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# SOFTWARE SIMULATION OF RESIDUAL STRESSES IN HIGH FREQUENCY LONGITUDINAL WELDED PIPES

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**Abstract -** This paper presents results obtained via experimental measurements of residual stresses in the cross sections of longitudinal welded pipes. The experiment was carried out in different dimensions and thickness of the pipes where it is noticed that the smaller the diameter of the pipe, the greater the residual stresses because the degree of deformation during the production of pipes with smaller diameter is greater. Residual stresses are measured with strain gages set upon the outside wall of the pipes. The results received from the gages show considering amount of stress captured in the pipe wall because of cold plastic formation process [1]. After cutting the rings, their opening is recorded, which is variable and depends on several parameters such as: ring diameter, thickness, type of material and its reinforcement as well as the degree of plastic deformation when forming the pipe sheath [2]. The difference in the display of the measuring tape when the ring is in the open and closed position is the residual deformation that corresponds to the residual stresses that occurs in the ring.

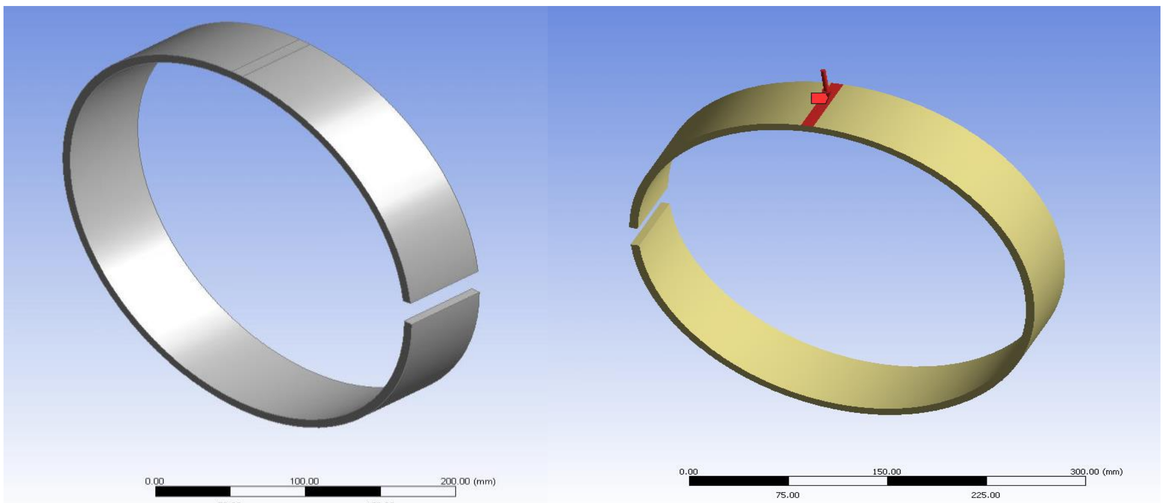
Keywords: residual stresses; longitudinal welded pipes; cold plastic formation; high frequency welding.

## 1. INTRODUKTION

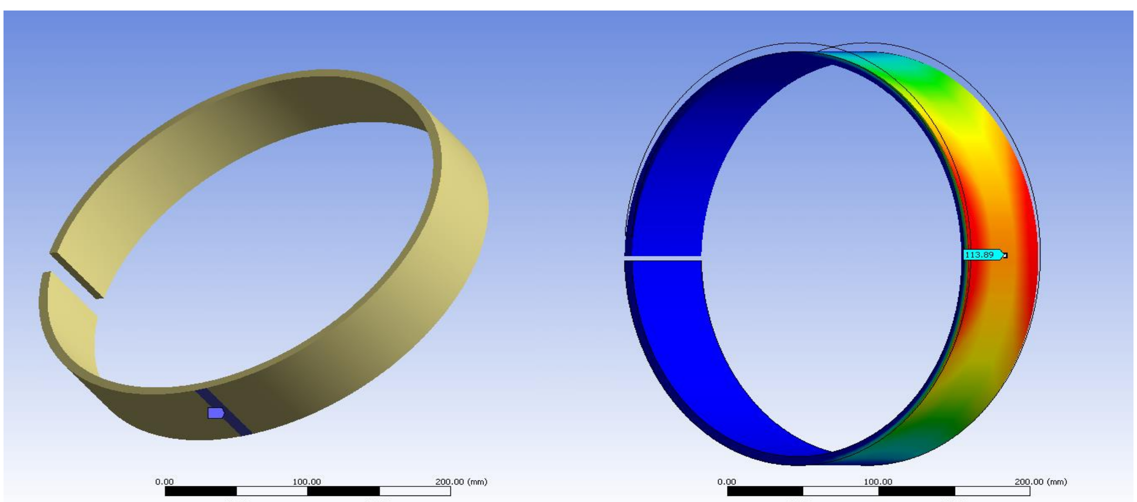
According the results from the experimental investigations, some stages from the production process can be separated as influential over the stress distribution in the final product. Plastic formation process and welding modes play crucial role for defining the technology and the quality of the final product[3]. Basic purpose of the plastic formation is achieving cylindrical shape of the steel sheet that has width equal to the pipe circumference. With longitudinal welding, forming of circumference is completed. Pipe shaping is continuous process. During material forming, material itself experiences elastic and plastic deformations that cause change in the mechanical properties like strengthening. Therefore, the material stress-strain distribution in the pipe cross section is changing significantly from the initial relaxed state[4]. In this paper it is investigated the influence of the plastic formation over the stress-strain distribution in pipe cross section and its influence in the mechanical properties of the final product [5]. Tests are conducted over pipes made of steel J55 API 5CT, H40 API 5CT and S235JRG2 welded with HF-ERW. Computer simulation of rings with the help of ANSYS software [6] was made in order to compare the results obtained with the experimental research of real models of rings separated by tubes of different diameters and thicknesses. Computer models are made according to the actual dimensions of the tested rings. Each of the rings is modeled individually, taking into account all the conditions of the tests performed in the laboratory. The computer models of the rings are loaded with forces measured during the tests. Computer simulation gave model that most accurately describes the stress-strain distribution [7]. Test samples are cut from random chosen pipes that are made in factory IMK-Uroshevac.

## 2. SOFTWARE SIMULATION OF RESIDUAL STRESSES AND STRAINS

In order to compare the obtained results with experimental research of real models of rings separated by pipes, a computer simulation of rings was performed with the help of ANSIS software. Computer models are made according to the actual dimensions of the tested rings. Each of the rings is modeled individually, taking into account all the test conditions performed in the laboratory. Computer models of rings are loaded with forces determined by tests (Table 1.). The following figure shows the load pattern and layout of the computer ring model [7].




a) model of the cut ring b) load of the ring from above




a) ring lowering b) deformed ring condition

Fig.1. Appearance of the computer model of the broken ring

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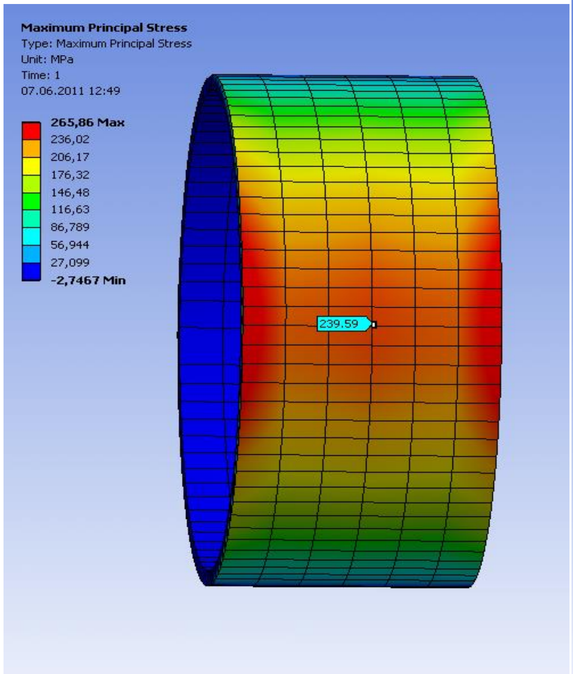
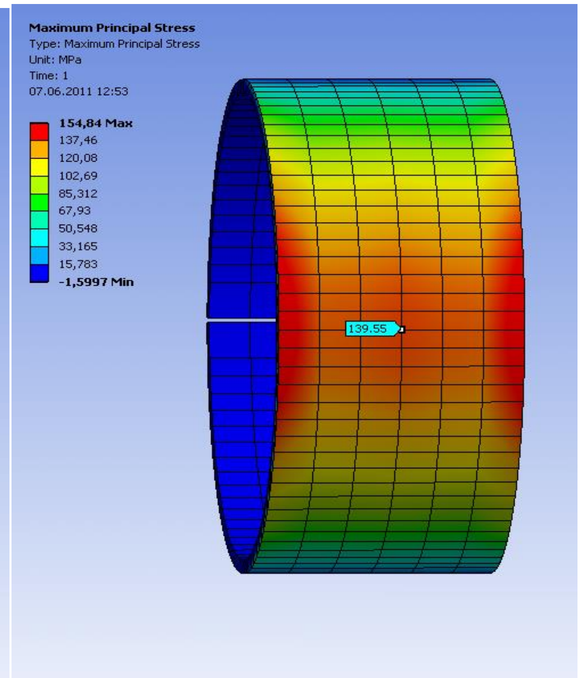
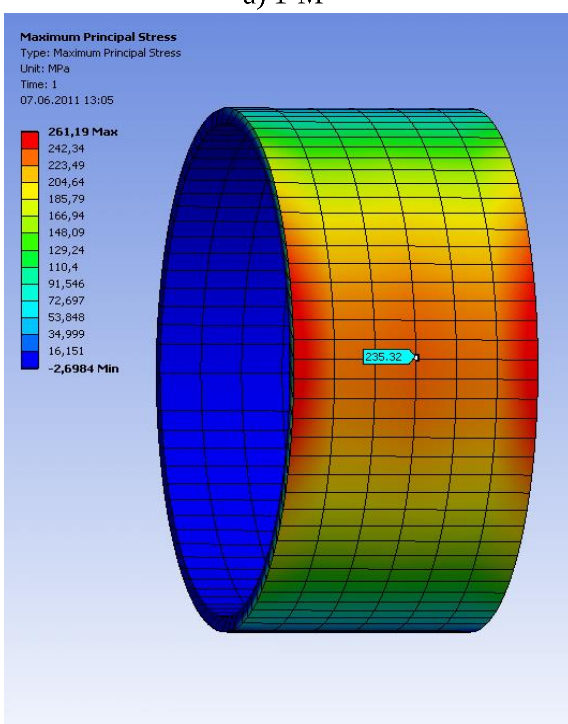
In addition, the stresess results for all tested rings are given through the figures.



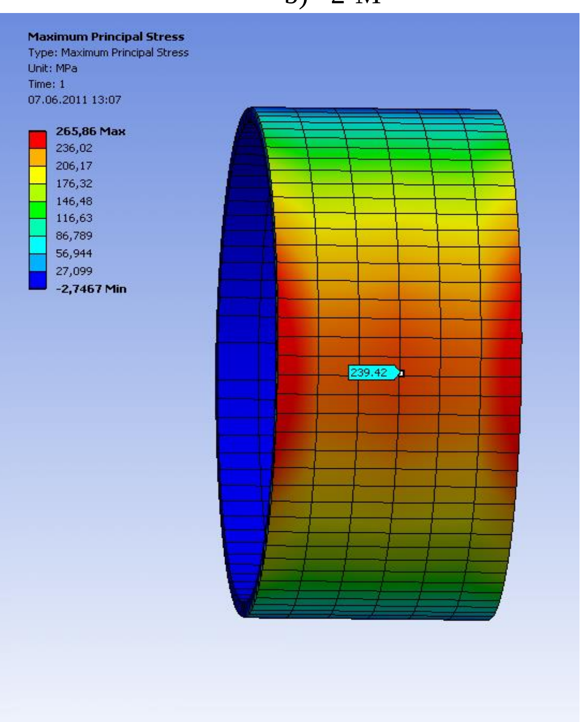

a) 1-M




b) 2-M

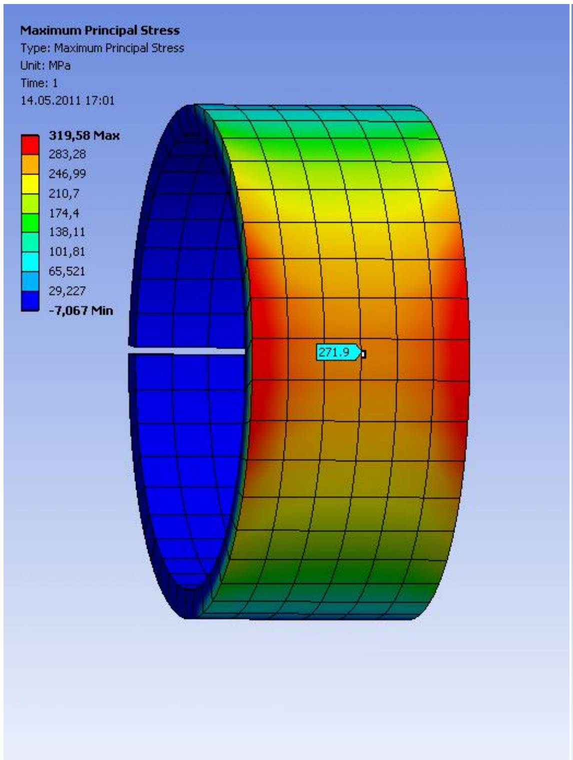



a) 1-V

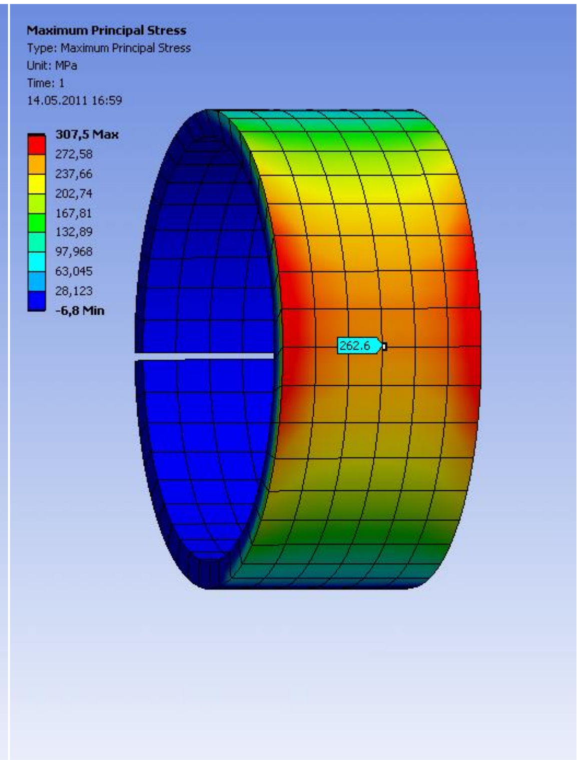



b) 2-V

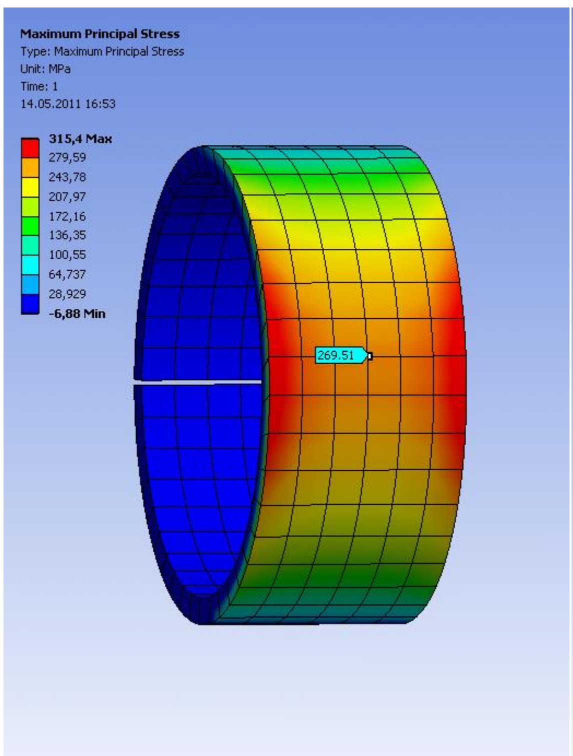
Fig.2 Rings Ø139,7×4,0 mm



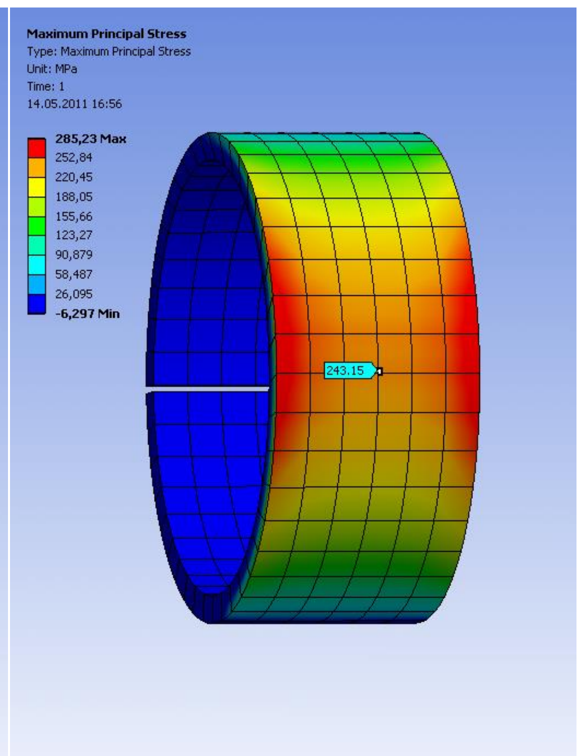

a) 1-V




b) 2-V

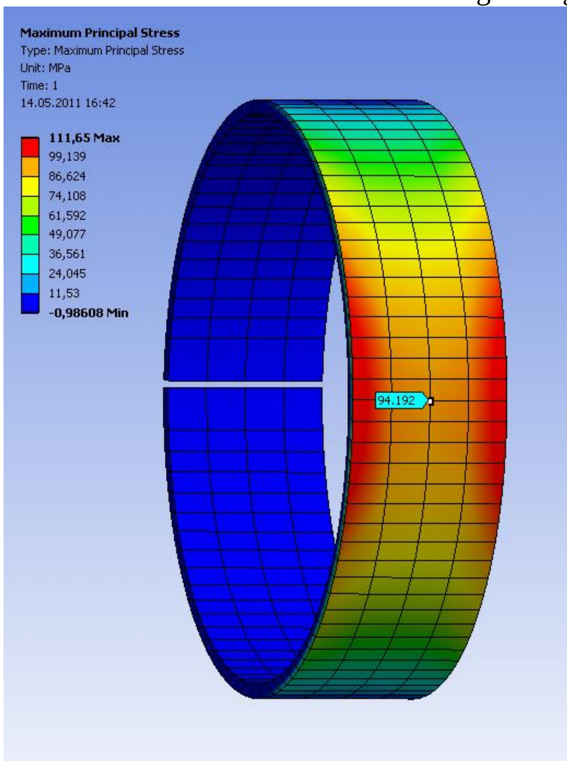



c) 3-M

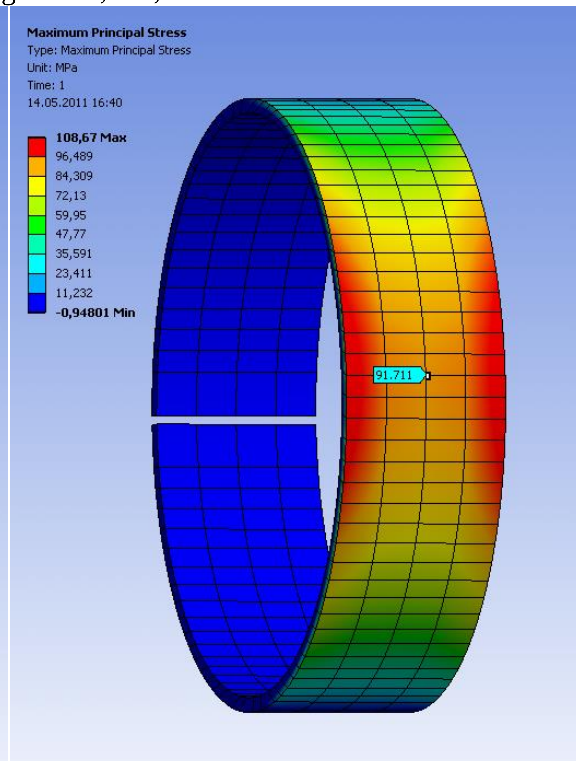



d) 4-M

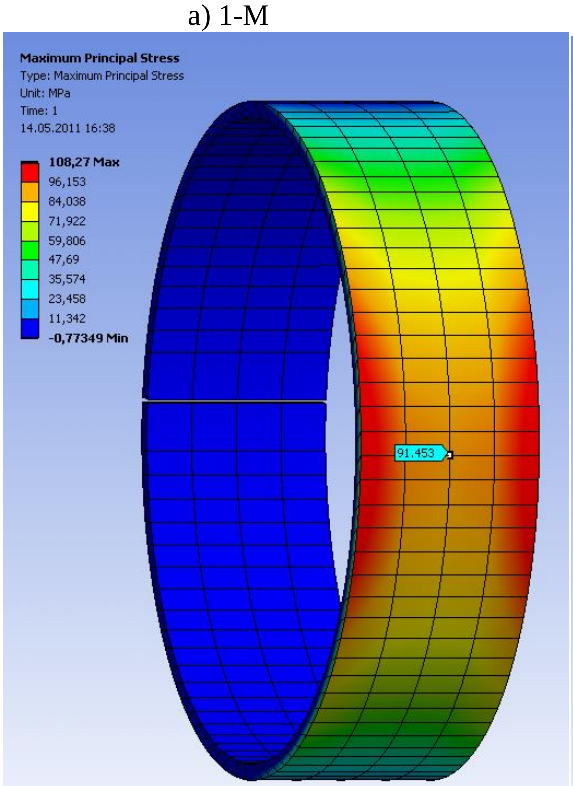
Fig.3 Rings Ø139,7×7,72 mm



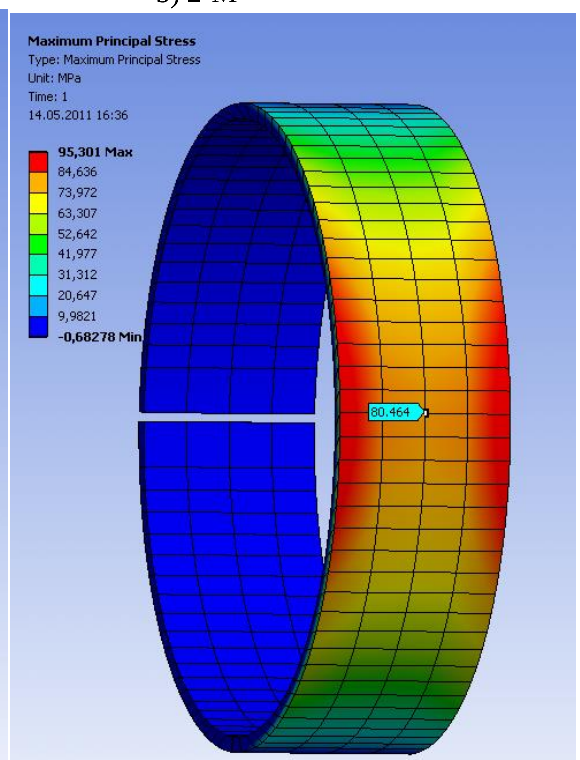

a) 1-M




b) 2-M




c) 3-V




d) 4-V

Fig. 4 Rings Ø219,1×5,0 mm

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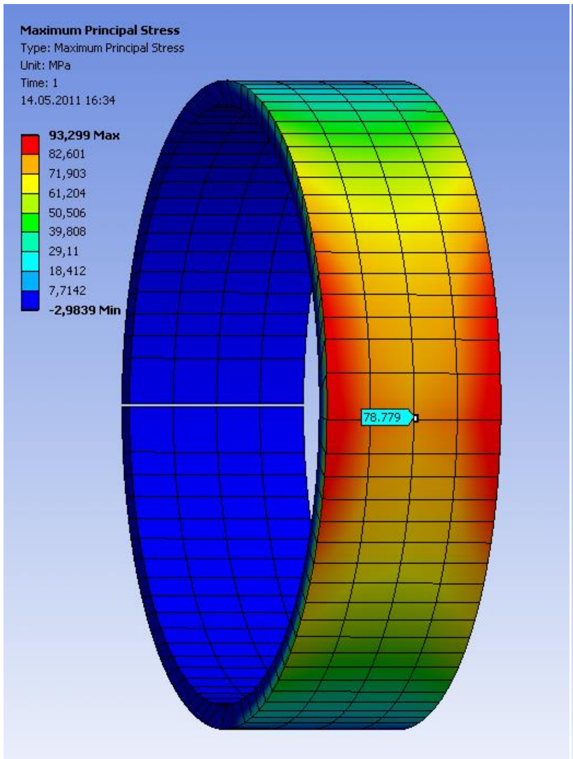
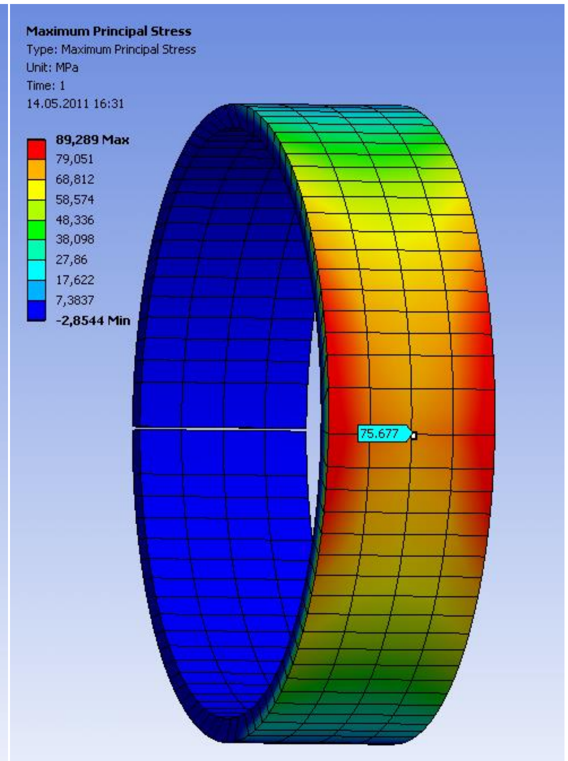
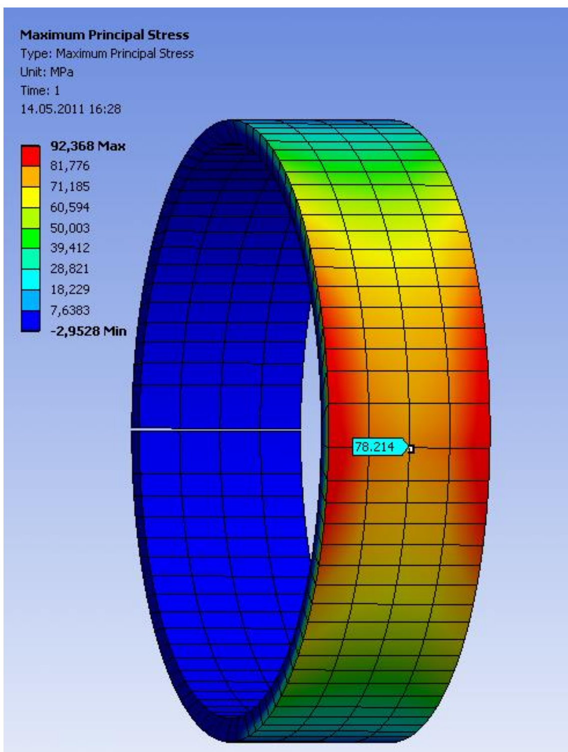


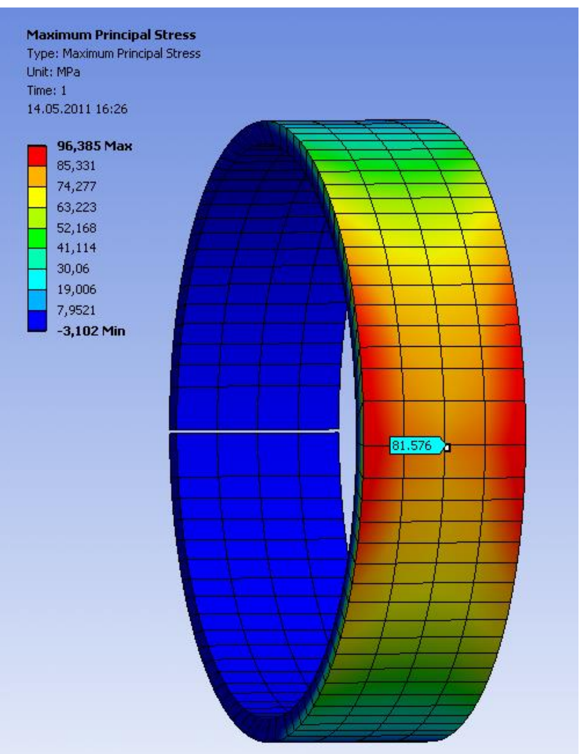

a) 5-V




b) 6-V

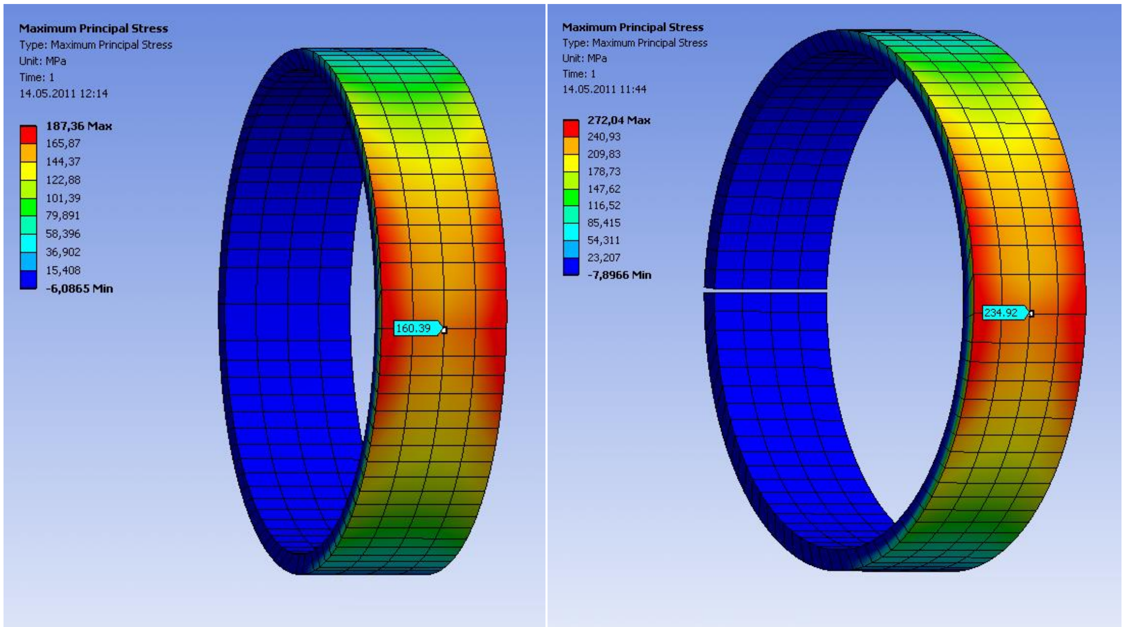



a) 7-M

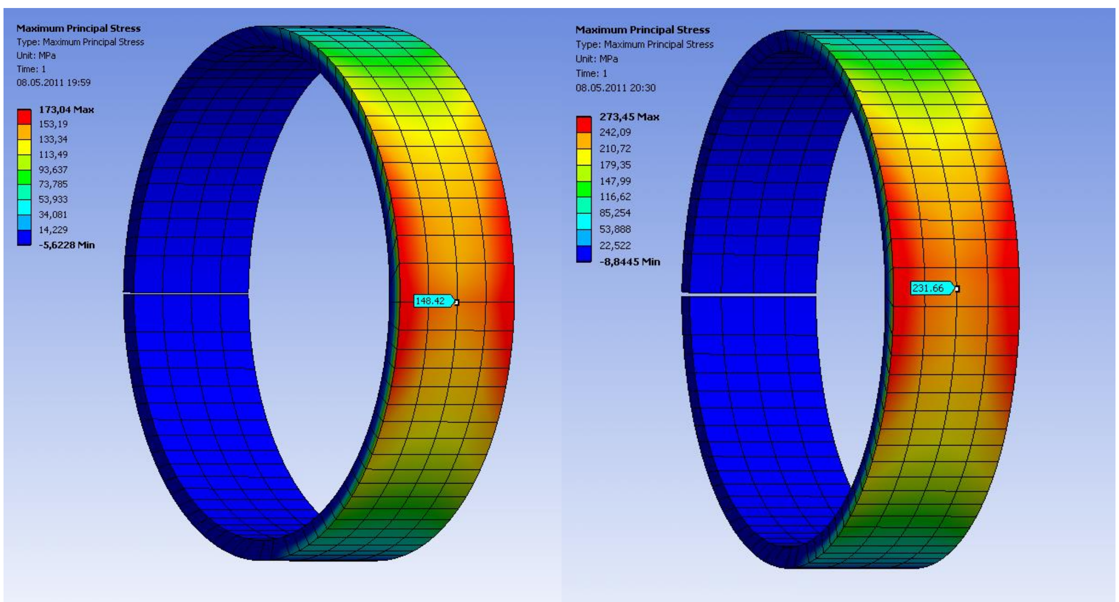



b) 8-M

Fig.5 Rings Ø219,1× 8,0 mm

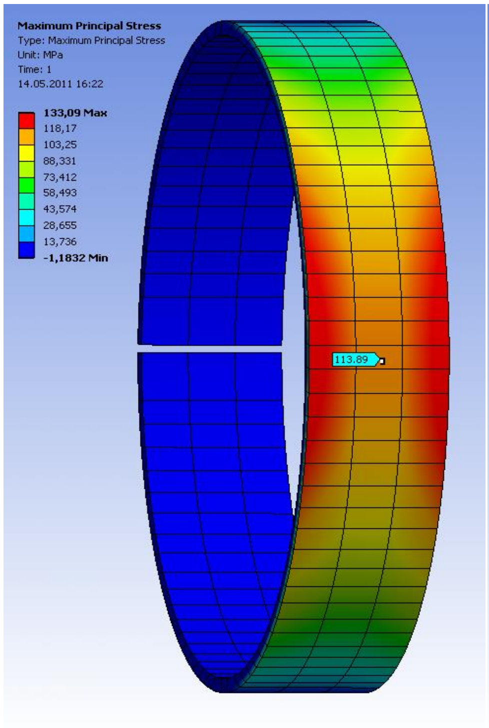



a) 1-V b) 2-M

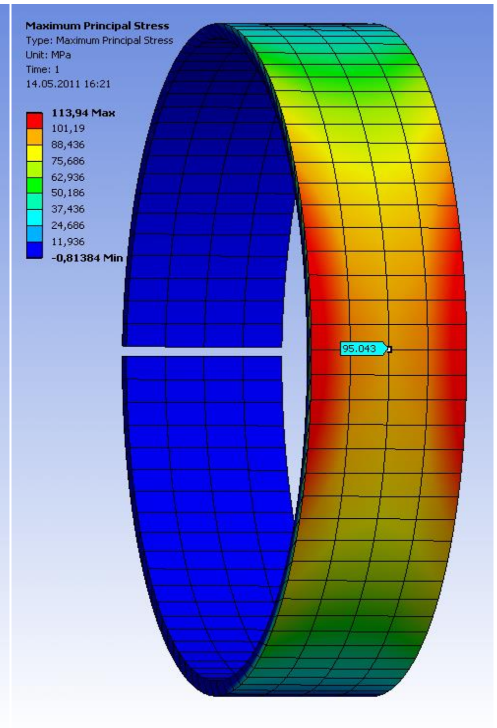



c) 3-V d) 4-M

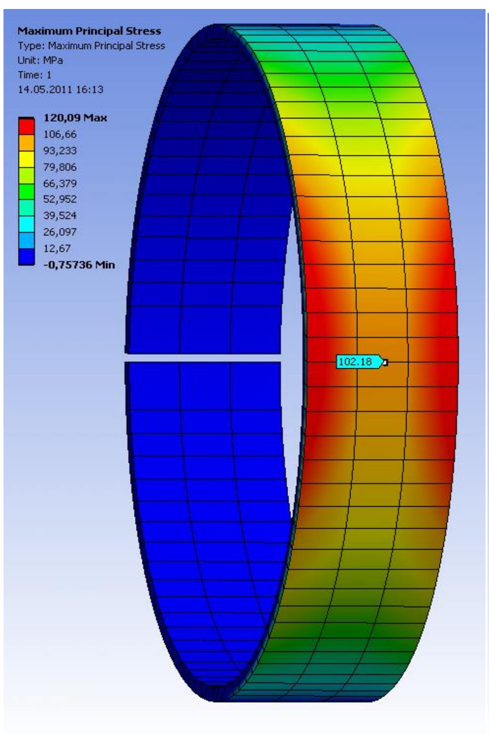
Fig.6 Rings Ø244,5×8,94 mm



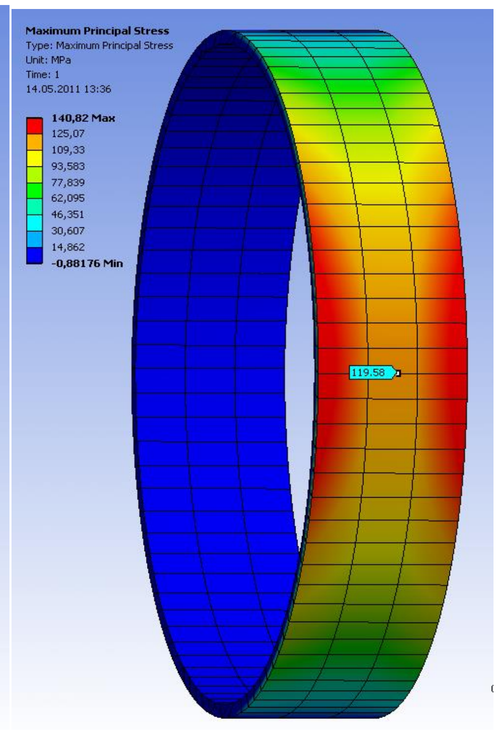

a) 1-M




b) 2-M

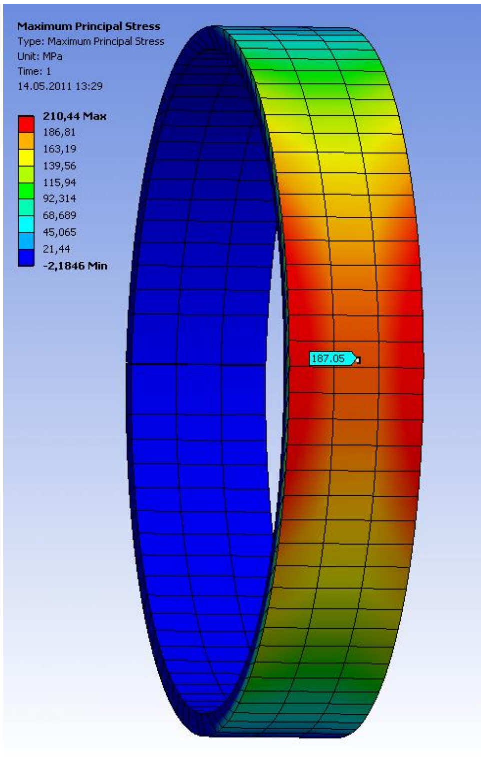


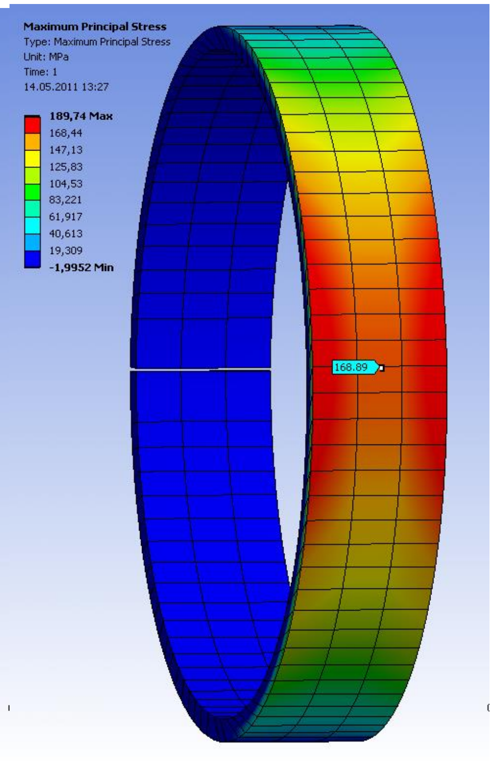

d) 3-V



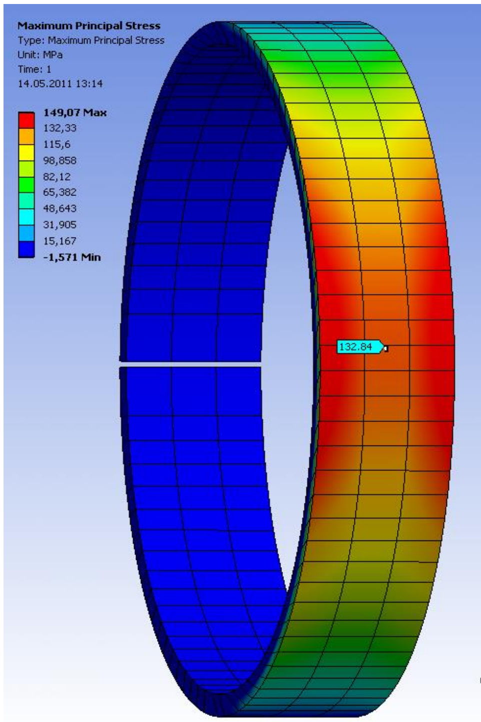

e) 4-V

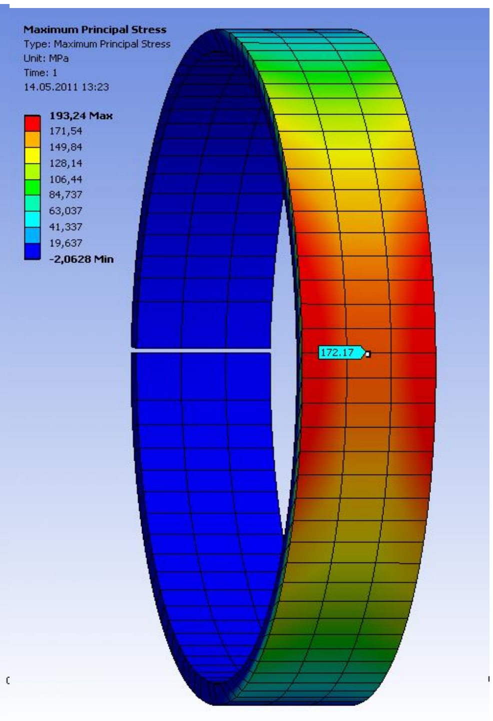
Fig.7 Rings Ø323,9×7,10 mm




a) 5-V b) 6-V




e) 7-M g) 8-M

Fig.8 Rings Ø323,9×10,0 mm

Table 1. Values of derived stresess computer simulations of rings

| Ring designation | Ring wall thickness t (mm) | Diameter of open ring D (mm) | Gap (mm) | Measuring residual stresses (Mpa) | Stresses obtained from computer simulation (Mpa) |
|---|---|---|---|---|---|
| | | | | | |
| 139,7 - 1M | 4,0 | 142,3 | 6,9 | 159,6 | 135,6 |
| 139,7 - 2M | 3,8 | 141,6 | 7,7 | 167,2 | 139,6 |
| 139,7 - 3V | 4,1 | 143,2 | 9,7 | 273,8 | 235,3 |
| 139,7 - 4V | 3,7 | 143,0 | 10,3 | 269,8 | 239,4 |
| 139,7 - 1V | 8,0 | 142,5 | 6,5 | 242,8 | 271,9 |
| 139,7 - 2V | 8,0 | 142,5 | 5,4 | 226,2 | 262,6 |
| 139,7 - 3M | 8,0 | 142,2 | 5,6 | 249,2 | 269,5 |
| 139,7 - 4M | 8,0 | 142,2 | 5,4 | 232,6 | 243,1 |
| | | | | | |
| 219,1 - 1M | 5,3 | 224,7 | 9,5 | 107,6 | 94,2 |
| 219,1 - 2M | 5,4 | 222,9 | 9,2 | 110,6 | 91,7 |
| 219,1 - 3V | 5,1 | 222,9 | 7,6 | 94,8 | 91,5 |
| 219,1 - 4V | 5,2 | 223,1 | 8,3 | 94,8 | 80,6 |
| 219,1 - 5V | 8,1 | 221,3 | 3,6 | 70,8 | 78,8 |
| 219,1 - 6V | 8,2 | 221,5 | 4,0 | 75,4 | 75,7 |
| 219,1 - 7M | 8,1 | 221,5 | 4,2 | 85,8 | 78,2 |
| 219,1 - 8M | 8,2 | 221,5 | 3,9 | 83,2 | 81,6 |
| | | | | | |
| 244,5 - 1V | 9,4 | 250,0 | 9,7 | 141,0 | 160,4 |
| 244,5 - 2M | 9,5 | 251,0 | 14,0 | 233,8 | 234,9 |
| 244,5 - 3V | 9,4 | 247,4 | 8,6 | 128,6 | 148,4 |
| 244,5 - 4M | 9,4 | 251,0 | 14,0 | 228,2 | 231,7 |
| | | | | | |
| 323,9 - 1M | 7,7 | 329,0 | 17,8 | 130,4 | 113,9 |
| 323,9 - 2M | 7,5 | 329,3 | 16,1 | 106,4 | 95,1 |
| 323,9 - 3V | 7,1 | 328,5 | 16,4 | 99,8 | 102,2 |
| 323,9 - 4V | 7,0 | 328,8 | 16,3 | 103,4 | 119,6 |
| 323,9 - 5V | 10,3 | 329,8 | 17,4 | 163,2 | 187,1 |
| 323,9 - 6V | 10,4 | 328,6 | 15,8 | 152,0 | 168,9 |
| 323,9 - 7M | 10,3 | 327,8 | 13,3 | 142,4 | 132,8 |
| 323,9 - 8M | 10,4 | 329,0 | 16,9 | 180,6 | 172,2 |

## 4. CONCLUSIONS

As final conclusions following statements can be given regarding residual stresses in cold formed longitudinal welded pipes:

[1] The results obtained from computer simulations also confirm the adequate selection of samples as well as the conclusions obtained from the analysis of mathematical models.

[2] The cross sections of the cold formed pipes contain captured stresses which are result of deformation and shaping of the plain sheet metal.

[3] This stresses can be measured and they are significant.

[4] Based on the results obtained from the theoretical and experimental work, the relation between residual stresses and level of deformation is clearly defined.

[5] The nature of the residual stresses is clearly from tension character which is easy to understand from opened rings.

[6] Residual stresses are in the range of 70 to 270 MPa which is shown in the Table 1.

[7] The presence of residual stresses can be from significant meaning for applications where pipes are used as constructive load bearing element, or pipes for drilling, which affects their strength.

[8] Residual stresses and deformations are larger in sections with smaller diameter opposite to bigger ones; first one experience more deformation that is causing deformation strengthening.

[9] The purpose of this paper and its results is to contribute in the general knowledge for improving the technology and production process of cold formed pipes.

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