

Editor-in-Chief B.E.Paton

Editorial board:

Yu.S.Borisov	V.F.Khorunov
A.Ya.Ishchenko	I.V.Krivtsun
B.V.Khitrovskaya	L.M.Lobanov
V.I.Kirian	A.A.Mazur
S.I.Kuchuk	Yatsenko
Yu.N.Lankin	I.K.Pokhodnya
V.N.Lipodaev	V.D.Poznyakov
V.I.Makhnenko	K.A.Yushchenko
O.K.Nazarenko	A.T.Zelnichenko
I.A.Ryabtsev	

International editorial council:

N.P.Alyoshin	(Russia)
U.Diltey	(Germany)
Guan Qiao	(China)
D. von Hofe	(Germany)
V.I.Lysak	(Russia)
N.I.Nikiforov	(Russia)
B.E.Paton	(Ukraine)
Ya.Pilarczyk	(Poland)
P.Seyffarth	(Germany)
G.A.Turichin	(Russia)
Zhang Yanmin	(China)
A.S.Zubchenko	(Russia)

Promotion group:

V.N.Lipodaev, V.I.Lokteva
A.T.Zelnichenko (exec. director)
Translators:
A.A.Fomin, O.S.Kurochko,
I.N.Kutianova, T.K.Vasilenko
PE «Melnik A.M.»
Editor
N.A.Dmitrieva
Electron galley:
I.S.Batasheva, T.Yu.Snegiryova

Address:

E.O. Paton Electric Welding Institute,
International Association «Welding»,
11, Bozhenko str., 03680, Kyiv, Ukraine
Tel.: (38044) 287 67 57
Fax: (38044) 528 04 86
E-mail: journal@paton.kiev.ua
http://www.nas.gov.ua/pwj
State Registration Certificate
KV 4790 of 09.01.2001

Subscriptions:

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

All rights reserved.

This publication and each of the articles
contained herein are protected by copyright.
Permission to reproduce material contained in
this journal must be obtained in writing from
the Publisher.

Copies of individual articles may be obtained
from the Publisher.

CONTENTS

SCIENTIFIC AND TECHNICAL

Makhnenko V.I., Poznyakov V.D., Velikoivanenko E.A., Makhnenko O.V., Rozyinka G.F. and Pivtorak N.I. Risk of cold cracking in welding of structural high-strength steels	2
Gorban V.F., Kharchenko G.K., Falchenko Yu.V. and Petrushinets L.V. Investigation of joints of titanium aluminide with titanium alloy VT8 produced by diffusion welding	7
Sabokar V.K., Akhonin S.V., Petrichenko I.K. and Yasinsky A.V. Pressure welding of titanium aluminide to other titanium alloys	10

INDUSTRIAL

Welding and Cutting 2009. Essen, Germany, 14–19 September 2009	13
Shelyagin V.D., Khaskin V.Yu., Mashin V.S., Pashulya M.P., Bernatsky A.V. and Siora A.V. Features of laser-MIG welding of high-strength aluminium alloys	21
Zelenin V.I., Kavunenko P.M., Tisenkov V.V., Teplyuk V.M., Poleshchuk M.A., Lebed V.D., Lipisy V.I., Bondarev S.V., Gavrilov S.A., Olgard N.T. and Cheburov S.A. Application of plasma-arc metallisation for restoration of wheel pairs	28
Tsaryuk A.K., Ivanenko V.D., Volkov V.V., Mazur S.I., Trojnyak A.A., Vavilov A.V., Kantor A.G. and Volichenko N.P. Repair welding of turbine case parts from heat-resistant steels without subsequent heat treatment	32

BRIEF INFORMATION

Lankin Yu.N. and Sushy L.F. Electrical conductivity of slag pool in electroslog welding with wire electrode	37
News	39

NEWS

International Conference «Improvement of Turbine Plants Using Methods of Mathematic and Physic Modelling»	40
Seminar on welding technologies «Full Readiness to Excelent Welding of Steel»	41
International exhibition «Weldex/Rossvarka-2009»	44
International Scientific and Technical Conference «Problems of Welding, Related Processes and Technologies»	46
International Conference «High Mat Tech»	48
Index of articles for TPWJ'2009, Nos. 1–12	49
List of authors	53



RISK OF COLD CRACKING IN WELDING OF STRUCTURAL HIGH-STRENGTH STEELS

V.I. MAKHNENKO, V.D. POZNYAKOV, E.A. VELIKOIVANENKO, O.V. MAKHNENKO,
G.F. ROZYNKA and N.I. PIVTORAK

E.O. Paton Electric Welding Institute, NASU, Kiev, Ukraine

Mathematical model of the risk of cold cracking in welding of structural high-strength steels is considered. The model is based on distributed data on the state of microstructure, content of diffusible hydrogen and stressed state in elementary volumes within the welded joint zone. It is shown that the model makes it possible to more precisely evaluate the local conditions of cold cracking on the basis of the above parameters.

Keywords: arc welding, low-alloy high-strength steels, brittle fracture, cold cracks, diffusible hydrogen, microstructure, stressed state, probability model

It is a known fact that the presence of quench structures, diffusible hydrogen and tensile stresses [1] are conditions that induce cold (hydrogen) cracks in welding of structural steels. As to the quantitative characteristics of the specified conditions, at present it is possible just to approximately evaluate critical values of the corresponding characteristics, allowing for locality of cold cracking processes, presence of a significant gradient of changes of these characteristics in a zone of welding heating, their strong mutual effect and other factors, by limiting their extreme demonstrations with almost no account for their mutual effects. Meanwhile, development of the methods (experimental and calculation) for determination of distributed parameters of the above characteristics in welding of different joints on structural steels, as well as the trends to optimization of the techniques to prevent cold cracks require development of more precise criteria of the risk of their formation.

It can be shown that many recent approaches [1] based on such integral characteristics as carbon equivalent in the HAZ [1], content of hydrogen in filler metal, degree of restraint and thicknesses being welded, used as the quantitative conditions for microstructure, diffusible hydrogen and effective stresses are of a very general character. They are far from providing an ambiguous determination of the quantitative characteristics of the conditions causing cold cracking at certain parameters of welding heating. It has been proved in recent decades, due to the development of the «Sysweld» and other types of computer systems, which help to obtain the calculation information on the distributed characteristics in the weld and HAZ metals regarding the cold cracking conditions, that zones of potential cold cracks do not always have the most extreme combinations of volumes of quench microstructures, content of diffusible hydrogen and level of tensile stresses. Often the zones with a maximum volume of martensite and content of diffusible hydrogen are within the compressive zones, or

the zones with high tensile stresses have a purely bainitic microstructure and low level of diffusible hydrogen, i.e. they are not potential centers of cold cracks. In other words, the proper, physically substantiated criteria that quantitatively connect, on the level of the distributed parameters, the necessary conditions for cold cracking to occur in welding heating of structural steels under consideration, are required.

An approach for development of such criteria, based on the following factors, is given below:

- probability assessment of the risk of cold cracking is performed in a specified area of a welded joint (certain region of the fusion zone or HAZ);
- initiation and propagation of cold cracks take place by the brittle fracture mechanism, i.e. determined by correspondent normal stresses $\sigma_{jj}(x, y, z)$ at a point with coordinates x, y, z , acting in an area with normal j and corresponding characteristic of resistance of a material, $A_j(x, y, z)$, to brittle fracture formation.

A_j is a function of microstructural state and content of diffusion hydrogen for a given steel.

The probability of brittle fracture in specific volume V , in compliance with the Weibull theory, is determined by dependence

$$P_j(V) = 1 - \exp \left[- \int_V \left(\frac{\sigma_{jj} - A_j}{B_j} \right)^\eta dV / V_0 \right], \quad (\sigma_{jj} > A_j). \quad (1)$$

In (1), integration is carried out only with respect to elementary volumes dV , where $\sigma_{jj} > A_j$, and A_j , η and $B_j V_0^{1/\eta}$ are the Weibull distribution parameters. As a rule, $\eta = 4.0$, and A_j and $\bar{B}_j = B_j V_0^{1/\eta}$ are determined experimentally.

The values of \bar{B}_j depend on the size of the volume V along the section with normal j (Figure 1). If stresses σ_{jj} and material resistance A_j in length l_j of this volume change but slightly, then a change of $dV = l_j dF$ can be made in integral of expression (1), where F is the cross-section area of volume V .

Accordingly, the following will be obtained instead of (1):