Wear Analysis of Multi Point Milling Cutter using FEA

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Abstract: - *The material removal process uses cutting tools in order to produce the desired shape of the work piece. Tool wear has been a problem for cutting tools, since cutting tools wear and break. Research has been accomplished in the tool wear field for tool life and more recently tool wear. The computer generation has created a method to simulate the material removal process. These computer simulations model the cutting tool reaction with the work piece. Many of the simulation models use finite element analysis to calculate the reaction of the cutting tool. Different finite element models are being used throughout the world for research. In this Paper the design aspects of surface milling cutter is analyzed. The objective considered is the design and modeling of surface milling cutter and to analyze various stress components acting on it. Various designing strategies are considered to design the effective surface milling cutter like outer diameter, inner diameter, radius, teeth angle etc .The design and analysis is carried out using the software like Pro-E and ANSYS*

Keywords: - ANSYS, Pro-E, Cutter, High Speed Steel, Milling, Speed

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1. INTRODUCTION

Now a days, metal cutting is a significant industry in economically developed countries, though small in comparison to the customer industries it serves. The automobile, railway, shipbuilding, aircraft manufacture, home appliance, consumer electronics and construction industries, all these have large machine shops with many thousands of employees engaged in machining. It is estimated that 15% of the value of all mechanical components manufactured worldwide is derived from machining operations. A thorough understanding of the material removal process in metal cutting is essential in selecting the tool material and in design, and also in assuring consistent dimensional accuracy and surface integrity of the finished product. Friction of metal cutting influences the cutting power, machining quality, tool life and machining cost. When tool wear reaches a certain value, increasing cutting force, vibration and cutting temperature cause deteriorated surface integrity and dimension error greater than tolerance. The life of the cutting tool comes to an end. Then the cutting tool must be replaced or ground and the cutting process is interrupted. The cost and time for tool replacement and adjusting machine tool increase the cost and decrease the productivity. Hence friction in metal cutting relates to the economics of machining and prediction of friction is of great significance for the optimization of cutting process Although various theories have been introduced hitherto to explain the wear mechanism, the complicity of the processes in the cutting zone hampers formulation of a sound theory of cutting tool wear. The nature of tool wear in metal cutting, unfortunately, is not yet clear enough in spite of numerous investigations carried out over the last 50 years. Friction of metal cutting is a result of complicated physical, chemical, and thermo-mechanical phenomena. Recently, the prediction of friction of metal cutting is performed by calculating tool life according to experiment and empirical tool life equations. Although the equation gives the simple relationship between tool life and a certain cutting parameters, it gives only the information about tool life. For the researcher and tool manufacturer, tool wear progress and tool wear profile are also areas of concern. Tool life equation gives no information about the wear mechanism. But capability of predicting contributions of various wear mechanism is very helpful for the design of cutting tool material and geometry. In addition, such tool life equations are valid under very limited cutting conditions. For example, when tool geometry is changed, new equation must be established by making experiment

The relative motion between cutter and the work piece can be in any direction and hence surfaces having any orientation can be machined in milling. Milling operation can be performed in a single pass or in multiple passes. Multi-pass operations are often preferred to single pass operations for economic reasons and are generally used to machine stocks that cannot be removed in a single pass. Various investigators have presented optimization techniques, both traditional and non-traditional, for optimization of multi-pass milling operation. Smith describes the International Standards Organization (ISO) standards for milling cutter geometry. Mohan describes profile relieve cutters in milling contour surfaces Davies describes bonding of carbide inserts to such tools as end-mills instead of brazing them. Milling plays a central role as a shape generating technique in the machining of hollow forms. Such hollow shapes are used in tools for presses, forges, and foundry work. Granger describes the selection of a milling cutter in terms of average chip thickness rather than in feed/tooth. This approach depends on a combination of factors including material, component design, and strength, rigidity of fixturing, and type and age of machine.

2. LITRETURE REVIEW

According to [Myeong 1999] wear effect of cutting tool by integrated tool wear effect for tool path generation in flat face milling without modifying the cutting conditions, the objective was that, a tool path methodology is presented. The cutting forces calculated on the specific cutting pressure and i.e. tangential and radial specific constant. These cutting coefficients are parameters of cutting, cutting velocity, feed rate, tool diameter etc. The calculations of tool deflection by using FEM and cantilever beam model compared and integrate it in tool path compensation process. In FEM model flat face mill modeled with solid modeling system and analyzed it and in cantilever beam model measured the deflection by both the forces act on beam concentrated and distributed. Then compared with each other both FEM and cantilever beam model, the cantilever beam model approach is better than FEM and it further used to integrate the tool path compensation [Myeong, 1999].[1]

According to [Rao, 2004] the modeling of tooth trajectory and process geometry in peripheral milling of curved surfaces and deals with variable curvature geometries and true tooth trajectories except constant geometry in past. Calculated feed rate per tooth, entry angle, exit angle, maximum undeformed chip thickness. By using these calculations model a true trajectory. True tooth tranjectory model the process geometry. Process variables vary significantly in both the cases whether it is convex or concave, selection of process parameter values like cutting speed, feed and depth of cut and in modeling, variables like, entry angle, exit angle, feed per tooth along cutter contact path, maximum chip thickness and surface error, and concluded that it is necessary to use a model which considers variation of work piece curvature. Also necessary to model a true trajectory [Rao, 2004].[2]

According to [Altintas, 2000; Budak, 1994] two different methods for force analysis i.e. mechanistic and mechanics of cutting models, in first calculated cutting force coefficient which are calibrated for certain cutting condition. Three cutting force coefficient in the direction, radial, axial and tangential [Altintas, 2000; Budak, 1994].[3]

According to [Armarego, 1969] the maximum torque and power also calculated after one revolution of tool. As the force coefficient affected by chip thickness, since it varies continuously, the average chip thickness is used . As a result this model is very time consuming and number of experiment were taken to find the cuttin forces. But it’s ery hi h accuracy force prediction for most application. So mechanics of milling approach is used and may reduce the tests. In this technique measured tool angles, velocity and force equilibrium conditions [Armarego, 1969]. [4]

According to [Budak, 2005] the modeling of tool done by cantilever beam model, segmented beam model, and finite elements modeling. After the tool is modeled, the clamping stiffness must be known for the total tool deflection [Rivin, 1999]. Then structural deformation model of the work piece determined by FEM. Controlling by feed rate scheduling, milling conditions. The results represented that the cutting deflection reduced by 65-78% for variable curved geometries [Budak, 2005]. [5]

3. MODELING OF MULTI POINT FACE MILLING CUTTER

The cutter as per the specifications mentioned above has been modeled in Pro-E. The Fig (1) shows the various views of the modeled milling cutter.

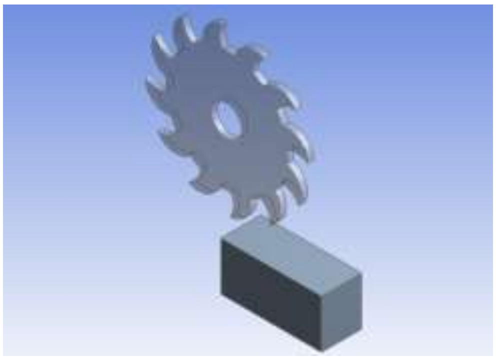


Figure 1: 3D-Model of Multi point milling cutter

Data of milling cutter

SR.NO.	DIA	SPEED	POWER	LOAD
1	212	50	5.50E+03	9914.674
2	212	100	5.50E+03	4957.337
3	212	500	5.50E+03	991.4674
4	212	1000	5.50E+03	495.7337
5	212	2000	5.50E+03	247.8668

Table 1: Data of milling cutter

4. FINITE ELEMENT ANALYSIS OF FACE 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 load (Wt) acting on a single tooth may be represented as:

Equation (1)
$$Wt = \frac{60{,}000\ H}{\pi D n}$$

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 [9]:

Equation (2)
$$\sigma = \frac{6W_1 l}{Ft^2}$$

The maximum allowable stress at the tip of the cutter is determined as:

Equation (3)
$$\sigma_{allowable} = \frac{StKL}{KTKR}$$

Where as:

St (AGMA bending strength) ¬ 44,000 psi

KR (reliability factor) = 1

KL (life factor) = 1

4. FINITE ELEMENT ANALYSIS OF MILLING CUTTER

Analysis of Milling Cutter: the milling cutter is a symmetrical body hence the analysis is carried out considering a single tooth of the cutter. Here, the analysis is done for 5 different spindle speeds ranging from 50 to 2000 rpm. The loads at these speeds are calculated and the corresponding Stresses acting on the tooth are found. Material of tool is M4 HSS, AISI 4340, M7 UNS and T15 UNS and work piece materials are structural steel, mild steel, cast iron and aluminum alloy.

Meshing of milling cutter:

Meshing has been done in ANSYS 14.5 by auto mesh generation 62049 and 10966 nodes and elements generated respectively.

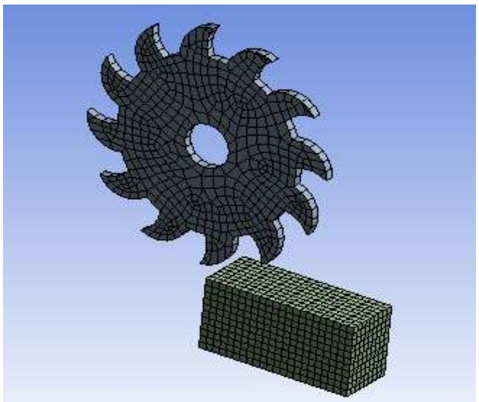


Figure 2: Meshing of milling cutter

Define angular velocity on milling cutter:

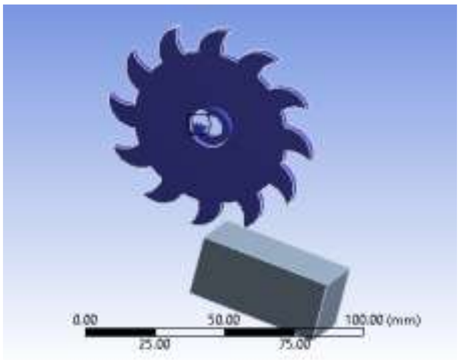


Figure 3: Define angular velocity on milling cutter

Define fixed support on milling cutter:

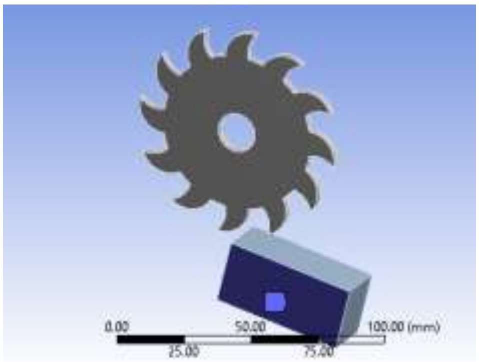


Figure 4: Define fixed support on milling cutter

CASE 1: For time=18 hrs, Here the speed is 50, 100, 500, 1000 and 2000 rpm. Four tool and work piece materials used for wear calculation, M4 HSS, AISI 4340, M7 UNS and T15 UNS are cutting tool materials and structural steel, mild steel, cast iron and aluminum are work piece materials The following image represents FEA based stress and variations.

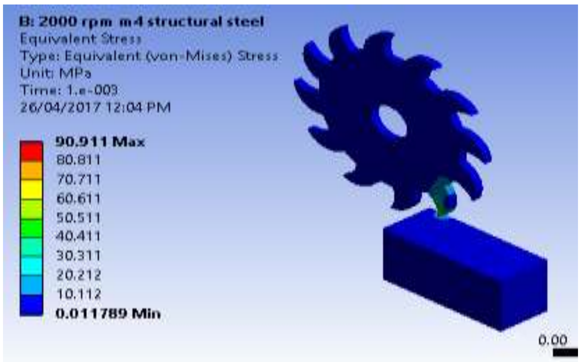


Figure 5: Stress results at 2000 rpm speed of M4 HSS and structural steel

CASE 2: For time=24 hrs, Here the speed is 50, 100, 500, 1000 and 2000 rpm. Four tool and work piece materials used for wear calculation, M4 HSS, AISI 4340, M7 UNS and T15 UNS are cutting tool materials and structural steel, mild steel, cast iron and aluminum are work piece materials The following image represents FEA based stress and variations.

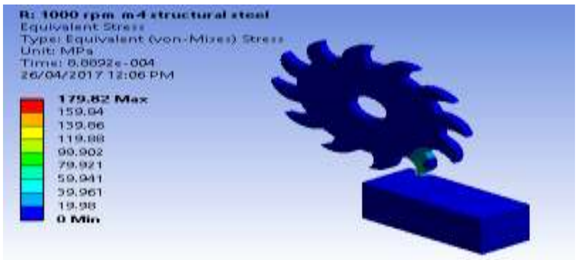


Figure 6: Stress results at 1000 rpm speed of M4 HSS and structural steel

CASE 3: For time=30 hrs, Here the speed is 50, 100, 500, 1000 and 2000 rpm. Four tool and work piece materials used for wear calculation, M4 HSS, AISI 4340, M7 UNS and T15 UNS are cutting tool materials and structural steel, mild steel, cast iron and aluminum are work piece materials The following image represents FEA based stress and variations.

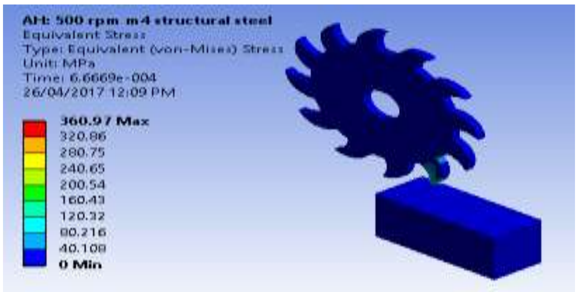


Figure 7: Stress results at 500 rpm speed of M4 HSS and structural steel

CASE 4: For time=36 hrs, Here the speed is 50, 100, 500, 1000 and 2000 rpm. Four tool and work piece materials used for wear calculation, M4 HSS, AISI 4340, M7 UNS and T15 UNS are cutting tool materials and structural steel, mild steel, cast iron and aluminum are work piece materials The following image represents FEA based stress and variations.

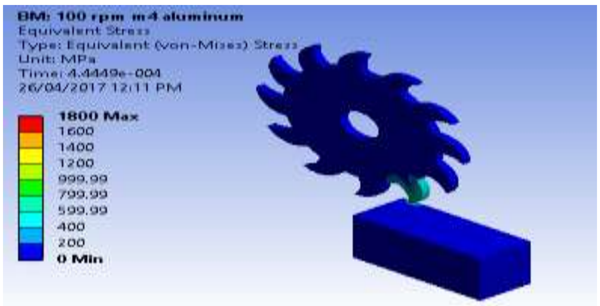


Figure 8: Stress results at 100 rpm speed of M4 HSS and structural steel

CASE 5: For time=42 hrs, Here the speed is 50, 100, 500, 1000 and 2000 rpm. Four tool and work piece materials used for wear calculation, M4 HSS, AISI 4340, M7 UNS and T15 UNS are cutting tool materials and structural steel, mild steel, cast iron and aluminum are work piece materials The following image represents FEA based stress and variations.

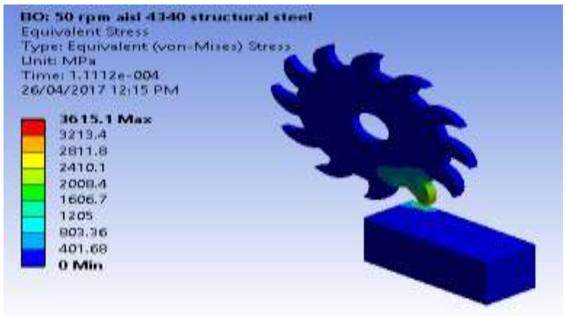


Figure 9: Stress results at 50 rpm speed of M4 HSS and structural steel

SR. NO.	DIA	SPEED	POWER	LOAD	STRESS (HSS Model)	STRESS (Theoretical)	STRESS (AISI 4340) Model
1	212	50	5.50E+03	9914.674	3613.2	2209.4	3229
2	212	100	5.50E+03	4957.337	1806.6	1104	1726.9
3	212	500	5.50E+03	991.4674	361.31	220.85	322.9
4	212	1000	5.50E+03	495.7337	180.39	110.3	616.21
5	212	2000	5.50E+03	247.8668	90.329	55.04	80.275

Table 2: Represents the Result for Model, Theoretical Stresses by varying Speed and Load

5. FLANK WEAR CALCULATIONS

Researchers and scientist have given several equations and techniques for calculating wear from one of these technologies from archards equation, wear have been calculated analytically.
According to Archard's equation

$\Delta V = k x S x L$

Where
ΔV = Change in volume due to wear
L = Sliding distance
S = Normal contact stress
K = Wear per unit pressure
Calculation of wear of milling tool for M4 HSS, M7 UNS, T15 UNS and AISI 4340 material
Volume of milling cutter teeth after deformation

$\boldsymbol{\Delta V = \tfrac{1}{2}(axcxh)}$

$= \tfrac{1}{2}(7x3x5)$

= 52.5 mm³ + 0.1256

ΔV = 52.6256 mm³

Details of the Flank wear calculations

To determine the nature of the effect of flank wear on the individual cutting force harmonics, The cutting parameters used in the simulation are as follows for M4 HSS tool material.

Sliding distance measured from milling machine for 18 hours is 110700 mm at the 50 rpm speed stress is 3612.8 MPA on structural steel work piece material.

Putting all the values in Archard's equation

ΔV = kxSxL

52.6256 = kx3612.8x110700 (teeth's are 12 and load is 9914.674)

K= 0.0156 mm

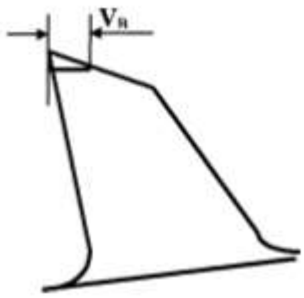


Figure 10: Flank wear at on face milling cutting tool

6. Results and Discussion

Followings are the results of milling cutter tool with different tool materials and work piece materials, four work piece and four tool materials are used to analyze the wear rate at different time and speed.

Following tables are representing the results of FEA and wear

18 hrs time period results

Work piece Material	Sr. No.	Speed	Stresses				Wear			
			M4 HSS	AISI 4340	M7 UNS	T15 UNS	M4 HSS	AISI 4340	M7 UNS	T15 UNS
Structural Steel	1	50	3612.8	3615.1	3617	3619.3	0.0156	0.0165	0.0166	0.0171
	2	100	1806.7	1808	1808.3	1808.7	0.0175	0.0184	0.0195	0.0198
	3	500	360.97	362.37	363.3	365.11	0.0210	0.0219	0.0229	0.0230
	4	1000	179.82	180.84	182.24	183.77	0.0405	0.0415	0.0425	0.0435
	5	2000	90.911	91.586	92.263	93.622	0.0615	0.0620	0.0625	0.0630
Mild Steel	1	50	3611.9	3613.9	3616.4	3618.1	0.0154	0.0163	0.0164	0.0169
	2	100	1805	1806.3	1806.7	1807	0.0173	0.0182	0.0193	0.0196
	3	500	360.02	361.44	362.37	363.75	0.0208	0.0217	0.0227	0.0228
	4	1000	178.73	181.08	181.32	182.24	0.0403	0.0413	0.0423	0.0431
	5	2000	90.563	90.237	90.911	92.263	0.0613	0.0618	0.0623	0.0628
Cast Iron	1	50	3610.7	3612.8	3615.2	3618.7	0.0152	0.0161	0.0162	0.0167
	2	100	1803.3	1805	1805.8	1807.5	0.0171	0.0180	0.0191	0.0194
	3	500	357.62	360.5	361.91	363.3	0.0206	0.0215	0.0225	0.0226
	4	1000	176.93	180.08	180.84	181.08	0.0401	0.0411	0.0421	0.0429
	5	2000	88.214	89.698	89.967	90.776	0.0611	0.0616	0.0621	0.0626
Aluminum	1	50	3607.6	3608.7	3609.5	3610.1	0.0148	0.0157	0.0158	0.0163
	2	100	1800	1801.7	1803.3	1805	0.0167	0.0176	0.0185	0.0190
	3	500	350.16	352.68	354.67	355.66	0.0202	0.0211	0.0220	0.0224
	4	1000	173.96	175.33	178.44	181.08	0.0397	0.0408	0.0416	0.0418
	5	2000	85.5	86.861	88.214	89.563	0.0607	0.0612	0.0617	0.0622

Table 3: 18 hrs time results

24 hrs time period results

Work piece Material	Sr. No.	Speed	Stresses				Wear			
			M4 HSS	AISI 4340	M7 UNS	T15 UNS	M4 HSS	AISI 4340	M7 UNS	T15 UNS
Structural Steel	1	50	3612.8	3615.1	3617	3619.3	0.0208	0.0213	0.0228	0.0233
	2	100	1806.7	1808	1808.3	1808.7	0.0233	0.0243	0.0253	0.0273
	3	500	360.97	362.37	363.3	365.11	0.0280	0.0296	0.0310	0.0316
	4	1000	179.82	180.84	182.24	183.77	0.0540	0.0546	0.0550	0.0566
	5	2000	90.911	91.586	92.263	93.622	0.0820	0.0830	0.0840	0.0845
Mild Steel	1	50	3611.9	3613.9	3616.4	3618.1	0.0206	0.0210	0.0225	0.0230
	2	100	1805	1806.3	1806.7	1807	0.0230	0.0240	0.0249	0.0270
	3	500	360.02	361.44	362.37	363.75	0.0278	0.0293	0.0307	0.0313
	4	1000	178.73	181.08	181.32	182.24	0.0538	0.0544	0.0547	0.0563
	5	2000	90.563	90.237	90.911	92.263	0.0818	0.0827	0.0838	0.0842
Cast Iron	1	50	3610.7	3612.8	3615.2	3618.7	0.0204	0.0208	0.0223	0.0228
	2	100	1803.3	1805	1805.8	1807.5	0.0227	0.0238	0.0247	0.0268
	3	500	357.62	360.5	361.91	363.3	0.0275	0.0290	0.0305	0.0310
	4	1000	176.93	180.08	180.84	181.08	0.0535	0.0541	0.0545	0.0560
	5	2000	88.214	89.698	89.967	90.776	0.0815	0.0825	0.0836	0.0840
Aluminum	1	50	3607.6	3608.7	3609.5	3610.1	0.0200	0.0204	0.0218	0.0220
	2	100	1800	1801.7	1803.3	1805	0.0223	0.0233	0.0244	0.0266
	3	500	350.16	352.68	354.67	355.66	0.0271	0.0285	0.0300	0.0306
	4	1000	173.96	175.33	178.44	181.08	0.0530	0.0535	0.0540	0.0546
	5	2000	85.5	86.861	88.214	89.563	0.0811	0.0820	0.0831	0.0835

Table 4: 24 hrs time results

30 hrs time period results

Work piece Material	Sr. No.	Speed	Stresses				Wear			
			M4 HSS	AISI 4340	M7 UNS	T15 UNS	M4 HSS	AISI 4340	M7 UNS	T15 UNS
Structural Steel	1	50	3612.8	3615.1	3617	3619.3	0.0260	0.0272	0.0280	0.0292
	2	100	1806.7	1808	1808.3	1808.7	0.0291	0.0301	0.0314	0.0320
	3	500	360.97	362.37	363.3	365.11	0.0352	0.0365	0.0372	0.0385
	4	1000	179.82	180.84	182.24	183.77	0.0675	0.0680	0.0685	0.0710
	5	2000	90.911	91.586	92.263	93.622	0.1025	0.1030	0.1035	0.1050
Mild Steel	1	50	3611.9	3613.9	3616.4	3618.1	0.0258	0.0270	0.0278	0.0290
	2	100	1805	1806.3	1806.7	1807	0.0287	0.0298	0.0311	0.0318
	3	500	360.02	361.44	362.37	363.75	0.0350	0.0363	0.0370	0.0382
	4	1000	178.73	181.08	181.32	182.24	0.0672	0.0677	0.0682	0.0707
	5	2000	90.563	90.237	90.911	92.263	0.01023	0.01028	0.1035	0.1048
Cast Iron	1	50	3610.7	3612.8	3615.2	3618.7	0.0255	0.0268	0.0276	0.0288
	2	100	1803.3	1805	1805.8	1807.5	0.0285	0.0296	0.0309	0.0315
	3	500	357.62	360.5	361.91	363.3	0.0347	0.0360	0.0368	0.0380
	4	1000	176.93	180.08	180.84	181.08	0.0670	0.0675	0.0680	0.0705
	5	2000	88.214	89.698	89.967	90.776	0.1020	0.1025	0.1032	0.1045
Aluminum	1	50	3607.6	3608.7	3609.5	3610.1	0.0251	0.0264	0.0272	0.0284
	2	100	1800	1801.7	1803.3	1805	0.0281	0.0292	0.0305	0.0311
	3	500	350.16	352.68	354.67	355.66	0.0342	0.0356	0.0363	0.0375
	4	1000	173.96	175.33	178.44	181.08	0.0665	0.0671	0.0676	0.0701
	5	2000	85.5	86.861	88.214	89.563	0.1016	0.1020	0.1028	0.1040

Table 5: 30 hrs time results

36 hrs time period results

Work piece Material	Sr. No.	Speed	Stresses				Wear			
			M4 HSS	AISI 4340	M7 UNS	T15 UNS	M4 HSS	AISI 4340	M7 UNS	T15 UNS
Structural Steel	1	50	3612.8	3615.1	3617	3619.3	0.0315	0.0320	0.0340	0.0352
	2	100	1806.7	1808	1808.3	1808.7	0.0352	0.0360	0.0374	0.0380
	3	500	360.97	362.37	363.3	365.11	0.0421	0.430	0.452	0.460
	4	1000	179.82	180.84	182.24	183.77	0.812	0.820	0.842	0.850
	5	2000	90.911	91.586	92.263	93.622	0.1230	0.1240	0.1250	0.1260
Mild Steel	1	50	3611.9	3613.9	3616.4	3618.1	0.0313	0.0318	0.0337	0.0350
	2	100	1805	1806.3	1806.7	1807	0.351	0.358	0.372	0.378
	3	500	360.02	361.44	362.37	363.75	0.419	0.428	0.449	0.458
	4	1000	178.73	181.08	181.32	182.24	0.810	0.818	0.840	0.848
	5	2000	90.563	90.237	90.911	92.263	0.1228	0.1238	0.1247	0.1258
Cast Iron	1	50	3610.7	3612.8	3615.2	3618.7	0.311	0.315	0.335	0.0347
	2	100	1803.3	1805	1805.8	1807.5	0.348	0.355	0.370	0.375
	3	500	357.62	360.5	361.91	363.3	0.416	0.425	0.447	0.458
	4	1000	176.93	180.08	180.84	181.08	0.808	0.815	0.0838	0.0845
	5	2000	88.214	89.698	89.967	90.776	0.1226	0.1236	0.1245	0.1255
Aluminum	1	50	3607.6	3608.7	3609.5	3610.1	0.0308	0.0311	0.0311	0.0343
	2	100	1800	1801.7	1803.3	1805	0.344	0.351	0.0366	0.0371
	3	500	350.16	352.68	354.67	355.66	0.0412	0.0421	0.0442	0.0455
	4	1000	173.96	175.33	178.44	181.08	0.0803	0.0810	0.0835	0.0840
	5	2000	85.5	86.861	88.214	89.563	0.1221	0.1232	0.1240	0.1251

Table 6: 36 hrs time results

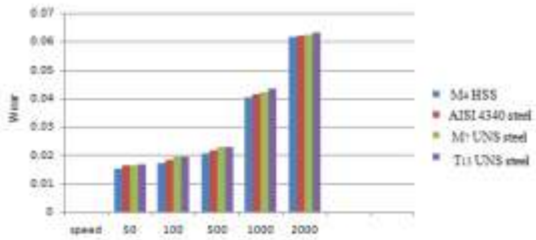
42 hrs time period results

Work piece Material	Sr. No.	Speed	Stresses				Wear			
			M4 HSS	AISI 4340	M7 UNS	T15 UNS	M4 HSS	AISI 4340	M7 UNS	T15 UNS
Structural Steel	1	50	3612.8	3615.1	3617	3619.3	0.0364	0.0389	0.0404	0.0409
	2	100	1806.7	1808	1808.3	1808.7	0.0408	0.0413	0.0428	0.0433
	3	500	360.97	362.37	363.3	365.11	0.0490	0.0506	0.0519	0.0536
	4	1000	179.82	180.84	182.24	183.77	0.0950	0.0961	0.0970	0.0991
	5	2000	90.911	91.586	92.263	93.622	0.1435	0.1450	0.1465	0.1470
Mild Steel	1	50	3611.9	3613.9	3616.4	3618.1	0.0362	0.0387	0.0402	0.0406
	2	100	1805	1806.3	1806.7	1807	0.0407	0.0411	0.0426	0.0431
	3	500	360.02	361.44	362.37	363.75	0.0488	0.0504	0.0517	0.0533
	4	1000	178.73	181.08	181.32	182.24	0.0948	0.0958	0.0968	0.0998
	5	2000	90.563	90.237	90.911	92.263	0.1433	0.1448	0.1463	0.1468
Cast Iron	1	50	3610.7	3612.8	3615.2	3618.7	0.0360	0.0385	0.0400	0.0404
	2	100	1803.3	1805	1805.8	1807.5	0.0405	0.0409	0.0424	0.0428
	3	500	357.62	360.5	361.91	363.3	0.0485	0.0502	0.0515	0.0530
	4	1000	176.93	180.08	180.84	181.08	0.0945	0.0955	0.0966	0.0995
	5	2000	88.214	89.698	89.967	90.776	0.1430	0.1445	0.1460	0.1465
Aluminum	1	50	3607.6	3608.7	3609.5	3610.1	0.0358	0.0383	0.0398	0.0402
	2	100	1800	1801.7	1803.3	1805	0.0402	0.0406	0.0425	0.0426
	3	500	350.16	352.68	354.67	355.66	0.0483	0.0500	0.0512	0.0527
	4	1000	173.96	175.33	178.44	181.08	0.0942	0.0952	0.0964	0.0992
	5	2000	85.5	86.861	88.214	89.563	0.1425	0.1441	0.1455	0.1460

Table 7: 42 hrs time results

Figure 11 Speed v/s wear graph

At 18 hrs time period on structural steel work piece material



7. CONCLUSION

Followings are the results discussions occurred in finite element analysis.

- Stresses on face milling tool tooth found is low in M4 HSS steel as compared to AISI 4340 steel, M7 UNS and T15 UNS steel, four work piece materials (structural steel, cast iron, mild steel and aluminum alloy 6061) were selected to perform finite element analysis and all the four materials of work piece M4 HSS is more accurate than other three steel.

- Wear on face milling cutting tool tooth found is low in M4 HSS steel as compared to AISI 4340 steel, M7 UNS and T15 UNS steel, four work piece material were selected to perform finite element

  analysis and all the cases M4 HSS more accurate than other three steel.
- Wear width is more in AISI 4340 steel, M7 UNS and T15 UNS steel as compared to M4 HSS, four work piece material were selected to perform finite element analysis and all the cases M4 HSS steel is more accurate than other three steel.
- M4 HSS tool life is more than AISI 4340 steel, M7 UNS and T15 UNS steel tool at all the work piece materials.
- At high cutting speed the wear rate is higher and at low cutting speed wear rate is lower on all the tool materials.

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