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RESIDUAL STRESS MANAGEMENT: INDUSTRIAL APPLICATIONS

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ABSTRACT

A concept of residual stress management (RSM) was proposed recently that addresses major aspects of residual stresses (RS) in welds and welded structures. According to the concept three major stages, i.e. RS determination, RS analysis and RS redistribution are considered and evaluated, either experimentally or theoretically to achieve the optimum performance of welded structures. The main stages of RSM are briefly discussed and examples of use of new engineering tools, the ultrasonic computerized complex for residual stress measurement, the software for analysis of the effect of residual stresses on the fatigue life of welded elements, and the new compact system for beneficial redistribution of residual stresses by ultrasonic peening are given.

Keywords: residual stress, non-destructive measurement of stresses, post-weld improvement treatment, ultrasonic peening.

INTRODUCTION

It is very important to consider the problem of residual stress as a complex problem including, at least, stages of the determination, the analysis and the beneficial redistribution of residual stresses. The combined consideration of the above-mentioned stages of residual stress analysis gives rise to so called Residual Stress Management (RSM) concept approach that addresses major aspects of residual stresses in welds and welded structures. According to the concept three major stages, i.e. RS determination, RS analysis and RS redistribution are considered and evaluated, either experimentally or theoretically to achieve the optimum performance of welded structures.

RESULTS AND CONCLUSIONS

The RSM concept includes the following main stages:

Stage 1: Residual Stress Determination; *Stage 2:* Analysis of the Residual Stress Effects.

Stage 3: Residual Stress Modification, if required.

A number of new advanced engineering tools for all three stages of RSM were developed recently at Structural Integrity Technologies (Sintec) Inc. (Markham, Canada) in cooperation with scientists from the National Academy of Sciences of Ukraine. The Ultrasonic Computerized Complex (UCC) (Fig.1a) was developed for residual stress measurement in laboratory and in field conditions (Kudryavtsev, 2007). The UCC allows determining uni- and biaxial applied and residual stresses for a wide range of materials and structures. One of the main advantages of the developed technique and equipment is the possibility to measure the residual and applied stresses in samples and real structure elements in bulk an din sub-surface layers.

The Ultrasonic Peening (UP) System (Fig. 1b) produces a number of beneficial effects in metals and alloys. Foremost among these is increasing the resistance of materials and welded elements to surface-related failures, such as fatigue, fretting fatigue and stress corrosion cracking.

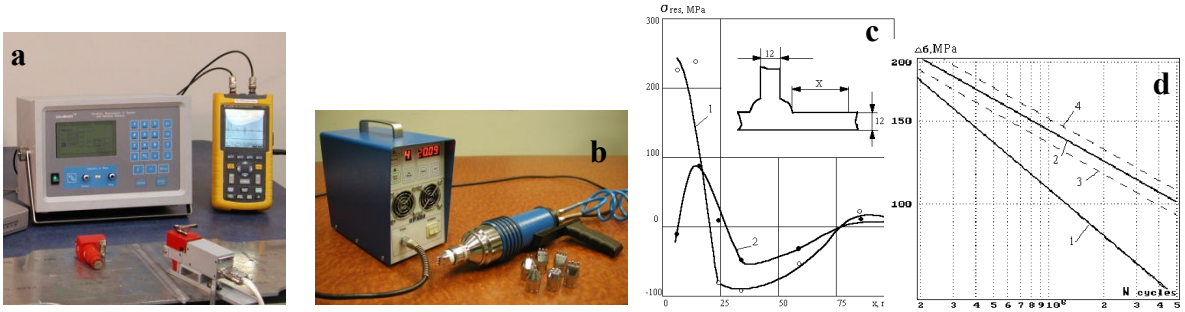

Fig. 1 - Ultrasonic Computerized Complex for residual and applied stress measurement (a) and advanced compact equipment for Ultrasonic Peening of materials, parts and welded elements (b) used to measure the stresses before (curve 1 in c) and after (curve 2 in c) UP treatment of a fillet welded joint, demonstrating a four-fold increase in fatigue life (d).

As an example of using the RSM concept, the residual stresses were measured in welded elements of a railway bridge span (Kudryavtsev, 2000). Figure 1c presents the results of residual stress measurement near the end of the fillet weld before and after application of the UP improvement treatment. The purpose of the improvement treatment application was the beneficial redistribution of the residual stresses. The level of tensile residual stresses near the weld before improvement treatment reached in this case 240 MPa. Such high tensile residual stresses are one of the main causes of the fatigue failures of welded elements. The application of the improvement treatment led to the redistribution of the residual stresses near weld zone from initial level to -10 MPa. The computer simulations showed (Fig. 1d) that such redistribution of the residual stresses caused a 45% increase in the limit stress range ($N=2\times10^6$ cycles) for this type of welded element: from 85 MPa to 123 MPa.

In summary, a number of new engineering tools for residual stress management such as ultrasonic computerized complex for residual stress measurement, technology and equipment for ultrasonic penning and expert system for fatigue assessment and optimization of welded elements and structures were recently developed, verified and used through the RSM concept in industrial applications.

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