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Microstructure, defects and fatigue response of high strength tool steels

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The martensitic tool steel family is tailored for different specific working environments, ranging from cold work to hot work applications demonstrating high hardness, toughness and wear resistance. Nowadays, their microstructure is continuously upgraded by either composition developments or processing techniques. Both ways introduce new types of defects making the investigation of their fatigue response of significance importance for the industry. This study presents a comprehensive comparison of four advanced tool steels in terms of their microstructure, common defects, and fatigue performance in the High Cycle Fatigue (HCF) and the Very High Cycle Fatigue (VHCF) regimes. The materials investigated belong to two categories: i) Cold work tool steels; one of medium and one of high alloying composition, and ii) Hot work tool steels, one manufactured through an ingot casting and forging route and one via additive manufacturing.

Microstructural analysis, conducted via SEM and EBSD, revealed varying levels of carbides and martensitic lath blocks sizes, which may influence both the fatigue performance and the type/size of defects present in each steel. Fatigue tests were carried out at stress ratios of R=-1 and R=0.1, using a servohydraulic machine in load control at 30 Hz frequency and an ultrasound machine in displacement control at 20 kHz frequency. The fractured surfaces were analyzed in depth via SEM.

The steel grades are compared based on their strengths, martensitic structures and defect size distributions. and the fatigue strength using probabilistic approaches and the Murakami model. Finally, failure probability curves were produced for each material. This analysis provides crucial insights into the relationship between microstructural features, defect distributions, and fatigue performance, which are essential for optimizing the design and manufacturing of martensitic tool steels, especially in the context of HCF and VHCF regimes.

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