STUDY ABOUT THE INFLUENCE OF CRYOGENIC TREATMENT ON THE IMPACT STRENGTH PROPERTIES OF C45 STEEL

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Abstract. The paper presents the influence of the subzero treatment on the impact strength properties of case steel C45. The modern processes employed to produce durable components include cryogenic treatment as well as conventional heat treatment. Metallic materials in various applications are subject to exploitation negative temperature of -10°C…-200°C. Limits of elasticity and flow resistance to plastic deformation, that in some cases and increase hardness and fatigue strength, with decreasing temperature. At low temperatures, however, the mechanical characteristics of particular importance, has tenacity, sensitivity decreased and the tendency of brittle fracture. Steels, cast iron and ferrous alloys for the cryogenic should not show (except in the smallest possible) the latter trend. The C45, behaviour of low temperature is one of the most important studies when we want to determinate the phase transformation in solid state and the results of impact strength properties of this material and this paper present some aspects of this.

Keywords: materials science, steel, heat treatment, cryogenic treatment, phase transformation, impact strength

1. Introduction

Cryogenic engineers in dealing with development, improvement and application of techniques and technologies that produce or use low and very low temperatures.

While the physical phenomena at very low temperatures, the line focuses its efforts on basic research in cryogenic engineering has the task of practical use, the phenomena related to very low temperatures, which have applications particularly spectacular but can be made using techniques and technologies , unconventional.

The main cause of the physical properties of materials change with temperature decrease is the decrease of vibration of atoms in the crystalline network, which is dependent on temperature.

Metallic materials in various applications are subject to exploitation negative temperature of -10°C…-200°C.

Limits of elasticity and flow resistance to plastic deformation, that in some cases and increase hardness and fatigue strength, with decreasing temperature [1-5].

At low temperatures, however, the mechanical characteristics of particular importance, has tenacity, sensitivity decreased and the tendency of brittle fracture.

Steels, cast iron and ferrous alloys for the cryogenic, should not show (except in the smallest possible) the latter trend.

The C45, behavior of low temperature is one of the most important studies when we want to determinate the phase transformation in solid state and the results of impact strength properties of this material and this paper present some aspects of this.

2. Materials and heat treatment

The studied steel C45 has the following chemical composition (% in weight): 0.47% C; 0.69 % Mn; 0.2% Si; 0.021%S; 0.021%P.

Heat treatment to improve is composed of a group of operations as follows: quenching followed by high tempering.

Apply quench carbon steel, low alloy steel or alloy in order to obtain a non equilibrium structure. It always consists of three distinct phases:

- heating in the austenite (heating with solid phase transformation of state);
- maintenance for chemical mixing austenite;
- cooling energy, able to avoid that pearlitic diffusion's transformation type or bainitic partial diffusion's transformation type.

Aims to quench heated iron is to obtain a solid solution with carbon "γ" and rapid cooling without seeking atomic diffusion at ambient temperature to obtain carbon α saturated iron, i.e. martensite.

All specimens for testing the resilience have undergone tempering operation. These were heated in an electric baking temperature of 850°C, while keeping time to equalize the temperature in samples being 20 minutes.

Cooling energy has been made in water; the water temperature is at room temperature, i.e. 20°C. After quenching operation, structure which is obtained is martensite hardening, a non equilibrium structure.

The quenched samples were performed such tests Rockwell hardness, resulting in values: 55 ÷ 58 HRC.

After quenching, samples were subjected to high-tempering operation.

Tempering operation, unlike the annealing and quenching operations, is not a unique stand-alone operation; it applies only after quenching operations and aims to facilitate specific changes only in hardened areas.

The changes are intended to bring the equilibrium structure obtained by quenching (quenching martensite), close to equilibrium structures with distinct properties.

The samples for testing the resilience of the high-tempering operation of 600°C, took 15 minutes during the maintenance to equalize temperature.

Following high-tempering operation, a tempering soorbite structure was obtained.

The high-tempering samples were performed such tests Rockwell hardness, resulting in values: 36 HRC for all specimens.

3. Low temperature mechanical testing technique

In principle, the low temperature mechanical tests are performed in the same way as at normal temperature. The difference is that the specimen is cooled prior to the desired temperature and then maintained at this temperature, within certain limits prescribed, the duration of testing.

Usually, samples are cooled to a temperature is equal to the test. This rule applies especially when specimens are cooled environment maintained throughout the test.

For small specimens that seek outside cooling, as for example, the samples of resilience, some of these rules provide cooling at temperatures below the test, corresponding to a difference of 1 K for each level of the ambient temperature of 10 K and test temperature, according with standard SR EN 10045-1:1993 [6].

Always required when handling specimens cooled off cooling facility, the rules are details of the time since removal of the specimen cooling to the test environment.

This range is limited to 5 sec for small samples with thickness of up to 10 mm, such as tensile test specimens for bending or shock and 15 sec for samples with thickness of 16...25 mm, as such specimens are loaded with test tubes for bending shock.

3.1. Cryostat technologies

Constructive solutions to achieve cooling devices called cryostat, which varies by type of test to be made after which the test specimens size.

They are used as premises at which the mechanical tests of materials, samples or cool technological purposes as: technology assembly, heat treatment, a.o.

In general, a cryogenic chamber is composed of three main parts, namely:

- Thermal insulation of the enclosure;
- Thermostatic chamber itself, which runs the operation for which was built;
- Cryogenic liquid supply system and drain the liquid or vapor.

One of the basic problems of design and implementation cryostat is the insulation from the external environment and achieving minimum energy consumption.

Thermal insulation cryostat presents some peculiarities related to very large temperature differences that arise between indoor temperature and the environment.

Currently five types of insulation are used, namely: the vacuum, in multiple layers, insulating powders, and foam insulation in the form of special insulation.

4. Experimental results

After heat treatment for improvement, has passed the test at low temperature impact bend. This test was performed inside the ROMAN S.A. Company.

Before testing, all samples were measured to see if they fall within prescribed limits contained in standards (SR EN 10045-1:1993) and then he passed the test at low temperature impact bend.

Impact bend test at low temperatures was conducted according to standard SR EN 10045-1:1993 [6].

The principle of this method consists in breaking a single shot, hammer-pendulum (Charpy), a specimen with a notch provided in the middle and placed freely on two supports in order to determine the amount of resilience for U notch specimens.

As this equipment were used:

a) pendulum hammer, according to standard SR EN 1499:1997.

b) cooling plant, which must provide:
  - uniform cooling of the specimens;

- a constant specified temperature, with deviations of up to ± 2°C;

c) thermocouple;

d) tongs.

The test was performed according to standard SR EN 1400-1998, with the following specifications [6]:

1. The samples are cooled in cooling facilities consist of a thermally insulated container, where specimens are placed on media such as to ensure their contact on all sides with the cooling medium are immersed.

2. As a refrigerant (until -75°C) was used ethanol and carbon dioxide snow (CO_2 solid), which has a temperature of vaporization at 194.6 K, a critical temperature to 1.6 10 kg/m^3 and the latent heat of 13700 J/kg.

3. Duration of maintaining the temperature of the samples specific cooling facility must be at least 5 minutes to cool in refrigerant. The samples were kept in the container for 10 minutes.

4. To measure temperature using a thermometer must fall at least 0.5 accuracy classes and have a maximum value of a division 1°C.

5. For handling and removal of samples from the cooling plant, has been used tongs cooled to the temperature of samples.

6. Breaking the samples was performed within 5 seconds of their removal from the installation of cooling.

7. The samples were focused on to a pendulum hammer-centering device, for the hammer-notch pendulum strikes the opposite side.

8. The test was performed for six different temperature levels, for each temperature level being tested a total of three samples.

After the bending test in cold shock standard (SR EN 10045-1:1993), were obtained different values of potential energy consumed “W_e “, presented in table 1 and figure 1.

Table 1. The potential energy consumed “W_e at break

Nr. crt.	W_e [J]					
	+ 20 °C	– 15 °C	– 30 °C	– 45 °C	– 60 °C	– 75 °C
1	75	71	68	46	29	7
2	74	75	65	55	24	7.1
3	76	73	71	48	27	6.9

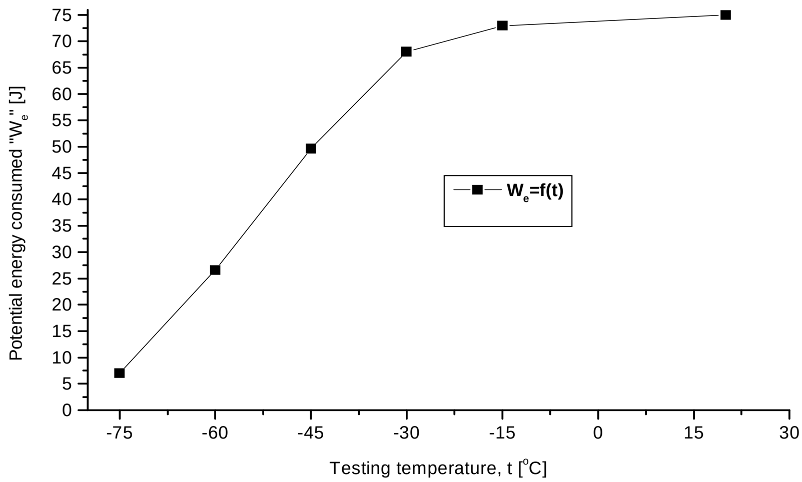

Figure 1. Variation of potential energy consumed “W_e by temperature

Following the evolution of potential energy consumed “W_e“to break the samples, be noted that these decreases with decreasing test temperatures [7, 8, 9].

After determining the amount of potential energy consumed to break samples, the impact strength values were determined using the formula [1, 10]:

$$KCU_2 = \frac{W_e}{S_0} \quad (1)$$

where:

W_e – the potential energy consumed to break the specimens, [J];

S_0 – specimen section [cm^2],

$$S_O = a_c \cdot b \quad (2)$$

where:

a_c - is located at the notch surface to the opposite side;

b is the specimen side.

The impact strength values are presented in table 2 and figure 2.

Table 2. The impact strength values obtained from bending test at low temperature shock

Nr. crt.	KCU_2 [J/cm^2]					
	+ 20 °C	– 15 °C	– 30 °C	– 45 °C	– 60 °C	– 75 °C
1	93.9378	88.4622	85.4909	57.4716	36.2776	8.8583
2	92.5469	93.7500	81.9672	68.8707	30.2044	9.0551
3	93.0238	91.3413	89.5569	59.9850	33.7500	8.7163

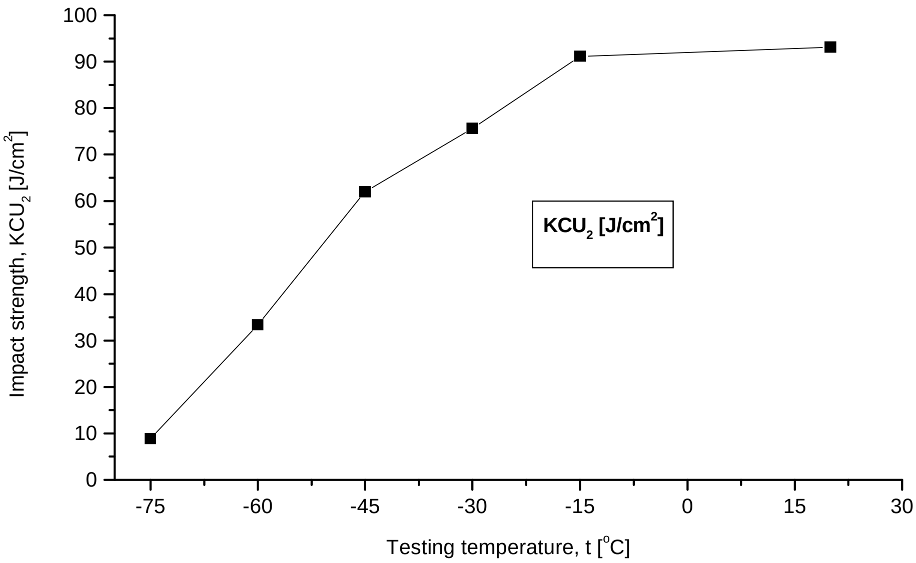

Figure 2. Variation of impact strength values with testing temperature

Analyzing figure 2, can be observed the dependence between the impact strength values and the testing temperature.

5. Conclusions

The main results are summarized as follows:

1. Aims to quench heated iron is to obtain a solid solution with carbon “γ” and rapid cooling without seeking atomic diffusion at ambient temperature to obtain carbon α saturated iron, i.e. martensite.

2. After quenching, the steel C45 structure consists of martensite (carbon-saturated iron α) and residual austenite with a hardness of 55 ÷ 58 HRC.

3. After quenching, samples were subjected to high-tempering operation.

4. Following high-tempering operation, a tempering soorbite structure was obtained.

5. After heat treatment for improvement, has passed the test at low temperature impact bend and this test was performed inside the ROMAN S.A. Company.

6. After cooling, maintaining samples at low temperatures and shock bending test at these temperatures, it has been a decrease in toughness with decreasing values of temperature observation from studying the table shows the recorded data were obtained from bending.

7. It is assumed that this decrease in mechanical properties, default values of impact strength, with temperature is due to residual austenite A_{rez} transformation into martensite, which has a strong influence on the mechanical properties of alloys. Martensite properties are dependent on the percentage carbon, thus high carbon content, reaching hardness of 66 HRC.

The dynamic analysis aimed at characterizing the potential harm from a work place during the working day.

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