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Real-time evaluation of tool wear detection system under wet machining based on electrical contact resistance

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Abstract

This study presents a real-time evaluation of tool flank wear detection system under wet machining based on electrical contact resistance. The developed tool wear detection system based on DC two terminal method uses the contact resistance between the tool and workpiece as a signal gauge to observe the progression of the tool wear during the cutting process. The contact resistance decreases as the increase of the flank wear contact area. Meanwhile, the influence of the thermo-electromotive force (E.M.F) is also measured and considered during the detection process. In the previous experiment, the target was the detection of the tool wear in face milling process, and also for uncoated solid square end mill by using a contact mercury transmission system. In this experiment, all attentions were focused on the new transmission system which is based on slip ring. The results of the experiment using the new slip ring transmission system on the present tool wear detection system based on DC two terminal method, demonstrates that the wear detection of the square end mill with indexable inserts has been done successfully under wet machining which was not possible in the previous system due to the isolation problem.

Keywords: Electric contact resistance, Electromotive force, Flank wear, in-process monitoring, Slip ring, square end mill, Lubricant.

1. Introduction

Tool wear is well known as degrades seriously the condition of the machined surfaces and causes undesirable inaccuracy in the workpiece and affects also the tool life, which weighs heavily on the cost of the machining process. The reason why a smart tool wear detection system is strongly required in order to detect the tool wear during the machining process earlier so that condition of the machining can be adjusted to prolong the tool life and replace it with a new tool in the case of the worn condition. A diverse amount of approaches has been accomplished on tool wear detection. However, there are still insufficiently explored areas related to tool wear detection and surface quality that make implementation and the use of this technology easy and efficient. In the previous experiment, we have evaluated different milling operations for face milling process with different types of cutting tools such as various inserts with a different coating and with different chip breakers only under dry conditions [1]. This paper aims to answer all the mentioned issues, by improving the present tool wear detection system by a new transmission system which allows the detection of the wear even under wet machining, which was not possible in the previous experimentations because the isolation had to be located between the vise and the workpiece.

2. Methodology

2.1. Determination of the sampling parameters

The measurement method system is composed on two terminals, R1 which represents the tool-work electrical contact resistance, the tool is isolated from the machine body by a polyimide film with a thickness of 50μm, placed between the tool shank and tool holder, the role of this film is to avoid the short circuit during the cutting process, as illustrated in figure 1.

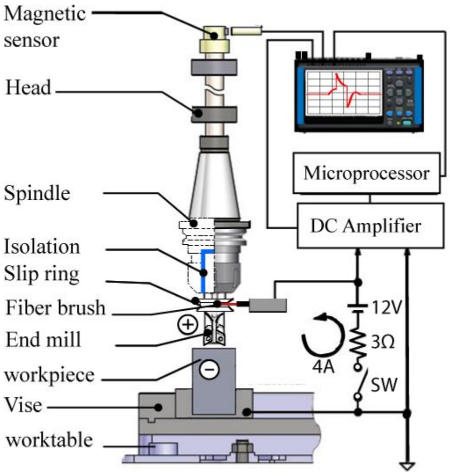


Figure 1. Experimentation setup.

Terminal R2 is the distinct resistance of the measurement circuit. E1 is the electromotive force (E.M.F) produced by the contact between the workpiece and the tool. A constant current of 4A is supplied to the circuit through 12V DC activating power supply and the resistance of 3Ω. The method of detecting the electrical contact resistance of the DC two terminal method is based on Ohm's law $R = V/I$, where R represents the contact resistance, V the voltage, and I the electric current. Thanks to a constant current in the circuit, the result is calculated by measuring the average of the voltage drop at the end of each resistance. The width of tool flank wear was measured at every cutting operation time constantly, then the relation between actual tool flank wear width and tool-work contact resistance was compared.

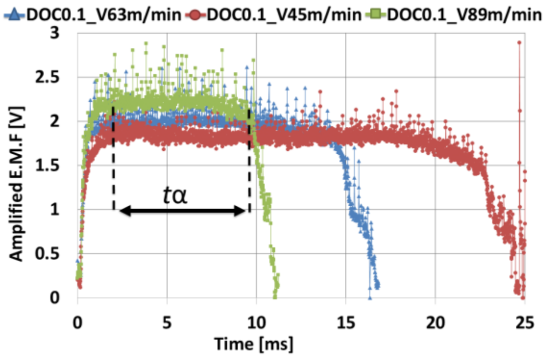


Figure 2. Typical EMF measurement in multi-revolution speed.

Figure 2 represents a typical result of the EMF measurement according to the time for different cutting speeds where t_α is the common interval of the sampling point of the constant EMF. This interval is derived by two threshold level V1 which specifies the starting point of measurement and V2 the endpoint as triggers [3].

2.2. Measurement of the contact resistance

The voltage drop was measured at the end of each resistance, the area of the tool flank wear was measured in every cutting operation during 4 seconds, then the relation between tool flank wear area and contact resistance was calculated and evaluated. Table 1 shows the specification of the milling condition applied in this experiment and table 2 shows the specification of the cutting condition.

Table 1. Specification of the milling condition.

Workpiece	Cutting Speed	Feed Rate	Cutting Fluid	DOCz	DOCy
S45C JIS Carbon Steel	89.1	0.50	Oil	0.5	0.7
Cutting speed *V* [m/min], Feed rate *fz* [mm/tooth], Depth of cut DOCz [mm], Depth of cut DOCy [mm].					

Table 2. Specification of the cutting tool.

Tool Reference	Coating type	Base material	Coating process	Resistance Ω
MJ NS740	Non coating	Cermet	PVD	0.17

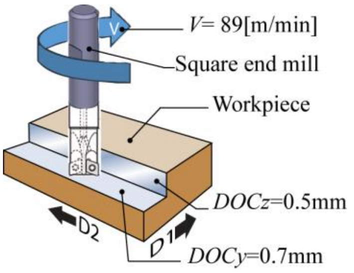
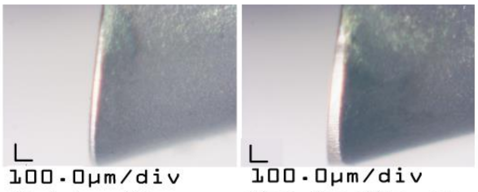


Figure 3. Shoulder milling application main method of measurement.

The end mill operation in Figure 3 has been configured according to the parameters shown in the table 1 and 2, where D1, D2 are the direction of the feed rate.

3. Result and Discussion

After the end of the milling operation, we can observe the area of the flank wear. The images in figure 4 illustrate the difference between the new and the worn cutting edge.



Flank face of the new tool

Flank face of the worn tool Area= 0.599mm^2.

Figure 4. Measurement of flank wear area.

As results, figure 5 shows that a clear correlation has been obtained between tool flank wear area and tool-work contact resistance under wet conditions as well as dry condition. A similar results has been also obtained for other cutting conditions such as different depth of cut. It can be also noticed that contact resistance in the wet machining is lower than dry condition. One of the reason which explains this inclination and the variation tendency is related to percentage of the conductivity in the lubricant and also the friction ratio.

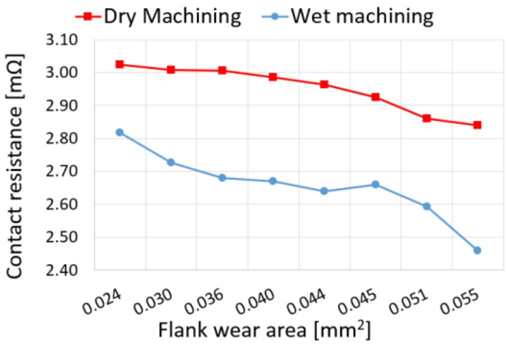


Figure 5. Relationship between tool flank wear area and tool-work Contact resistance for dry and wet machining.

4. Conclusion

The results of the experiment shows that thanks to the new improved transmission system which consists of the slip ring, the fiber brush and the new location of isolation. The present wear detection system is now able to detect flank wear even under a wet machining operation. In addition, instead of the precedent built-in transmission system [4], the new one is mobile and able to be installed in any milling machine easily. However, some noise still persists in the output signal. The reason of this noise has to be identified and considered. In addition, the difference between dry and wet conditions has to be investigated with more experimentations to clarify more the variation tendency.

5. References

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