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Effect of carbide precipitation along grain boundaries on the high-temperature service performance of 4Cr5Mo2V steel

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This study employed the electrical resistivity method to uncover the phenomenon of carbide precipitation along grain boundaries in 4Cr5Mo2V die casting die steel under specific quenching and cooling rates, and delved into the impact of this phenomenon on the high-temperature service performance. By comprehensively utilizing characterization techniques such as Scanning Electron Microscopy (SEM), X-ray Diffraction (XRD), and Transmission Electron Microscopy (TEM), this paper elucidated the precipitation patterns of carbides under different quenching processes, and established a connection between carbide precipitation along grain boundaries and the deterioration of high-temperature mechanical properties and thermal fatigue resistance. The research findings indicate that within the temperature range of 898 to 1022℃, MC-type carbides rich in V and Mo tend to precipitate along grain boundaries. As the quenching rate gradually decreases, the phenomenon of carbide precipitation along grain boundaries becomes more pronounced, exerting a significant negative influence on the resistance to temper softening and impact toughness of 4Cr5Mo2V steel. Notably, when the quenching rate is as low as 0.05 ℃/s, the hardness of the steel, after being held at 600℃ for 48 hours, decreases by 60% compared to oil-quenched samples. Furthermore, an analysis of impact fracture morphology reveals that under lower cooling conditions, the fractures exhibit reduced shear lips and diminished dimples, indicating an increase in material brittleness. Regarding thermal fatigue performance, the significant precipitation of carbides along grain boundaries accelerates the formation and propagation of thermal fatigue cracks, resulting in wider and deeper cracks, and even pronounced crazing at the macroscopic scale. During thermal fatigue cycling, the carbides precipitated along grain boundaries promote the aggregation and coarsening of M23C6-type carbides, weakening their pinning effect on dislocation movement, thereby leading to a substantial decrease in dislocation density and further compromising the thermal fatigue resistance of steel.

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