Abstract

This doctoral dissertation addresses a critical challenge in the mining and processing industries – the wear of working components in crushing machines, particularly jaw crushers, which are fundamental to the primary and secondary stages of raw material comminution. Due to high operational costs and the technological limitations of existing materials, there is a pressing need for novel material and technological solutions.

Traditionally, high-manganese steels – also known as Hadfield steels – are employed in these applications. These materials are characterized by exceptional impact toughness, a capacity for intense strain-induced hardening under high contact pressures, and a high resistance to impact wear. However, under conditions dominated by abrasive wear, where the contact pressures are insufficient to activate the full self-hardening effect, high-manganese steels can undergo accelerated degradation. An additional concern is their brittleness, associated with the formation of deleterious carbide precipitates during casting and/or heat treatment.

In response to these challenges, the present work investigates the possibility of modifying the microstructure of X120Mn12 high-manganese steel to enhance its resistance to abrasive wear while preserving or improving its impact toughness. The primary research objective was the development and verification of a two-stage heat treatment procedure involving isothermal soaking and subsequent reaustenitization. This approach aimed to deliberately trigger the particle-stimulated nucleation (PSN) mechanism of recrystallization. The central hypothesis was that such a heat treatment would successfully initiate PSN, resulting in significant microstructure refinement and, consequently, enhanced abrasive wear resistance and improved impact toughness in X120Mn12 steel used for crusher components.

A comprehensive microstructural analysis was conducted using light microscopy, scanning and transmission electron microscopy, chemical and elemental composition analysis, and diffraction techniques. Mechanical property evaluations included hardness and Charpy impact testing. Tribological assessments – crucial to this study – included abrasive wear resistance testing and analysis of wear surface morphology. Additionally, the in-situ propagation of cracks in the material was observed within the chamber of a scanning electron microscope.

The conducted research demonstrated that the two-stage heat treatment effectively initiated PSN and substantially refined the microstructure of X120Mn12 steel. The reaustenitization temperature proved to be a key parameter governing microstructure evolution, carbide spheroidization and dissolution, and the reconfiguration of the dislocation substructure. The analysis of mechanical and tribological properties confirmed that the modified microstructure positively influenced performance characteristics. The greatest increase in abrasive wear resistance was observed after reaustenitization at 950°C, which was attributed to favorable microstructural transformations driven, among others, by the PSN mechanism. Importantly, the improvement in wear resistance was accompanied by an increase in impact toughness, marking a significant achievement of this work.

The findings confirm that the controlled activation of the PSN mechanism via appropriately designed heat treatment constitutes a promising route for optimizing the properties of high-manganese steels. The developed two-stage heat treatment protocol has the potential to increase the service life of crusher working components, thereby reducing operational costs and enhancing efficiency in the mining sector.