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Integrated Surface Vacuum-Plasma Hardening of Tools from High-Alloyed Quick-Steel Steel

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Abstract: *A process has been developed for the combined surface treatment of high speed steel, which includes nitriding, surface alloying and subsequent coating. In this work, the kinetic laws of nitriding of high-speed steels of various degrees of alloying are determined, which consist in accelerating the growth of the nitrided layer during its processing in a gas plasma of a vacuum-arc discharge in comparison with traditional ion nitriding.*

Keywords: *cutting edge of the cutter, carbide segregation, powder metallurgy, abrasive tool, absorption coefficient, cutting edge parameters, tool life.*

1.INTRODUCTION

Despite the high wear resistance of cutting tools made of high-speed steels, they are still subject to wear and damage. In this case, up to 80% of failure cases occur in breakdowns, chipping and mowing of the cutting wedge. High-speed steels are made both in the classical way (casting steel into ingots, rolling and forging), and using powder metallurgy methods (spraying a stream of liquid steel with nitrogen). The quality of high speed steel is largely determined by its degree of knowledge. In case of insufficient forging of steel made by the classical method, carbide segregation is observed. In the manufacture of high-speed steels, a common mistake is to approach it as a "self-hardening steel." That is, it is enough to heat the steel and cool in air, and you can get a solid wear-resistant material. This approach absolutely does not take into account the features of high alloy tool steels. Before hardening, high-speed steels must be annealed. In poorly annealed steels, a special type of marriage is observed: a naphthalene fracture, when it has normal hardness of steel, it has increased fragility. A competent choice of the hardening temperature ensures the maximum solubility of dopants in α-iron, but does not lead to grain growth. In addition, in the process of production of hard alloys, a number of fairly common structural defects arise.

Hard alloys are produced by powder metallurgy — sintering mixtures of fine particles of chemical compounds with metal binder powder. The technology of powder metallurgy is almost perfected, but all hard alloys have one drawback — the presence of residual micro porosity. [1]

As a result of extensive experimental observations and scientific research, the features of tool damage were identified. The prevailing wear usually appears on the back or on the front surface of the tool, which is associated with cutting conditions and the properties of the tool and the processed material. [2] On the front surface, the tool wears out as follows: at a certain distance from the cutting edge, a hole is formed with a gradual increase in its size. When the back surface of the tool wears out, parallel longitudinal recesses (grooves) are formed, usually starting from the cutting edge and located along the line of action of the cutting force.

2.MAIN PART

In tool wear, the formation of grooves manifests itself most often. Depreciation on any tool surface leads to a change in cutting geometry, distortion of the cutting edge. The roughness of the machined surface increases, the dimensions of the workpiece change, the permissible indicators of cutting force and temperature are exceeded. Numerous studies in the field of metal cutting show that the main types of wear of a cutting tool are adhesive and abrasive, and they are accompanied by phenomena associated with fatigue and diffusion processes. Depending on the cutting conditions, usually one type of wear becomes predominant, although others may be realized.

The processes of tool wear during cutting have been dealt with by many scientists. Experiments show that with adhesive wear during cutting, wear occurs due to torn particles of material from the surface of the workpiece. [3]

These torn particles are transferred to the surface of the instrument and form growths on it with a sufficiently high hardness. At the same time, particles are transferred back from the tool surface to the surface of the material being processed. During cutting, the resulting growths are unstable and are continuously removed along with the material of the part, leaving recesses in the places of formation. The growths, as a rule, are formed directly at the cutting edge of the incisor, it is here that the strongest setting occurs. For a cutting tool operating at significant surface stresses, not only, and in some cases, not so high hardness of the surface layer as ductility is essential. A fragile tool is not operable under dynamic loads, and they are inevitable in real cutting processes. The spallation of particles of high hardness from a surface subjected to significant contact stresses is the process of formation of abrasives that intensively destroy the surface of the part. The abrasive wear of the cutting tool and its features have been sufficiently studied. Damage due to abrasion is manifested in the form of scratches or grooves on the working surfaces of the cutting part of the cutter. An analysis of the types of damage and their causes revealed the following features. Damage can result from the mechanical action of very solid inclusions (carbides and oxides) present in the structure of the workpiece. [4]

In the process of cutting, solid inclusions will work as an abrasive tool, penetrating into the surface of the tool and scratching it. If the hardness of the cutting part of the cutter decreases due to heat, then the origin of the scratching action increases. Of course, the size of solid inclusions and the nature of their distribution play an important role here. At the same time, damage can form in the form of scratches, grooves, elongated grooves after the action on the surface of the tool is divided, having increased hardness, runaway fragments or growths. These particles, acquired as a result of strain hardening hardness significantly higher than the hardness of the outer layers of the cutting surface of the tool, especially experiencing increased heat during cutting, also act as an abrasive. Certain contributions of the origin of adhesive and abrasive wear can be assumed to be approximately equal. In this case, the cause of adhesive wear is adhesive hardening, which occurs due to covalent, metal, ionic, and intermolecular bonds, y abrasive wear-adhesive hardening with the creation of separable scratching solid particles and scratching the cutter with inclusions in the workpiece, which are always present.

The application of tool materials with wear-resistant coatings provides an approach to solving the problem of the "ideal" tool, which has high wear resistance. A tool with a wear-resistant coating will satisfy the highest requirements for its quality, reliability and performance.

The widespread use of instrumental materials with coatings in industry allows us to solve a number of important tasks:

- a significant increase in the durability and reliability of the forming tool;
- increasing the life of the tool and increasing the productivity of the processes of forming parts;
- reduced consumption of expensive tool material and scarce elements such as Co, W, Ta, Mo for their preparation;
- increase the properties of the surface layer of the tool and the dimensional accuracy of the workpiece;
- increasing the productivity of machine tool equipment by increasing the cutting speed and feed.

The main methods of applying wear-resistant coatings, taking into account the features of the occurrence of the process of creating a coating, are divided into the following groups:

- The first group includes methods for applying coatings formed due to counteractions between gas-vapor mixtures arising by connecting the metal carrier and the second component, which serves as both a reducing agent and a carrier gas. In this case, the surface substructure of the tool material and the interdiffusion reactions between the condensate and the tool simultaneously make a great contribution to the process of coating formation;
- The second group includes a variety of PVD processes. During physical deposition of the coating, the material of the workpiece is converted to a gaseous state from the solid phase as a result of sputtering under the influence of kinetic energy of collision of material particles or as a result of evaporation due to thermal energy. The energy, distribution and particle flux density are determined by the application method, process parameters and the shape of the particle source.
- The third group includes coating methods due to the interaction of the workpiece with a high-energy plasma flow (plasma and detonation methods) or mechanical particles, however, it should be noted that such coatings are practically not used in tool production.

When processing the surface of high-speed steels, mechanical, light energy and the energy of charged particles are irreversibly converted into heat. In this case, part of the energy can be allocated to surface removal, part - is irreversibly lost in the form of heat, and part - is converted into absorbed latent energy and remains in the thin surface of the part as part of defects and structural changes that ultimately lead to hardening of the metal. The status of modified hardened surfaces is estimated by the size, sign and nature of the distribution of residual stresses, changes in the crystal structure, the range of defective components of the alloy phases, etc.

Thus, an increase in the hardness of the tool and a decrease in the coefficient of friction during cutting favorably affect the wear resistance of the tool.

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