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Comparative Failure Analysis of Ferrous and Non-Ferrous Heat-Treated Materials

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Abstract

Heat treatment is a controlled process that uses the application of thermal energy to change the microstructure without implementing the melting process. Ferrous materials are used in improving the overall strength of the materials such as enhancing strength, ductility, and tensile strength. Heat treatment of non-ferrous alloys is usually defined as the property that determines to achieve the properties such as physical, electrical, mechanical, and magnetic.Failure aspects of the heat treatment for ferrous and non-ferrous materials might includethermal shocks during heat treatment and consideration of the contact of furnace near the walls of the container during heat operation.

Keywords: Ferrous alloys, Non-ferrous materials, Heat treatment, cooling, tensile strength

Introduction

The process of Heat treatment is used for the molding of physical and mechanical properties of the ferrous alloys. These materials consist of various alloys such as steel and cast iron and are used for hardening or softening the alloys to improve their toughness and resistance power. This involves the process of heating of alloy at a particular temperature for a fixed interval of time and cooling down quickly to get the desired shape. Heat treatment is a controlled process that uses the application of thermal energy to change the microstructure without implementing the melting process in it. The atoms in the alloy vibrate rapidly after heating and move with a zig-zag motion. This results in the conversion of new bonds with them and the reorganization in the change of structure of the material. The change in the structure of the material alters some properties of materials such as ductility, hardness, Strength, wear resistance, and a lot more.

Literature Review

Heat Treatment of Ferrous and Non-Ferrous Materials

Heat treatment process for the ferrous alloy normally takes the temperature above the critical temperature that is raised through the lower temperature value followed through the cooling process. This is done for attributing the improvement in the machinability of alloys at a certain temperature. The tempering process for the alloy is done at a temperature than the lower critical temperature and quenching of iron is used to obtain the appropriate quality through cooling (Ishak *et al.* 2020). This cooling is done through the medium of water sprinkling or oil bath.

Furthermore, Heat treatment of ferrous alloys is used for the preference of significant changes in their properties to make perfect use in the market. Heat treatment of non-ferrous alloys is usually defined as the property that determines to achieve the properties such as physical, electrical, mechanical, and magnetic. It is used in the metallurgical process for obtaining the desired form of materials after the process of heat treatment and cooling. Materials of Non-ferrous alloy consist of small crystals refered as grains that are responsible for determining the collective mechanical behavior of metal (Zhang *et al.* 2022). Heat treatment is an effective method that evaluates the properties of metals through controlling the rate of diffusion and cooling efficiency.

Heating of the metal alloy of ferrous and non-ferrous materials is done for the predetermined timing with a certain temperature. This hardening of steel includes the pre-heating at 850 degree Celsius and after that process of austenizing occurs at 1030 degree Celsius (Gussone*et al.* 2023). The last step for hardening involves quenching at 45 degrees Celsius which involves rapid cooling for acquiring their mechanical properties.

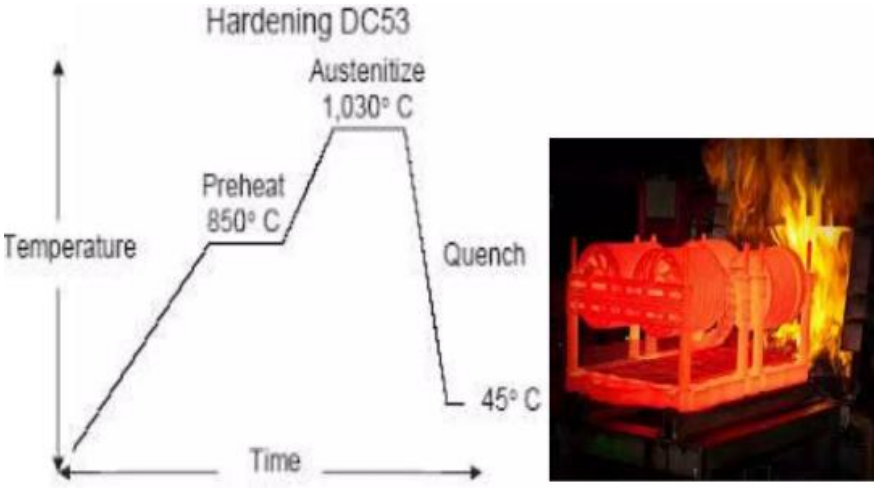

Figure 1: Heat Treatment of Ferrous and Non- Ferrous Metals

(Source:Gussone*et al.* 2023)

This helps in manipulating the properties of alloys such as tensile strength, elasticity, ductility, and a lot more. The effects of composition and with time and temperature factors also play an important role in the quenching of the alloy materials.

Importance of Ferrous and Non-Ferrous Materials

Ferrous materials are used in improving the overall strength of the materials such as enhancing strength, ductility, and tensile strength. Ferrous metals are preferred in heating treatment for the reason that possesses high iron in basic form, magnetic properties, high tensile strength, and so on. Metals of non-ferrous characteristics do not possess tensile strength, light weighted, and hold importance in electronic applications (Devaraj *et al.* 2021). The process of cooling and heat treatment also plays a major role in reforming the ferrous and non-ferrous materials' strength enhancement that enables them for wider applications (Zhao *et al.* 2022). These metals of non-ferrous are used for the pipelines in case of flexibility requirements and light weighted materials. Ferrous metals are also used in pipelines with large requirements due to their higher composition and increased tensile strength.

	Ferrous Metals	Non-Ferrous Metals
1.	Contains any amount of iron in its basic form.	Does not contains any amount of iron in its basic form.
2.	That's why they possesses magnetic property and makes them prone to corrosion.	They do not possess magnetic property, but resist corrosion much better than ferrous metals.
3.	They have a high tensile strength since they can carry a high amount of strain.	They have very low tensile strength.
4.	They have the ability for oxidation, known as corrosion. Oxidation of ferrous metals forms as a reddish-brown deposit on the surface & is oxide of iron.	They have typically lighter weights, higher melting points & are basically resistant to corrosion.
5.	Typically used when the magnetic attraction of iron may be a disadvantage. (used where strength is the primary focal point)	Ideal for electronic & electrical applications.
6.	Eg., pig iron, steel, cast iron, etc.	Eg., cobalt, aluminium, zinc, etc.

Table 1: Comparison of Importance between ferrous and non-ferrous metals

(Source: Devaraj *et al.* 2021)

This consists of various pipes with the application of ferrous and non-ferrous materials such as galvanized form and steel shapes that are used in a diverse manner. Galvanized iron pipes are used in the plumbing systems of supply and sewage signifies its benefits to provide durability, life span, and tensile strength. Non-ferrous materials are important for the manufacturing industries and their economic growth regarding production (Qu *et al.* 2019). It consists of aluminum, copper, and zinc that are used in

the sectors of engineering, automation, and construction field. The characteristics represented through it are thermal conductivity, electrical isolation, and resistance to corrosion that distinguish them from ferrous materials. This holds importance in enhancing the economy of a country and depicting the largest share through the manufacturing process. These materials also help to provide employment in the industrial and production sectors.

Methodology

This research paper uses the structured methodology for managing complex data and also helps to produce the accessible structure for failure analysis of ferrous and non-ferrous heat-treated materials. The paper also uses the idea of positivism philosophy that is used to adhere to the knowledge acquired from observation (Rajabalee and santally 2021). This is used for gaining knowledge in the analysis of the failure of ferrous and non-ferrous heat-treated materials. The qualitative approach is used in this research paper for the data collection and analyzing its various aspects. It helps in analyzing the importance of ferrous and non-ferrous materials with the development of a hypothesis according to the data analysis. The descriptive research design focuses on the information that describes the situation and condition of an issue. It helps in developing the methods to evaluate the cause of failure in heat treatment of ferrous and non-ferrous materials. The research paper uses probability sampling that helps the researcher to select resources randomly for the study of various aspects of heat treatment. Secondary resources used in this research paper are collected from Google Scholar, ProQuest, PubMed, and so on (Ramadhan and Daryati 2022). Furthermore, the paper includes the qualitative strategy of data analysis that is used for the key elements in the Heat treatment process of ferrous and non-ferrous materials.

Finding and Discussion

Effect of sample material on the Various Surfaces

The analysis and optimization of ferrous and non-ferrous materials with the completion of the CNC process bring sufficient changes. These changes in the surface roughness were found to operate on the machining conditions. High quality of milling cutters are used in the beginning which refers to the high carbon steel in comparison to low steel carbon milling cutters (Bejaxhin and Ramkumar 2021). The carbide of tungsten used carbide cutters that are relatively stronger, ductile, and possess a high rate of wear resistance. The milling cutters are used for speedy applications against ferrous and non-ferrous materials. This arises issues due to higher speed regarding rotation with the enhancement of cutting of ferrous and non-ferrous materials. Roughness with the cutting of these materials is evaluated at various

locations signifies a high impact on the middle area (Chuchala*et al.* 2021). This represents the better roughness in the middle area in comparison to the other ends.

Enhancement of speedand rateof feeding for Ferrous and Non-Ferrous Materials

The major factors are included in the surface as the rate of feeding and rotational speed. This signifies that with the increase in feed rate, roughness on the surface also get decreases. This movement of cutters for the ferrous and non-ferrous materials with the perfect speed generates fine cutting with the various slots in machines (Chen *et al.* 2021). The characteristics of the maintenance of surfaces show small sizes in cutting materials that are considered best for ferrous materials. This change in the surface from a size variation of 0.5 mm to 1 mm depth that is safe for operating ferrous and non-ferrous materials (Žagar*et al.* 2021). This represents the depth of the cut with the larger speed that can help in the improvement of surface quality in milling.

It has been found that the stress and temperature value for ferrous and non-ferrous materials indicate the effective stress and optimization of the main impact with the continuous collaboration of surface roughness. The stress and roughness value shows the minimum value that respects the properties of non-ferrous materials (Merta*et al.* 2021). This signifies the failure aspects of ferrous and non-ferrous materials with the brittle deformation, and temper embrittlement that creates causes in degradation of toughness in ferrous and non-ferrous heat-treated materials.

Heat treatment operation for ferrous and non-ferrous metals includes the various furnace equipment available, thermal shock,contact of furnace near walls of the container,treatment errors during heating process and position of furnace during quenching.This also included the elevated temperature and straightening operation for ferrous and non- ferrous metals. Hardening Tendency for the ferrous and non-ferrousmetals in the heating affected zone depends on their chemical composition and cooling rate during welding .Chromium and manganese are included in the treatment process that recommended for steel consumption a value greater than 0.18% carbon (Dewangan, *et al.* 2022).This value recommend the percentage comparison between the failure heat treatment analysis of ferrous and non-ferrous metals in terms of hardening tendency .Two problems alsocomes in the comparative analysis such as cold cracking in which the maximum hardness in 350 V. The service cracking that shows the hardness value as a chemical composition and cooling time from 800 to 500 degree Celsius(Alhuzaim*et al.* 2021).The cause of cold cracking related to many factors such as material thickness thermal efficiency and other variables.

Conclusion

From the above discussions, it has been concluded that Heat treatment process for ferrous and non-ferrous materials operate above the critical temperature that is raised through the lower temperature value followed through the cooling process. Heat treatment of non-ferrous alloys used in the determination to achieve the properties such as physical, electrical, mechanical, and magnetic. It is used in the metallurgical process for obtaining the desired form of materials after the process of heat treatment and cooling in comparison to materials of ferrous that possess tensile strength, light weighted, and hold importance in electronic applications during heat treatment. The various alloys of ferrous and non- ferrous alloy leads to possess wear resistance inthe cutting process. Failure aspects of the heat treatment for alloys are through verification of various furnace equipment available, avoid of thermal shock during heat treatment andconsidering the contact of furnace near walls of the container.The treatment errors during heating process and position of furnace of during quenching is higher in case of non- ferrous alloys is higher in comparison to ferrous alloys.

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