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Review Paper on Effect of Heat Treatment Procedures on Microstructure and Mechanical Properties on Nodular Iron

Yadav Rahul Kumar[1], Hemendra Patle[2], Puran Gour[3]

[1]Research Scholar Master of Technology (APS) Department of Mechanical Engineering, NIIST, Bhopal

[2]Assistant professor, Department of Mechanical Engineering, NIIST, Bhopal (M.P.)
[3]Principal, NIIST, Bhopal (M.P.)

Abstract: The heat treatment can also shed light on the superb mix of mechanical qualities that S.G. iron was able to achieve. The manufacture of Austempered Ductile Iron (ADI) is the most current advancement in this field. It offers a remarkable blend of high tensile strength, superior corrosion resistance, wear resistance, and a sizable level of flexibility. These reasons lead to the austenitization of S.G. or ductile iron when a highly advantageous combination of several qualities is needed. However, because it calls for regulated heating and isothermal material retention, this kind of treatment is a little more difficult. Therefore, it's important to identify some appealing strategies for S.G. Iron property growth. Conventional heat treatment techniques, including as annealing, normalizing, and tempering the material, have been used in the current work. A comparison has been made between the mechanical qualities obtained by different techniques. Two distinct S.G. Iron grades—one with copper and the other without—have been employed in this work. It has also been researched how the alloying element, copper, affects things.

***Keywords**:* Heat Treatment, Tensile Test, S G Iron, Aus tempered, Mechanical Properties

Introduction: Numerous heat treatment techniques exist, all of which depend on the choice of temperature, holding time, heating rate, and cooling rate. These heat treatment parameters control how elements diffuse through the material and have a significant impact on how the steel changes in characteristics. As a result, the first subchapter provides pertinent diffusion statistics for a few elements while describing the common diffusion process in steels. When creating tool steels, popular heat treatment techniques include homogenization, normalization, step annealing, stress relief, soft annealing, hardening, and tempering.

Each serves a distinct function and is regarded as an essential link in the tool steel manufacturing process. Despite the advancements made in the first half of the 1900s in the production of malleable and gray irons, foundrymen persisted in their quest for the perfect cast iron, a "gray iron" that possessed mechanical qualities that surpassed those of mellow iron. Speaking at the American Foundrymen's Society (AFS) meeting in 1943, J.W. Bolten said the following. We kindly ask for your indulgence to allow us to ask you one question.

Will gray iron truly achieve control over graphite shape? Visualization of a substance, processing (as cast) graphite flakes or clustering that resembles mellifluous iron flakes rather than lengthy flakes. For castings that are carbide as-cast, annealing—also known as full annealing—is required. The samples are kept at 900 degrees Celsius for two hours, plus an extra hour for every inch of section thickness. Cool to 700oC after that, and stay there for five hours. Lastly, cool to 480°C at a maximum pace of 110°C per hour, then let air cool

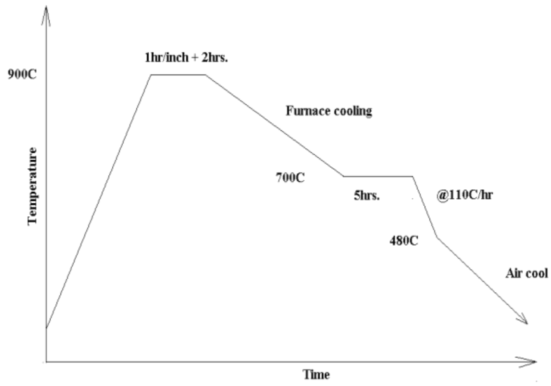

Fig 1: Annealing heat treatment

Literature Review

Wanhui Huang and Liping Lei et.al.(2023), a strategy combining intercritical quenching, pre-tempering, and tempering processes was implemented to optimize the microstructures and mechanical properties of 5CrNiMoV steel. By intercritically quenching at 1050 °C, pr-tempering at 600 °C, and tempering at 550 °C, the steel exhibited a comprehensive performance with a yield strength of 1120 MPa, an ultimate tensile strength of 1230 MPa, and an elongation of 8.2%. [1] **Madhusudan Baghel et. al. (2022)** A modified stir casting method was used to fabricate novel Al6082 composites reinforced with 0, 0.3, 0.6, 0.9, and 1.2 wt% of multiwalled carbon nanotubes (MWCNTs). A field emission scanning electron microscope was used to examine the microstructure, while elemental evaluation was performed with an energy dispersive X-ray spectrometer. MWCNTs/Al6082 composites were subjected to a heat treatment cycle (T6) to enhance their mechanical strength. Mechanical alloying and ultrasonication enhanced the wettability during fabrication resulting in the uniform distribution of MWCNTs up to 0.9 wt%.[2] **O.O. Agboola et.al (2020)** Quenching is one of the major processes of heat treatment of medium carbon steel that aims at improving its mechanical properties. However, the effectiveness of this process is dependent on several control factors that must be maximized to obtain optimum results in terms of hardness, yield strength, ultimate tensile strength among others. This study aims at optimizing the process of improving the mechanical properties of medium carbon steel by varying some key factors like the quenchant used (A), heat treatment temperature (B), and soaking time (C). The measured responses in this study were the hardness, yield strength (YS), and ultimate tensile strength (UTS). [3] **Roman kuziak et.al (2019)** The paper presents metallurgically based approach allowing the design of the parameters of the pearlitic rail head heat treatment to obtain the targeted mechanical properties. The described solutions enable predicting the progress of phase transformations, final microstructure and mechanical properties distribution in the pearlitic rail subject to heat treatment. It also allows the optimization of the cooling conditions to obtain a strictly defined distribution of mechanical properties in the rail head. The program is developed as a result of research activities performed in the HyPremRail R&D project. The core of the program consists of the phase transformations model which is implemented in the numerical code based on the FEM for heat transfer calculations.[4] **Ananda Hegde et. al (2019)** Austempered Ductile Iron (ADI) belongs to the family of cast irons whose mechanical properties are altered using austempering heat treatment process. The objective of this paper is to study the effects of heat treatment parameters on manganese alloyed ADI. Hence, austenitization temperature, austempering temperature and austempering time are taken as the control variables along with the manganese content in the material. The effects of heat treatment are studied by measuring the ultimate tensile strength and the hardness of the material. The regression equations are developed to relate the various parameters under study. [5] **Sunpreet Singh et. al. (2019)** Fused filament fabrication (FFF), an economic additive manufacturing (AM) method, is largely used for the fabrication of customized components (of medical, engineering, architectural, toy, artistic, etc. industries). However, the poor mechanical and surface properties are critical barriers limiting the growth of FFF. Therefore, a novel heat treatment approach has been utilized to improve the overall performance of printed parts. The parts were made with acrylonitrile-butadiene-styrene (ABS) with three infill densities (20, 60, and 100%) and annealing was carried out by changing the levels of temperature (105, 115, and 125 °C) and time duration (20, 25, and 30 min).[6] **MP Prabhakaran et. al. (2019)** In this investigation, laser welding process parameters have been optimized for austenitic stainless steel (AISI316) and low carbon steel (AISI1018) materials by using Taguchi based grey relational analysis. Butt joint trials were carried out using 3.5 kW diffusion-cooled slab CO_2 laser by varying laser power, welding speed, and focal distance. The optimum parameters have been derived by considering the responses such as tensile strength and microhardness. The optimal parameters are laser power 2600 W, welding speed 1.5 m/min and focal distance 20 mm. [7] **M. Araghchi et. al. (2018)** Residual stresses induced during quenching of aluminum alloys cause dimensional instability and distortion. In this study, the effects of different concentrations of polyalkylene glycol (PAG) quenchants on residual stresses and mechanical properties of 2024 aluminum alloy were investigated. Surface residual stresses were measured by using hole-drilling strain-gauge method. Also, mechanical properties and microstructure of the heat-treated samples were analyzed using hardness measurements, tensile tests, and transmission electron microscopy. Results showed that quenching into a 15% polymeric solution and aging at 190 °C for 12 h cause 50% reduction in residual stress as compared with quenching in water at 20 °C and naturally aging. Moreover, tensile strength decreased by 104 MPa (~ 20%) in compared with the T6 sample.[8] **Stefania Toschi (2018)** The aim of the present work is the study of T6 heat treatment of A354 (Al-Si-Cu-Mg) casting alloy. The heat treatment was optimized by maximizing mechanical strength of the alloy while keeping the treatment cost effective, reducing treatment time and temperature. Due to the presence of low melting compounds, a double stage solution treatment was proposed. The first stage was aimed at the homogenization and dissolution of the low melting phase while a second stage at a higher temperature was evaluated to foster dissolution of Cu/Mg rich intermetallics and keep the solution time and temperature as low as possible.[9]

Research Objectives: The objective of this work is to determine the mechanical properties and microstructure of heat-treated ductile iron with two different grades. One is with Cu and other is without Cu. After that compare these properties with different treatment conditions, the treatment conditions are mainly tempering at different temperature and austempering at constant temperature and variation of time. Mechanical properties are:

1. Tensile strength (U.T.S., 0.2% elongation),
2. % Elongation,

Then these mechanical properties are related with microstructure and fracture surfaces of the different samples after treatment

Methodology

Material selection

There were two ductile iron grades utilized. There was a distinction between these two grades: one had copper in it, while the other did not. They received the designations Grade A and B. Table 1 lists the chemical compositions of the raw materials utilized in this study that were acquired using the weight chemical analysis method

Table 1: Chemical Composition in %

All are in wt %	C	Si	Mn	Cr	Ni	Mg	Cu	S	P
Grade A	3.55	2.1	0.18	0.03	0.12	0.038	0.41	0.009	0.024
Grade B	3.57	2.22	0.23	0.03	0.42	0.045	………	0.011	0.026

Tensile Testing Machine

A tensile tester, also known as a pull tester or univeral testing machine (UTM), is an electromechanical test system that applies a tensile (pull) force to a material to determine the tensile strength and deformation behavior until break.

A typical tensile testing machine consists of a load cell, crosshead, extensometer, specimen grips, electronics and a drive system. It is controlled by testing software used to define machine and safety settings and store test parameters specified by testing standards such as ASTM and ISO. The amount of force applied to the machine and the elongation of the specimen are recorded throughout the test. Measuring the force required to stretch or elongate a material to the point of permanent deformation or break helps designers and manufacturers predict how materials will perform when implemented for their intended purpose.

Fig-2 Tensile Testing Machine

Heat Treatment

Heat treating is a process where heat is applied to a material and then cooled to improve its performance, durability, and properties. Heat treating can be used to soften metal to improve formability. It can be used to harden parts, to improve their strength. Heat treating can be defined as every process that is employed, and changes the physical properties of a material (e.g. metal) by either heating or cooling it.

Some common forms of heat treatments include:

Hardening: When a metal is hardened, it's heated to a point where the elements in the material transform into a solution. Defects in the structure are then transformed by creating a reliable solution and strengthening the metal. This increases the hardness of the metal or alloy, making it less malleable.

Annealing: This process is used on metals like copper, aluminum, silver, steel, and brass. These materials are heated to a certain temperature, are held at that temperature until transformation occurs, and then are slowly air-dried. This process softens the metal, making it more workable and less likely to fracture or crack.

Tempering: Some materials like iron-based alloys are very hard, making them brittle. Tempering can reduce brittleness and strengthen the metal. In the tempering process, the metal is heated to a temperature lower than the critical point to reduce brittleness and maintain hardness.

Case Hardening: The outside of the material is hardened while the inside remains soft. Since hardening can cause materials to become brittle, case hardening is used for materials that require flexibility while maintaining a durable wear layer.

Normalization: Similar to annealing, this process makes the steel more tough and ductile by heating the material to critical temperatures and keeping it at this temperature until transformation occurs.

Conclusion: The correlation between the microstructures and mechanical properties of Ductile Iron were studied along with their fracture surfaces for two different heat treatment processes- Quenching and Tempering; and Austempering. We also studied the effect of copper on the microstructures, mechanical properties and fracture surfaces after heat treating.

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