutting tool geometry and results were saved in computer; then the graph's of tool-chip interface temperature vs. various cutting parameters were obtained. the experimental results reveal that the main factors of the increasing cutting temperature are cutting speed (V), feed rate (S),and depth of cut (h), respectively. It was also determined that simultaneously change in cutting speed and federate has the maximum effect on increasing cutting temperature. Much research has been undertaken into measuring the temperatures generated during cutting operations. Investigators have attempted to measure these cutting temperatures with various techniques used to evaluate the temperature during machining.

Keywords:- *Single* Point Cutting Tool (HSS) tool and Carbide tip tool (P - 30), Computer Aided Design (CAD), Centre lathe, Fluke 62 max IR thermometer (Range -40 ^{0}C to 650 ^{0}C), Finite Element Analysis, Solid Modeling.

I. INTRODUCTION

Machining is one of the most common manufacturing processes for producing industrial pieces of desirable dimensions. Removal of unwanted material from a work piece and obtain specified geometrical dimensions and surface finish is done by machining. Those cutting condition and quality of machining operation can be determined by understanding the deformation characteristics of material removal process and the distributions of the process variables such as stresses and temperatures in machining (Pantalé et al., 2004). There are considerable amount of research devoted to develop analytical, mechanistic and Finite Element Method (FEM) based numerical models to simulate metal cutting processes. This is due to finite element methods can be adapted to problems of great complexity and unusual geometry. Moreover, they are an extremely powerful tool in the solution of important problems in thermal analysis, fluid mechanics, and mechanical systems also. (Hutton, 2004) FEM based simulation models are primarily focus on conventional machining and prediction often goes to chip formation, computing distributions of strain, strain rate, temperatures and stresses on the cutting edge, in the chip and on the machined work surface among those researches have been performed (Pantalé et al., 2004 and Özel, 2006). An investigation of heat generation in cutting tool was performed by varying cutting parameters at the suitable cutting tool geometry and results were saved in computer; then the diagrams of tool temperature vs. various cutting parameters were obtained. the experimental results reveal that the main factors of the increasing cutting temperature are cutting speed (V), feed rate (S),and depth of cut (h), respectively. It was also determined that simultaneously change in cutting speed and feed rate has the maximum effect on increasing cutting temperature.

1.1 PROBLEM STATEMENT

Single-point cutting tool is principally used in the manufacturing of components with required surface finish. The setup parameters for the turning process are usually selected with the aid of trial cutting experiments conventionally, which are both time consuming and costly.

II. LITERATURE REVIEW

The purpose of this chapter is to provide a review of past research efforts related to orthogonal cutting, turning, single-point cutting tool and finite element analysis. A review of other relevant research studies is also provided. Substantial literature has been studied on model geometry, material model and properties, and finite element analysis of single-point cutting tool. There are information can be found on method to develop numerical model also. The review is done to offer insight to how past research efforts have laid the groundwork for subsequent studies, including the present research effort. The review is detailed so that the present research effort can be properly tailored to add to the present body of literature as well as to justly the scope and direction of the present research effort.

III. TURNING

Turning is one of the typical machining processes that remove unwanted material in which the work piece is rotated with utilization of a single point tool by producing chips. It is accomplished by using lathe as machine tool. The adjustable variables for turning process are the cutting speed *Vc* (f.p.m. or m.s-1) which is velocity of the cutting tool travel to the left as the work piece, the feed *f* (i.p.r. or mm.rev-1) that refer to the distance of the tool travels horizontally per unit revolution of the work piece, and the depth of cut *d* (in or mm) where the cutting tool is set. To a good approximation, the chip is produced in plane strain and hence the width of chip is equal to the unreformed chip width since the depth of cut (*d*) is usually at least five times the feed (*f*) (Kalpakjian, and Schmid, 2006). Figure 2.1 illustrates main features of a typical turning process where work piece, cutting tool, and machining parameters are shown.

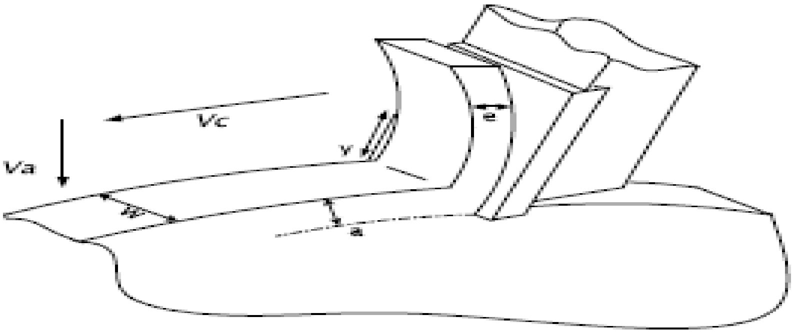

Figure 2.1: Turning process

[Lower and Shaw][1] developed analytical prediction model for the measurement of cutting temperature during machining. They concluded that the cutting temperature is the function of cutting speed and feed rate.

$\theta t = V\ 0.5 * t\ 0.3$ (1)

Where, θt = Average cutting temperature
V = cutting speed
t = undeformed chip- thickness or feed rate.

[Stephenson][2] and [Wardeny et al][3] suggested that the temperature distribution in the tool may be obtained by using information about the changes in the hardness and microstructure of the steel tool. It is necessary to calibrate the hardness of the tool against the temperature and time of heating and samples of structural changes at corresponding temperatures. These methods permit measurement of temperatures to an accuracy of ± 25 ^{0}C within the heat affected region.

[ABHANG L.B.][4] worked to measure the tool-chip interface temperature experimentally during turning of EN-31 steel alloy with tungsten carbide inserts using a tool-work thermocouple technique. First and second order mathematical models are developed in terms of machining parameters by using the response surface methodology on the basis of the experimental results. The results are analyzed statistically and graphically. The metal cutting parameters considered are cutting speed, feed rate, depth of cut and tool nose radius. It can be seen from the first order model that the cutting speed, feed rate and depth of cut are the most significantly influencing parameters for the chip-tool interface temperature followed by tool nose radius. Another quadratic model shows the variation of chip-tool interface with major interaction effect between cutting speed and depth of cut (V*D) and second order (quadratic) effect of cutting speed (V^2) appears to be highly significant. The results show that increase in cutting speed, feed rate and depth of cut increases the cutting temperature while increasing nose radius reduces the cutting temperature. The suggested models of chip-tool interface temperature adequately map within the range of the cutting conditions considered. Temperature on the chip-tool interface is important parameters in the analysis and control of machining process. Due to the high shear and friction energies dissipated during a machining operation the temperature in the primary and secondary shear zones are usually very high, hence affect the shear deformation and tool wear. In a single point cutting, heat is generated at three different zones i.e. primary shear zone, chip tool interface and the tool work-piece interface. The primary shear zone temperature affects the mechanical properties of the work piece-chip material and temperatures at the tool-chip and tool-work piece interfaces influence tool wear at tool face and flank respectively. Total tool wear rate and crater wear on the rake face are strongly influenced by the temperature at chip-tool interface. therefore, it is desirable to determine the temperatures of the tool and chip interface to analyze or control the process. To measure the tool temperature at the tool chip interface many experimental methods have been developed over the past century. Since at the interface there is a moving contact between the tool and chip, experimental techniques such as standard pre calibrated thermocouples cannot be used to measure the interface temperature.

[S.K. Chaudhary et al.][5] Predicted cutting zone temperatures by natural tool work thermocouple technique, when machining EN 24 steel work piece and HSS with 10% cobalt as the cutting tool. The results indicated that an increase in cutting speed and feed rate resulted in an increase in tool wear and cutting zone temperature increases with the increase in the cutting speed. While in the whole range of feed the temperature increases with increase in feed rate.

[Federi com Aneriro et al.][6] Investigated the influence of cutting parameters (cutting speed, feed rate and depth of cut) on tool temperature, tool wear, cutting forces and surface roughness when machining hardened steel with multilayer coated carbide tools. A standard K-type of thermocouple inserted near the rake face of the tool was used to measure the interface temperatures. They concluded that the temperature near the rake face increases significantly when the depth of cut changes from 0.2 to 0.4 mm. The increase in contact length between chip and rake face could be responsible, since it grows, together with uncut chip cross-section. Similar trend was observed in the cutting forces, tool wear and surface roughness during machining of hardened steel.

[H. Ay and Yang][7] used a technique with K thermocouple to analyze temperature variations in carbide inserts in cutting various materials such as copper, cast iron aluminum 6061 and AISI 1045 steel. They observed oscillations in temperature near the cutting edge, which were more marked for ductile materials and less in the hard –machining materials. These observations were attributed to the chip formation and its contact with the work material.

[Kashiway and Elbestawi][8] investigated the effect of cutting temperature on the integrity of machined surface. It has been shown that cutting temperature has a major effect on the integrity on the machined surface. The undesirable surface tensile residual stresses were attributed to the temperature generated during machining. Therefore, controlling the generated tensile residual stresses relies on the understanding of the effect of different process parameters on the cutting temperature.

[B.Findes, et al][9] Studied the influence of cutting speed, feed rate and depth of cut on cutting pressures, cutting force and on cutting temperature, when machining AISI H11 steel treated to 50 HRC work piece material with mixed ceramic tool. The results show that depth of cut has great influence on the radial cutting pressure and on cutting force. The cutting pressure and cutting force increase with an increase in depth of cut and feed rate. It is found that increase in cutting speed increases cutting zone temperature rapidly. It is also noted that cutting speed seems to influence temperature in cutting zone more significantly than the depth of cut and feed rate.

[W. Grzesik][10] His work related to create a FEM simulation model in order to obtain numerical solutions of the cutting forces, specific cutting energy and adequate temperatures occurring at different points through the chip/tool contact region and the coating/substrate boundary for a range of coated tool materials and defined cutting conditions. Results showing how the tool chip interfacial friction influences the temperature distribution fields as the effect of using coated tools are the main and novel findings of this paper. The various thermal simulation results obtained were compared with the measurements of the average interfacial temperature and discussed in terms of various literature data. The finite element simulations performed demonstrate the existence and localization of the secondary shear zone. A good agreement was achieved, especially for uncoated and three-layer coated tools, between predicted and experimental values of cutting temperatures. It was documented that coatings cause that areas with the maximum temperatures are localized near the chip and work piece. In consequence, the maximum interface temperature exists in the vicinity of the cutting edge. i.e. in the first part of the tool-chip contact. Also the substrate is distinctly cooler in comparison to uncoated tools.

[Kazban Roman V.][11] His work related to the machining industry for cost reduction and increases in productivity have contributed to new interest in high-speed machining. Even though, many model for machining exist, most of them are for low-speed machining, where momentum is negligible and material behavior is well approximated by the quasi-static laws. In machining at high speeds momentum could be large and the strain rate can be exceedingly high. For these reasons a fluid mechanics approach to understanding high-speed, very high-speed and ultra-high speed machining is attempted here. Namely, a potential flow solution is used to model the behavior of the material around a tool tip during machining at high speeds, i.e. greater than or equal to 100 m/s. It is carefully argued that the potential flow solution is relevant and can be used as a first approximation to model the behavior of a metal during high-speed, very high-speed or ultra-high-speed machining events. At a minimum, the potential flow solution is qualitatively useful in understanding mechanics of high-speed, very high-speed and ultra-high-speed machining. Interestingly, the flow solution predicts that there is a “stagnation" point on the rake face, not at the tool tip as is usually assumed. Because the “stagnation" point is not at the tool tip, the flow solution predicts a significant amount of deformation in the work piece resulting in large residual strains and a possible related temperature rise on the finished surface. To verify the fluid flow model, an experimental apparatus has been designed to examine fluid flow in orthogonal machining. Experiments were conducted at room temperature for different Newtonian fluids, cutting conditions and cutting tools. It was seen that, indeed, the “stagnation" point is not at the tool tip. Next, a modified Hopkinson bar apparatus is employed to simulate dry orthogonal machining at 30 m/s cutting velocity. A focused array of Mercury-Cadmium-Tellurium infrared detectors is used to measure the temperature distribution. A three-component quartz force transducer is utilized in measuring the cutting and feed forces. Measurements of the cutting and feed forces contributed to the ability to prove the steady-state conditions as well as to estimate the coefficient of friction on the tool rake face along with the partition of the thermal energy produced during the high-speed machining process. Force measurements show that at this speed, on the upper boundary of the range of cutting velocities for high-speed machining not high enough to be very-high speed or ultra-high speed cutting, the role of momentum is negligible and the cutting event is dominated by material deformation, making the fluid model less applicable. Much higher cutting speeds, beyond the capability of this apparatus, are needed to make the fluid approach accurate. Not-surprisingly, measurements of temperature distributions showed little heating of the finished surface. Therefore, a study of the temperature fields generated during machining with a cutting tool that has a wear-land was performed. It is seen that the wear-land contributes significantly to the heating of the work piece and, at this speed, is the most likely mechanism for the generation of residual stress and a temperature rise on the finished surface.

IV. CONCLUSION

As the single point cutting tool is one of the major part of machining process, to increase tool efficiency and performance along with its life. it is very necessary to analysis it by thermally and statically. Because increase in depth of cut and speed friction increase which causes thermal stress along the tool. Many researcher works on this, to improve the life & efficiency by doing different analysis and experimental set up with different models. But still lots of works to be done in future.

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