ISSN No:-2456-2165

Experimental Study of Maximum Temperature and Temperature Changing Profiles during Drilling in Pure Aluminum Blocks Under Varying Cutting Conditions

Asim Ahmad Riaz[1], Naveed Ullah[2]
Department of Mechanical Engineering University of Engineering & Technology
Peshawar, Pakistan

Abstract:- Tool life and Surface finish of the part are the key considerations during machining. This research aims to precisely calculate the temperature rise and temperature variation trend during drilling of pure aluminum blocks to a specific depth under varying cutting conditions. The thermal rise due to friction occurs at the multiple cutting edges during shear interaction between cutting tool and work piece were investigated using non-contact infrared temperature sensor. A 10mm End Mill cutter of High-speed steel coated with titanium is used for drilling in Aluminum blocks using conventional universal milling machine. A series of experiments were conducted for different nine combinations under varying tool speeds (43, 77, 141 rpm) and feed rates (0.53, 0.97 and 1.94 mm/min) during dry drilling to a drill depth of 10mm. Each combination is tested for two samples for statistical analysis and results authentication.

Keywords:- *Temperature variations, Drilling, Endmill Cutter, Infrared Temperature Sensor, Pure Aluminum.*

I. INTRODUCTION

As machine downtime adversely affect the performance of production setups. There are many reasons which lengthen machine downtime and decrease availability of machine for production. One of the major causes in machine downtime is the depreciation in required properties of tools during machining. Proper coating and proper lubricant oil can reduce tool wear and reduce temperature rise while drilling under varying cutting condition. Temperature rise during machining effect the morphology of tool cutting edges as well as decline the finishing quality of final geometries. The paper aims to investigate the instant temperature rise at varying cutting condition during machining of pure aluminum blocks.

R. Muhammad et al. studied the effect of feed rate and tool speed on the temperature rise and concluded that with increase in the cutting speed, the temperature rise increases [1]. S. Rawat and H. Attia studied the temperature rise for composite material during drilling under dry cutting condition and found a steady temperature of 210 °C for spindle speed of 1500 rpm and feed rate of 20 mm/rev. He also found that rate of rising temperature increase from 5 °C/s to 63 °C/s as the feed increase from 20 µm/rev to 200 µm/rev [2].

Research studies have been conducted to investigate the tool wear and temperature rise during dry machining condition and found the temperature rise is due to large shear strain in the primary shear zone and due to friction at the tool-chip interface which result in the decrease in tool life. The generated heat effect the surface finishing, cutting energy and cutting forces. [3-5]. M. Nouari et al. concluded for aluminum alloy AA2024 that increase in the cutting speed leads to an increase in the tool-workpiece interface temperature, which results in aluminum transfer from the workpiece to cutting tool via diffusion mechanism [6]. An infrared pyrometer (IR pyrometer) is employed to find temperature along the milling path. The IR pyrometer was arranged to follow the cutter at a distance of 17 mm and to predict the milling temperature. In the same way, in another study, IR pyrometer was used to measure surface temperature of thin walled workpiece and developed an inverse heat transfer model to measure temperature distribution at the interface of tool tip-workpiece chips [7-8]. Dewes et al. used ball mill cutter to record tool-workpiece interface and chip temperatures during milling using both thermocouple and infrared camera techniques [9]. Coz et al. concludes that changes in the feed and speed values lead to worst condition at the tool rake face which results in temperature rise [10].

Bagci and Ozcelik Studied the temperature rise during dry drilling of AA-7075-T651 and concluded that feed rate and speed has no significant effect on drill bit temperature. [11]. In another research, they studied continuous and step wise drilling of AISI 1040 steel and AL 7075-T651 materials, it is observed that temperature decreases with increase in feed rate for the same drill depth. Further it is observed that temperature of drill bit increases with increase in spindle speed for AISI 1040 steel during step wise dry drilling but for AL 7075-T651, it decrease with spindle speed [12].

II. EXPERIMENTAL SETUP AND PROCEDURE

A series of experiment were conducted to investigate instant temperature variation trends during dry drilling at varying cutting parameters. For experimental work, blocks and rods of pure aluminum were cut into required dimension using power hack saw. Then it is filed for surface smoothness and were clamped in machine vice of milling machine for drilling operation using End Mill cutter. The tool speed and feed rates were selected as per milling machine tool specification and limitation.

A. Material and Cutting parameter:

Pure Aluminum is the subject material used in the current study. The elemental composition of the aluminum block is confirmed with EDS analysis. The samples of Aluminum blocks with 3×3×1 cm dimension were used (Figure 1). A 10mm End Mill cutter of High-speed steel coated with titanium is used for drilling in aluminum blocks using conventional universal milling machine tool under varying tool speed and feed rate. The samples were dry drilled to a depth of 10 mm under varying tool speeds (43, 77, 141 rpm) and feed rates (0.53, 0.97 and 1.94 mm/min). The process setup is depicted in figure 2;

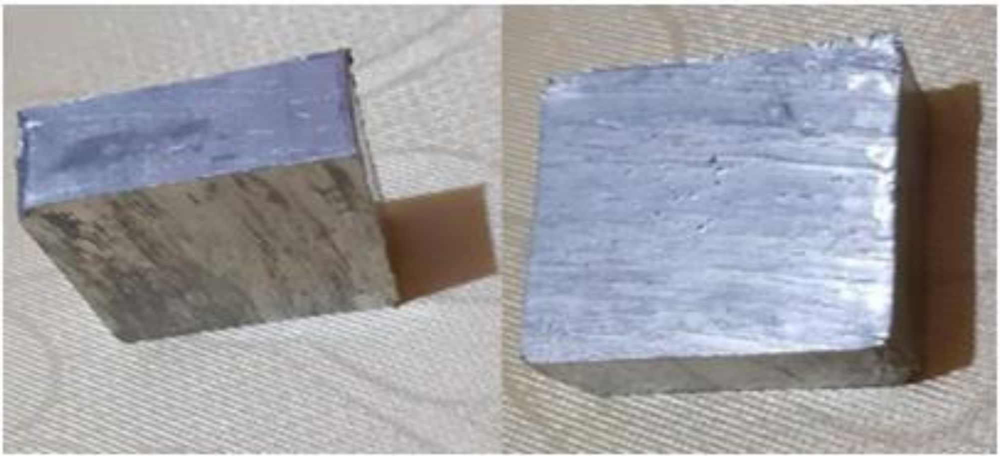

Fig 1:- Sample of Aluminum Blocks

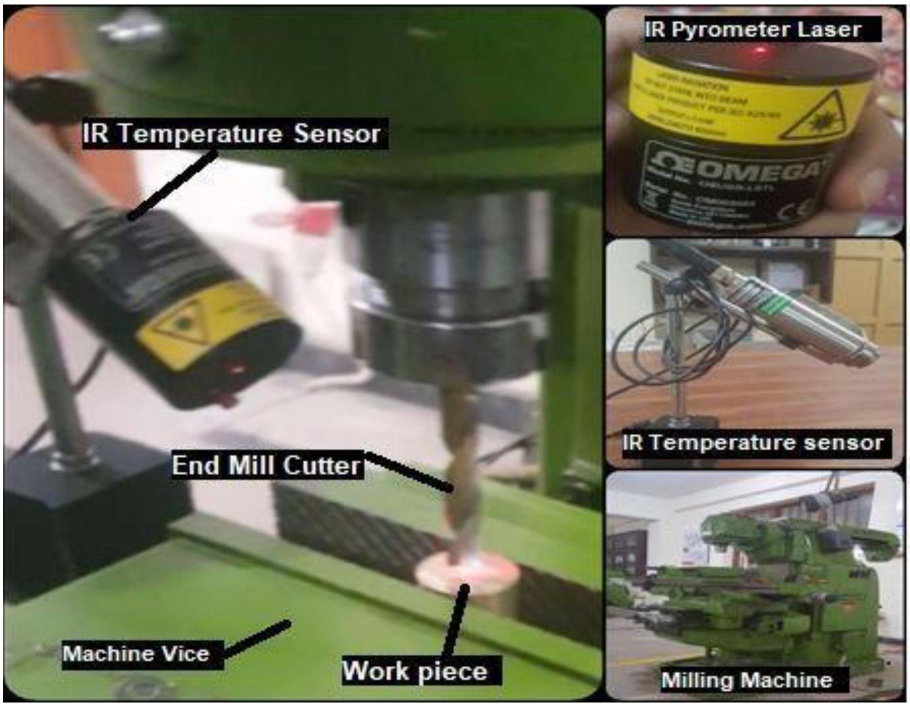

Fig 2:- Experimental Setup for Temperature Measurement

ISSN No:-2456-2165

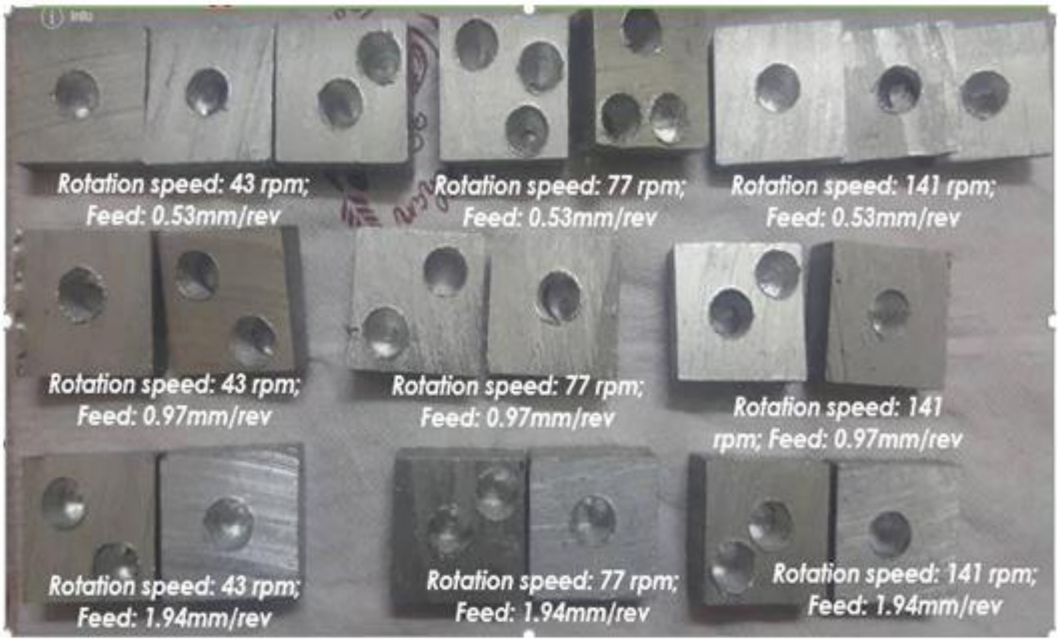

Fig 3:- Samples after Drilling at Different Cutting Conditions

(Figure 2) and instant temperature rise graph were noted in tabulated form through software interfacing.

B. Instant Temperature Measurement:

During sample drilling using end mill cutter, the instant temperature rise and temperature variation profiles were measured using non-contact infrared temperature sensor (Model: OS180-USB) as shown in figure 2. Before drilling and measuring temperature, sample surface emissivity values were calculated at different temperature and then an average value is selected. Tests were performed to find value for emissivity for pure aluminum with rough polish surface. i.e. E = 0.26. The infrared temperature sensor were mounted using magnetic stand and fixed at distance recommended by manufacturer. The laser beam is focused at the tool cutting contact edges i.e. 'Omegasoft'. The tabulated values were then graphed in Microsoft Excel sheet.

III. RESULTS AND DISCUSSION

A. Maximum Temperature Measurement and Temperature changing Profiles:

The following table 1. shows the cutting parameters and maximum temperature rise during drilling against each combination. The temperature changing profiles for each cutting condition are shown in the succeeding graphs in the figure 4. Each combination is tested for two samples for statistical analysis and results authentication.

S.No.	Tool Speed (rpm)	Feed rate (in/min)	Specimen	No of Holes/Condition	Depth of cut (mm)	Hole Diameter (mm)	Maximum Temperature (°C)			Average (°C)
							Hole 1	Hole 2	Hole 3	
1	43		2	3	10	10	55.2	59	61.7	58.6
2	77	0.53	2	3	10	10	66.1	72.3	73.7	70.7
3	141		2	3	10	10	84.2	88.4	82.1	84.9
4	43		2	3	10	10	86.1	89.9	92.5	89.5
5	77	0.97	2	3	10	10	96.1	93.4	98.6	96.0
6	141		2	3	10	10	110.6	104.5	107.5	107.5
7	43		2	3	10	10	131.6	129.6	137.1	132.8
8	77	1.94	2	3	10	10	144.6	149.8	154.4	149.6
9	141		2	3	10	10	163.2	171.8	178.4	171.1

Table 1:- Drilling parameters and Results of Maximum Temperature Rise during drilling for each set of cutting conditions

ISSN No:-2456-2165

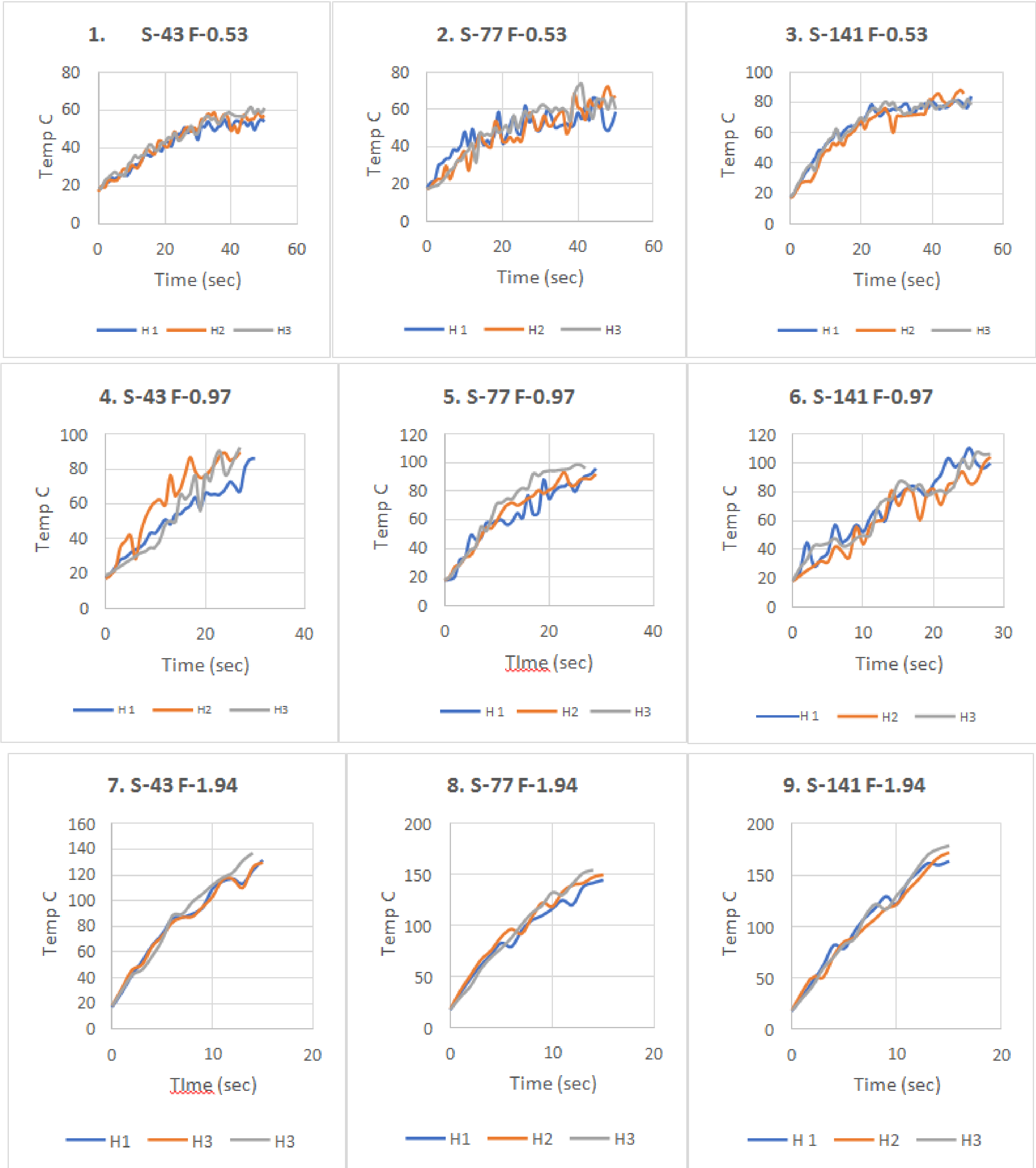

Fig 4:- Instant Temperature Changing Profiles during Drilling for Each Set of Cutting Condition (1-9)

IV. CONCLUSION

In this research work, instant temperature changing profile and maximum temperature rise were measured using infrared Temperature sensor (IR Pyrometer) with changing cutting parameters i.e. Feed rate and Cutting tool speed. It is observed that temperature varies with drill depth, cutting speed and and feed rate. The temperature increases at the tool-tip during drilling with increasing drill depth due to large shear deformation. Further, increase in the tool cutting speed and feed rate increases maximum temperature rise as well as steeper the temperature profile. If we compare variation in temperature during drilling for tool speed and feed rate, it is observed that temperature rise is more for changing feed rate as compared to tool speed. If we double the tool speed for a constant feed rate, the changes in temperature is not significant but if we double feed rate for a constant cutting speed, the temperature variation is significant. Therefore, it is concluded that changes in temperature rise and variations during drilling at lower rpm is majorly due to changing feed rates rather than cutting tool speed.

REFERENCES

[1]. R. Muhammad, N. Ahmed, Y. M. Shariff, and V. V Silberschmidt, "Effect of cutting conditions on temperature generated in drilling process: A FEA approach," in *Advanced Materials Research*, 2011, vol. 223, pp. 240– 246.
[2]. S. Rawat and H. Attia, "Characterization of the dry high speed drilling process of woven composites using Machinability Maps approach," *CIRP Ann.*, vol. 58, no. 1, pp. 105–108, 2009.
[3]. A. Moufki, A. Molinari, and D. Dudzinski, "Modelling of orthogonal cutting with a temperature dependent friction law," *J. Mech. Phys. Solids*, vol. 46, no. 10, pp. 2103–2138, 1998.
[4]. E. O. Ezugwu and Z. M. Wang, "Titanium alloys and their machinability—a review," *J. Mater. Process. Technol.*, vol. 68, no. 3, pp. 262–274, 1997.
[5]. A. R. Machado and J. Wallbank, "Machining of titanium and its alloys—a review," *Proc. Inst. Mech. Eng. Part B J. Eng. Manuf.*, vol. 204, no. 1, pp. 53–60, 1990.
[6]. M. Nouari, G. List, F. Girot, and D. Gehin, "Effect of machining parameters and coating on wear mechanisms in dry drilling of aluminium alloys," *Int. J. Mach. Tools Manuf.*, vol. 45, no. 12–13, pp. 1436–1442, 2005.
[7]. J. Lin, "Inverse estimation of the tool-work interface temperature in end milling," *Int. J. Mach. Tools Manuf.*, vol. 35, no. 5, pp. 751–760, 1995.
[8]. C. Ming, S. Fanghong, W. Haili, Y. Renwei, Q. Zhenghong, and Z. Shuqiao, "Experimental research on the dynamic characteristics of the cutting temperature in the process of high-speed milling," *J. Mater. Process. Technol.*, vol. 138, no. 1–3, pp. 468–471, 2003.
[9]. R. C. Dewes, E. Ng, K. S. Chua, P. G. Newton, and D. K. Aspinwall, "Temperature measurement when high speed machining hardened mould/die steel," *J. Mater. Process. Technol.*, vol. 92, pp. 293–301, 1999.
[10]. G. Le Coz, M. Marinescu, A. Devillez, D. Dudzinski, and L. Velnom, "Measuring temperature of rotating cutting tools: Application to MQL drilling and dry milling of aerospace alloys," *Appl. Therm. Eng.*, vol. 36, pp. 434–441, 2012.
[11]. E. Bagci and B. Ozcelik, "Analysis of temperature changes on the twist drill under different drilling conditions based on Taguchi method during dry drilling of Al 7075-T651," *Int. J. Adv. Manuf. Technol.*, vol. 29, no. 7–8, pp. 629–636, 2006.
[12]. E. Bağci and B. Ozcelik, "Investigation of the effect of drilling conditions on the twist drill temperature during step-by-step and continuous dry drilling," *Mater. Des.*, vol. 27, no. 6, pp. 446–454, 2006.