International Scientific-Technical and Production Journal

The Paton WELDING JOURNAL

April 2010 # 4

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) 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.

CONTENTS

ANALYSIS OF FACTORS OF SUBSOLIDUS CRACK FORMATION IN WELDING METALS WITH FCC-STRUCTURE OF CRYSTALLINE LATTICE (Review)

A.A. SLIVINSKY
NTUU «Kiev Polytechnic Institute», Kiev, Ukraine

The paper gives terminological analysis of the phenomenon of subsolidus cracking in welding. Structural and technological factors affecting subsolidus crack formation in welding of various materials with fcc-structure of the crystalline lattice are considered. The need for generalizing the current concepts on this issue with application of modern physical models from the field of dislocation theory of plastic deformation and brittle fracture mechanisms at high-temperature creep is noted.

Keywords: *fusion welding, subsolidus cracks, austenitic steels, nickel, aluminium, copper alloys, terminological analysis*

In keeping with the generally accepted concepts, a separate kind of brittle intercrystalline (intergranular) fracture of weld and HAZ metal is called subsolidus cracks in welding. They initiate after completion of solidification in completely solidified metal, but at high temperatures, sufficient for predominant development of viscoplastic deformation in it [1–5]. In foreign publications, including several normative documents (DVS 1004-1, DIN 8524-3 and DIN EN ISO 6520-1), this type of hot cracks are usually called ductility dip cracks (DDC).

In terms of the widely accepted N.N. Prokhorov deformation-kinetic theory of technological strength [6–11] it is not quite correct to call hot cracks of only a certain type like that, as any cases of cracking in welding are related to the joined metal staying in the appropriate temperature range of lower ductility, so-called brittle temperature range (BTR). On the other hand, the phenomenon of an abrupt ductility drop in steels and alloys suitable for high-temperature plastic deformation during their staying in the temperature range of $(0.5–0.8)T_{melt}$ and the thus caused cracking at hot forming (forge rolling, stamping, press-forging treatment) or heat treatment has been known for many years [12–14], which is exactly what led to inclusion of the term of «ductility dip cracks» into the international welding terminology.

Despite a long-time study of the phenomenon of ductility dip or subsolidus cracks, the mechanism of their formation in welding is not completely clear yet. Proceeding from analysis of published sources, we can unambiguously state only the presence of a number of common features, characteristic of subsolidus crack formation. Numerous studies of subsolidus crack surface fractography [1, 15, 16] point to their development at high temperatures, as well as the brittle, intergranular or intercrystalline nature of fracture at the moment of initaition and growth of these defects. However, these investigations, as a rule do not give any grounds to state the presence of liquid inclusions on grain boundaries during cracking.

In addition, presence of a subsolidus brittle temperature range in a certain material, unlike the «solidification BTR», is not objectively attributable to the very specifics of the fusion welding process. While potential susceptibility to solidification cracking is demonstrated by all the structural alloys at any welding processes, as well as with some other pressure welding processes, accompanied by material overheating above the solidus temperature, initiation of subsolidus cracks requires running of special structural and phase transformation in the solid metal, the probability of which essentially depends on its composition. The most susceptible to formation of subsolidus hot cracks in welding or heat treatment are metallic materials with face-centered cubic (fcc) crystalline lattice: austenitic class steels [16–18], nickel- [2, 4, 13, 19–24], aluminium- [25], copper- [26], gold- and platinum-base [27] alloys.

Results of numerous studies of weldability of these materials point to a set of certain predominantly structural factors, influencing subsolidus cracking in welding. They include grain size, type, geometry and orientation of intergranular boundaries in relation to acting stresses, presence of precipitates of other phases, segregation of impurities or higher concentration of dislocated atoms on intergranular boundaries, as well as welding heat input and temperature rate of deformation.

Thermally activated grain coarsening increases the extent of BTR and reduces the material deformability [28, 29], and also intensifies the processes of intergranular slipping [2] under the impact of welding stresses, thus promoting crack initiation. On the other hand, the results of investigations conducted by the authors of [30] with nickel alloys of different structure and composition, do not point to the presence of a strict interrelation between the susceptibility to subsolidus cracking and base metal grain size.

ɳqdqʎəʎ bɆ dədɆbʎɜə d ɛɔɑɔʎ ɟqqdʎqʎè