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Research on residual stress reduction by a low frequency alternating magnetic field

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Abstract

Based on previous research of strong pulsed magnetic treatment, the effect of a low frequency alternating magnetic field on welding residual stress was studied. The experimental results show that by low frequency alternating magnetic treatment, the residual stresses in both rigid restrained specimens and welded specimens are reduced. Furthermore low frequency alternating magnetic treatment has the feature of simple equipment and easy operation. © 1998 Elsevier Science S.A.

Keywords: Residual stress; Magnetic treatment; Welding; Magnetic vibration; Stress relaxation

1. Introduction

A large number of studies have been carried out to reduce or relieve residual stress in products [1–6]. As a new stress reducing method, magnetic treatment can not only avoid particular harmful effects and drawbacks of heat treatment but also is a quick operational procedure. Some practical applications have shown that magnetic treatment can increase the service life of some kinds of machine tools and it was inferred that the effect is caused by residual stress relief in the tools [7].

Because the equipment for low frequency alternating magnetic treatment (LFMT) is relatively simple and convenient for practical applications, the goal of the present work is to investigate the effect of LFMT on the residual stress of both rigid restrained tensile specimens and welded specimens using a new type of equipment.

2. Experimental procedure

In order to observe the stress relaxation with magnetic treatment directly, a type of tube-shape uniaxial tensile specimen was made. The thickness of the tube wall was 3 mm and the material was low carbon steel. The specimens were loaded on a Gleeble-1500 thermal and mechanical simulation machine at a constant tensile displacement, and subjected to magnetic treatment. The variations of the load were measured simultaneously. The frequency of the magnetic field was 1, 5 and 10 Hz and the intensity of the field was about 10^4 A m^{-1}. In the course of the magnetic treatment over a limited time, no apparent temperature rise took place in the specimens.

Two kinds of welded specimens were adopted. Welding deposition specimens made of HT70 steel ($200 \times 75 \times 10$ mm, shown in Fig. 1) were produced with a robot and the deposited weld bead was on the centerline of each specimen. The residual stress was measured using the blind hole method. The arrangement of the points for measurement is shown in Fig. 1. Points 1, 3 and 5 were measured before magnetic treatment whilst point 2, 4 and 6 were measured after magnetic treatment. The stresses at the middle points between points 1, 3, 5 were used as the initial residual stresses and compared with the stresses at points 2 and 4, to enable the effect of the magnetic treatment on the residual stress to be evaluated.

Welding restraint specimens (430 mm $\times$ 365 mm $\times$ 32 mm, shown in Fig. 2) with a double-V butt weld made of HT50 steel were produced in two steps. First, two restraint welds with each of 90 mm length were made at both ends, then the main weld in the middle was

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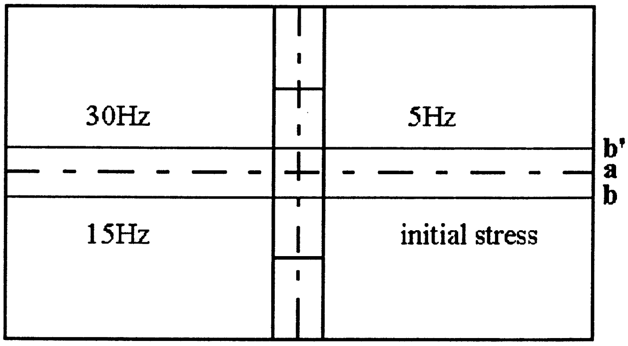

Fig. 1. Welding restraint specimen and sections for residual-stress measurement and magnetic treatment.

finished. The initial residual stress was measured at section b (shown in Fig. 2). The magnetic treatment was done at areas that were exactly symmetrical with the areas to which section b belongs. The residual stress was measured after magnetic treatment and the results of the measurement were compared with the values of

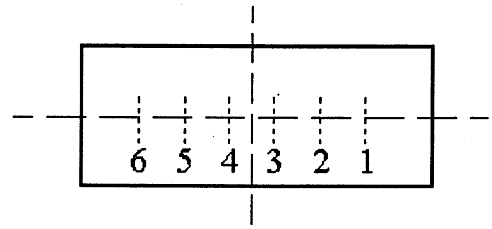

Fig. 2. Welding deposition specimen and arrangement of the residual-stress measuring points.

the initial residual stress. The frequencies of the magnetic field adopted were 5, 15 and 30 Hz respectively. The intensity of the magnetic field was about 10^4 A m^{-1}.

3. Results and discussion

Fig. 3 shows the curves of displacement and load of uniaxial tensile specimens when treated by LFMT. In the course of magnetic treatment, the tensile displace-

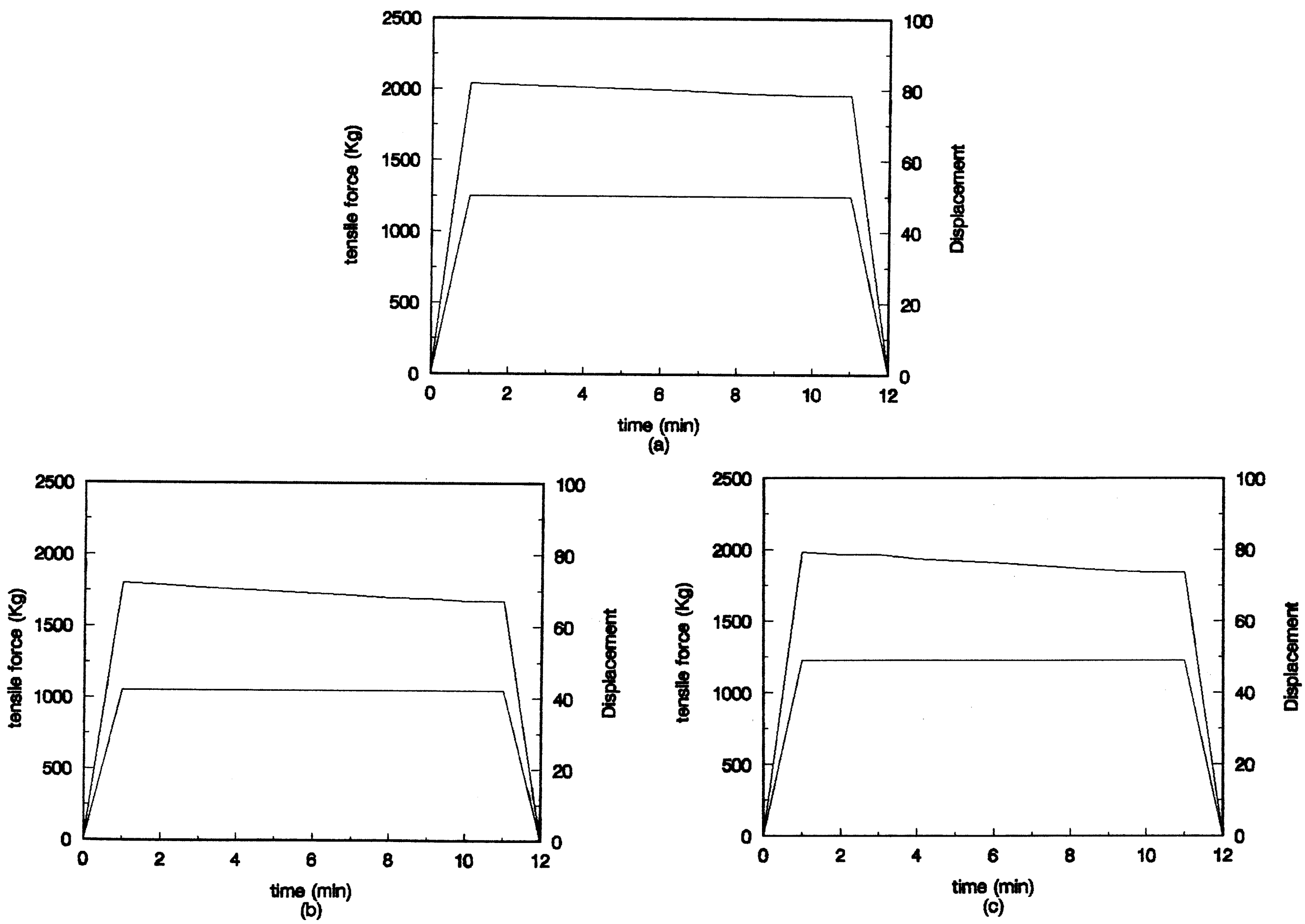

Fig. 3. Curves of displacement and load of a uniaxial tensile specimen in the course of LFMT: (a) 1 Hz; (b) 5 Hz; (c) 10 Hz (the unit of displacement is μm).

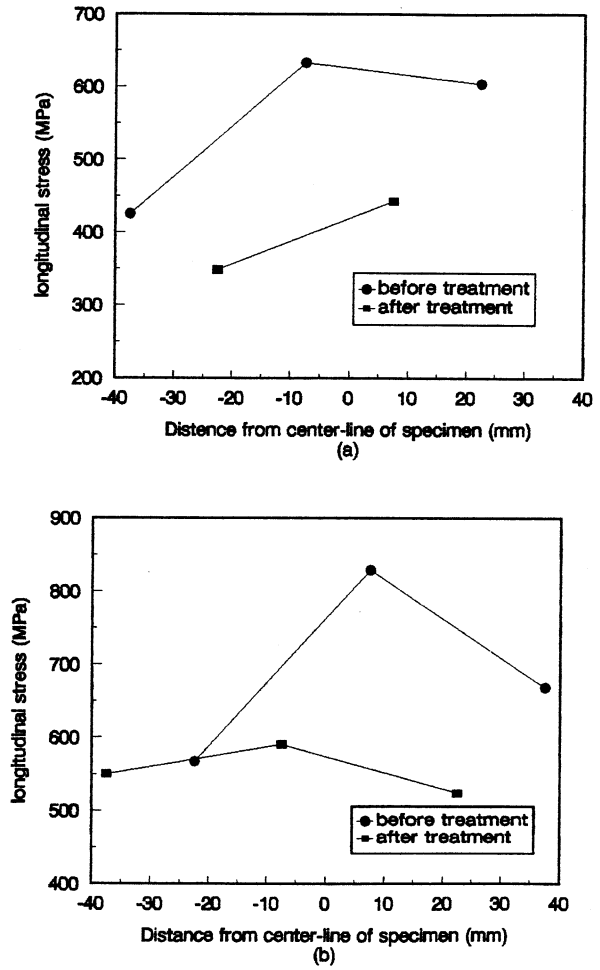

Fig. 4. Comparison of longitudinal residual stress in welding deposition specimens before and after LFMT: (a) No. 1 specimen; (b) No. 2 specimen.

ment was nearly constant and the loads reduce continuously and slowly decline. After treatment, the curves of load became horizontal. The load reduced by 80 kg when the frequency was 1 Hz, the load reduced by 100 kg when the frequency was 5 Hz, and by 120 kg when the frequency was 10 Hz. The tests thus establish that there is a tendency to stress relaxation in specimens during LFMT.

The results of magnetic treatment on the welding deposition specimens are shown in Fig. 4a and b. The residual stress in the center-line of the specimens indicates a remarkable reduction, and the magnitude of the reduction being about 170 MPa with an average reduction of about 30% or so. As shown in Fig. 5, the welding restraint specimen was subjected to magnetic treatment at three different frequencies. After treatment, the transverse residual stress was reduced generally. In the areas near to the weld bead, the magnitude of residual-stress reduction by 5 Hz LFMT is a little greater than that by 15 Hz and 30 Hz treatment. The

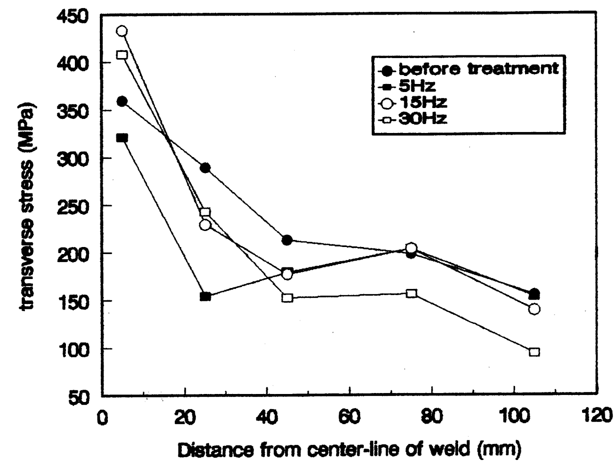

Fig. 5. Comparison of the transverse residual-stress distribution in welding restraint specimens before and after LFMT with three fre

longitudinal stresses also have a tendency to reduce, but the magnitudes of reduction are relatively small.

Although the mechanism of magnetic treatment needs to be studied further, from the difference of SPMT and LFMT, it is possible to infer from the above results that the intensity and frequency of the magnetic field and the duration of treatment all have an influence on the stress-reduction effectiveness. The residual-stress reduction is essentially caused by accumulation of all kinds of non-elastic strain (at micro- and macro-scales) that occur in the materials. On one hand the emergence and development of these strains need to consume energy, so that the intensity and duration of the magnetic field must satisfy particular requirements, on the other hand the course of the dynamic non-elastic strain must have an optimum responsive range of frequency of magnetic field because the magnetic vibration in the material that is caused by the periodic magnetic field may make a significant contribution to the stress relaxation.

4. Conclusions

By low-frequency alternating magnetic treatment, the residual stress in both uniaxial tensile specimens and welded specimens tends to reduce. The intensity, frequency and duration of the magnetic field all have an influence on the effects of the treatment. Research on the optimization of the parameters of the magnetic treatment and the mechanism of stress reduction are currently in progress.

Acknowledgements

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