International Scientific-Technical and Production Journal

The Paton WELDING JOURNAL

October 2012 # 10

English translation of the monthly «Avtomaticheskaya Svarka» (Automatic Welding) journal published in Russian since 1948

Founders: *E.O. Paton Electric Welding Institute of the NAS of Ukraine International Association «Welding»*

Publisher: *International Association «Welding»*

Address:
E.O. Paton Electric Welding Institute,
International Association «Welding»,
11, Bozhenko str., 03680, Kyiv, Ukraine
Tel.: (38044) 200 82 77
Fax: (38044) 200 81 45
E-mail: journal@paton.kiev.ua
URL: www.rucont.ru

State Registration Certificate
KV 4790 of 09.01.2001

Subscriptions:
$324, 12 issues per year,
postage and packaging included.
Back issues available.

CONTENTS

ŋqdqɣəʏ bƎ dədƎbʏɜə d əɑɓɔɣ ɟqddʏqɣè

EXPERIMENTAL STUDY AND MODELLING OF THERMAL-DEFORMATION PROCESSES OCCURRING IN WELDED JOINTS ON NICKEL SUPERALLOYS

K.A. YUSHCHENKO[1], **V.A. ROMANOVA**[2], **R.R. BALOKHONOV**[2], **V.S. SAVCHENKO**[1], **N.O. CHERVYAKOV**[1] and **A.V. ZVYAGINTSEVA**[1]

[1]E.O. Paton Electric Welding Institute, NASU, Kiev, Ukraine

[2]Institute of Strength Physics and Materials Science, SB RAS, Tomsk, Russia

Results of experimental and numerical investigations of the processes of deformation and fracture of welded joints on nickel superalloys under conditions of mechanical and thermal loading are presented. Structural transformations were investigated, and thermal-deformation processes in the heat-affected zone (HAZ) during the welding cycle process were evaluated. The mechanisms of initiation and propagation of hot cracks in the HAZ metal near the fusion line were determined, and local plastic strains under the thermal cycle condition were assessed. Evolution of the stress-strain state in the HAZ metal was analysed in terms of physical mesomechanics, and conclusions on the role of grain boundaries in the processes of initiation and propagation of cracks were made.

Keywords: *arc welding, nickel superalloys, welded joints, thermal loading, inter-grain boundaries, hot cracks, numerical modelling*

Nickel-base superalloys are characterised by high mechanical properties, but low weldability. They exhibit sensitivity to hot cracking under the welding cycle conditions. Experimental data [1–4] indicate that the thermal cycle of welding leads to substantial structural transformations of material in the HAZ adjoining the fusion line. Mostly hot cracks form in this zone.

To find out causes of hot cracking under the welding cycle conditions it is necessary to have a clear idea of the kinetics of the deformation processes and evolution of the stress-strain state in different zones of a welded joint. So far the information available on these phenomena is scanty, as experimental studies are extremely labour-intensive, and money- and time-consuming.

This article describes experimental and numerical studies of the processes of deformation and fracture of welded joints on nickel alloys under conditions of thermal loading. Structural transformations were investigated, thermal-deformation processes in the HAZ metal during the welding cycle were evaluated, the mechanisms of initiation and propagation of hot cracks under the thermal-force effect conditions were determined, and local plastic strains in the HAZ metal in welding of austenitic nickel alloys were assessed by using experimental methods.

Models of the materials under investigation were developed by allowing for the internal structure, and the deformation processes under the thermal cycling conditions were modelled on the base of the obtained experimental data. Development of the model of a material provides for determination of the explicit temperature dependence of its physical-mechanical properties. At a level of the polycrystalline structure, the sources of the concentration of stresses, initiation of plastic shears and microcracks are grain boundaries.

At the mesoscale level the model described the grained structure in its explicit form, and structural transformations fixed in the HAZ metal during the welding cycle processes were allowed for through phenomenological dependences of mechanical properties upon the temperature. Evolution of the stress-strain state in different regions of HAZ under the heating–cooling thermal cycle conditions was investigated numerically.

Investigation of the deformation processes and peculiarities of structural transformations in the HAZ metal under the welding cycle conditions. Investigations were carried out on nickel alloy IN738LC. As shown experimentally, phase transformations of the $\gamma' + \gamma \rightarrow \gamma \rightarrow \gamma + \gamma'$ type occurs in the HAZ region wherein the propagation of cracks takes place. Precipitation of the fine γ'-phase occurs in the HAZ region adjoining the weld. Size of the γ'-phase particles in the base metal and HAZ is 0.4–0.9 and 0.05–0.15 μm, respectively (Figure 1).