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British View ISSN 2041-3963 Volume 10 Issue 1 2025
Impact factor 8

CHANGES IN THE STRENGTH PROPERTIES OF THE PROCESSED MATERIAL DURING THE DEFORMATION PROCESS

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Abstract. The article provides information on the main factors that determine the quality of parts during mechanical processing. According to it, the durability of cutting tools is mainly considered in the process of processing parts, that is, in general, the service life of the tool depends on the cutting conditions, high-precision design of geometric parameters, thermal conditions in the cutting zone, and other parameters. Factors that significantly affect durability are the hardness and stress state of the workpiece material. The results of research have been published, which show that when all of the above factors are met, the possibilities of increasing the service life of cutting tools are improved.

Keywords. tool, material, mechanical processing, geometric accuracy, process, strength, transformation, operation, mechanical engineering, technology, modernization, operation, localization.

INTRODUCTION

Ensuring the priority development of mechanical engineering, envisaged by the decrees of the Government of the Republic, is associated with the intensification of mechanical processing processes and the improvement of the quality of manufactured products. The essence of these processes is largely determined by the characteristics of plastic deformation, since most metals and alloys are prone to the transformation of strength properties during plastic deformation and the real properties of the metal, manifested in the dynamics of the technological operation, determine the nature of the process itself and the formation of the final operational properties of the part.

The processing of materials by cutting is presented as a high-speed, energy-loaded and local process of plastic deformation with a complex asymmetric scheme of force action. The application of fundamental laws of the theory of plasticity and strength in their pure form to this process is difficult, and often impossible. Therefore, the study of the features of the process of transformation of the strength properties of the processed material in real technological processes of mechanical processing continues to be an urgent task of the theory and practice of mechanical engineering. Disclosure of the laws of these processes will allow more accurate prediction of the operational properties of machine parts and the operability of the cutting tool, will open up prospects for modernization of traditional technological operations and can be the basis for the creation of new types of mechanical processing.

LITERATURE REVIEW

In technological processes, it is necessary to achieve different values of the strength properties of the processed material. For example, when cutting off blanks, the processing efficiency can be significantly increased if the softening of the processed material is as maximum as possible. Or, conversely, during finishing operations, it is desirable to transform the strength properties of the processed material towards their increase, which will improve the wear resistance of the finished surface. In this case, the requirements for the spread of deformation into the depth of the processed surface (to the size of the plastic deformation zone) in both processes also differ. Localization of deformation in the case of cutting will reduce the energy costs of this operation. In the second case, an increase in the deformation zone is required to strengthen the surface [1].

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DISCUSSION

Control of the strength properties of the processed material will allow solving practical problems of intensifying the processes of mechanical processing and improving the functional properties of manufactured products.

Since “the energy costs for plastic deformation in technological processes of mechanical processing make up more than 80% of the total work” [3], the main reserve for controlling these processes is embedded in the features of the course of plastic deformation.

The relationship of “real” strength properties, expressed through resistance to deformation, with temperature and speed conditions determines the nature of the course of the mechanical processing process. Data reflecting this relationship will allow a reasonable solution to the problem of controlling the technological process or the need for its modernization.

The regulation of the hardening or softening of the material being processed in mechanical processing processes is most often carried out by changing the temperature and speed conditions, which is practically realized through changing the cutting conditions: modes, tool geometry, coolant, etc.

RESULTS

The influence of temperature on the hardness of metals

Perhaps the largest number of works are devoted to the study of cutting temperature as a parameter determining the state of the tool-worked material system. Almost all studies in the field of contact friction or cutting of metals are directly or indirectly related to the study of temperature or its distribution. This is due to the fact that temperature affects almost all characteristics of the cutting process, predetermining such important indicators as the durability of the cutting tool, accuracy, quality of the machined surface, etc.

As the temperature increases, processes develop that contribute to an increase in the level of plasticity (a drop in hardness) of the polycrystalline material. In these materials, which include industrial steels and alloys, softening can be observed up to a temperature close to the temperature of the onset of disruption of the solid state of crystals, i.e. the beginning of melting of grains or boundaries.

In practice, as the temperature increases and cooling from high temperatures occurs, other processes may occur simultaneously with those noted above in steels and alloys, which contribute to an increase in hardness. Let‘s consider them.

Limitation of the possibility of slip in crystals, including: distortion of the solid solution lattice by high alloying, dispersion hardening in the temperature range of 600 – 1000, transformation of δ – ferrite into a brittle σ – phase in approximately the same temperature range, embrittlement of δ – ferrite at 475 °C in high-chromium steels, ordering of the structure in a number of precision and other alloys.

Increase in the amount of δ – ferrite in steels such as 1XI8H9T and others from point 1 to point 5 with increasing temperature.

E.Zh. Herbert‘s conclusion is demonstrated in Fig. 1. According to the author, such a pattern is typical for steels and many non-ferrous metals.

A characteristic feature of the curve is three increases (P_1, P_2, P_3) and three decreases (D_1, D_2, D_3). These six “remarkable points” are repeated at very specific temperatures. In particular, the strongest decrease in D_2 is observed at a temperature between 100 and 150 °C.

When studying the influence of temperature on the change in the proportionality limit of twisted wire, it turned out that the proportionality curve has almost exactly the same form as the curve shown in Fig. 1, having approximately the same points of increase and decrease of this limit with increasing temperature (experiments of Goffe and Thomson, 1922). This coincidence of the type of curves, in the opinion of Professor F. Glebov, undoubtedly indicates the commonality of the phenomena occurring, leading to adequate results both in relation to the ability to harden, and in relation to some other properties of metals.

It should be noted that the indicated experiments were conducted without taking into account the influence of cutting speed. Let us consider how the hardness of the tool material (high-speed steel, heat-treated to HRC62-65) measured according to Herbert will change according to the data presented in the works of Professor Glebov [2].

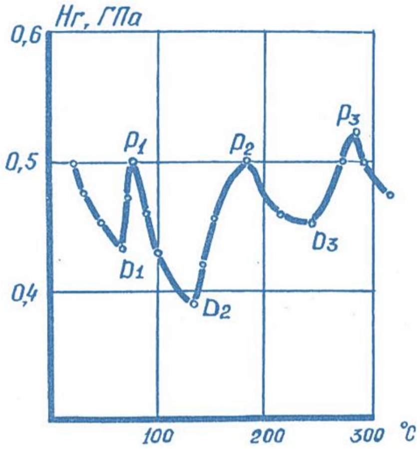

Fig. 1. Effect of processing temperature on the hardness of the measured

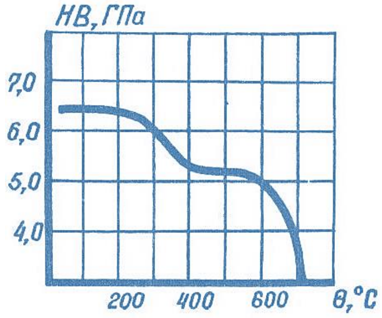

Fig. 2. Dependence of hardness on temperature at values corresponding to the cutting process.

The relationship between Brinell hardness and temperature is shown in Fig. 2. Fig. 3 shows the same relationship, but with hardness measured after cooling. Comparing the two relationships, one can note the loss of hardness at a temperature of ≈ 600°C in Fig. 2, while after cooling the hardness is retained at 800°C. However, it should be emphasized that the relationship, in our opinion, rather reflects the effect of heat treatment on hardness at room temperature than the properties of the material at the corresponding temperatures.

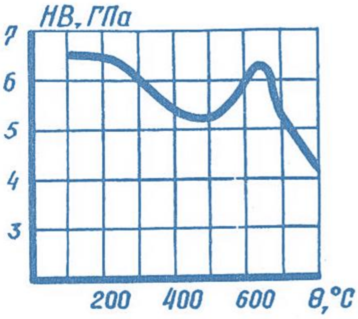

Fig. 3. Hardness measured after heating (to the temperatures of Fig. 2) and subsequent cooling.

There [1] the dependence of temperature on cutting speed is given for materials of different hardness, which show that an increase in the hardness of the material being processed generally leads to an increase in the cutting temperature. Similar dependencies were obtained by V.V. Tsotskhadze for eight different steels.

According to T.N. Loladze [2], “at high modes, when a high temperature develops in contact, the hardness of the contact layers decreases significantly, and can be 10-20 times less than at room temperature.” For example, for hardened steel KhVG, given in Table 1, the hardness decreases with a change in temperature from 200°C to 900°C by more than 30 times.

Table 1.

Hardness values of HB at different temperatures

Material	Temperature, °C										
		200	400	500	600	700	800	900	1000	1100	1200
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
P18	720	700	620	570	515	425	120	50	25	20	–
1X18H9	420	390	325	260	180	115	75	50	26	12	10
ХВГ hardened	–	610	515	400	130	6 0	37	20	–	–	–
Ст.40	280	256	198	–	120	–	28	–	10	18	5
TI5K6	300	112	920	–	725	–	540	–	390	310	230
У10	280	256	198	150	120	64	28	15	10	8	–

Data obtained for $\dot{E} = 10^3$ c

There are a number of analytical dependencies of the influence of temperature on the hardness of a material according to Brinell [4]. Silin S.S. and Talantov N.V. [5] believe that the softening processes begin to outpace the hardening process above a certain critical temperature, which is determined by the binding energy of atoms in the crystal lattice. In their opinion, this temperature should be the first Debye temperature [7].

$$T_g \approx 120A^{-5/6} \cdot \rho^{1/3} \cdot T_{pl}^{1/2}, \tag{1}$$

where, A – is the average atomic weight,

ρ – is the density,

T_{pl} – is the melting point.

The softening processes will develop more intensively at high deformation rates (above 10^5 c^{-1}). It is known that the amount of heat released during plastic deformation per unit of time is determined [8]

$$Q \approx \sigma_b \cdot \varepsilon \cdot c \tag{2}$$

where, σ_b – ultimate strength,

ε – rate of plastic deformation,

c – coefficient taking into account dimensionality.

The heat released during plastic deformation is used to heat the environment to a certain temperature.

$$t_{def} \approx 0.3 \cdot 10^{-6} \cdot \varepsilon \cdot \sigma_b, \tag{3}$$

At the same time, in the works of [9], on the contrary, a greater softening effect of temperature is indicated during deformation at low deformation rates. In this case, three characteristic ranges of temperature influence are assumed. It is believed that in the first and third ranges, called cold and hot, respectively, a change in deformation temperature has an insignificant effect on strength properties. In the second (warm deformation), such an effect is very significant. Similar conclusions can be made when analyzing the state diagrams given in the work of [10,11].

In the studies of the ranges of the greatest influence of temperature are also noted.

In the work of the change in hardness from temperature is associated with the thresholds of the beginning and end of recrystallization. The concept of dynamic recrystallization is introduced. It is indicated that the values of the temperatures of the beginning and end of dynamic recrystallization differ significantly from those determined in statics [12,13].

A number of authors associate the degree of softening with the time of action of heat sources. Others believe that it depends on the homologous temperature (the ratio of the temperature during processing to the melting temperature of a given processed material).

In general, the strengthening effect of temperature in mechanical processing is determined by specific conditions of plastic deformation and, to a large extent, by the speed and degree of deformation.

CONCLUSION

A method and installation for determining the strength properties of a material in high-speed deformation processes have been developed. The method, based on loading the material under study by rolling, allows creating conditions for plastic deformation close to the processing of materials by cutting, as well as simulating isothermal conditions necessary when studying the autonomous influence of temperature and process speed.

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