FRACTURE SURFACE OBSERVATION OF ARMOX 500T IN DEPENDENCE ON TEMPERATURE

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Abstract

Fracture surface gives us the information about material properties. Fracture can be ductile or brittle in dependence on consumed energy. As far as the fracture surface is concerned, we distinguish the plastic and brittle fracture. The aim of the article is to show the fracture surface of steel ARMOX 500T after the impact bend test in dependence on temperature.

Keywords: Toughness, hardness, chemical composition, temperature, fracture surface

1 Introduction

Nowadays, there are plenty of tests which allow assessing the material resistance against failure. These tests are divided into two groups. Firstly, the comparative tests which are simple, cheap and repeated. The impact bend specimen test is one of them. Secondly, the specific tests, on the base of which the characteristics can be identified.

In the presented work, there were carried out the experimental tests of mechanical properties of ARMOX 500T under laboratory conditions and there were assessed fracture surfaces in dependence on the temperature within tests. Experimental measurements were performed in the temperature range -30°C to + 20°C. There were used the experimental bars with dimensions 10x10x55 mm with V – notch. Shape and dimensions of specimens are depicted in Fig. 1.

There were determined toughness, hardness, material chemical composition, selected heat treatment, temperature by which the impact bend test was performed and the fracture surface analysis of the test specimens within the experiments.

2 Experimental tests

Fracture surface gives us the information about material properties. Fracture can be ductile or brittle in dependence on consumed energy. As far as the fracture surface is concerned, we distinguish the plastic and brittle fracture. Acquirement of limit conditions depends on the damage accumulation dynamics which is function of the sub-structural and structural conditions, technological characteristics of production, external loading, environment and action time of these factors [1]. Free enthalpy of the system is reduces during fracture.

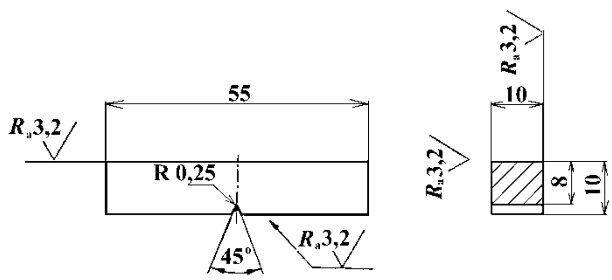


Fig. 1 *Shape and dimension of specimen*

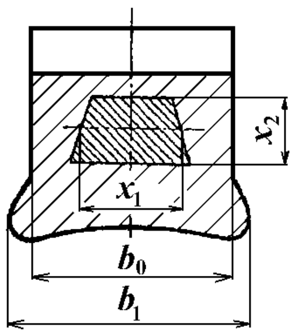
Fracture area is characterized by a specific shape of the surface. It documents the deformation under triaxial tension, which occurs in the notch during bending [2].

Generally, the shape of fracture surface is primarily dependent on the crystal lattice of the given metal. While the metals with face centered lattice have tendency to ductile fracture, materials with hexagonal lattice at room temperature tend to brittle fracture, with increasing temperature plastic fracture can be achieved. The fracture of metal materials with body centered lattice is determined by temperature, loading speed and tension (wall thickness, notches), depending on the loading conditions the fracture character is changing. At higher temperatures the fracture is usually ductile, at low temperatures it is brittle fracture. The change in fracture behavior due to the drop in temperature is called by the term transit fracture behavior and the temperature is transit temperature.

Hardness of material is the ability of solid material to put resistance against other bodies' penetration. For mutual comparison of hardnesses evaluated by various methods and for their conversion to tensile strength the conversion tables are compiled for steel materials (i.e. STN ISO 4964 Steel. Hardness comparison diagrams). For practical use and quick reference using hardness tests it is possible to obtain information about the strength of treated material [3].

The individual steels properties are influenced by chemical composition like the amount of various components present in steels. The strength of steels increases with increasing content of C but only until 1.2 % of volume. Concurrently, brittleness, hardness and hardenability increase. The weldability deteriorates and the melting point decreases. Additive elements (manganese, silicon, chromium, nickel, copper) can significantly change the properties of steel [4]. Sulfur and phosphorus have adverse effects, their influence begins to be significantly manifested at 0.035% concentration.

The temperature to perform the impact bend test was determined to be in the range -30°C to +20°C. The appearance of the fracture surface after breakage is significant. It characterizes plastic or cleavage fracture, in the case that the tests are performed at various temperatures, it allows determine the transit temperature. The percentage of plastic fracture $\boldsymbol{P}_{\mathrm{L}}$ [%] is determined by measuring the dimensions of crystalline fracture area on the fracture surface $\boldsymbol{S}_{\mathrm{KL}}$ (Figure 2). By fracture surface evaluation it is possible to obtain also another deformation characteristics – so called lateral expansion $\boldsymbol{\Delta b}$, which is determined as the difference between lengths $\boldsymbol{b}_1$ and $\boldsymbol{b}_0$.



$$S_{\mathrm{KL}} = x_1 \cdot x_2 \left(mm^2\right)$$

$$P_{\mathrm{KL}} = \frac{S_{\mathrm{KL}}}{S_0} \cdot 100(\%)$$

$$P_{\mathrm{L}} = 100 - P_{\mathrm{KL}}(\%)$$

$$\Delta b = \frac{b_1 - b_0}{2} \quad (\mathrm{mm}) \qquad (1)$$

Fig. 2 *Evaluation of plastic fracture percentage P_L and lateral expansion Δb*

3 Experimental results

The test specimens were made from bar with cross-section 10x10 mm. Total number of specimens for the purposes of experiment was 18. Hardness of the material in supplied state was in average 489,125 HB. Test on each specimen was performed according to STN ISO 148-1 (420381): Metal materials – Impact bend test by Charpy. Part 1: Test method (V notch) and STN 42 0382 tests at dropped temperatures.
Hammer with nominal energy 150 J was used. Chemical composition of ARMOX 500T is shown in Table 1.

Table 1 *Chemical composition*

C %	Si %	Mn %	Cr %	Ni %	Mo %	B %	P %	S %
0.32	0.1-0.4	1.2	1.0	1.8	0.7	0.005	0.015	0.01

The specimens were divided into 6 groups; three specimens were in each group. Cooling temperature of specimens was chosen in accordance with running conditions of laboratory.

Course of the impact energy change is depicted in Fig. 3. Fig 4 presents the characteristic fracture surface of ARMOX 500T in dependence on particular experimental temperature. There are 6 pictures, others were identical. Based on the facts that not only energetic criterion can be used to determine the transit temperature but also the morphological evaluation of the fracture surface we assessed the area of the plastic – ductile fracture and area of the brittle – crystalline fracture. Basic characteristics are depicted in Fig. 2. We followed up the area of brittle fracture on the observed fracture surfaces. Particular fracture surfaces are shown in Fig. 4.

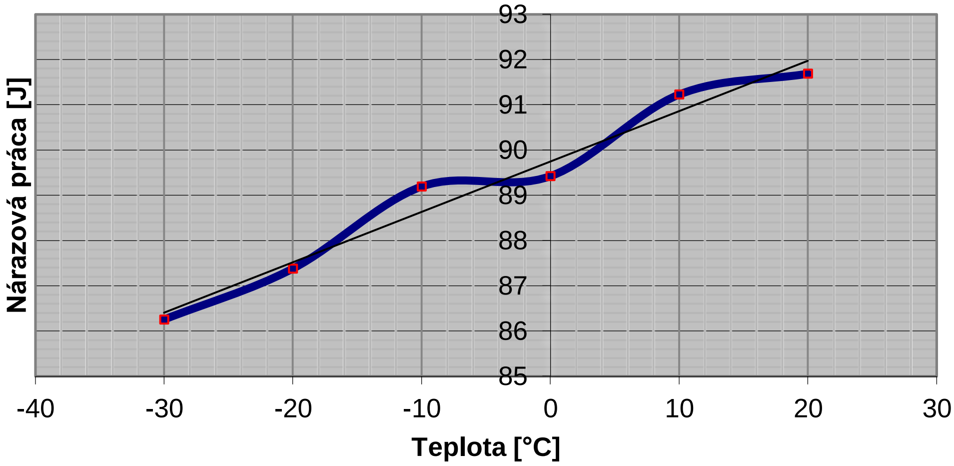


Fig. 3 *Course of the impact energy change in dependence on temperature*

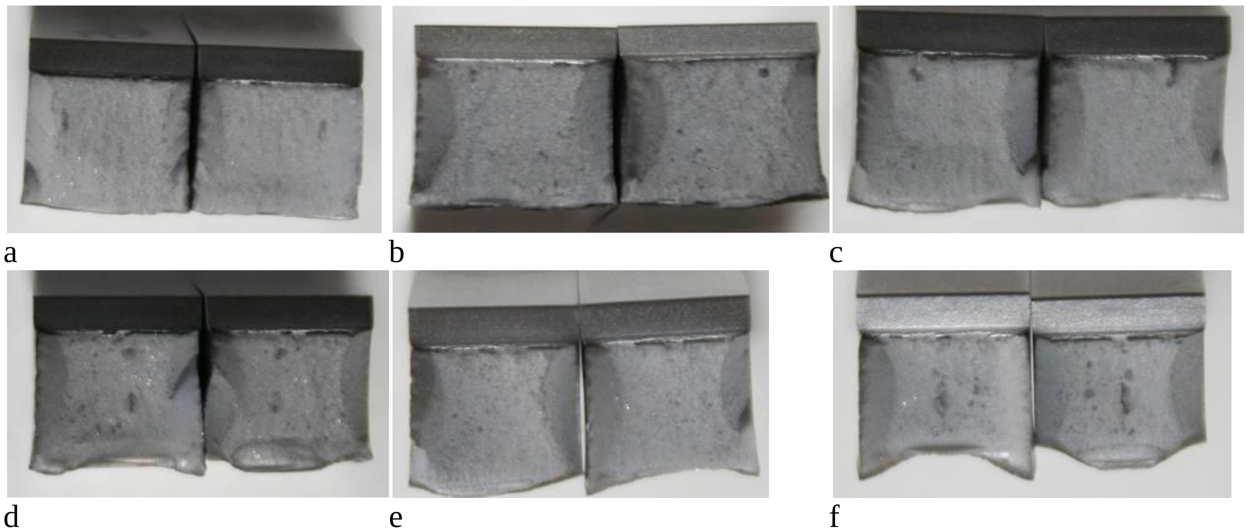


Fig. 4 *Fracture surface*
a) at temperature -30°C, b) at temperature -20°C, c) at temperature -10°C,
d) at temperature 0°C, e) at temperature 10°C, f) at temperature 20°C

There is the characteristic shape for the area of the plastic, ductile fracture for all observed specimens. Figure 4 presents the fracture areas of specimens after experimental test. Some of specimens show particular differences for the fracture surface shape as well as different mechanism of the deformation and fracture. We have not identified the areas of brittle fracture for any specimens.

Deformation work is proportional to the section deformation expressed by the deformation characteristic. Since the correlation between characteristics KC and Δb was experimentally verified, the surface changes towards the brittle fracture have been evaluated by deformation characteristics changes. Consequently, the lower deformation characteristic the much brittle material.

Table 2 shows that deformation characteristic for experimental material is 0.1 mm and it has not changed dramatically in dependence on temperature. Fracture surface presents plastic fracture with deformation, there is observed 10 % of brittle fracture. Figures present course of triaxial stress within the specimen section, deformation within the core is similar. There is observed low transverse enlargement on the specimens.

Table 2 *Deformation characteristics and energy of the hammer*

No.	Dimensions of notch area before test		Area	Dimensions of notch area after test		Deformation characteristic Δb	Energy of hammer	Temperature of specimen
	a	b		b_1	b_0			
	[mm]	[mm]	[cm^2]	[mm]	[mm]	[mm]	[J]	[°C]
1	10	10	0.8	10.1	10	~0.05	86.2	-30
2				10.1	10		86.5	
3				10.12	10		86.4	
4				10.1	10	~0.05	87.3	-20
5				10.1	10		87.2	
6				10.1	10		87.3	
7				10.12	10	~0.06	89.1	-10
8				10.12	10		89.2	
9				10.14	10		89.0	
10				10.14	10	~0.07	89.4	0
11				10.14	10		89.3	
12				10.16	10		89.4	
13				10.18	10	~0.1	91.2	10
14				10.2	10		91.2	
15				10.22	10		91.3	
16				10.2	10	~0.1	91.7	20
17				10.2	10		91.8	
18				10.18	10		91.9	

4 Discussion

In macrostructural analysis the focus is laid on characteristic marks on fracture surface. Overall we can assess whether the fracture was accompanied by plastic deformation or not. On the presented pictures is evident that we deal with low energy fractures, only minor deformation is present. Originally rectangular cross-section (8x10 mm) was essentially unchanged and lateral expansion can be identified. There was found out fracture with low deformation, fracture surfaces are fine-grained.

The experiment has confirmed material suitability for its using in the hard conditions and environments. It proofed not only impact work but also fracture surface shape.

5 Conclusion

Mechanical properties are final properties of given material, which underline its suitability for specified function and use in practice. Knowing and improving the mechanical properties of construction materials is motivated by their optimal use in machines and equipment manufacturing. Material ARMOX 500T has confirmed its suitability for using in hard condition and has fulfilled conditions for high resistant materials. Particular pictures of fracture surfaces as well as the impact work and deformation characteristics document enough that the relation on temperature for this material has not had dramatic effect.

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