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Optimization and Process Control in Small Diameter End Mill

Pedagadi Mohana Madhav
M.Tech (CAD/CAM)
Department of Mechanical Engineering,
Kakinada Institute of Technological Sciences,
A.Agraharam- Ramachandrapuram,
East Godavari, AP.

Mr.D.Vijaya Prasad
Associate Professor
Department of Mechanical Engineering,
Kakinada Institute of Technological Sciences,
A.Agraharam- Ramachandrapuram,
East Godavari, AP.

Abstract:

The recent technological progressions in industries have offered ascent to the continually growing requests for small structures, sensors, and parts. Small-milling is a promising method to create these scaled down structures, sensors, and parts. Yet, small-milling still confronts some significant difficulties, tormenting further provision of this innovation. The most noticeable around them is small burr formation. Burrs created along the completed edges and surfaces in small-milling operation have huge effect on the surface quality and performance of the completed parts and small structures. In any case, deburring of small-parts is not conceivable because of bad accessibility and tight tolerances in small segments. One of the methods to minimize small burr formation in small milling is by enhancing the geometry of the device. As minimization of small burrs still remains a key test in small machining, not many researchers have worked in this field. The main aim of the research work is to present finite element analysis of flat end mill small cutters used in small milling by varying geometry of the tools. Apart from this, study has been done in detail on burr formation in small milling and what factors affect it. Burr formation simulation has been carried out while varying the tool geometry.

The outcome of the research will be a static finite element analysis of small burrs formed during small-milling which can help in determining tool life and a detailed dynamic analysis of small burrs formed during small-milling operation in Al6061-T6 which can benefit the aerospace industry in various ways. The results obtained during the analysis may be used for further research for burr minimization through tool optimization and process control.

Introduction

The fabrication of a wide variety of parts and products in various fields, like aeronautics, automotives, biomedical, medical and electronics requires proper finishing for proper mating and functioning of products. A variety of operations like milling, drilling, turning, grinding, EDM and water jet cutting are utilised to fabricate and finish parts. One of the most common and important form of machining is the milling operation, in which material is cut away from the workpiece in the form of small chips by feeding it into a rotating cutter to create the desired shape. Milling is typically used to produce parts that are not axially symmetric and have multiple features, such as holes, slots, pockets, and even three dimensional surface contours. Contoured surfaces, which include rack and circular gears, spheres, helical, ratchets, sprockets, cams, and other shapes, can be readily cut by using milling operation. Recently, small milling process has gained immense popularity due to market requirements and technological advancements which has lead to fabrication and use of small structures. It

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possesses several advantages like ease of use, capability to produce complex three dimensional geometries, process flexibility, low set-up cost, wide range of machinable materials and high material removal rates.

This chapter develops the background for the present work and discusses the need to take up this work. It presents a review of available relevant literature. Objectives of the present work along with methodology adopted to accomplish them are also discussed here.

Background

With the growth in technology, the expectations from products have greatly increased. More and more complex shaped parts of varying sizes are being designed, developed and used for a wide variety of industrial applications.

Motivation

Conventional milling has a wide range of industrial applications and is used where there is a requirement of complex shapes, removal of large amounts of material, and accuracy. However, with the advancement in technology, more and more industries are leaning towards the use and fabrication of miniaturized parts and products. In the present scenario, smallmachining is increasingly finding application in various fields like biomedical devices, avionics, medicine, optics, communication, and electronics. Among all small-machining operations, small-milling and small-drilling are the two most important operations.

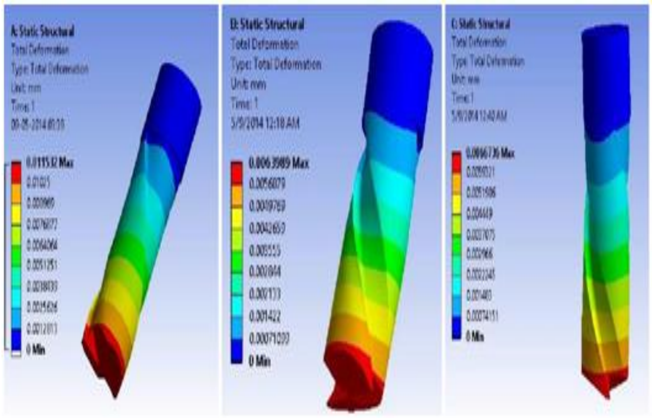
Problem Definition

This work is an attempt to optimize small milling tool parameters for minimization of small burrs formed during small machining. The objectives of this work are stated as follows:

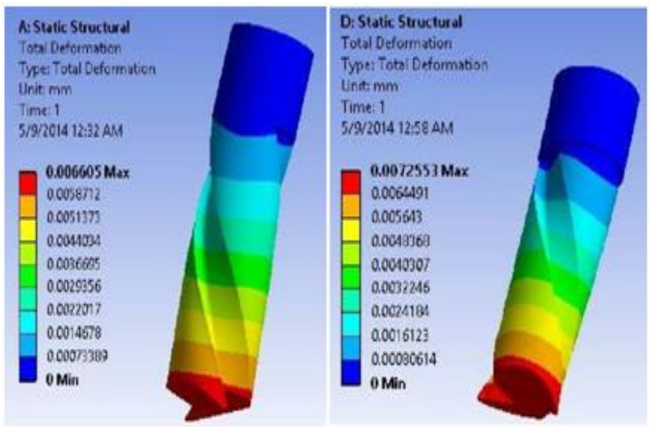
- To develop three-dimensional solid models of two flute and four flute flat-end small milling cutters.
- To perform the static finite element analysis of the tools during small milling.
- To perform the finite element detailed analysis of the tool and work piece combination during small milling.
- To perform burr formation simulation in small milling.

Results

Figures 5.3 and 5.4 show the result for static analysis with deformed mesh and Von Mises stress respectively for the applied load for two flute flat end mill of diameter 0.3 mm.



(a) Rake angle = 0º, Relief angle = 10º, (b) Rake angle = -2º, Relief angle = 6º, (c) Rake angle = 3º, Relief angle =8º



(d) Rake angle = 5º, Relief angle = 5º, (e) Rake angle = 5º, Relief angle

Figure 5.3: Total deformation in the case of two flute small end mills

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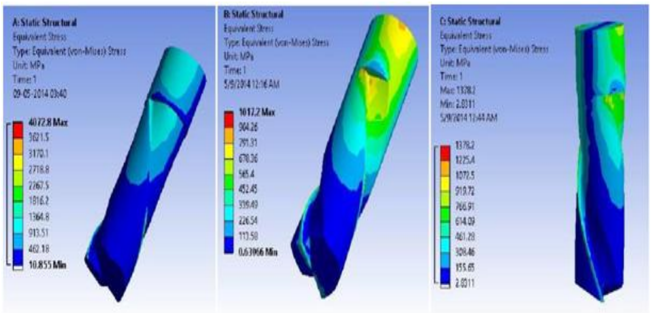
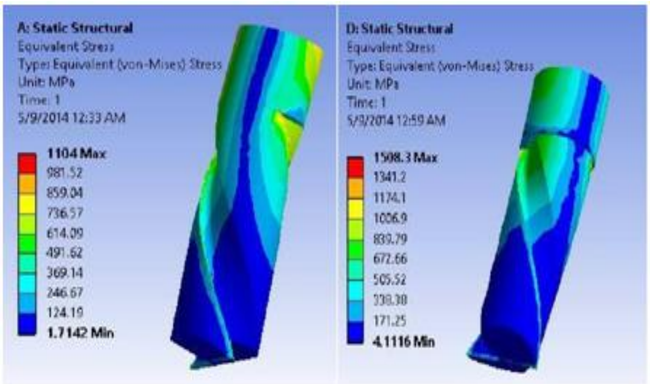


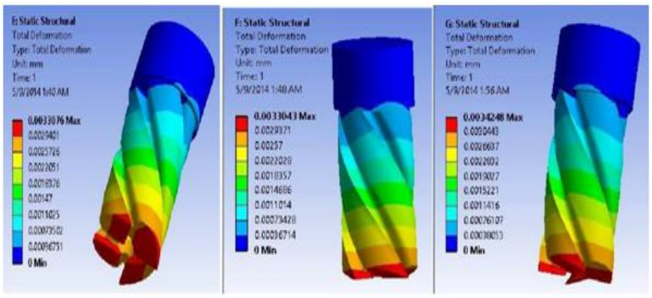
(a) Rake angle = 0º, Relief angle = 10º,(b) Rake angle = -2º, Relief angle = 6º and (c) Rake angle = 3º, Relief angle =8º



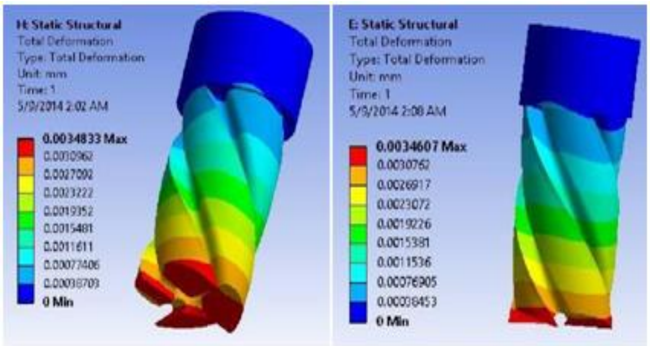
(d) Rake angle = 5º, Relief angle = 5º,(e) Rake angle = 5º, Relief angle = 6º

Figure 5.4: Von Mises stress in the case of two flute small end mills

Figures 5.5 and 5.6 show the result for static analysis with deformed mesh and Von Mises stress respectively for the applied load for four flute flat end mill of diameter 0.3 mm

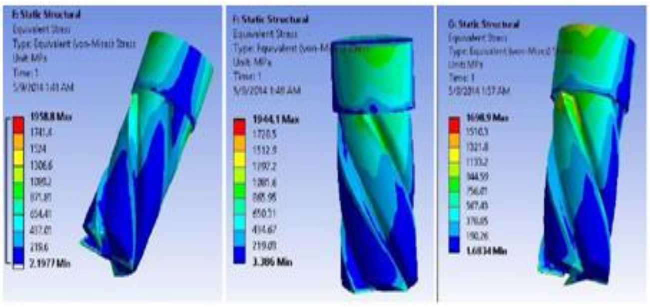


(a) Rake angle = 0º, Relief angle = 10º,(b) Rake angle = -2º, Relief angle = 6º and (c) Rake angle = 3º, Relief angle =8º

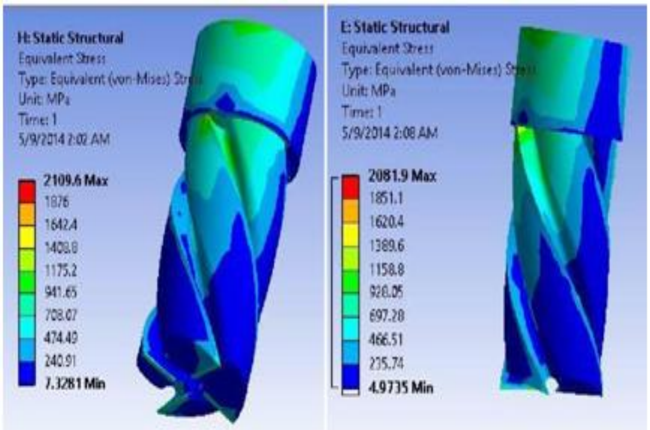


(d) Rake angle = 5º, Relief angle = 5º,(e) Rake angle = 5º, Relief angle = 6º

Figure 5.5: Total deformation in the case of four flute small end mills



(a) Rake angle = 0º, Relief angle = 10º,(b) Rake angle = -2º, Relief angle = 6º and (c) Rake angle = 3º, Relief angle =8º



(d) Rake angle = 5º, Relief angle = 5º, (e) Rake angle = 5º, Relief angle = 6º

Figure 5.6: Von Mises stress in the case of four flute small end mill

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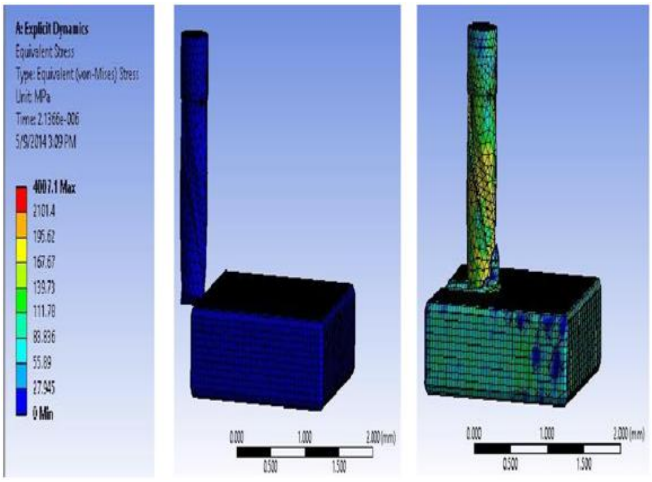
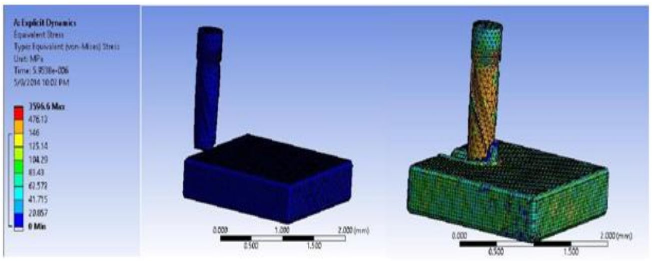
Results

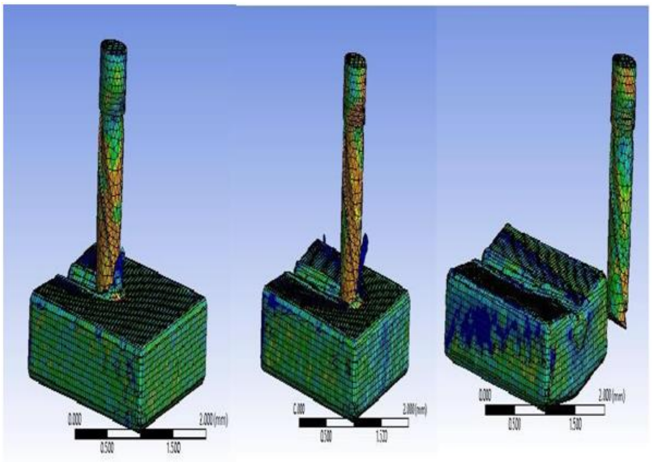


(a) Entry of tool into the workpiece,(b) Chip formation initiation,(c) Chip flow,(d) Chip separation and (e) Exit of tool from workpiece

Figure 5.7: Simulation of small burr formation using tool with rake angle 3º and relief angle 8º



(a) Entry of tool into the workpiece,(b) Chip formation initiation



(c) Chip flow,(d) Chip separation and (e) Exit of tool from workpiece

Conclusions

This chapter concludes the technical sum-up of the thesis work on three-dimensional geometric modeling and analysis of small end milling cutters and simulation of small burrs formed during small milling of Al6061-T6 alloy by using a tungsten carbide two flute small Concluding remarks.

Burr formation is a major hindrance to good surface finish in case of both macro and small milling. However, burr formation in case of small milling is of greater importance than in case of conventional milling as burrs formed in the former case are of sub-smallmeter size and deburring processes are expensive, and sometimes impossible. Hence, burr minimization is the only way of obtaining good surface finish in smallstructures.

To minimize formation of burrs in case of small milling, either the cutting conditions or the tool geometry can be optimized. In this work, tool geometry optimization has been tried to be achieved by performing FE analysis on tools with different sets of rake and relief angles, for both two flute and four flute small end mills. The results of the static finite element analysis of the tungsten carbide flat end small milling tools offer the conclusion that in the given cutting conditions, the least amount of Von Mises stress generated in case of a two flute flat end small mill cutter is for a cutter having rake angle -2º and relief angles of 6º and that in the case of four flute end small mill cutter is for a cutter having rake angle 3º and relief angle 8º.
FE dynamic analysis of the tool-chip interaction in the small milling process as performed and small burr formation process was simulated using ANSYS 13.0 software.

Future scope

The results obtained from static FE analysis of small end mills can be used in future to predict tool life and to choose the correct cutter geometry from available options for performing various small milling operations.

The results obtained from dynamic analysis of small burrs formed during small-milling operation in Al6061T6 can benefit the aerospace industry, which utilises this alloy for fabrication of a large number of components.

The results obtained during the analysis may also be used for further research for burr minimization through tool optimization and process control.

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