

INSTALLATION TO REALIZE THE CRYOGENIC HEAT TREATMENTS

MIRELA GHEORGHIAN, DORU CIUCESCU

Universitatea din Bacău

Abstract: The heat treatment under 0°C (273 K) is a continuation of the quenching at negative temperatures, especially at those inferior to that of the M_s point. The aim of this treatment is the complete transformation of residual austenite in martensite. It is applied to steels with carbon content greater than 0,6%C, at which the M_s point is situated between -3°C (200K) and -93°C (180K) and to alloy steels, at which the M_s point is situated between -100°C (173K) and -140°C (133K).

In the paper is described an installation for realizing the cryogenic treatments, which use an frigorific agent prepared outside-liquid nitrogen.

Keywords: residual austenite, cryogenic cooling, bearings

1. INTRODUCTION

The cryogenization of metals is known for almost 60 years ago as being an efficient method to improve the durability or of “the life of using” and to reduce the residual austenite in the tool-steels and bearing steels. The theoretical bases were put starting in 1937 by the researches of A.P.Guleaev, G.V.Kurdjumov, S.S.Steinberg, N.A.Minchevici, T. Kuruklis, M.Cohen, S. De Poy, P. Gordon etc.

The under 0°C heat treatment is a modern and efficient method which correctly applied in the chain of technological operations determines the considerable improvement in running of tools and machine organs from alloy steels or non-iron alloys.

The under 0°C (273 K) heat treatment is a continuation of the quenching at negative temperatures till the M_s point, from which derives the name of under 0°C quenching, quenching at cool or cryogenic quenching (temperatures are inferior to -150°C). It were made many researches in this field [1], [3], [5] and the results certify the opportunity to apply the under 0°C heat treatments at which the point of the end of martensitic transformation – M_f is under 0°C .

2. THE INFLUENCE OF CRYOGENIC HEAT TREATMENTS ON MARTENSITIC TRANSFORMATIONS

The aim of cryogenic treatments is the transformation as much as complete of residual austenite in martensite. They are applied to the tool-steels with a carbon content greater than 0,6%C, at which the M_f point is situated at -73°C (200K) till -93°C (180K) and at alloy steels at which the M_f point is situated between -100°C (173K) and -140°C (133K).

As much as the M_s point is at lower temperature as much the cryogenic quenching is more efficient. But, not all the tools and machine organs have to contain a more reduced residual austenite. According to the specific

working conditions it must exist and a certain toughness, therefore, consequently, a certain ratio martensite/residual austenite (gauging of residual austenite), ratio which may be established just by under 0°C quenching. The under 0°C heat treatment may be efficient if, at the environmental temperature and the classical quenching, the residual austenite is great enough (surpasses 10%). This heat treatment is imposed to the pieces at which the existence of residual austenite is non-wished because of its negative effect on the physico-mechanical and operation properties (durability, hardness, wear resistance etc) and on the dimensional stability. So, the under 0°C quenching has as effects: 1) the growing of the hardness and durability of the bearings, cutting tools, plastic deformation tools and measuring tools; 2) the growing of the hardness of the quenching and carburizing steels; 3) the growing of compression stresses to the prejudice of those of elongation in the surface layers for quenched and carburized steels with favorable effect on the fatigue resistance; 4) the important reducing of residual austenite from the surface of the quenched and grinded pieces; under the influence of the temperature which is radiated during the grinding at intensive regimes, the residual austenite may be transformed in martensite producing superficial microcracks; 5) the dimensional stabilisation of measuring tools, bearings and high precision pieces; 6) dimensional correction of tools and machine organs by a controlled transformation of residual austenite in martensite.

Usually, in industry and research there are used the following negative temperatures: 1) low temperature of -20°C for "gauging" the residual austenite in the meaning of the stabilization of bearing steels with 1,3-1,6% Cr and tool steels with 5-13% Cr undergone to a grinding at rigorous dimensions concomitant with the obtaining of a high hardness, but also of carburized and quenched steels with residual austenite under 10%. After this treatment is made immediately a tempering at 140...200°C for maintaining of a high hardness; 2) low temperatures at -70°C...-50°C to obtain a high hardness of bearing steels and for tools with 5...13% Cr, of carburized and quenched materials with residual austenite under 5%, if the operating temperature is about -20°C, of the cast irons and steels at which is imposed a satisfactory impact resistance at -40° C which work at low temperatures for long time. After this treatment is made a tempering at more than 140°C; 3) low temperatures of -120°C till the cryogenic temperatures of -196°C are used for bearings, especially in researches, but also in industry to stabilize dimensionally the carburized pieces in aeronautics and to recover small dimensions after grinding.

The heat treatments at low and cryogenic temperatures is a method which offers many advantages and may be applied to quenched cast irons and steels and may conduct at the improving of the properties of treated materials. The transformation of residual austenite in martensite may be realized either by a tempering at temperatures above 200°C applied after a classical quenching, or by applying of a under 0°C heat treatment

The variants of applying the low and cryogenic temperatures treatments are given in the figure 1 [2]. It is to be mentioned that the variants presented in this figure are covering for the indications from the literature. The heating for quenching may be done in maximum productivity conditions and according to the thermo-physical characteristics (especially the thermic conductivity) of the steel. The residual austenite varies quantitatively with the temperature of the cooling medium after an exponential curve, so it will be never to zero in the quenched steels.

The presense of austenite in the quenched steels is conditioned by the following factors: chemical composition, heating temperature, cooling ratio, positioning of the points M_s and M_f etc. The growing of the quantity of the residual austenite is influenced by the carbon content more than 0,55%.

The quantity increase of alloy elements in austenite implies also the increase of residual austenite by the fact that the majority of alloy elements decrease the M_s and M_f points and, in this way, it is increasing the stability of austenite.

If the heating temperature is greater, the degree of alloying of the austenite is also greater by dissolving in austenite of a great quantity of carbides and the quantity of residual austenite will be greater. The increase of the heating temperature influences the quantity of residual austenite and the important decrease of the M_s and M_f points. The increase of the heating ratio determines after the normal quenching the decrease of the quantity of the residual austenite by realizing a smaller degree of alloying of the austenite and the obtaining of a finer grain, which favours a fuller transformation of the austenite in martensite.

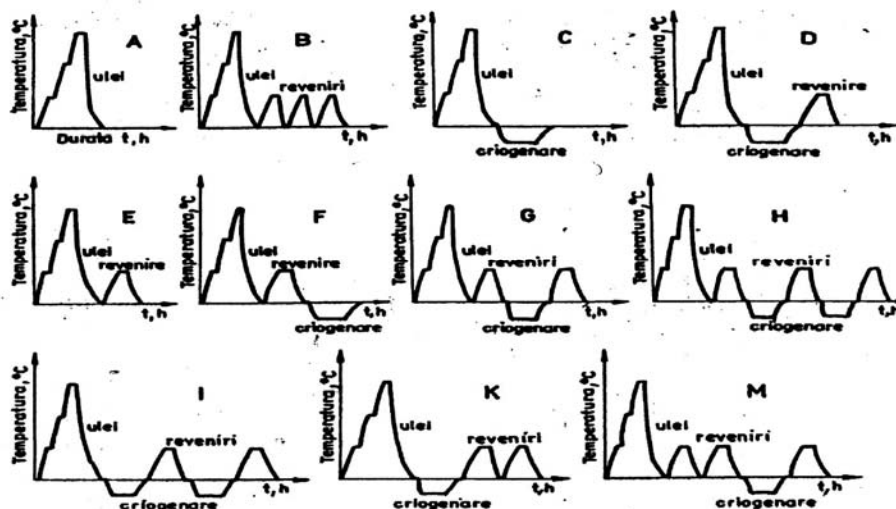


Fig. 1. The variants of applying of the cryogenic treatment at high speed steels [2].

The maintaining time between the classical and cryogenic quenching conducts to the stabilization of the austenite. So, for a 90% transformation of the austenite is necessary a decrease of the temperature till -50°C , if the cooling is made immediately after quenching. At a 30 minutes maintaining at the ambient temperature for the same degree of transformation, it is necessary a temperature of -100°C , but after one hour of maintaining at 20°C , the temperature must decrease at -190°C . The cooling diagram under 0°C is presented in figure 2.

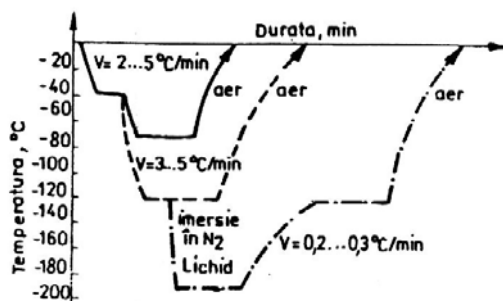


Fig.2. The cyclogram of the cryogenic treatment in the field of $200^{\circ}\text{C} \dots 0^{\circ}\text{C}$

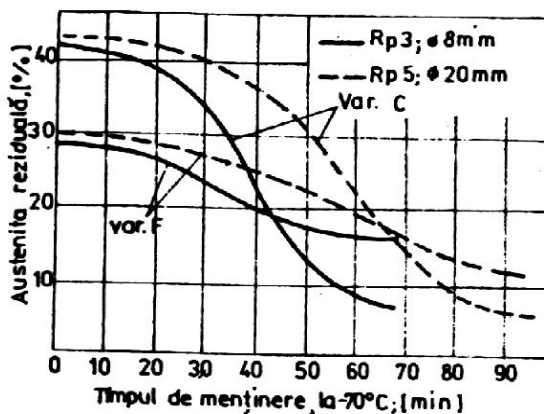


Fig. 3. The maintaining time at the cryogenic temperature of -70°C for high speed steels

As it may observe in the figure 2, the cooling in the cryogenic field may be made directed with maintaining steps in the aim of uniforming the temperature in the volume of the steel and of avoiding the crick danger, even if the level of cooling is little (in change, the immobility of atoms is increased) [2].

The maintaining time at under 0°C has not a great importance on the results of the heat treatment; it must only to ensure the uniforming of the temperature in all volume of the steel. However, the maintaining times at the final temperature are about 60...90 min according to the dimensions of the pieces in order to uniforme the temperature in the volume of the pieces. The researches made in high speed steels has shown that in the maintaining time takes place a decrease of the quantity of residual austenite. Long maintaining times at -70°C conduct to the

decrease of the thermal productivity without the contribution to the reducing of the quantity of the residual austenite. The heating of the steels at the environmental temperature after the cooling and the maintaining under 0°C is made in still air. The tempering applied after the cryogenic treatment has the role of destressing and of dimensional stabilizing and is done at temperatures which realize maximum hardnesses.

3. THE WORKSHOP CRYOSTAT

The workshop described and realized in the frame of this paper has the principle scheme in the figure 4. The operating principle is the realizing of the negative temperature and the keeping constant of this temperature a certain time by vaporization of the agent from the feeding tank. The cryostat uses the agent prepared outside, respectively liquid nitrogen and has the possibility to decrease the temperature till -150°C. This installation is included in the category of absorption installations.

The feeding tank 1 contains liquid nitrogen, in which is immersed a thermo-resistor 2 which will heat the liquid nitrogen and will allow its vaporization. At the interface liquid-vapour appears a pressure which push the liquid nitrogen through the transfer tube 4. Because the exceeding pressure from the feeding tank, the liquid nitrogen is pushed through the transfer tube in the coil in the working room. The circulation of the nitrogen from the feeding tank through the working room is favoredized by the effect of thermo-siphon created by the electrical heater. The pressure of the freezing agent is indicated by the manometer 4.

To avoid the appearing of a dangerous pressure in inside of nitrogen tank, on the circuit of working fluid is placed a safety valve 5, those the discharge pressure may be adjusted by a taring screw. By the transfer tube circulates a mixture of liquid – vapour nitrogen in which the percentage of liquid phase is determinant in the stabilized regime. In the vaporizer takes place the complete vaporization of nitrogen and the heating of vapours due to the absorbed heat from the working room. The steel samples are introduced in the working room and the inside atmosphere is cooled in the same time with the immersed pieces.

The vapours pass through the electromagnetic valve and are drained by the connection of hot vapours. The temperature regulating is made by an electronic thermostat at which the temperature traducer is a resistor Pt 100 introduced in the working room. The working temperature is programmed by a thermostat and is maintained constant with a $\pm 2^\circ\text{C}$ precision. As long as the working temperature is not yet achieved, the electromagnetic valve remains open. In th same time the liquid nitrogen circulates permanently through the vaporiser. If the working temperature is reached surpassed, the thermostat commands the decoupling of the electromagnetic valve which prevents the access of the liquid nitrogen through the vaporiser. At the increase of the temperature in the thermostating recipient, it is opening once again the electromagnetic valve and resumes the circulation of liquid nitrogen through the vaporiser. In the period when the circulation of the nitrogen is stopped, the overpression is drained through the safety valve 5.

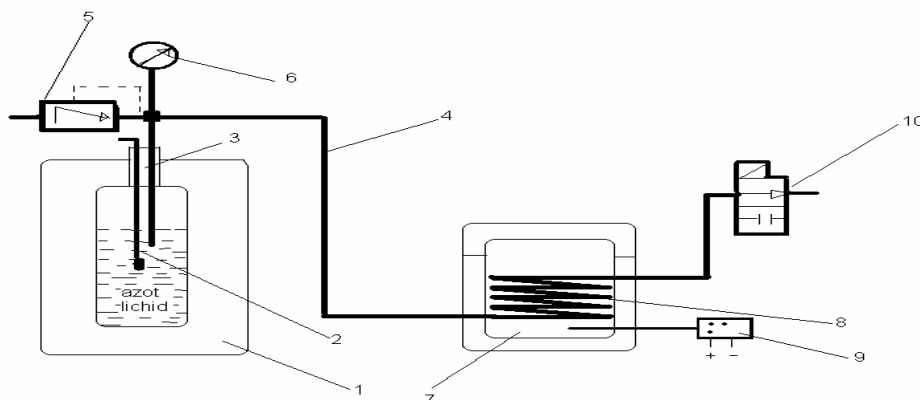


Fig.4. The principle scheme of the workshop cryostat

- 1 – liquid nitrogen tank; 2 – heating resistor; 3 – tank plug; 4 – transfer tube; 5 – safety valve;
6 – manometer 0-25 MPa; 7 – working room; 8 – vaporiser (coil), 9 – temperature sensor (PT 100);
10 – electromagnetical valve EV 3.

A general view of the cryostat is given in the figure 5.



Fig.5. A general view of the workshop cryostat

The electrical scheme of the cryostat is given in figure 6.

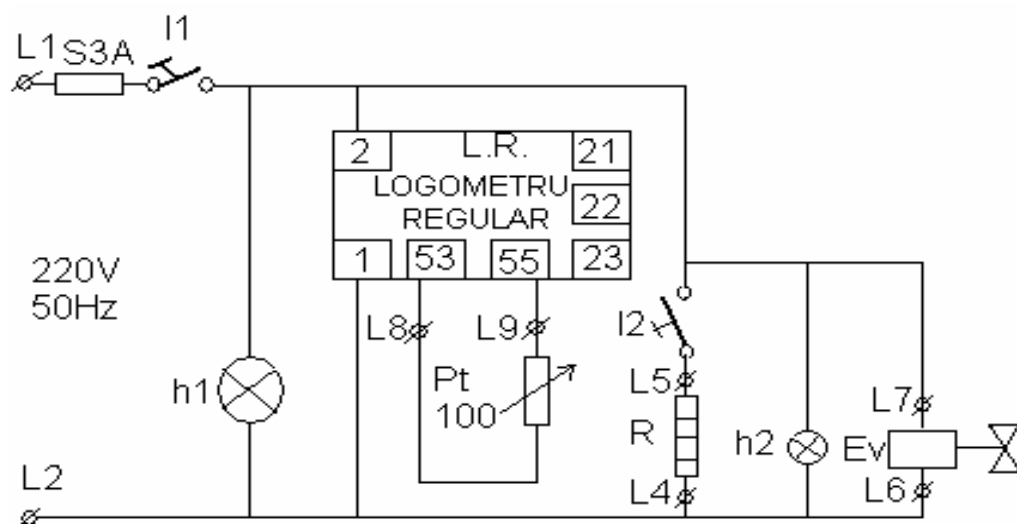


Fig. 6. The scheme of the electronic thermostat: L1...L9-switch clamps; S-fusible 3A; I1-power switch; I2-switch of the heating resistor; h1-power signalling lamp; h2- signalling lamp of the heating resistor; Pt 100-temperature sensor (thermoresistor), R- heating resistor 500 W, Ev- electromagnetical valve; L.R.-regulating logometer -150°C-0°.

The principle scheme of regulating logometer LR 192 is given in figure 7.

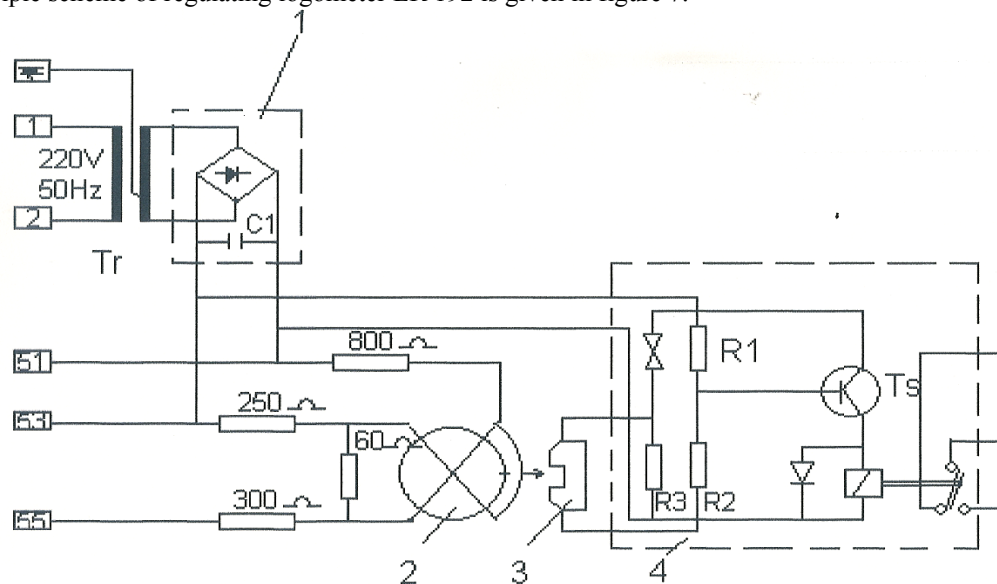


Fig. 7. The principle scheme of regulating logometer (LR 192): Tr-power transformer; 1- block rectifier; 2-mobil frame; 3-inductiv sensor; 4-switching amplifier with relays.

4.CONCLUSIONS

The heat cryogenic treatments applied in the continuation of the quenching allows the reducing of the austenite quantity till 1-3% and a favorable redistribution of chromium between the matrice and carbides with benefic effects on the durability.

From the analyse of the influence of residual austenite on the mechanical properties results that is obtained better properties when in the steel remains a certain quantity of residual austenite. But a minimum quantity of „gauged” residual austenite for ensuring the dimensional stability with reasonable costs is obtained due to the under 0°C treatment.

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