NUMERICAL STUDY OF THE LOCAL STRESS FOR A CIRCULAR FILLET CORNER

Dorian Nedelcu
“Eftimie Murgu” University Reşiţa

1. INTRODUCTION

The components from the engineering domain include section variation due specific elements (thread holes, grooved wedge, thrust collar, etc.), where the experimental and theoretical studies show local stress with increased values comparative with the calculated stress values by classical resistance formulas. The paper present a numerical study of the local stress for a circular fillet corner with tensile force applied on a rod shaped and comparative results of the numerical and experimental data.

2. THE FILLET CORNER GEOMETRY

The section variation of the fillet corner geometry will generate local stress due to the transition of „D” diameter to „d” diameter and also due to the radius „r” of the rod shaped. The main parameters which influence the value of the local stress are the geometrical ratio „r/d” and „D/d”, figure no. 1.

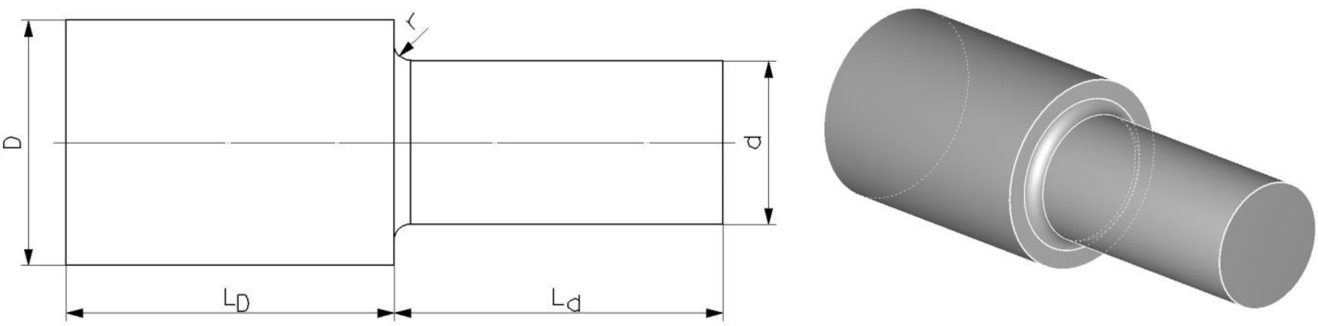

Figure no. 1 The fillet corner geometry of the rod shaped

3. THE EXPERIMENTAL DATA

The value of maximal local stress „σ_{max}” is calculated with the coefficient „α_σ” with formulas:

$$\sigma_{\max} = \alpha_\sigma \cdot \sigma_n \tag{1}$$

where:

$$\sigma_n = \frac{4 \cdot F}{\pi \cdot d^2} \tag{2},$$

and „σ_n” parameter from relation no. (1) is the nominal stress value for the section with „d” diameter, calculated with classical resistance formulas, for tensile force applied.

The experimental studies on the section with the fillet corner geometry where made for elastic regimes and statically loads. For this conditions the material will not influence the local stress value; the main parameters which will influence the local stress value are geometrical parameters of „r/d” and „D/d” ratio. The variation of „α_σ” coefficient as a function of „r/d” ratio for parametrical values of „D/d” ratio is presented in figure no. 2 [1], where it can be observed the increasing influence of the coefficient for increasing values of „D/d” ratio and reduced values of „r/d” ratio.

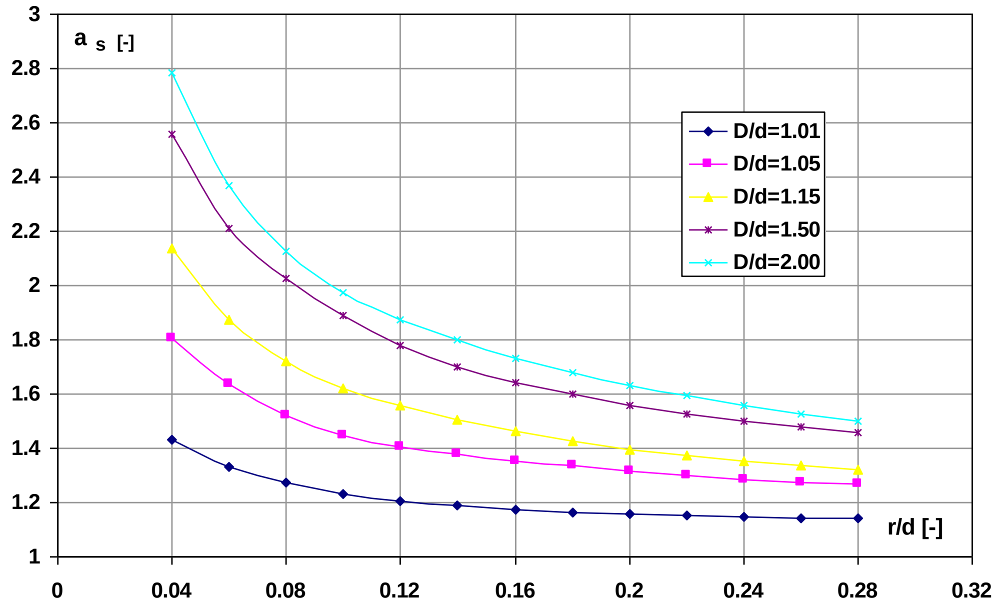

Figure no. 2 The variation of „ασ" coefficient as a function of „r/d" ratio for parametrical values of „D/d" ratio

4. THE STEPS FOR NUMERICAL SIMULATION

The numerical simulation of the stress and deformation for the section with the fillet corner geometry was made with finite element method (FEM), with Cosmos Design Star software [2], [3]. The 3D geometry was generated with CAD software Autodesk Inventor [4].

The steps for numerical simulation are:

- create 3D model with Autodesk Inventor software, for geometrical dimensions of the figure no. 1;
- import 3D model in Design Star;
- define the characteristics of linear static study;
- select the material for 3D model;
- define applied loads and restraints;
- mesh the model;
- running analysis;
- plotting results;
- modify the geometry and running the new study.

5. THE NUMERICAL SIMULATION CONDITIONS

For numerical simulation is imposed the value of the diameter d=30 mm and the length $L_D=l_d$=80 mm. From the following values of the „D/d" ratio: 1.01, 1.05, 1.15, 1.50, 2.00 results the values for „D", diameter: 30.3, 31.5, 34.5, 45, 60 mm. From the following values of the „r/d" ratio: 0.04, 0.08, 0.12, 0.16, 0.2, 0.24, 0.28 results the values for „r" radius: 1.2, 2.4, 3.6, 4.8, 6, 7.2, 8.4 mm. And so will obtain 35 version for fillet corner geometry, for each version is important to calculate with numerical simulation the maximal value of local stress $\sigma_{Von\ Mises}$ for a tensile force F_Z=70700 N applied to the rod shaped.

The rod shaped will be fixed to the origin point with the length on Z direction. The fixed condition consist on 0 values for Z translation, so U_Z=0 condition will be applied, and the force will be applied on the opposite face, figure no. 3.

For mesh there will be chosen parabolic tetrahedral solid elements, each element has 4 nodes and 6 median nodes connected by 6 edges. Every node has 3 degrees of freedom, which are the translations corresponding to the three orthogonal directions. For increasing the precision of the calculated values is imposed a fine mesh in the fillet corner zone, figure no. 4.

From Cosmos library, was chosen an steel material, with the following properties: the Modulus of Elasticity E=2.1 x 10^5 N/mm^2, Poisson's Ratio 0.28 and density 7900 kg/m^3.

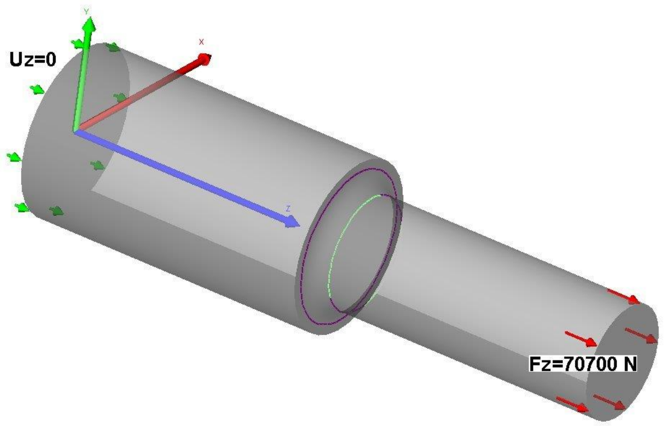

Figure no. 3 Restraints and loads applied to the geometry

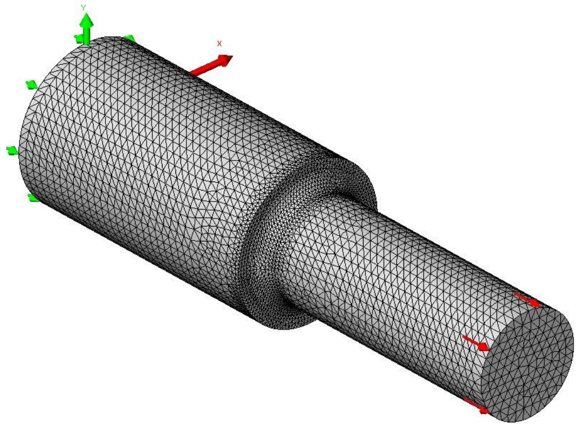

Figure no. 4 The mesh

6. THE NUMERICAL SIMULATION RESULTS

The numerical simulation results are presented in tables no. 1, 2, 3, 4, 5, with the following notations:

- „α_σ” – the value of the experimental coefficient for „r/d” and „D/d” parameter, figure no. 1;
- „σ_{max}” – the maximal stress value calculated with formulas no. 1 for experimental values of „α_σ”coefficient;
- „$\sigma_{Von\ Mises}$” - the maximal stress value obtained with finite element method;
- „$\alpha_{\sigma\ FEM}$” – the numerical simulation coefficient calculated with formulas:

$$\alpha_{\sigma\ FEM} = \frac{\sigma_{Von\,Mises}}{\sigma_n} \tag{3}$$

- „σ_n” – the value 100.02 MPa of the nominal stress in the section with „d” diameter, calculated with classical resistance formulas no. (2), for tensile load F_z=70700 N.
- ε_r [%] – the percentage error between the experimental and simulation coefficient values.

The numerical simulation results are presented graphically in figure no. 5, 6, 7, 8 and 9 for both experimental and simulation coefficient values.

Due to the limited paper space in figure no. 10, 11, 12, 13, 14, 15, 16 will be presented the maps of the stress values „$\sigma_{Von\ Mises}$” resulted form the numerical simulation, but only for D/d=1.50 ratio.

Table no. 1

D/d	**1.01**		**r/d**	**r [mm]**	**α_σ**	**σ_{max} [N]**	**$\sigma_{Von\ Mises}$ [N]**	**$\alpha_{\sigma\ FEM}$**	**ε_r [%]**
d	mm	30	0.04	1.2	1.431	143.17	133.30	1.33	-7.40
ld	mm	80	0.08	2.4	1.276	127.62	120.50	1.20	-5.91
D	mm	30.3	0.12	3.6	1.208	120.80	117.20	1.17	-3.08
LD	mm	80	0.16	4.8	1.176	117.59	115.40	1.15	-1.90
Fz	N	70700	0.2	6	1.156	115.59	115.50	1.15	-0.08
σ_n	MPa	100.02	0.24	7.2	1.147	114.70	113.20	1.13	-1.33
			0.28	8.4	1.140	114.02	112.50	1.12	-1.35

Table no. 2

D/d	1.05		r/d	r [mm]	α_σ	σ_{max} [N]	$\sigma_{Von\ Mises}$ [N]	$\alpha_{\sigma\ FEM}$	ε_r [%]
d	mm	30	0.04	1.2	1.807	180.72	162.10	1.62	-11.48
ld	mm	80	0.08	2.4	1.522	152.27	140.20	1.40	-8.61
D	mm	31.5	0.12	3.6	1.407	140.75	135.80	1.36	-3.64
LD	mm	80	0.16	4.8	1.355	135.55	131.10	1.31	-3.39
Fz	N	70700	0.2	6	1.317	131.72	127.70	1.28	-3.15
σ_n	MPa	100.02	0.24	7.2	1.286	128.67	125.90	1.26	-2.20
			0.28	8.4	1.266	126.63	123.10	1.23	-2.86

Table no. 3

D/d	1.15		r/d	r [mm]	α_σ	σ_{max} [N]	$\sigma_{Von\ Mises}$ [N]	$\alpha_{\sigma\ FEM}$	ε_r [%]
d	mm	30	0.04	1.2	2.137	213.73	187.80	1.88	-13.81
ld	mm	80	0.08	2.4	1.720	172.02	169.50	1.69	-1.49
D	mm	34.5	0.12	3.6	1.556	155.58	155.40	1.55	-0.12
LD	mm	80	0.16	4.8	1.462	146.25	147.30	1.47	0.71
Fz	N	70700	0.2	6	1.395	139.55	140.80	1.41	0.89
σ_n	MPa	100.02	0.24	7.2	1.354	135.43	138.10	1.38	1.94
			0.28	8.4	1.320	132.04	134.30	1.34	1.69

Table no. 4

D/d	1.50		r/d	r [mm]	α_σ	σ_{max} [N]	$\sigma_{Von\ Mises}$ [N]	$\alpha_{\sigma\ FEM}$	ε_r [%]
d	mm	30	0.04	1.2	2.556	255.68	229.60	2.30	-11.36
ld	mm	80	0.08	2.4	2.026	202.62	184.20	1.84	-10.00
D	mm	45	0.12	3.6	1.780	178.02	171.70	1.72	-3.68
LD	mm	80	0.16	4.8	1.643	164.36	161.50	1.61	-1.77
Fz	N	70700	0.2	6	1.559	155.91	152.10	1.52	-2.51
σ_n	MPa	100.02	0.24	7.2	1.499	149.91	147.80	1.48	-1.43
			0.28	8.4	1.458	145.81	143.80	1.44	-1.40

Table no. 5

D/d	2.00		r/d	r [mm]	α_σ	σ_{max} [N]	$\sigma_{Von\ Mises}$ [N]	$\alpha_{\sigma\ FEM}$	ε_r [%]
d	mm	30	0.04	1.2	2.782	278.29	261.70	2.62	-6.34
ld	mm	80	0.08	2.4	2.129	212.91	221.20	2.21	3.75
D	mm	60	0.12	3.6	1.876	187.64	190.70	1.91	1.61
LD	mm	80	0.16	4.8	1.734	173.40	170.60	1.71	-1.64
Fz	N	70700	0.2	6	1.632	163.21	159.80	1.60	-2.14
σ_n	MPa	100.02	0.24	7.2	1.560	156.00	152.00	1.52	-2.63
			0.28	8.4	1.500	150.06	145.30	1.45	-3.28

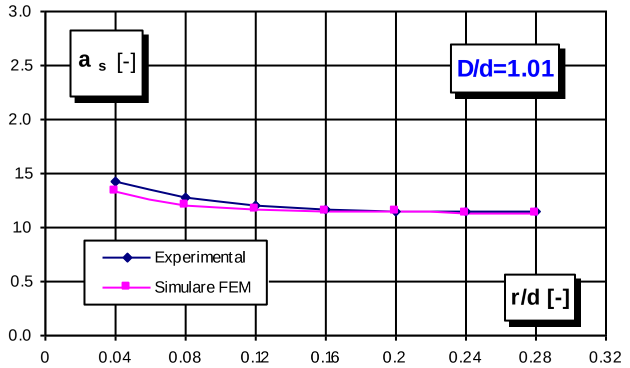

Figure no. 5 The variation of the coefficient for D/d=1.01 ratio

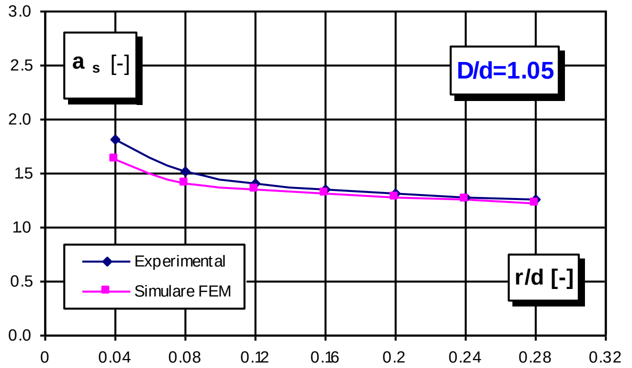

Figure no. 6 The variation of the coefficient for D/d=1.05 ratio

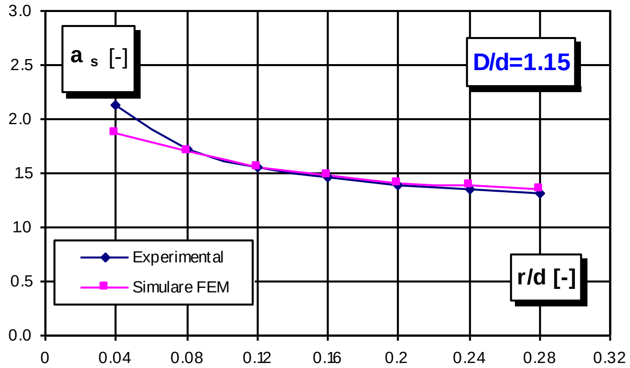

Figure no. 7 The variation of the coefficient for D/d=1.15 ratio

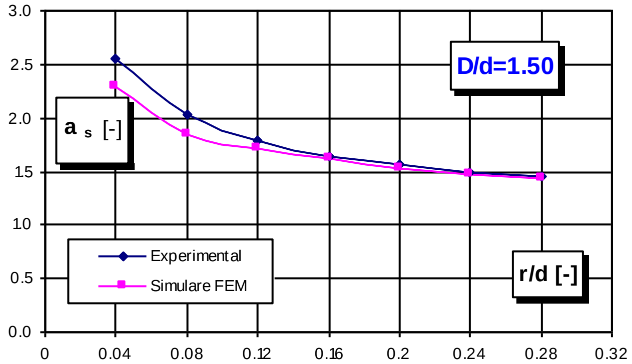

Figure no. 8 The variation of the coefficient for D/d=1.50 ratio

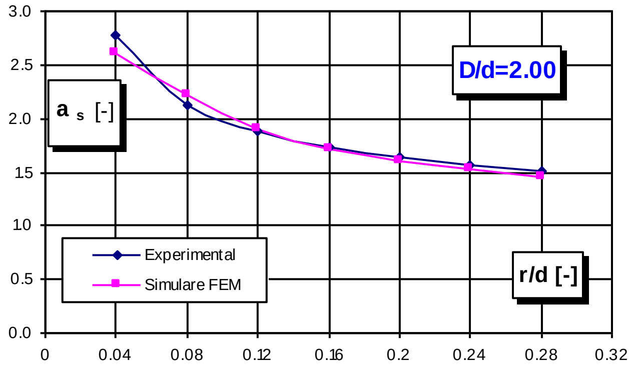

Figure no. 9 The variation of the coefficient for D/d=2.00 ratio

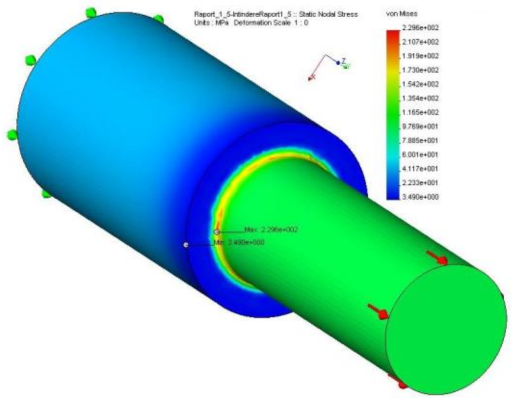
Figure no. 10 The stress values for D/d=1.50 and r/d=0.04 ratio

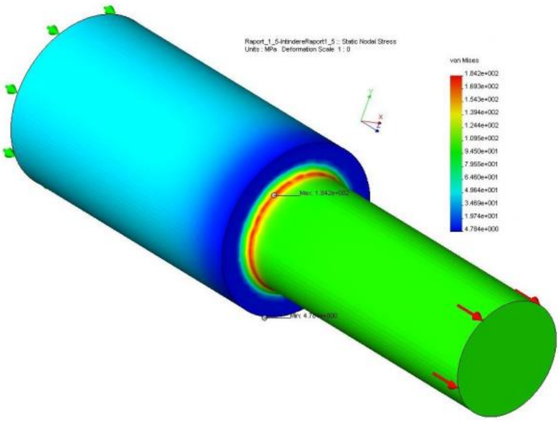
Figure no. 11 The stress values for D/d=1.50 and r/d=0.08 ratio

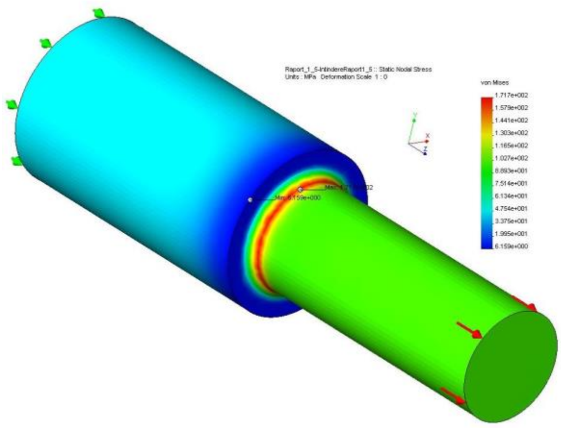
Figure no. 12 The stress values for D/d=1.50 and r/d=0.12 ratio

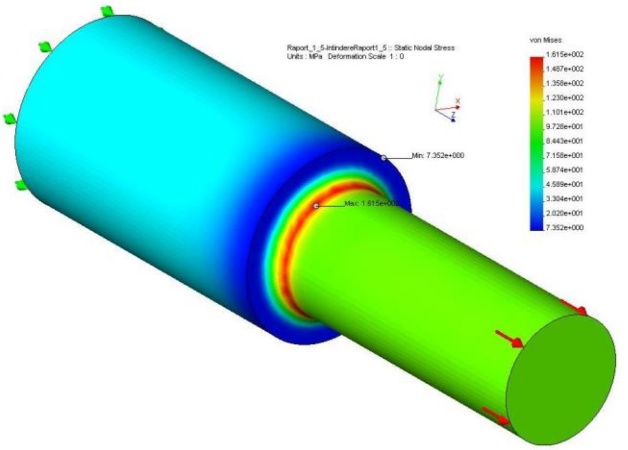

Figure no. 13 The stress values for D/d=1.50 and r/d=0.16 ratio

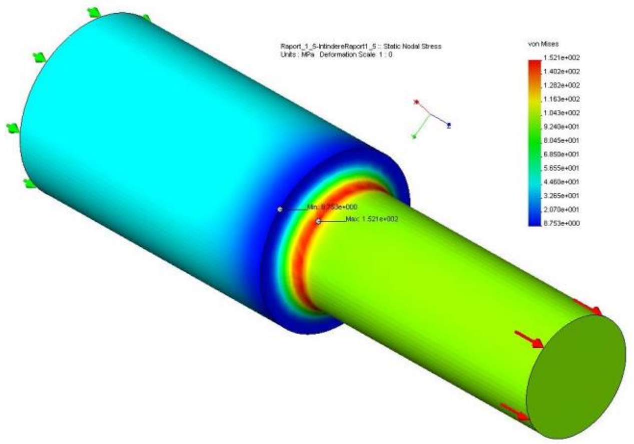

Figure no. 14 The stress values for D/d=1.50 and r/d=0.20 ratio

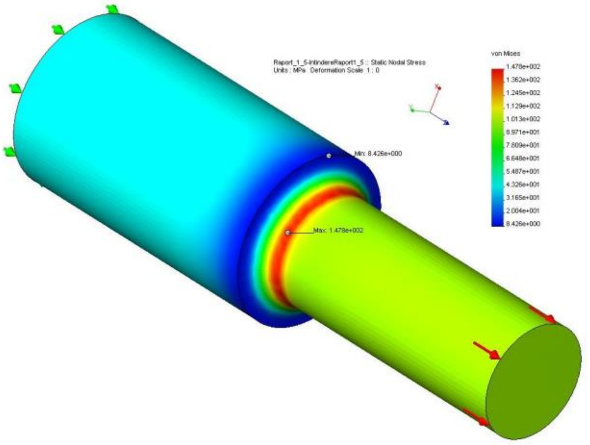

Figure no. 15 The stress values for D/d=1.50 and r/d=0.24 ratio

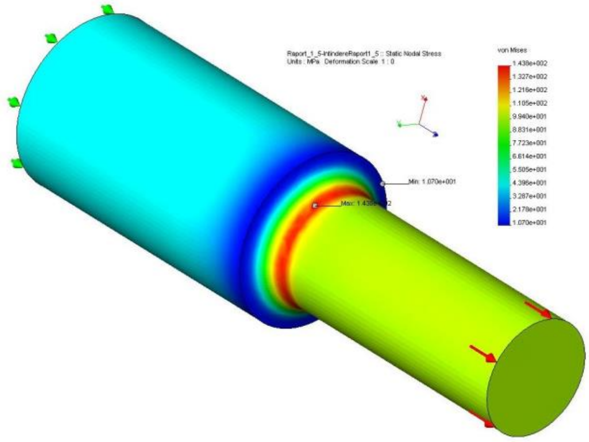

Figure no. 16 The stress values for D/d=1.50 and r/d=0.28 ratio

7. CONCLUSIONS

The local stress values resulted from the numerical simulation are comparable with the experimental values, with differences for small values of „r/d” ratio. The maximal percentage error is 13.81%, obtained for D/d=1.15 and r/d=0.04 ratio. From 35 calculated points, 27 points present values for percentage error smaller than 5%. Numerical simulation is a veritable tool for technical phenomenon analysis as an alternative to the experimental studies and give to the designer the possibility to find optimal solution by selection from the multiple numerical studies.

8. BIBLIOGRAPHY

[1] Blumenfeld, M., Buzdugan, Gh. şi colectiv, Manualul Inginerului Mecanic. Materiale, Rezistenţa Materialelor. Stabilitate elastică. Vibraţii., Vol. II, Editura Tehnică, Bucureşti, 1973, pag.713.

[2] Mănescu,T.Ş., Nedelcu D., Analiză structurală prin metoda elementului finit, Editura „Orizonturi Universitare” Timişoara, ISBN 973-638-217-6, Octombrie, 2005.

[3] Nedelcu D, Mănescu, T.Ş, Câmpian C. V., Finite Element Through COSMOS M/Design STAR, FME Transactions Volume 32, Number 1, 2004, University of Belgrade, Faculty of Mechanical Engineering YU ISSN 1451-2092, 2004.

[4] Nedelcu, D. Modelare parametrică prin Autodesk Inventor, Editura „Orizonturi Universitare” Timişoara, ISBN 973-638-116-1, Mai, 2004.