ON THE RELATION OF TOOL LIFE TO CUTTING FACTORS IN TURNING OF ALUMINIUM ALLOY

By

Á. Kardos

Technical University, Budapest, Department of Technology of Machine Production

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Presented by Prof. F. Lettner

Investigation of tool life forms a certain part of machinability research. This report deals with results and methods of tool life investigation referring to one kind of aluminium alloy (2.8% Cu; $\sigma_B = 24$ kg/mm^2), and carried out within the machinability research program of the Technical University, Budapest, Department of Technology of Machine Production. During these tests, materials of abt. 1 ton weight had been used.

1. Determination of the relation of cutting speed to tool life

In machinability research the machinability index of a certain material is usually determined by a cutting speed involving a given tool life, under established conditions. (For acceptance test purposes, a German state factory of armaments was the first to prescribe machinability tests of the material, by considering the relation of cutting speed to tool life as an index of machinability [1].)

The experimentally estimated value of cutting speed has been used by Taylor to characterize the machinability of materials (sequence of machinability indices on the basis of v_{20} [2]), or according to American practice, on the basis of the mutual relation of cutting speed values [3, 4] and in addition, in standard specifications relating to machinability (in the Soviet Union [5], and in Hungary [6]).

According to the above mentioned method of Taylor, one number suffices to determine the machinability of metals with respect to tool life. On the other hand, according Glebov's suggestion [7], besides the cutting speed value v_{60} (or v_{20}, or generally v_n), the exponent "m" of tool life — as an index of variation — should be included. Subsequently, some other authors have adopted the same principle [8, 9, 10, etc.], and have elaborated methods in order to make it applicable for a more detailed estimation of larger quantities of material. According to a recent tendency in scientific research, scientists usually establish the entire relationship between cutting speed and tool life, including the determination of relative machinability.

In the first series of the here described experiments, we intended to determine the relationship between cutting speed and tool life (v versus T) just for a chip cross-section that corresponds to well chosen experimental, as well as from workshop's viewpoints.

During the preliminary tests [11], the tool's geometrical form was chosen as follows: $\gamma = 30°$, $\alpha = \alpha_1 = 10°$, $\varkappa = 45°$, $\tau = 15°$, $r = 0.5$ mm; in our further experiments, the same form has been maintained. All tools were sharpened at once in order to reduce the chances that might have unfavour-

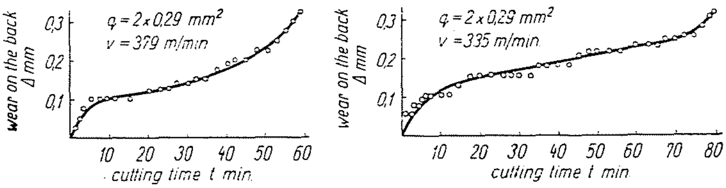

Fig. 1

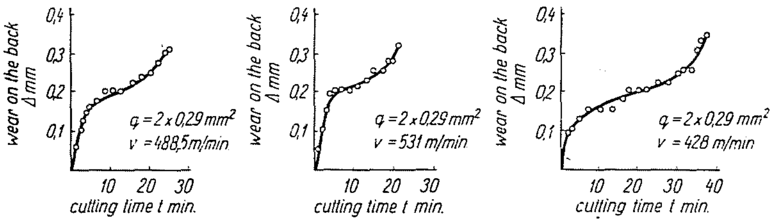

Fig. 2

able bearing on experimental results. For plotting the wear curves, the wear on the back of the tool, was measured by means of a Brinel-microscope. Time was measured by means of stoppers at an accuracy of 0,01 min.

The results were obtained by taking 5 measurements into consideration.

Wear curves are shown in Fig. 1 and 2; the initial testing data are given in Table 1.

When machining a given material by a given tool, in cutting a chip of a cross-section of $q = 2 \times 0.29$ mm^2, we obtained, on the basis of experimental results evaluated by a semi-graphical method (see Fig. 5), the following formula expressing the relationship between cutting speed and tool life:

$$v = \frac{1370}{T^{0.33}}.$$

In this formula the tool life exponent is greater than for steels and other heavy metals as known from other tables. This reveals the fact that

Table 1

(First series of tests)

Measuring item	Marking on the tip	Cut depth f, mm	Advance per revolution e, mm/rev	Cutting speed v, m/min	Tool life T, min
1	6	2	0.29	335	75
2	10	2	0.29	379	53
3	5	2	0.29	428	31.5
4	14	2	0.29	488.5	20.6
5	15	2	0.29	531	17.3

— for the given alloy — the increase of cutting speed involves a slower diminuation of tool life than in the case of harder materials.

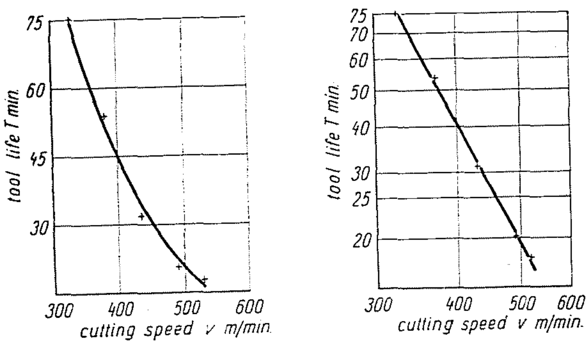

Fig. 3

According to the above obtained formula, a tool life of 1 minute is bound to a cutting speed of 1370 m/min. This is a decisive argument for refusing — mainly for practical reasons — the suggestion made by certain German researchers, according to which short tests based on a cutting speed (v_1) involving the tool life of 1 minute should be taken as basis of comparison. From the given formula, the cutting speed (v_{60}) that involves a tool life of 60 minutes is $v_{60} = 350$ m/min.

2. Relation between tool life and cutting factors

The task is, to find experimentally (usually in the explicit form for the cutting speed v) the expression for the following functional relationship:

$$T = \varphi(v, e, f)$$

The further purpose of these experiments was to draw the possible consequences, and to set up tables and nomographs for practical use. During ca. forty years, efforts have been made to find formulas for these relationships with reference to steel machining. As we know, similar experiments for deter-

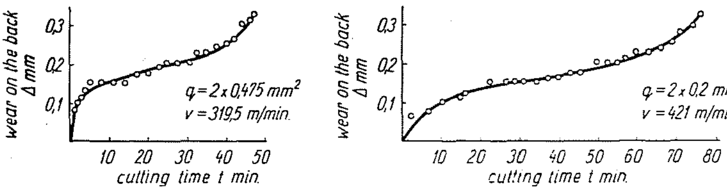

Fig. 4

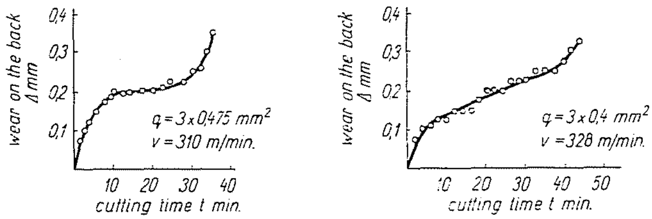

Fig. 5

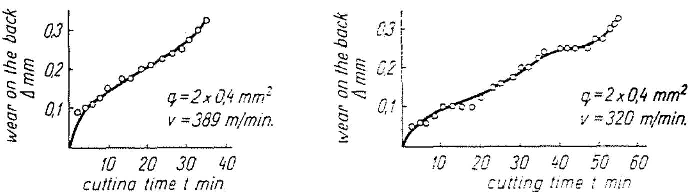

Fig. 6

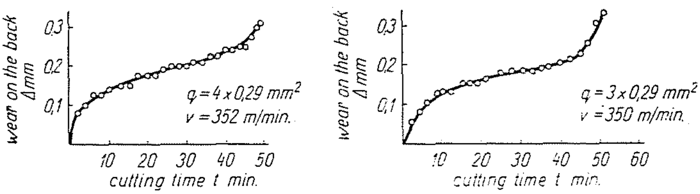

Fig. 7

mining the expression of these correlations, with reference to light metals and alloys, have not yet been carried out anywhere.

Considering aluminium alloys, the main trend of these tests does not differ from that of the examination of steel machining.

Generally the assumed form of the relationship put to test is:

$$T = \frac{C}{e^z \cdot f^v \cdot v^{\frac{1}{m}}}$$

or in a more usual form:

$$v = \frac{C_v}{e^y \cdot f^x \cdot T^m},$$

where C and C_v are constants coordinated to the actual work and tool pair. On the other hand, the experimentally determined four constants C_v, y, x, m, are assumed to be invariable within a certain range of the cutting values.

The wear curves are shown in Fig. 4—7.

The measuring results are summarized in Table 2. By making use of the compensation method of calculation, the following formula is obtained:

$$v = \frac{741}{f^{0.195} \cdot e^{0.52} \cdot T^{0.30}}$$

and the explicit form for tool life:

$$T = \frac{2{,}23 \cdot 10^9}{f^{0.63} \cdot e^{1.70} \cdot V^{3.25}}.$$

Table 2

(2nd series of tests)

Measuring item	Marking on the tip	Cut depth f, mm	Advance per revolution e, mm/rev	Cutting speed v, m/min	Tool life T, min
1	13	2	0.2	421	69
2	5	2	0.4	320	47
3	15	2	0.4	389	28.8
4	6	2	0.475	319.5	40
5	10	3	0.29	350	47
6	14	3	0.4	328	37.5
7	14	3	0.475	310	30
8	10	3	0.29	352	435

Generally, experimental results are usually to be calculated by graphical methods. For comparison's sake, before finding results by calculation, we applied the graphical method of evaluation, too.

1. In order to plot the curves representing the functions v versus T as shown in Fig. 8, the tests were carried out in cutting a chip with the cross-section area

$q = 2 \times 0.29$ mm², and $q = 2 \times 0.4$ mm², respectively.

The curves are drawn of the basis of visual compensation.

2. For determining the relationship v versus e, we applied two series of tests ($f = 2$ mm, and $f = 3$ mm). Since the measurements had yielded various values of tool life, we had to redress the numerical results according to the already established relation of v versus T. Therefore, we chose as basis

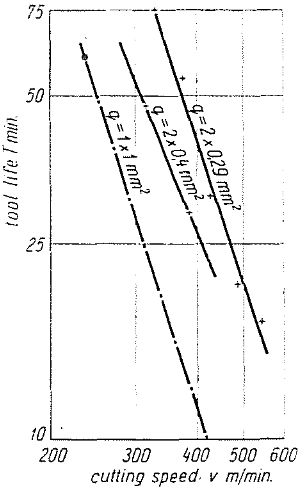

Fig. 8

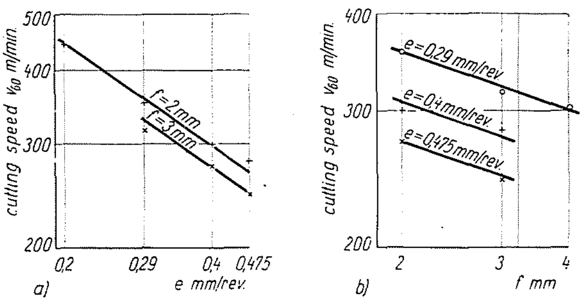

Fig. 9

the tool life $T = 60$ min; consequently these curves represent the functions v_{60} versus e, as shown in Fig. 9a.

3. In order to find the relationship v versus f, three series of tests ($e = 0.29$ mm/rev.; $e = 0.4$ mm/rev.; $e = 0.475$ mm/rev.) were carried out. In the same way, as mentioned in point 2. the results were redressed on the basis of a 60 min. tool life (Diagram showing v_{60} versus f in Fig. 9b).

4. The above stated expressions suffice to determine the general basic formula. To this end, the constants y and x can be calculated; and by extrapolation the cutting speed involving a 60 min. tool life in cutting a chip with a cross-section of 1 mm² can be found.

In Fig. 8 showing the diagram v versus T, the straight line corresponding to $m = 0.33$ (for $q = 2 \times 0.29$ mm²), and the point belonging to the values $q = 1$ mm² and $T = 60$ min, are delineated.

By drawing, through the aforementioned point, another straight line parallel to the former one representing $m = 0.33$, we find by the section point on the v axis the cutting speed value v_1 belonging to the tool life $T = 1$ min, numerically equalling the constant C that represents the interdependence of work and tool.

As a final result we obtain:

$$v = \frac{800}{e^{0.56} f^{0.23} \cdot T^{0.33}}$$

Although these constants deviate from those obtained by pure calculation, the magnitude of variations does not affect the practical applicability. Consequently, the graphical method can be recommended for the calculation of tool life tests.

3. Recapitulation of consequences

1. Relation of cutting speed to tool life: for a chip cross-section of $q = 2 \times 0.29$ mm², and for the aluminium alloy put under test, the formula deduced by a semi-graphical method is as follows:

$$v = \frac{1370}{T^{0.33}}$$

The exponent $m = 0.33$ is responsible for the relationship characterized by a slower tool life diminuation involved by an increased cutting speed, than would be the case in steel turning.

2. The relationship between tool life and cutting factors can be expressed as follows:

$$T = \frac{2.23 \cdot 10^9}{f^{0.63} \cdot e^{1.70} \cdot v^{3.25}}$$

namely, within the experimental range of basic values that were evaluated by calculation; or in a more conventional form:

$$v = \frac{741}{f^{0.195} \cdot e^{0.52} \cdot T^{0.30}}$$

3. The series of tests should not only help us in finding scientific correlations, but also in satisfying practical claims, namely, by yielding useful information data for workshop practice. Based on these experimental results, nomographs (Fig. 10 and 11) and tables were set up for the experimental range. All the basic values given in this table refer to a 60 min tool life. In

Cutting speed V_{60} m/min

Feed, e mm/rev	Cut depth, f mm			
	2	2.5	3	4
0.2	439			
0.25	390	376	360	340
0.3	354	341	332	341
0.35	327	314	302	285
0.4	305	293	282	268
0.45	286	276	264	250
0.5	273	262	252	237

Conversion factors:

T_{min}	30	45	60	75	90
K_T	1.23	1.08	1	0.93	0.68

Fig. 10

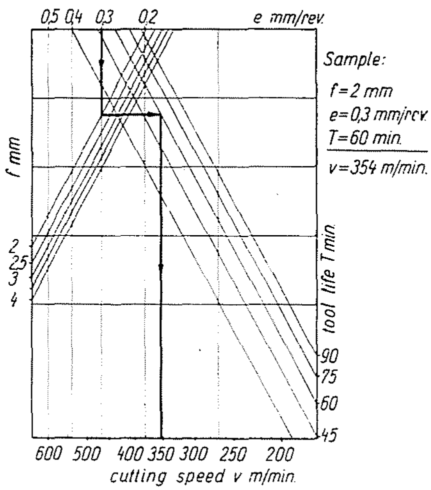

Fig. 11

addition, correctional factors are given for the purpose of conversion. The correctional factor for a 90 min tool life has been determined by means of extrapolation of the results, permissible from well considered viewpoints; also tool advance (per revolution) limits have been extrapolated, for an admissible, not important range.

Summary

In this paper a series of experiments relating to tool life in machining a given aluminium alloy is reported; testing principles and experimental details are described, the problem of evaluation of results is dealt with. Finally a table and a nomograph is given for their use in workshop practice.

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Á. KARDOS; Budapest, XI. Sztoczek u. 2 sz. Hungary