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Propagation of the Lamellar Cracks

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The aim of the study is to include studying the effects of the interaction of lamellar cracks and their effect on the degradation of the structure. Lamellar cracking phenomenon is most common in the construction of welded ship hulls, bridges, pressure vessels and piping. The structures of these, as a result of errors in production and welding cracks. The sudden breakage occurs in the construction of real time, although they have been designed properly in terms of both the volume of the stress and strain. The growth of these cracks, at a rate equal to the speed of sound in the material, it is a sudden breakage.

Keywords: Experimental tests, lamellar cracks, numerical method, finite element method.

1. Introduction

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In the case of tests carried out on samples of metal stress state analysis laboratory methods. Using acoustic emission, thermography method allows the analysis of deformation, but does not reflect the view of the state of stress.

Based on typical images metallographic steel sheets were admitted to study distributions of artificial joints. Fig. 2 shows an example of brushed steel metallographic perlityc – ferritic non-metallic inclusions in the form of manganese sulfide MnS and Al_2O_3showing lamellar cracks.

Figure 1 View of the sample just before tearing and after tearing of the samples

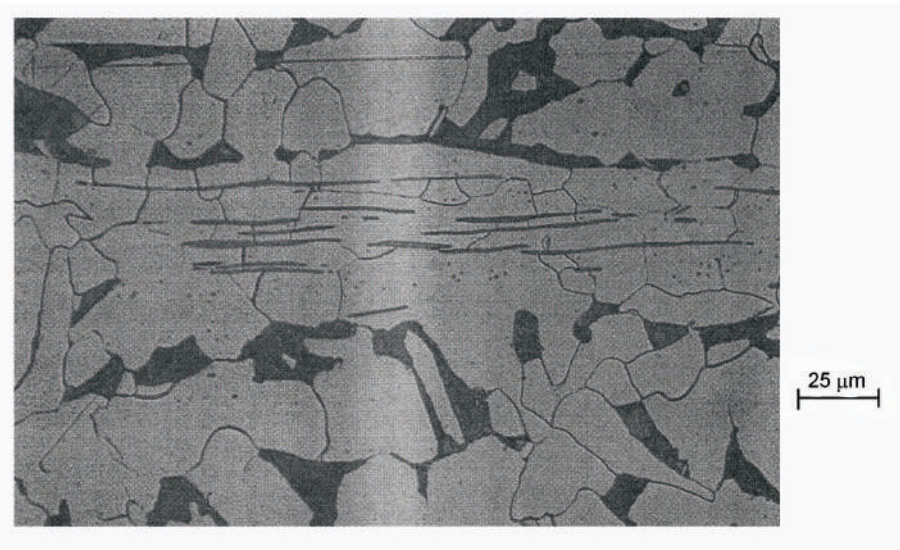

Figure 2 View metallographic grinding sheet of non-metallic inclusions

2. Numerical calculation of the plates steel

Metallographic examination supplemented by numerical calculations allow analysis of lamellar cracks of their interaction in the phase preceding the destruction.

Calculations were performed using finite element method (ANSYS program).

For the analysis of stresses and deformations in part modeling sheet structure used flat triangular element A six PLANE2.

It was assumed:

– Plane strain and the left edge of the restraint structure of the model,

– Displacement of the right edge of the model with $\varepsilon_x = 0.06$ %.

Analyzed models perlitic- ferritic steel structure with on metallic inclusions – lamellar.

Steel structure was modeled by adopting the following material data:

– Ferrite: elastic material order;

Young's modulus in the range of elastic $E = 204$ GPa

Young's modulus in the range of plastic $E_p = 10$ GPa

Poisson's ratio $\nu = 0.3$

yield strength $R_e = 150$ MPa

tensile strength $R_m = 300$ MPa

– Non–metallic inclusions:

Young's modulus $E = 1$ MPa

Poisson's ratio $\nu = 0.499$

In view of the slight value of Young's modulus non–metallic inclusions was assumed that these voids. The small size of the inclusions required to modeled steel structure was the analysis of the micro. Constructed corresponding FEM model, in which the unit of length adopted micrometer [μm].

ANSYS program was used 14 analyzed models built with flat triangular elements called PLANE 2 Each node has two degrees of freedom – the ability to move in two mutually perpendicular directions. A finite element mesh of the model (used for numerical simulation) are presented in Fig. 3.

Model loaded displacements in the plane strain, which corresponds to the hypothesis of cross–sectional plane of the bottom beam during operation.

The geometry and materials of models were chosen to correspond to the actual specimens used in the experiments. The mechanical properties correspond to – stress–strain relationships (used for numerical calculation) are presented in Fig. 4.

Since the crack may propagate when the normal to the surface tension are slots extending causing separation of a gap Burzynski decided to use the hypothesis to determine the reduced stresses. Hypothesis Burzynski is a modification of hypotheses Huber. It allows to take into account the effect of the difference between the tensile strength and compressive strength. This approach allows you to visualize the places which produce the maximum stress reduced with a significant impact on a tensile component.

After the numerical calculations corresponding longitudinal load in displacements equal $\varepsilon_x = 0.06$ % (280 MPa) was prepared according to the map of reduced stress hypothesis Burzynski. Then the chosen element, in which the equivalent stresses reach a critical value ($\cong$280 MPa). This element are disappearing and the crack is expanding (*element birth and death*). Then repeated calculations without this element of the new structure is a method of lost items. After a series of calculations gave the crack path.

Non–metallic inclusions cause delamination of the structure, cracks perpendicular to the lamellar inclusions (slots) as well as along the stretching direction. occurs here changes in stress distributions which can increase the shear stress along the lines connecting the vertices of the inclusions. Figs 5 and 6 show non–metallic inclusions cause delamination of the structure, cracks perpendicular to the lamellar inclusions, all the places where the stress exceeds this value are marked in gray.

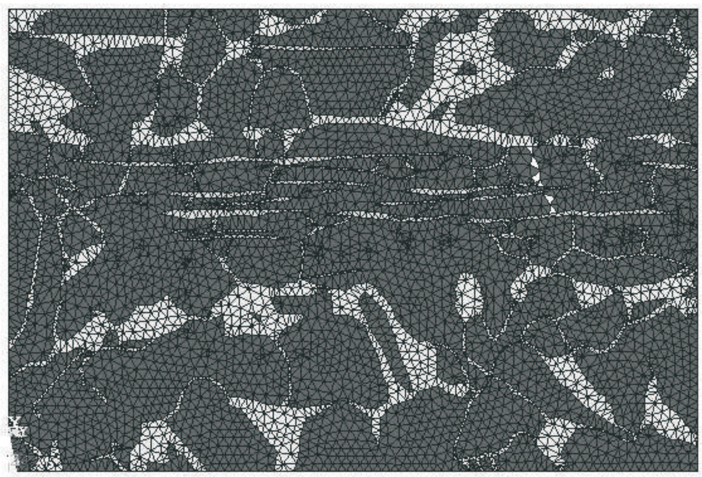

Figure 3 Finite element mesh of the model

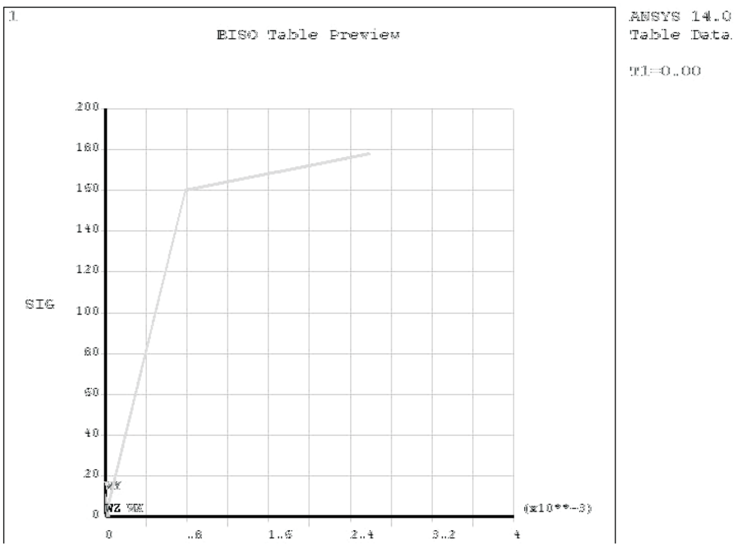

Figure 4 Steel structure was modeled by adopting the following material

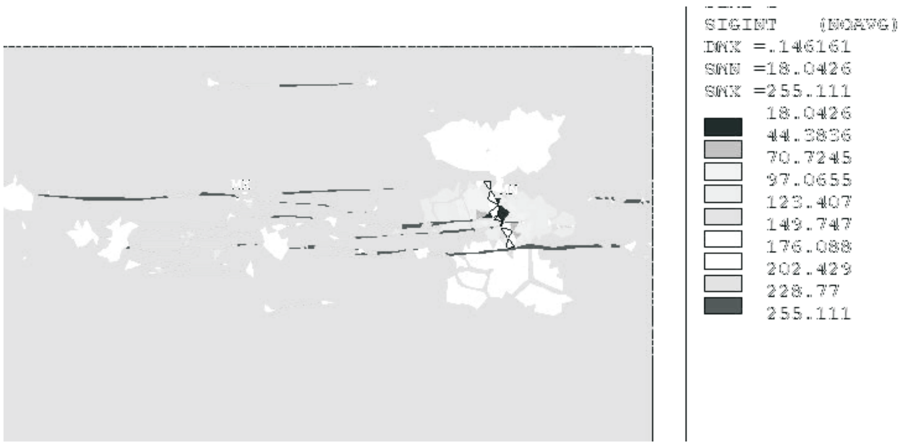

Figure 5 Non–metallic inclusions cause delamination of the structure, cracks perpendicular to the lamellar inclusions

Figure 6 Distribution of reduced stresses according to Huber's hypothesis in the model studied using the metallographic method obtained by means of the finite element method

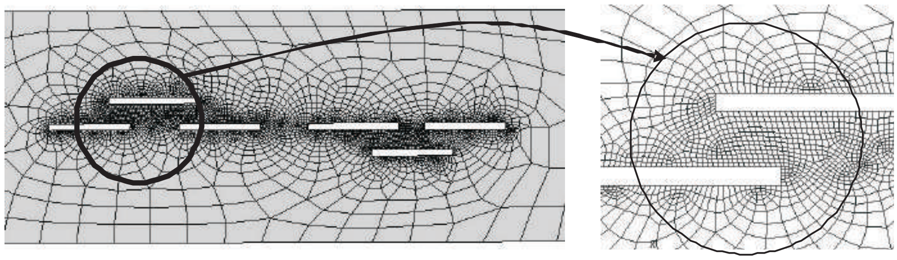

Figure 7 Finite element mesh of the model

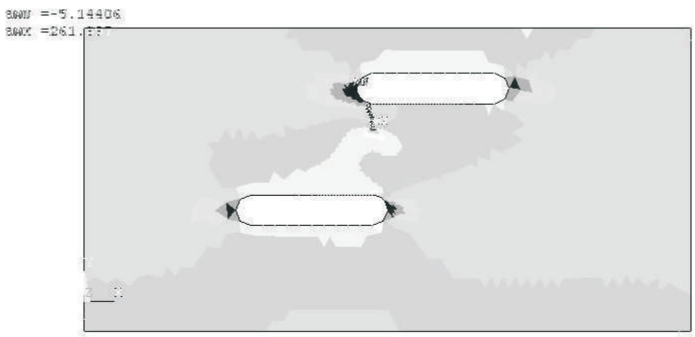

Figure 8 Numerical calculations of the process of cracking. The beginning of cracking and the blow up cracks

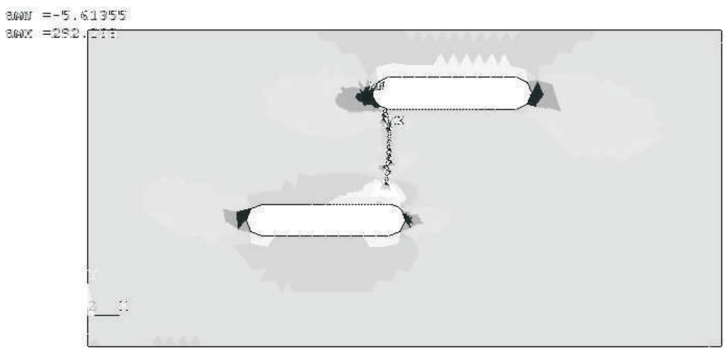

Figure 9 Calculations of the process of cracking that elements in tip of crack are disappearing, the crack is expanding

Figure 10 Distribution of reduced stresses according to Huber's hypothesis in the model obtained by means of the finite element method

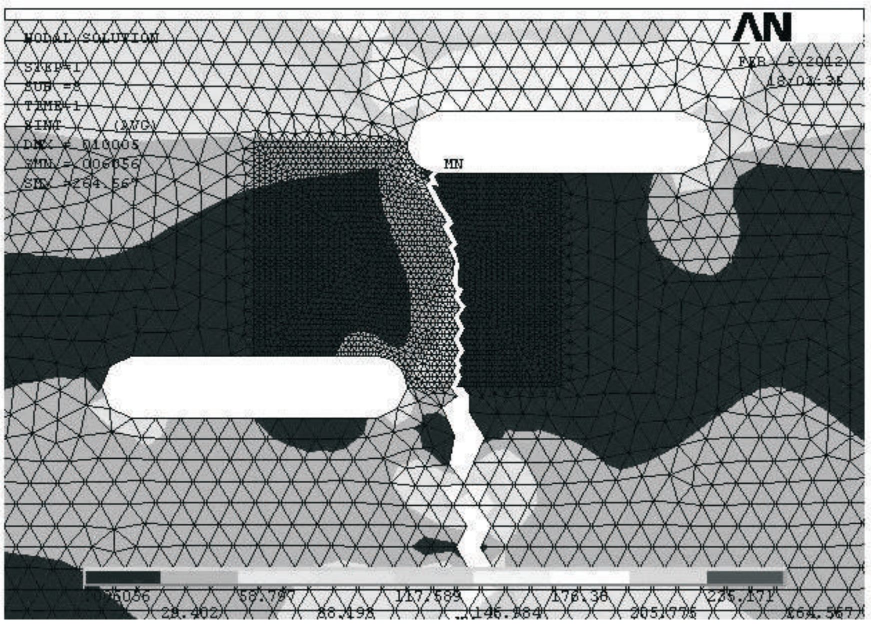

Figure 11 Of deforming damage in the phase and the and finite element mesh of the model applied up to calculations

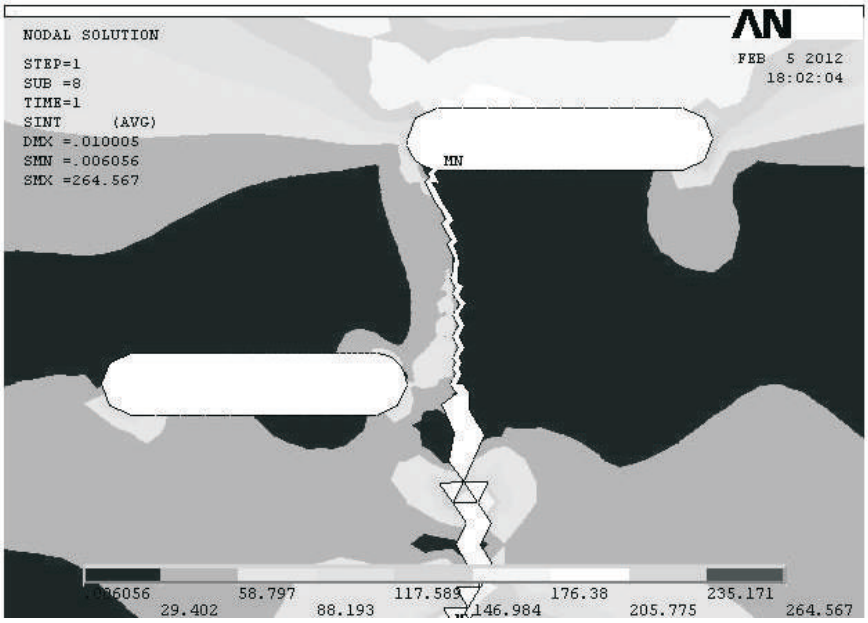

Figure 12 Distribution of reduced stresses according to the maximum shear stress hypothesis in the model studied using the numerical method according to cracks propagation obtained by means of the finite element method

In next pictures another stages in a process of cracking were described. The element, in which stresses exceed the critical value is disappearing, a crack is coming into existence and a new structure is formed. We are repeating calculations again, critical stresses cause destroying the next element still a crack which in consequence will cause the fracture is coming into existence.

Figs 8, 9 and 10 show maps of stress reduced by hypothesis Burzynski (in model of ferritic metallographic section). Stress scale ends at the 284 MPa, all the places where the stress exceeds this value the elements are disappearing.

3. Conclusions

The numerical method, as a modeling method for research, is very well suited to analysis of the formation and propagation of lamellar cracks.

This method makes it possible to determine the stress state not only at a specific point, but also to show the entire stress field. It makes it possible to quickly determine points of stress concentration, and thus potential places for formation and propagation of cracks.

The application of the numerical method is relatively fast and inexpensive. It is also easy to model inclusions, voids, and possible strengthening of the material (e.g. reinforcement).

This method, like every research method, should be used along with other methods, e.g. experimental and numerical.

It is particularly effective to compare test results with results obtained using the finite element method; this is because, using this method, a numerical image of reduced stresses according to the crack propagation.

The metallographic experimental method is very well suited to validation of a numerical model based on the finite element method.

This method makes it possible to determine distribution of reduced stresses according to Huber's hypothesis in the model studied using the metallographic method obtained by means of the finite element method.

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