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Influence of value of the criterion of blunting on the selection of the brand of hard alloy and optimum cutting speed when turning austenitic steel

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Abstract. A mechanisms of wear carbide tool when turning of austenitic steel 18-8 by cutters from firm hard-alloys of various groups (WC-Co, TiC-WC-Co, TiC-TaC-WC-Co) were studied. During wear resistant tests it is established, that the prevalence of one of the two mechanisms of wear (of adhesion-fatigue or diffusional) depends on the brand of hard alloy. It is shown, that *in* machining by titanium-containing carbide tool the intensity of the growth of the wear platform on the back surface of the tool as wear changes. This is due to the smooth transition from the predominance of adhesion-fatigue wear to prevalence of diffusional wear. Therefore, the intensity of wear should be considered as current, depending on the value wear platform, and value of the criterion of blunting is influence on the selection of the brand of hard-alloy and optimum cutting speed.

In theory and practice of cutting of metals much attention is pay to the selection of the most effective brand of hard alloy and to definition of optimal cutting speed. The urgency of this problem increases in the case of cutting of austenitic steels and other materials that are hard to machining.

The appointment of a hard alloy is produced mainly on the basis of the machined material and the type of machining (the machining type is qualitatively to fix – roughing, semi-finishing and finishing). Optimum cutting speed, i.e. the speed corresponding to the maximum path length of cut up to a specified criterion blunting (permissible value wear) tool, is considered as a fixed, unchanging from the beginning of cutting to blunting the tool under given conditions (machined and tool materials, modes of cutting, tool geometry, and so on).

It has been established that a wide range of cutting speeds in machining austenitic steel at the wear platform at the rear surface of tool prevails plastic contact – complete adhesion of the machining material to the tool, with plastic flow of the machined material [1]. However, adhesive-fatigue wear is retained to high cutting speeds and hence high temperatures at the wear platform, – especially for tools made of titanium-containing hard-alloys of TiC-Wc-Co and TiC-TaC-WC-Co. This is associated with the unstable chip formation seen in cutting austenitic steel, which leads to cyclic fluctuation of the forces and thermal loads on the wear area of the tool's rear surface [2, 3]. It influence on the peculiarities of tool wear. It is important to establish this peculiarities.

The endurance-tests carried out by the longitudinal turning austenitic steel 18-10 (Fe and C $\leq$ 0,12 %, Cr 18 %, Ni 10 %, Ti $\leq$ 0,8 %), showed that when choosing a brand of hard alloy and value of optimal cutting speed should take into account the criterion of blunting the tool (in most cases – allowable width h_{re} of the wear platform on the rear surface).

In our experiments we used cutters with mechanically fixed plates of various hard alloys – WC 94-Co 6, TiC 15-WC 79-Co 6 and TiC 8-TaC 12-WC 71-Co 9. The speed v of cutting was changed from 15 to 180 m/min at supply 0.3 mm/turn and cutting depth 1.5 mm. The basic geometric parameters of cutters: front angle $\gamma = 0^o$; rear angle $\alpha = 10^o$; primary plane angle $\varphi = 45^o$; tip radius r = 0.3 mm. As an indicator for durability used resultant path length L to blunting (h_{re} = 0.3 mm).

The obtained dependences of the total path length L traveled to achieve of wear h_{re} = 0.3 mm, from speed v is presented in Fig. 1.

Monotonously decreasing character of the L(v) dependence for WC 94-Co 6 alloy (curve 1 in Fig. 1) is connected with the known fact – low resistant of tungsten carbide by diffusional dissolution in machined steels. Therefore, in the entire investigated speed range dominated diffusional wear, the intensity of which is sharply in-creased with increasing of the speed and temperature of cutting. Therefore, WC 94-Co 6 alloy cutters the best results only at low v (30 and 45 m/min; at speed v = 15 m/min wear was so low that the test is not fully drawn) are obtained.

At higher speeds (60 and 90 m/min) the highest wear resistance showed cutters of TiC 8-TaC 12-WC 71-Co 9. For them dependence L(v) has a maximum near v = 60 m/min (curve 2 in Fig. 1), which also explains the well-known [4, 5] fact: the increase of the cutting speed for titanium hard alloys has replaced the predominant mechanism of wear – adhesive-fatigue wear to diffusional wear.

Testing of TiC 15-WC 79-Co 6 cutters, in any speed not managed to bring to the criterion of blunting h_{re} = 0.3 mm. The cutters was premature to removing due to the

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dominant wear of the tip of the cutter, wear of the secondary cutting edge and a corresponding catastrophic deterioration in the quality of the processed surface. So the L(v) dependence for

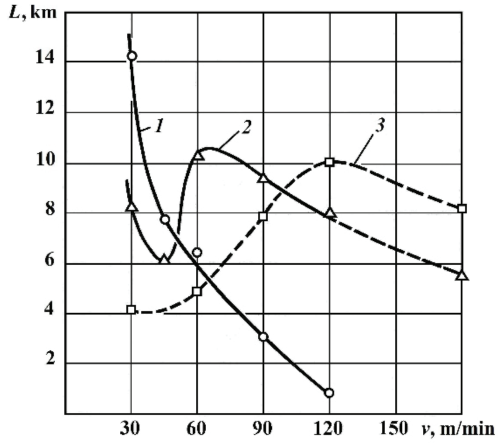

Fig. 1. Dependence of the total path length L to blunting (h_{re} = 0.3 mm) from the speed v of cutting for compared hard-alloys
WC 94-Co 6 (1),
TiC 8-TaC 12-WC 71-Co 9 (2)
and TiC 15-WC 79-Co 6 (3)

TiC 15-WC 79-Co 6 (curve 3), which also has extreme character, was obtained by extrapolation of source endurance curves to h_{re} = 0.3 mm (also the values of total path length L for TiC 8-TaC 12-WC 71-Co 9 at speeds from 120 to 180 m/min) and is shown in Fig. 1 as the dashed line.

Thus, in the practically applicable range of cutting speeds when turning of austenitic steel, best results showed the tool of TiC 8-TaC 12-WC 71-Co 9. However, analysis of initial endurance curves h_{re}(L) (here h_{re} – the current value of wear, and L is the path length from the beginning of test) showed that this is true not always. On Fig. 2 summarizes the dependencies h_{re}(L) for cutters of comparable hard alloys at v = 60 m/min (as per Fig. 1 the best is hard alloy TiC 8-TaC 12-WC 71-Co 9, and this speed is optimal for him).

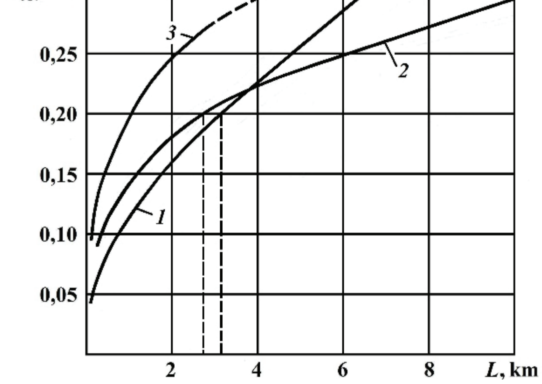

Fig. 2. Dependence of value of wear h_{re} from the cutting path length L at cutting speed v = 60 m/min for compared hard-alloys:
WC 94-Co 6 (1),
TiC 8-TaC 12-WC 71-Co 9 (2)
and TiC 15-WC 79-Co 6 (3)

From Fig. 2 it is seen that in all length of the path L the greatest wear h_{re} showed a fragile, sensitive adhesive-fatigue wear TiC 15-WC 79-Co 6 hard-alloy (curve 3). Moreover, the predominance of this mechanism of wear is saved to high speeds and temperatures of cutting [3] due to the instability of chip formation, inherent to cutting austenitic steels [6, 7] (it is impossible not to notice, that the unfortunate title of the articles [6, 7] is the result of the editor's error; initial author's version was «Instability of Chip Formation and the Dependence of the Thermal Conductivity of Machined Material on Temperature»).

Curves h_{re}(L) for hard-alloys WC 94-Co 6 and TiC 8-TaC 12-WC 71-Co 9 (respectively, 1 and 2 in Fig. 2) are intersect. Therefore, if the criterion of blunting was made lower value h_{re}, such as 0.2 mm, the path of cut up blunting the show WC 94-Co 6 alloy cutter – 3.15 km vs. 2.7 km by TiC 8-TaC 12-WC 71-Co 9 (see builds on Fig. 2, made by the vertical dashed lines).

Intersection curves is explained by the change of the prevailing wear TiC 8-TaC 12-WC 71-Co 9 alloy not only with the growth of v, but at cutting fixed-value – due to blunting the tool and a corresponding increase in temperature on a wear platform [8]. For sharp cutter temperature at the wear platform is small, prevails adhesive-fatigue wear mechanism, generating total high wear intensity. With a blunting of cutter temperature at the wear platform growing and intensity of the adhesive-fatigue wear decreases, i.e. the instrument starts working in the prevalence of dif-fusion wear, resistance which TiC 8-TaC 12-WC 71-Co 9 alloy much higher than that of WC 94-Co 6. There-fore, the slope of the curve h_{re}(L) for TiC 8-TaC 12-WC 71-Co 9 (2) becomes smaller than for WC 94-Co 6 (1). As a result, to achieve of the criterion of blunting h_{re} = 0.3 mm cutter TiC 8-TaC 12-WC 71-Co 9 alloy is considerably larger total path length of cutting (10.3 km, compared 6.4 km from WC 94-Co 6).

This result is rather unexpected – in the appointment of a lesser magnitude criterion of blunting, which is characteristic of the transition from semi-finishing to the finishing machining, the best result was a show WC 94-Co 6 hard-alloy, the scope is closer to the semi-finishing processed than TiC 8-TaC 12-WC 71-Co 9 (flexural strength 1.5 GPa by WC 94-Co 6 versus 1.3 GPa at TiC 8-TaC 12-WC 71-Co 9 [9]). In addition, hard-alloy WC 94-Co 6 belongs to the group of application K (processing of cast-iron, nonferrous metals, etc.) and not to group M (processing of high-alloyed steels), as TiC 8-TaC 12-WC 71-Co 9 [5]. Thus, the criterion of blunting can essentially (and non-obviously) influence the choice of the brand of hard-alloy. It becomes clear why in single and small batch production in the processing of small non-rigid parts made of high-alloyed steels (when you want to minimize cutting forces and often reface the tool) are often used WC-Co cutters.

Not less interesting results were obtained when comparing the dependencies h_{re}(L) obtained by TiC 8-TaC 12-WC 71-Co 9 cutters at machining with different cutting speeds v (Fig. 3).

As can be seen from Fig. 3a, for the alloy WC 94-Co 6 curves are positioned so that for a more lesser cutting speed (providing a increase total path length to blunting) curve h_{re}(L) is located entirely below, than a similar curve

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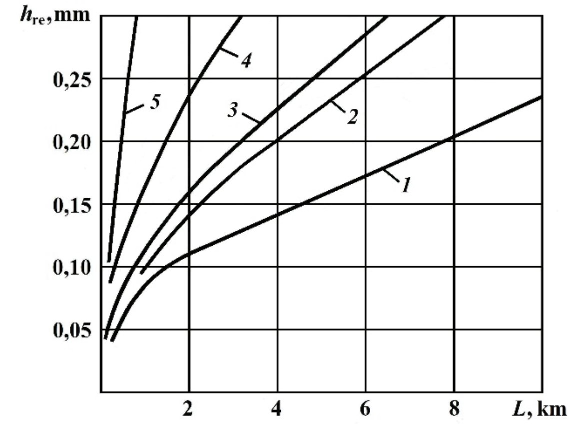
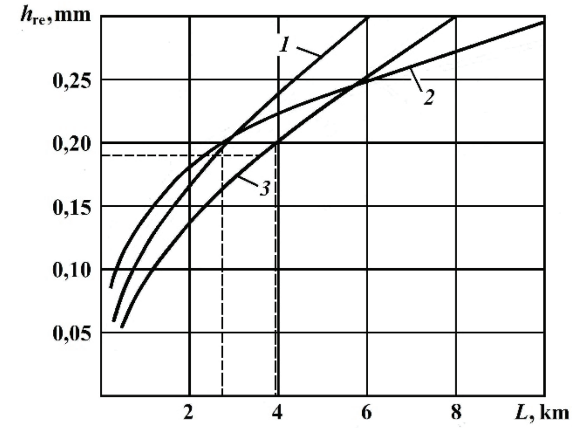
for less bigger speed. This can be considered a convincing evidence of the prevalence of diffusion wear not only in the entire investigated range of speeds (curve 1 in Fig. 1), but at all value of h_{re} (in Fig. 3a we see, that at all value of the criterion blunting with increase v path length steadily decreases).

Different picture is observed for the alloy TiC 8-TaC 12-WC 71-Co 9 (see Fig. 3b): curves intersect. Therefore, the value of the optimal speed becomes a dependent by value of the criterion of blunting. For example, when assigning a value of criterion blunting the h_{re} = 0.3 mm up to speed 60 m/min (curve 2) bigger total path length than v = 120 m/min (curve 3). If you take a smaller value of the criterion of blunting, for example h_{re} = 0.2 mm (when performing for finishing operations or



a)



b)

Fig. 3. Dependence of the value of wear h_{re} from the path length L at different cutting speeds v in turning 18-10 steel by hard-alloy cutters WC 94-Co 6 (a: 1 – v = 30 m/min, 2 – v = 45 m/min, 3 – v = 60 m/min, 4 – v = 90 m/min, 5 – v = 120 m/min) and TiC 8-TaC 12-WC 71-Co 9 (b: 1 – v = 45 m/min, 2 – v = 60 m/min, 3 – v = 120 m/min)

for small non-rigid details), the more profitable it would be a speed of 120 m/min (L = 3.9 km vs. 2.7 km to 60 m/min – see made a vertical dashed straight lines building in Fig. 3b). Interbreeding of the curves in Fig. 3b is explained by the change of the prevailing mechanism of wear with increasing h_{re}. At most, this manifested for v = 60 m/min (curve 2; this curve is already appeared in Fig. 2, and comments are given above). When cutting with v = 120 m/min at small wear platform intensity of adhesion-fatigue wear was less than at v = 60 m/min, is due to the higher of the contact temperature. Or another, already prevailed diffusion wear, the intensity of which was less than the intensity of adhesion-fatigue

wear at v = 60 m/min. Therefore, wear platform at v = 120 m/min grew slower, and to achieve h_{re} = 0.2 mm cutter makes bigger path length. However, with further increase h_{re} intensity of the prevailing diffusion wear for v = 120 m/min changes slightly. At the same time, at speed v = 60 m/min transition to the dominance of the diffusion wear, the intensity of which is much less than at cutting with v = 120 m/min, due to the lower temperature. As a result, to achieve the value criterion of blunting h_{re} = 0.3 mm cutter makes a longer total path length already at v = 60 m/min.

Thus, the value of optimum cutting speeds also can depend from criterion of blunting, and the term «optimum cutting speed» needs some correction. In the conventional sense of the optimal speed is mean some originally established cutting speed, that unchanged from the beginning of cutting to blunting the tool and provides the maximal path length of cutting (the maximum number of de-tails when machined to blunting of tool for production). At that, the wear rate defined as the ratio of value of the criterion of blunting to the resulting path length of cutting ($J = h_{re}/L$). Results of conducted research suggest the advisability of introducing a concept of current intensity of wear: $J_c = dh_{re}/dL$.

As we see in Fig. 3b, for small values of the h_{re} value J_c is minimal for v = 120 m/min, but for large values of h_{re} – for v = 60 m/min. Therefore optimum cutting speed is best defined not as a fixed, but as current. The current optimal speed corresponds to the minimum value of current intensity of wear J_c, which in turn depends from the distance traveled cutting and degree of blunting the tool. At continuously changing the cutting speed in the course of machining on the criterion of minimizing the current intensity of wear can be achieved significantly bigger the resulting path length to blunting than using a fixed speed. For example, the machining of 18-10 steel with hard-alloy cutter TiC 8-TaC 12-WC 71-Co 9 can start at speed v = 120 m/min and machine to value of blunting $h_{re} \approx 0.19$ mm. At this value h_{re} are equalized current intensity of wear for speeds of 120 and 60 m/min (tangent lines to curves 2 and 3 in Fig. 3, b in the points of intersection of the horizontal dashed line corresponding to h_{re} = 0.19 mm, have the same degree of slope). If after reaching this value of wear reduce speed up to 60 m/min, the path length of cutting to blunting h_{re} = 0.3 mm may increase to 11,5 km (this is easy to verify by doing simple graphic manipulation with curves 2 and 3 in Fig. 3b).

The possibility to increase tool life in such a way is confirmed by experiment. Even a single step reduction of the cutting speed from 120 to 60 m/min, made at reaching the value h_{re} = 0.2 mm, the path length to blunting increased by 15 % (at the value of criterion blunting h_{re} = 0.3 mm) compared with the path length at a constant speed of 60 m/min.

When using adaptive systems to continuously adjust the speed of cutting at blunting of cutting tool effect may be even higher.

The results obtained make it possible to improve the efficiency of machining austenitic steels by a more informed choice of the brand of hard-alloy and by correct cutting speed as wear of the tool.

In addition, when turning austenitic steels is of great importance the correct assignment of the front angle of the instrument, providing a different effect on the prevailing mechanism and wear rate of tools made of hard-alloys of different groups [10]. For resistant to adhesion-fatigue wear cutters from WC 94-Co 6 increase to angle γ leads to a decrease of the contact temperature and decrease of wear rate due to the suppression of the diffusion component. Hard-alloy TiC 15-WC 79-Co 6 good resistance to diffusion wear, but fragile in terms of the adhesion-fatigue effect. Therefore, the influence of front angle on wear resistance is the opposite of TiC 15-WC 79-Co 6, and to increase the resistance necessary to reduce the angle γ. For TiC 8-TaC 12-WC 71-Co 9 dependence of the resistance of the angle γ is more complex. At small cutting speeds to increase the resistance of the cutting angle should be reduced, and when the cutting speed – increase [10].

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