Cutting tools simulation with different parameter

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Abstract. Previous studies have described that micro-devices either with analysis and simulation viewing that micro tools a very central role in micro machines, and microtool geometry has a direct upshot on the value of the last process. Design geometry micro milling tools for was taken from macro tools, where can be assumed that adverse effects occurring during the process of milling is analogical, which basically means the formation of chip and the process of kinematic is in the kind of tools. In this research also mentioned that there is often structural detail that inhibits miniaturization. To define the optimal parameters in the micro milling then that should be taken into account is to take effect of minimum chip, cutting refraction, and spindle run-out, development is required for the model of micro milling forces.

Keywords: micromachining, milling, simulation, cutting tool.

1. Introduction
Micromachining is a very significant and fundamental expertise for miniature components and mechanisms. Since it developed the movement of scientific growth for few years back, micromachining is predictable to be an important role in today’s manufacturing knowledge [1]. Due to the nature of the miniature, the micro machine tool is exposed to excessive wear and tear because of this, poor surface quality and productivity that has a very high standard. The power present in the micro milling process can root deformation of the tool or workpiece and can change the process of forming the thickness of the chip, cutting strength. Small devices make damage detection very difficult to see. Thus, the simulation on the cut style is used with the element method up to the defect determination.

Basically, the word micro machining is in place of the machining of the sizes among 1μm to 999 μm. Though, the machining production cannot be accomplished directly by a conservative tool, system and technologies [2].

The current commercial micro endmills show that micro end mills geometry mainly comes from macro endmills, this is a rescale process. Fabrication of micromilling cutters is an interesting task to do because of its relatively small size. Common defects that occur related to these tools are geometric deviations / deviations and resolutions / integrity that are not good from the cutting edge.

Studies that study various tool geometries are used to make micro milling devices more competent. Used abaqus FEM software, von misses voltage and cutting force be able to be searched thus that the defects can be detected. Macro machining determines the wear of a defective device by measuring the edge of a tool but the micro grinding tool is too small that can be measured and analyzed. Using simulation prsoes, cutting strength has been identified to determine tool wear. His knowledge can advance to develop micro milling tools that are more precise and efficient so that their development appears.
Thus, the FEM method is used to see the results of the analysis of the heat spreading, tool wear, cutting force then voltage of the micro grinding tool. How to get von misses stress, the modeling analysis method in abaqus is used for the required model. Tool geometry is an important consideration for reducing tool eye wear and extending tool life.

By reducing the macro milling component, the size and impact of the tool can reduce stiffness. Because of the nature of the reduction scale, micro machine tools occur more than before, so that poor surface quality and productivity have certain limits. Micro milling results in the thickness of small formation chips which are known as challenges. The thickness of the chip depends on the machine material and the geometry of the tool which is very problematic to know [2]. The force created in the micro milling process can origin distortion of the tool or workpiece and can change the thickness of the chip, cutting strength. Due to the small dimensions that make it a problem to detect damage to the sharp edges [3]. Thus, to determine the defects that occur, simulations of the cutting force are carried out using the finite element method.

There is a limit to the current scale reduction procedure from macro milling to micro milling. Unlike in a large size macro or milling process, the dimensions of the chip load and geometry currently available for micro milling operations are lower than those currently available, this process presents a difficulty in modeling and controlling processes. Very significant structures such as geometry and cutting parameters requirement carefully and measured to prevent premature wear and damage to cutting tools.

The scope of this research is to see the results of tool geometry simulation using the FEM, namely ABAQUS / CAE software. These tools have developments with sharp edges that have variations, 0.26 μm and 0.52 μm. While the diameter of all tools is constant at 260μm.

The parameters and cutting conditions for this micro grinding process are resolute in the model. Workpieces use AISI D2 material and cutting tools by Titanium Alloy. Workpieces to be used in static conditions which are cutting tools that move horizontally for cutting. The speed used is 2000 rad/s with anticlockwise alternation.

2. Methodology

The geometry tool used in the research is the critical edges of the tool bit. Where is the process, the ends of the cutting tool are significant the micro-milling process considers getting a better surface finish. In process, the boundaries of the tool affect the strength of the tool because the area of the range of the edge is sharp rather than sharp edges. Even though the cutting edge of the small tool becomes weaker, it reduces the cutting strength on the sharp edge. In addition, the edges affect the strength of cutting, misses-stress and heat distribution which will reduce the life of the tool or make defects in the device.

Because of the small edge radius, a negative rake angle will occur immediately in this process. Emersion from a negative rake angle will cause hijacking and elastic recovery on the surface [2]. In this case, considering the cutting depth is required, the cutting depth needs to be greater than the smallest the material will not be cut but forces the tool to go down through the thickness of the chip. The figure explains the procedure of piracy and flexible reposssession in the micro milling method.

Phase 1 – Development of design specification for the new micromilling cutting tool
- To confirm about specification required by the industry for micromilling cutting tool
- To set specification for new design

To design new micromilling cutting tool based on required specification To perform Finite Element Analysis (FEA) simulation on the new design To optimize the simulation process in order to finalize the optimize design micromilling cutting Tool

Phase 3 – Tool fabrication and machining test
- To fabricate optimized cutting tool design
• To perform machining test of fabricated cutting tool

Phase 4 – Characterization of cutting tool after machining test
• To characterize of the surface integrity, morphology, surface roughness and microhardness

Phase 5 – Design procedure for development of micromilling cutting tool
• To model the machining parameters and characteristic to be used as design guideline to design micromilling cutting tool

The Johnson Cook material model describes the behavior of plastic for steel when the strain level becomes high and the temperature also becomes high involved. The JC material model replicates a specific type of Von Misses curvature [5].

Dynamic algorithms explicitly look at the central operator - the difference where displacement occurs and speed is deliberate in terms of quantity known at the start of the increase [5].

The process of combining the structures of pure Langarian and Eulerian investigation. In this method the existing mesh is not committed to the material and reduces distortion and updates the permitted chip geometry. The development of the chip is thus replicated through adaptive meshing and working material plastic movement [2]. This tool is an effective tool in improving mesh value in analyzing large distortion difficulties.

Abaqus is software which has the ability to generate a computational model and perform the simulations required. To complete the process of simulation and investigation of the chip formation and material deformation, the Johnson-cook material model technique and Arbitrary Langrian Eulerian method need to be implemented. ABAQUS software is used to analyze sophisticated finite elements to provide a solution to see linear dynamics, non-linear, explicit and multi-body and has been adopted in many engineering scientific disciplines.

Abaqus/CAE has the ability to create and generate Abaqus models. It can also perform analysis on the simulation results where it can be manipulated to achieve the objective of the intended study. This software is familiar and popular for research institutions and for academic usage because of its extensive material demonstrating capability, and also the program’s ability to be customized. This assists users to generate and simulate the contact phenomena and chip formation and is effective in generating the solutions for micromachining modeling analysis as well. Abaqus also has the ability to collect good multi-physical capabilities, such as structurally well-structured acoustic-structural, piezoelectric, and structural capabilities, manufacture it more attractive to simulate manufacture levels where several fields requirement to be combined.

3. Result and Discussion
The simulation cutting process is carried out using the finite element method, namely Abaqus software in many types of tools model. The results shown from data collection in the simulation of the micro grinding process. From the results, it can be seen and clearly understood that the parameter of the milling tool is precious by von misses voltage, normal force and temperature circulation. Finite Element Manufacturing is done using bits with dissimilar sharp edges, radius 0.26 μm and 0.52 μm and no edge propagation.

The cutting strength acting on cutting tool needs to be measured while the machining process. Cutting force generation shown in Figure 1 through the process with FEM.
The highest increase when cutting occurs in the M3 model, where the increase is 51%. This tool is very widely available in the market and is often used.

Rounded edges tend to be more wear compare with smaller roundness or roundness. In the start of machining with a big startup cutting force, the edge of the tool becomes dull at the end of process machining. Cutting on the edges and work pieces with large contact areas can provide great friction where there is more force and increased wear on sharp edges. This can be seen in table 5.

The influence that can make cutting force increase in micro milling is the interaction area of the workpiece and the increased equipment where the tool starts to be used at one time or the displacement of the workpiece. Therefore, this can make the device vulnerable when the tool geometry is changed. The wear of the chisel can produce tool wear on the sharp edges.

| Model  | Tool Geometry  | Cutting force generation, kN | Increase in percentage, % |
|--------|----------------|------------------------------|---------------------------|
| Model 1| Sharps Edges   | 3.43                         | 5.04                      | 32                        |
| Model 2| 0.2μm          | 5.01                         | 8.04                      | 38                        |
| Model 3| 0.5μm          | 5.05                         | 10.24                     | 51                        |

Von Misses distribution voltage caused by plastic deformation distribution which is not the same. Von Misses the voltage distribution can be seen in Figure 2. In Figures 3 to 6 shows various looks at the time of cutting affect von misses distribution in the process in machining at the start and end of the progression.
Figure 3 Stress Spreading of 4 Flutes Tool Parameter

Figure 4 Von Misses Stress Distribution at (a) Start (b) End of cutting process for no cutting edges

Figure 5 Von Misses Stress Distribution at (a) Start (b) End of cutting process for 0.26 μm cutting edges

Figure 6 Von Misses Stress Distribution at (a) Start (b) End of cutting process for 0.52 μm cutting edges
Increases when von misses stress spreading can be realized. Various types of critical edges can be due to von misses’ voltage distribution. If a higher edge of the cutter causes more to pass the voltage distribution in the process.

The higher von misses’ stress distribution voltage occurs in the M3 model which is 2.31GPa to 6.02 GPa with an increase of 62%. Whereas the M1 model provides a low increase in von misses stress by 5%. Through simulation, von misses emphasize increasing rapidly as the cutting edge increases. Workpiece materials that experience contact with sharp edges indicate greater stress for all stress distribution conditions. As a result, a bigger voltage is needed to cut the workpiece that allows it to exceed the yield strength limit of the workpiece.

Table 2 Von Misses Stress 4 Flutes [19]

|                     | Beginning | End    | Percentage growth % |
|---------------------|-----------|--------|----------------------|
| Cutting Force       | 25.57 mN  | 63.93 mN | 60.0                |
| Von Misses Stress   | 2060 Pa   | 2289 Pa | 10.0                |

Table 3 Von Misses Stress 4 Flutes Type in This Study

|                     | Beginning | End    | Percentage growth % |
|---------------------|-----------|--------|----------------------|
| Cutting Force       | 3.43 kN   | 5.04 kN | 32.0                |
| Von Misses          | 2.26 GPa  | 2.37 GPa | 5.0                |

4. Conclusion
To get cutting strength when distribution cutting, voltage and thermal with different sharp edges through simulation was achieved. The output and results with finer meshing will provide more accurate results. From this research, it shows that the tools in the M1 model have low cutting strength, voltage and heat distribution.

The M1 model in this study provides guidance for new condition tools for milling and the M2 and M3 models present the tools used that have wear edges. This event shows that the need for cutting force for tools that have edge use. Predictions for all results have been achieved that no edge rounder provide better performance in the micro grinding process which requires lower cutting forces. Low cutting forces can reduce the risk of deflecting. Smaller cutting forces also make machining more efficient because the force required for task completion is lower and does not require high speed when rotated. Therefore, through this research it can be concluded that the objectives to be achieved as voltage, cutting strength and distribution thermal for various cutting edges have been found using the Abaqus Software.

References
[1] M.Rahman, H.S. Lim, K.S. Neo, A. Senthil Kumar, Y.S. Wong, X.P. Li. (2007), Tool-based nano finishing and micromachining, Journal of Materials Processing Technology, Vol. 185, pp. Pages 2–16.
[2] T.Masuzawa and H.K.Tonshoff (1997), Three-Dimensional Micromachining by Machine Tools, Presented at the Scientific Technical Committee Paper Discussion Sessions.
[3] G. Bissacco, H.N. Hansen, L. De Chiffre. 2-3, 30 August 2005, Micromilling of hardened tool steel for mould making applications, Journal of Materials Processing Technology, Vol. Volume 167, pp. 201–207.
[4] J.Gomar, A. Amaro, E. Vázquez, J. Ciurana, and C. Rodríguez. 2011, Micro-machining of 3D geometries for medical applications, The 4th Manufacturing Engineering Society International Conference (Mesic) (2011), pp. 449-456.
[5] F Z Fang, H Wu, X D Liu, Y C Liu and S T Ng. 2003, Tool geometry study in micromachining. Micromech. Microeng. 13, pp. 726 -731.
[6] Ziyang Cao, Hua Li 2010, Investigation of Micro-Milling Force Based on Miniature Machine Tool, Applied Mechanics and Materials, Vol. 29-35, pp 1074-1078.

[7] Xiang Cheng, et.al. 2011, A study on the micro tooling for micro/nano milling, Int. J. Adv. Manuf Technol 53:523–533.

[8] J. Fleischer et al. 2008, Design and Manufacturing of Micro Milling Tools, Microsyst Technol 14:1771–1775.

[9] Shih-ming Wang, et al. (2012), Development of micro milling force model and cutting parameter optimization, Trans. Nonferrous Met. Soc. China 22 s851–s858.

[10] R. Jalili Saffar, M.R. Razfar, O. Zarei, E. Ghassemieh “Simulation of three-dimension cutting force and tool deflection in the end milling operation based on finite element method” Simulation Modelling Practice and Theory, 2008.

[11] S L Soo et al. 2016, Three-dimensional finite element modelling of high-speed milling of Inconel 718, Proc. Instn Mech. Engrs Vol. 218 Part B: J. Engineering Manufacture.

[12] J. Sun al. 2009, A comprehensive experimental study on surface integrity by end milling Ti–6Al–4V, Journal of Materials Processing Technology 209, 4036–4042.

[13] L. Zhou al. 2015, Analytical modeling and experimental validation of micro end-milling cutting forces considering edge radius and material strengthening effects, International Journal of machine Tools & Manufacture 97, 29–41.

[14] Bing Wu al. 2013, Cutting Force Analysis in Micro Milling of Steel, Advanced Materials Research Vols. 774-776 pp 1017-102

[15] François Ducobu al. 2016, Dynamic simulation of the micro-milling process including minimum chip thickness and size effect, Key Engineering Materials Vols 504-506 pp 1269-1274.

[16] Xuemei Yu al. (2009), Finite Element Simulation and Analysis of Size Effect in Micro-milling Process, Applied Mechanics and Materials Vols. 16-19 pp 1159-1163.

[17] Adetoro, M. B., & Wen, P. H. (2008). Simulation of end milling on FEM using ALE formulation. In Abaqus user’s conference (pp. 1-19)

[18] A. Nasri al. 2016, 3D Parametric Modelling of Milling Cutter Geometry from Analytical Analysis, International Journal of Science, Technology and Society; 4(2): 35-40.

[19] Sooraj V. S. et al. 2011, An experimental investigation on the machining characteristics of microscale end milling, Int J Adv Manuf Technol 56:951–958.

[20] Tao Wu, Kai Cheng and Richard Rakowski, “Investigation on Tooling Geometrical Effect of Micro Tools and the Associated Micro Milling Performance,” Journal of Engineering Manufacture, 2012.