EFFICIENT METHODS FOR OBTAINING MARTENSITIC STEELS

Atakhonova Sayyora Koraboyevna
Associate Professor, Andijan State Technical Institute
Email: ataxonova.sayyora@mail.ru.
Ozodakhon Khoshimjon qizi Jabaraliyeva.
4th-year student ozodajabaraliyeva3@gmail.com

Abstract: This article analyzes efficient methods for obtaining martensitic steels. The heat treatment processes necessary for the transformation of steel into a martensitic structure, including quenching and low tempering methods, are reviewed. Factors affecting the formation of martensite, such as chemical composition, cooling rate, and the role of alloying elements, are discussed. Recommendations are given to improve the efficiency of production processes and enhance the mechanical properties of steel.

Keywords: Martensitic steel, heat treatment, quenching, tempering, phase transformation, alloying elements, cooling rate, mechanical properties, martensite formation, crystal structure, microstructural changes, strength, hardness, temperature regime, deformation, ductility, alloy steel, steel production, heat treatment, metallurgy.

1.Introduction

Martensitic steels are widely used in mechanical and military industries, tool manufacturing, and the automotive sector due to their high hardness, wear resistance, and strength. The main feature of these steels is their martensitic phase, which forms as a result of rapid cooling from the austenitic phase. The formation of martensite helps control the mechanical properties of the metal. This paper examines efficient methods for obtaining martensitic steels, their scientific basis, and practical significance. Main Properties of Martensitic Steels. Martensitic steels contain carbon in the range of 0.2% to 1.2%. As the carbon content increases, the hardness of the steel rises, but its brittleness also increases. These steels are characterized by: High hardness and wear resistance. Strength and durability. The ability to be controlled by heat and mechanical treatment. Susceptibility to phase changes under temperature influence. Martensite formation requires heating the steel to a high temperature (austenitization) and then rapidly cooling it. During this process, the iron crystal lattice undergoes deformation, and carbon atoms become trapped in the lattice, leading to martensite formation.

2.Research and methods

This is the most common and reliable method for obtaining martensitic steels. It consists of the following stages:

Austenitization. The steel is heated to the required temperature (800-1100°C), depending on its carbon content. Higher carbon steels require higher temperatures. The heating duration depends on the steel's size and alloying elements. Rapid cooling (quenching) The steel is rapidly cooled in oil, water, or polymer solutions.The higher the cooling rate, the greater the likelihood of martensite formation.Excessive cooling increases internal stresses, so selecting the optimal cooling medium is crucial. Tempering. To reduce excessive brittleness, the steel is reheated in the range of 150-700°C. High-temperature tempering can transform martensite into bainite or ferrite-pearlite structures. Low-temperature tempering helps retain hardness while reducing brittleness. Cooling using liquid metals or solutions .Unlike conventional quenching methods, liquid metals (such as sodium or barium-based solutions) are sometimes used as cooling agents. The advantages of this method include: Fast and uniform cooling. Reduction of internal stresses in the steel.Suitability for complex-shaped parts requiring precision[2-3].

3. RESULTS AND ANALYSIS

This method involves the formation of martensite through mechanical deformation, mainly observed when austenitic steels undergo cold working.mCold rolling can induce martensite formation. Plastic deformation alters the positioning of carbon atoms, leading to martensite formation.This method is widely used in the aerospace and automotive industries. Laser and Induction Heating for Martensite Formation. Modern technologies for high-precision and localized hardness improvement include:

Laser heating – Used for local martensite formation. High-speed heating followed by rapid cooling results in a martensitic layer.

Induction heating – Uses an electromagnetic field to rapidly heat the steel surface, followed by cooling. This method is effective for large metal components. These methods offer advantages over traditional approaches: Cost-effective and fast. Lower risk of deformation. Suitable for precision applications. Carbon and nitrogen diffusion for martensite formation Sometimes, the hardness of martensitic steel surfaces is increased through carbon and nitrogen diffusion:

Nitriding – Introducing nitrogen into the steel surface to create a high-hardness layer.
Carburizing – Carbon diffusion leads to the formation of a hardened martensitic surface[4].

Carbonitriding – Simultaneous diffusion of carbon and nitrogen enhances wear resistance. Martensitic steels' high mechanical properties make them widely applicable in various industries: Tool manufacturing – Used for drill bits, knives, stamping dies, and molds. Military industry – Utilized for armor plates and specialized weaponry. Automotive industry – Employed in engine components, gears, and bearings. Aerospace and astronautics – Used for load-bearing structures and engine components[5].

Table 1. Chemical Composition of Martensitic Steel

Steel Grade	C (%)	Mn (%)	Cr (%)	Mo (%)	V (%)	Ni (%)	B (%)	Other Elements
40X13	0.36-0.45	0.60	12-14	-	-	-	-	Si, P, S
30X13	0.26-0.35	0.60	12-14	-	-	-	-	Si, P, S
20X17H2	0.16-0.22	0.80	16-18	1.50-2.00	-	-	-	Si, P, S
X17CrNi16-2	0.15-0.20	1.00	16-18	-	-	1.50-2.50	-	Si, P, S
X30CrMoN15-1	0.26-0.34	0.50-1.00	14-16	0.80-1.20	-	-	0.01-0.05	Si, P, S
431 (AISI)	0.12-0.22	1.00	15-17	-	-	1.25-2.50	-	Si, P, S

4.Conclusion

Among the efficient methods for obtaining martensitic steels are conventional heat treatment, deformation-induced martensite formation, laser and induction heating, and cooling using liquid metals or solutions. Each method has its unique advantages and is chosen based on the application and required mechanical properties. Innovations in technology continue to optimize martensite formation, opening new possibilities in metallurgy and engineering.

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