Study on Groove Wear in Finish Turning of Steels

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Abstract

Finish-turning tests by carbide tool are performed using various cutting fluids, argon gas and workmaterials with different hardness, to investigate the cause of groove wear occurrence from various points of view through detailed observation of grooving. From the experiments, the followings are attained.

(1) Groove wear is caused by the following two reasons;
  1) Work-hardening of surface layer of workpiece
  2) Partial decrease of wear resistance of tool

(2) Cutting fluids are very effective in the decrease of grooving. Particularly, spindle oil having a moderate permeability and lubricant ability gives prominent effects on it.

1. Introduction

In finish-turning of steels with carbide tool, a favorable surface can be obtained, since finish-turning is performed within the high cutting speed range in which the bult-up-edge does not occur. However, the problem of groove wear to be formed on end-cutting-edge is still remained unsolved, and the copying of groove wear to finished surface is now considered to be main reason of increase of finished surface roughness.

The author has already investigated[1] the influence of groove wear on surface roughness together with the influence of cutting condition on groove wear. Besides, he has further analyzed the change of shape of groove wear in the progress of cutting. However, the phenomena of wearing are very complicated and have many unknown points. As regards the cause of groove wear, a satisfactory explanation has not yet been given until now. Recently, the author has performed various turning tests, using various cutting fluids, argon gas and work materials with different hardness. And in this paper, the causes of groove wear are examined from various points of view through detailed observation of grooving.

2. Author's opinion for the reason of groove formation

The process of groove formation has been studied by several workers, which are thermal stress or thermal fatigue[2] on tool, oxidation[3] of tool-work and work-hardening[4] of surface layer of work materials due to a previous cut. In case that several grooves are produced at an interval (at feed distance) as Fig. 1, work-hardening may probably be reasonable explanation for it, because it is not admitted that the change of temperature and chemical interaction are especially remarkable at the bottom groove,

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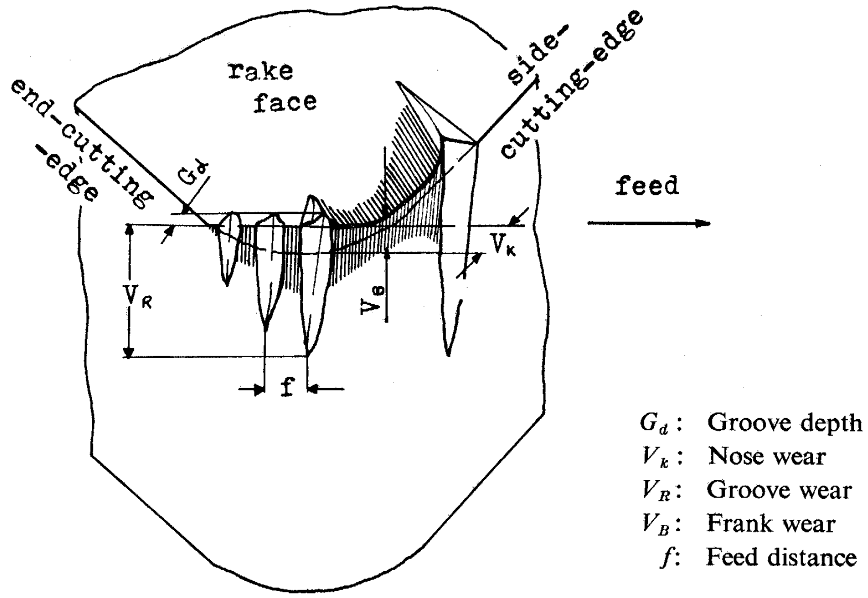

Fig. 1 Wear type of cutting edge in turning of carbon steels.

as stated by K. Okushima[5]. However, it is a fact that the grooves wear due to cutting with oxygen gas is larger than that of dry cutting and that the groove wear due to cutting with argon gas is smaller[6]. The above shows that the groove formation should be explained not only by work-hardening but also by partial decrease of wear resistance of tool by oxidation, because it is not considered that there is a difference of degree of work-hardening between the use of oxygen or argon gas and dry. By using high speed steel tool, A. Ishibashi and A. Katuki[7] show that groove formation is caused by partial decrease of wear resistance of tool due to unequal catalytic effects by margin surface immediately after turning, and they eventually deny the view of work-hardening of workpiece. Author performed a turning test with carbide tool under the condition of without unequal catalytic effect. In this experiment, the appearance of grooves reached several numbers. In case that several numbers of grooves are produced, it is clear that the later grooves are not formed by unequal catalytic effect of margin surface immediately after turning. These certify that the effect of work-hardening should not be completely neglected in grooving.

Consequently, author's opinion is that it is desirable to take into consideration the following reasons for groove formation.

(1) Work-hardening of the surface layer of workpiece.

(2) Partial decrease of wear resistance of tools due to oxidation.

Basing on the above theories, it is supposed that groove wear will be shown as Fig. 2 for the use of cutting fluids, argon gas and dry. In dry turning, both the reason of (1) and (2) will take part in grooving. In turning with argon gas, groove formation will

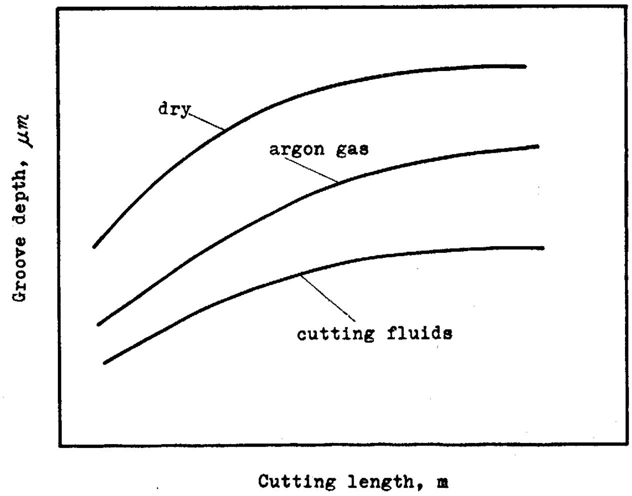

Fig. 2 Presumed relation between cutting length and groove depth under various cutting circumstances.

not be influenced by (2) of the above reasons. Therefore, the groove formed in turning with argon gas will probably be smaller than that in dry turning. In turning with cutting fluids, there will be no influence by (2) of the reasons. Besides, the influence due to (1) of the reason will be more reduced by lubricant ability of cutting fluids. Accordingly, grooves formed with cutting fluids will perhaps be smaller than with argon gas owing to the effect of lubricant. In order to give an evidence for the above theories, an experiment has been carried out as follows.

3. Experimental procedure

Equipments used for tests

Lath-Japan-Cazeneuve HB–360X, 750 mm distance between centers with 5 kw variable speed motor. Spindle speed 60–3000 rev/min.

Measurements of surface roughness

R_{max} is obtained from the surface profiles given by Tokyo Seimitu's Surfcom 20B.

Measurements of depth of grooves

The depth of grooves is measured by scale from groove photograph magnified (view from rake face of tool).

Work materials

S55C, SUS304, SS41, SNCM9 in the form of 80 mm outside diameter and 250 mm length.

Tool materials

Carbides — Standard steel cutting grade (P01) with tool dimension (0, 0, 0, 5, 5, 90, 0.3).

Cutting condition

Cutting speed: 150 m/min
Feed rate: 0.05 mm/rev
Depth of cut: 0.2 mm
Supply of argon gas: 16 l/min
Supply of cutting fluids: 3 l/min

Test procedure

Turning tests were taken along the work material with a carbide tool. After a certain time turn, work material was removed from the machine, and surface roughness (R_{max}) was measured and also the depth of groove. Then, relation between surface roughness and depth of groove under various cutting circumstances and conditions were examined.

4. Results and discussions

4.1 Influence of cutting circumstance on grooving

Fig. 3 shows the relation between groove depth and cutting length under various circumstances. As seen in this Fig., the obtained result shows the tendency presumed beforehand and generally shown in Fig. 2. Namely, the result clearly shows the effects

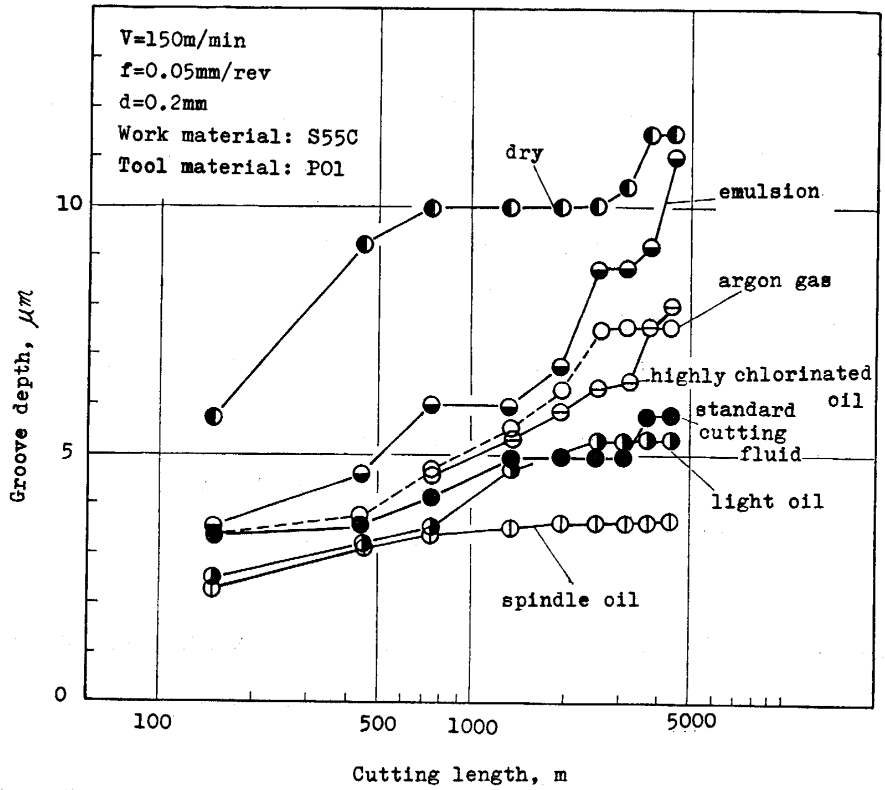

Fig. 3 Relation between cutting length and groove depth under various cutting circumstances.

of argon gas and cutting fluids as illustrated in section 2.

Assuming that the influence of (2) on grooving is completely eliminated by the use of argon gas, it is said that the influence of work-hardening is about 60% of total groove depth in dry turning.

As for the effect of cutting fluids for grooving, it has been found that different kind of cutting fluids shows different effect on grooving as follows;

1) Groove depth in case of spindle oil and light oil is prominently smaller than others.

2) In case of highly chlorinated oil with high viscosity, it is comparatively large.

3) Especially in case of emulsion, it becomes larger than that of argon gas.

The followings are considered in relation to the above results;

1) Spindle oil and light oil have moderate permeability and lubricant action. Moreover, this turning test is performed in light cutting. Therefore, it is considered that their effects on the reduction of grooving are remarkable in comparison with others. Namely, groove depth becomes much smaller than others.

2) As highly chlorinated oil has a high viscosity as shown in the Table 1, its permeation ability into cutting edge become more difficult in high cutting speed. Thereby, the effect of highly chlorinated lubricant decreased. This is deemed to be main reason for the formation of comparatively larger groove depth.

3) In case of emulsion, the test was done by using emulsion of 7 times dilution. It is supposed that the poured emulsion easily scattered during turning due to low viscosity of the emulsion and cutting-off of air into cutting edge was not satisfactory due to insufficient cover by the emulsion. This consideration was confirmed by a supplemental test carried out with the emulsion of 2 times dilution. According to the confirmation test, its groove depth became considerably smaller than that of argon gas.

Table 1. Cutting fluids used in this experiments.

classification of oils	emulsion (7 times dilution with water)	highly chlorinated oil	standard cutting fluid	light oil	spindle oil (No. 60)
viscosity R (30°C)	32	212	168	41	70

The progress of grooving was observed under various cutting circumstances (view from rake face) and shown in Fig. 4. The slope of side-cutting-edge side flank (A-flank) of groove is strongly influenced by the direction of chip-flow. As regards the slope of A-flank, there is no much difference since direction of chip-flow is experimentally same in spite of different cutting circumstance. However, a much difference is observed in the slope of B-flank in compliance with different cutting circumstance. This is probably considered since squeezing action to B-flank of groove by chips are different under different cutting circumstances. The slopes of B-flank become steepest in dry turning and gentlest in turning with spindle oil.

Surface roughness under various cutting circumstances is also compared in Fig.

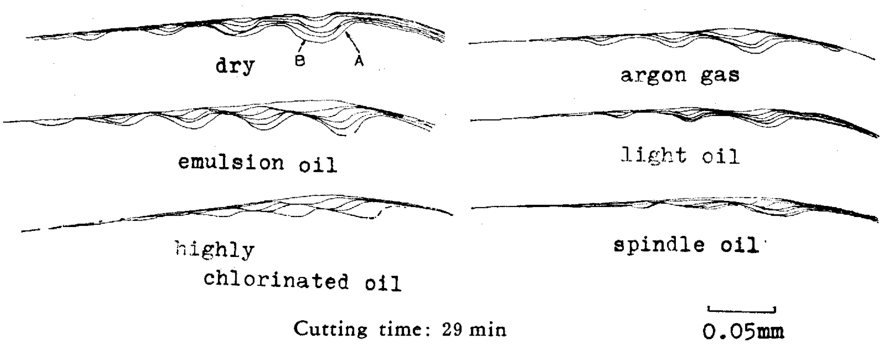

Fig. 4 Development of groove wear with cutting under various cutting circumstances.

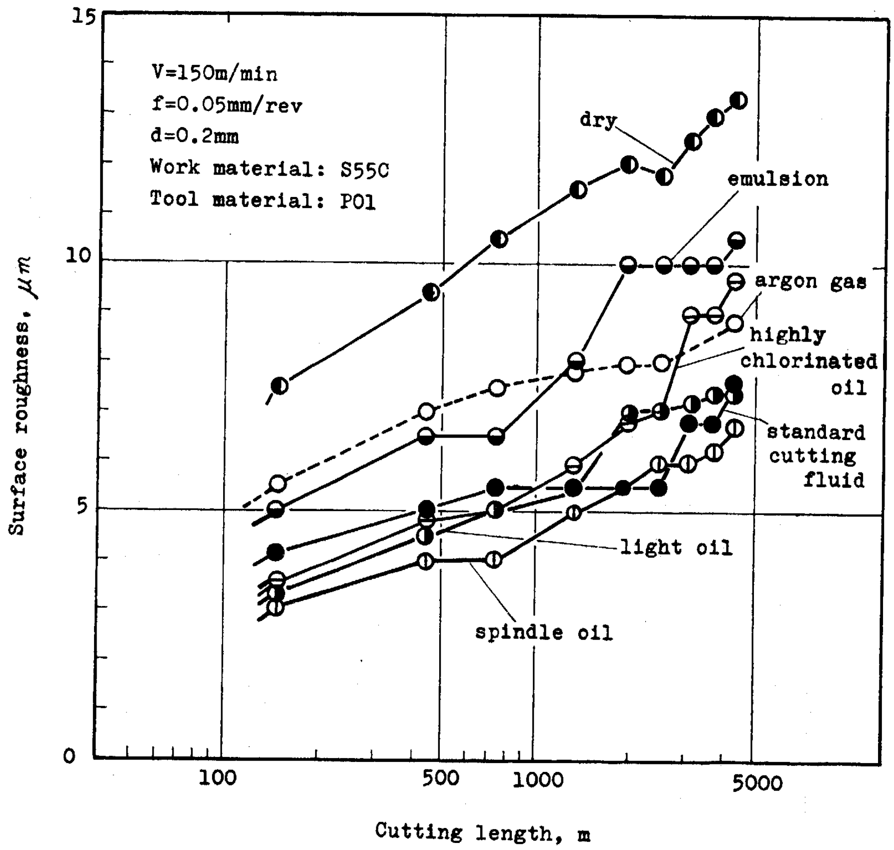

Fig. 5 Relation between cutting length and surface roughness under various cutting circumstances.

5. From Fig. 3 and Fig. 5, it is noticed that surface roughness and groove depth have a linear relation, i.e. the deeper the groove, the larger the surface roughness. The above clearly shows that coping of groove wear to finished surface occurs in turning. Increase rate of surface roughness in accordance with the increase in cutting length is gentle in spindle oil, and therefore a steady finish turning is done in this case.

4.2 Relation between grooving and work materials

Fig. 6 and Fig. 7 show the relation between R_{max} and groove depth in turning of SUS304 and SNCM9, which is shown for spindle oil, argon gas and dry respectively. In general, the same tendency as S55C is shown, as in Fig. 6 and Fig. 7, but there are

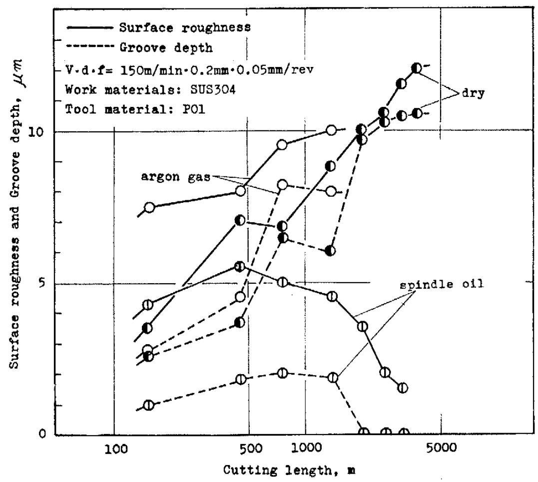

Fig. 6 Relation between cutting length and surface roughness, groove depth under various cutting circumstances in turning of SUS 304.

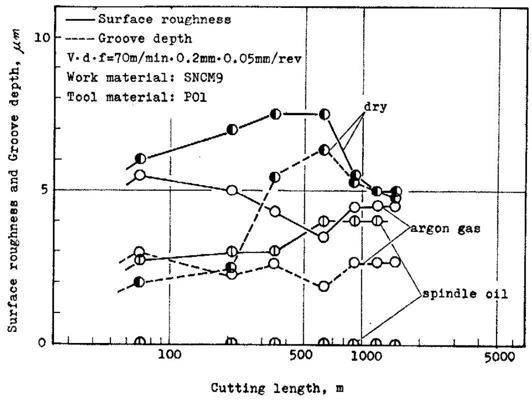

Fig. 7 Relation between cutting length and surface roughness, groove depth under various cutting circumstances in turning of SNCM9.

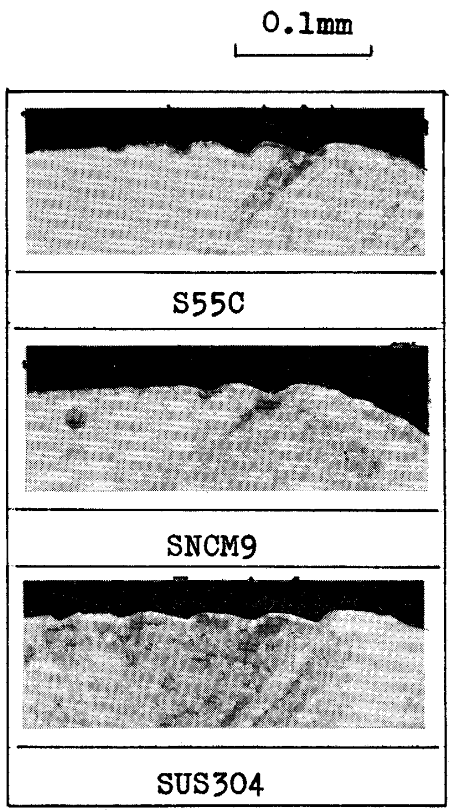

Fig. 8 Difference of groove shapes in turning the different work materials.

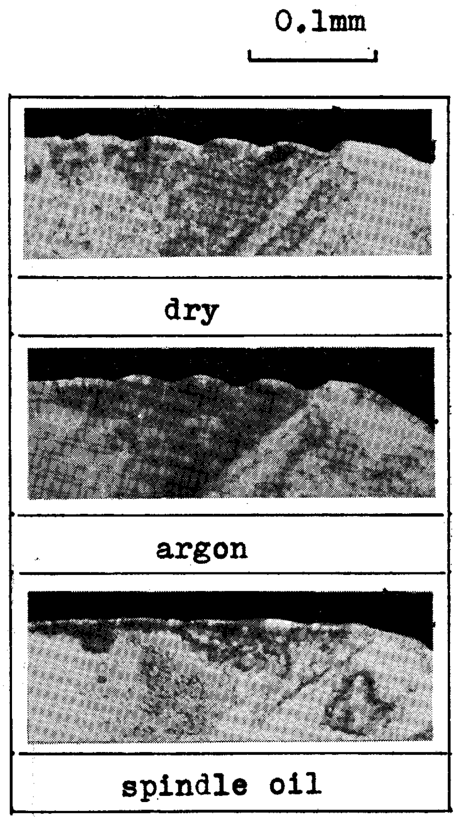

Fig. 9 Difference of groove shapes under various cutting circumstances in turning SUS 304.

some differences in their dimensions and slopes.

Groove depth can be expressed as difference of wearing rate between concave and convex parts of groove, and therefore, if wear rate of concave of groove is faster than that of convex, groove depth will become deeper. Groove shapes after a certain time turn was observed under various work materials and shown in Fig. 8. Interesting trend is shown in this Fig. i.e., grooves are formed V-shape with same length A and B-flank in turning of S55C and SNCM9, but are different in SUS304. The above will be perhaps explained from that the chipping of cutting edge is easily occurred in turning of SUS304. Tool is rapidly attacked in turning of SUS304, thereby several grooves appear after only a few minutes turn. Their groove depth is however often shallower than S55C owing to the chipping of cutting edge. Then in turning of SUS304, the groove depth in argon gas is deeper than that of dry. This is also explained from the fact that the chipping of cutting edge in argon gas is less than that of dry as shown in Fig. 9. The turning of SNCM9 was done at low cutting speed 70 m/min (without bult-up-edge), because, in cutting speed more than 90 m/min, grooves do not appear due to high temperature of tool-chip contact surface.

5. Conclusion

From this experiment of turning of steels with carbide tool, the followings are made clear.

(1) Groove wear is caused by the following reasons;

1) Work-hardening of the surface layer of workpiece

2) Partial decrease of wear resistance of tool

(2) Partial decrease of wear resistance of tool is mainly caused by oxidation. Therefore, groove wear in turning with argon gas is smaller than that in dry turning.

(3) Cutting fluids are very effective in decreasing groove wear. Particularly, spindle oil having a moderate permeability and lubricant action gives a prominent effect.

(4) Different groove of shape is formed by different work materials.

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References

1) K. Sakuma and T. Fujita: Tech. Rept. Kyushu Univ., **47**, 3 (1974)
2) H. Nakamura: Jour. of the Japan Soc. of Machine and Tool., **7**, 10 (1958)
3) E. J. Tuininga: Annals of C. I. R. P., 14 (1965/1966)
4) P. Albrecht: Microtecnic., **10**, 3 (1956)
5) K. Okushima and Y. Kakino: Trans. of the Japan Soc. of Lubricant Engineering., **18**, 2 (1973)
6) C. A. Gieszen: Annals of the C. I. R. P., **18**, (1970)
7) A. Ishibashi and A. katuki: Trans. of the Japan Soc. of Mechanical Engineering., **39**, 324 (1973)