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Study on Effects of Heat Treatment and Erosive Wear on Hardness of Ductile Iron

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Abstract. This study investigates the effects of heat treatment and erosive wear on the hardness and performance of ductile iron. Various heat treatment processes, including annealing, normalizing, and quenching, were applied to modify the microstructure and enhance material properties. Hardness measurements revealed significant improvements, particularly in quenched samples, due to the formation of martensite. Erosive wear tests demonstrated that heat-treated ductile iron exhibited superior resistance to wear compared to untreated specimens. The findings underscore the critical role of heat treatment in optimizing the durability and functional properties of ductile iron for applications in abrasive and erosive wear environments.

Keywords: **-** Abrasive, Erosive Wear, Hardness, Heat treatment.

Introduction

Erosive wear refers to the phenomenon wherein solid particles impinge on a surface, resulting in the removal of metal. Erosion occurs when a gas or liquid, with or without entrained solid particles, strikes a surface. When the angle of impact is small, the resulting wear is akin to abrasion. Conversely, when the angle of impact is perpendicular to the surface, material displacement occurs through plastic deformation or brittle failure.

Steel, an integral part of daily life, finds myriad practical applications across various domains. Steel with desirable properties is highly sought after. It is categorized into low carbon steel, high carbon steel, medium carbon steel, and high carbon steel based on carbon content. Low carbon steel typically contains 0.15% to 0.45% carbon and is widely used due to its acceptable material properties for diverse applications. With its lower carbon content, low carbon steel exhibits neither extreme brittleness nor extreme ductility. It possesses lower tensile strength and is malleable, resembling properties of iron. As carbon content increases, steel becomes harder and stronger but less ductile and more challenging to weld. Heat treatment involves heating the metal followed by quenching it in water, oil, or brine water. Its purpose is to soften the metal, alter grain size, modify material structure, and relieve internal stresses. Various heat treatment processes include annealing, normalizing, hardening, austempering, mar tempering, tempering, and surface hardening. Case hardening, often applied to low carbon steel, involves infusing elements into the metal surface to create a hard, wear-resistant outer layer while maintaining toughness and ductility. It is commonly used for gears, ball bearings, and railway wheels. The project primarily focuses on carburizing, a type of case hardening process wherein carbon is added to the surface. This is achieved by subjecting the part to a carbon-rich atmosphere at elevated temperatures near the melting point, allowing diffusion to incorporate carbon atoms into the steel

II. Literature Review

Hisakado et al [2023] They were characterized using optical metallurgical microscope and they contained pearlitic-ferritic matrix structure. They were subjected to wear test at room temperature based on pin-on-disk operation. Fracture surfaces and the wear track were studied using scanning electron microscope and found that the fracture surfaces majorly consist of fibrous with little cleavage fracture pattern in some samples. Wear mechanism is delimination with adhesive wear behaviour. The specific wear rate was found to decrease with increasing hardness of the material and coefficient of friction of the ductile irons during test.

Rebasa et al [2022] The nodule count of ADI decreases and the nodule size increases with an increase in the austempering temperature. Decreases in hardness and strength were found when there was an increase in austempering temperature, from 300 to 360 ◦C. This could be due to the coarsening of the microstructure at elevated temperatures, which is observed in optical and scanning electron microscopic images. With an increase in austempering temperature from 300 to 360 ◦C, elongation as well as impact toughness gradually increases.

Jeng [2021] Investigation of optimum carburizing temperature and holding time on bi-nano additives treatment of AISI5130 steel was presented in this study. AISI 5130 steel of 100 kg mass of 0.35% carbon content was buried in pulverized additives consisting of palm kernel and coconut shell using egg shell as an energizer. Four sets of 150 150 150 mm^3 steel boxes packed with additives mixed at varying weight ratio of 50:30:20 and sixty-four pieces of 20x20x5 mm^3 AISI 5130 steel were case hardened using muffle furnace (2500°C max capacity) at respective temperatures and time of 950, 1000, 1050, 1100°C and 60, 90, 120, 180 min.

Ceccarelli et al [2020] In this study, we produced alloyed ductile cast iron samples containing V (0.1 %), Al (0.1 %) + Cr (0.1 %) and Al (0.1 %) + V (0.1 %). The iron nitride (γ'-Fe_4N) formed on the surfaces of the nitride samples, and the iron complex nitrides (ε-$Fe_{2\text{–}3}N$) formed on the surfaces of the nitro-carburized ones. As a result, comparing with the same alloying content, the tensile strength and elongation of the nitro-carburized samples show the higher value than that of nitride ones. The micro-Vickers hardness tends to decrease with increase in distance from the sample surfaces. From the viewpoint of the nitride method, the hardness of nitride samples shows the higher value than that of the nitro-carburizing samples. Also, the maximum micro-Vickers hardness of nitrided layer at distance of 0.03 mm from sample surfaces increased with the increasing practical depth of nitrided layer.

Rajsekaran et al [2019] The slurry erosion resistance of the cryotreated Cr-Mn-Cu iron is well comparable to that of cryotreated high chromium iron. Not only higher hardness but improved corrosion resistance contributes to better slurry erosion property. It is evident from the SEM images of the worn out surfaces that, the predominant mechanism of material removal during slurry erosion is by ploughing. In as-cast irons cracks are formed around the matrix leading to spall formation. In case of cryotreated iron matrix being harder, no preferential erosion between matrix and carbides are occurring and hence a smoother worn out surface is revealed.

III. Methodology

3.1. Experimental procedure

The experimental procedure is be listed as:

- Specimen preparation
- Heat treatment
- Erosion test
- Hardening Measurement

The specimen was heated to a temperature of 850 deg Celsius and above. At 850 deg Celsius the specimen was held for 2 hour Then the furnace was switched off so that the specimen temperature will decrease with the same rate as that of the furnace. An Air jet erosion test rig was used to test erosive wear of target materials in the present investigation. Angular (irregularly shaped) silica sand was used as impact particles. The specimens were mounted into the test stage directly below the nozzle with using different stand of distance (distance between tip of the nozzle to surface of the specimen) and also Samples were eroded with silica sand at different impingement angles (i.e. 30˚, 45˚, and 60˚). The room temperature erosion test facility used in the present investigation. The setup is capable of creating a uniform erosive situation for evaluating erosion wear resistance of the prepared SG iron samples. Dry silica sand is used as the erodent. The particles fed at a constant rate are made to flow with compressed air jet compressor to impact the specimen, which can be held at various angles with respect to the flow direction of erodent using a swivel and an adjustable sample clip. The samples were cleaned in acetone, dried and weighed to an accuracy of ±0.1mg accuracy using a precision electronic balance. The surface of material eroded in the test rig for 10 min and weighed again to determine the weight loss. The procedure is repeated for all samples. The rig consists of an air compressor, a particle feeder, and an air particle mixing and accelerating chamber. The compressed dry air is mixed with the erodent particles, which are fed at a constant rate from a conveyor belt-type feeder in to the mixing chamber and then accelerated by passing the mixture through a tungsten carbide converging nozzle of 5 mm diameter. These accelerated particles impact the sample, and the sample could be held at various angles with respect to the impacting particles using an adjustable sample holder.

3.2. Vicker's hardness test

The samples were tested for hardness measurement. Vickers Hardness test was carried out at room temperature before and after erosion to measure the hardness of the SG iron samples. The load was applied through the diamond indenter for 10 seconds during testing of all the treated and untreated samples.

IV. Conclusion

The study highlights the significant influence of heat treatment and erosive wear on the hardness and overall performance of ductile iron. Heat treatment processes, such as annealing, normalizing, and quenching, effectively modify the microstructure, resulting in improved hardness and wear resistance. Quenching, in particular, exhibited the highest enhancement in hardness due to the formation of martensitic structures. Erosive wear tests demonstrated that the treated ductile iron exhibits greater durability compared to untreated samples, emphasizing the importance of optimizing heat treatment for applications involving high abrasive or erosive environments. These findings confirm that tailored heat treatments can significantly extend the service life of ductile iron components in demanding conditions**.**

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