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Static and Dynamic Analysis of End Mill Tool for Stability

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ABSTRACT

Milling is a very commonly used manufacturing process in the industry due to its versatility to generate complex shapes in variety of materials at high quality. Due to the advances in machine tool , CNC, CAD/CAM, cutting tool and high speed machining technologies in last couples of decades ,the volume and the importance of milling have increased in key industries such as aerospace ,die/ mold, automotive and component manufacturing. But however the unstable machining (namely chatter vibration) is one of the main limitations for high speed machining which shortens the tool life and decreases machined surface quality. In this paper static and dynamic analysis of end mill tool with different geometry is carried out by Finite element analysis (FEA), also some practical equations are developed to predict the static and dynamic properties of end mill tool And the results obtained by both the methods are nearly same. However in case of static analysis amount of deflection of tool for a particular value of cutting force can be easily determined, while in case of dynamic (modal) analysis natural frequencies and mode shapes can be determined.

Introduction

Milling is a most widely used process for manufacture of discrete mechanical components. Numerous efforts have been made to improve the efficiency of milling by reducing the machining time. The dimensional accuracy of end mill tool depends upon the rigidity of set up , radial and axial depth of cut and on the thrust force produced .since end mill tool acts like a rotating cantilever which is gripped by the machine tool spindle, the end deflection for a given cutter is directly proportional to thrust and to the effective overhang

High speed machining demands has increased in recent year such as, automotive, aerospace, and die/mould manufacturing industries. since due to the advantages such as higher material removal rates , better surface finish, lower cost etc milling is effectively used in such areas. However the unstable machining (namely chatter vibration) is one of the major limitation for high speed machining which consequently shortens the tool life and hampers the surface quality required to be produced on work piece/job.This paper static and dynamic analysis of end mill tool with different geometry is carried out by Finite element analysis (FEA), also some practical equations are developed to predict the static and dynamic properties of end mill tool.End mill tool is a segmented beam , whose one segment is for the part of the flute and other segment is for the shank as shown in figure below:

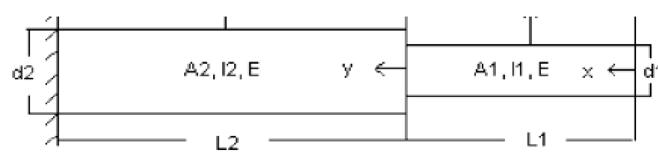

Fig.1. The geometry of the beam (tool) with two different geometric segments.

d1 : Mill diameter

d2 : shank diameter

L1 : flute length

L2 : overall length

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Problem Definition:

The unstable machining (namely chatter vibration) is one of the major limitation for high speed machining which consequently shortens the tool life and hampers the surface quality required to be produced on work piece/job. Therefore it is required to determine the static and dynamic analysis (behavior) of end mill tool with different geometry and material conditions.

Also in order to reduce the effect of chatter vibration on the end mill tool , some vibration absorber (damper) can be provided for the tool and consequently static and dynamic analysis can be carried out so that tool life and quality of surface finish can be improved effectively.

Methodologies:

In this paper both FEA and Analytical methods have been used for static and dynamic analysis of end mill tool. The main objective of static analysis is to determine the deflection of end mill tool, while dynamic (modal) analysis used to determine the mode shapes and natural frequencies of the cutting tool structure. A four flute end mill tool of HSS and carbide material along with its various dimensions (selected from design data book) is used for static and dynamic analysis.

Analytical Method:

Static characteristics for end mill tool can be easily determine by following equations which is same for HSS and Carbide tool

$$\text{deflection}_{\max} = C\frac{F}{E}\left[\frac{L1^3}{D1^4} + \frac{(L2^3 - L1^3)}{D2^4}\right]^N$$

Where , F = cutting force

L1 = flute length

L2 = overall length

D1 & D2 = mill and shank diameter .etc

Values for C, F, L1, L2, D1, D2, E are selected from design data book and susituted in

equation (1) to determine the tool defletion for HSS and Carbide tool.

$\text{deflection}_{\max}$ (for HSS tool) = 0.216239 mm

$\text{deflection}_{\max}$ (for carbide tool) = 0.00785 mm

However Dynamic analysis by analytical method is used to determine the natural frequency of end mill tool with the help of the following equation which is same for HSS and Carbide tool :

$$\omega = (\beta L1)\sqrt{\frac{EI1}{\rho A1L1^4}} \quad \text{or} \quad \omega = (\alpha L2)\sqrt{\frac{EI2}{\rho A2L2^4}}$$

Where ,

ω = natural frequency

L1 = flute length

L2 = overall length

A1 & A2 = mill and shank area .. .etc

By substituting the values of LI, L2, A1, A2, E etc in equation (2) the natural frequencies for HSS and Carbide tool is determined .

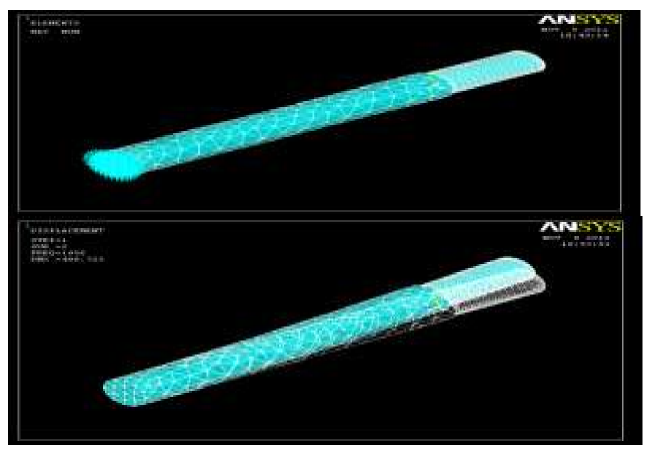
ω (for HSS tool) = 1399.89 HZ

ω (for Carbide tool) = 2019.54 HZ

FEM Method:

In this case end mill tool is simplified as a beam element by ignoring complex tool geometry and dynamic (modal) analysis is carried out to determine the natural frequencies of the tool.

Below image shows the meshed model of end mill tool by imposing the boundary conditions on it.



Whereas the natural frequencies with FEM tool can be found out as mention in the below image, this natural frequency is nearly equal to the analytical method.

Conclusions:

Static and Dynamic properties of end milling tools are very important for machining precision and chatter stability. In this paper, methods for modeling structural properties of milling tools are presented. Static and dynamic analysis of tools with different geometry and material are carried out by finite element analysis (FEA). Also some practical equations are developed to predict the static and dynamic properties of tools. And the results obtained by both the methods are nearly same. However in case of static analysis amount of deflection of tool for a particular value of cutting force can be easily determined, while in case of dynamic (modal) analysis natural frequencies and mode shapes can be determined.

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