FEM analysis in identifying the turning parameters for dimple structure fabrication

Mohd Nor Azam Mohd Dali[1,2], Jaharah A.Ghani[2,*] , Che Hassan Che Haron[2]

[1)] Politeknik Ungku Omar, Jalan Raja Musa Mahadi, 31400 Ipoh, Perak, Malaysia.
[2)] Department of Mechanical and Material Engineering, Faculty of Engineering and Built Environment, Universiti Kebangsaan Malaysia, 43600 Bangi, Selangor, Malaysia.

[*]Corresponding e-mail: jaharah@eng.ukm.my

Keywords: Third wave; dimple structure; surface texturing

ABSTRACT – The application of Third Wave Advant Edge software is very helpful and effective in determining the suitable range of cutting condition and to minimize the number of experiment in producing dimple sturucture using turning process. Orthogonal array in Taguchi method is utilized to accommodate the cutting parameters such as cutting speed, feed rate, depth of cut and vibration frequency to carry out the simulation. The input values of cutting tool geometries were similar with past studies. Approximately there are 20 ranges of cutting parameters of speed and feed rate tested to obtain the cutting force vs the length of cut that lead to rough estimation of dimple structure sizes for the actual machining. Dynamic frequency is tested in order to observe the potential use of low frequency which is based on the ability and stability of the vibration assisted tooling developed in the range of 15 – 25 Hertz. From the simulation, the machining parameters with cutting speed of 4 – 35 m/min, feed rate of 0.01 – 0.6 mm/rev and depth of cut of 0.01 – 0.05 mm are found suitable for dimple fabrication for A3xx casting Aluminum alloy based on the shape of cutting force graph.

1. INTRODUCTION

FEM analysis is one of the useful methods and effective in attaining quick results in terms of both time and cost saving. According to Arrazola et al. [1], FEM analysis is able to lower the operational cost than directly carried out the machining experiment. In addition it will provide information that are challenging to measure such as temperature, pressure. There are generally three types of commercial finite element analysis software and important for users to select the right one for their application in order to obtained an accurate results [2]. The widely used FEM software in metal cutting are Deform, Advant Edge and Abaqus [2], where the simulation results are proven to be consistent and similar to the experimental results obtained by previous researchers. Therefore, in this study, FEM analysis helps to reduce the number of range for the cutting condition to obtain the cutting force graph vs the length of cut.

Taguchi method was utilised for conducting the experiment. According to Thakur et al. [3], the Taguchi method is a design with highly potential in performing the experimental design of engineering processes that requires result or optimum parameters combination. This method allows a simple approach for both effective and systematic on an optimum design for performance, quality and cost [4]. Machining parameters will effect the shape and dimple size. Parameters that had been investigated by Guo & Ehmann [5] were cutting speed, feed rate, cutting tool geometry and shape of the vibration trajectory. The parameters that influence the tool life and surface quality are cutting/vibration condition, elliptical vibration cutting technique, binder material and grain size [6].

This research is focused on the graphical form of cutting force versus the length of cut in determining the range of the cutting condition that is suitable for dimple fabrication. Crucial parameters considered in the simulation include the cutting speed, feed rate, cutting edge radius, rake angle, relief angle as well as the frequency of the dynamic tool.

2. METHODOLOGY

The orthogonal array L_9 in Taguchi method which can accommodate three levels cutting parameters was used as shown in Table 1. The flow chart shown in Figure 1 for the simulation methodology.

Table 1 Three levels cutting parameters.

Level	Cutting Speed (m/min) A	Feed Rate (mm/pus) B	DOC (mm) C	Frequency (Hertz) D
0	10	0.4	0.01	15
1	15	0.5	0.03	20
2	20	0.6	0.05	25

3. RESULTS AND DISCUSSION

From the simulation result, the range of cutting speed is chosen based on the graph obtained which has the frequency cutting force shape that gives a gross estimate of dimple structure formation. The machining parameters with cutting speed of 4 – 35 m/min, feed rate of 0.01 – 0.6 mm/rev and depth of cut of 0.01 – 0.05 mm are found suitable for dimple fabrication for A3xx casting Aluminum alloy. Based on the length of cut it shows that the cutting was took place at a distance of about 10 µm, which can be considered as the dimple structure diameter formation. This result is similarly obtained by previous researches. Yan et al. [7] able to fabricate the dimple structure diameter of 200 µm and

282 µm using milling operation, Roy et al. [8] successfully fabricate 400 µm diameter using micro tooling. While, Guo & Ehmann [9] successfully fabricate 40 µm dimple structure diameter using assisted turning and also Zhang et al. [10] fabricate 140.9 ± 2.8 µm diameter by the same process. Machining experiment is carried out to validate one of the simulation result at that cutting condition of cutting speed 7 m/min, feed rate 0.4 mm/rev, DOC = 0.05 mm and frequency 20 Hertz. Figure 2 shows the cutting force in *X* and *Y* direction vs length of cut (mm). This shape of cutting force graph indicates that the process is intermittent and able to produce the dimple structure. The dimple produced is shown in Figure 3 with dimple size of 523 µm with depth of 70 µm.

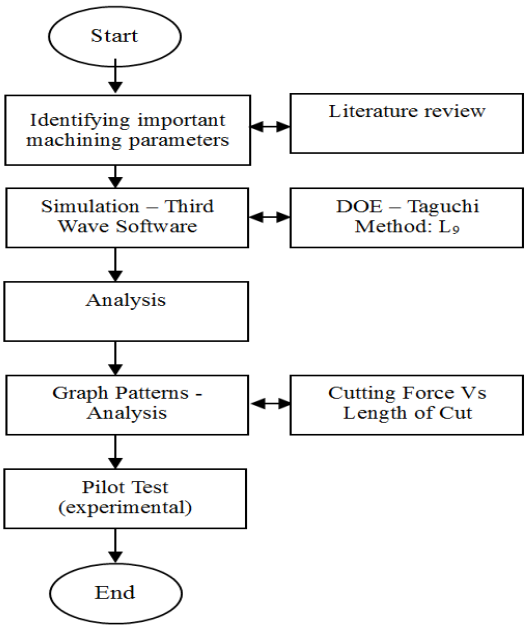

Figure 1 Simulations flow chart.

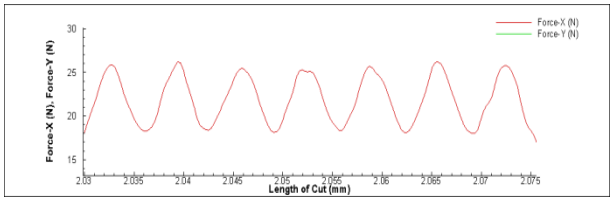

Figure 2 Cutting force in *X* and *Y* direction vs length of cut (mm).

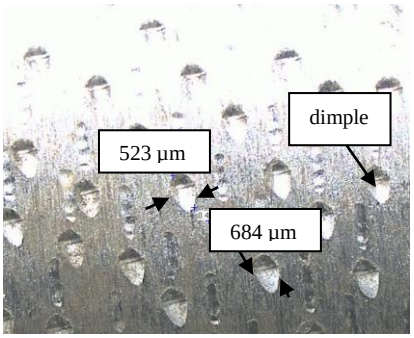

Figure 3 Dimple structure fabricated using developed assisted tooling in turning process at cutting speed 7 m/min, feed rate 0.4 mm/rev, DOC = 0.05 mm and frequency 20 Hertz.

4. CONCLUSION

The range of turning parameter obtained from the simulation that can produced dimple structure for A3xx casting Aluminum alloy are cutting speed of 4 – 35 m/min, feed rate of 0.01 – 0.6 mm/rev and depth of cut of 0.01 – 0.05 mm.

5. REFERENCES

[1] P.J.Arrazola, D.Ugarte, J.Montoya, A.Villar, S. Marya, "Finite element modeling of chip formation process with Abaqus/Explicit™ 6.3," in *VIII International Conference on Computational Plasticity*, 2005, pp. 1-4.

[2] A.Bareggi, G.E.O'Donnell, A.Torrance, "Modelling thermal effects in machining by finite element methods," in *24th International Manufacturing Conferance*, 2007, pp. 263-272.

[3] D.Thakur, B. Ramamoorthy, L. Vijayaraghavan, "Optimization of high speed turning parameters of superalloy inconel 718 material using taguchi technique," *Indian Journal of Engineering and Materials Sciences*, vol. 16, pp. 44-50, 2009.

[4] S.Thamizhmanii, S.Saparudin, S.Hasan, "Analysis of surface roughness by turning process using taguchi method," *Journal of Achievements in Materials and Manufacturing Engineering*, vol. 20, no.1-2, pp. 503-506, 2007.

[5] P.Guo, K.F.Ehmann,"An analysis of the surface generation mechanics of the elliptical vibration texturing process," *International Journal of Machine Tools & Manufacture*, vol. 64, pp. 85–95, 2013.

[6] J.Zhang, N.Suzuki, Y.Wang, E.Shamoto, "Fundamental investigation of ultra-precision ductile machining of tungsten carbide by applying elliptical vibration cutting with single crystal diamond," *Journal of Material Processing Techonology*, vol. 214, pp. 2644-2659, 2014.

[7] J.Yan, Z.Zhang, T.Kuriyagawa, H.Gonda, "Fabricating micro-structured surface by using single-crystalline diamond endmill," *Int J Adv Manuf Technol*, vol. 51, pp. 957–964, 2010.

[8] T.Roy, D.Choudhurya, A.B. Mamat, B. P.Murphy, "Fabrication and characterization of micro-dimple array on Al_2O_3 surfaces by using a micro-tooling,"*Ceramics International*, vol. 40, pp. 2381–2388, 2014.

[9] P.Guo, K.F.Ehmann,"Development of a tertiary motion generator for elliptical vibration texturing," Precision Engineering, vol. 37, pp. 364-371, 2013.

[10] R.Zhang, P.Steinert, A.Schubert, "Microstructuring of surface by two-stage vibration-assisted turning," in *6th CIRP International Conference on High Performance Cutting, HPC2014*, vol. 14, pp. 136-141, 2014.