Process development and mechanical properties of hardmetals

Experimental investigations and numerical simulations

W. Kayser, S. Loginkin, K. Jiang, A. Kaletsch, C. Broeckmann

Institute for Materials Applications in Mechanical Engineering (IWM)
Univ.-Prof. Dr.-Ing. Christoph Broeckmann
http://www.iwm.rwth-aachen.de/

Contact
Dr.-Ing. Anke Kaletsch
E-Mail: A.Kaletsch@iwm.rwth-aachen.de
Phone: +49 241 80 96268
Cemented carbide related research and services

**Simulation of type II. residual stress:**
- EBSD-based modelling strategy
- Temperature dependent elasto-viscoplastic description of the binder
- Orthotropic elastic description of WC
- Crystal plasticity for viscoplastic description of the binder alloy

**Fatigue crack growth in hard metals:**
- Simulation of the crack path in dependence of the microstructure and tensile cyclic loads
- Qualitative prediction of “Paris-Parameters” \( \frac{da}{dN} = C \Delta K^n \)
- Calculation of \( K_{lc} \)
- Calculation of macroscopic material data using homogenization

**Manufacturing**
- Selective laser melting of cemented carbide components with furnace sintering afterwards (SLM+LPS)
- Numerical simulation of the liquid phase sintering process
- Field assisted sintering of WC-Co hardmetals

**Characterization:**
- Thermophysical properties: Dilatometry (1600°C), DSC (1400°C), deformation dilatometry under protective atmosphere (1500°C), laser flash analysis (thermal diffusivity, 1300°C)
- Porosity (mercury-porosimetry), density (helium pycnometer, classical archimedes)
- Microstructural characterization: EBSD, FIB, EDS, FESEM,STEM….
Sintering Mechanisms of WC-Co in the Field Assisted Sintering Technology (FAST)

Motivation: Enhancement of the consolidation and the material properties of WC-Co

Objective: Fundamental knowledge about the FAST procedure and the role of the electrical current
Simulation of type II residual stress in cemented carbides

EBSD

Orientation Imaging Microscopy + ABAQUS

Model

Solve the nonlinear problem

Verification

Phase averaging

Results

Phase averaging

Hydrostatic stress [MPa]

Temperature [°C]

-800 -600 -400 -200 0 200 400 600 800 1000 1200 1400 1600 1800 2000

WC hcp
Co fcc
Co hcp

WC8Co WC SIM
WC8Co Co SIM
WC8Co WC EXP RT
WC8Co WC EXP H1
WC8Co WC EXP C1
WC8Co WC EXP H2
WC8Co WC EXP C2

5000
2500
1000
500
0
-500
-1000
-1500
-2000
-2500
-3000
-3500
-4000

-σ [MPa]

25°C
Fatigue crack growth in cemented carbides

Model creation

\[ U_y = 0 \]

\[ U_x = 0 \]

Initial Crack ~2.6 μm

Loading characteristics

\[ \sigma_{ij} \]

\[ R = 0.1 \]

Qualitative prediction of fatigue crack growth rate

\[ \frac{da}{dN} (m/cycle) \]

\[ \Delta K (MPa.m^{1/2}) \]

Simulation of the crack path

2700 Cycles
Estimation of macroscopic material behavior using homogenization techniques

Homogenized macroscopic creep

\[ \varepsilon = \frac{1}{V} \int \sigma_{ij} \, dV \]

RVE + constitutive material description

Different load cases + homogenization

Homogenized macroscopic stress strain response

\[ \sigma_{ij} = \frac{1}{V} \int \varepsilon_{ij} \, dV \]

\[ \varepsilon_{ij} = \frac{1}{V} \int \varepsilon_{ij} \, dV \]