IOP Conf. Series: Materials Science and Engineering **135** (2016) 012003 doi:10.1088/1757-899X/135/1/012003

Communication research between working capacity of hard-alloy cutting tools and fractal dimension of their wear

K Arefiev, V Nesterenko, N Daneykina

National Research Tomsk Polytechnic University, Tomsk, Russia

E-mail: nest2004@ bk.ru

Abstract. The results of communication research between the wear resistance of the K applicability hard-alloy cutting tools and the fractal dimension of the wear surface, which is formed on a back side of the cutting edge when processing the materials showing high adhesive activity are presented in the paper. It has been established that the wear resistance of tested cutting tools samples increases according to a fractal dimension increase of their wear surface.

1. Introduction

To produce details and knots of nuclear reactors the steels of an austenitic class are used, usually processed with cutting tools of the K applicability groups. High working capacity of these tools can provide high standards and safety of production. Therefore, it is important to forecast wear resistance of the cutting tools at their use.

The structure of firm alloys of the K applicability group at their production and operation is exposed to saturation by various gas elements of the surrounding atmosphere [1]. The interaction intensity of firm alloy components with atoms and molecules of the gas environment is defined by the technology of their preparation, impurity existence in their composition, and the modes of composite agglomeration in general and the conditions of their operation. The covalent, ionic and hydrogen bonds are formed along with metal communication between atoms in components structure of a firm alloy. Thereof, the destruction of a hard-alloy surface contacting to the processed material, due to the intensive intermolecular interaction caused by adhesive processes will be essentially heterogeneous. At the zone of hard-alloy material wear, as a rule, there are the signs of fragile, viscous and mixed types of the destruction, arising through separation of elementary fragments of carbide and cobalt phases. Primary the character of this or that type of destruction assumes the formation of some microrelief of the wear and its fractal dimension. A preliminary radiation exposure of the hard-alloy cutting plates by gamma rays influences components interaction with gas elements appearing as a result mainly at high temperatures, and predetermines some change in the destruction nature of a surface and the microrelief formation with fractality of a bit different size in comparison with control samples.

2. Experiment technique

The research of wear resistance of the hard-alloy cutting plates of the K applicability group was carried out on a thread-cutting lathe. The steel 12X18H10T causing an intensive adhesive wear was used as the processed material. The processing was made by the hard-alloy cutting plates of the industrial BK6 brand, relating to the above specified group K. Test cutting speed was 70 m/mines and, approximately, it was an optimum one (providing the minimum intensity of wear). The speed of the longitudinal movement of a cutter – 0.23 mm/turn (I), the cutting depth – 1.5 mm. Wear resistance was estimated in minutes (T) of operating time of the cutting tool to the established criterion of a tool dulling (extent of loss of the cutting properties) – wear on a back surface of the cutting wedge equal to 0.8 mm.

The gamma ray exposure of the cutting tools was made in a special radiation unit with a fluency near of 10^{17} gamma-quant/cm^2. The morphology of a wear surface was investigated using the contactless three-dimensional MICROMEASURE 3DSTATION profile meter of the French firm STIL. Investigation of a wear surface was made by the pulse light bunch generated by a halogen lamp with a frequency of 100 Hz. This frequency provided the most accurate reproduction of a profile of wear. The sizes of ledges and hollows of a microrelief were defined from a difference of the intensity of falling and reflected light. The roughness of a profile of a surface was estimated based on the results of its measurement on the piece equal 0.5 mm. The received profiles processing was made with a special program, being a part of a profile meter. The size of fractal dimension was defined in the automatic mode, based on the obtained data on a roughness of the measured profile. Roughness control and the determination of fractal dimension were made on the wear facet located on a cutting plate back surface in its central zone. The places of diagnosing were constants for all workout cutting plates subjected to coordinate control.

3. Results and discussion

Processing of the materials causing an intensive adhesive wear is carried out, as a rule, with the K applicability group hard-alloy cutting tools, which are exposed to intensive oxidation by atoms and molecules of oxygen of the surrounding gas environment. The formed superficial oxide structures carry out a role of solid greasing when cutting and shield intermolecular interactions. They also have a great influence on process of formation of development degree of a contact surfaces roughness of a cutting tool. Processes of adsorption of oxygen and other gas elements have a great influence on formation of oxide films, their destruction because of adhesion and formation of a roughness on contact surfaces of the cutting tool. As measurements and control showed, a microrelief of a formed wear surface possesses fractal properties [2]. It is shown that the area of rough surface is not aspiring to its final limit, but increases sedately at a reduction of measurement scale. The main characteristic of fractal surfaces is their fractal dimension. The degree of development of rough structure of a wear surface - fractal dimension is closely connected with mechanochemical and electro physical properties of a surface and near-surface layer.

Fig. 1 shows dependence of time change of the cutting plates functioning on the established criterion of a tool dulling, depending on size of fractal dimension created on their facet of wear. It follows that the increase in roughness development of a wear facet, fractal dimension leads to an increase of wear resistance of cutting plates.

The initial degree of dispersion of carbide grains in structure of a firm alloy, their distribution by sizes, composition of carbide grains, structure and properties of a cobalt sheaf, structure and degree of deficiency of interphase borders, availability of impurity, sorption properties of carbide grains and the formed microrelief as well as electric and thermal properties of a surface and volume have their impact on the formed fractal dimension on a wear surface. The vacancy deficiency of the workout material structure has also its influence on the size of the formed development of microrelief, and its specific surface also. The deficiency increase promotes adsorption intensification with a wear surface of atoms and molecules of surrounding gas environment.

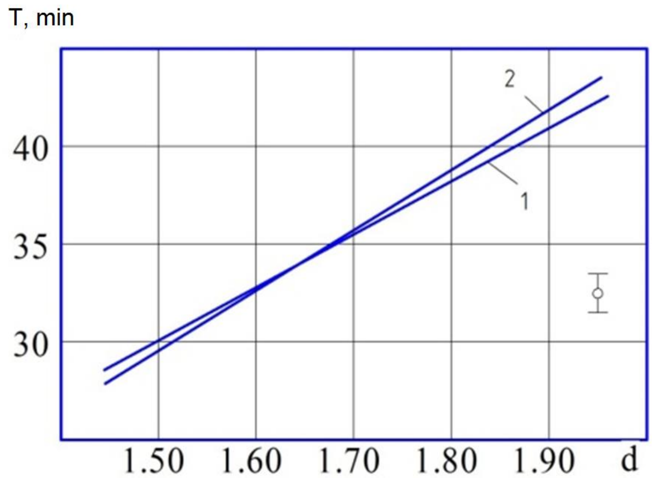

Figure 1. Change of wear resistance of the cutting plates from a firm alloy of BK8 when cutting steel 12X18H10T depending on the size of fractal dimension of a facet of wear: 1 – control plates, 2 – control plates previously processed by gamma rays.

The formation process of a surface microrelief, the wear facet of hard-alloy groups of the K applicability of the cutting plates can be compared to the process of formation of a microrelief on a surface with the phenomena of self-organization of a matter in areas of coverage of high temperatures and pressure. Self-organization process, formation of a microrelief, necessary for degree of development, assumes, in turn, adsorption of oxygen, necessary for intensity, and sufficient oxidation of contact surfaces of the cutting plate [2]. The formed oxide films thus shield processes of adhesion, transfer heat, weight and are solid greasing. Owing to realization of an order of self-regulation when machining materials increase in coefficient of friction, components of forces of cutting decline sharply in quality of the processed surface coming at higher values of the parameters of characterizing process of destruction of the cutting wedge, and the general wear resistance of the cutting tools increases.

The process of adsorption of molecules of oxygen contact surfaces of the hard-alloy cutting tools of the K applicability group consists of two stages [3]. The first stage includes physical adsorption. Its intensity is connected with extent of polarization of molecules of oxygen by a wear surface on the cutting wedge. In turn, the polarizing ability of a surface depends on development of a microrelief. With an increase in a microrelief development of a wear facet degree of the concentration of oxygen on its nominal surface wear unity increases. Under certain conditions, the physical adsorption of oxygen on surfaces transforms into a chemical one. The second stage of adsorption includes a chemical interaction of oxygen atoms with atoms of contact surfaces. As a result, chemical compounds of oxygen with carbide of tungsten and cobalt are formed on its surface. Superficial oxide film structures are formed on the basis of covalent or ionic types of communications formed between atoms.

Many internal and external factors influence the formation of a certain type of chemical bonds in oxide structures. With growth of free carbon as a part of a firm alloy, and some impurity alkaline and the alkaline earth metals (potassium, sodium, calcium), a probability of complex oxide formation compounds increases, which are formed due to interaction of several oxides [4]. In this case, superficial and near-surface structures of oxides are formed, for example, on the basis of tungsten, cobalt and other elements. The share of covalent communication between elements increases and their destruction happens in the zone of contact of the cutting and processed materials. Then formation of the increased development of a microrelief of a wear facet occurs. Oxide destruction has the subsequent disperse nature; oxide carbide particles and conglomerates of a surface also promote their more effective role as solid greasing in contact zones.

Thus, the development degree of the formed microrelief of wear platforms on contact surfaces will depend on a character of the formed chemical bonds between elements of a surface of carbide grain and oxygen, and the intensity of the fragile destruction happening in micro volumes of superficial and near-surface structure of a firm alloy. In addition, both factors, a character, and the process of formation of chemical bonds, and the subsequent destruction of the created superficial and near-surface structures are closely connected and have an essential mutual impact. A low viscosity coefficient of destruction of carbide grains has a great influence on a degradation of a surface layer and the formation of the developed microrelief, which is characterized by high fractal dimension.

It provides, on one hand, a low crack resistance of oxide and oxide carbide layers on a carbide component, and on the other- an effective branching of the formed superficial cracks.

Big ability to cracks branching, formed at destruction of near-surface structure, is provided by high degree of vacancy deficiency of a firm alloys structure. Thereof there is also a considerable concentration of vacancies, small and large pores in superficial oxide and the oxicarbide structures, which are formed on contact surfaces of the cutting tool. The main part of dot defects in oxidic and oxicarbide tungsten films is made by cationic vacancies, and in oxidic films of cobalt by anion vacancies [4]. With increase in concentration of both types of vacancies, at simultaneous decrease in their associations (small and large pores), development of a microrelief at destruction of superficial structures increases. Intensity of capture of atoms and molecules of oxygen a contact tool surface (contact happens to the processed material) increases with pressure decrease in intercontact area (space between contact surfaces). The pressure in intercontact area is lower; the capture is stronger, than the atoms get into this area and molecules of oxygen. Process of capture happens in the conditions of the high competition between various active centers - the centers of capture of a surface.

The most probable centers of capture are the following structural defects: anion vacancy in a combination with an electron in structure of an oxidic film of tungsten; cationic vacancy in a combination with a hole in structure of an oxidic film of cobalt; an impurity ion and cationic vacancy in a combination with anion vacancy in structure of oxide of tungsten; an impurity ion and anion vacancy in a combination with cationic vacancy in structure of oxide of cobalt, the atomic centers in crystals with monovalent cationic impurity; ions of one and bivalent impurity in anion vacancy in structure of oxide of tungsten, periodic process of transition of an impurity ion of a cationic sub lattice in anion and vice versa and process of deformation hashing of cationic and anion sub lattices [5]. The considered static and dynamic active centers have the lowered energy of ionization and actively interact with oxygen molecules.

Process of superficial diffusion of the captured atoms and molecules of oxygen is one of the main stages in realization of effective adsorption of oxygen. In the course of diffusion atoms and molecules of oxygen find optimum in the thermodynamic relation of situation with the purpose of formation of connection with metal.

Formation of oxides leads to decrease in superficial energy and adhesive activity in relation to the processed material. Thus, the probability of local destructions on a surface from action of adhesion decreases and, respectively, the size of fractal dimension of a microrelief is stabilized.

The size of the fractal dimension formed at a wear surface depends little on the time of cutting and significantly depends on the cutting speed temperature.

The most developed rough surface on a back side of the cutting wedge (a wear facet) is formed at some optimum temperature, corresponding to optimum speed of cutting. The development of a microrelief of a surface of wear is lower below and above the optimum temperature of operating in a contact zone on a back surface of the cutting tool, and the size of fractal dimension is less, than that which turns out at an optimum speed of cutting. At temperatures, below optimum, low development of a microrelief of a surface of wear and small size of fractal dimension are caused by insufficiently high intensity of oxidation of near-surface area of a firm alloy. It leads to the formation of oxidic films of poor quality – with insufficiently high shielding ability to resist to adhesive manifestations and to carry out lubricant function. The inefficiency of oxidic structures is a consequence of low level of their stoichiometry. The oxygen deficiency is formed owing to insignificant activity of the adsorptive processes and including their second stage.

IOP Conf. Series: Materials Science and Engineering **135** (2016) 012003 doi:10.1088/1757-899X/135/1/012003

At temperatures, (speeds) above optimum, low development of a microrelief of a wear surface and small size of fractal dimension are caused by intensive formation of oxidic films and their intensive sublimation. It occurs owing to high activity of the adsorptive processes, high speed of oxidation of a surface and high speed of evaporation of the created oxides. Both in the first and in the second cases on contact surfaces of the cutting wedge, owing to intensive adhesion the facet surface of wear which is characterized by the low size of fractal dimension is formed.

A preliminary radiation processing of the cutting plates with gamma rays changes somewhat the size of fractal dimension of a wear surface. Its influence depends probably on a condition of internal structure of firm alloys: availability of impurity in components, initial extent of internal oxidation of structure, character and degree of deficiency of components. There are some options of samples with slight increase and decrease of fractal dimension in a party of tested cutting plates in relation with samples in a control party.

4. Conclusion

It is possible to assume that radiation has its impact on the sorption processes, which in turn are generally a function of a structure condition of firm alloy components. On the basis of stated above it is possible to draw conclusions that the wear resistance of the hard-alloy cutting plates of the K applicability group is defined by of a degree of superficial and near-surface oxide and the oxicarbonic structures formed. With the increase in fractal dimension of a wear surface the duration of trouble-free functioning of the cutting plates has a tendency to growth.

References

[1] GOST 3882 – 74

[2] Roldugin V I 2008 *Fisikochimija poverchnosti* (M.: Intellekt) p 563

[3] Krilov O V 1981 *Adsorbzija i katalis na perechodnich metallach i ich ocsidach* (M.: Chimija) p 286

[4] West A 1988 *Chimija tverdogo tela* (M.: Mir) p 588

[5] Parfenovich I A 1977 *Elektronnie zentri okraski v ionnich cristallach* (Irkutsk) p 208

[6] Tretykov Yu D 1978 *Tverdofasnii reakzii* (M.: Chimija) p 359