Finite element and experimental analysis of stresses state for circular plates

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Abstract. The paper analyzes the states of stresses that are born in a circular plate with radial ribs placed on one side, under the action of different pressures. The study is done using the finite element method and the experimental method. For this purpose, the value of the stresses for the plate is determined, in case of different solicitations. From the analyzed study we can see the close results that have been obtained.

1. Introduction

Circular or annular plates, of constant or variable thickness, connected with rigidity elements-by casting, bonding or welding-, are met in numerous engineering domains. Radial and/or annular ribs can be disposed symmetrical or not, toward the middle surface of the proper plate.

The engineering ability introduced, to decrease materials consuming, to abase the own weight, to intensify the thermal transfer process, alternative solutions such as: substitute materials (for example composite materials), rigidity by ribs.

The searches had been done to establish the displacements and stresses states at plates rigidified with ribs can be grouped in:

a) Approximate calculus methods of the stresses and displacements states [1,2,3,4,5];

b) Methods which abase the study at behavior of the compound elements: plates and ribs, that are considered with different leaning ways;

c) Calculus methods that abase the structural orthotropic at material orthotropic;

d) Numerical methods [6,7,8,9];

e) Experimental methods [10,11,12].

2. Plate analyze using finite element method

We analyze the plate with ribs, having 32 holes, and geometrical characteristics from figure 1, using finite element method. We consider that the plate is fixed on circumference of the holes for the screws, which clamp this plate by the experimental recipient corp.

We present the calculus variants with finite elements, which are expressed using COSMOSWORKS and ANSYS programs. The plate stresses distribution, at 0, 2 MPa pressure is presented in figure 2. If we use the ANSYS program for the same plate, in the same conditions, we obtain near values of stresses, excepting the values around the holes for the screws, which represent stress concentrating.

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Stresses from figure 3 are obtained at 0, 2 pressure MPa, using a plan which pass through the centers of two exactly contrary holes, which are situated between two neighbor holes.
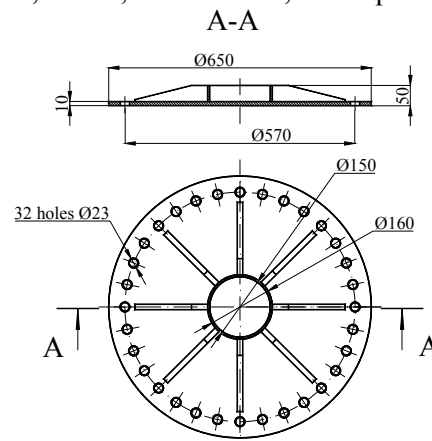Stresses values are given in table 1, both 0, 2 MPa and 0,3 MPa pressure.

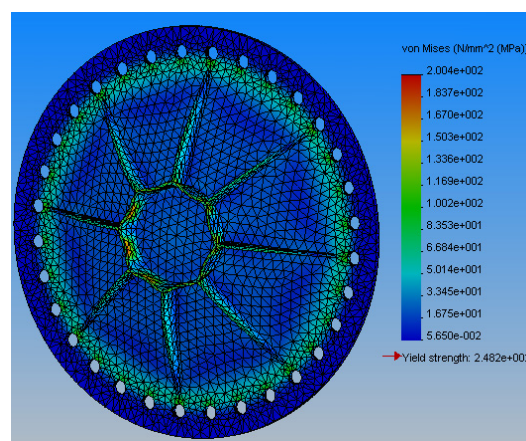**Figure 1.** Geometrical characteristics of the circular plate with ribs

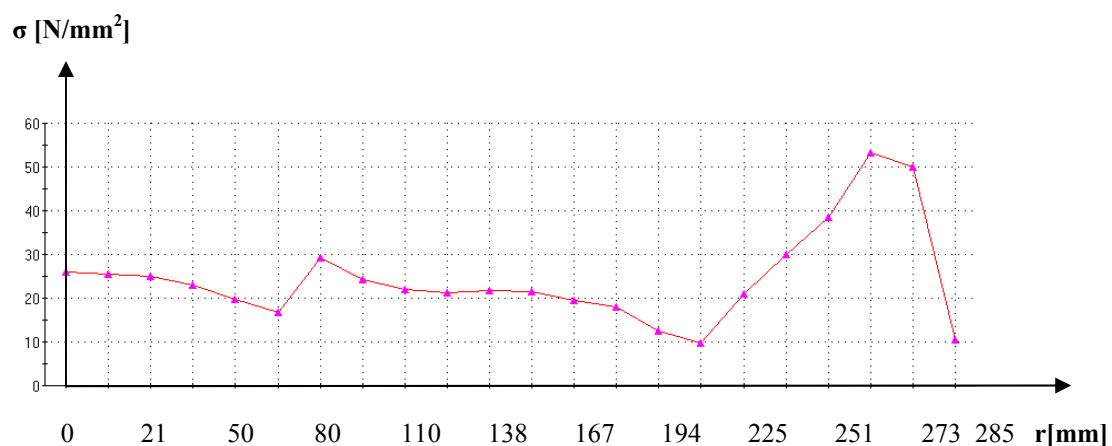**Figure 2:** Stresses of the fixed plate with ribs, at 0,2 MPa pressure, using COSMOSWORKS program

Figure 3. Stresses of the fixed plate with ribs, using a plan which pass through the centers of two exactly contrary holes, which are situated in a median plan between two neighbor holes at 0,2 MPa pressure, using COSMOSWORKS program

Table 1. Stresses σ [N/mm^2] at 0,2 and 0,3 MPa pressures, from the fixed plate with ribs

r [mm]	0	7	21	36	50	66	80	95	110	124
p=0,2 MPa	25,94	25,6	25,01	23,11	19,77	16,76	29,15	24,18	21,98	21,15
p=0,3 MPa	36,92	36,44	35,6	32,89	28,14	23,85	41,5	40,38	31,28	30,11

138	152	167	178	194	211	225	239	251	262	273	285
21,81	21,54	19,47	18,06	12,45	9,661	20,95	32,25	43,73	66,57	91,06	28,6
31,05	30,66	27,72	25,71	17,73	13,75	29,82	45,91	62,24	94,75	129,6	40,71

3. Plate analyze using experimental method

In the experimental case, we take into account the measuring of specific linear deformations of the external points of the plate and calculus of the radial, circumferential and equivalent stresses, in the same conditions, using the strain gauges. The strain gauges which are used, are KM120, with R=120 Ω resistance and K=2,04 ± 2 % elastic constant. The components of the experimental stall are presented in figure 4. The zones where the strain gauges are fixed on the plate are presented in figure 5.

We have been read the radial and circumferential deformations values, both at the increase and the decrease of the pressure, having the values: 0,05; 0,1; 0,15; 0,2; 0,25; 0,3 MPa. We had been realized the processing of the experimental data using Mathematic program, accepting a linear variation, which depend of attempt pressure. So, we had been obtained the figures 6, 7 and 8. We have been obtained the equivalent stresses values, which are represented in the table 2, using the fourth resistance criterion.
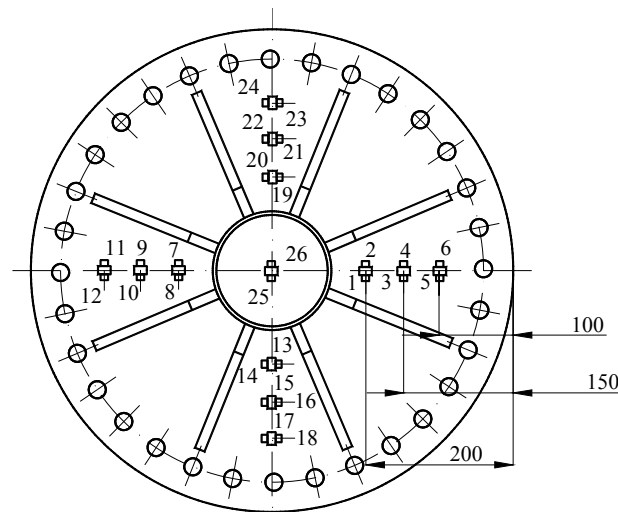

Figure 4. Experimental stall

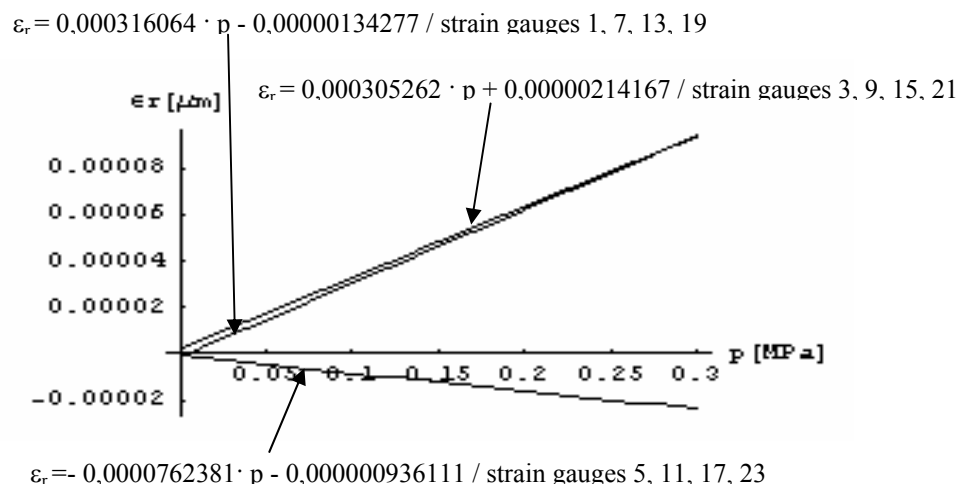**Figure 5.** The position of the strain gauges on the ribbed plate

$\varepsilon_r = 0{,}000316064 \cdot p - 0{,}00000134277$ / strain gauges 1、7、13、19

$\varepsilon_r = 0{,}000305262 \cdot p + 0{,}00000214167$ / strain gauges 3、9、15、21

$\varepsilon_r = -0{,}0000762381 \cdot p - 0{,}000000936111$ / strain gauges 5、11、17、23

Figure 6. The approximation straight lines of the radial linear specific deformations

$\varepsilon_\theta = 0{,}000399667 \cdot p + 0{,}00000132222$ / strain gauges 2、8、14、20

$\varepsilon_\theta = 0{,}0002885 \cdot p + 0{,}000000255556$ / strain gauges 4、10、16、22

$\varepsilon_\theta = -0{,}000912738 \cdot p - 0{,}00000525$ / strain gauges 6、12、18、24

Figure 7. The approximation straight lines of the circumferential linear specific deformations

$\varepsilon_r = 0{,}000430667 \cdot p + 0{,}0000013$ / strain gauges 25, 26
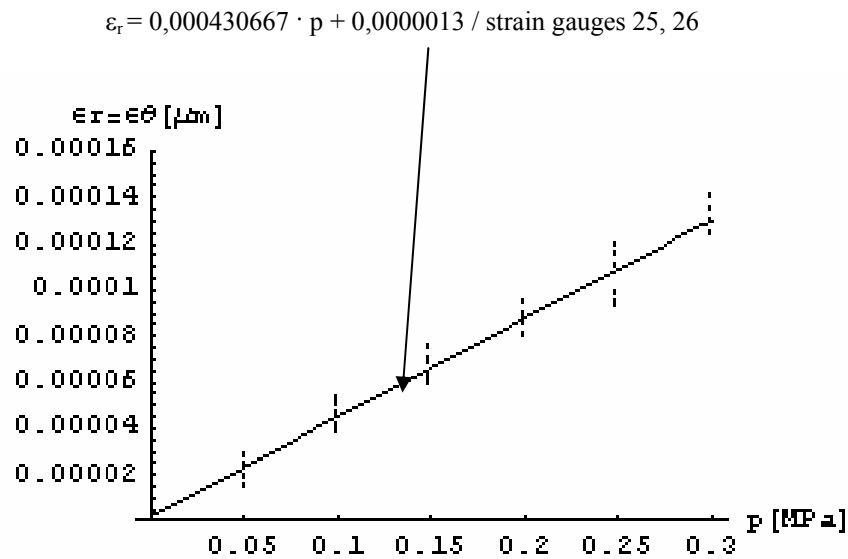
Figure 8. The approximation straight lines of the radial and circumferential specific deformations from the center of the plate.

Table 2. Equivalent stresses $\sigma_e \left(IV \right) \left[N / mm^2 \right]$, deducted on the experimental way

r [mm]	0	125	175	225
$\sigma_e \left(IV \right)$ / **p =0,2 MPa**	26,2	21,6	18,2	38,9
$\sigma_e \left(IV \right)$ / **p =0,3 MPa**	39,2	32,4	27,1	57,7

4. Results comparison

We take into account the deformations, respectively stresses values, which are produced in different points of the plate. The stresses distribution, showed in figures 9 and 10 are obtained, in the median field between two ribs, using the finite elements method (MEF) and the experimental method (ME).
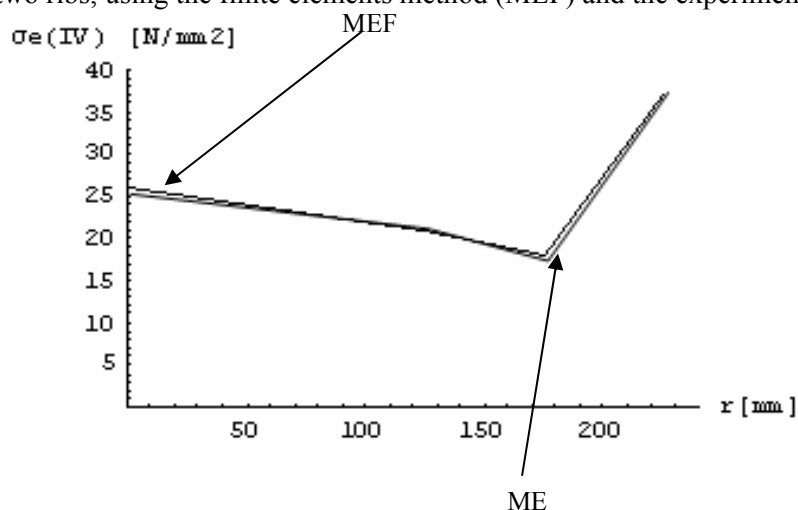
Figure 9. The values variation of the equivalent stresses, calculated on the basis of the fourth resistance theory, for the experimental ribbed plate, in median field which is situated between two consecutive ribs and 0,2 MPa pressure, using MEF and ME methods

ME

σe(IV) [N/mm2]

MEF

Figure 10. The values variation of the equivalent stresses, calculated on the basis of the fourth resistance theory, for the experimental ribbed plate, in median field which is situated between two consecutive ribs and 0,3 MPa pressure, using MEF and ME methods
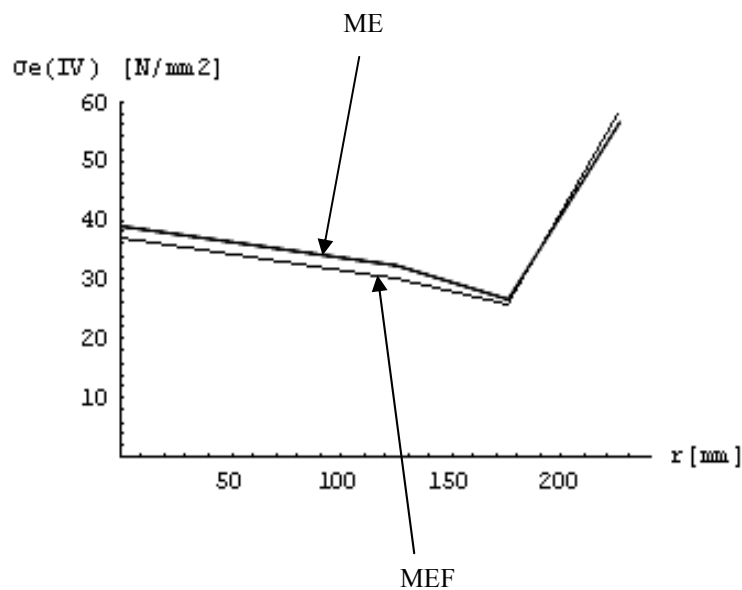
We have been observed for the obtained stresses with the two methods. If we calculate the deviations between the two methods, using the formula $\Delta = \dfrac{\sigma_{ME} - \sigma_{MEF}}{\sigma_{ME}}$, we obtain values which are situated between 7,7÷7,9.

5. References

[1]   Timoshenko S, Woinowsky-Krieger S, *Theory of plates and shells,* McGraw Hill Education, 2010

[2]   Vanam B, Rajyalakshmi M, Inala R, *Static analysis of an isotropic rectangular plate using finite element analysis (FEA)*, Journal of Mechanical Engineering Research, Vol. 4, 2012, pp. 148-162

[3]   Mekalke G, Kavade M, Deshpande S, Analysis *of a plate with a circular hole by FEM,* Journal of Mechanical and Civil Engineering, 2012, pp.25-30.

[4]   Wang Y, Rongqiao X, Haojiang D, *Threedimensional solution of axisymmetric bending of functionally graded circular plates*, Elsevier Composite Structures 92, 2010, pp.1683–1693

[5]   Sukla B, *The FEM analysis on circular stiffened plates using ANSYS,* Bachelor of Technology diss., National Institute of Technology, Rourkela, 2009

[6]   Meghare T, Jadhav P, *A simple higher order theory for bending analysis of steel beams*, International Journal of Civil Engineering, volume 2, Issue 4, 2015, pp-31-38

[7]   Manzoor S, Vinay G, *A Study on Composite Steel Tubes*, International Journal of Civil Engineering, EFES, 2015

[8]   Gujar P, Ladhane K, *Bending Analysis of Simply Supported and Clamped Circular Plate*, International Journal of Civil Engineering, Volume 2, Issue 5, pp. 69-75, 2015

[9]   Popa C, *Solicitation states at circular plates,* Modelling and optimization in the machines building field, Bacau, 2004, vol I, MOCM 10, pp. 263-268

[10]   Popa C, *Displacement analyze for circular plates,* Al III-lea Simpozion International "Mecatronica, Microtehnologii si Materiale Noi", Targoviste, 2006

[11]   Constantin Alexandrina Mihaela ,*Theoretical concepts for physical preparation of athletes*, Scientific Journal of Education, Sports and Health, No 2 Supplement,vol. XVII, ISSN 2344 – 5645, ISSN-L 1453-0201,2016.

[12]   Cursaru D, Neagu M, Bogatu L, *Investigations on the Oxidation Stability of Biodiesel Synthesized from Different Vegetable Oils* Revista de chimie 64(4) pp 438-441, 2013.