FACTORS THAT INFLUENCE THE STEEL HARDENING PROCESS

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Abstract: This paper is an analysis of the factors that influence the processes taking place in martensitic hardening of steels and the results of hardening. Thus, the main features highlighted are: strengthen steels, liquid cooling that occurs during hardening.

1. INTRODUCTION

In the current technologies for processing of metallic materials, heat treatments have an important place, being responsible for both technological properties and final properties of the part that is produced from the material. One of the most important is the hardening heat treatment. Over time, a large number of steels have been and diversified hardening processes appeared which, can produce high hardness and tensile strength and at the same time, as low as possible internal tensions.

Next, we will refer only to martensitic type hardening of steels, which mainly consists of: obtaining austenitic structure by heating, followed by a rapid cooling in order to obtain the martensitic structure.

2. CHARACTERISTICS OF STRENGTHENED STEELS

2.1 Basic characteristics

These characteristics are determined by the steel making process and by operations suffered during the quenching process. These are

a) C*hemical composition*, which influences decisively: the thermophysical parameters and the quenching capacity of steel. All alloying elements excepting the cobalt, decreases the thermal conductivity of the steel which includes it.

b) *Thermal effusivity* of steel and of the cooling medium. Thermal effusivity is a quantity that influences the temperature of initial contact [2], which is established in the first instant of contact of a body of temperature T1 and effusivity E1, with a cooling media of average temperature T2 and effusivity E2:

$$T_{ci} = \frac{T_1 \cdot E_1 + T_2 \cdot E_2}{E_1 + E_2} \qquad (1.1)$$

where T_{CI} is the initial contact temperature, in ° C

c) *The initial structure of steel*, which is determined by the thermal history of the part and the way the part was processed (casting, forming, etc.)..

d) *The form and dimensions of the part,* determines the distribution of mass in space and therefore will determine the thermal gradient section of the part, during cooling, affecting quench results. In the same time this parameter has direct influence on the size of internal tensions.

e) *The state of part surfaces*, refers to the size or roughness of the surface or it's chemical nature (oxides, and so on) and has a direct influence on heat exchange, part-coolant. Roughness in general has little influence on the rate of cooling, but high roughness increases the cooling speed. As far as surface oxides are concerned, to a certain thickness (hundredths of mm) lead to the growth in cooling rate, and over this thickness leads to lower cooling rate [2].

2.2 Technology parameters of quenching

Austeniting (heating) parameters. Austenitic structure obtained by heating is characterized mainly by the austenite grain size and degree of homogenization. These quntities, which have a decisive influence on the mechanical properties after quenching, are determined by the following parameters: temperature and duration of austeniting.

a) *Austeniting temperature* is chosen so as to obtain a homogeneous austenite and fine grain size. A too high austeniting temperature favors coarse grain leading to a rough martensite which is harder but fragile.

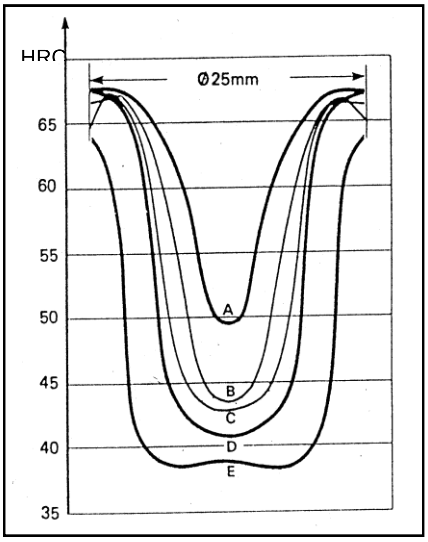

Figure 1. Influence of grain size of austenite on the hardness of steel with 0.75% C; 0.75% C, A- large grains E - average grains [3].

b) *The duration austeniting* is responsible for completion of structural transformations, austenite homogenization and of austenite grain growth which has as result, on one hand, increased hardness and hardening depth, (Figure 1), and on the other hand, the increasing fragility of tempered steel and thus, the risk of cracking. As a result, this increase is not recommended in practice for increasing of hardenability.

Cooling parameters. The cooling of austenite, in order to transform it into martensite or bainite is done using certain cooling medium at a temperature lower than the austeniting temperature. These cooling media can be: liquids, gases, solids or mixed.

Cooling of a austenited parts using a cooling liquid, is the evolution of temperature field in the part's volume during cooling. Heat exchange between part and a certain cooling liquid, can be influenced by modifying the following parameters:

a) initial temperature of the part;
b) cooling liquid temperature;
c) part-liquid relative speed (shaking);
d) concentration of the liquid - for liquid solutions.

These are the main technological parameters by which we can influence to some extent, the evolution of temperature field in the volume part and therefore the results of quenching part.

2.3 Final Features

Quenching is a heat treatment technology which has an important impact on most metal products, due to mechanical properties that are provided to them. So a heat treatment cycle specific to hardening, applied to a steel, together with structural changes and internal tensions, produces the following main effects [12, 13]:

a) **Modification of mechanical properties.** The bainitic or martensitic structure, resulting from hardening of steel, results on one hand, in increased hardness, elastic limit, tensile strength, fatigue resistance and wear resistance, and on the other hand, a decreased resilience, elongation at break and tensile shrinking.

b) **Changing of dimensions.** This is due to the difference between specific volumes of the structural constituents before and after quenching, and of internal tensions. These dimensional changes depend on a number of factors: the type of steel, hardening parameters, form and product dimensions, and so on.

c) **Forming of internal tensions.** Quenching of a part, implies the existence of cooling operation which has an evolutionary nature from the outside inwards and is accompanied by phenomena of contraction and phase transformation with changes in specific volumes. These phenomena produces internal tensions in the part, which are currently classified as: *heat stress* - caused by non simultaneous contractions of the parts sections, *structural stress* - caused both by differences in specific volumes of existing and newly formed phases and the non simultaneous occurrence of new phases in the part's section; *tensions of the crystal lattice*, which are produced in each grain, being specific for equilibrium phases obtained by a martensitic type transformation. The last of these tensions are reflected in the hardness of the phase and therefore they can be useful in certain circumstances. All these internal tensions overlap, so that the resultant tensions can lead to elastic deformation, plastic deformation or even local cracking of part material.

Some of these deformations, which remain present in the part after quenching, in turn may generate new internal tensions. These tensions, together with the structural tensions of the crystal lattice, which also are present after quenching, form the so-called residual tension.

In conclusion, at the part level, thermal stresses and structural tensions can manifest themselves through structural deformation or cracking of the part and therefore should be reduced as much as possible, and the tensions of the crystal lattice is manifested by increasing hardness, so conditions will be created for these to show up in desired parts of the work piece.

Factors that influence and determine the quenching process are presented in Table1.

Technological characteristics of a steel in relation to its ability to cool, are:

- *hardening capacity*, which is the maximum hardness that can be achieved by hardening steel (it's martensite hardness);
- *hardenability*, which is the ability to harden steel for a certain depth.