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STUDY ON THE STRESS DISTRIBUTION ROUND AN INNER CONCENTRATOR SITUATED INSIDE A WELD BEAD

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Abstract.

The paper presents the theoretical as well as experimental results on the stress distribution round a spherical-shaped concentrator placed inside an axially stressed cylindrical specimen. The values of the stresses concentration real and theoretical coefficients have been determined for several positions of the inner defect.

Preliminaries.

The welding process causes non-homogenous zones inside the metal. The most sensitive part of the weld bead is the end crater-containing slag inclusions-or the generation of beads when process is reassumed. These inclusions are inner defects. Due the specific conditions of the solidification process, the metal situated around them has a particular structure and behavior when compared with metal from weld bead without any defects.

The presence of inner defects lead to the disturbance of the stress distribution both in their vicinity and in the whole body as well. This vicinity and in the whole body as well. This phenomenon is usually called "stressed concentration" while the cause determining it is termed "concentrator".

Within the specialized literature the stresses distribution is studied both theoretically and experimentally for numerous cases of external concentrators, the results being in most cases shown under the form of some diagrams, [1], [2].

The stresses concentration phenomenon round an inner defect has not been thoroughly studied, the acceptance or rejection of a part with inner concentrator being in most cases made on a subjective basis, according to one's personal experience.

The paper intends to present - both experimentally and by use of finite element method (FEM) - the stresses - shaped situated in a weld bead monoaxially stressed by both static and dynamic loads.

Determination of the stress state by FEM.

Several monoaxially stressed cylindrical specimens including a spherical - shaped concentrator, placed eccentricity to the longitudinal axis were considered.

The FEM-model design has taken into account the fact that the part exhibits one sole cross symmetry plane (pane A-A, fig. 1), as well as one sole longitudinal one (plane B-B, fig 1).

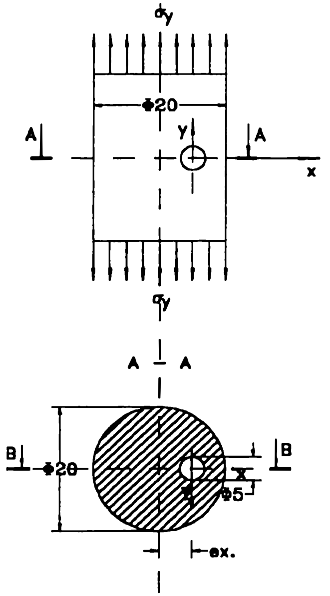

Fig. 1. The specimen shape and dimensions

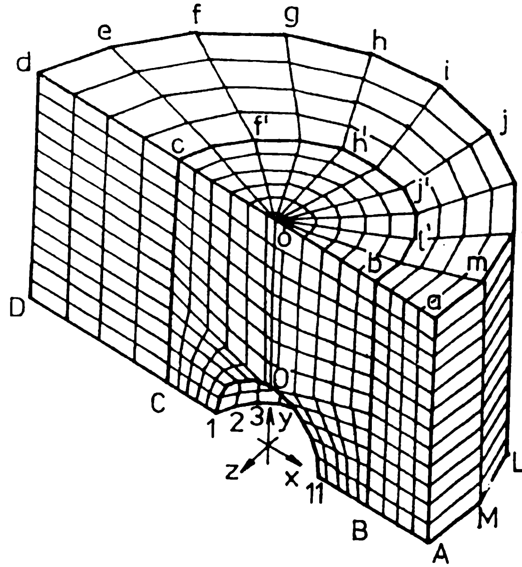

Fig. 2. The model axonometric view

Five cases have been studied for eccentricities ex=0, 1, 2, 3 and 4 mm respectively.

The meshed model is made up of two distinct volumes. The inner volume has the same dimensions as well as the same sampling mesh for all the studied cases containing 70 pentahedron elements and 600 hexahedron elements. From one case to another it is only the longitudinal axis eccentricity that differs. The outer volume fills in the inner volume up the reaching the specimen corresponding shape.

Figure 2 presents the sampling mesh for a 2 mm eccentricity.

In figure 3 it is shown the sampling mesh in the median cross - section (plane A-A).

In figure 4a the variation of σ_y stresses on the defect contour is plotted. The σ_y distribution in the cross symmetry plane (ex=4mm case) in Ox axis direction is represented in fig. 4b.

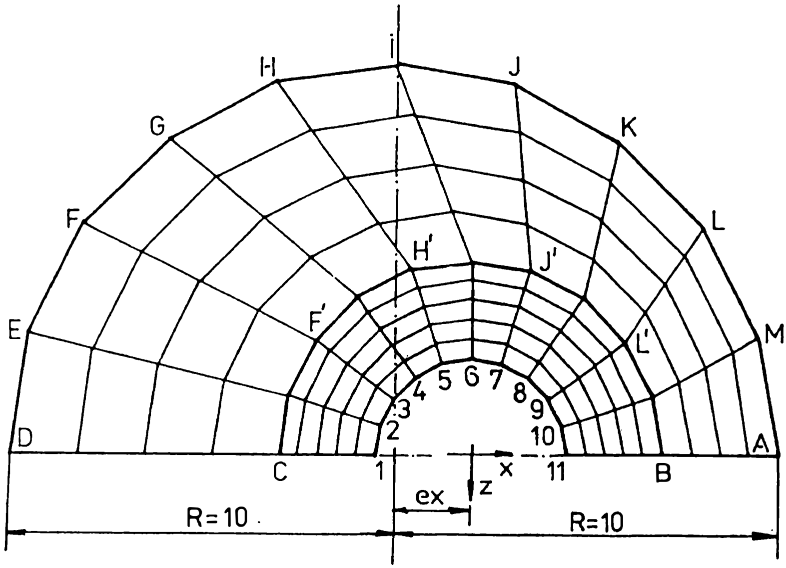

Fig. 3. Section in the model xoz plane

The σ_y stresses values along the defect contour in the symmetry cross section are given in the table 1. All the five cases of eccentricity were taken into account.

Table 1. The σ_y stresses on the defect contour [N/mm^2]

σ_y	Node no. Fig. 3										
	1	2	3	4	5	6	7	8	9	10	11
σ_y (ex0)	0.6248	0.5358	0.3268	0.2032	0.0080	0.0250	0.0080	0.2032	0.3268	0.5358	0.6248
σ_y (ex1)	0.7314	0.7893	0.8284	0.8284	0.7895	0.7318	0.7898	0.8289	0.8291	0.7900	0.7321
σ_y (ex2)	0.7315	0.7894	0.8285	0.8286	07897.	0.7321	0.7903	0.8296	0.8298	0.7909	0.7330
σ_y (ex3)	0.7310	0.7889	0.8280	0.8282	0.7895	0.7321	0.7905	0.8301	0.8306	0.7920	0.7341
σ_y (ex4)	0.7307	0.7886	0.8279	0.8283	0.7897	0.7324	0.7913	0.7952	0.9329	0.7952	0.7374

By use these results one can determine the values of the stresses concentration coefficients round an inner defect:

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

assuming:

σ_{max} = the maximum tensile stress;

σ_n = the tensile stress.

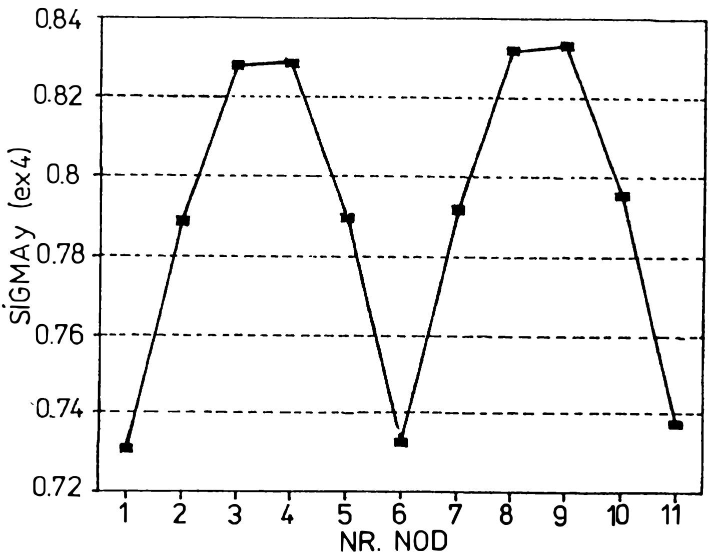

Fig. 4. σ_y stresses [N/mm^2] variation on the (A-A) cross section.

The obtained results are given in table 2.

Table 2.

Eccentricity [mm]	0	1	2	3	4
Coefficient α_k	1.9618	2.5999	2.6055	2.6081	2.6253

The determination of stress distribution by experimental means.

a). The electrical tensometry method.

The measurements of the strain round an inner defect situated inside a body in order to determine the stresses concentration coefficient, a special design strain gage was produced, [4].

The strain gage was included in a plastic cast specimen, in the desired position and direction, in the points equivalent to the nodes of the sampling mesh used in FEM.

The test specimen were monoaxially stressed. By measuring the electrical resistance variation of the included strain gages, the effective stresses in variation points situated inside the body have been determined. The obtained experimental results are shown in table 3.

Table 3.

Eccentricity [mm]	0	1	2	3	4
σ_y stress [N/mm^2]	0.5939	0.7830	0.7910	0.7970	0.8030
α_k coefficient	1.8650	2.4586	2.4837	2.5026	2.5214

b). Static tensile stress method.

Specimen having the shapes and dimensions according to figure 1 were monoaxalliy stressed by use of a static testing machine.

The obtained values are given in table (4).

Table 4.

Eccentricity [mm]	0	1	2	3	4
α_k coefficient	1.6380	2.2168	2.2344	2.2563	2.3044

c). Fatigue tensile test method.

The already presented methods gave the possibility of calculation of the theoretical stresses concentration α_k round an inner defect.

The real coefficient of the stresses concentration is to be determined during fatigue tensile loads according to:

$$\beta_k = \frac{(\sigma_R)}{(\sigma_R)_k} \tag{2}$$

assuming:

(σ_R) = fatigue resistance (specimen without inner defects);

$(\sigma_R)_k$ = fatigue resistance for a test specimen having inner concentrators (defects).

In order to determine the fatigue resistance by use of Wöhler method number of minimum of 8-10 similar test specimens were manufactured from plastic material by superposition of several layers successively applied.

The presence of inner defects spherical shaped was simulated according to the conditions of the experiment.

Both metallic and non-metallic inclusions were simulated. The final shape and dimensions of the test specimens were obtained after a cold working process. All the test specimens were sorted in the end after a final non-destructive inspection.

The fatigue tests were performed on a dynamic testing machine capable of a maximum load of a 200 kN and a 600 cycles/minute.

By use of a Wöhler curves the fatigue resistance were established for each type, shape and eccentricity inner defect.

The values of the real stress concentration coefficients for the case of welding joints having inner defects were calculated according to equation (2).

Conclusions.

The finite element method, electrical tensometry and static tensile method are very useful in determining the values of the theoretical coefficients of stresses concentration round an inner defect. A comparison of the results given by these three method had shown a good concordance. However, the experimental values could are slightly lower than those given by FEM. This could be explained by difficulties in a precise positioning of the strain gages.

The eccentricity increase influence in the same direction the stresses concentration coefficient.

Knowing the sensivity coefficient of the material, added to the results established by the paper one can determine the fatigue resistance of welding joints containing inner defects.

The fatigue test gave the possibility to obtain the values of the real stress concentration coefficient according to the type of the inner defect and its positioning in the weld bead.

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