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# Biaxial elasto-plastic strain-stress state implementation in the case of the simple tension

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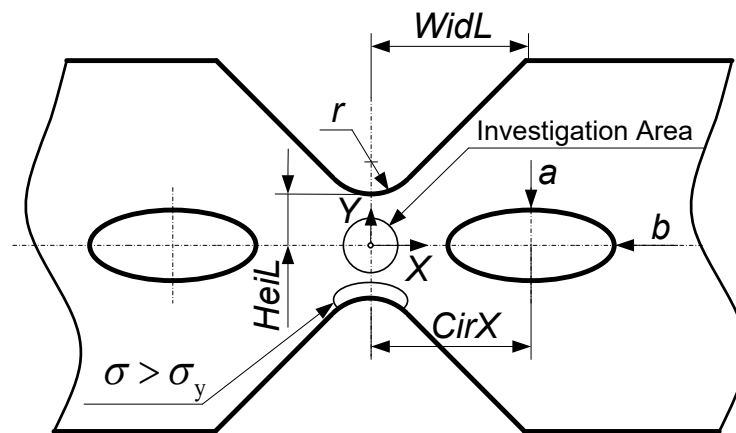
**Abstract.** Biaxial stress state obtaining in the flat tensile specimen is the main subject of this paper. Numerical simulation is the main method of investigation. All calculations were performed in ANSYS. The specimens with different geometry and location of the pairs of raisers stresses are considered. The choices of small plastic strains are shown. The interrelation of actual geometry of the specimen and the shape and size of advanced biaxial area is investigated. The experimental verification of the numerical simulation results is presented.

## 1. Introduction

It is a matter of common knowledge that the thin wall metal constructions are often used in the biaxial stress state operation conditions. The metal durability in this case is different from the uniaxial loading metal durability. There is no reliable academic failure criterion for plane stress state of metal. For this reason the in situ method of material testing is the best. This method must be based on the direct examination of material properties. Existing testing equipment for biaxial stretching is of the limited availability and very expensive. The unique specimen designing is another tentative solution of the above mentioned problem.

There are many researchers who designed special specimens for simple tension in the recent years [1-5 et al.]. As a rule the plane stress state in these specimens was formed due the stress raisers location. In some cases the specimen elastic strain-stress state displayed the state that take place in the tube, i.e. situation with principal stresses ratio close to 0.5 [5]. The general form of these specimens is shown in figure 1. The desired results are obtained due to corresponding geometry and location of the two symmetrical pairs of stress raisers. It must be emphasized that all results were obtained for the elastic loading zone. At the same time we must realize that in some case the actual stress level may be larger than flow point, as it is shown in figure 1.





**Figure 1.** Specimen geometry and advanced strain area.

The main goal of this article is to obtain the specimen, which will represent two-dimensional stress state under the conditions of small elasto-plastic deformations.

## 2. Method and material

Numerical simulation method was offered as a prime tool for task solution. Numerical experiment was conducted under ANSYS [7, 8]. PLANE182 four node finite elements were used. There were two degrees of freedom in each mode. Five millimeters steel 20 plates were used for numerical simulation and experimental verification. The yield stress of this steel was 320 MPa. For every specimen configuration the principal stress ratio fields were plotted (figure 3).

Variation of shape and size of the stress raisers was performed as specified in the articles [4, 5].  $HeiL, WidL, CirX, r, a, b$ : are the main varying parameters (figure 1).

## 3. Results and discussion

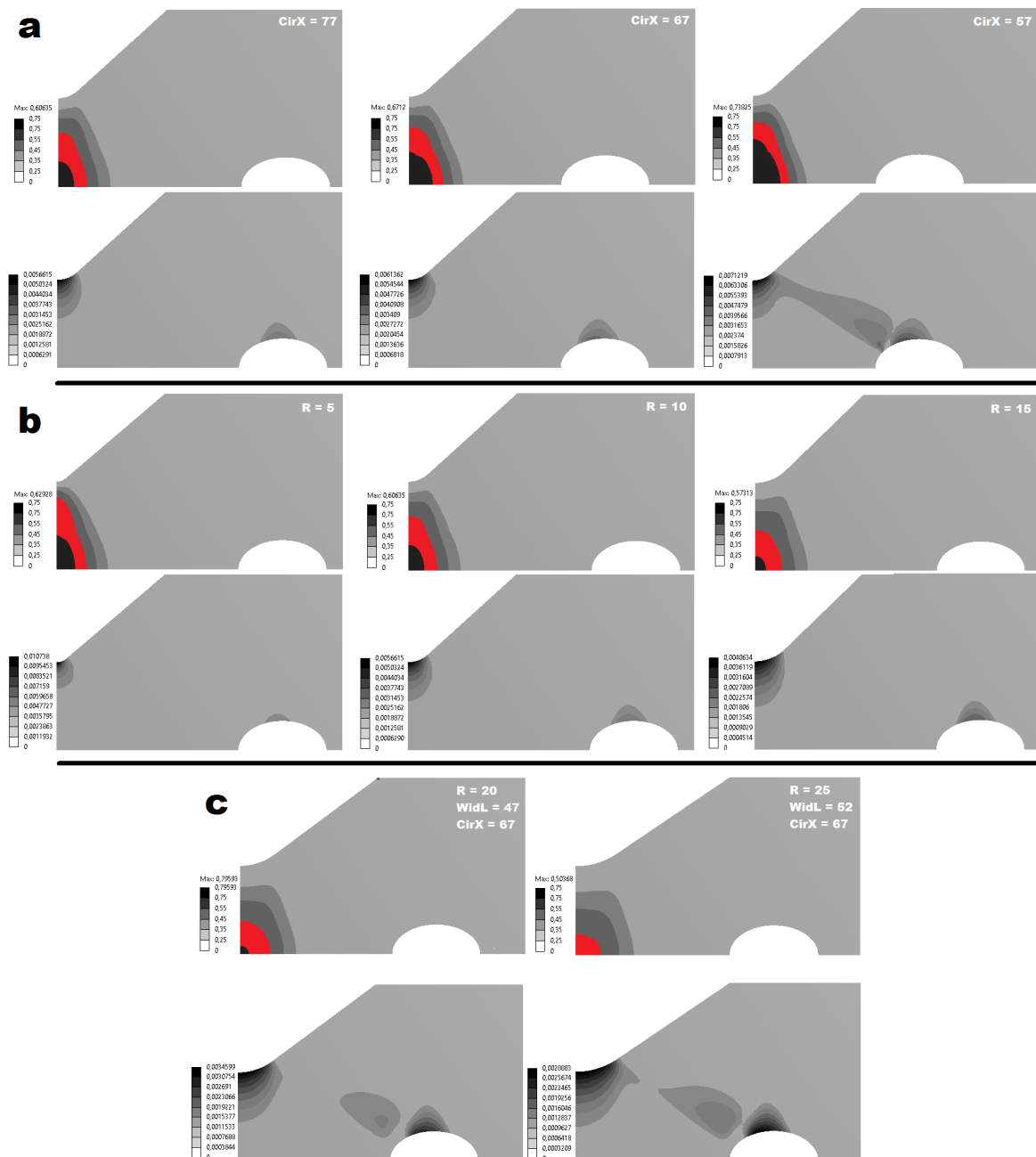
As it appears from the results of simulation the distance between U-shape and elliptical stress raiser has the greatest effect on the forming of ratio=0.5 area (Figure 2). The shape of distribution of the second principle stress does not depend on the specimen geometry. Redistribution of stresses in passing from elastic to plastic deformation depends on the first principle stresses distribution.

Let us consider the influence of different specimen parameters. The advanced plane area (one where principle stresses ratio is close to 0.5) is contracted and moved from the centre of specimen in the case of decreasing of the distance between specimen and elliptical cut centre. The plastic deformations are reformed and concentrated along the line, which connects stress raiser peaks. The value of the plastic strain is increased from 0.5% to 0.7%.

The U-cut radius rounding from 5 mm to 15 mm is modifies the distance between raisers as well as reformation of plastic strains in centre part of specimen and in the elliptical raiser pick area. Plastic deformation is decreased from 1% to 0.5% in the U-cut peak.

Mutual increasing of  $WidL$  and  $R$  from 47 mm to 52 and from 20 mm to 25 mm respectively at a constant  $CirX$  (67mm) leads to reducing the inter raiser distance. The strains are collected along the line that connects raiser peaks. Simultaneously the maximum plastic deformation is decreased from 0.35% to 0.29%. The advanced biaxial area is drifted to the centre and reduced. Providing that the inter raiser distance is going on to decrease the area with principle stress ratio close to 0.5 disappears.

It has been argued that plastic strains redistribution and radical changes of plane state of the centre part of specimen occurs when distance between stress raisers approaching the half of specimen width.



**Figure 2.** Biaxial stress-strain area (in red) and elastic strain in the different geometry specimens

#### 4. Experimental verification

To confirm the results of simulation the set of natural experiments was performed. In-situ method of strain measurement was used (Figure 3). Rosette-type strain gages were arranged on the both sides of the spacemen that to minimize the bend effect in view of inaccuracies of specimen positioning.



**Figure 3.** Test specimen.

The test specimens were loaded up to the 50 kN with step of 500 N. Measurement average deformations v.s. step of loading were:  $\varepsilon_1 = 20.31$ ,  $\varepsilon_2 = 7.23$ ,  $\varepsilon_3 = 10.23$ . Then the principle stress ratio is:

$$\frac{\sigma_1}{\sigma_2} = \frac{\varepsilon_1 + \mu \varepsilon_2}{\varepsilon_2 + \mu \varepsilon_1} \quad (1)$$

With respect to the obtained results, the principal stresses and proper ratio value are:

$$\sigma_1 = 305.69 \text{ MPa}, \sigma_2 = 167.98 \text{ MPa}, \quad (2)$$

$$k = \frac{\sigma_2}{\sigma_1} = 0.55 \quad (3)$$

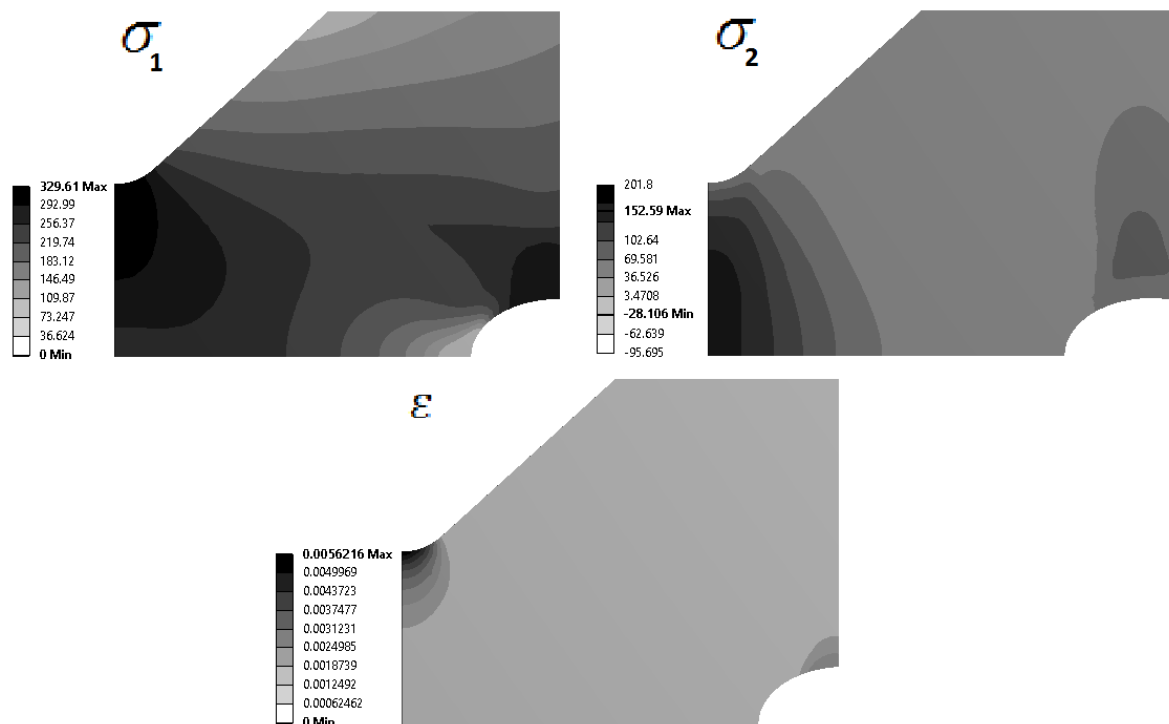
The principle stresses and plastic strains distributions are presented in Figure 4. These results were obtained as results of numerical simulation. Two principle stresses and their ratio are:

$$\sigma_1 = 329.61 \text{ MPa}, \sigma_2 = 152.59 \text{ MPa}, \quad (4)$$

$$k = \frac{\sigma_2}{\sigma_1} = 0.46 \quad (5)$$

## 5. Conclusion

1. On the advanced the biaxial stress area with plastic strains or without, difference tensile specimen geometry is needed.
2. In the case of small plastic deformation such tensile specimens are required that the ratio between two stress raisers to specimen width will be less than 0.5.



**Figure 4.** First, second principal stresses and plastic strain in test specimen.

## References

- [1] Lyapichev D M 2015 Ocenka vliyaniya napryazhyonnogo sostoyaniya podzemnyh gazoprovodov na ih stojkost' k korrozionnomu rastreskivaniyu *PhD thesis* Moscow p 146
- [2] Podhalyuzin S Z 1986 Razrabotka metodov povysheniya rabotosposobnosti magistral'nyh truboprovodov *PhD thesis* Moscow p 160
- [3] Bellet D, Morel F, Morel A and Lebrun J L 2011 A biaxial fatigue specimen for uniaxial loading. *Int. J. Strain* **47** 227-40
- [4] Tsarkov A V and Pashchenko V V 2016 Chislennoe modelirovanie ispytaniya na prochnost' listovyh obrazcov v usloviyah dvuhosnogo napryazhyonnogo sostoyaniya *Svarka i diagnostika* **6** 11-5
- [5] Tsarkov A V, Pashchenko V V and Zinoveva O I 2014 Issledovanie vliyaniya konzentratoren napryazhenij na NDS v ploskih obrazcah trub pod davleniem *Inzhenernyj vestnik Dona* **4** 10
- [6] Tsarkov A V and Pashchenko V V 2014 Metodika provedeniya chislennykh ehksperimentov pri issledovanii NDS trub pod davleniem *State sci. conf. proc. Prikladnye problemy mekhaniki* pp 160-7
- [7] Chigarev A V, Kravchuk A S and Smalyuk A F 2004 *ANSYS dlya inzhenerov: spravochnoe posobie* (Moscow Mashinostroenie) p 512
- [8] Zienkiewicz O C and Taylor R L 2000 *The Finite Element Method* (Butterworth-Heinemann)