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Influence of cleanliness, carbide size and hardness on HCF strength and fatigue mechanisms in carbide-rich cold-work tool steels

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Wear-resistant tool steels with high carbide contents are essential to optimize performance and lifetimes of cutting, stamping and extrusion tools used for industrial massive cold forming applications. Tool service life is primarily constrained by wear resistance and fatigue strength. However, the complex connection between the steel manufacturing process and the fatigue strength has not yet been studied and understood profoundly. In addition, the impact of heat treatment (hardness) on fatigue performances of high vanadium alloyed tool steels has not been thoroughly investigated so far.

To investigate these influences on the High Cycle Fatigue (HCF, NG = 107) strength, rotating bending tests (RBT) were performed on AISI A11 (V10, X245VCrMo10-5-1) steel at four different, application-relevant hardness level. The raw materials were produced by three different industrial manufacturers using Hot Isostatic Pressing (HIP) of gas atomized powder with subsequent hot working (HW). The HW process and the HW degree φ were systematically changed during raw material fabrication to compare three differently hot worked conditions of the AISI A11 steel.

In accordance with prior findings by Murakami & Endo for low alloyed steels, which indicate that increasing hardness correlates with enhanced HCF strength, the results presented here show that this also holds for carbide-rich tool steels. Higher hardness can improve HCF strength and performance, but only at very high cleanliness and small carbide sizes (preventing carbide coarsening and clustering).

Noticably, it is not only the atomization process that significantly influences crack initiation and fatigue strength, but also the grain size distribution used for HIP as well as the technique (type) and degree φ used for HW. This phenomenon can be attributed to the direct manipulation and control of critical defect sizes (non-metallic inclusions or coarsened, primary vanadium carbides) within the steel microstructure.

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