ANALELE UNIVERSITĂȚII
"EFTIMIE MURGU" REȘIȚA
ANUL XIII, NR. 1, 2006, ISSN 1453 - 7397

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Numerical Simulation with Finite Element Method of the Plate with Concentrator

The paper compares calculus made by Cosmos M Design Star software with classical and statistical calculus for a plate with concentrator.

Stress concentrator around round groove of the plate

The dimensions of the analysed plate are presented in figure 1 and 2. The two round groove is the geometry which will generate the stress concentrator. The maximal stress will appear in B and C points.

For tensile process of the plate with P force, figure 1, the maximal stress value from B and C points will be expressed as:

$$\sigma_{\max} = \alpha_k \cdot \sigma_n \tag{1}$$

where the values of α_k coefficient are experimental determined [1] and the σ_n stress is expressed by:

$$\sigma_n = \frac{P}{b \cdot h} \tag{2}$$

For bending process of the plate with M moment, figure 2, the maximal stress value from B and C points will be expressed as::

$$\sigma_{\max} = \alpha_k \cdot \sigma_n \tag{3}$$

where the values of α_k coefficient are theoretical determined [1] and the σ_n stress is expressed by:

$$\sigma_n = \frac{M}{W} \tag{4}$$

and the coefficient of resistance is expressed by:

$$W = \frac{b \cdot h^2}{6} \tag{5}$$

Table 1 and figure 3 present the values of α_k coefficient, as function of r/h ratio, from where it can be seen that the coefficient values are smaller for bending comparative with tensile process of the plate.

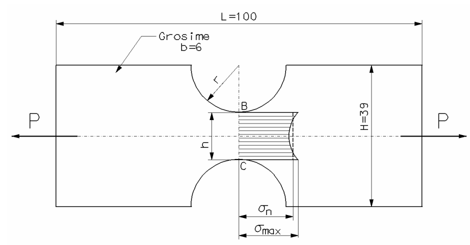

Figure 1. The tensile loads

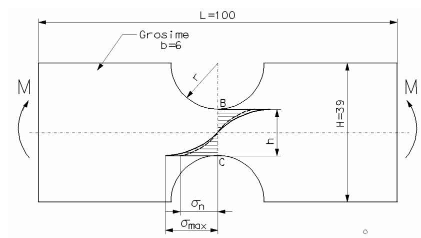

Figure 2. The bending loads

Table 1

The values of coefficient α_k										
Ratio r/h	1	0.9	0.8	0.7	0.6	0.5	0.4	0.3	0.2	0.1
Tensile	1.22	1.26	1.30	1.34	1.41	1.52	1.64	1.80	2.02	2.32
Bending	1.15	1.16	1.17	1.20	1.24	1.29	1.35	1.44	1.58	1.87

With the dimensions L=100 mm, H=39 mm, b=6 mm and the fixed values of the ratio r/h, the h distance is expressed by:

$$h = \frac{H}{1 + 2 \cdot (r/h)} \tag{6}$$

The final dimensions of the plate are presented numerical in table 2 and graphical in figure 4.

Table 2

The geometric dimensions of the plate												
Ratio	r/h	-	1	0.9	0.8	0.7	0.6	0.5	0.4	0.3	0.2	0.1
Distance	h	mm	13	13.93	15	16.25	17.73	19.5	21.67	24.38	27.86	32.5
Radius	r	mm	13	12.54	12	11.38	10.64	9.75	8.67	7.31	5.57	3.25

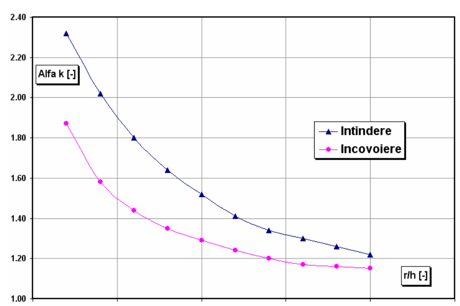

Figure 3. The α_k variation as function of r/h ratio

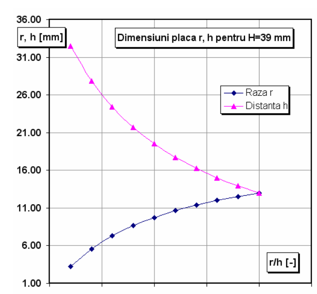

Figure 4. The h and r variation as function of r/h ratio

Numerical simulation with finite elements for tensile process

The numerical simulation of tensile process of the plate with P=6000 N was made for 10 version of the geometry corresponding to the r/h ratio (Table 2).

With **Open** option form **File** menu will be loaded into Cosmos M Design Star [2], [3], the 3D geometry generated with Microstation Modeler [4], figure 1.

There was created 10 linear static analysis study with solid mesh, for 10 values of the r/h ratio. The material selected was Alloy Steel, with the following characteristics: coefficient of elasticity E=2.1 x 10^5 N/mm2 and Poisson's ratio $\nu = 0.3$.

The plate is fixed in the origin, with length in X direction and force P=6000 N will be applied on the opposite side, figure 5. The mesh parameters are presented in table 3 and figure 6 present the mesh of the plate for the ratio r/h=0.8.

Table 3

Ratio r/h	Distance h	Radius r	Number of finite elements	Nodes number	The medium size of finite elements [mm]
1	13.00	13.00	48925	74634	1.3625
0.9	13.93	12.54	48490	74133	1.3675
0.8	15.00	12.00	46.254	70.793	1.373
0.7	16.25	11.38	46567	71282	1.3791
0.6	17.73	10.64	47120	72099	1.3858
0.5	19.50	9.75	46862	71805	1.3931
0.4	21.67	8.67	47355	72602	1.4012
0.3	24.38	7.31	47423	72594	1.4098
0.2	27.86	5.57	46838	71679	1.4186
0.1	32.50	3.25	47119	72076	1.4266

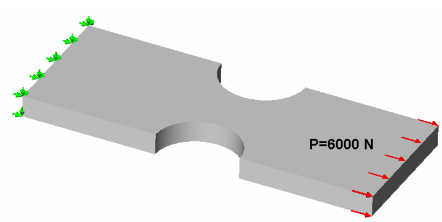

Figure 5. Loads applied to the geometry

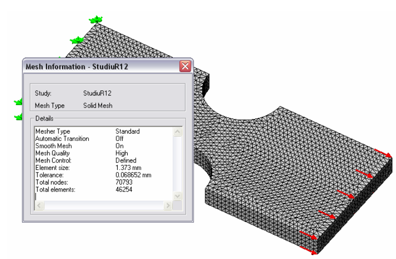

Figure 6. Mesh parameter

The FEM numerical results for tensile process of the plate (Von Mises stress $\sigma_{max\ FEM}$) are presented in table 4, compared with experimental values of α_k coefficient and theoretical values of stress calculated by with 1 and 2 formula.

Table 4

Ratio	Experimental coefficient	Teoretical stress		Tensiune VonMises FEM	Coefficient (FEM)	Procentual deviance
h/r	α_k	σ_n	σ_{max}	$\sigma_{max\,FEM}$	$\alpha_{k\,FEM}$	ε
-	-	MPa	MPa	MPa	-	%
1	1.22	76.92	93.85	100.80	1.31	6.90
0.9	1.26	71.79	90.46	97.39	1.36	7.11
0.8	1.30	66.67	86.67	93.03	1.40	6.84
0.7	1.34	61.54	82.46	89.68	1.46	8.05
0.6	1.41	56.41	79.54	86.32	1.53	7.86
0.5	1.52	51.28	77.95	83.50	1.63	6.65
0.4	1.64	46.15	75.69	81.42	1.76	7.03
0.3	1.80	41.03	73.85	79.94	1.95	7.62
0.2	2.02	35.90	72.51	76.92	2.14	5.73
0.1	2.32	30.77	71.38	77.40	2.52	7.77

The reserved paper space is not enough to show all the graphical results, so will be presented only FEM VonMises stress results for r/h=0.8 and 0.5 ratio, figure 7 and 8. In table 4, the FEM value of α_k FEM coefficient is expressed by:

$$\alpha_{k\,FEM} = \frac{\sigma_{\max FEM}}{\sigma_n} \quad (7)$$

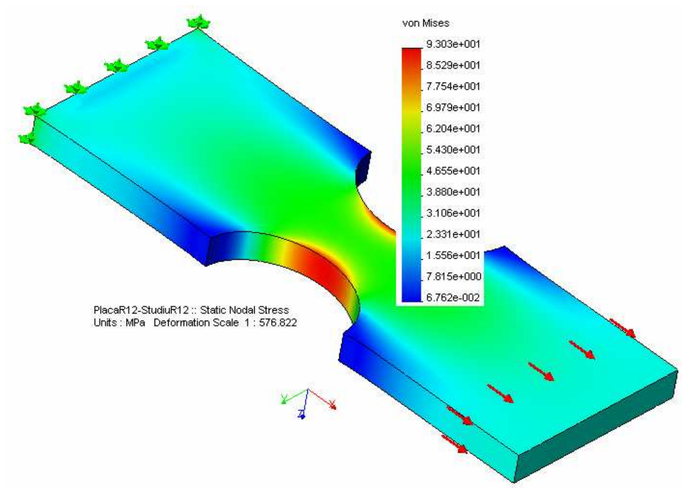

Figure 7. VonMises stress for r/h=0.8 ratio

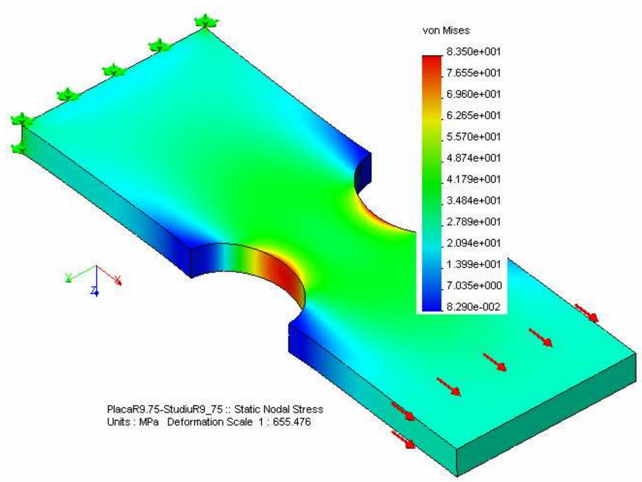

Figure 8. VonMises stress for r/h=0.5 ratio

Figure 9 present the curves of the $\alpha_{k\ FEM}$ coefficient comparative with experimental values. Because the VonMises values form FEM calculus are bigger than theoretical values, the values of α_k FEM coefficient are also bigger comparative with experimental values, for procentual deviance domain 5.73%…8.05%.

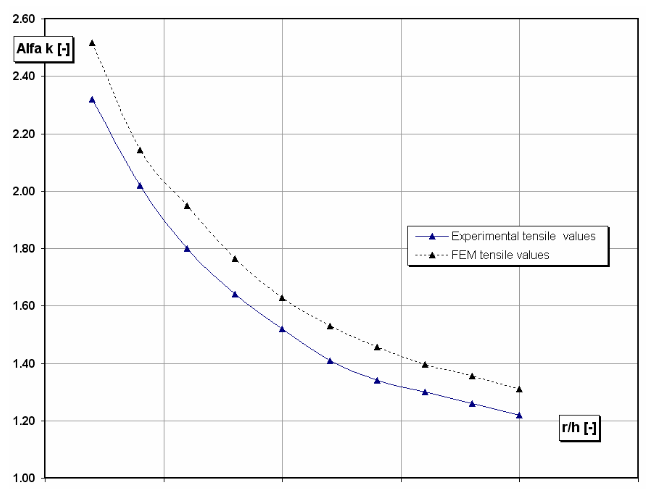

Figure 9. The variation of α_k coefficient for tensile process of the plate

Numerical simulation with finite elements for bending process

The numerical simulation of bending process of the plate was made for 10 version of the geometry corresponding to the r/h ratio (table 2), with force P=250 N, which will generate the bending moment:

$$M = P \cdot L = 250 \cdot 0.1 = 25\ Nm \qquad (8)$$

There was created 10 linear static analysis study with solid mesh, for 10 values of the r/h ratio. The material is the same like the tensile process of the plate.

The plate is fixed in the origin, with length in X direction and the moment M=250 Nm will be applied on the opposite side, figure 10. The mesh parameters are the same presented in table 3.

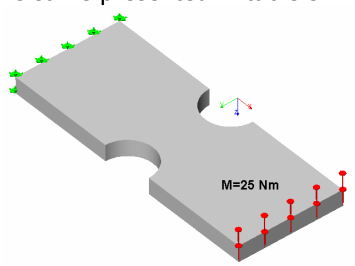

Figure 10. Loads applied to the plate

The FEM numerical results for bending process of the plate (Von Mises stress $\sigma_{max\ FEM}$) are presented in table 5, compared with theoretical values of α_k coefficient and stress calculated by with 3 and 4 formula.

Table 5

Ratio	Experimental coefficient	Teoretical stress		Tensiune VonMises FEM	Coefficient (FEM)	Procentual deviance
h/r	α_k	σ_n	σ_{max}	$\sigma_{max\ FEM}$	$\alpha_{k\ FEM}$	ε
-	-	MPa	MPa	MPa	-	%
1	1.15	147.93	170.12	174.80	1.18	2.68
0.9	1.16	128.86	149.48	156.40	1.21	4.42
0.8	1.17	111.11	130.00	136.10	1.22	4.48
0.7	1.20	94.67	113.61	119.10	1.26	4.61
0.6	1.24	79.55	98.65	102.90	1.29	4.13
0.5	1.29	65.75	84.81	88.32	1.34	3.97
0.4	1.35	53.25	71.89	75.92	1.43	5.30
0.3	1.44	42.08	60.59	65.13	1.55	6.97
0.2	1.58	32.22	50.90	55.00	1.71	7.45
0.1	1.87	23.67	44.26	49.63	2.10	10.82

The reserved paper space is not enough to show all the graphical results, so will be presented only FEM VonMises stress results for r/h=0.7 and 0.4 ratio, figure 11 and 12.

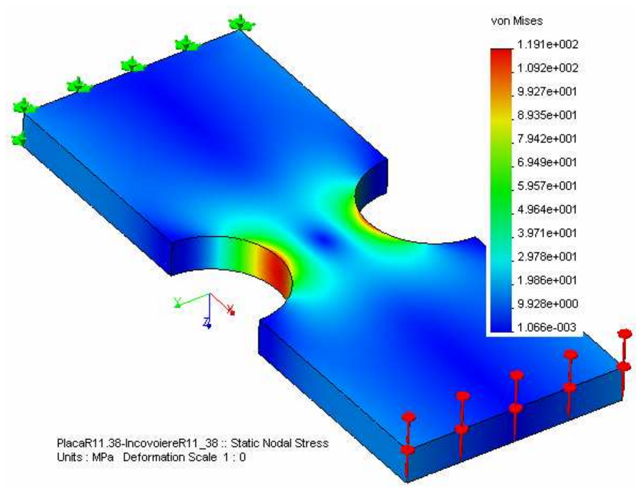

Figure 11. VonMises stress for r/h=0.7 ratio

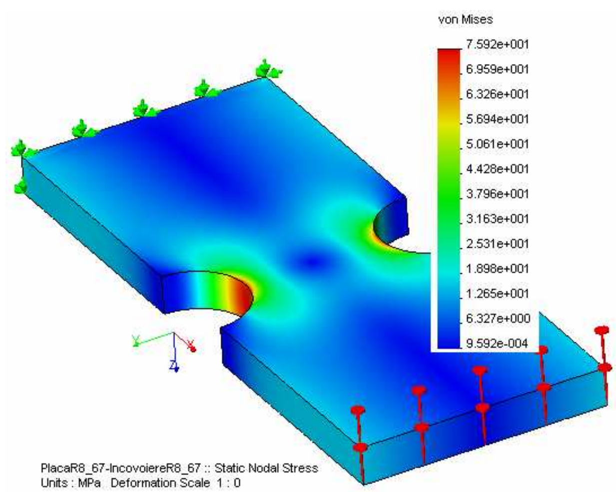

Figure 12. VonMises stress for r/h=0.4 ratio

Figure 13 present the curves of the $\alpha_{k\ FEM}$ coefficient comparative with theoretical values. Because the VonMises values form FEM calculus are bigger than theoretical values, the values of α_k FEM coefficient are also bigger comparative with experimental values, for procentual deviance domain 2.68%…10.82%.

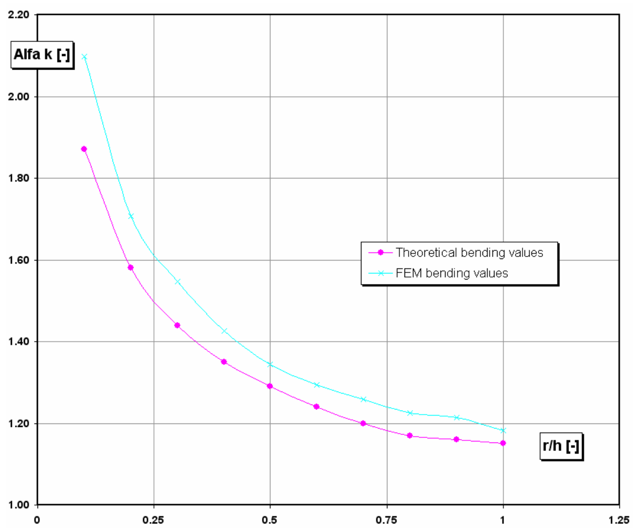

Figure 13. The variation of α_k coefficient for bending process of the plate

Conclusions

From numerical and experimental values results the following conclusions:

- the numerical values calculated with FEM are the same with experimental or theoretical values for the α_k coefficient, in the domain of procentual deviance 5.73%...8.05% for tensile process of the plate and 2.68%...10.82% for bending process of the plate; the values from FEM calculus are slight superior then experimental / theoretical values;
- for both loads type of the plate (tensile and bending) the FEM curves and experimental / theoretical curves of α_k coefficient are similar.

References

[1] Nicolae Posea *Rezistenţa materialelor*. Editura Didactică şi Pedagogică, Bucureşti, 1979.

[2] Tiberiu Ştefan Mănescu, Nedelcu Dorian, *Analiză structurală prin metoda elementului finit*, Editura „Orizonturi Universitare" Timişoara, ISBN 973-638-217-6, Octombrie, 2005.

[3] ******** Design Star *User Guide Reference Manuals*

[4] Dorian Nedelcu *Proiectarea asistată de calculator prin Microstation*, Editura „Eurostampa", Timişoara, ISBN 973-8244-03-X, Aprilie, 2001

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