VIBRATORY LOWERING OF RESIDUAL STRESSES IN WELDMENTS

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ABSTRACT

The results of the study of the effect of Vibratory stress relieving on mechanical properties of the welded joints and the stability of weldment size are outlined.

KEYWORDS

Strength tests, notch and fracture toughness, measurement of the volume of residual stresses in welded joints, measurement of strains, utilization of Vibratory stress relieving in practice.

INTRODUCTION

During the welding process residual stresses, which usually create three-dimensional stresses, are formed in welded joints. In welded joints of annealed weldments mainly with larger material thickness the residual stresses can form unfavorable three-dimensional tensile stress state which can decrease strain properties of a joint, lower the dynamic load carrying capacity of weldments, cause strains in as-machined as-loaded condition or brittle failure of weldments etc. These drawbacks are solved in manufacture by proposing stress relief annealing of weldments. Majority of weldments is annealed in order to assure the stability of their dimensions and shape during their service life. A considerably lower number of weldments is annealed for other reasons, e.g. to improve mechanical properties of welded joints, to lower hydrogen contents in the weld metal and to avoid weldments cracking, to decrease the hardness of transition zone in a welded joint etc.
Expensive stress relief annealing of weldments can be in the majority of cases replaced by Vibratory stress relieving, later VSR only. Weldments are subjected to vibratory stress relieving on the mechanical eccentric vibrator with 1 to 200 Hz revolutions.

From the technical viewpoint vibratory stress relieving can be used as replacement of residual stress relief annealing in majority of selected weldments. The VSR procedure has been introduced and used with much success in Czechoslovakia. At the same time the effect of VSR on mechanical properties of welded joints of weldments and on the hygiene of work was investigated in more detail.

This paper gives a brief description of the advantages of VSR procedure in comparison to stress relief annealing and that of the effect of vibration on some properties of welded joints and weldments having been attained in the course of this study.

MEASURED RESIDUAL STRESSES IN UNVIBRATED AND VIBRATION STRESS RELIEVED WELDED JOINTS.

To solve the problem of VSR effect on welded joint properties also the three-dimensional residual stresses were measured. We wanted to find out to what extent the residual stresses are lowered after vibratory stress relieving. The welded specimens 30x650x1100 mm in size were used for the measurement of residual stresses. The longitudinal welded joint type x 30 fabricated with N 70 flux and A 107 wire was located in the central part of specimens. One specimen remained unvibrated and the other was subjected to vibration at four resonance levels. The three-dimensional residual stresses were measured in a welded joint in the central part of specimens / Jesensky, 1984/.

The measured three-dimensional stresses in the unvibrated welded joint are shown in fig. 1a and those in vibratory stress relieved joint are shown in fig 1b.

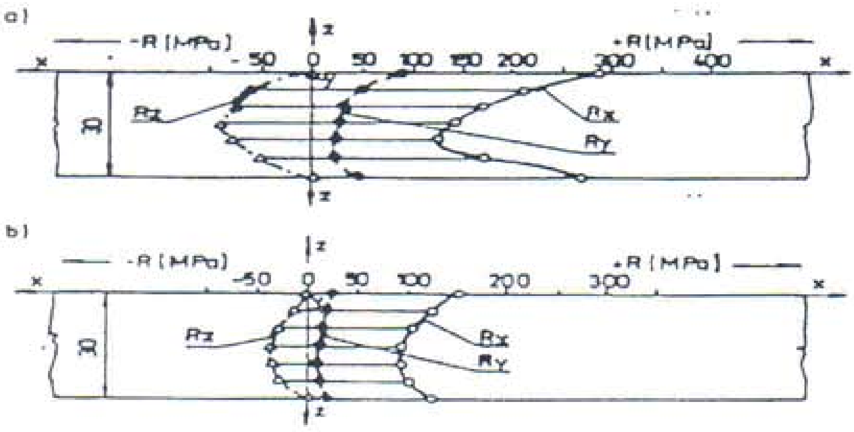


Fig. 1. The course of measured three-dimensional residual stresses in x 30 welded Joint of Fe 430 D / csn 41 1449.1/ steel
A - as welded, b - Vibratory stress relieved specimen, Rx - along the weld, Ry - normal to the weld, Rz - along weld thickness, /+/ tension , /-/ pressure.

The values of measured residual stresses in these welded joints – being valid also for other welded joints – prove that after vibration the three-dimensional residual stresses on the surface and through material thickness of a welded joint are lower by 40 to 80% in comparison to those in unvibrated welded joints.

For measurement of three-dimensional residual stresses the semi-destructive method which is based on removing of the studied zone in shape of a cylinder ∅ 30mm through the joint thickness was used. The foil strain gauges type 1.5/120 L/11/manufacure by hottinger Baldwin messtechnik, West Germany/ cemented on the frame of a three-dimensional sensor were used as measuring elements. The sensor is filled up with Belzona mixture into the opening bored through ∅ 8mm material thickness, From the measured values prior to and after boring a hole the three-dimensional residual stresses are determined employing graphical – numerical method / Jesensky, 1983/.

Further measurement of surface residual stresses was done e.g. on welded beams made of Fe 510 B /CSN 41 123.1/ steel, shown in figs. 2a and 3b. The beams were joined by manual arc process with E 52.33 coated electrode according to CSN standard.

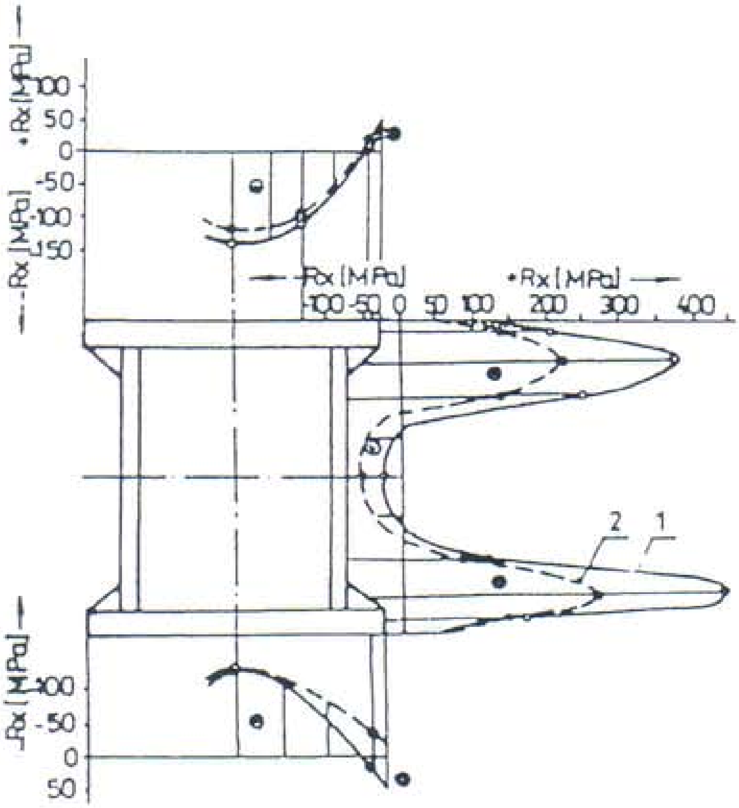


Fig.2. Measured surface residual stresses in welded beams of
Fe 510B/CSN 41 1523.1/ steel,
1 – stresses in as-welded beam,
2 – stresses after Vibratory stress relieving.

One beam remained unvibrated and the other was subjected to vibratory stress relieving at four resonance levels. Fig. 2 shows the course of surface residual stresses in unvibrated and vibratory stress relieved beam. Also in this case a substantial lowering of residual stresses after vibratory stress relieving can be seen.

The surface residual stresses were measured by tensometric method which consists in cutting prisms 20 x 20 mm in size along the beam circumference. The HBM strain gauges type 1.5/120 ly11 which were commented on the material surface in the shape of rosette of O°, 90° were used as measuring elements.

MEASUREMENT OF STRAINS IN WELDED BEAMS AFTER PLANING

During the study of this problem except for other measurements also strains in the above mentioned welded beams shown in Fig. 3 were measured.

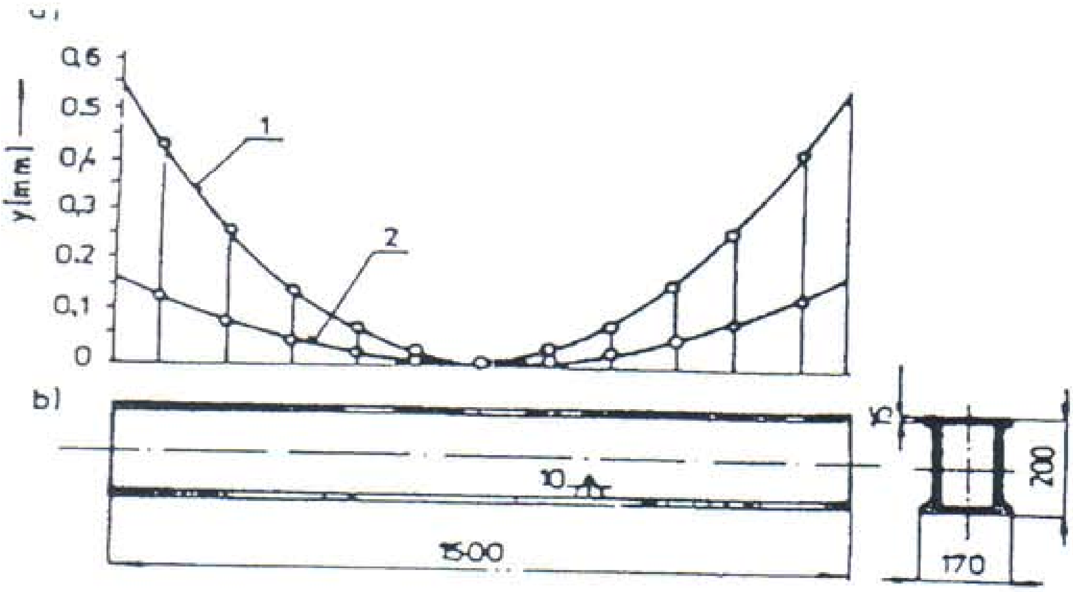


Fig. 3. Measured strains "y" of welded beams after machining one flange 5mm in depth, a - longitudinal strains in 1 - as-welded beam, 2 - Vibratory stress relieved beam, b – MMA welded beam of Fe 510 B steel using E 52.33 electrode according to CSN Standard

One beam was untreated. The other beam was vibrated to lower residual stresses and to stabilize dimensions at four max. 120Hz resonance levels. The strains "y" /Fig. 3a/ in the unvibrated and vibratory stress-relieved beam by aid of deflectometer.

After gradual machining – 2+2+1 = 5 mm planing from one flange –the total strains-deflections "y" /fig.3a/ were measured.
The course of strains designed 1- for as-welded beam, that designated 2- corresponds to vibratory stress relieved beam.

The measured value in fig 3a prove that after vibratory stress relieving of the beam the residual stresses were lowered and their shape was stabilized / Jesensky, 1984/.
Substaially higher strains were measured in the unvibrated beam. At the same time it has been pointed out that the measuring system was calibrated and it's maximum deviation between single measurements represented +/- 0.15mm.

STRENGTH AND YIELD STRENGTH OF MATERIAL OF UNVIBRATED AND VIBRATORY STRESSRELIEVED WELDED JOINTS.

For the solution of this task the strength tests of welded joints in different steels with strength values varying between 370and 700 mpa were performed. The measured values of welded joints in bars have proved that vibration exerts a negligible effect on yield strength and tensile strength of welded joint material. A slight increase in yield strength, practically within the scatter of measured values / Haramia, 1982/ was proved in Vibratory stress relieved joints.

NOTCH AND FRACTURE TOUGHNESS OF UNVIBRATED AND VIBRATORY STRESS RELIEVED WELDED JOINTS

The samples for measurement of notch and fracture toughness were fabricated from Fe 430 D / CSN 41 L449.1 / steel welded joints from above mentioned specimens 30mm in thickness.

The course of measured values of notch toughness in dependence of temperature / measured by Haramia, 1982 / is shown in Fig. 4.

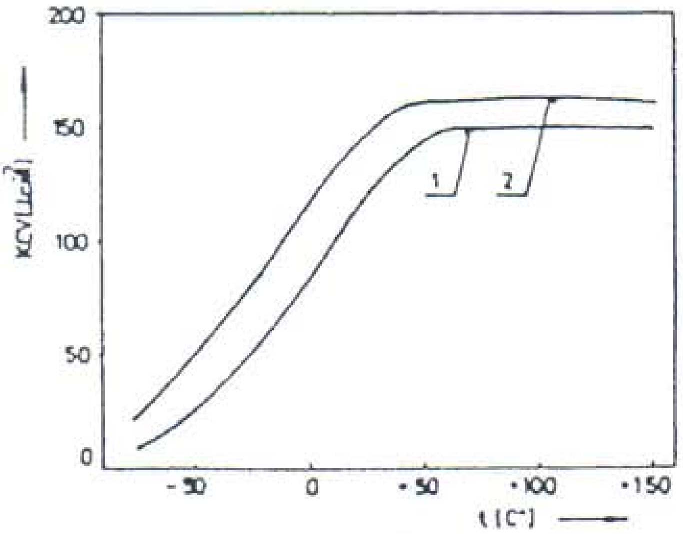


Fig.4. The course of notch toughness KCV in dependence on temperature measured in specimens with X30 joint in Fe 430 D steel, 1 – as-welded, 2 – VSR specimen.

The course of fracture toughness in dependence on temperature / Haramia, 1982/ is shown in fig.5.

The Measured values in Figs. 4 and 5 and those of other welded joints have proved that the notch and fracture toughness values of Vibratory stress relieved joints are higher than those of unvibrated joints.

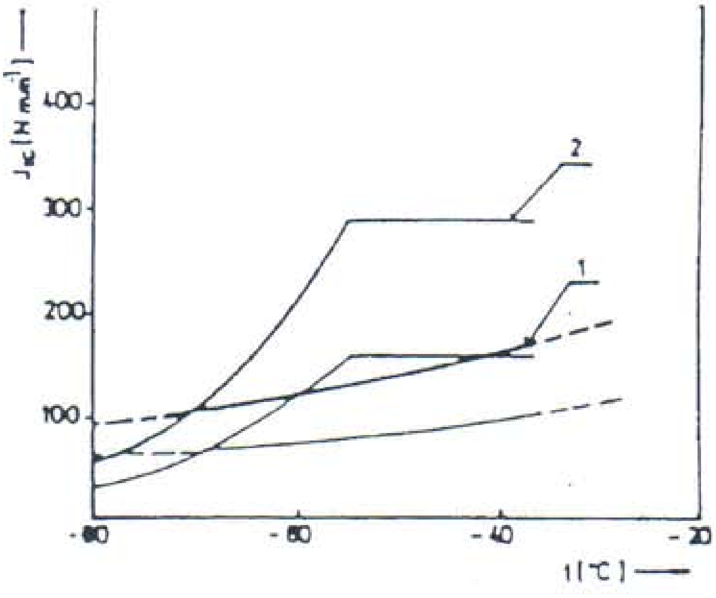


Fig.5. The course of notch toughness JIC on temperature measured in specimens with X30 joint in Fe 430 D steel, 1 – as-welded, 2 – VSR specimen

THE EFFECT OF VIBRATORY STRESS RELIEVING ON FATIGUE STRENGTH.

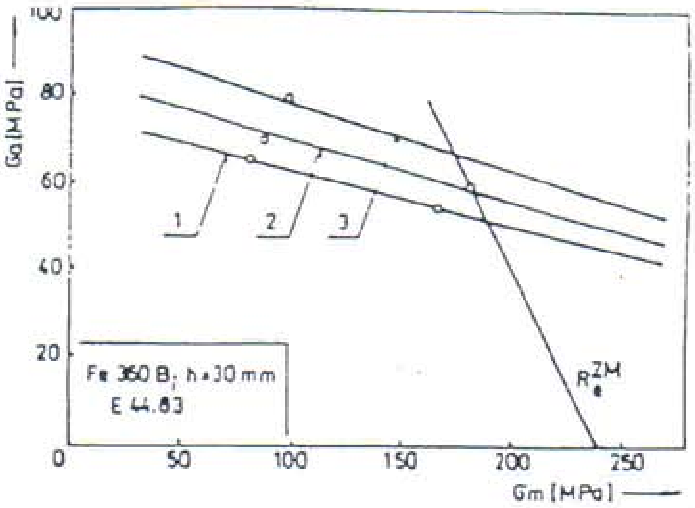
To solve the problem of VSR application the fatigue strength of welded joints and weldments in dissimilar steels was studied.

Fig.6 shows the results of fatigue tests of welded specimens 30mm in thickness with X30 mm in thickness with X30 welded joint in Fe 360 B steel / Fig. 6a/ fabricated by manual arc process employing E 44.83 coated electrode and that in Fe 430 D steel fabricated by submerged arc process employing N and A 107 wire / Fig.6b/.

The measured values in Fig. 6 prove that fatigue strength in Vibratory stress relieved joints was not decreased / dependence designated with no.2/. Similar results were attained also in other welded joints of different steels and in welded beams. The vibratory stress relieving of welded joints and weldments does not cause decrease in their fatigue strength.

HYGIENE OF WORK AT VIBRATORY STRESS RELIEVING OF WELDMENTS.

By the introduction of VSR into manufacture also the tasks of hygiene of work with respect to higher noisiness by vibratory stress relieving of weldments were solved. The guidelines for Vibratory stress relieving of weldments and hygiene of work / Jesensky, Horny, Vranka, 1986/ have been elaborated. Except for specifications of vibratory stress relieving of parts this guideline also contains the measures of safety and hygiene of work in accordance with the CSN Standard.



b)

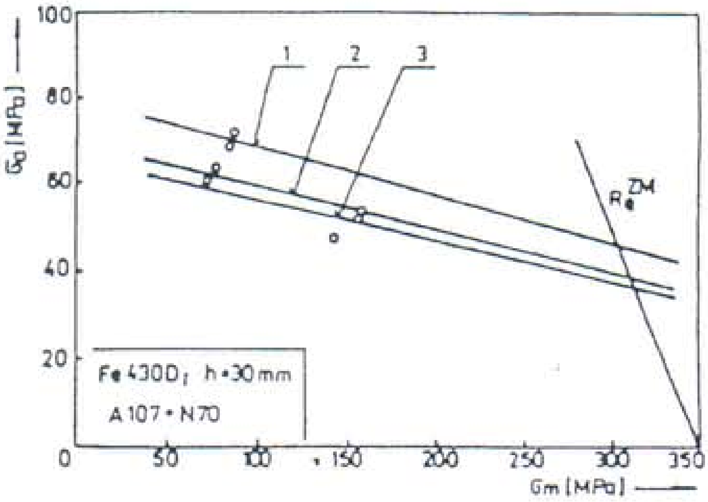


Fig .6. Measured values of fatigue strength in welded joints, a - dependence of stress amplitude on mean stress in Fe 360 B steel specimens, b - the same dependence in Fe 430 D specimens, 1 - as-welded condition, 2 - after Vibratory stress relieving, 3 - after stress relief annealing, Re - Yield strength of base metal.

CONCLUSIONS

Based on hitherto attained research results and experience in practical use of VSR weldments the introduction of VSR into practice can be recommended. The Vibratory stress relieving can be employed for stabilization of the size of suitable weldments prior to their machining and servicing as a replacement of stress relief annealing . Much experience and good results were attained with VSR in our manufacturing plants.

The VSR process is used for lowering of residual stresses and stabilization of the size of different weldments such as frames of forming machines, machine frames, grey cast iron castings, etc. which were up to now subjected to stress relief annealing.

According to hitherto obtained findings the shape and size of suitable VSR weldments were sufficiently stabilized after vibratory stress relieving and in exploitation. As a fact, VSR does not negatively affect the static and dynamic strength of welded joints and weldments, fracture and notch toughness and homogeneity of welded joints.

Based on the attained data the implementation of VSR procedure as replacement of stress relief annealing for the stabilization of size of weldments, castings and forging leads to high savings of production costs to our national economy. The saving of thermal energy has to be emphasized first of all because in VSR procedure it does not exceed 3% of energy required for annealing of weldments and in average 5% of production costs.

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