Comprehensive Analysis of Mechanical and Thermodynamic Properties of Inconel 718 Across the Entire Compositional Range

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Abstract

This study investigates the mechanical and thermodynamic properties of Inconel 718 across its entire compositional range, providing a comprehensive understanding of its behavior under various conditions. Inconel 718, a nickel-based superalloy, is renowned for its excellent strength, corrosion resistance, and thermal stability, making it a preferred material in high-temperature and high-stress applications such as aerospace, power generation, and chemical processing. The paper explores the effects of compositional variations on critical properties, including tensile strength, hardness and fatigue performance. The influence of compositional variations on the alloy's performance characteristics has been systematically analysed. Our findings reveal significant correlations between the concentrations of key alloying elements (such as Nb, Mo, and Ti) and critical properties like yield strength, ductility, thermal stability, and phase transformation temperatures. Notably, the optimization of niobium content was found to enhance precipitation strengthening, while variations in molybdenum levels directly impacted the alloy's high-temperature oxidation resistance. Thermodynamic properties such as thermal conductivity, specific heat, and thermal expansion are analyzed to evaluate the alloy's suitability for extreme operational environments. The study employs theoretical modeling, thermodynamic simulations, and a review of experimental data to correlate compositional changes with performance metrics. The thermodynamic assessments elucidate the stability ranges of various phases, providing insights into the alloy's behavior under different thermal conditions. This comprehensive analysis not only advances the fundamental understanding of Inconel 718's material properties but also offers valuable guidelines for tailoring its composition to meet specific industrial requirements. The implications of this research extend to improving the design and longevity of components subjected to extreme environments, thereby contributing to advancements in high-performance engineering applications.

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