Residual Stresses in Cobalt-Diamond Composites

H.-A. Crostack, U. Selvadurai-Laßl

Lehrstuhl für Qualitätswesen; Universität Dortmund, Leonhard-Euler-Str. 5, 44227 Dortmund, Germany

Cobalt-diamond composites are suitable as cutting tools due to their mechanical and physical properties. During the sintering of diamond particle reinforced cobalt thermally induced stresses can be initiated. Unfavourable residual stresses reduce the lifetime of cutting tools made of such composites. Therefore the knowledge of residual stresses and their dependency on production parameters of cobalt-diamond composites is very important. This influence was investigated in the work reported here. The lateral distribution of residual stresses was of special interest.

As cobalt shows a good diamond bonding associated with a sufficient wear resistance in the case of diamond loss [1] it was chosen as matrix material. The cobalt powder used for the powder metallurgic route of composite manufacturing had particle sizes below 40 µm. The diamond particle size covers a range from 300 to 450 µm. Cobalt powder with or without diamond were pre-pressed uniaxially with a compaction pressure of 550 N/mm². The green compacts were then sintered in a vacuum furnace. Some samples were additionally hot pressed isostatically (HIP).

The residual stresses in sintered samples was analysed by means of diffraction and the sin²ψ-method [2]. Here the lattice strain analysed at different angles ψ is plotted against sin²ψ and in a linear case the slope of the line is proportional to the stress. The cobalt matrix was investigated with Fe-Kα-radiation which allows to analyse the (222)-reflection at a high 2θ angle of 142.2°. This allows a high precision at residual stress measurement using sin²ψ-methode.

The influence of diamonds on the stresses in fine cobalt matrix was investigated on different samples after vacuum sintering and after HIP with and without diamond particles. The (222)-reflection of cobalt exhibited a significant shift to a lower angle of about 0.1° [20] due to increased lattice spacing if diamonds were embedded. It is assumed that carbon penetrates into the cobalt cell. The reflections intensity in pure cobalt showed no texture. The plot of lattice spacings against sin²ψ was linear (Fig. 1a). Applying a Youngs modulus of 208 GPa and Poisson constant of 0.32 the slope corresponds to a pressure stresses of −85 ± 5 MPa. A good linearity was found at vacuum sintered samples also. Here pressure stresses of −76 ± 2 MPa exist.

Figure 3: d/sin²psi-plots of pressed, vacuum-sintered and afterwards hipped samples,
The residual stresses of cobalt-diamond composites differ from the one of pure cobalt samples produced by identical technological parameters. Adding diamond particles to the metal powder results in changes of reflection intensities and deviations of the linearity. The intensity of reflections changed strongly and point at texture or grain coarsing. Additionally the d/sin^2psi-plots of vacuum-sintered and HIP diamond-cobalt composites show a significant scatter of the lattice spacing (Fig. 1b). Both exhibited a much lower slope and pressure stress than pure cobalt. These pressure stress values indicate that during the manufacturing of all samples the compaction pressure was probably too high. The pressure stresses in the samples after vacuum sintering and after HIP were –18 ± 7 MPa and –44 ± 2 MPa, respectively.

To study the lateral distribution of residual stresses small areas around a single diamond selected by a 2 mm hole-mask of Pb were analysed first. Thus, the local stresses in the direct neighborhood of diamonds could be compared with the stress in diamond-free areas (Fig. 2). Due to the mismatch of thermal expansion coefficients between cobalt and diamond tensile stresses in diamond-cobalt-composites are expected. In the composite shown in Fig. 2 the pressure stresses (-86 ± 3 MPa) in Co-matrix is diminished by the reinforcement with diamond particles to a value of –24 ± 8 MPa.

![Fig. 2: d/sin^2 -distribution of cobalt matrix surrounding a diamond and without diamond](image)

For increasing the lifetime of such composites in cutting tools further investigation of dependence on manufacturing parameters on the residual stresses and cutting behaviour is needed.

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**References**