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Rodica Rădulea, Cincă-Ionel Lupinca

Temper Fragileness Study for RUL 2 Steel

This paper presents an experimental study about the tenacity variation depending on the tempering temperature of the steel RUL2 grade, within q wide range of temperatures. By this analysis it is possible to study the cooling of the above mentioned heat treatment on the temper fragileness.

1. Introduction

The ball-bearing steel RUL2 grade is intended for the production of ball-bearings and machineries designated to support shafts or axles where, between the component parts, there is a relative rolling motion. The ball-bearings, being subjected in operation to alternating loads, have very high amplitude. They must have a high resistance to wear and fatigue, also a purity degree as high as possible.

The lifetime and reliability in operation of parts and mechanical elements depend on their correct design also by the proper selection of parts to be manufactured.

To asses the danger of fragile fracture of metallic materials it is used the transition temperature ductile-fragile that is currently determined by means of tenacity. A test method providing close results of real behavior in operation of one part often used in practice is the impact bending sock also known as the impact test, determined by Charpy or Izod test. This test, design to subject the material to the most severe conditions encouraging the brittle fracture, is marked by high speed of load applying, by breaking the sample tests in one impact also the presence of a slot in "U" or "V" shape. Changing the section of the sections by the presence of the slots generates tri-axial stress in the moment of testing the samples determining a brittle fracture in the ductile material, respectively the ductile-brittle transition.

In order to asses a material in respect of its ductile-brittle transition, on impact test to a single temperature is not enough. There are necessary several assessments on a wide range of temperatures. By determining the values of the metallic material impact strength to different levels of temperature and by plotting its curve depending on the temperature it is possible to establish the transition temperature of the metallic material.

Theoretically, the cooling speed of a part shouldn't influence the tempering result since all the characteristic stages of this heat treatment are performed during heating and maintaining. However, both practice and researches have shown that slow cooling in the heat treatment furnace of thin parts or in free air of thick parts involve a brittleness phenomenon of steel, which can be seen by decreasing the impact breaking energy at lower temperatures.

The factors determining and influencing the processes leading to the occurrence of brittleness are many, and their individual way and direction of influence could not been emphasized accurately.

A deciding factor in the occurrence of this fragileness is the long time maintaining within the fragileness limits and the slow cooling up to the environmental temperature.

The tempering of steel out of which were performed ball-bearing heaving an almost exclusive pearlite structure (90…100% lamellar pearlite) is represented by the occurrence, during heating, of several disturbances in the variation of mechanical properties (especially of the impact strength). Presently, these phenomena are less explained.

2. Experimental results

For the experimental study of RUL 2 steel temper fragileness there were performed 25 normal Charpy U normal sample tests RUL 2 steel, ISO type, delivered in forged condition, having the chemical composition as shown in Table 1.

Chemical composition of ball-bearing steel, RUL 2 [%] **Table 1**

Steel grade	C	Mn	Si	Cr	S_{max}	P_{max}
RUL 2	1,02	1,10	0,50	1,40	0,02	0,023

a) For experimental researches, the test samples were subjected to specific heat treatments as follows: the test samples were subjected to a normalizing heat treatment at a temperature of 860 ^{0}C and to a spheroidizing annealing heat treatment at a temperature of 720 ^{0}C, in a fixed-hear of head electrically furnace, in order to obtain spheroidal pearlite structure. The heat treatments applied lead to the experimental results represented by cyclogamas shown in (Figures 1 and 2).

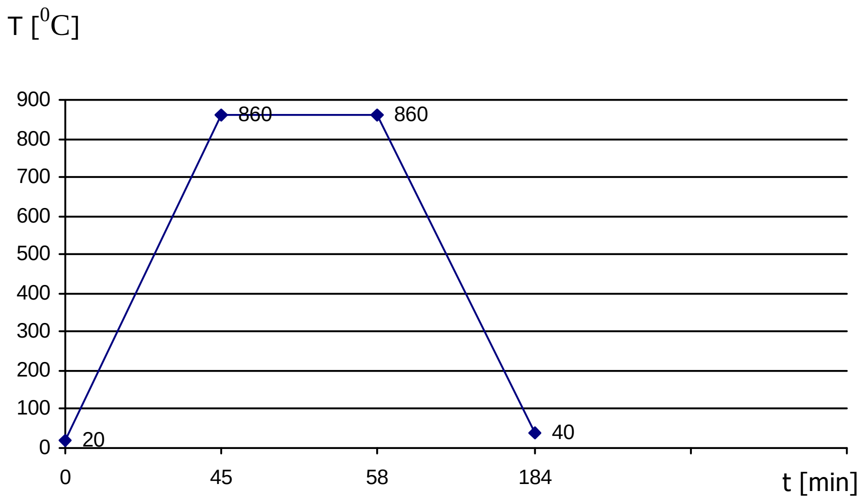

Figure 1. The cyclogram of normalizing heat treatment

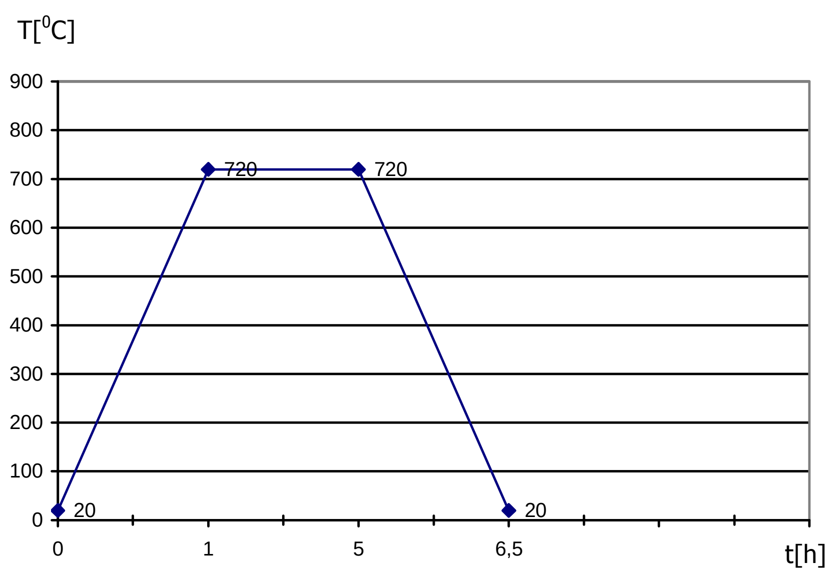

Figure 2. The cyclogram of spheroidizing annealing heat treatment

b) In order to obtain a high hardness, the test samples were subjected to a volume martensitic hardening at a temperature of 840 ^{0}C oil quenched. To avoid breaking of samples, hardening was performed at a pre-heating step as it can be noticed in Figure 3.

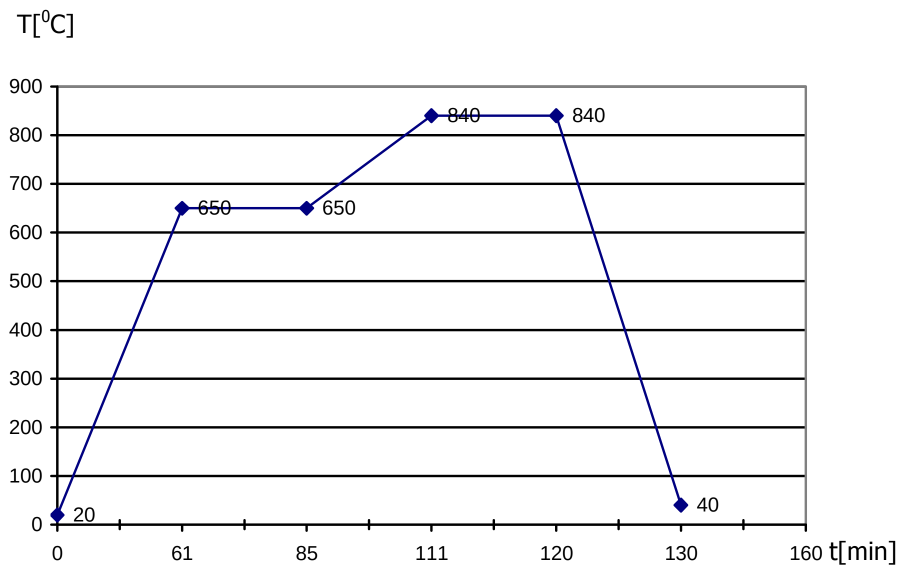

Figure 3. The cyclogram of hardening heat treatment

c) The test samples were subjected to a tempering heat treatment, by gradual heating in steps of 50 ^{0}C, within the temperature range of 150-700 ^{0}C, allowing thus to analyze the brittleness of RUL2 steel in case of applying a low, medium, respectively high tempering. Two test samples have been put successively in the furnace, being maintained for 30 minutes at the tempering temperature, applying different cooling cycles for each test sample: slow cooling in free air and fast cooling in water.

The impact strength of test samples was determined by means of a friction pendulum having a potential energy of 300 J, the impact value being read directly on the measuring gauge. The experimental results obtained are shown in Table 2.

Values of RUL 2 steel impact strength depending on the tempering temperature and on the cooling environment **Table 2**

Number of test samples	T_{rev} [^{0}C]	KCU [J/cm^2]	
		Cooling medium	
		Water	Air
1	150	12	9
2	200	6	8
3	250	5	7
4	300	3	3
5	350	12	6
6	400	8	10
7	450	8	8
8	500	12	12
9	550	20	18
10	600	22	18
11	650	25	25
12	700	30	38

Based on the experimental results obtained, the transition temperature curves can be plotted for the two cooling cycles, this being shown in Figure 4.

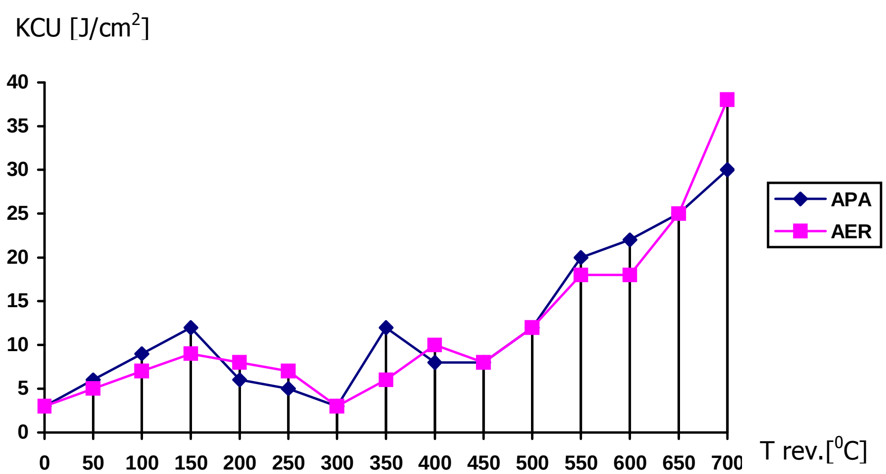

Figure 4. Ductile-fragile transition temperature curves for RUL 2 steel

3. Conclusion

- It is noticed that, within the temperature range of 150-550 ^{0}C for both cooling cycles applied, a sudden decrease of the impact strength occurs at the tempering temperature, disturbance known as irreversible fragileness;
- Considering the fact that once occurred this fragileness cannon be removed, it is recommended for RUL 2 steel to avoid tempering within the temperature range of 150-550 ^{0}C, respectively a low or medium tempering;
- Within the temperature range of 550-650 ^{0}C, a decrease of impact strength of steel can be noticed in case of a slow cooling, this variation leading to the occurrence of temper fragileness at high temperature. Plotting of the variation KCU= f(T_{rev}), shows that this fragileness can be removed by fast quenching of steel in water from the tempering temperature, showing that RUL 2 steel is marked within the temperature range of 550-650 ^{0}C by a reversible temper fragileness;
- In order to avoid the temper fragileness of RUL 2 steel it is recommended to apply the tempering heat treatment within the temperature range of 550-650 ^{0}C, with fast water quenching, respectively a high tempering.

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Addresses:

- Assist. Eng. Rodica Rădulea, "Eftimie Murgu" University of Reşiţa, Piaţa Traian Vuia, nr.1-4, 320085, Reşiţa, r.radulea@yahoo.com
- Lect. Dr. Eng. Cincă-Ionel Lupinca, "Eftimie Murgu" University of Reşiţa, Piaţa Traian Vuia, nr.1-4, 320085, Reşiţa, c.lupinca@uem.ro