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EFFECT OF FEED RATEAND RACK ANGLE ON CUTTING FORCE AND GENERATED TEMPERATURE IN AN ORTHOGONAL TRUNING PROCESS

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ABSTRACT: - In this research, a FEM simulation of orthogonal turning process is made. The effects of feed rate and rack angle of cutting tool on cutting force and generated temperature are analyzed. The analyses are curried out using MSC Marc 2013. Cutting tool is considered rigid in the modelling. While work hardening of workpiece material is considered in analysis to provide more accurate results. The results are compared to previous experimental analysis for same material and cutting conditions and show good agreement. Current analysis show that cutting forces increase with the increase of cutting feed, and decrease with the increase of rack angle of cutting tool. Results also show that the temperature rise increase significantly with increase of cutting feed, while change of rack angle does not have clear effect on temperature rise.

Keywords*;* orthogonal cutting, MSC Marc, rack angle, cutting feed.

1- INTRODUCTION

Turning is a very important machining process in industry and has countless applications. The process has been used to reduce the diameter by using the single-point cutting tool which removes the material from the surface of a rotating cylindrical work piece(1). In orthogonal cutting it is observed that the cutting forces and the temperature are directly depended on the cutting parameters such as; Cutting speed, feed rate, depth of cut, tool material, geometry (rake angle) and work piece material, which need to be determined for optimize parameter. Finite element analysis are widely used for calculating the temperatures in the tool, chip and work piece, as well as cutting forces, plastic deformation (shear angles and chip thickness), therefore it's become the main tool for simulating metal cutting processes(2). Researchers have long investigated the effect of different rake angles on cutting forces and temperature, by using modeling and analysis software Ansys, Hendri Yanda et al.(2)studied the effect of rake angle on stress, strain and temperature on the edge of carbide cutting tool in orthogonal cutting. They used FEM simulation of seven simulations for various rake angles of -15 deg, -10 deg, -5 deg, 0 deg, +5 deg, +10 deg, and +15 deg. They showed that the increasing of rake angle in positive section cause a decrease in cutting force and, increasing the rake angle in negative section, increases the cutting force, at constant feed rate and depth of cut. The investigation conducted by Jaharah A.G, et al.(3)presented simulation of turning process of AISI 1045 and carbide tool using finite element method**.** They found that the temperature increases when using negative rake angle. Negative rake angle will increase the cutting force and therefore high heat will be generated in the range of -5° to 5°tool rake angle. Ship-Peng Lo(4) presented an analysis of cutting under different rake angles 5, 10, 15 and 20º using the finite element method show that the increase of rake angles from 10 to15º caused to decrease in the cutting force during required machining, but in the rake angles from15 to 20º the cutting force slightly decrease. The investigation conducted by L. B. Abhang and. Hameedullah[5]found that the maximum temperatures occur in the contact zone between the chip and the tool. There are three main sources of heat generation during the process of cutting metal with a machine tool. Heat is produced in the primary shear zone as the work piece is subjected to large irreversible plastic deformation (Shear- zone).Yaseen. S. J.[6] in his theoretical study of temperature distribution in turning process using a finite element analysis (Deform 3D) show that the effect of different rake angles, feed rates, work piece material on temperature distribution, when the feed rate increase, the cutting force increase due to increase chip section, that cause to high temperature generation, while increasing the rake angle in the positive section cause to reduces the cutting temperature. Satyanarayana Kosaraju et al.[7] presented experimentally study the effect of different rake angles(0^0, 4^0, 8^0, 12^0, 16^0, 20^0) and feed rates (0.022, 0.048, 0.088, 0.108, 0.132 mm/rev) on cutting forces in an orthogonal turning process, by machining EN8 hollow cylindrical work piece, the increase of different rake angles from(0^0 to 20^0) in the positive section cause to, decreases in cutting force and increasing continuously in feed rate with constant of cutting speed and depth of cut. Yash R. Bhoyar et al.[8] show in their study finite element analysis on temperature distribution in turning process using (deform-3D), the maximum interface temperature exists in the first part of the tool-chip contact. G. Ravi Kumar et al. [9] in their analysis show that the maximum temperature during machining process distribution along the rake surface, which is influences to the tool life. Ashutosh. V and Prof. Suman. S. [10] experimentally studied the influence of tool rake angle. They showed that the main cutting force is increased as the tool rake angle increases from 0^0 to 16^0 with several materials of work piece. Lungui. N and Borzant. M. [11] investigated the effect of cutting speed and feed rate on tool geometry, temperature and cutting forces in machining AISI1045 carbon steel using FEM simulation. Their study show that as increasing the feed rate, the temperature increases. The highest value of the temperature (889 °C) is obtained for the feed rate value of 0.2 mm/rev, also the highest values of cutting forces increases as the feed rate is increased. Patil P. K, et al. [12] made analytical investigation of the cutting forces on single point cutting tool by using the MATLAB analysis. The results reveal that by increasing rake angle the forces on cutting tool will decrease.

In current research, the effects of change in rack angle and feed rate on cutting force and temperature rise are analyzed. Workpiece material and cutting conditions are taken similar to those obtained experimentally by a previous research [7].

2. FEM ANALYSIS

The analyses are curried out using MSC Marc 2013 finite element software. The workpiece material is EN8. The mechanical properties of this material are available in literature[13]. MSC Marc allows dealing with complex material models. Such as temperature dependent mechanical properties and strain hardening- dependent plastic properties. But Marc does not facilitate direct dealing with both effects (temperature and strain hardening) simultaneously on plastic properties of material. Several tests were made to evaluate the effect of each parameter on accuracy. It is concluded that strain hardening has the dominant effect on accuracy. So the work hardening of material is considered in analysis. Friction coefficient between cutting tool and workpiece (and chip) is taken as 0.2 [14]. A total of 30 FEM analyses were performed with 6 different rakeangles 0,4,8,12,16,20 Degrees at a constant depth of cut of 2.5 mm at 5 different feed rates0.022,0.048,0.088,0.108and 0.132. These values are selected according to previously published experimental results[7] to facilitate comparison. The analysis considered as plane strain with thickness (which is the cutting depth 2.5 mm).Cutting tool is considered rigid in analysis and modeled as geometric solid object in MSC Marc. The heat generated due to plastic strain is considered in analysis.The maximum generated temperature in each case of analysis is determined and plotted in results. It is to be mentioned that the FEM analyses are performed as quasi-static steady state analysis for both structural and thermal analyses.So the obtained temperature values do not reflect accurate temperature distribution on workpiece and chip. But, they can be used to provide good indication on actual maximum temperaturegenerated on each cutting condition. Due to the complex and highly nonlinear metal cutting process, mesh adaptability feature is utilized in building the model in Marc software. This feature is very important in simulation of such complex process which contains chip formation and separation from original workpiece. Snapshots of some of the analyzed conditions are shown in figures 1, 2, and 3.

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3. RESULTS AND DISCUTION

A total of 30 orthogonal turning conditions are analyzed on MSC Marc. Results of the effect of rack angle on cutting force under different cutting feeds are shown in Fig. (4). Results show clear reduction of cutting force with the increase of rack angle. The change of force with rack angle is severe at smaller rack angle as shown in the figure. The effect of cutting feeds on cutting force under different rack angles is shown if Fig. (5). It is clear that the cutting force is directly proportional to cutting feed. The relation tends to be linear.

Figure (6) shows the effect of rack angle on temperature rise under different cutting feeds. It can be concluded that change of rack angle does not result in clear change in resulting temperature rise during cutting. But, the effect of feed change has a significant effect on resulting change in values of temperature rise as shown in Fig. (7). Where it is clear that temperature values tends to increase as feed values increase.

Results of current research are compared to those obtained experimentally for same material and cutting conditions. Figures 8 and 9 show that results obtained numerically are in a very good agreement with experimental results.

4. CONCLUSIONS

In this research a numerical analysis of orthogonal turning procedure is presented. The analysis is done using MSC Marc FEM software. Results are compared to those obtained experimentally of identical workpiece and cutting conditions and show very good agreement. The following conclusions can be drawn from presented research;

1- Efficiently and carefully built FEM models of orthogonal turning process can provide accurate results compared to more expensive experimental analysis.
2- Cutting force decreases with the increase of rack angle of cutting tool. This reduction tends to be more drastic at lower angles.
3- The increase of cutting feed results in proportional increase in cutting force.
4- Change in rack angle does not result in significant change in maximum temperature generated during turning.
5- Generated temperature values tend to increase with the increase of feed.

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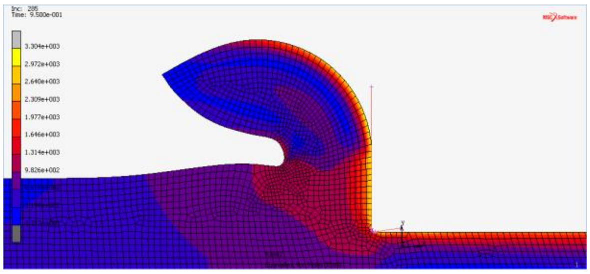

Fig. (1) Von Misses stress for case of 0° rack angle and 0.088 mm/rev feed

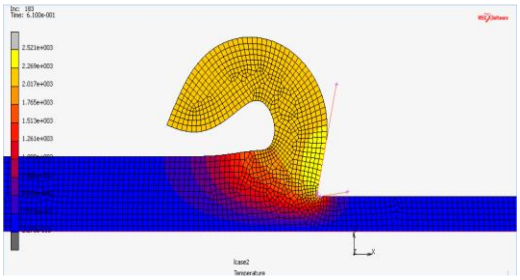

Fig. (2) Temperature distribution for case of 12° rack angle and 0.108 mm/rev feed

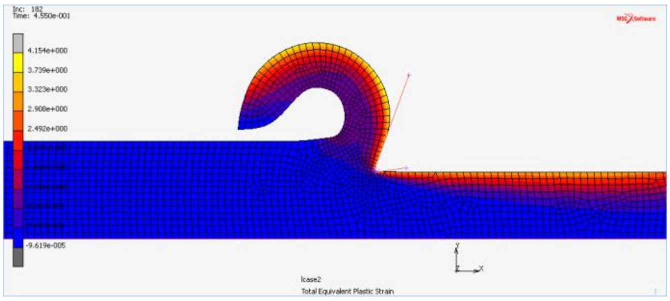

Fig. (3) Equivalent plastic strain case of 20° rack angle and 0.048 mm/rev feed

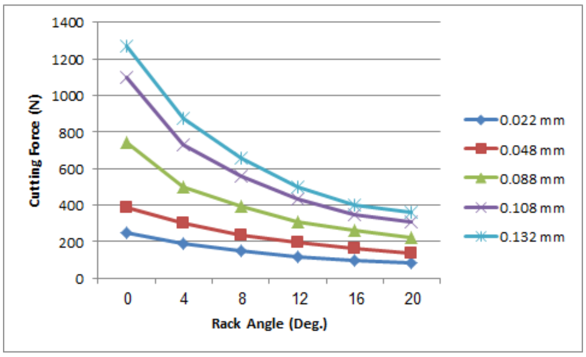

Fig.(4) Effect of rack angle on cutting force under different cutting feeds

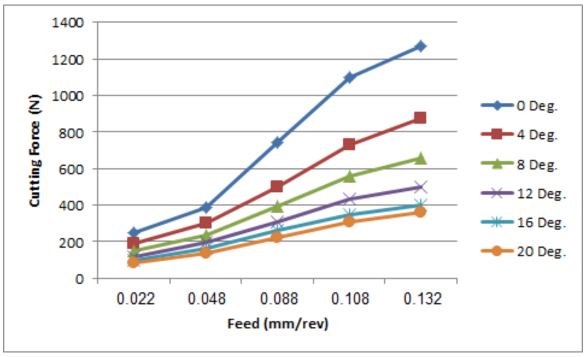

Fig.(5) Effect of cutting feeds on cutting force under different rack angles

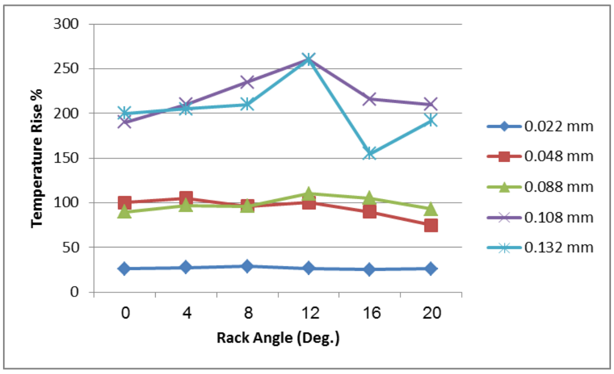

Fig.(6) Effect of rack angle on temperature rise under different cutting feeds

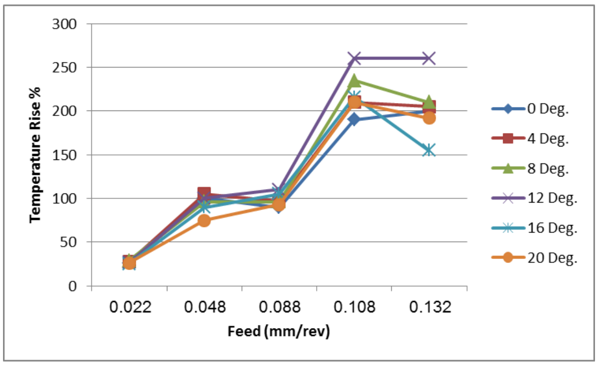

Fig.(7) Effect of cutting feeds on temperature rise under different rack angles

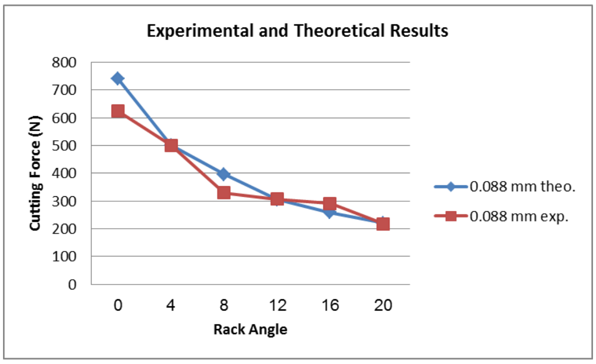

Fig.(8) Comparison of current results with experimental results of Ref.(7) at 0.088 mm feed

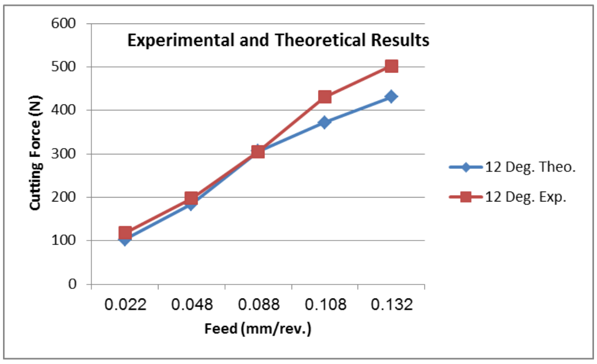

Fig.(9) Comparison of current results with experimental results of Ref.(7) at 12^o rack angle

تاثير زاوية الجرف ومعدل التغذية على قوة القطع ودرجة الحرارة المتولدة في عملية الخراطة

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الخلاصة

تم في هذا البحث اجراء تحليل باستخدام طريقة العناصر المحددة لعملية الخراطة. تمت دراسة تاثير زاوية الجرف ومعدل التغذية على قوة القطع ودرجة الحرارة المتولدة. التحليلات اجريت باستخدام برنامج مارك 2013. تم اعتبار قلم القطع جسما صلبا اثناء النمذجة.بينما اخذ بالاعتبار تاثير التصليد بالانفعال لمادة المعدن المقطوع, وذلك للحصول على دقة اعلى. تمت مقارنة نتائج البحث الحالي مع تلك المستخرجة عمليا ببحث منشور مسبقا واظهرت النتائج تقاربا جيدا بينهما. نتائج التحليل الحالي تظهر بان قوى القطع تزداد بازدياد التغذية وزاوية الجرف. النتائج تظهر كذلك بان ارتفاع درجة الحرارة يزداد بشكل ملحوظ بازدياد التغذية, بينما ليس لتغير زاوية الجرف تاثير واظح على الارتفاع بدرجة الحرارة.