Trends in
Mechanical Engineering & Technology
ISSN: 2231-1793 (Online)
ISSN: 2347-9965 (Print)
Volume 14, Issue 2, 2024
DOI (Journal): 10.37591/TMET
STM JOURNALS
http://engineeringjournals.stmjournals.in/index.php/TMET/index
Review TMET

Phase Transformation of Manganese Steel: A Role of Alloying Elements

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Abstract

Low alloyed steels that are both strong and ductile are the primary focus of new material concept work due to economic considerations. One key to making good use of these materials is applying the right heat and thermo mechanical treatments. Phase transitions can be influenced by using different alloying procedures. Microstructural evolution and mechanical characteristics were investigated in relation to varying manganese, silicon, and chromium levels. Developing high-strength flat rolled steels that combine a sufficient elongation with a high tensile strength is a major focus of contemporary sheet steel research. Because the formability of most engineering materials decreases with increasing strength, it is extremely challenging to obtain a material with both high tensile strength and good elongation. Due of their impact on the microstructure and strength, the alloying elements' selection is crucial. The largest contribution of the steel composition is related to the effect of alloying elements on the microstructure, which determines most of the mechanical properties of the final product. The objective of the study is the alloying effects of Mn on the corrosion properties of low carbon steels in sulfuric acid were examined through surface analyses.

Keywords: Low carbon steel, ultrafine-grained material, martensite structure, phase transformation, manganese steel

INTRODUCTION

The high manganese steel (HMS) that was invented by Robert Hadfield in 1882 is still utilized for railroad components like crossings and rock-handling equipment due to its incredible ability to work-harden upon impact [1]. HMS is composed of Austenite, which is water-quenched in accordance with the conventional heat-treatment procedure, and it has a low hardness [2]. In contrast, when subjected to high loads, it undergoes work-hardening and becomes a known wear resistant material. Linear board is a common usage for this material. The HMS is the liner of the wet-grinding machine, therefore it takes a beating from the impact, abrasion, and corrosion of the slurry. Part of the scientific community is currently focused on studying the wear process under high load as a result of HMS [3, 4]. Improving the HMS's characteristics using second phase particles is an area of intense interest for several researchers [5-7]. Several studies have investigated the impact and abrasion characteristics of HMS under acidic conditions. Work hardening could improve wear resistance under high-load conditions, and the harden lay spring is the primary source of wear mass loss. Some lining boards used in wet-grinding machines, however, do not undergo substantial work hardening due to the low load. Presently, the lining boards function in an environment with reduced energy impact, abrasion, and corrosion. It is, hence, highly pertinent to study the HMS's impact corrosion and abrasion process under low impact energy.

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Received Date: June 21, 2024
Accepted Date: July 23, 2024
Published Date: August 21, 2024

Citation: Pravin Sharma, Vivek Patel, Adarsh Kr Singh, Amit Tiwari. Phase Transformation of Manganese Steel: A Role of Alloying Elements. Trends in Mechanical Engineering & Technology. 2024; 14(2): 15–20p.

In addition to making the metal more resistant to wear and tear and enhancing its ductility, manganese also makes the metal more tougher. One of the earliest alloys steel, manganese, was discovered in 1882 by the English metallurgist Sir Robert Abbott Hadfield. He came up with the idea of adding a high manganese percentage to molten iron to make a steel with exceptional toughness and hardness as well as other desirable properties [8]. The advancement of advanced high strength steels (AHSS) is driven by the growing demands of the automobile industry for lightweight construction and enhanced passenger safety. Medium manganese steels contain a ferritic matrix with ultrafine grains and volume fractions of retained austenite (RA) that are capable of reaching 40% vol.% in their microstructure. The chemical composition of these steels typically consists of 0.05-0.2 weight percent C and 3-10 weight percent Mn. [9]. Their ultimate tensile strengths (UTS) are greater than 800 MPa and their total elongations (TE) may reach 40%, demonstrating an exceptional blend of strength and ductility. The formation of MnS inclusions allows the elimination of toxic sulfur when Mn, one of the earth's plentiful elements, is added to steel. Because of its greater solubility in austenite compared to ferrite, manganese (Mn) stabilizes austenite in steel. The presence of MnS is said to inhibit localized corrosion in steel. Stainless steel pitting corrosion starts at MnS inclusions [10] and hydrogen transport pathways in low carbon steel [11]. It has been found that when the manganese content in stainless steel increases, the repassivation rate of the alloys in the steel decreases [12]. Additionally, although manganese is present in stainless steel at a concentration of about 6%, it does not contribute to the corrosion resistance of the material [13]. The effect of Mn on the corrosion behavior of low alloy steel in sulfuric acid has not been clearly reported and the mechanism for a small addition of Mn in steel is also not clear. Cleary [14] conducted weight loss test and the results indicated a poor corrosion resistance of low alloy steel in sulfuric acid solution when the Mn content of the steel was above 1.2%. However, the inhibitory effect of Mn ions on the hydrogen evolution reaction of iron in a sulfuric acid solution is also reported [15]. In this study, the alloying effects of Mn on the corrosion properties of low carbon steels in sulfuric acid were examined through surface analyses.

LITERATURE REVIEW

According to Ma, Y. et al. [16], batch-annealed Fe–5.7Mn–0.11C (wt.%) steel had an excellent uniform plasticity of 34% and a high tensile strength of 878 MPa. Its mixed microstructure consisted of polygonal ferrite (a) and 29 vol.% retained austenite (c). The effects of the C concentration and cooling rate on the structure and tensile characteristics of batch-annealed Fe–5Mn–(0.01–0.4)C (wt.%) steels were then investigated by Amit Tiwari et al. [17While steels with a C concentration of less than 0.1 weight percent remained insensitive to cooling rates, steels with a C content of more than 0.1 weight percent benefit from rapid cooling rates, such as those achieved by water quenching. The effects of batch-annealing temperature and Mn concentration on the microstructure and tensile features of Fe–(4–8) Mn–0.1C (wt.%) steels were investigated by Zhao, Y. et al. [18].. Increases in manganese content were associated with improvements in ductility, tensile strength, and the volume percentage of retained c. Retained volume fractions, independent of Mn concentration, improved with increasing batch-annealing temperature before falling with subsequent increases in temperature.

Recently, researchers looked at medium Mn steels (Mn content less than 7 weight percent) and C content less than 0.2 weight percent that underwent continuous annealing to determine its impact on microstructure and tensile characteristics. Steel specimens with a composition of Fe-5Mn-0.2C (wt.%) and an intercritical temperature of 650°C for 1–5 minutes demonstrated an excellent combination of ductility (20–30%) and tenacity (850–950 MPa), according to a research by Schneider, R. et al. [19]. The impact of the intercritical annealing temperature on the c stability, tensile characteristics, and yield point elongation of continuously annealed Fe-6Mn-0.05C (wt.%) steel was investigated by Han, J.; Lee et al. [20]. After being annealed at 780°C for 2 minutes, the Fe-6Mn-0.1C-3Al (wt.%) steel demonstrated a compelling combination of high tensile strength (1000 MPa) and significant uniform softness, according to Grajcar, A. et al. [21]. (30%).

The remarkable mechanical characteristics of medium manganese steels, whether annealed in batches or continuously, are due to a TRIP phenomena in the retained c, which accounts for a substantial volume proportion of 20–40%. A significant portion of the preserved c was achieved by intercritical annealing at temperatures ranging from the start (As) to the completion (Af) of the reverse transformation from a to c in a specific steel. The α phase, which is a peculiar microstructure seen in hot-rolled medium Mn steels, breaks down into the c and a phases during the intercritical annealing operation. A substantial volume proportion of retained c is observed once intercritical annealing is complete, as the reversed c becomes more stable by the partitioning of c stabilizing elements, such as Mn and C, from a to c while maintaining the annealing temperature.

A dearth of literature exists, however, on the impact of heating rate during continuous annealing on critical temperatures, kinetics, and processes of the reverse transformation as it pertains to medium manganese steels. Even though medium Mn steels may be made by adjusting the heating rate, no one has compared the stabilities of diffusionally and diffusion-less reversed c phases [22, 23]. Figure 1, discusses about sheet steel properties of steel grades.

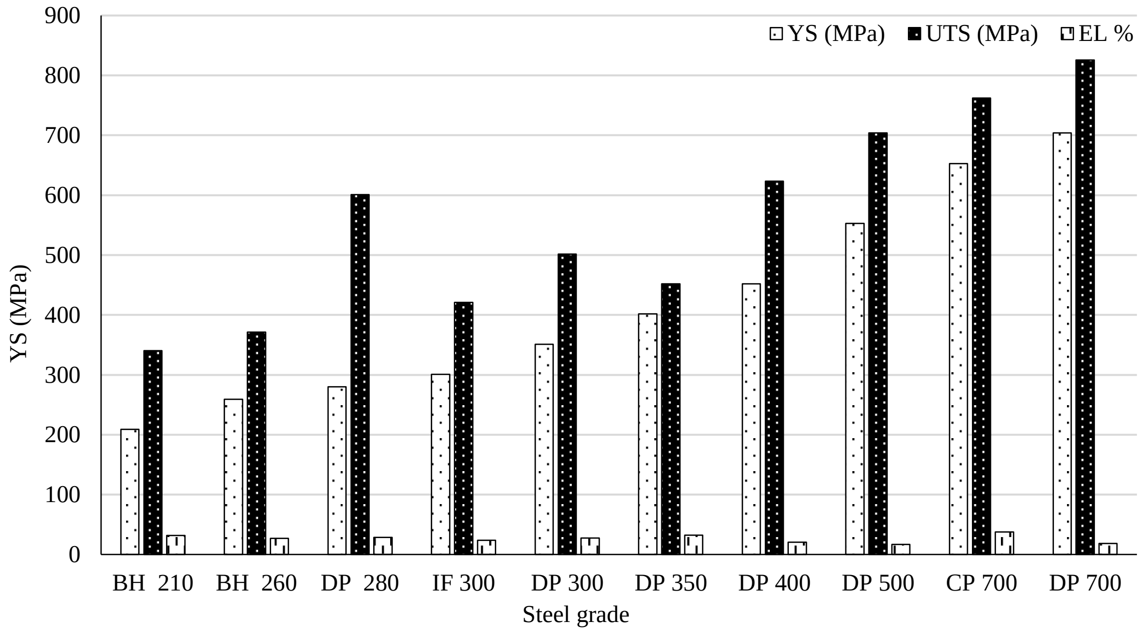

Figure 1. Sheet steel properties of steel grades.

DISCUSSION

Figure 2 shows pictures of unaltered materials under a microscope. Samples 700ND (Figure 2a-b) and 690ND (Figure 2 c-d) have microstructures that are validated by hardness data to be composed of fine martensite. Also present in the samples subjected to greater heat treatments is a portion of uniaxial ferrite (Figure 2 a-d). Ferrite fractions for samples 730ND and 778ND were determined to be 10% and 18%, respectively. Tests for microhardness have verified the existence of ferrite. An very wide range in its value is caused by ferrite, which also lowers the alloy's hardness. Due to its high ferrite content, the 700ND sample has the softest texture. Consistent with previous research, the ferrite grains are organized in bands that correspond to manganese segregation in medium-Mn steels.

After 5 hours of annealing at 700°C and 750°C, a tiny quantity of ferrite was obtained from the non-deformed samples because the ferritic transition began, but its extent was very slow. In ordinary low carbon steels with Mn < 2 wt%, the ferritic alternation typically occurs quite quickly, which should be noticed. The ferritic transition was considerably retarded when the Mn concentration was increased by 1%. Both Amit Tiwari et al. [24] and Nakada, N et al. [25] corroborate these findings. Furthermore, several papers have demonstrated that the phase change kinetics is substantially quicker in the equivalent inter-critical annealing (ferrite (martensite)!austenite, rather than austenite!ferrite), leading to a rapid accumulation of ferrite.

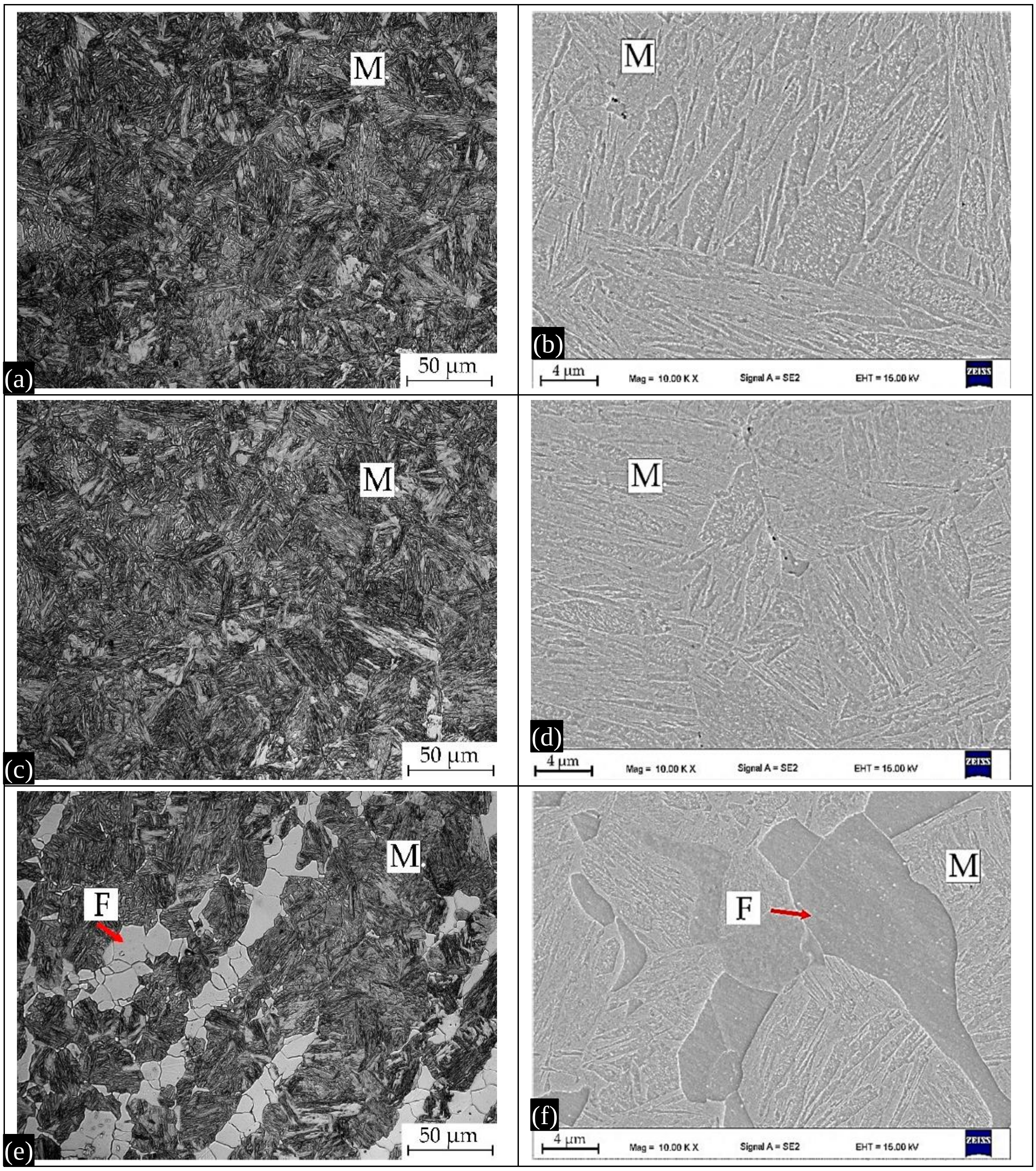

Figure 2. Light and SEM microscopic images of non-deformed samples: (a-b) sample 700ND; (c-d) sample 750ND.

CONCLUSION

This research investigates the rate of ferritic transition in lean medium-Mn steel during isothermal annealing after heat deformation in significant detail. In a ferritic matrix of 0.17C-3.1Mn-1.6Al-0.04Nb-0.22Mo-0.22Si steel, the goal was to stabilize the remaining austenite while reducing the temperature to a minimum. Thermal and mechanical treatments have been applied to the material. This study looked at medium-Mn steels that had been thermos mechanically treated and had a 1.5% Al content, specifically at the correlations between microstructure and properties. A considerable influence on the quantity and stability of preserved austenite was seen for manganese contents ranging from 3.3% to 4.7%. In the steel with a lower Mn concentration, around 17% of this phase was present initially, whereas in the 5Mn-1.5Al steel, about 11%. The addition of 0.2% Mo and medium-Mn content greatly improved the hardenability of the steel.

Funding Sources

No particular grant was given to this research by governmental, private, or nonprofit funding organizations.

Data Availability Statement (DAS)

There is not any data for this paper.

Conflicts of Interest

The authors state that none of their currently known financial conflicts or interpersonal connections could have made an impact on the work presented in this the newspaper.

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