DRILLING TEMPERATURE OF Al-17%Si ALLOY WITH HSS, CARBIDE AND DIAMOND COATED DRILLS

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ABSTRACT The study involves basic research to determine the optimum cutting condition from revealing the relationship between the drilling temperature and flank wear on drills. The drilling temperature was measured by infrared ray thermometer that method was easy to compare with thermocouple method. On the other hand, the effect of hole depth on drilling temperature under various feed rates and spindle speeds has been examined. It was possible that the width of drill wear can be roughly predicted from drilling temperature. The following facts are ascertained from the obtained results. (1) The flank wear of drills related mutually drilling temperature, therefore, it's possible that the flank wear of drill was predicted by measuring drilling temperature with an infrared ray thermometer. (2) Drilling temperature with diamond coated carbide drill is lower than that of HSS and carbide drills. (3) The drilling temperature increased as the depth of hole was deep.

Keywords: *Drilling temperature, Flank wear, Infrared ray thermometer, Chip morphology, Diamond coated carbide drills*

1. INTRODUCTION

Now, it has been getting a lot of attention, that the work materials and cutting process to be damaged with breakage of drill that occurred by progressing of flank wear in drilling while to employ CNC machines. Therefore, developments of both prediction on flank wear progress and optimum conditions in drilling have been expected.

In recent research, some technical feasibility of cutting temperature measurement with infrared ray may be almost the most promising. Therefore, in this experiment, measurement of drilling temperature have demonstrated by using infrared ray thermometer in non-contact way. Three kinds of drills (HSS, Carbide and Diamond coated carbide) were used in the experiment for measuring the flank wear of drill and drilling forces. A series of drilling tests were performed on drilling of hyper-eutectic aluminum-silicon alloy. This type of alloy contained between 16 to 23 % silicon has been used in audio and automotive industry extensively such as for rollers, cylinders and brake drums, because they have superior for mechanical properties, wear and heat resistance, and chemical stability. In machining of the alloys, however, tool wear progress rapidly, so this type of alloy is classified as very difficult material to machine.

2. EXPERIMENTAL PROCEDURE

Slabs of Al-17%Si alloy were strengthened by JIS T6-heat treatment after extruded. Every work piece for drilling test was provided to solid block (140 x 100 x 30 mm) by machining from the slabs. The chemical composition and mechanical properties of this alloy are given in **Table 1.** The maximum grain size of primary silicon in the alloy was about 50 μm, and segregation was not observed.

In the present investigation, three sorts of twist drills ; HSS (High Speed Steel), carbide (K10) and diamond coated carbide, were chosen. These drills have the same geometry with the point angle of 118 degree and diameter of 7 mm. HSS, carbide and diamond coated carbide drill were called to H drill, C drill and D drill respectively. The detail configurations of the drills and drilling parameters in this experiment are shown in **Table 2.** The measurement point of flank wear on cutting edge of drill lips was defined 0.2 mm away from margin of drills. The flank wear was measured using an optical microscope set at 50x magnification on an X-Y table equipped with digital linear encoder giving 0.001 mm resolution.

Table 1 Chemical composition and mechanical properties of work material.

Composition	(mass%)	Al-17.0Si-4.5Cu-0.57Mg-0.26Fe
Tensile strength	(MPa)	436
0.2%Yield strength	(MPa)	409
Elongation	(%)	2.4
Hardness	(HV)	180

Table 2 Details of drill and drilling conditions.

Tool material		HSS, Carbide, Diamond coated carbide
Diameter	(mm)	7
Point angle	(deg)	118
Helix angle	(deg)	30
Cutting speed	(m/s)	0.37 ~ 1.47
Feed rate	(mm/rev)	0.05 ~ 0.20
Depth of hole	(mm)	14 ~ 28
Cutting fluid		None

The drilling experiment were carried out under the dry cutting conditions on a CNC drilling center (Maximum spindle speed 66 rev/s ; Stepless drive ; 4kW) made by YKK industrial Co. The drilling parameters of spindle speed and feed rate applied to the machine were varied from 16 rev/s (0.37 m/s) to 66 rev/s (1.47 m/s), and from 0.05 mm/rev to 0.20 mm/rev respectively, and depth of hole was changed of 14, 21 and 28 mm (4 times diameter). To measure the drilling resistance, about torque and thrust, current changes of spindle and feed drive motors in the CNC drilling center were recorded by a thermal array recorder. The drilling temperature was measured by thermometer with infrared ray (MINOLTA model 505S), and the range of temperature for measurement is 223 K to 773 K. The measurement systems of drilling temperature and forces are shown in **Fig.1**. The temperature at the point that is 0.5 mm away from the wall of drilled hole near bottom was measured by this method. However, this temperature may consider to indicate the average value. In order to compensate the temperature with infrared ray thermometer, drilling temperature was measured by a thermocouple type of thermometer at same time with same point of work piece to be heated. There is a good linear relationship between both methods to know the real drilling temperature.

3. RESULTS AND DISCUSSION

3.1 Drilling temperature

In this study, drilling temperature were measured when drilling of 28 mm depth holes using HSS (H), carbide (C) and diamond coated carbide (D) drills.

Figure 2 shows both relationship between temperature and feed rate, and width of worn cutting edge of drills and feed rate for various cutting speeds. The tests were started to use no worn H drills, and only one hole was drilled. The drilling temperature by H drill increases gradually with increasing of feed rate and cutting speed. The progressed rate of drilling temperature grew remarkably to high with the increase of cutting speed. The width of flank wear decreased as the feed rate increased. As the feed rate is higher, the drilling time gets shorter, and the drilling efficiency will improve. However, drilling force becomes larger with increasing of feed rate, so that the drilling temperature rise up higher with frictional heat have remarkably generated.

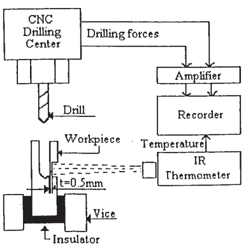

Fig.1 Schematic illustration of experimental apparatus.

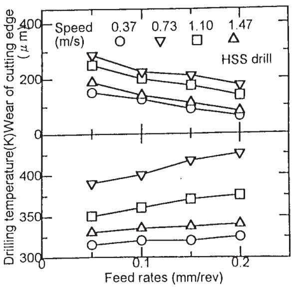

Fig.2 Relationship between both temperature and wear, and feed rate for HSS drill.

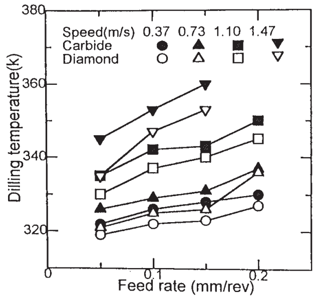

Fig.3 Relationship between temperature and feed rate with both drills of carbide and diamond coated drills.

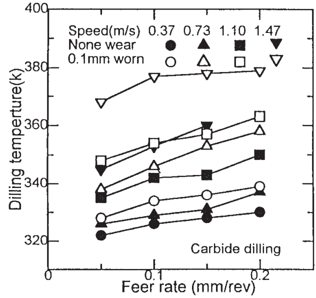

Fig.4 Relationship between temperature and feed rate with both drills of none wear and 0.1 mm worn.

The relationship between temperature and feed rate with C and D drills is shown in **Fig.3**. Drilling temperature with D drill is lower than that of C drill. The temperature increased clearly as the drilling speed was increased.

Figure 4 shows the relationship between temperature and feed rate with both C drills of none wear and 0.1 mm worn under various drilling speeds. The drilling temperature with worn drill was higher than that of none wear under all drilling conditions. The gap of drilling temperature between both drills was widely as drilling speed was higher. The temperature curves with both none and worn drills roughly increased parallel with feed rate was to higher under same drilling speed.

A relationship between temperature and width of worn cutting edge on carbide drills were examined to fixe the conditions applied to the machine with speed of 0.37 m/s and 1.47 m/s, feed rate of 0.10 mm/rev and depth of hole 28 mm. This result which were obtained in the way described above are shown in **Fig.5**. The both of drilling temperature and drilling force (torque and thrust) increased as the flank wear progressed, until the width of flank wear of cutting edge reached to 0.37 mm. Drilling temperatures at speed of 0.37 m/s were smaller than drilling with 1.47 m/s. The increasing rate of drilling temperature changed not monotony, it however rose high. But, the increasing rate of drilling temperature decreased while the flank wear was increasing.

3.2 Depth of hole

Figure 6 shows the effect of hole depth varied 14, 21 and 28 mm on temperature with carbide drill for various feed rate and speed. The temperature increased as depth of hole was to deep under all of drilling condition, so that drilling temperature closely related with depth of hole.

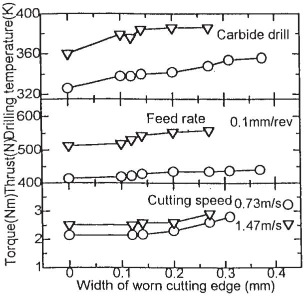

Fig.5 Relationship between both temperature and drilling force, and the width of worn cutting edge on drills.

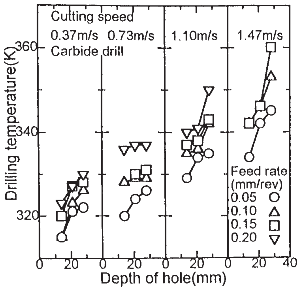

Fig.6 Effect of hole depth on temperature for various feed rate and speed with carbide drill.

Therefore, the drilling temperature rose sharply as depth of hole becomes deeper under cutting speed of 1.10 m/s and 1.47 m/s. The effected of hole depth on drilling force for various feed rates and speeds are shown in **Fig.7** (thrust is shown in **(a)** and torque is shown in **(b)**). The thrust and torque increased as depth of hole became deeper, increasing rate of these forces, however, decreased hole depth became deeper, generation of heat with friction at the end of drill grew up more, so that the shear strength at shear front decreased as temperature increase. Therefore, the increasing rate of drilling forces decreased.

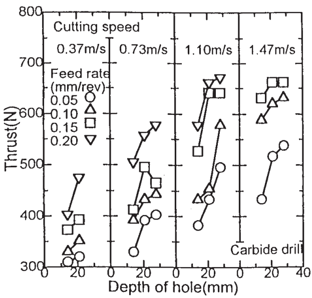

Fig.7(a) Effect of hole depth on thrust for feed rate and speed.

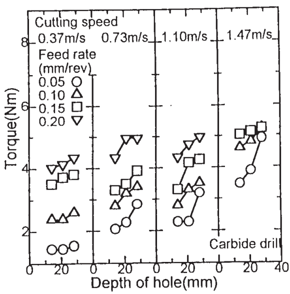

Fig.7(b) Effect of hole depth on torque for feed rate and speed.

4. CONCLUSIONS

The drilling temperature and performance in drilling of Al-17%Si alloy with the HSS drill, carbide drill and diamond coated carbide drill under various cutting speed and feed rate were studied base on to observe flank wear and drilling forces. The results of the present investigation lead to the following conclusions.

1) The flank wear of HSS drills related mutually drilling temperature, therefore, it's possible that the flank wear of drill was predicted by measuring drilling temperature with a infrared ray thermometer.

2) Drilling temperature with diamond coated carbide drills are lower than that of carbide drills. The other way, it's lower when to be used carbide drills than that be used HSS drills.

3) The hole depth related mutually drilling temperature.

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