Wear mechanisms of sintered polycrystalline diamond (PCD) in machining of Ti alloys characterized by advanced microscopy and spectroscopy

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Sintered polycrystalline diamond (PCD) are widely used in different applications, e.g. cutting processes, due to their outstanding properties. These properties include high thermal conductivity, highest hardness, low affinity and a sharp cutting edge and are based on chemical composition and microstructure.
The trend in cutting technology is to expand the application of PCD tools to machining of Ti alloys. To reach this goal it is vital to understand the basic interaction between the PCD material and the Ti alloy in terms of wear development. In this research work, an optimized PCD material for machining of Ti alloys was used. This PCD material consists of submicron sized diamonds and well controlled amount of Co. The cutting application was performed as longitudinal, external turning with cutting data based on statistical design experiments in combination with high pressure coolant. The PCD materials were characterized using scanning electron microscopy (SEM) imaging (Zeiss Supra 55 and Helios 650 Nanolab (FEI Company)), scanning transmission electron microscopy (STEM), electron energy loss spectroscopy (EELS) and energy dispersive X-ray spectroscopy (EDXS) (C_S-corrected Titan^3 G2 60-300 kV (FEI Company), GIF Quantum ERS (Gatan Inc.)) before and after machining. STEM imaging and EELS mapping verified the presence of graphite, amorphous carbon and curved graphite planes in the surface-near region. STEM analysis showed that graphite is present in the bulk to some extent after sintering independent of the composition and diamond grain size. However, the amount of graphite in the bulk was not markedly affected by neither the manufacturing process nor the cutting process. After machining of Ti, the diamond grains show a smooth surface and only a few monolayers at the surface of the diamond grains are transformed as verified by EELS mapping.
The role of Co promoting the wear development via phase transformation will be discussed. From the STEM imaging and analysis, it is suggested that the wear of the optimized PCD material occurs preferably at the nanoscale by phase transformation and diffusion governed by kinetics and thermodynamics and is not dominated by adhesion and attrition. However, more analysis of worn PCD tools comprising different microstructures and compositions as well as cutting data are required to understand wear mechanisms and wear development of PCD tools in machining of Ti alloys in more detail.