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ANALYSIS OF FRACTURE MECHANISM OF CAST STEEL UNDER HYDROSTATIC PRESSURE

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Preliminary Note – Prethodno priopćenje

Plastic deformation and damage evolution in low-carbon cast steel containing non-metallic inclusions are analyzed experimentally and numerically. The cast steel was subjected to the heat treatment: normalizing, oil quenching and tempering. Tests were carried out at hydrostatic pressure of 500 MPa and 1 000 MPa. In the tensile test the tensile strength, elongation and reduction of area were examined. Fractography of the specimens was carried out to observe fracture mechanisms. The finite elements method has been used for modelling of deformation of the specimens. The computer simulation was performed using ABAQUS system. The computed output was compared with experimental results

Keywords: cast steel, heat treatment, metallography, mechanical properties, computer modelling

INTRODUCTION

In metallic materials, plastic deformation and failure mechanisms depend on the stress state [1]. In our previous paper, the fracture of cast steel in the spatial state of stress was analyzed [2]. The Gurson model [3-5] for a material containing voids and inclusions on which voids form was used to explain the failure process at the spatial stress state. In this work, the fracture of cast steel subjected to high external pressure is analyzed.

EXPERIMENT AND RESULTS

Experiments have been performed on a low-carbon cast steel. The chemical composition of the material is presented in the Table 1.

Table 1 **Chemical composition / wt%**

C	Mn	S	Cr	Ni	Mo
0,21	0,38	0,042	0,74	0,085	0,42

Two types of heat treatment were used to improve the cast steel:

- normalising at 920 °C, 2 h, oil quenching and tempering at 490°C, 2 h (cast steel type I);
- normalising at 920 °C, 2 h, oil quenching and tempering at 350 °C, 0,5 h (cast steel type II).

As a result of heat treatment the ferritic-pearlitic structure of the material was obtained [2].

For the tensile test carried out at high hydrostatic pressures the specimens 2,5 mm in diameter and 15 mm long were used. The tensile test was performed on the samples placed in the chamber filled with petrol. The applied hydrostatic pressure was 500 MPa and 1 000 MPa.

The dependence of tensile stress and sample elongation was determined for a pressure of 500 MPa and 1 000 MPa (Figures 1 and 2).

The tensile-strain curve was determined for samples with a diameter of 2,5 mm and 15 mm long at ambient

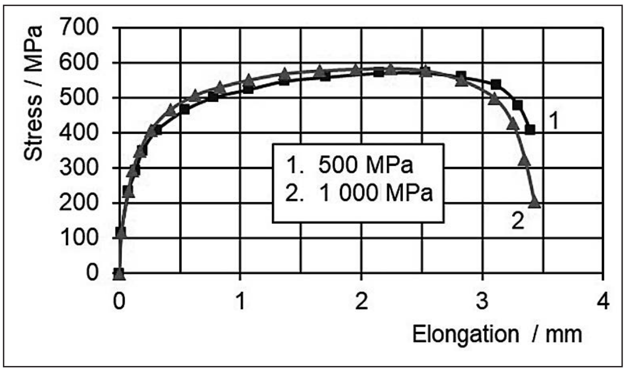

Figure 1 Stress-elongation relation of cast steel I, 500 MPa and 1 000 MPa

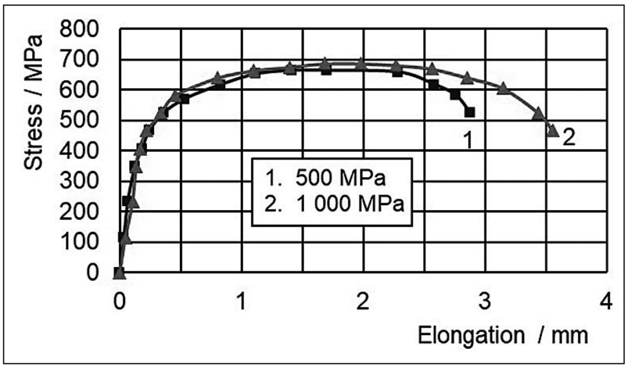

Figure 2 Stress-elongation relation of cast steel II, 500 MPa and 1 000 MPa

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Table 2 **Results of the tensile test**

Material	E / GPa	ν	R_e / MPa	R_m, / MPa	A / %
Cast steel I	213	0,28	280(1)	607(2)	8,5
Cast steel II	212	0,28	320(1)	750(2)	8,2

(1) offset yield stress, (2) true stress

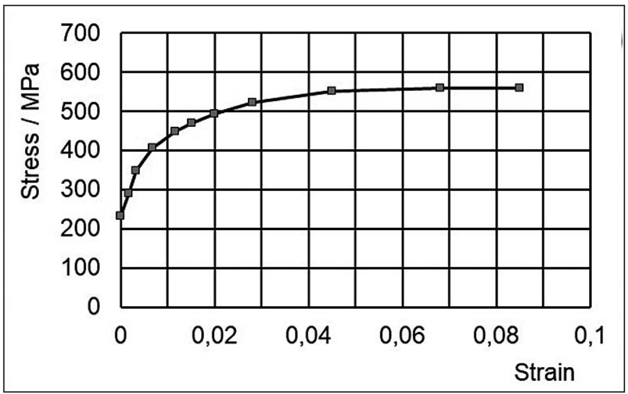


Figure 3 Stress-strain curve for cast steel type I

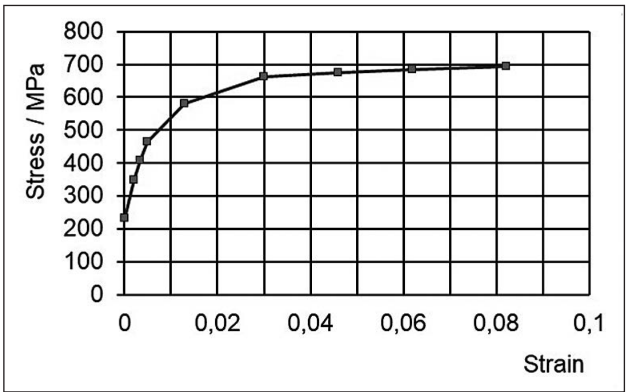


Figure 4 Stress-strain curve for cast steel type II

pressure. Three tests were performed for each cast steel. The averaged results are shown in Figure 3 and 4.

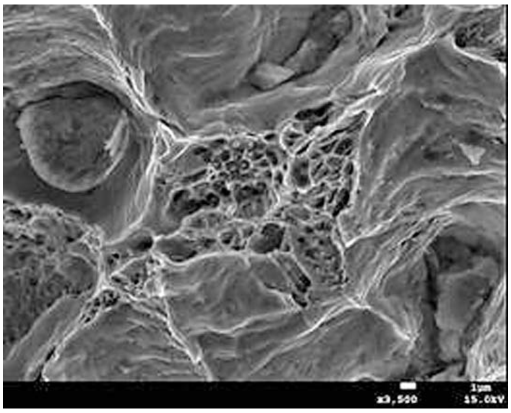
The yield stress R_e, the ultimate tensile strength R_m and the elongation A were determined in the tests. The modulus of elasticity E and the Poisson ration v have been obtained by the acoustic method (Table 2).

The fractographic examination showed the ductile fracture with a small amount of shear morphology and the stress state. Some photographs of microregions in the centre of samples were taken (Figures 5 and 6).

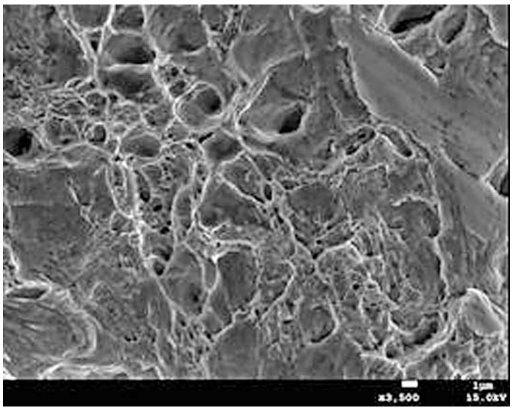
COMPUTER SIMULATION

A computer simulation of stretching of cast steel subjected to hydrostatic pressure was carried out. The 3D model of the stretched sample was analyzed in the Abaqus program (Figure 7) [6].

After reaching the maximum uniform deformation in the sample, a slight perturbation was applied to initiate the neck in the sample. The sample was stretched until the breaking stress value obtained in the experiment (Figure 8).

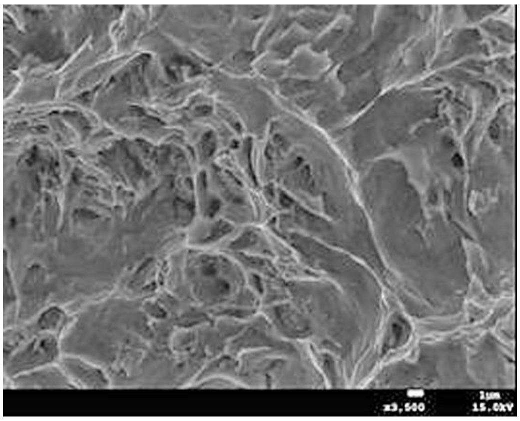


a)



b)

Figure 5 Tensile test of material type I, fracture surface at centre of sample, a) 500 MPa, b) 1 000 MPa



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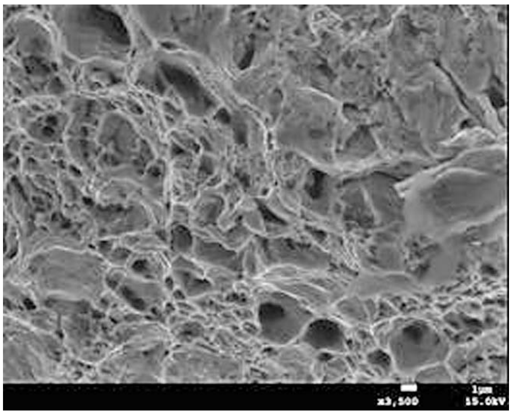

b)

Figure 6 Tensile test of material type II, fracture surface at centre of sample, a) 500 MPa, b) 1 000 MPa

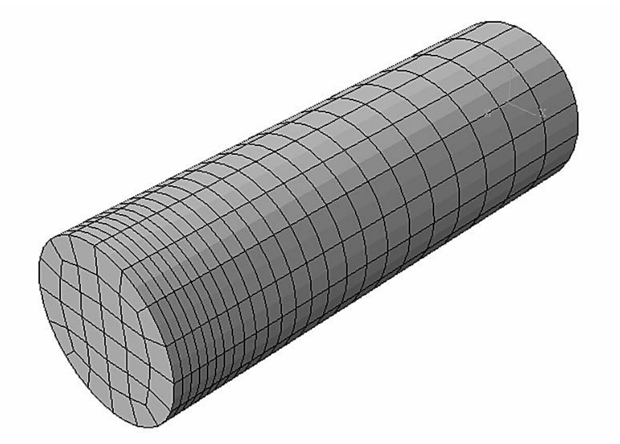

Figure 7 Model of the half of sample

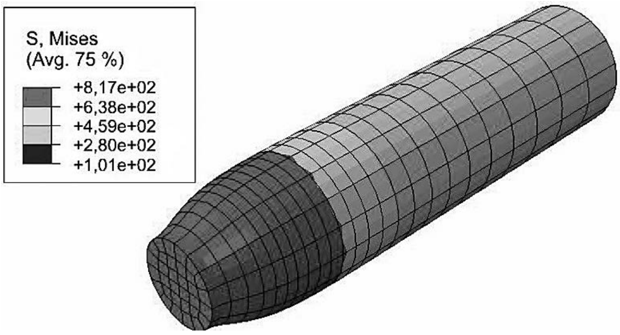

Figure 8 Stretched sample, cast steel I, 1 000 MPa, the Mises stress

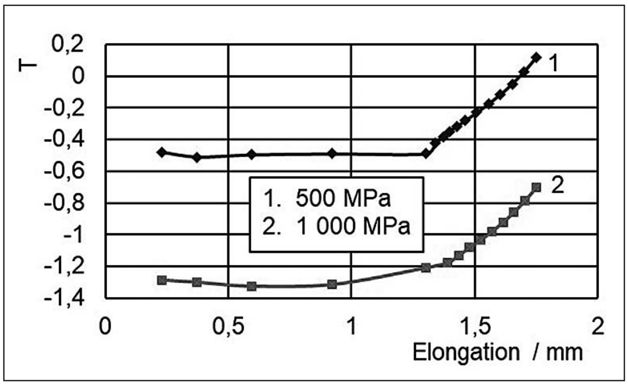

Figure 9 The stress triaxiality (T), cast steel I, 500 MPa (the higher curve), 1 000 MPa (the lower curve), elongation of half of sample

The triaxiality of the stresses in the center of the neck was numerically determined for the sample stretching process. Initially, the triaxial stress has a negative value, and after the initiation of the neck it grows monotonically (Figure 9 and 10). The final values of the triaxial stresses indicate the possibility of generating voids around inclusions in the cast steel I for the external pressure of 500 MPa (Figure 11).

CONCLUSIONS

The two tested cast steels have been analyzed in different states of external stress. The observed fracture mechanisms in the materials depend on the state of

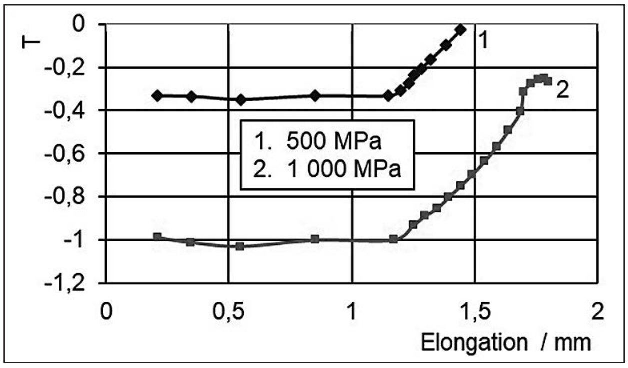

Figure 10 The stress triaxiality (T), cast steel II, 500 MPa (the higher curve), 1 000 MPa (the lower curve), elongation of half of sample.

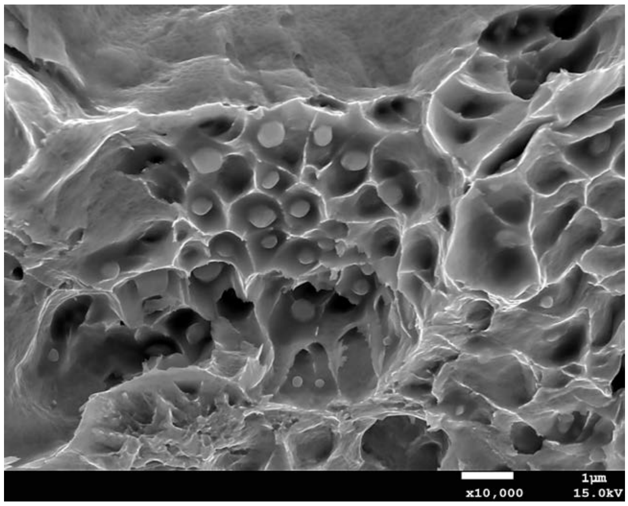

Figure 11 Voids around inclusions in the cast steel I, fracture surface for 500 MPa

stress. In the centre of the notched specimens the stress triaxiality was negative. So that any void generation process was not take place during faluire. The ductile fracture and fracture by shear was observed in the centre of a neck.

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Note: Translated by Małgorzata Laczek, Kielce, Poland