EAN '92
30th Conference of Experimental Stress Analysis
30. konference o experimentální analýze napětí
2. - 5. 6. 1992 ČVUT Praha Czechoslovakia

DETERMINATION OF STRESSES AND STRAINS FOR CYCLIC LOADS IN AN ELASTO-PLASTIC STATE

URČENÍ NAPĚTÍ A DEFORMACÍ PŘI OPAKOVANÉM ZATĚŽOVÁNÍ V PRUŽNĚ PLASTICKÉM STAVU

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Mezní stavy pevnosti ocelových konstrukcí jsou ovlivněny přítomností zbytkových napětí, vyvolaných technologickým procesem při výrobě. Je naznačen postup určení zbytkových napětí pomocí tenzometrického měření. Příklad je vypočten programem TENZO na PC AT/286.

Keywords : residual stress,strain gauge, elasto-plastic,program, perforated flat plate

Limit strength states of steel structures are influenced by a technological process which causes residual stresses. A structure are often loaded in elasto-plastic states during a technological process. Fixing of tubes into openings of a perforated flat plate by rolling is an example. Values of residual stresses are importand, if the medium flowing throngh tubes can cause then a stress corosion cracking.

The Matar´s method (drilling of opening) cannot be used in any cases, than an originated opening is not possible always to remove by welding or grinding. We are often interested in a response of material under loading during all technological process. We can determine residual stresses at the finish of technological process using strain gauge method, if relations strain-stress $\varepsilon_t = f(\sigma)$ for a monotonic loading and $\Delta\varepsilon_t = f(\Delta\sigma)$ for a branch of hysteresis loop is known. Numerical analysis method is demonstrated in |1|. This process has following steps:

1. Calculation of residual strains ε_0, ε_{45}, ε_{90} in the direction of strain gauges from after welding measured residual stresses σ_1 and σ_2.
2. This step is used when strains and stresses reach the absolute maximum at time i. Determination of total strains from pressure p and residual stresses on stress-strain curve for monotoninc loading $\varepsilon_t = f(\sigma)$, Figure 1. Calculation of the strain intensity ε_{tr} using of Poisson´s coefficient ν for elasto-plastic state.
3. This step is used when strains and stresses do not reach the absolute maximum at the time i. Determination of the range of total strains from pressure p on a branch of hysteresis loop $i\,j$ (where $j \leqq i-1$) $\Delta\varepsilon_t = f(\Delta\sigma)$, Figure 1. Calculation of the range of strain intensity $\Delta\varepsilon_{tr}$.
4. Calculation of $\varepsilon_{tr,i}$ and $\sigma_{r,i}$ at the end of a branch of a hysteresis loop in the time i.
5. Calculation of principal stresses σ_1, σ_2 and stress intensity σ_r. These stresses are residual stresses at the end of every pressure cycle. An itteration procedure have to be used for determination of ε_{tr} and σ_r in the time i using

step 2 until 5. Relations $\varepsilon_{tr} = f (\sigma_r)$ or $\Delta\varepsilon_{tr} = f (\Delta\sigma_r)$ and strength rule for σ_r have to be fulfiled.

6. Stress components in an axis direction of a weld σ_x and in a perpendicular direction on this axis σ_y are calculated from σ_1 and σ_2.

Relations $\varepsilon_{tr} = f (\sigma_r)$ and $\Delta\varepsilon_{tr} = f (\Delta\sigma_r)$ are taken either for material Ramberg-Osgood type or for ideal elasto-plastic material.

Residual stresses was determinated in a perforated flat plate and tubes (Figure 2) using program TENZO, Table 1.

Table 1. Residual stresses calculated by program TENZO

Tube outside ligament $S_y = 642,1$ MPa				Ligament of perforated flat plate; $S_y = 334,2$ MPa			
half cycle	σ_1 [MPa]	σ_2 [MPa]	σ_r [MPa]	half cycle	σ_1 [MPa]	σ_2 [MPa]	σ_r [MPa]
1	-7,0	434,6	438,1	1	-36,6	35,1	-62,1
2	-27,0	-90,1	-80,1	2	2,7	9,0	-8,0
3	29,5	556,2	542,1	3	-62,4	44,8	-92,3
4	-27,0	-90,1	-80,1	4	4,7	15,8	-14,0
59	108,2	548,6	503,3	23	-330,1	-20,9	-320,1
60	-712,7	-533,4	-642,1	24	-344,2	-68,2	-315,7
61	-381,6	-44,5	-361,4	25	-338,8	-50,2	-316,7
62	-629,4	-508,4	-578,4	26	-345,6	-72,7	-315,6

When stresses σ_1 and σ_2 are calculated from a half-cycle ε_1, ε_2, without program TENZO, we get different values from values of Table 1. For example we get for tube $\sigma_1 = 833,5$ MPa and $\sigma_2 = 4780$ MPa.

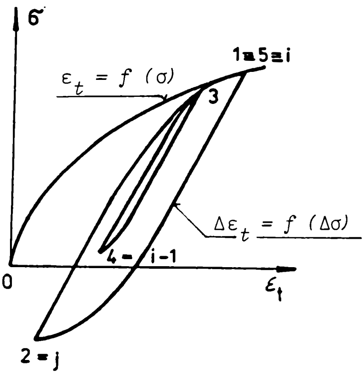

Figure 1.

History of loading

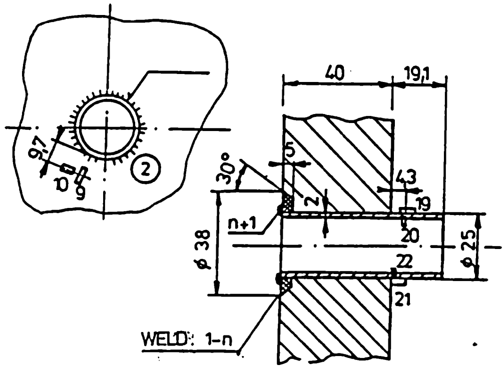

Figure 2.

Detail of structure

[1] Vejvoda, S.: Fatigue Life Prediction of the Repaired Pressure Vessel. In: 4th Int. Conf. on Structural Failure, Product Liability and Technical Insurance. Vienna, July 6-9, 1992.

[2] Vejvoda, S.: Strain Gauge Measurament of Tubes Fixing into Cooler Hydrokrak by Rolling. IAM Brno, No. 1673/91 (in Czech)

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