

Modeling Static Cutting Forces And Stresses in the Face Milling Inserts

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Abstract—This study has analyzed the mechanical processes that would lead to an optimal design of indexed milling tools that have WC inserts. This thesis deals with the finite element stress analysis at the rake face of milling inserts with three dimensional shape. It was idealized by simplifying cutting forces uniformly distributed loading and elastic behavior was assumed. Simulation was run on tungsten carbide specimens. Firstly, the shape of the insert cutting edges under the varying angles of the inserts were suggested. Then, an observed cutting force model was made. This permits analyzing the outcomes of the finite element stress on the cutting forces. A time-sensitive analysis was also made to observe the dynamic cutting forces and utility for the milling process. Afterwards, the models were put in a computer program to make the protocols of the models. The results show that there is a local maximum tensile stress on the rake face of the insert. It is also shown that there exist high shear stresses near the insert edge and that the normal stress decreases exponentially from a maximum value at the loading tool edge to minimum value at the other side of the insert. Results obtained are similar to those of orthogonal cutting but very much dependent on the shapes of the insert.

Key Words : Face milling, Finite element stress, Three dimensional Insert, Cutting force, CNC, WC

I. INTRODUCTION

In the past, the research on the milling insert was mainly focused on modeling the machinery and operations of common face milling cutters with different geometries, such as cylindrical, ball-end and tapered. Recently, several researchers have been utilizing analytical, numerical and experimental methods to analyze the mechanical efficiencies of various models of milling insert.

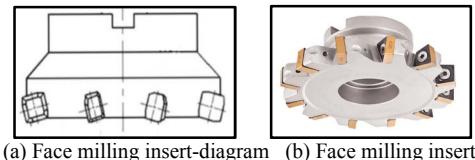
Organized tools appeared in the mid-20th century presenting innovative work in the study of inserted face milling cutters. Inserts represent financial advantages over other models of inserts since higher material removal rate (MRR) is potentially due to their high heat resistance. Analytical process models, that allow trustworthy predictions of cutting forces and machine-tool vibrations, provide the optimum process parameter selection, which is a problem before making cutting tests.

The face milling process is one of the most extensively used metal-cutting processes because of its high metal removal rate. The general forms of wear are the crater and flank wear in milling as in other cutting processes like turning. As cutting time increases the crater becomes deeper so that the resulting weakening of the insert edge can lead to breakage. Tool life is defined by specified values of these forms of wear of the flank and rake face.

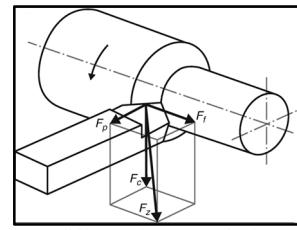
Main issues are to utilize the cutting forces and to avoid loud vibrations, as high and changing cutting force power generally indicate noises. This is the main decreasing factor for increasing MRR, as it may cause severe machining issues.

II. DATA AND RESULTS

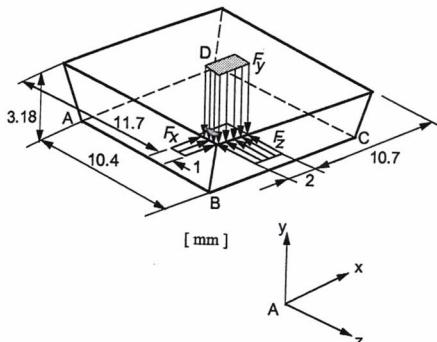
A. Face Milling Body and Forces on the Insert



(a) Face milling insert-diagram (b) Face milling insert



(c)3 different forces on the insert
(F_c:cutting force, F_f: feed force, F_p: passive force)



(d) Sharp edged insert

Fig.1. Face milling insert(a)(b), 3 different forces on the insert(c) and assumed loading condition for the sharp edged insert(d)

For the finite element stress analysis for the insert shown in the Fig.1, the system was idealized by simplifying the cutting forces that are uniformly distributed along the surface and the elastic behavior was assumed.

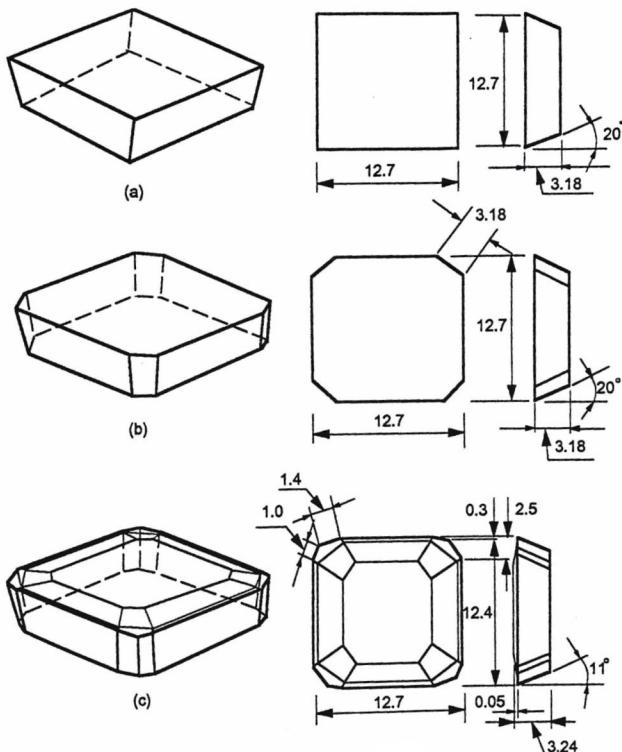


Fig.2. 3-type insert

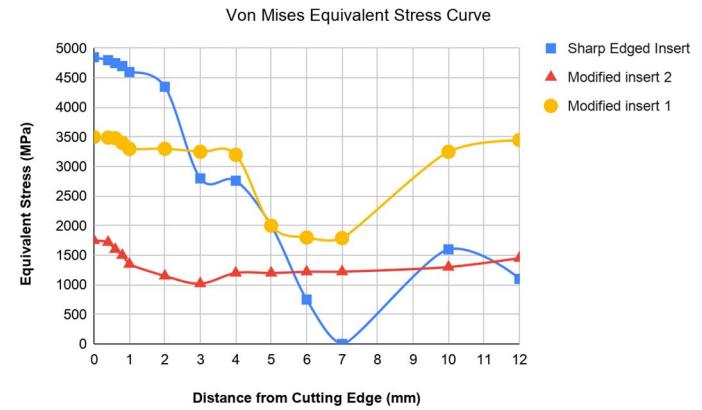


Fig.3. Equivalent stress distribution for the inserts

The results for the three different types of the inserts in the Fig. 2 show that there is a local maximum tensile stress on the rake face of the insert.



Fig.4. Stress distribution along z-axis for the inserts

It is also shown that there exist high shear stresses near the insert edge and that the normal stress decreases exponentially from a maximum value at the loading tool edge to minimum value at the other side of the insert.

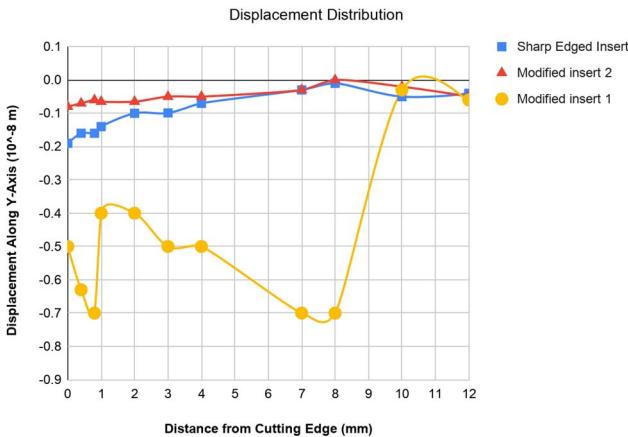
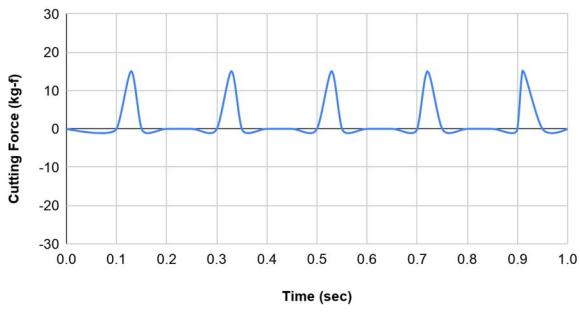


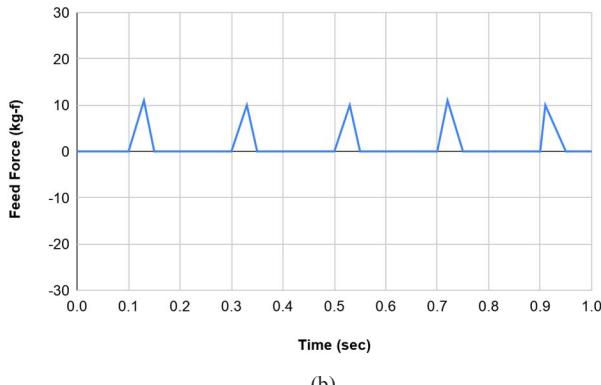
Fig.5. Displacement along the y-axis for the 3 inserts

There are three principal forces acting on the modified tool tip 2 during a turning process: The cutting or tangential force acts downward on the tool tip and the force is the largest among the three forces.

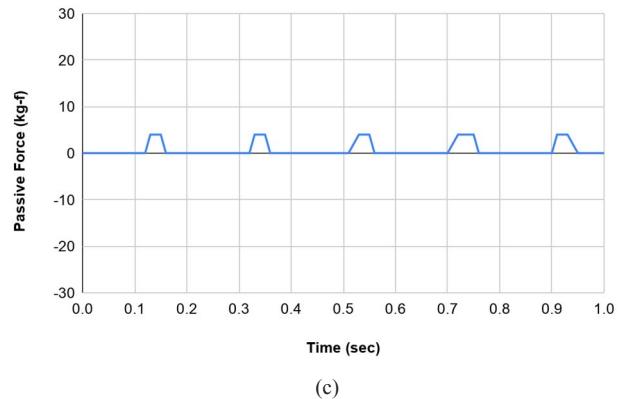


(a)

The feed force acts along the axis of the workpiece and perpendicular to the other two forces. The magnitude of the force is second largest among the three forces.



(b)



(c)

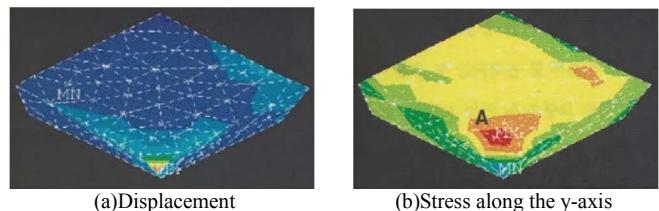
Fig.6. Cutting force data (modified insert 2)

The parallel force acts perpendicular to the axis of the workpiece and perpendicular to the other two forces. The magnitude of the force is the smallest among the three forces.

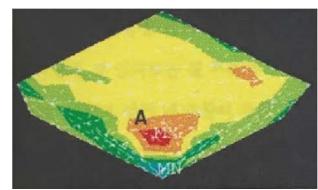
The results show that there is a local maximum tensile stress on the rake face of the insert. It is also shown that there exist high shear stresses near the insert edge and that the normal stress decreases exponentially from a maximum value at the loading tool edge to minimum value at the other side of the insert.

C. Stress and Displacement Distributions

To find stresses on the insert, forces along the x, y and z axes were assumed and FEM(Finite Element Method) was used to calculate the stresses. Deformations along the x, y and z axes in the inserts were also found.



(a)Displacement



(b)Stress along the y-axis



(b)Stress along the z-axis

Fig.7. Stress and displacement distribution for the sharp edged insert

For the modified milling insert shown in the Fig. 8 shows:

- The least cutting forces
- Stresses(shear and normal) in the insert are smallest

The results for the three models(a, b and c) show local maximum tensile stress occurs on the rake face of the insert and high shear stresses occur near the insert edge.

Also normal stress decreases exponentially from a maximum value at the loading tool edge to minimum value at the other side of the insert.

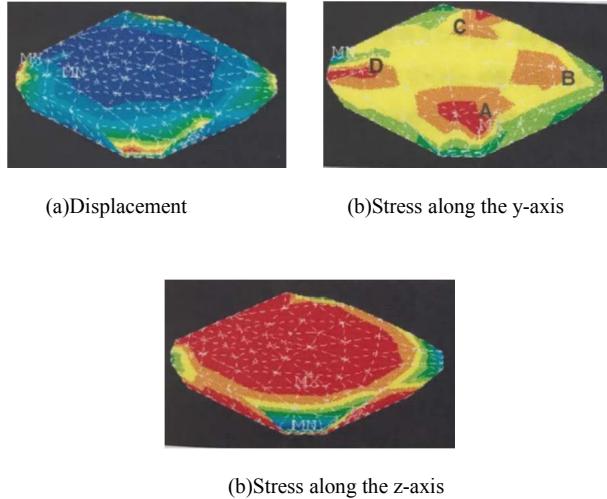


Fig.8. Stress and displacement distribution for the insert with modified edge (modified insert 2)

local maximum tensile stress was observed on the rake face of the insert. It is also shown that there exist high shear stresses near the insert edge and that the normal stress decreases exponentially from a maximum value at the loading tool edge to minimum value at the other side of the insert.

IV. DISCUSSION

Recently, researchers showed a uniform cutting force model for inserted cutters that can be utilized for various types of machining operations. Industry has developed new technology by using cutting tools with tungsten carbide inserts that are being operated in machining of super alloys. The tungsten carbide inserts cutting tools are more precise and therefore the use has been increased due to higher temperature resistance when compared to carbon inserts. However, the success of this process is dependent on the correct selection of process parameters.

Three different cutting forces were observed from cutting tests with a CNC milling machine. Then, the cutting force design was certified with cutting experiments measuring cutting forces and observing chips. After receiving modal testing, cutting forces and vibrations were assessed by means of the time sensitive model. A series of simulations were accomplished to conclude stability limits at certain operating conditions using the time domain model, and established a model.

The results show local maximum tensile stress occurs on the rake face of the insert and high shear stresses occur near the insert edge. Also normal stress decreases exponentially

from a maximum value at the loading tool edge to minimum value at the other side of the insert. Results obtained are similar to those of orthogonal cutting but very much dependent on the shapes of the insert.

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