International Journal of Engineering Research and Development
e-ISSN: 2278-067X, p-ISSN: 2278-800X, www.ijerd.com
Volume 10, Issue 4 (April 2014), PP.62-68

"Analysis of Gear Milling Cutter Using Finite Element Analysis"

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Abstract:- Milling is a process of producing flat and complex shapes with the use of multi-tooth cutting tool, which is called a milling cutter and the cutting edges are called teeth. The axis of rotation of the cutting tool is perpendicular to the direction of feed, either parallel or perpendicular to the machined surface. The machine tool that traditionally performs this operation is a milling machine. Milling is an interrupted cutting operation: the teeth of the milling cutter enter and exit the work during each revolution. This interrupted cutting action subjects the teeth to a cycle of impact force and thermal shock on every rotation. The tool material and cutter geometry must be designed to withstand these conditions. Cutting fluids are essential for most milling operations .In this Paper the design aspects of milling cutter is analyzed. The objective considered is the design and modeling of milling cutter and to analyze various stress components acting on it. By taking two different material i.e. HSS and Cemented Carbide to check stress and deformation. The design and analysis is carried out using the software like Pro-E and ANSYS.

***Keywords* :-** ANSYS, Pro-E, cutting fluids, cutting edges, High Speed Steel, Milling Speed, Cemented Carbide.

I. INTRODUCTION

Milling, for example, has its own particularities, such as variation on the unreformed chip thickness (*h*), interrupted cuts, etc. Models developed for turning and adapted to milling, working with average chip thickness, can yield reasonable results in terms of force. There are operations, however, where a more accurate result is needed and then, the discrepancies may become unacceptable. That is the case with high speed milling, which uses very low chip thickness. In this case, the cutting edge radius almost equals the unreformed chip thickness and the rake angle tends to be highly negative. The material seems to be removed like in abrasive processes (Shaw 1996). Additionally, the main parameters describing the models are a function of other ones related to the tool (material, geometry, coating, etc.) and the machine (rigidity, speed, position control, etc.). In order to investigate the end milling process in some cutting conditions, at any particular combination tool-machine-work piece, a simple and fast method is needed to find the main parameters of the classical existing models and study some new ones. Milling is a process of producing flat and complex shapes with the use of multi-tooth cutting tool, which is called a milling cutter and the cutting edges are called teeth. The axis of rotation of the cutting tool is perpendicular to the direction of feed, either parallel or perpendicular to the machined surface. The machine tool that traditionally performs this operation is a milling machine. Milling is an interrupted cutting operation: the teeth of the milling cutter enter and exit the work during each revolution. This interrupted cutting action subjects the teeth to a cycle of impact force and thermal shock on every rotation. The tool material and cutter geometry must be designed to withstand these conditions. Cutting fluids are essential for most milling operations.

Fig. 1: Gear milling cutter

II. LITERATURE REVIEW

Chittibomma Tirumalaneelam and Tippa Bhimasankara Rao(2013)developed geometric design model of a end milling cutter in terms of three-dimensional (3D) parameters. For analysis they took a single teeth of cutter. By taking different load condition analyze the stress and strain.[1]

Mohammed and Tandon (2013) proposed a shape design methodology in order to develop the geometry of a generic special shaped milling cutter. The proposed three-dimensional parametric definition of the cutter with varying the rake angle of the insert and insert seat was analyzed using FEM.[6]

III. KINDS OF MILLING CUTTER

3.1 Plain Milling Cutter

The most common type of milling cutter is known as a plain milling cutter. It is merely a metal cylinder having teeth cut on its periphery for producing a flat horizontal surface.

3.2 Metal Slitting Saw Milling Cutter

The metal slitting saw milling cutter is essentially a very thin, it is ground slightly thinner toward the center to provide side clearance. It is used for metal sawing and for cutting narrow slots in metal.

3.3 End Milling Cutters

End milling cutters, also called end mills, have teeth on the end as well as the periphery. The smaller end milling cutters have shanks for chuck mounting or direct spindle mounting. Larger end milling cutters are called shell end milling cutters and are mounted on arbors like plain milling cutters. End milling cutters are employed in the production of slots, keyways, recesses, and tangs. They are also used for milling angles, shoulders, and the edges of work pieces.

3.4 Concave and Convex Milling Cutters

Concave and convex milling cutters are formed tooth cutters shaped to produce concave and convex contours of one-half circle or less. The size of the cutter is specified by the diameter of the circular form the cutter produces.

3.5 Corner-rounding Milling Cutter

The corner-rounding milling cutter is a formed tooth cutter used for milling rounded corners on work pieces up to and including one-quarter of a circle. The size of a cutter is specified by the radius of the circular form the cutter produces, as with concave and convex cutters.

3.6 Special Shaped-formed Filing Cutter

Formed milling cutters have the advantage of being adaptable to any specific shape for special operations. The cutter is made for each specific job. In the field, a fly cutter is made to machine a specific shape.

3.7 T-Slot Milling Cutter

The T-slot milling cutter is used to machine T-slot grooves in worktables, fixtures, and other holding devices. The cutter has a plain or side milling cutter mounted to the end of a narrow shank. The throat of the T-slot is first milled with a side or end milling cutter and the headspace is then milled with the T-slot milling cutter.[2]

IV. GEOMETRY OF MILLING CUTTER

The milling cutter is a multiple point cutting tool. The cutting edge may be straight or in the form of various contours that are to be reproduced upon the work piece. The relative motion between the work piece and the cutter may be either axial or normal to the tool axis. In some cases a combination of the two motions is used. For example, form-generating milling cutters involve a combination of linear travel and rotary motion. The figure below shows the gear milling cutter.

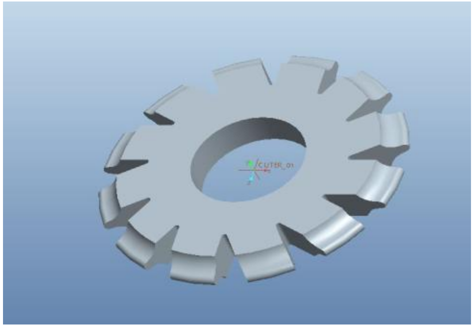

Fig 2: Pro-E model of milling cutter

Table 1: MATERIAL PROPERTIES OF TOOL MATERIAL

Materials	HSS	Cemented Carbide
Density (kg/m3)	7980	12100
Young’s modulus, E (GPa)	210	558
Poisson’s ratio, n	.30	.22

V. FINITE ELEMENT ANALYSIS OF GEAR MILLING CUTTER

In order to perform a finite element analysis, it is necessary to determine the forces acting on the cutter. From the given conditions the force acting on the cutter (W) may be calculated as:[4]

$$W_t = \frac{60{,}000H}{\pi D n}$$

Where H is the power in kW, n is the speed, in rpm, and D is the diameter of the cutter.

The stress calculation at the tip of the tooth of the cutter is estimated based on the concept of gear tooth stresses. The stress at each speed is determined by[4]

$$\sigma = \frac{6W_t l}{Ft^2}$$

The maximum allowable stress at the tip of the cutter is determined as[4]

$$\sigma_{\text{allowable}} = \frac{S_t K_L}{K_T K_R}$$

Where as,

S_t (AGMA bending strength) = 44,000 psi

K_R (reliability factor) = 1

K_L (life factor) = 1

VI. ANALYSIS OF GEAR MILLING CUTTER

The basic steps for performing analysis are listed below:

- Create the model geometry and mesh
- Identify the contact pairs
- Designate contact and target surfaces
- Define the target surface
- Define the contact surface
- Apply necessary boundary conditions
- Define solution options and load steps
- Solve the contact problem
- Review the results

VII. RESULTS AND DISCUSSION

For W=4184.84N, Here the speed is 100rpm for which the load is 4184.84 N. The following image represents FEA based stress and deformation variations.

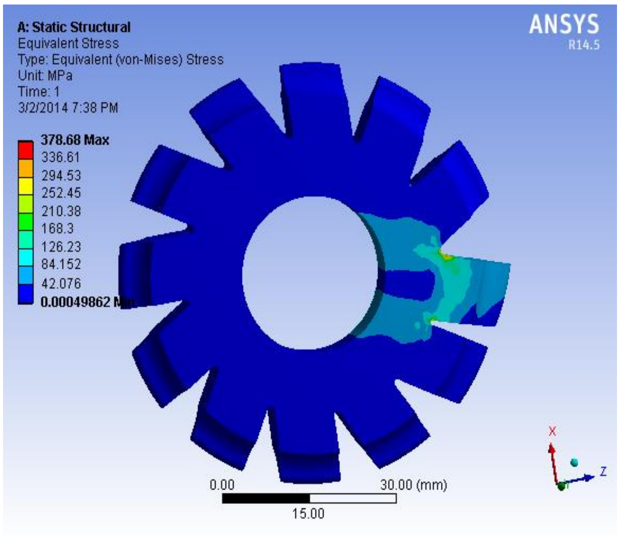

Figure 3: Equivalent stress for N=100

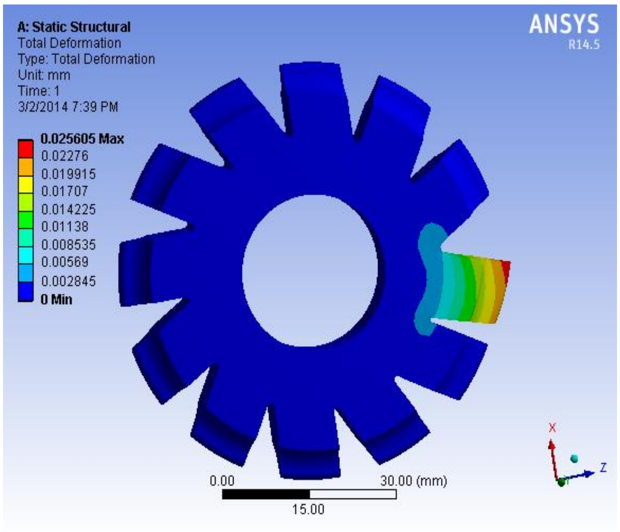

Figure 4: Deformation for N=100

For W=836.97 N, Here the speed is 500rpm for which the load is 836.97 N. The following image represents FEA based stress and deformation variations.

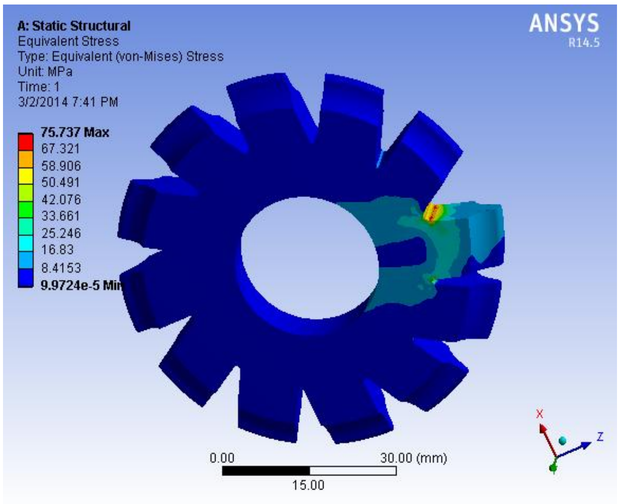

Figure 5: Equivalent stress for N=500

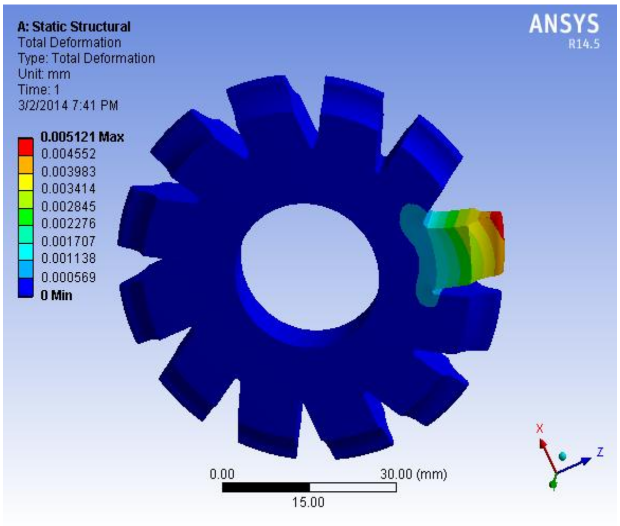

Figure 6: Deformation for N=500

For W=418.48 N, Here the speed is 1000rpm for which the load is 418.48 N. The following image represents FEA based stress and deformation variations.

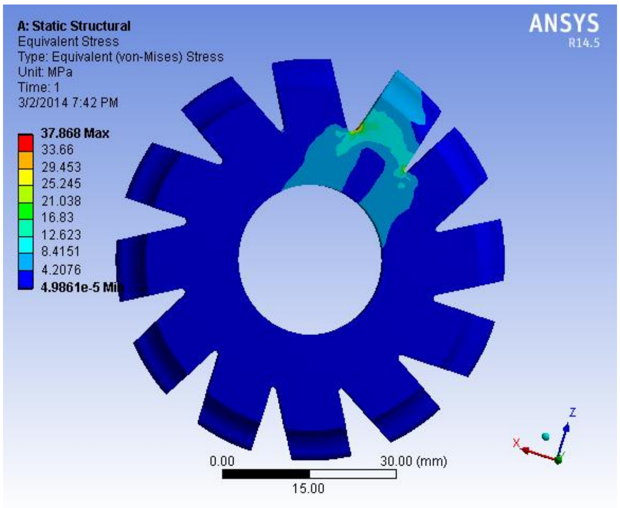

Figure 7: Equivalent stress for N=1000

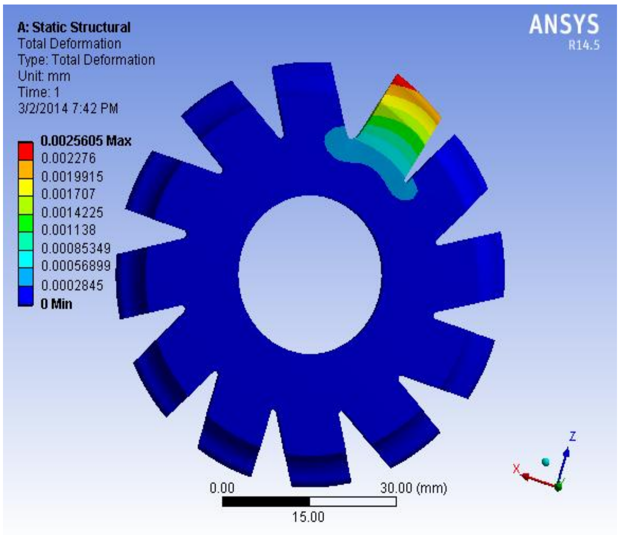

Figure 8: Deformation for N=1000

Table 2: Results Using Tool Material As Hss

Sr no.	Speed (rpm)	Stress (therotical)	Stress (ansys)	Deformation
1	100	376.64	378.68	0.0250
2	200	188.92	189.34	0.0120
3	300	125.55	126.23	0.0085
4	400	94.16	94.67	0.0064
5	500	75.33	75.73	0.0051
6	600	62.77	63.11	0.0042
7	700	54.80	54.10	0.0036
8	800	47.08	47.33	0.0032
9	900	41.85	42.08	0.0028
10	1000	37.66	37.86	0.0025

Table 3: Results Using Tool Material As Cemented Carbide

Sr no.	Speed (rpm)	Stress (ansys)	Deformation
1	100	337.70	0.0095
2	200	168.85	0.0047
3	300	112.57	0.0031
4	400	84.43	0.0024
5	500	67.54	0.0019
6	600	56.23	0.0015
7	700	48.24	0.0013
8	800	42.21	0.0011
9	900	37.52	0.0010
10	1000	33.77	0.0009

VIII. CONCLUSION

This work illustrates an advanced modeling paradigm that can be used to accurately model a special shaped milling cutter and thus, opens up paths to define conveniently various customized cutters. Here, different design activities, such as geometric modeling, finite element analysis and design improvements have been integrated. As is evident, the approach illustrated in this paper is flexible and easy to use. This approach can also be used to design any complex mechanical component, specifically for the cutter design, it produced the cutting variables that yield the minimum cost of manufacturing. The different design activities, such as design solid modeling, and finite element analysis, have been integrated. The values obtained are compared with the model and theoretical stress values of the special shaped milling cutter. It was observed from the results, both stresses and deformation values were reduced for cemented carbide than thetool material HSS.

ACKNOWLEDGMENT

I would like to thank my Guide, **Professor Mr. J. G. INGALE** for his time and support. In addition, I would like to thank my friends for sharing their experience in Pro-E and ANSYS. Finally, I would like to thank my family for their support and putting up with me for these past few months moral and financial support during my studies.

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