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Case Hardening: A Heat Treatment process for Hardness and Toughness, Necessary for Some Spare Parts Manufacture/Production

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ABSTRACT

Numerous industrial components or spare parts require a hard resistant surface, known as the case and relativity soft, tough and shock resistant inside called the core. This paper therefore runs through all the processes that are necessary in heat treating steels and alloys and finally case hardening which is required for structures of parts needed in the industries. It is the application of this heat treatment known as case hardening that we can obtain a structural member that is hard and soft, i.e. strong and tough. Hardness refers to the ability to resist wear while toughness is the ability to resist tear. Therefore a steel or alloy piece that contains these amazing qualities has its special applications in gears and cams, etc. A combination of the ability to withstand shock and serration makes this topic case hardening attractive for heat treatment of steels and alloys.

Introduction

Heat treatment is associated and involves the heat treating steels and alloys to achieve the desired working condition of a spare part. This helps in the estimation of life of an equipment or machinery. Thus, the expected life of equipment can be determined (Lilly, 2012). Heat treatment is an operation or a combination of operations, involving the process of heating and cooling of an alloy or steel in the solid state for obtaining certain desirable conditions or properties. (Khurmi and Gupta, 2009).Khurmi and Gupta (2009) also stated that the main reasons and objectives of heat treatment is to achieve improved durability, better machinability, homogenous structure, and relief from internal stress arising from hot or cold working, and also improved electrical and magnetic properties.

Heat Treatment Process

Heat treatment processes can be classified as annealing, normalizing, hardening, tempering, case hardening, surface hardening, etc.

Annealing

Annealing is primarily the process of heating a metal which is in a distorted structural state, to a temperature which will remove the instability or distortion and then cooling it, at a slow rate so that the room temperature structure is stable and strain-free (Khanna, 1998). Annealing also describes a number of different thermal treatments which are applied to metals and its alloys (Higgins, 1998). The purpose of annealing is to reduce hardness, though a number of other properties. Like stable structure, refining and harmonizing the grain structure, improved machinability, improved cold working characteristics, improved mechanical, physical, electrical and magnetic properties, as well as removal of residual stress, gas and desired micro-structure. There are 3 major process of annealing which are described below:

Stress Relieving Annealing

Khama (1998) describes stress relieving annealing as eliminating stresses produced by casting, quenching, machining, cold working, and welding. This equally applies to ferrous and non-ferrous metals. Stress relief is desirable when a casting is to change dimensions to a harmful degree during machining or use. For these stresses, if not removed may later cause failure of the casting. To relieve thermal stress, this may require heating the casting to a temperature where the relaxation of the residual elastic stress is brought by plastic deformation corresponding to the elastic strain. This may not affect the metallurgical structures. The temperature required for a stress relief of casting is from 0.3 to 0.4 of the melting point. Process Annealing (Khanna, 1998) enumerated it as the process of annealing that takes place below the lower critical temperature, which is sub-critical.

This is applied to remove the effects of cold work, to soften and permit further cold work in sheet metal and wire industries. In this process, ferrous alloys are heated to a temperature close to and below, the lower limit of transformation, usually between (550 -650)^{0C}, and held at that temperature, and then cooled in air to soften the alloy as in wire drawing (Khama, 1998). Furthermore, it is associated with only partial recrystalisation of the distorted ferrite since mild steel contains only a small volume of strained pearlite and a high degree of softening is required. Process annealing does not generally involve any phase change, and the constituents, which are ferrite and cementite, remain present in the structure throughout this process. Finally, process annealing is usually carried out in batch-type or continuous furnaces, with an inert atmosphere of burnt coal gas, and cast-iron annealing pots may be used with their lids being tined on with clay.

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Full Annealing

Also (Khama, 1998) enumerates, full annealing as thus: full annealing is annealing a ferrous alloy by austenitizing and then cooling slowly, in the furnace itself, through transformation stages. The austenitizing temperature for hypoeutoid steels is between 723^0C and 910^0C. Full annealing therefore, involves the following processes: heating the steel or alloy to a proper annealing temperature in the austenitic zone; holding the alloy or steel object at a temperature for a defined period of time, depending upon its thickness or diameter, for about (2-3) minutes per thickness so that it becomes completely austenitic; finally, cooling very slowly the alloy or steel object through the transformation range in the furnace or in any good heat insulating material, till the object acquires the desired low temperature.

As a result of the very slow cooling involved, annealing comes close to an Fe-C equilibrium diagram. Thus, the slow cooling associated with full annealing enables the austenite to decompose at a low degrees of super-cooling so as to form.

1. A pearlite + ferrite structure in hypereutectoid steels and
2. A pearlite + cementite structure in hypereutectoid steels

The full annealing removes stains, induces softness, improves machinability, also improves formability and improves electrical and magnetic properties. As enumerated by Khama, (1998), alloys and steels heat treatment are made possible by the eutectoid reaction in the iron-carbon system, as the heat treatment processes involve the transformation or decomposition of austenite. Thus, the nature and appearance of the transformation products develop a variety of useful physical and mechanical properties in steels and alloys.

Cooling rate plays an important role in the transformation of austenitic to pearlite or martenisitic etc. This is because it depends upon one element being soluble in another in the solid state in different amounts, under different circumstances. Thus, the theory for heat treatment is based on the principle that an alloy experiences change in structure when heated above a certain temperature and when it again undergoes a change in structure when cooled to room temperature. Therefore, cooling rate is an important factor in developing different (soft and hard) structures.

Stages of heat treatment processes involve these three processes:

1. Heating a metal or alloy to a definite temperature.
2. Holding and soaking at that temperature for a sufficient period of time to allow necessary changes and austenitizing to occur.
3. Cooling at a rate necessary to obtain desired properties associated with changes in the nature, form, size and distribution of micro-constituents (such as ferrite, pearlite, martensite, etc). This slow cooling from above the critical temperature in steel will produce a partite (soft) structure, while rapid cooling, depending upon steel composition, gives rise to a martenstic (hard) structure.

Normalizing

Normalizing, according to Higgins, (2004), resembles the full annealing of casting, in that the temperature attained is similar; it is only the method of cooling that the process differs. Whereas, in annealing, cooling is retarded or slowed further, while in normalizing, the steel is removed from the furnace and allowed to cool in still air. Khanna (1998), stated that normalizing or quenching in air consists in heating steel and its alloys to about $(40 - 50)^0$C above its upper critical temperatures, and holding it at that temperature for a short time and then cooling it in still air at room temperature. That type of structure obtaining by normalizing will depend largely on the thickness of cross section as this will affect the rate of cooling.

Hardening

Higgins (2004) stated that when a piece of steel containing sufficient carbon is cooled rapidly from above its upper critical temperature, it becomes harder than it would be if allowed to cool slowly. The degree of hardness produced may vary depending on such factors as the initial quenching temperatures, the size of the work and diameter, the consistent properties of quenching medium, the degree of agitation and final temperature of the quenching medium.

Khanna (1998) also enumerated that hardening is heat treatment of steel or alloys which increases its hardness by quenching. He posits that tools and machinery parts which will undergo heavy duty service are often hardened, that the hardening of steel requires the formation of martensite, that quench hardening and tempering are applicable to the treatable steels, containing carbon in excess of 0.3% and perhaps containing other alloys, and that the maximum percentages increase in steels is obtained between (0.35 and 0.60) % carbon.

Tempering

This occurs when a steel or alloy is hardened and followed by tempering. In this case, steel with sufficient carbon content of (0.35 to 0.70)% carbon is heated to $(30 \text{ to } 50)^0$C and held at that temperature from (15 to 30) minutes per 25cm of cross section. This is thus cooled rapidly or quenched in a medium of brine or oil.

Case Hardening

Khurmin and Gupta (2009) stated that it is desirable in many engineering applications to have steel being used to have a hardened surface to resist wear and tear; also at the time have a tough interior or core to be able to absorb shocks. This type of treatment is applied to gears, ball bearings, railway wheels and cams, etc. It is of note that splined shafts and worm wheels require these characteristics to function.

These processes below are the means by which case hardening can be achieved:

1. Carburizing
2. Cyaniding
3. Nitriding
4. Induction hardening
5. Flare hardening
6. Surface hardening

Carburizing

This is a method of introducing carbon into solid iron base alloys such as low carbon steels in order to produce a hard surface case, also known as cementation which thus increases the carbon content by the process of absorbance and diffusion. Thus, the basis for which this paper is presented. The processes involved heating a low carbon steel containing 0.2% carbon and lower in content with gaseous solid or liquid carbon containing substances for several hours. The high carbon steel surface obtained is hardened by quenching from the austenitic temperature, for depths of 1.27mm. Although, a low carbon steel containing carbon content up to 0.25% cannot be hardened appreciably by this hardening process. These steels are enriched in carbon on their surface before hardening and cooled by quenching.

Carburizing can be done by using the high carbon content of oxy-acetylene flame to case harden a low carbon steel. In this process, the gas flame of oxy-acetylene is operated in one of the three types of its flame, which is carburizing flame, amidst the two of oxidizing and normal flames. In this carburizing flame, more acetylene is opened up for combustion which produces sooth. The excess carbon is trapped by the low carbon steel which finally leads to case hardening being obtained. Also carburizing can be achieved by putting a machined low carbon steel in fire containing charcoal or coal where the steel absorbs the carbon, thus leading to case hardening.

Other methods of heat treatment to obtain hard surface is surfacing as a process of depositing a metal or alloy over the other to improve its wear resistant properties like resistant to abrasion, corrosion or friction (Parmer, 2003). This can be done by clapping, hard surfacing and buffering to achieve corrosion resistant and wear.

Conclusion

This paper has taken time to galvanize different types of heat treatment processes of steels and alloys and finally, dwelt on the subject case-hardening. This case hardening processing is a panacea to achieving wear resistant and though engineering component for use in our industries. Hardening as the objective of this paper is a process of making or depositing hard surface materials called the case and the core or inside the material called soft. It therefore behooves on this paper to make some recommendations.

Recommendations

After a careful study of all the process of heat treatment and case hardening in particular, this paper makes the following recommendations:

1. The need for the use of case hardening will help in easy machining and fabrication of spare parts in college workshops. This is because the low carbon steels are easy to produce for its softness is good in machining and later case hardened to make for a hard surface.
2. When breakdown occurs according to (Lilly 2012), for example, an unplanned failure of a motor bearing may cause the shaft to drop and seizing of the rotating parts. It is therefore, necessary for replacement. In an urgent situation, such spare parts can be produced and where hardening is required, it can be done by case hardening heat treatment.
3. Case hardening is also an economical way of producing necessary parts in industries by a worker. According to (Lilly, 2012), the worker interacts with his/her work place and his tools when performing a given task - in this case, his tools and means of producing some tools for industrial use.

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