Abstract

The motivation for undertaking research in the area of glass-crystalline binder modification with aluminoborate whiskers used in alumina abrasive tools is the growing interest in increasing the strength properties of abrasive grain bonding systems. Strengthening ceramic binders while controlling the phase boundary structure has an impact on the ultimate mechanical strength of abrasive tools.

The classic type of ceramic bond used for manufacturing grinding wheels is vitrified bond, however, due to its amorphous structure, it is characterized by low resistance to brittle fracture. In view of the above, glass-crystalline binders are increasingly used, the mechanical properties of which can be adjusted by appropriate selection of the chemical composition, allowing crystallization of finely dispersed phases with the desired properties. Attempts are also being made to introduce inclusions into the glass matrix in the form of fibers or ceramic whiskers, mainly because of their high strength and Young's modulus. The examples known from the literature of research on this type of binder modification concern only superhard tools tested under static conditions. However, the effect of this type of reinforcement of ceramic bridges on the wear mechanism and operating properties of grinding wheels has not been studied.

The dissertation presents a study of the strengthening of a selected glass-crystalline binder with aluminoborate whiskers, bonding alumina abrasive grains. Chapter one provides an introduction to the subject matter undertaken in this thesis. The second chapter provides a literature analysis of the state of the art on the structure and properties of alumina abrasive grains and ceramic binders used to bond them into an abrasive tool, the basics on the mechanics of brittle fracture and Young's modulus of porous ceramic composites, as well as a description of the wear mechanisms of abrasive grains and ceramic binders. An extensive analysis of the source texts shows that the wear mechanism of ceramic abrasive tools is determined by a number of factors, including the type of abrasive grain, the properties of the bond and the strength of attachment of the abrasive grains in the grinding wheel by the bond. The least desirable type of wear of a grinding wheel is bond bridge fracture, as this phenomenon leads to rapid volumetric wear of the tool and thus does not allow full utilization of the cutting potential of the grains of the active surface of the grinding wheel. For this reason, research work is being undertaken to increase the mechanical properties of binders, which is focused, among other things, on the intended modification of the microstructure of bridges with reinforcing crystalline phases while controlling the structure of the interfacial

boundary. An interesting but so far insufficiently explored solution is the use of ceramic whiskers as a reinforcing phase of the binder.

Based on the conclusions of the analysis of the source texts, the objectives, hypotheses, research problems and scope of the work were specified, which are included in Chapter 3. The next chapter (Chapter 4) describes the methodology of the conducted research. This chapter includes the characteristics of the materials used to manufacture the tested grinding wheels and a description of the research methods used to achieve the stated objectives of the work. The research work undertaken concerned the study of the wettability of alumina abrasive grains through the selected glass-crystalline bond, the determination of the effect of modification of the glass-crystalline bond with aluminoborate whiskers on the evolution of the microstructure of the joint zone, tensile mechanical strength and Young's modulus of alumina grinding wheels, studies of the operating properties of grinding wheels with a basic glass-crystalline bond and a bond modified with whiskers, and studies of the morphology of the active surface of grinding wheels after the grinding process.

Chapter 5 contains the results of the research and their discussion. The selected heat treatment parameters of the tested abrasive tools allowed the crystallization of the designed inclusions, both of fine-dispersed (gahnite) and aluminoborate whiskers. It was also shown that for certain percentages of the whisker precursor added to the abrasive masses, it is possible to achieve the effect of strengthening the bonding bridges, which results in different mechanical properties of the grinding wheels, tested under static and dynamic conditions. The increase in the tensile strength of tools with whiskers in the bonding bridges is the result of the activation of additional mechanisms that increase fracture energy, including those associated with the pulling of whiskers from the amorphous matrix, deflection or branching of cracks. At the same time, the effect of an increase in the value of the Young's modulus E of grinding wheels resulting from the presence of a whisker phase with a high E modulus (about 400 GPa) was confirmed. Achieving such effects made it possible to obtain an abrasive tool with a significantly reduced proportion of binder (V_s = 5.5%), whose wear character is different from that of a grinding wheel without whiskers. A smaller share of binder in the tool results into an increase in porosity while maintaining its high mechanical properties, which makes it possible to apply this type of grinding wheel in grinding processes of hard-to-machine materials, for which high-porosity grinding wheels are recommended. The final chapter of this dissertation provides a summary and conclusions, and indicates directions for further research.