Influences of Water Base Cutting Fluids on Tool Wear at Low Cutting Speed in Turn of Carbon Steels

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Abstract

Fundamental turning tests of carbon steels at low cuuting speed are made by using water base cutting fluids in various kinds of tool materials, to investigate the excessive wear phenomenon at the portion near center of tools in machining of holes using water base cutting fluids. From the experiments, the following results are mainly attained: (1) The reasons of tool wear in the low cutting speed will be not attributed to chemical interaction between tool and work due to temperature, but the actions of mechanical attrition. (2) The amount of wear in water base cutting fluids is remarkably different from dry or cutting oils, which is attributed to the differences of falling type of the built-up-edge and type of chip flow. (3) The selections of suitable cutting conditions and tool materials for the work materials are the most significant for using water base cutting fluids at the low cutting speed.

1. Introduction

Water base cutting fluids has been mainly using at the high cutting speed due to the cooling effect of it[1]. However, it is often obliged to use at the low cutting speed since putting the cost of cutting fluids down or etc.

And also when it is used in machining of holes by reamer or "BTA" deep-hole-tools, the cuts at low cutting speed are certainly made at the portion near center of tools. In case that it is used at the low cutting speed, a crater wear on rake face of tools and flank wear are remarkably caused in comparison with the case of dry cutting or cutting oils, which are in trouble with use of it.

Accordingly, this paper presents the study of influence of the water base cutting fluids and tool materials on tool wear behaviors by fundamental turning test at the low cutting speed.

2. Experimental methods

Turning tests were performed in the case of water base cutting fluids (emulsion type), normal cutting oils and dry cutting, and tool wear, finished surface, cutting resistance and etc. were compared under each cutting circumstance. After a certain time turn, tool and work materials were removed from the machine, and tool wear and surface roughness (Ra) were measured. Built-up-edge (B. U. E) and a friction coef-

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ficient during cutting between tool face and chip are also examined by mean of approximate orthogonal cut, cutting of tubular work edge.

The Lath used for tests is Japan-Cazeneuve HB–360X type, 750 mm distance between centers with 5 KW variable speed motor, spindle speed 60–3000 rpm. Measurements of surface roughness (Ra) and the depth of crater wear (K_T) are obtained by Tokyo Seimitu's Surfcom 20B, and flank wear (V_B) is given from the value of micrometer with Olympus's microscope.

Work materials used are carbon steels S55C in the form of 80 mm outside diameter and 250 mm length, and tool materials with tool dimension (−5, −5, 5, 5, 15, 15, 0.4) are as shown in table 1.

Table 1. Tool materials used in this experiments.

Tool material	Carbide tool					Cermet	High speed steel
	P20	M10	K20	P01	Al	SUZ	SKH4
Hardness Hv	1431	1574	1459	1679	1600	1500	877

Cutting fluids used for this experiments are shown in table 2, and they are supplied with volume of 3 l/min. Cutting conditions are as follows.

Table 2. Cutting fluids used in this experiments.

Classification of oils	Emulsion (50 times dilusion with water)	Emulsion (2 times dilusion with water)	Normal cutting oil
JIS	W1–1	W1–1	1–2

Cutting speed $V=15, 20, 30, 40, 50, 60, 80$ mm/min
Feed rate $f=0.1$ mm/rev
Depth of cut $d=1$ mm

3. Results and discussions

Tool wear types in turn of carbon steels are shown in Fig. 1. Fig. 2 shows the metallurgical structures of tool materials used for this tests. The carbide tool (P01) is mainly made of large round triple carbide grains, P20 is large WC grain in the form of square and small round triple carbide grain, M10 is mainly small triple carbide, K20 is mainly WC grains. Large square form grains in cermet tool (SUZ) contained much TiC are triple carbide (W, T_i, T_a) C, and carbide tool (Al) made of very small grain size is mainly formed of WC grains.

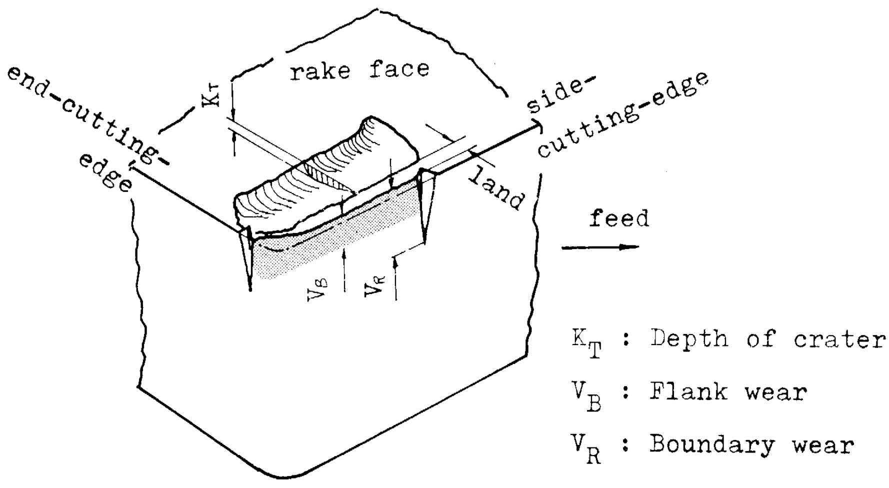

Fig. 1 Wear type of tool cutting edge.

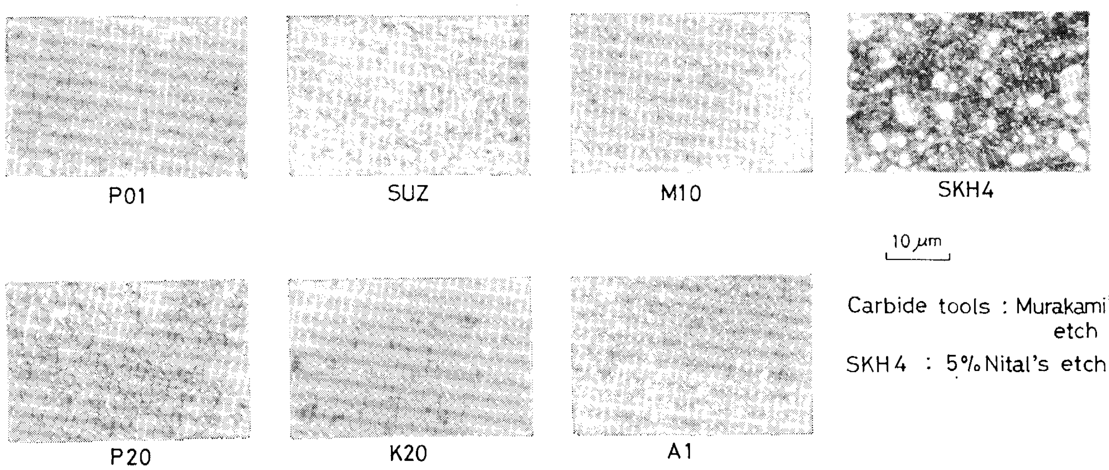

Fig. 2 Metallurgical structures of tool materials.

Relations between the crater depth (K_T) and cutting length (L) are shown in Fig. 3 (a). As seen in this Fig., K_T gets greater in accordance with the progress of cut. Especially, in case of water base cutting fluids, it becomes larger. The K_T was compared between water base cutting fluids and dry cutting, and shown under various tool materials in Fig. 3 (b). From this, it is noticed that the K_T in Wet (emulsion) is larger than that of in dry under every tool material. This is probably considered since the type of the B. U. E carried away with chip and type of the chip flow are different between in Wet and dry as mentioned latter. As for high speed steel SKH4 ($V=40$ m/min), the K_T of it in dry cutting is larger than in Wet (emulsion). The above cleary shows that the wear of SKH4 at 40 m/min cutting speed is in range of diffusion wear due to high temperature. In low cutting speed (20 m/min), the K_T of it in dry is smaller than in Wet (emulsion) same as other tools. These are attributed to sencitive property for temperature of high speed steel tools[2].

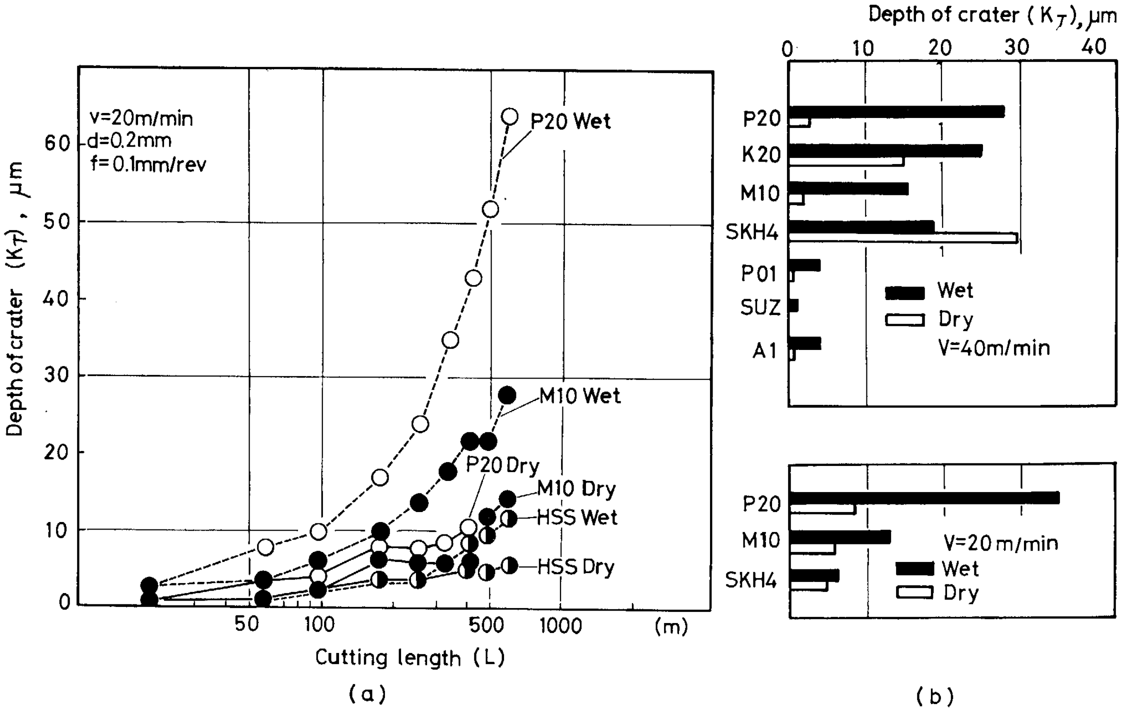

Fig. 3 Comparison of crater wear between wet (emalsion) and dry cutting.

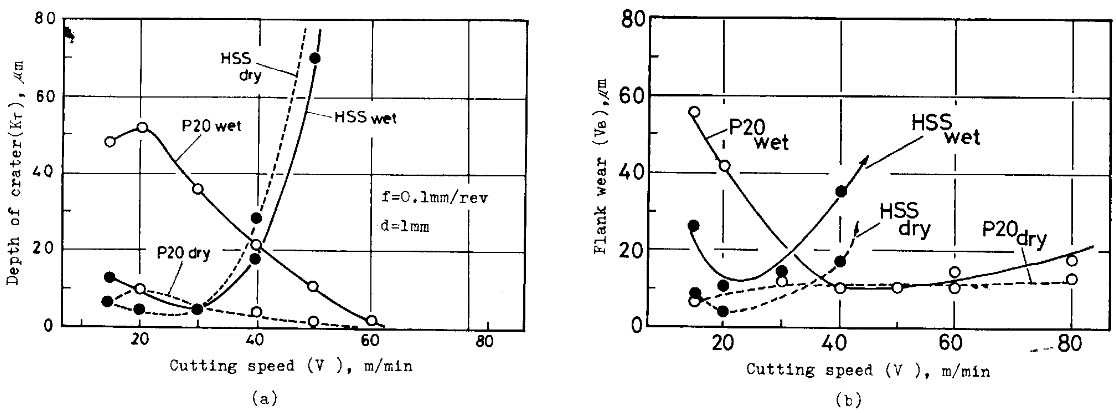

Fig. 4 Influences of cutting speed on tool wear.

Fig. 4 shows influences of cutting speed on the K_T and the flank wear (V_B) for carbide tool (P20) and high speed steel (SKH4). The K_T of P20 in Wet (emulsion) gets to maximum value at about 20–30 m/min cutting speed. This tendency is also recognized in dry cutting.

In SKH4, the K_T is very small, and it also becomes less with increase in cutting speed within about 30 m/min. However, it remarkably becomes greater in cutting speed more than 40 m/min through being in region of diffusion wear as mentioned beforehand.

As shown in Fig. 4(b), it is noticed that influences of cutting speed on the flank wear (V_B) indicate same tendency in case of crater wear. From the fact tool wear decreases in accordance with increase in cutting speed (cutting temperature) as described above, it is cosidered that the reasons of tool wear caused in this low cutting speed will be not attributed to chemical interaction between tool and chip due to high temperature, but actions of mechanical attritions[3]. The pictures of tool wear under dry and emulsion are shown in Fig. (5), (6). For P20, there is a large crater with a wide land along side-cutting-edge in emulsion, but there is almost no crater, a land, and is

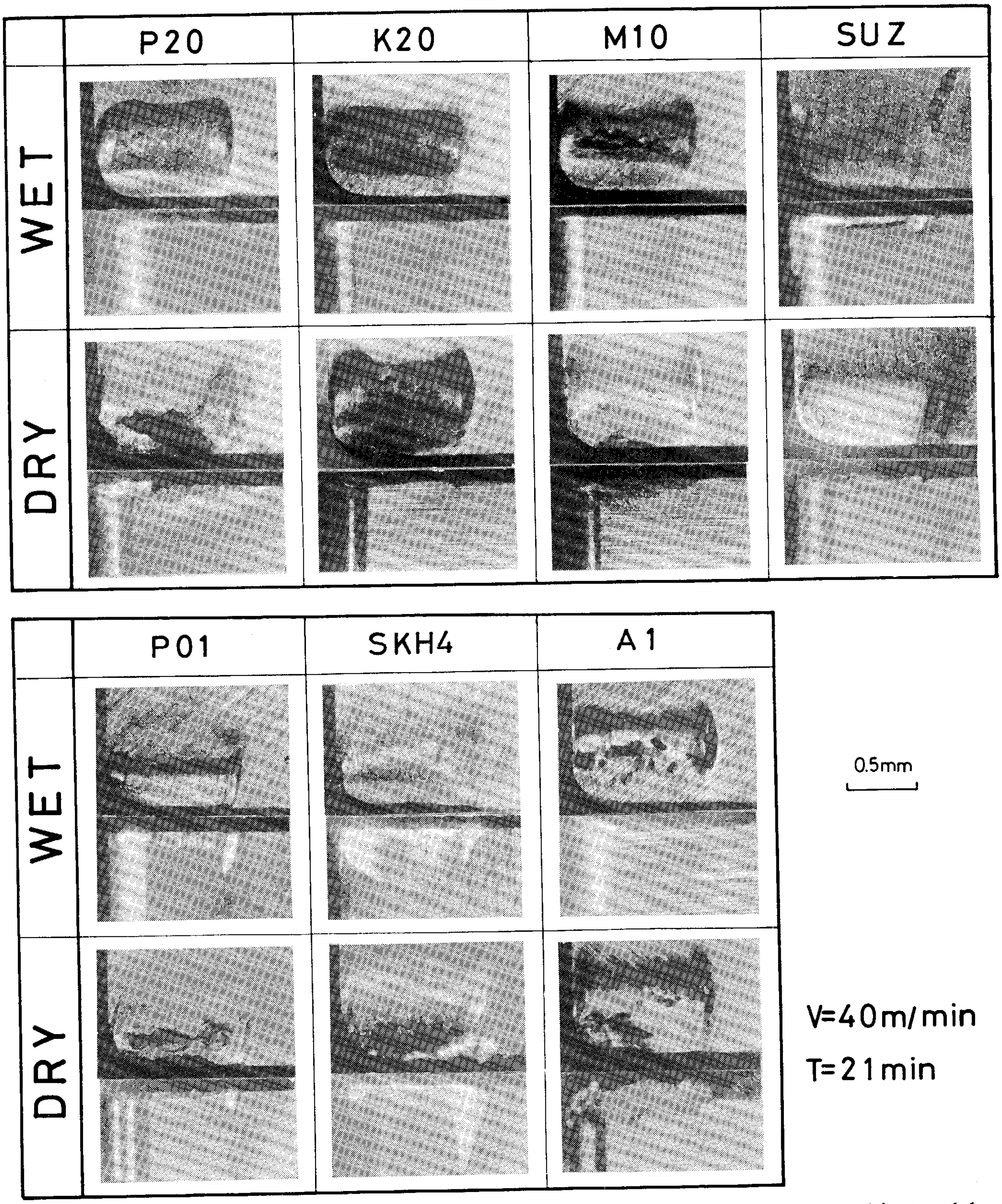

Fig. 5 Comparison of tool wear under various kinds of tool materials between wet (emulsion) and dry.

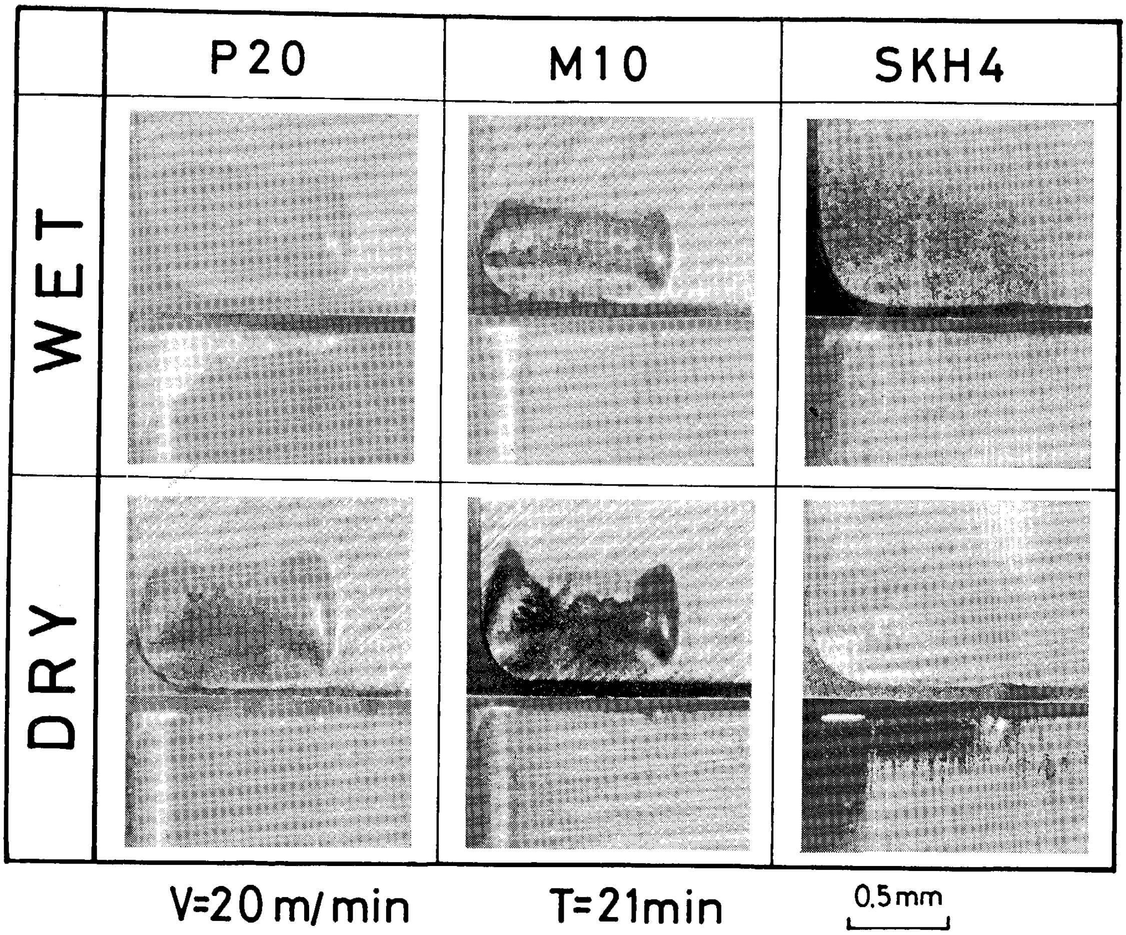

Fig. 6 Comparison of tool wear under various tool materials between wet (emulsion) and dry.

a grooving wear at boundary portion and small chipping on cutting edge in dry.

These differences of wear between in dry and emulsion are recognized other tool materials as shown in this Fig.. M10 has a wider land and smaller K_T than P20 or K20, moreover there is no chipping on cutting edge, which say M10 is considerably suitable in turn of low cutting speed under water base cutting fluids. The amount of wear in A1 is not very different from M10, and its flank wear (V_B) is not also seen in Wet (emulsion), but is seen chipping in dry. For SKH4, its K_T in dry is larger than in emulsion at 40 m/min cutting speed, a opposite tendency is however recognized at 20 m/min. Its V_B becomes larger in emulsion, which is known generally[4]. However, as seen in Fig. 6 its V_B is small and not different from dry cutting. The above clearly shows there are suitable region of cutting speed which the flank wear of SKH4 does not becomes greater even in water base cutting fluids.

It may be considered that the difference of tool wear between emulsion and dry cutting have a relation to built-up-edge (B. U. E). Accordingly, the B. U. E during turn is observed by mean of quickly getting away tool from work materials having tubular form, and shown in Fig. 7. When the B. U. E hardened during cutting is carried away with chip, it will attack a rake face of tool. The following two can be considered for type of carried away.

(1) A portion of the B. U. E is carried away.

(2) A whole of the B. U. E is carried away.

The dropping fragments of the B. U. E are smaller in case of type (1), and they are larger in type (2). Fig. 8 shows a profile of dropping fragments of the B. U. E in emulsion and dry. As shown in this Fig., they in emulsion are smaller than in dry.

It can be said from above that the B. U. E carried away with chip is performed by type of (1) in emulsion, and by type of (2) in dry[5]. And the B. U. E is the highest in about 20–30 m/min as shown in Fig. 7.

The higher B. U. E will be more easily carried away with chip during cutting, which are deemed to be main reason for getting to maximum value of crater depth (K_T) in

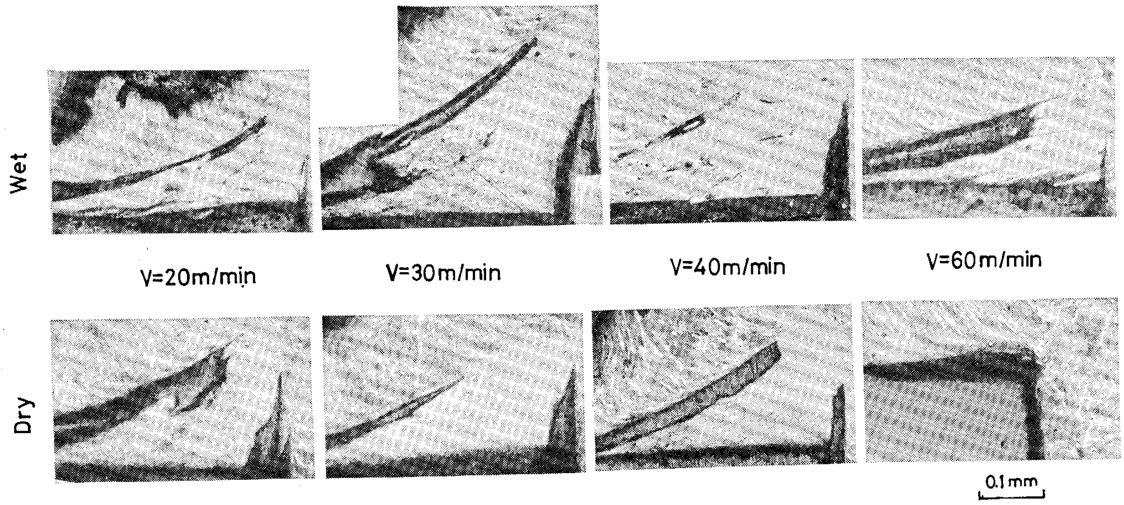

Fig. 7 Differences of B・U・E during cutting between wet (emulsion) and dry cutting.

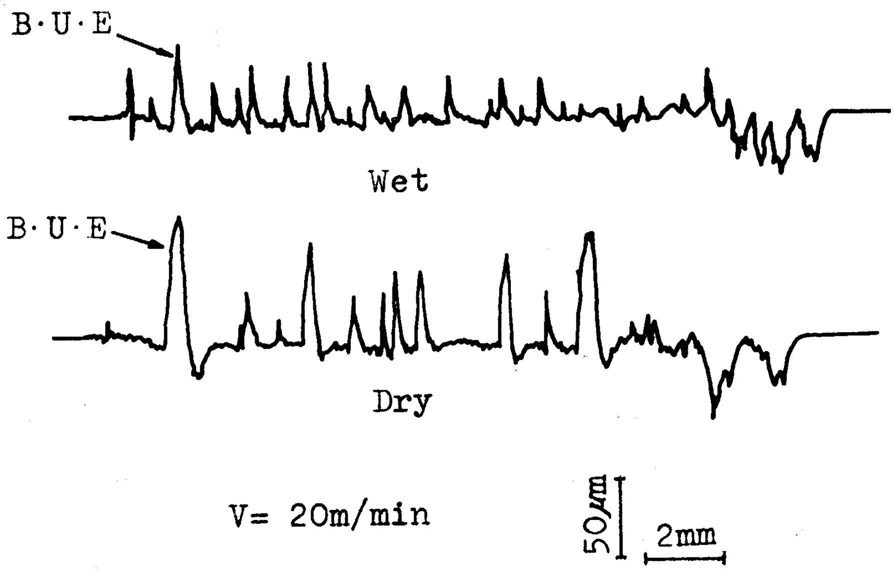

Fig. 8 Profiles of finished surface of workpiece.

about 20–30 m/min as seen in Fig. 4(a). To investigate the reasons which a crater wear is not seen in dry, the tool face-chip contact conditions are examined under in emulsion and dry. The sections of chip under both cutting conditions are shown in Fig. 9. They are remarkably different, the back face of chip (face of side contacting

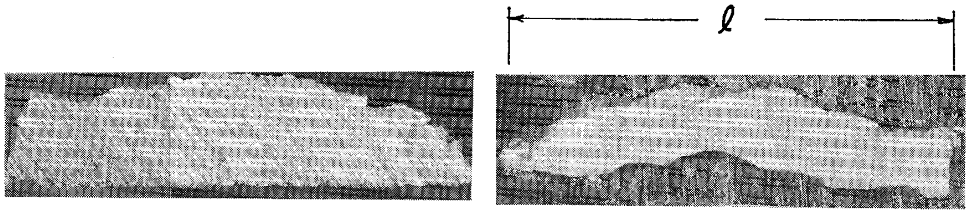

Fig. 9 Difference of chip sections between wet (emulsion) and dry cutting.

tool face) is about straight in emulsion, but is upheaved in the middle in dry. In case of the former, the tool-chip contacts may be worked at a whole of length (l) of chip section, and in case of the latter it only at the both edges of chip sections. It is considered due to above reason that the crater wear is not found in dry cutting. The fact the K_T of SKH4 is smaller than P20 or K20 in spite of having lower hardness in comparison with carbide tools will be also due to the separations of the B. U. E same as in dry of carbide tools as well as the differences of metallugical and mechanical characteristic between sintered allon and froged alloy.

After this, the turning tests used the water base cutting fluids mixed with the various rations and normal cutting oil were performed, to investigate the influences of them on the K_T or V_B. The K_T of P20 is not very different between 50 times dilution with water (1: 50) and 2 times (1: 1), and also the V_B of the former is even smaller than the latter as seen in Fig. 10. From this, it can be said that much water should be diluted from the view of the cost of oil in turn with carbide tool. The K_T in normal cutting oil is smaller than emulsions, but there are small chipping along side-cutting-edge, which may be explained from the fact the B. U. E-tool face adhesions in normal cutting oil is stronger than emulsions. In case that the normal cutting oil is used, though the K_T and V_B are smaller than emulsion (1: 50), the small chipping can be found.

Fig. 11 shows the relations between the surface roughness (Ra) and the cutting length (L) under both conditions of emulsion and dry. As shown in this Fig., the Ra in emulsion is better than dry under every tool materials. This is due to smaller dropping fragments of the B. U. E in emulsion.

From the facts described until this, it will be considered that the selections of suitable cutting conditions and tool materials for the work materials are the most significant in using the water base cutting fluids.

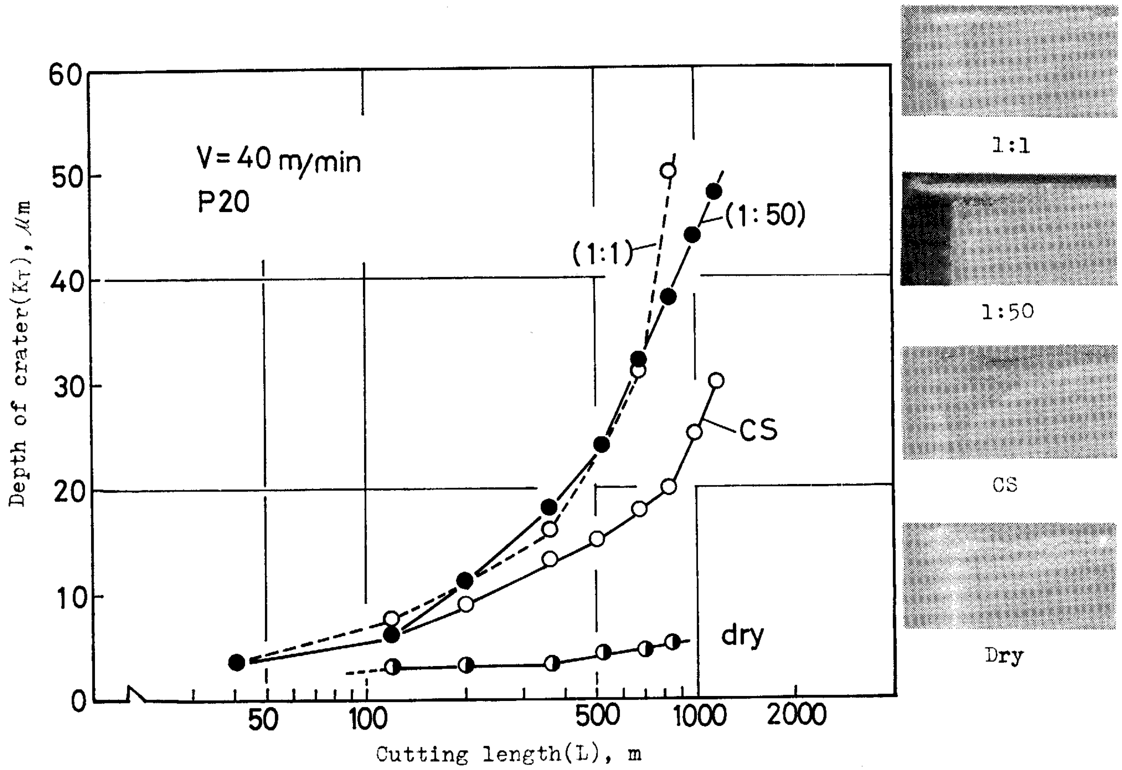

Fig. 10 Relation between depth of crater and cutting length under various cutting circumstances.

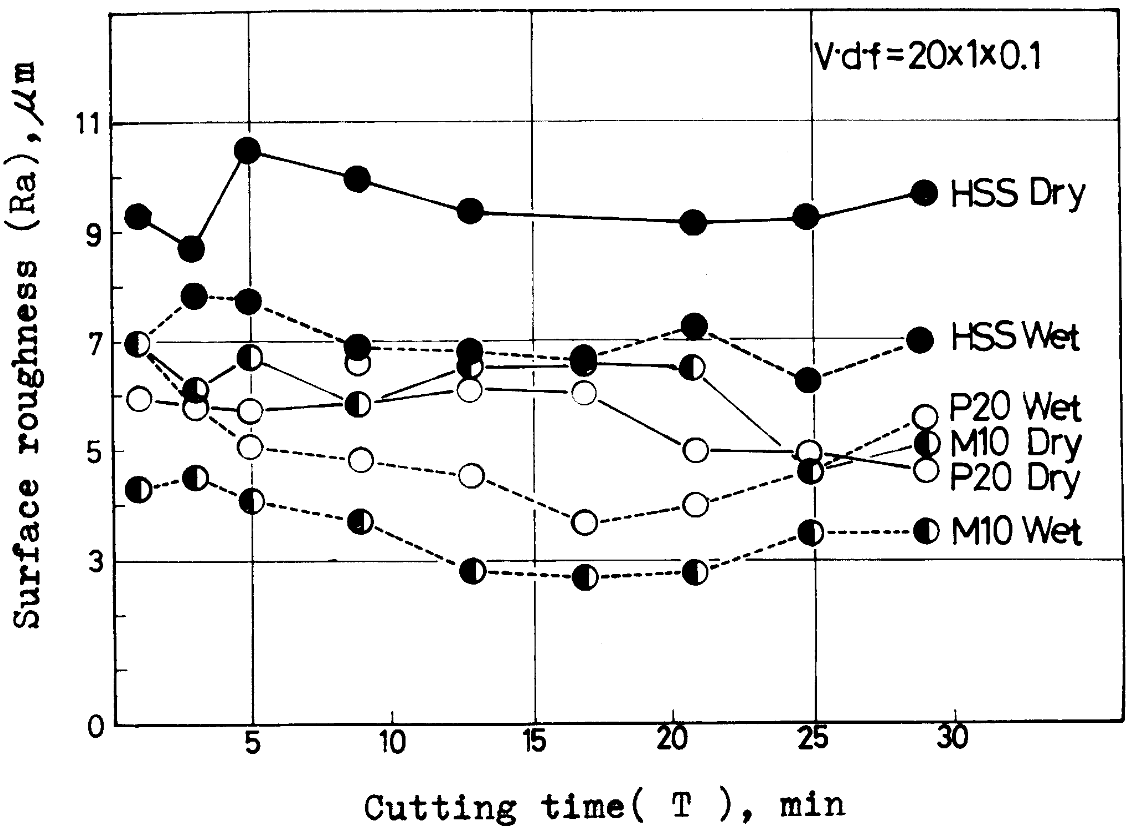

Fig. 11 Relation between surface roughness and cutting time.

4. Conclusions

From this experiment of turn of steels in using water base cutting fluids, the following are made clear.

(1) It is considered that the reasons of tool wear in this low cutting speed will be not attributed to chemical interaction between tool and chip due to high temperature but the actions of mechanical attrition, because the wear decreases in accordance with increase in cutting speed.

(2) The amount of wear in water base cutting fluids is remarkably different from dry or cutting oil, which is attributed to the differences of falling type of the B. U. E and type of chip flow.

(3) When the water base cutting fluids is used in low cutting speed, the selections of suitable cutting conditions and tool materials for the work materials are the most significant.

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