Analysis of heat generation and material deformation according to CNC Milling

Sang-yeob Lim [a*], Min-Chul Kim [a], Joonyeop Kwon [a]
[a]*Materials Safety Technology Development Division Korea Atomic Energy Research Institute, Daejeon 34057, Republic of Korea*
[*]*Corresponding author: sylim@kaeri.re.kr*

1. Introduction

In order to evaluate the structural integrity of nuclear materials and to secure an irradiation embrittlement characteristic DB, a machining technology is being developed to evaluate the mechanical strength of nuclear reactor components (nuclear power plants, nozzle units, internal structures, etc.). For the machining of the irradiated material, it is required to use a limited number of processing equipment for the purpose of preventing radiation of the test space and the researcher. Wire-EDM equipment based on CNC (Computer Numerical Control) processing was used to evaluate the mechanical properties of the sample in order to secure the shape precision and the repeatability of processing. Additionally, CNC milling is used to perform hole and surface processing.

However, it was confirmed that there was a difference in the mechanical strength of the milled materials. As shown in Fig. 1, it can be seen that the machining temperature changes depending on the machining speed, workpiece and tool material in high-speed machining [1-4]. In addition, in order to perform a machining of difficult-to-cut materials such as alloy 690 used in the nuclear field, it is necessary to analyze material changes and machinability according to material temperature changes according to machining parameters [10-14]. Additionally, cutting oil is used for cooling and lubrication purposes, but the use of cutting oil must be controlled to minimize the generation of liquid waste in a radiation environment. [4-16].

In this experiment, we tried to understand the heat generation characteristics of the workpiece according to the change of parameters of CNC milling, the cooling effect and machinability according to dry cutting and coolant consumption, and the temperature change characteristics of the workpiece during machining [7-18]. In addition, changes in the material microstructure that occur through such processing were confirmed.

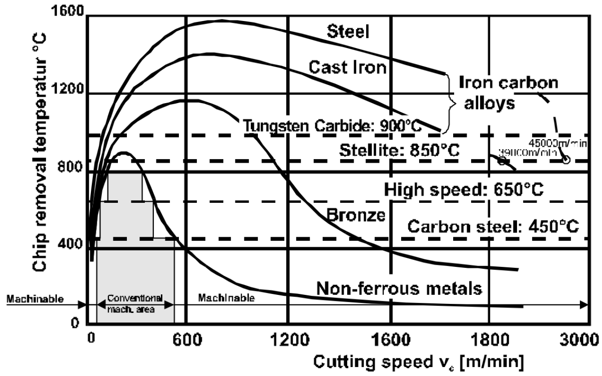

Fig. 1. Temperature as a function of cutting speed [19-20].

2. Experiment

In this experiment, SA508 was machined using the high-speed machining center CM-1 (compact-mills, Haas) equipment. Table I shows the specifications, materials, and tools of the parameters used in the experiments. Dry cutting and wet cutting experiments were performed on SA508 material to understand the effect of heat generation and coolant properties on changes in parameters such as spindle speed, cutting speed, and coolant usage and usage. In order to measure the temperature change occurring during processing in real time, thermocouples were manufactured by spot welding at intervals of 1 cm. In addition, the temperature distribution was confirmed using the temperature image measured with an infrared thermal imaging camera before and after processing.

Table 1. Specification of experimental equipment, tools and materials.

<table>
<tr><td rowspan="2">Machine type</td><td>Max spindle speed</td><td rowspan="2">Material</td><td rowspan="2">Tool</td><td>Diameter</td></tr>
<tr><td>Max feed tooth rate</td><td>Type</td></tr>
<tr><td rowspan="2">HSM</td><td>4,900 RPM</td><td rowspan="2">SA508</td><td colspan="2">Φ10</td></tr>
<tr><td>2,000 (μm/sec)</td><td colspan="2">TiAlN coated Solid End Mill</td></tr>
</table>

3. Results

3.1. Spindle rotation speed control

In order to check the temperature characteristics according to the change in the spindle rotation speed of the workpiece, when the rotation speed was gradually increased to 700, 1400, 2100, 3500, 4900 RPM, the temperature of the processing tool was 35, 39, 41, 45, 53℃. It was confirmed that there was a gradual increase.

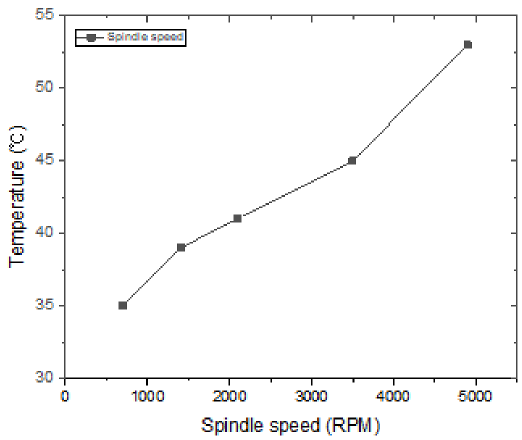

Fig. 2. Spindle speed VS Temperature.

3.2. Feed rate control

In order to confirm the temperature characteristics according to the change in the feed amount of the workpiece, the amount of increase in the temperature of the workpiece was checked while gradually increasing the feed amount to 10, 100, and 500 mm/min based on 3000 RPM. Heat generation showed a tendency to gradually increase as the cutting speed increased, and the smaller the cutting speed, the larger the temperature difference with respect to the feed rate.

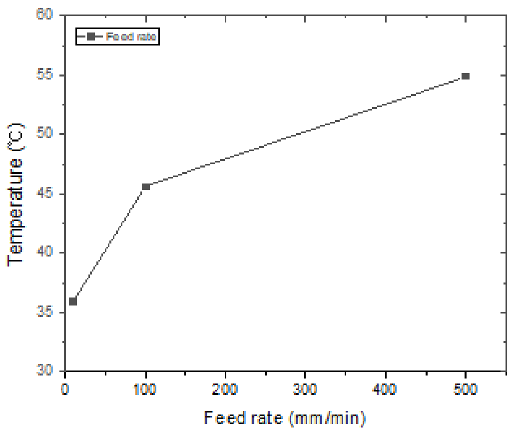

Fig. 3. Feed rate VS Temperature.

3.3. Processing depth control

By fixing the feed of the processing material and gradually changing the processing depth to 10, 500, 1,000, and 2,000 ㎛, the temperature increase of the processing material was confirmed.

3.4. Coolant control

The feed and processing depth of the workpiece were fixed, and the amount of increase in the temperature of the workpiece was checked while turning on/off the cooling water. When the cooling water is turned on, the temperature of the workpiece is about 32°C, and it is confirmed that the temperature does not rise according to the processing.

3.5. Micro-structure analysis

To analyze the effect of the CNC milling layer on the specimen, hardness test was performed with a Vickers hardness tester, and cross-section polishing was performed to analyze the microstructure change of the material. It was also compared to the as-received SA508.

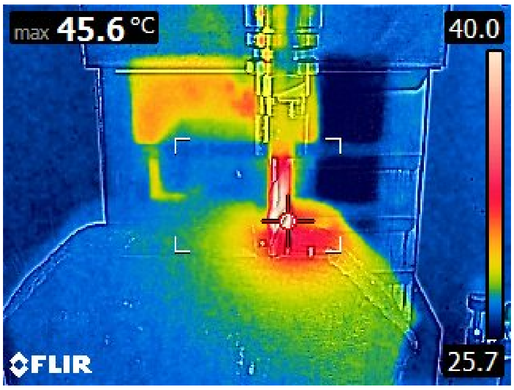

Fig. 4. Thermal imaging of milling operation.

3. Conclusions

1. To measure the temperature change occurring in CNC milling process, a method for analyzing the thermal change of the workpiece using a thermocouple and a thermal imaging camera was established.

2. In the case of SA508 sample, when the processing speed was increased, the temperature of the workpiece during processing showed a tendency to gradually increase.

3. The effect of cutting oil showed excellent cooling performance when cooling oil was used, and when cooling oil was not used, temperature improvement occurred according to the machining speed, axial depth of cut and radial depth of cut.

REFERENCES

[1] C. salomon, Verfahren zer bearbeitung von metallen oder bei einer bearbeitung durch schneidende werkzeuge sich ahnlich verhal tenden werkstoffen, German Patent no. 523594, 1931.
[2] G. L. Criger, High speed machining in production, SAMPE Quaiierly, 12 April 1981.
[3] J. Tlusty, High speed milling, Proceedings of the 6th IMEC, Osaka, Japan, pp. 35-42, 1994.
[4] J. R. Coleman, No myth high speed nachining, Manuf. Eng. 61, Oct 1992.
[5] J. Gough, High speed machining for toolmaking applications, Prec. Toolmaker 8, 1990.
[6] H. Schulz, High speed machining - some of the latest developments, Metalworking World 3, 1994.
[7] F. J. McGee, High speed machining - study: method for aluminum workpiece, Am, Machanist, 1979
[8] E. M. Trent, Metal culling, 3rd edition, Butterworth, London, ISBN 07506 I 0689, 1991.
[9] T. Moriwaki, "High-Speed Machining", CJRP, Vol.4 1, 1992.
[10] 1-1. Schut, "High-Speed milling of Dies and Molds-Cutting Condition and Technology", CIRP, Vol.44, 1995.
[11] Nam-Sub Seo, Metal Cutting Theo1y, Dong myoung sa, Korea, 1985.
[12] Young-I-la Yum, The Cutting Theory of Machine Tool, Dong myoung sa, Korea, 1992.
[13] D. G Flom, R. Komanduri and M. Lee, High Speed Machining of Metals, Annual Review of Materials Science, Vol 4, pp 231, 1984
[14] R I Kmg and R I Vaughn, A Synoptic Review of High-Speed Machining from Salomon to the Present, Pioc of ASME, High Speed Machining Conf, PED 12, 1984
[15] ZhIJte Tang, "Tool replacement strategies and the prec1s1on of tool monitoring system m advanced manufacturing system ", Transact10n of NAMRI/SME, Vol26, pp 255-260, 1995.
[16] Di Yan, T I El-wardany and M A Elbestawi, "A mul11-senso1 strategy for tool failwe detection in m1llmg", MTM, Vol.35, No 3, pp 383-398, 1995
[17] H Schulz, "Hochgeschwind1gke1ts-beabe1tung", HANSER, 1996
[18] H Schulz, "High-Speed m1llmg of Dies and Moulds-Cutting Condition and Technology", CIRP, Vol44, 1995
[19] Die & Mould Making Application Guide, Sandvik Coromant, 1999.
[20] Schulz H., Moriwaki T., High – speed machining, Ann. of the CIRP, 1992, t. 41, nr 2, s. 637 – 642.