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DURABILITY INCREASE OF MONOCRYSTAL CUTTING PLATES OF SYNTHETIC CORUNDUM – A REVIEW

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ABSTRACT

Results of researches on wear resistance of cutting plates made of synthetic corundum at their continuous illumination are resulted in this clause. Using known theories of solid-state physics the model of dispositions movement in a cutting plate is offered. According to calculations and experiences it is established, that at cutting plate`s illumination the deterioration on a back side will be minimal.

Key words: *Corundum, Non-Ferrous Metals, Dislocation, Monocrystal and Deformation.*

1. Introduction

The aim of work is a dislocation inside of crystals made of synthetic corundum and the physics of cutting plate wear during the different conditions of elaboration.

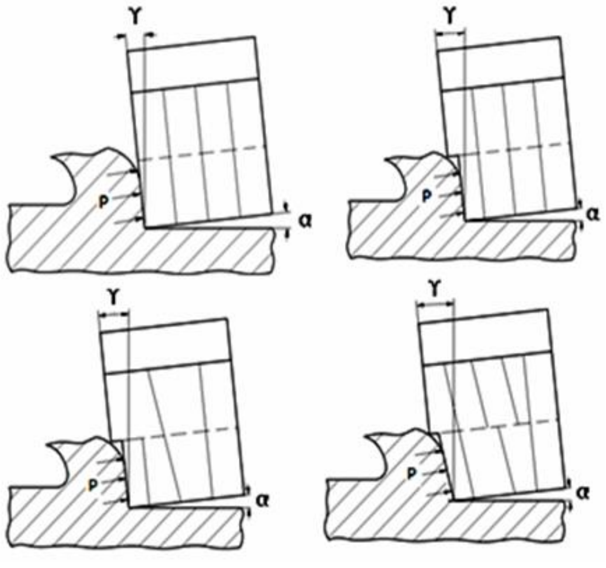

Fig. 1 The Scheme of the Origin and Displacement of the Verge Dislocation at Shearing Deformation of the Cutting Plate

2. Defects in Monocrystals of Synthetic Corundum

Ruby crystals usually have different kinds of microscopical and macroscopical (bubbles, extrinsic inclusions, sliding tracks, twin layers, mosaic blocks, etc.) defects. Defects in ruby crystals are classified according to the geometric sizes. We distinguish 4 group types (fig. 1) of different defects in monocrystals of synthetic corundum- dot (zero-dimensional) – vacant junctions in the lattice;linear and chains of dot defects, which can be of the following verge; rifle and mixed; two-dimensional, three – dimensional [1]. Dot defects are considered as small defects and usually the situation is related to one atom (vacancy, interstitial atom). The other 2 groups aren't considered here, as the work is devoted to the braking of monocrystal dislocations which have dot and linear types of defects.

One of the main defects which essentially has influence on the physical properties of crystal are dislocations and remaining tenses connected with them. There are individual dislocations and their accumulations in synthetic corundums. Linear dislocations appear during the deformation displacements in planes, occupied with atoms densely called sliding planes.

2.1 Scheme of origin and moving of a screw disposition

Let's study a simple cubic lattice with {100} type of plane. For OCK lattice sliding planes are considered to be {110}, {112} and {123} and for GCK lattice is {111}. [2]

If we have affection on the crystal with P power, the plane area marked with dotted line can be broken off.

Rifle dislocation is a disposition of atoms for plane cubic lattice (fig. 2). If we affect on the crystal with P power, A_1 plane marked with a pointer can be broken off along the line (a). After that the lower and the upper halves of A_1 plane are combined with displacement of one lattice period (b).

Constant affect on the crystal can break the next plane (flat), in consequence of which the lower and the upper halves of A_2 plane combine with displacement (b) etc. So, there appear rifle dislocations in the crystal, which will move along the sliding plane in the case of any affect at the break expense of adjacent plane halves. Let's take into account that the break of new plane takes place on the dislocation line, as a great part of dislocations of crystal lattice are here.

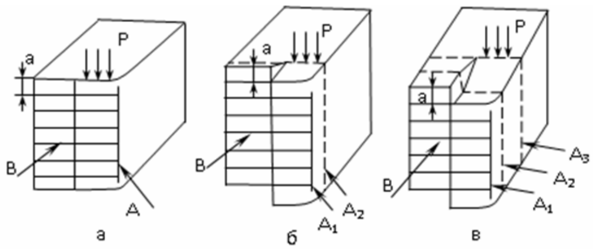

Fig. 2 Scheme of Origin and Moving of a Screw Disposition at Shift Deformation of a Cutting Plate

2.2 Rifle dislocation energy

Deformation energy of crystal lattice is connected with dislocation, which can be calculated, using the approach of continue for remote areas of crystal because of dislocation and the model of interactive atoms for small distances from dislocations.

Taking into consideration the typical values in (1) we will get the density of rifle dislocation energy according to the unit of length

$$U/l = 4\cdot 10^{-9}\,Joule/m,$$

and for one interatomic distance will be

$$U/l = 10^{-18}\,Joule/atom$$

It is a great value which surpasses the energy of thermal movement of atoms. In this case the dislocation can't appear as a result of thermal movement, it needs disbalance processes, for example crystal deformation.

Different types of mechanisms of dislocation breaks are known: interaction with dot defects, phonon wind, relaxation of slow backgrounds and so on [3].

Dislocation movement can be caused by mechanic affect on the crystal, which is characterized by its dependence of movement velocity from the applied tense, i.e. curve suppleness [3]

Dislocation displacement in zero-defect parts of crystal, which don't contain plugs, take place with high velocity, comparing with sound velocity in the given material. According to the break mechanisms, dislocations are classified as dynamic and thermofluctuational. The latter is classified according to the overcoming of dot ogstacles – hoving of dot defects and hoving on dislocations.

2.3 Verge type of dislocation

It is known, that the verge type of dislocation creates a powerful compression and extended areas of crystal lattice. In extended places it is preferable to move big atoms of tincture substitution and in compressed ones – small atoms substitution tincture from the energetic view point. Inculcation of specially big atoms is profitable to move to the area of extended crystal lattice near dislocation.

In this case near the dislocation there probably will appear an accumulation of tinctures, which lowers local deformation near dislocation and dislocation energy. During the plastic deformation it will be difficult to displace such kind of dislocation, as dislocation will move to a new place, where its energy will be higher. Separate dot defects and their accumulations firm the dislocation. Crystal parts with extended crystal lattice near the dislocation are considered as peculiar canals of relieved diffusion. It is known, that the diffusion in strong deformated areas where dislocation density is high takes place quicker than in not deformated ones.

Dot defects often disappear getting on the edge of unnecessary half-plane, causing dislocation thereat the form of that half- plane is changed. It is also considered that the dislocations are inclined to the origin dot defects during the displacements, especially vacancies, appearing near the edge of unnecessary plane, thereat the edge form of that "half –plane" is changed. The dislocation line in such processes (called dislocation creeping) is mixed (crept) to a new place.

3. Dislocation Breaking

Now a number of new methods of density increase of material are used, which allow to reach the strength limit about ; most of them are connected with introduction of extra obstacles to dislocation displacements. Such obstacles can be considered aforesaid different defects.

3.1. Crystal lighting methods

Crystal lighting is one of the methods of dislocation breaking. It is well known that during the mechanical experiences of cadmium sulphide monocrystals the effect of light influence is found out on their strong characteristic. [4].

With the purpose of discovering the aforesaid effect a number of experiments were done on study of lighting influence of cutting zone on durable cutting plates of synthetic corundum (ruby "Rose", ruby P-2) and leucosapphire at a subtle elaboration of bronze BrOCS 5-5-5 and duraluminium D16 [5,6]. Orientation of cutting plates with 6x6x6 mm sizes was conducted in such way that the position of cutting blade was very convenient from the optical axis and there were no risks, chips, scratches on the working surfaces of the cutting plates. As a source of light a projector was used with a lamp of 500 Watt power. During the elaboration of bronze BrOCS 5-5-5 and duraluminium D16 had been used correspondingly the following regimes of cutting:

If the subtle elaboration of non-ferrous metals with cutting plates of synthetic corundum and leucosapphire during the normal conditions the way length froms 210 000 up to 250 000 m, in this case the picture of cutting zone with lighting is quite different. So, during the elaboration of duraluminium D1 with cutting plates of synthetic corundum the way length is about 350 000 m and during the elaboration of the same material with the cutting plates of leucosapphire is about 260 000 m. Analogous affect is observed during the elaboration of bronze BrOCS 5-5-5 with aforesaid cutting plates. Such lengths of cutting ways can be achieved only by using diamond instruments. In this case the lighting of the cutting zone by light significantly increased the durability of cutting plates. Thereat, monocrystal color has its sufficient affect on plate durability, as its absorption ability is higher in comparison with colorless monocrystal.

4. Dislocation Displacement via Photo Plugs

Here we find an analytical definition of wear size on back surface of monocrystal cutting plate during the subtle elaboration of non-ferrous metals taking into account the lighting of cutting zone.

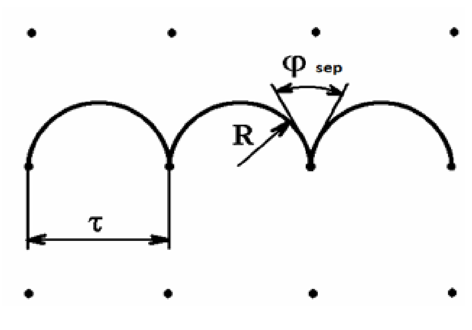

Fig.3 The scheme of the dislocation displacement via photo plugs

In the result of corundum crystal lighting there appear braking centres with corresponding plane in each sliding plane of infected dislocation. Let's consider that they are placed in the junctions of square lattice (fig. 3).

Displacement tensions τ are given with a formula, at the presence of which dislocations will overcome the centre of fixation [7].

$$\tau = \frac{w}{R_{\text{в}}} = \frac{2w}{L_{\text{в}}} \cos\frac{\varphi_{sep}}{2} = \frac{2w}{b} N_{\Phi}{}^{1/2} \cos\frac{\varphi_{sep}}{2} \qquad (1)$$

Work of friction power on back surface of cutting will be equal:

$$A = F_{fric} L = \tau s L = \tau b \delta L \qquad (2)$$

Where F_{fric} - is friction power on back surface of cutting place, L – is a friction way, $s = b\delta$ –wear part on back surface of cutting plate, τ – shearing stress on s wear part.

Let's take the work of friction power in the following form:

$$A = mP_z vt \qquad (3)$$

where P_z is the main cutting power, v - is cutting speed, t is time during of which L way is passed, m - is a part of work, spent on friction of back surface of cutting plate.

Consequently, $mP_z vt = \tau\delta Lb$, where wear size on back surface of cutting plate will be equal:

$$\delta = \frac{mP_z vt}{Lb\tau} = \frac{mP_z}{b\tau}, \qquad (4)$$

As it is already evident in works [4,7] in the result of monocrystal lighting by source of light with E lighting in each sliding plane on infected dislocations there appear braking centres, in spite of it dislocation separation from the centres under the affect of shearing stress τ takes place at some angle of separation

$$\tau = \alpha(\varphi_{sep}) n\sqrt{E} \qquad (5)$$

Where, $\alpha(\varphi_{sep})$ is a factor, depended on φ_{sep} separation angle; E is lighting; n is correction factor, experimentaly defined. So we will finally get for the back surface of cutting plate:

$$\delta = \frac{mP_z}{\alpha(\varphi) nb\sqrt{E}} \qquad (6)$$

Analysing the formula (5) we come to conclusion that according to the light increase on back surface of cutting plate the wear is decreased, which is confirmed by the given experiments [5,6]. As an elaboration by cutting plates of systematic corundum is a finishing plate, so the plates should be of high durability and stability of cutting blade.

Durability of cutting plate of systematic corundum (Ruby "Rose", ruby-2 and leucosapphire) had been investigated with lighting and as a cutting instrument had been used front single-tooth cutter, cutting plates of which were firmed mechanically and were cut obtained crystal synthetic corundum. The experiments were leaded at the following cutting regimes:

For aluminium alloys:

$$v = 280 m/\min,\ s = 0.02 mm/\min,\ t = 0.1 mm.$$

For copper alloys:

$$v = 250 m/\min,\ s = 0.02 mm/\min,\ t = 0.05 mm.$$

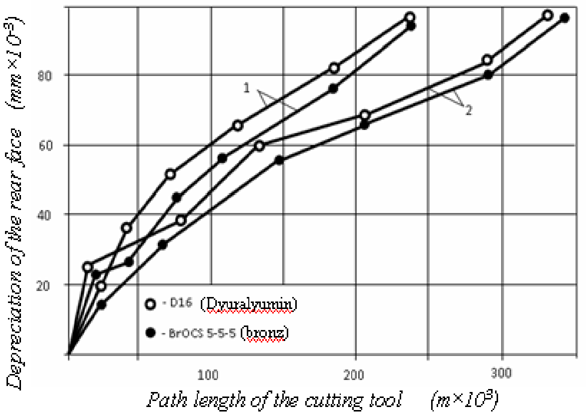

Fig. 4 The wear dependence from the cutting way length. 1-without lighting, 2-with lighting

The graphics of dependency of verge under the length of cuting way are brought forth in the fig. 4, during the elaboration of duraluminium D16 and bronze BrOCS 5-5-5.

5. Conclusions

The graphics show that (by way lighting of cutting plate wear of back verge up to 100mkm) it reaches 340,000 m, which can be provided by using diamond cutting chisels.

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