EXPLORING THE MECHANICAL PROPERTIES AND WEAR RESISTANCE OF TRIP/TWIP MANGANESE STEELS

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Abstract *:This article explores the impact of stacking fault energy (SFE) on induced plasticity, encompassing strain hardening, grain size hardening, solid solution hardening, and precipitation hardening in manganese steel displaying TRIP/TWIP phenomena .*

It demonstrates how TRIP and TWIP influence the mechanical and sliding wear characteristics of manganese steel, noting that TWIP enhances strength via improved plasticity .

The study highlights the significant role of microalloying elements in intermetallic precipitation, which enhances the steel's hardness and strength, *leading to improved sliding wear resistance in both lubricated and unlubricated conditions .*

Keywords: *TRIP, Transformation Induced Plasticity; TWIP, Twinning Induced Plasticity; SFE, Stacking Fault Energy; AHSS, Advanced High-Strength Steels.*

1. Introduction

Manganese steels, known for their high toughness, strength, wear resistance, and non-magnetic properties, are utilized in various applications due to their work hardening capabilities .

The focus in the automobile industry is shifting towards Advanced High-Strength Steels (AHSS) like TRIP and TWIP steels, aiming to reduce vehicle weight while enhancing strength and toughness .

While ferrite steels offer high elongation, manganese steels can achieve strengths up to 1.8GPa through Intermetallic precipitation and can improve toughness and ductility via TRIP and TWIP mechanisms .

2. Intermetallic Precipitation and Strengthening Mechanism

Intermetallic precipitation in steels is conducted after dissolving carbides and nitrides in the austenite phase to avoid reducing the number of precipitates, which would decrease strength .

Alloying elements like Nickel, Molybdenum, Niobium, Vanadium, and Tungsten can form finer precipitates, leading to better refinement of microstructures .

Larger precipitates can serve as nucleation sites for nanoprecipitation, and hot-rolling enhances mechanical properties; however, rolling at higher temperatures can lead to greater grain size and precipitate density .

3. TRIP/TWIP Steels

TWIP steels, characterized by high strain hardening, are promising candidates for applications requiring multi-phase steel with austinites .

Alloying elements like Copper, Niobium, Chromium, Nickel, Titanium, Vanadium, and Boron enhance mechanical and tribological properties; Copper increases retained austenite, while Aluminum increases SFE for the TWIP effect .

Stacking fault energy (SFE) is crucial for induced plasticity: low SFE leads to TRIP steels, intermediate SFE to TWIP steels, and high SFE to MBIP steels .

4. Mechanical Properties of TRIP/TWIP Steels

Young's modulus in TRIP/TWIP steels is temperature-dependent, decreasing as temperature drops below the Neel temperature, and carbon has less impact on Young's modulus in Fe-Mn-C steels .

Microalloying with Niobium increases yield and tensile strength but decreases elongation in Fe-25Mn-3Si-3Al steel, while increased cold reduction rolling and annealing temperature can increase nanoscale mechanical twins .

Cold rolling can significantly increase yield and ultimate tensile strength, though elongation may be restricted, and TRIP steels can achieve ultimate tensile strengths up to 1100 MPa with total elongation of 35–40% .

5. Influence of Elements on TRIP/TWIP Phenomenon

Vanadium promotes twinning activity, improving mechanical properties, and can exhibit both TRIP and TWIP phenomena with high UTS, YS, and TE when used in medium manganese steel processed via cold rolling and intercritical annealing .

Carbon and Manganese are austenite stabilizers that enhances lattice parameters and may cause severe segregation, while Silicon reduces Neel temperature and increases solid solution hardening .

Aluminium suppresses cementite precipitation, increases SFE, and delays fracture, while Niobium and Molybdenum influence peak stress due to precipitation and solid solution strengthening and can hinder grain growth .

6. Sliding Wear Assessment of Steels

Ageing treatments significantly reduced wear rate due to intermetallic precipitates, and sintered samples of high vanadium high speed steel showed optimal tribological capabilities .

TRIP phenomenon significantly improved hardness and work hardening, while thermo-mechanically processed samples possessed better wear resistance in comparison with as cast samples .

Micro alloying and heat treatments increases wear resistance and hardness of the steel, and increased austenitization temperature results in higher yield strengths and wear resistance .

7. Conclusion

Manganese steels are valued for their hardness, strength, and wear resistance, making them suitable for applications in demanding environments, with induced plasticity achieved by adjusting SFE values for TRIP, TWIP, and MBIP .

TWIP steels benefit from annealing and deformation-induced twins, and grain refining and precipitation hardening can further enhance strengthening processes .

Microalloying elements like Niobium, Molybdenum, and Vanadium significantly alter the TRIP/TWIP phenomena, leading to potentially greater sliding wear resistance due to hardness, intermetallic precipitants, and induced plasticity .

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