STUDYING THE HEAT TREATMENT FURNACE FOR OPTIMISING THE QUALITY PARAMETERS OF HEAT TREATED STEEL BEARING

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ABSTRACT: The properties of a metal or an alloy restrict its scope of application. These properties can be varied within limits by several methods, heat treatment being one of them. In the present work we have discussed the three principal heat treatment processes: austenitising, quenching and tempering of a bearing steel. The factors affecting a heat treatment cycle for SAE 52100, a bearing steel, are discussed in this paper. This grade of steel can attain a high hardness as well as excellent wear resistance. The resulting duplex structure obtained from heat treating this steel is the optimum for bearing applications as the hard carbide particles can bear the load and the soft matrix renders a tough core. Homogeneous, single phase tempered martensite can lead to improved strength and ductility of bearings. This paper discusses the effects of heat treatment process parameters on the heat treatment cycle of a bearing steel.

Keywords: Heat Treatment, Austempering, Bearings, Austenitising, Quenching, Tempering

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INTRODUCTION:

Although heat treatment operations have strong bearing on the final product quality, heat treatment process parameters are often arrived at through empirical or trial and error methods [1]. The present work describes an engineering approach to the design of heat treatment cycles in an industrial salt bath hardening operation.

Industry accepted heat treatment processing cycles might sometimes lead to longer product development time, sub-optimal level of operation at lower process efficiency, and higher energy consumption [1]. This article elaborates on important engineering issues to be considered in salt bath hardening of bearing steel such as: selection of austenitising temperature and soaking time, selection of appropriate salt, rectification of salt, tempering cycle and quality control measures.

The heat treatment operation is an important step in the manufacturing of these bearings. Proper control during this operation is essential to obtain product with stringent dimensional control as well as high wear-resistance.

APPROACH TO DESIGN OF THE HEAT TREATMENT CYCLE:

Hardening of steel is achieved by transforming the ferrite-pearlite phases to austenite phase by heating to hardening temperature, holding at that temperature, followed by rapid cooling such as quenching. Here rapid cooling means that cooling rate is equal to or more than the upper critical cooling rate. This low temperature transformation of austenite leads to martensite which is a hard micro constituent of steel. Under standard processes, it is difficult to obtain a 100% martensitic structure. There will always be a minimal amount of retained austenite in the structure. It is desirable to transform this retained austenite to ensure complete hardness and minimize distortion during the service.

It is important to note that not all steels behave in the same way. The higher carbon steels (hypereutectoid, i.e. over 0.77% carbon) are prone to having much more retained austenite than the hypoeutectoid grades. Additionally, the section size of the job and hardenability of the steel used greatly affects the as quenched microstructure. Retained austenite will not automatically transform to martensite in low alloy hypereutectoid grades. It becomes metastable. This can be good or bad depending on its application. For example, some bearings are designed to have a certain amount of retained austenite to promote toughness. When there is a desire to force retained austenite to transform to martensite (as in the case of blades), a sub-zero quench is used and this is followed by a temper. For the low alloy steels with carbon up to about 0.50%, most of the time a single temper is sufficient to accomplish the technical goals. Some grades do require double tempering, but a triple temper is almost never required.

For complete hardening, hardening temperature should be such that homogeneous austenite with minimum grain size is produced. This is achieved by heating hypoeutectoid steel (with %C < 0.8) to 30-50 degrees above Ac_3 temperature. For hypereutectoid steel (with %C > 0.8) are heated 30-50 degrees above Ac_1 temperature. During the subsequent quenching operation, the cooling rate should be high enough to avoid transformation to softer phases like pearlite and bainite.

The important metallurgical issues in designing a hardening cycle for bearing steels are [1]:

- Selection of austenising temperature.
- Adequate soaking time for thermal homogenization of the component.

- Selection of appropriate quenching media to obtain required cooling rate.
- Cooling the component to the room temperature.
- Tempering temperature and time.

However, several other practical aspects, such as selection of salt and its neutrality maintenance, need to be addressed for successful industrial scale hardening. These issues are elaborated in the following section.

STEEL GRADE: Identification of the steel grade is the most important parameter for designing a hardening cycle. The composition falls in the AISI Type SAE 52100 grade, which falls in the group of hypereutectoid steel. These characteristics make it desirable for many bearings that are subjected to impact during use. It has a good machinability and is readily formable by forging. SAE 52100 grades respond uniformly to normal heat treatments and is widely used steel for many purposes.

SELECTION OF SALT FOR PROCESS: When selecting a salt for a given application, the following issues must be considered:

- The required heating temperature of the steel part must lie within the working range of the salt;
- The melting point should be low to avoid prolonged heat-up times for heavy loads;
- The salt must be compatible with quenching media; and
- The ease with which the salt is washed from the work-piece after heat treatment and the affinity of salt for moisture must be considered.

At present MNC-661 heat treatment salt or WNS 720 salt in the austenitising baths are used. Both these salts have a melting point of 660^0 C and recommended working ranges (820^0C to 860^0 C) and (720^0C to 900^0 C) respectively. Though the heat treatment requirements fall in these ranges, temperature fluctuations due to several reasons often lead to increase in this temperature to 950^0C. One of the important reasons for this rise in temperature is the aging of machinery. This may oxidise the salt as well as increases the possibility of oxidation and decarburization in the work-piece. Therefore, a suitable alternative has to be identified.

WNS salt is always a good option for austenitising but using it barely leads to scale formation. For a scale free heat treatment, we again need to add NaCN. If this salt is used without NaCN "ELECTRO" REGENERATOR should be used. The working range of this salt also increases to 950^0C if an economiser is added to it. But all these add to complexities in salt preparation.

However, the ETS 150 salt used in the quenching/tempering bath is a good option for the corresponding heat treatment processes. Composition: KNO3 – 55%, NaNO2 – 42%, NaNO3 - 3%, Melting point = 135^0C. Working range =

160^0C to 550^0C.

SELECTION OF AUSTENITISATION TEMPERATURE: Proper control of salt bath temperature in the austenitizing range is important, as very high bath temperatures will result into grain growth while lower temperatures will prevent the complete transformation of pearlite to austenite [1].

The time-temperature-transformation diagram for this grade is given in. The Ac1 temperature for this grade of steel is (732^0 to 743^0C), so the recommended austenitising temperature (bath temperature) for this grade of steel should be in the range of (775^0 to 845^0C). For complex shapes and larger parts, it is recommended to preheat the work-piece at around 650^0C for stress relieving prior to hardening.

As best practice, uniformity surveys should be conducted in the salt baths before charging the load at a given heat treatment temperature. These surveys are usually made by holding thermocouples in the top, centre and bottom of the bath as illustrate. The soaking time in a salt bath should be sufficient to heat the work-piece through its cross-section and enable the complete phase transformation to austenite. Longer times will result in grain growth and decarburization at the surface [1].

SALT RECTIFICATION: Neutral salts used for austenitizing steel become contaminated with soluble oxides and dissolved metals during use. As the build-up of these oxides and dissolved metals renders the bath oxidizing and decarburizing toward steel, it is necessary to periodically rectify the bath. In the case of salt bath furnaces with immersed electrodes, daily rectification of the bath is required. For the recommended barium chloride-based salts rectification should be done by adding 125 gm. of boric acid (for each 100 kg of salt) and inserting a 3-inch graphite rod for one hour for every 4 hours of operation [1].

TEMPERING: Tempering modifies the properties of quenched hardened bearing steel and renders a desirable combination of strength, hardness and toughness. This treatment lowers hardness, strength and wear resistance of the hardened steel marginally. However, this marginal loss is adequately compensated by relieving internal stresses, restoring ductility and toughness and transformation of retained austenite. In general, two or more shorter tempering cycles are recommended for complete transformation of the retained austenite and for tempering the freshly formed martensite during cool-down after the first tempering cycle. The suggested double tempering process for the SAE 52100 bearing grade steel calls for a 45 minutes treatment at 392 F (200^0 C). Tempering in this range is used when maximum hardness has to be attained. Here, the tetragonal martensite becomes cubic, and, the transitional precipitate of epsilon carbide occurs. Also the toughness shall progressively increase with the tempering temperature. This kind of steel should be tempered immediately after hardening, preferably before they reach room temperature, to prevent or minimize cracking.

EXPERIMENTAL:

Bearings of 20mm inner diameter and 15mm width (thickness ~ 3mm) were austenitized to various temperatures: 810^0C 830^0C, 850^0C, 870^0C and 885^0C for 15 minutes to dissolve the pro-eutectoid carbides in the austenite. Then they were quenched to 210^0C in a salt bath and moved to an air tank. The samples were then taken to a tank containing brine solution at 36^0C followed by tempering to 190^0C for 1 hour. After tempering the bearings were cooled to room temperature in air. The entire process was carried out on the shop-floor of an industry and slight deviations from ideal situations like time-lag between two heat treatment operations, slight air cooling while transferring bearings from one bath to another were neglected to simulate the real industrial environment.

OBSERVATIONS and DISCUSSIONS:

When heat treated in the aforementioned conventional way, we get desirable hardness and microstructure.

But literature confirms that bearings heat treated in this way may lead to failure of these specimens in a completely brittle manner with zero elongation. The low strength of some of these specimens at high hardness can probably be attributed to the completely brittle behaviour of the material, which prevents it from deforming around any micro-structural discontinuity and thus increases the effect of the imperfection. The variation in strengths of these specimens is attributed to the variation in location and amount of such discontinuities.

Discussion of austempering and some other modifications made in the heat treatment cycle of SAE 52100:

The austempering process after austenitising, involving quenching to a temperature above the point where martensitic transformation begins and below the range where high temperature transformation products are formed [2]. The quenched material is held at a constant temperature to transform austenite to lower bainite, and then cooled to room temperature. The austempering treatment lowers the amount of distortion and residual stress and gives a tougher structure as well as high hardness with high carbon content. The austempering process may be followed by sub-zero treatment to transform any austenite remaining before tempering the specimen. But executing sub-zero treatments in industries is a tedious task and so the conventional heat treatment of immersing the samples in brine water is followed.

However, following the route of austempering followed by sub-zero treatment and tempering always gives the best combination of strength and ductility, though a slight decrease in hardness occurs, which is normally compensated by the strength we achieve. If we austemper a sample from 830^0C, it may fail without yielding too, probably due to insufficient hardenability of the material when austenitized at that temperature. The lack of hardenability may have led to form upper bainite during the rapid cooling to austempering temperature. Upper bainite which is known to have poor ductility and impact strength must have avoided rendering the optimum strength and ductility [2]. As we go on increasing the temperature of austenitisation, hardenability will increase but we have to increase the holding time to complete the isothermal transformation to lower bainite. This increase in time of holding again needs to be optimised to increase the production of an industry.

REMARKS: A lot of research has been done on the heat treatment cycle of bearing steels. The process involving austempering was not accepted widely because of the wide variation in properties obtained with small variations in temperatures and operating parameters. The conventional heat treatment cycle mentioned in our experimental procedure is followed widely with slight variations in operating environments. Further researches on this topic are not carried out nowadays as there is search for some new steel which may be applied to ultra-high strength applications.

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