Experimentální Analýza Napětí 2009
Experimental Stress Analysis

RESIDUAL STRESSES AND PROBLEMS CONNECTED WITH THEIR VERIFICATION

František Trebuňa [1], František Šimčák [2], Patrik Šarga[3] & Peter Trebuňa [4]

Abstract: In the contribution are solved problems of determination of residual stresses including the methods of their evaluation. At the same time are given the methods originally developed on the workplace of authors. Very interesting is a question of verification of residual stresses and their influence by stiffness of the structure. This question was solved in cooperation with VUZ Industrial Institute Bratislava in the frame of project APVV-99-045105 [9].

1. Introduction

During the solution of project of introducing new thermoresistant steels of types T23, T24 and 9-12% Cr for production of energetic equipments and their components arise questions connected with solution of their weldability with respect to itself, but also with the elements of standard steel 15 128.

Experimental program of the project supposes combinations of weld connections of steels P23+15128 (thick-walled pipes), T24+15128, T23+9-12% Cr, 9-12% Cr + austenitic steel.

On the workplace of Faculty of Mechanical Engineering, Technical university of Košice are top-class equipments and program systems for application of hole-drilling method for determination of residual stresses. Reached opinions with application of hole-drilling method were reached during solution of State project 2003 SP 51/028 00 09/028 09 11. All that allows solution of heavy task of determination of residual stress quantification in welds by using strain-gages of producers HBM and MM [5,6,7,8].

Measurement because of incremental drilling was performed by equipment SINT-MTS 3000. Evaluation was ralized according to ASTM by program systems RESTAN and MEZVYNA.

2. Measurement of residual stresses by system SINT MTS-3000

Measurement and evaluation chain consists of system SINT-MTS 3000 for measurement of residual stresses, strain-gage apparatus SPIDER 8, source of pressured air, reduction valve with filter and computer with corresponding software. Scheme of measurement chain is in Fig.1.

[1] Dr.h.c. mult. Prof. Ing. František Trebuňa, CSc.; Technical University in Košice, Department of Applied Mechanics and Mechatronics, Letná 9, 04082 Košice, Slovakia, frantisek.trebuna@tuke.sk
[2] Prof. Ing. František Šimčák, CSc.; Technical University in Košice, Department of Applied Mechanics and Mechatronics, Letná 9, 04082 Košice, Slovakia, frantisek.simcak@tuke.sk
[3] Ing. Patrik Šarga, PhD.; Technical University in Košice, Department of Applied Mechanics and Mechatronics, Letná 9, 04082 Košice, Slovakia, patrik.sarga@tuke.sk
[4] Ing. Peter Trebuňa, PhD.; Technical University in Košice, Department of Management and Ekonomics, Letná 9, 04082 Košice, Slovakia, peter.trebuna@tuke.sk

Measurement and evaluation chain consists of system SINT MTS 3000 for measurement of residual stresses, strain-gage apparatus SPIDER 8, source of pressured air, reduction valve with filter and computer with corresponding software. Scheme of measurement chain is in Fig.1.

For computation of residual stresses are in program systems the following treatments:

- Standard ASTM E 837-01,
- Integral method,
- Method of power series,
- Kockelmann method,
- MEZVYNA.

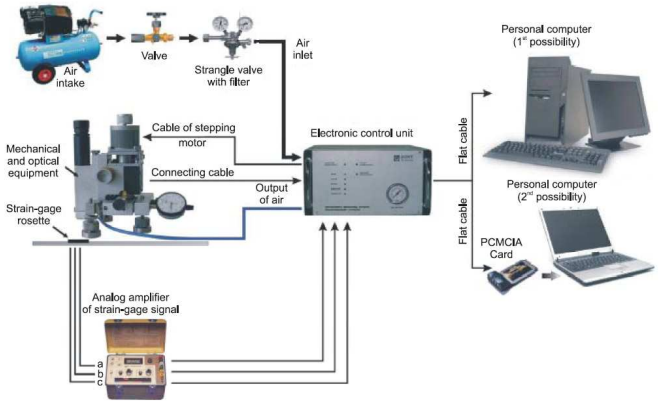

Figure 1: *Measurement chain*

Measurement of magnitudes and directions of principal residual stresses was realized on specimens made of steel P91 that were designed and manufactured in VUZ Industrial Institute Bratislava. With using of strain-gage apparatus SPIDER8 as a part of hardware chain was necessary to use half-bridge circuit of strain-gages. There were used 2 types of strain-gages from fy Vishay Micro-Measurements EA-06-062 RE-120/SE a CEA-06-062 UM-120.

In Fig.2 is labeled the position of strain-gages including their orientation.

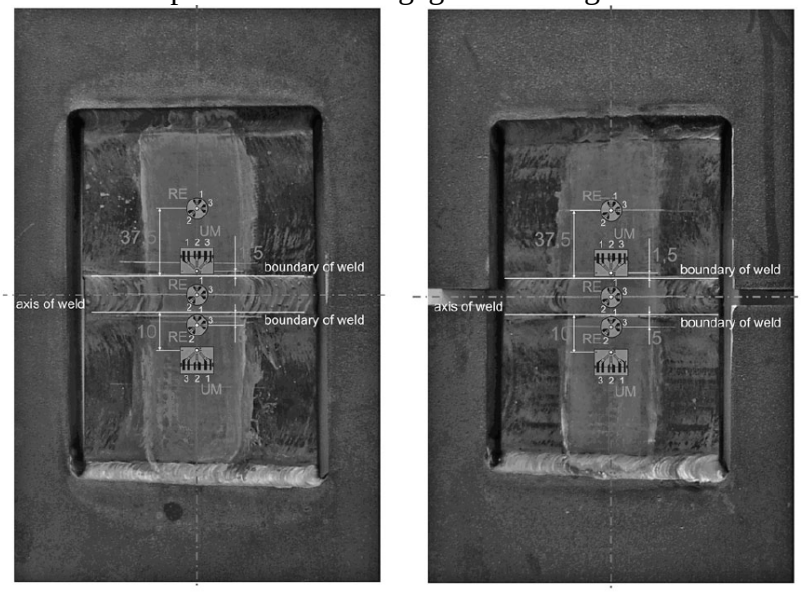

Figure 2: *Position, labeling and orientation of sensors on a whole and sawed frame, respectively*

During detailed visual inspection was found out that during the welding arose relatively high ruggedness that do not allow measurement of residual stresses in location of weld axis. Fulfilling of this ruggedness by strain-gage glue should allow application of strain-gages, but it should remarkably decrease sensitivity of sensors. This fact was tested on special

prepared specimen with milled ruggedness oriented perpendicular to one of principal strain. That was a reason why authors provided alignment of roughness by abrasive disc with conditioner from fy M-M and intensive refrigeration. Increasing of temperature on the surface by using of this technology did not cross 30°C.

3. Magnitudes of residual stresses and their directions determined from released defromations during hole-drilling

As was mentioned before for the evaluation of measured data were used program systems allowing determination of residual stresses levels according to ASTM E 837-01, integral method, method of power series, Kockelmann method and program MEZVYNA.

Because there was known material (steel P91), chemical composition and Poisson ratio $\mu = 0{,}3$ for elastic state, the authors for a material with identical chemical composition have chosen from catalog of materials [10] Young modulus $E = 2{,}17 \cdot 10^5$ MPa that was used for evaluation of measurement. In case that Young modulus of material is different, it is necessary to multiple determined stresses by coefficient $k = \mathrm{E_{real}}/2{,}17.10^5$.

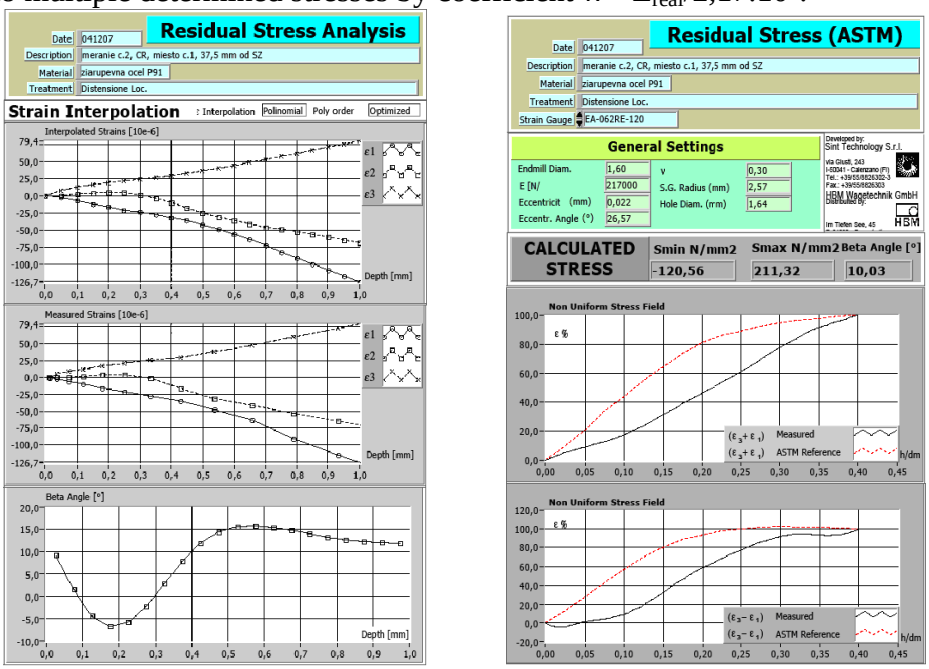

Figure 3: *Charts of measured and interpolated values of released deformations and residual stresses according to ASTM for measurement No.2*

4. Discussion of measured and determined magnitudes of residual stresses

In Table 1 are given magnitudes of maximal and minimal principal normal stresses determined by programs according to ASTM E837-01 for a specimen positioned in the whole as well as in partitioned frame for individual measurement locations.

From the measured values is seen that higher levels of stresses are in specimen on whole frame. The reason is that the frame is relatively stiff and in the process of welding and after coding of specimen prevents dilatation of specimen or leaving the plane.

After evaluation of reached results has to be taken into account a fact that the angles of grid 1 are for maximal or minimal stress, respectively. The decision is made according to state if the measured deformation in grid 1 is bigger or smaller than on the grid 3. These facts are described in report [9].

Table 1 *Magnitudes of residual stresses determined according to ASTM in locations of individual sensors on a whole and partitioned specimen*

Location Type of sensor	CR			RR		
	σ_{max} [MPa]	σ_{min} [MPa]	φ [°]	σ_{max} [MPa]	σ_{min} [MPa]	φ [°]
1 RE	211,3	-120,6	+10,0	159,7	-46,8	-16,8
2 UM	180,9	36,4	36,7	82,0	34,3	39,3
5 RE	140,2	54,3	-84,4	99,1	37,8	-85,6
3 UM	109,7	25,1	48,9	110,3	8,3	51,0
4 RE	88,6	68,8	-8,7	104,3	77,6	7,3

5. Conclusions

Measured values of residual stresses as well as their angle changes with respect to main grid clearly document that methodology used in experiment is acceptable. On one specimen is necessary to provide minimally three drillings, which is time consuming.

The welds by which is the specimen connected to frame influence remarkably results of measurement and prevent unambiguously determine influence of weld in question.

Acknowledgement

The contribution was elaborated with the support by project APVV-99-045105.

References

[1] Determining Residual Stresses by the Hole-Drilling Strain-Gage Method. ASTM Standard E 837-01.

[2] Schajer, G.S., Altus, E.: Stress Calculation Error Analysis for Incremental Hole-Drilling Residual Stress Measurement. Journal of Engineering Materials and Technology, Vol. 118, No. 1, 120-126, 1996

[3] Schajer, G.S.: Application of FiniteElement Calculations to Residual Stress Measurement. Journal of Engineering Materials and Technology 103, 157-163, 1981.

[4] Schajer, G.S.: Strain Data Averaging for the Hole-Drilling Method. Experimental Techniques, Vol. 15, No. 2, 25-28, 1991

[5] Trebuňa, F., Šimčák, F.: Kvantifikácia zvyškových napätí tenzometrickými metódami. Grafotlač Prešov, 2005, 134 str.

[6] Trebuňa, F., Šimčák, F., Bocko, J., Trebuňa, P., Senko, P., Šarga, P.: It is possible to consider „standard“ methods of determination of residua stresses by hole-drilling to be definitive? EAN 2004, Kašperské Hory, str. 273-276.

[7] Trebuňa, F., Šimčák, F., Buršák, M., Bocko, J., Šarga, P., Pástor, M., Trebuňa, P.: Quantification of residual stresses in hot rolled sheets by the hole drilling method, Metalurgija, vol. 1, 2007, p.41-46.

[8] Trebuňa, F., Šimčák, F., Senko, P., Šarga, P., Pástor, M., Trebuňa, P.: Nové možnosti určenia zvyškových napätí vyvolaných výrobou, prípadne montážou a ich uplatnenie v plynárenských potrubných sústavách, Slovgas, 5/2006, str. 18-22.

[9] Trebuňa, F., Šimčák, F., Šarga, P., Trebuňa, P., Pástor, M.: APVV-99-045105 Zvariteľnosť žiarupevných ocelí novej generácie pre energetické celky s vyššou účinnosťou. Štúdium vývoja zvyškových napätí pri výrobe a opravách energetických celkov metódou odvrtávania. Čiastková úloha 2, Etapa č.2. Košice, január – december 2007, str. 88

[10] Fürbacher, I. a kol.: Lexikon technických materiálů. Verlag Dashöfer. 2005