ANYAGVIZSGÁLÓK LAPJA
MINŐSÉGBIZTOSÍTÁS * ÁLLAPOTELLENŐRZÉS
Elektronikus folyóirat
2008/1

Some Comparisons of Residual Stress Measurements on Pressurized Pipes by the Hole Drilling and Magnetoelastic Methods*

Václav Linhart[1] , Jana Sigmundová[1)] , Vladislav Ochodek[2]

Kulcsszavak: csövek nyomás alá helyezése, maradó feszültség mérése, lyukfúrás, magneto-elasztikus módszer
Keywords: pipe pressurizing, residual stress measurements, hole drilling, magnetoelastic methods

Összefoglalás

Magas folyáshatárú hegesztett gázcsővezetékek acélcsöveinek megmunkálásakor jelentős maradó feszültségek kialakulásával kell számolni. A feszültségek csökkentésének lehetősége a csövek előzetes nyomás alá helyezése (akár egészen a folyáshatárig). A folyamat paramétereinek optimalizálása érdekében végrehajtott maradó feszültség vizsgálatok eredményeit mutatják be a szerzők cikkükben.

Summary

Residual stress measurements on pressurized pipe-bodies made of X70 steel have been realized. Measurements after pressurizing by the hole drilling and magnetoelastic methods gave in most part of cases comparable values of stresses and they were similar their courses.

Pressurizing close above the yield point gave relevant decrease of stress level, pressurizing close under this point gave less favourable results.

Introduction

During manufacturing of welded pipes for gas pipelines made of steels with high yield point, the formation of high residual stresses comes about. They can often reach up to the yield point value. Since the thermal stress relieving would contribute to degradation of strength properties, an important approach to their decreasing is pressurizing of pipes up to yield point. Plastic deformation, which occur during this operation lead to the decreasing and redistribution of stresses. To optimize this pressurizing process, which is often called “stress test“, some data from measurements of residual stress are needed to be obtained , to optimize conditions for this operation.

Material of the pipes

Measurements were carried out on pressurized bodies (length app. 4m), prepared of spiral welded pipes DN 500, made of thermo-mechanically treated steel L485MB (X70) – $R_{t\,0,5}$ =493 MPa, R_m =605 MPa.

Methods for residual stress measurements

Hole drilling strain gage method is described in ASTM Standard [1] and in other documents, e.g. [2]. On drilling a small (ø1,5 mm) and shallow (2 mm) hole a stress balance on the pipe surface will be changed. Deformations being formed are measured using special strain gage rosettes. Of the three strain measured components, the main stress **σ**max and **σ**min are then evaluated according to [2]. From measured strains, orientation of the planes **σ**max and **σ**min can be also evaluated.

Magnetoelastic method

Method utilized changes the Barkhausen magnetic noise in stress field. On acting magnetic field on material an orientation change of Weiss domains comes about. In a coil surrounding magnetized metal these changes manifest themselves like current impact. These current impacts can be observed acoustically like so called Barkhausen noise. Basic principle of the method is known for a long time, but only in the last years, proper sophisticated instrumentation was successfully developed, e.g. [3].

The method was successfully used for measuring of residual stresses in research works of VŠB - Technical University Ostrava [5].

*A 24. Duna-Adria Szimpóziumon elhangzott előadás szerkesztett változata

1)SVÚM a.s., Praha , e-mail : linhart@svum.cz

2)VŠB - Technical University Ostrava , e-mail :vladislav.ochodek@vsb.cz

Results of stress measurements on pressurized pipe-bodies after stress tests [4,7]

Pressurizing up to value σv [1])= 0,96 $R_{t\,0,5}$, dwell time 5 minutes

This level of pressurizing is usually used by producer of pipes, with dwell time 45 s. Results of residual stress measurements by hole drilling method are on Fig.1, by the magnetoelastic method on Fig.2.

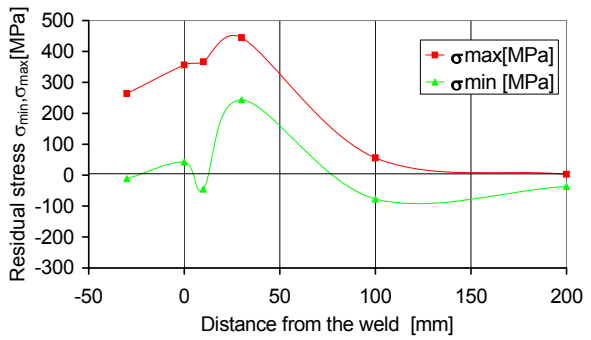

Fig.1 Hole drilling method, results of residual stress measurements (pressurizing up to □V=0,96 $R_{t\,0,5}$ (p=21,7 MPa) 5 minutes)
1. ábra Lyukfúrásos módszer, visszamaradó feszültségek mérése (nyomás alá helyezés □V=0,96 $R_{t\,0,5}$ (p=21,7 MPa) 5 percig)

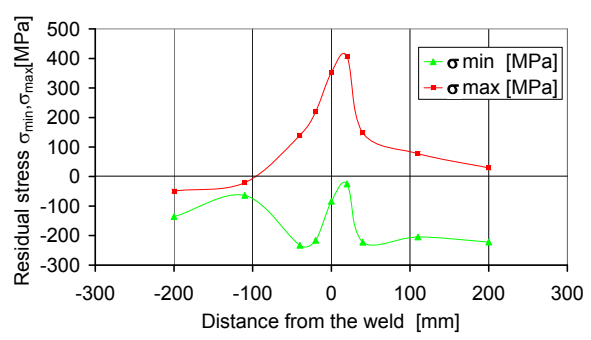

Fig.2 Magnetoelastic method, results of residual stress measurements (pressurizing up to □V=0,96 $R_{t\,0,5}$ (p=21,7 MPa) 5 minutes)
2. ábra Magnetoelasztikus módszer, visszamaradó feszültségek mérése (nyomás alá helyezés □V=0,96 $R_{t\,0,5}$ (p=21,7 MPa) 5 percig)

The course of stress components by both methods is similar not only in the course, but also in max. stress values in the weld vicinity - σ_{max}=+400 to+450 MPa. Level σ_{max} in places far from the weld tends to zero value. Stress component σ_{max} acts in plane approximately parallel to the spiral weld.

The second stress component σ_{min} which acts approximately in the plane perpendicular to the weld is low : +200 MPa or -30 MPa, alternatively.

It was showed that even after this pressurizing stress level σ_{max} in weld area is still unfavourably high.

Pressurizing firstly up to σ_v =1,01$R_{t\,0,5}$,1 hour, and secondly subsequently up to σ_v=0,92 $R_{t\,0,5}$ 30 minutes.

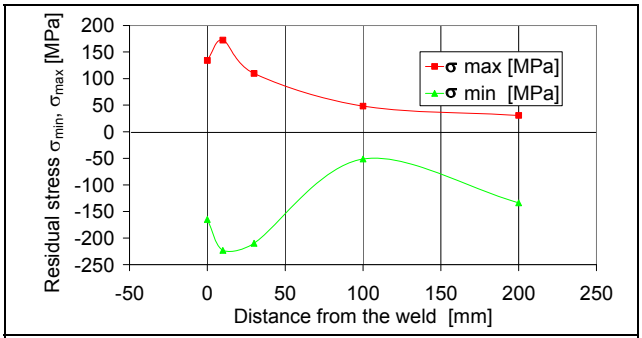

Fig.3 Hole drilling method, results of residual stress measurements (pressurizing up to □V=1,01 $R_{t\,0,5}$ 1 hour and □V =0,92 $R_{t\,0,5}$, 30 minutes)
3. ábra Lyukfúrásos módszer, visszamaradó feszültségek mérése (nyomás alá helyezés □V=1,01 Rt 0,5 1 óra és □V=0,92 Rt 0,5 30 perc)

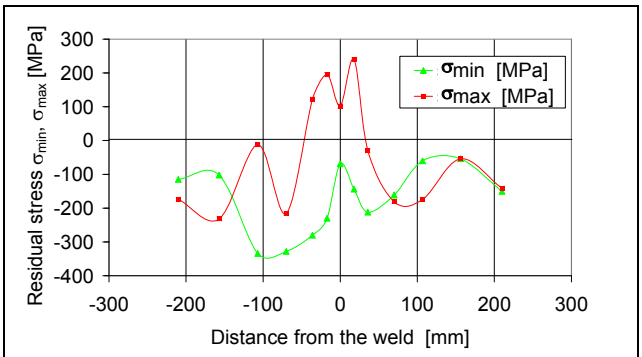

Fig.4 Magnetoelastic method, results of residual stress measurements (pressurizing up to □V=1,01 $R_{t\,0,5}$ 1 hour and □V =0,92 $R_{t\,0,5}$, 30 minutes)
4. ábra Magnetoelasztikus módszer, visszamaradó feszültségek mérése (nyomás alá helyezés □V=1,01 $R_{t\,0,5}$ 1 óra és □V=0,92 $R_{t\,0,5}$ 30 perc)

Such type of pressurizing is used at stress tests of pipelines. Results of measurements with both methods are on Fig.3 and Fig.4. The courses of stress components σ_{max} in shape are similar in both cases. The highest values reached according

[1]) $\sigma = \sqrt{\sigma_\varphi^2 + \sigma_L^2 + \sigma_\varphi . \sigma_L}$ = stress intensity HMH

σ_φ = circumferential stress σ_L = longitudinal stress

to first method are σ_{max} = +180 MPa, according to the second method approximately +230 MPa. At the distance of 200 mm from weld, appropriate levels are low : +30, and -130 MPa respectively.

The courses of components σ_{min} are similar in character by both methods. They reach values from -170 to -250 MPa in the weld by hole drilling method, and from -80 to - 220 MPa by magnetoelastic method. At the distance of 200 mm from the weld they reach values

σ_{min}= -180 and /or -140 MPa using the second method.

Pressurizing up to σ_v= 1,05 $R_{t\,0,5}$, 1hour

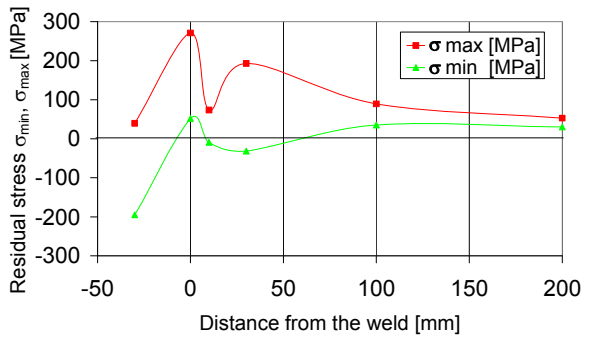

Fig.5 Hole drilling method, results of residual stress measurements (pressurizing up to σ_V=1,05 $R_{t\,0,5}$ 1 hour)
5. ábra Lyukfúrásos módszer, visszamaradó feszültségek mérése (nyomás alá helyezés σ_V=1,05 $R_{t\,0,5}$ 1 óra)

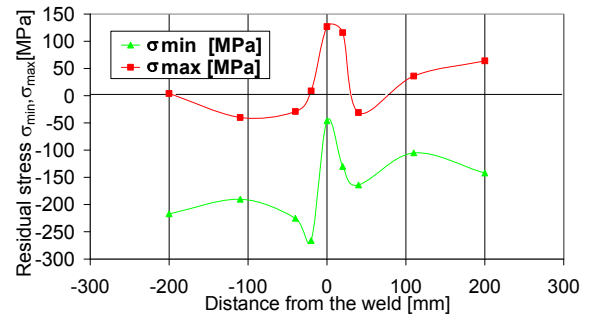

Fig.6 Magnetoelastic method, results of residual stress measurements (pressurizing up to σ_V=1,05 $R_{t\,0,5}$ 1 hour)
6. ábra Magnetoelasztikus módszer, visszamaradó feszültségek mérése (nyomás alá helyezés σ_V=1,05 $R_{t\,0,5}$ 1 óra)

Results of residual stress measurement after pressurizing are in Fig.5 and Fig. 6. Stress courses determined by both methods are similar though measured values σ_{max} in the welds show differences. By hole drilling method the highest value of these stresses is +270 MPa, by the magnetoelastic method only +125 MPa. At the distance 200 mm from the weld they decreased to approx. 50 MPa.

Stress σ_{min} attain at both methods low values, approx. ± 50 MPa in the weld, and -200MPa, respectively -260 MPa out of this region.

Discussion on some deviations in results of both methods

Because two used methods work on quite different principle, an agreement of results cannot be expected to be complete.

At drilling method average stresses in surface layer (to the depth 2mm) assert themselves in the results. For used magnetoelastic method the results are stress characteristics in thinner surface layer (≤1mm). Incidental interference by this thin surface layer condition, e.g. influence of surface treating by grinding, can be expected.

At the magnetoelastic method definite deviations of measured values in material with different structure cannot be eliminated - e.g. welds and their vicinity. Influence of these changes can be described by calibration very hardly, especially in thin transient areas.

At hole drilling method are needed to be expected higher deviations in stress values from real ones have to be expected, on the other hand, if residual stress components exceed 65% R_e [6].

Hole drilling method results from simple and evidential measuring of strains. Measuring results obtained at individual drilling depth are control indicators of correctness of measuring.

Conclusion

1. Both methods gave comparable values of stress level in the weld and in adjacent places for most part of our measurements on spiral welded pipes pressurized up to yield point.
2. Also stress courses have similar character in dependence on location from weld.
3. Some deviations in measurement results of both methods are discussed.
4. Residual stress measurements showed favourable influence of pressurizing close above Rt 0,5 level on the overall decrease of stress level in pipes.
5. Pressurizing close under R_t 0,5 gave less favourable results.

References

[1] "Standard Test Method for Determining Residul Stresses by the Hole Drilling Strain Gage Method ". Standard ASTM E 837-01, 2002

[2] „Measurement of Residual Stress by Hole Drilling Method“ Vishayś Techn. Note Nr. TN- 503-5, 1985

[3] Devices for magnetoelastic measurement : Rollscan 200 (producer Strestech Oy, Finland) and Meb-2c (producer Mag-Lab Sc. Poland)

[4] V. Linhart, I.Černý, J. Sigmundová : „Evaluation of sensibility to SCC and residual stress determination on X70 gas pipes“. Technical report No.530 0278 /1, SVÚM a.s. Prague, 2006

[5] V. Ochodek: „Measurement of residual stress by magnetoelastic method on X70 gas pipes“. Research report of VŠB-Technical University Ostrava , Ostrava , 2006

[6] Y.C. Lin, C.P. Chon :“Error induced by local yielding around hole in hole drilling method for measuring res. stress of material“. Material Science and Technology, 6, V.11, 1995

[7] V. Linhart, J. Sigmundová, V.Ochodek :“ Some comparisons of residual stress measurements..a.c.“24th Danubia-Adria.Symposium on Developments in Exp.Mechanics.2007 p.79,80

Acknowledgement

This research was carried out within the project MPO FT-TA/091