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CONTENTS

COMPARATIVE EVALUATION OF SENSITIVITY OF WELDED JOINTS ON ALLOY INCONEL 690 TO HOT CRACKING

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Sensitivity of metal of the welds made with wires Inconel® 52 and Inconel® 52MSS to hot cracking was evaluated. The machine testing methods (Varestraint-Test and PVR-Test), which provide for forced deformation of test specimens during welding, were used. The welds made with wire Inconel 52MSS were shown to be more resistant to ductility dip cracking, but several times more sensitive to solidification cracking. Evaluation of ductile properties of the weld metal using the «Ala-Too» machine showed that the Inconel 52MSS type weld metal had no ductility dip, whereas the Inconel 52 type weld metal was characterized by a pronounced decrease in the elongation values.

Keywords: *TIG welding, nickel alloys, filler wire, weld metal, evaluation of crack resistance, ductility dip range, grain boundary, forced deformation*

Welded joints on high-alloy steels with a stable austenitic structure and nickel alloys are known to be characterised by high sensitivity to hot cracking during fusion welding. As to their nature, hot cracks can be subdivided into two types (Figure 1): solidification (type 1) and underbead (type 2) cracks that form in the process of thermal-force loading of the multi-pass weld metal zones [1]. The temperature range of formation of the solidification cracks depends on the range of the solid-liquid state of metal during solidification of the weld. The lower limit of this range is determined by the value of solidus temperature at the end of solidification, T_S. The ductility dip temperature range is determined by an approximate ratio of $(0.6–0.8)T_S$ [2]. In this range the cracks initiate and propagate along the boundaries of high-angle austenitic grains [3].

The sensitivity to hot cracking is determined by the following factors [4–8]:

- chemical composition of the weld metal in terms of the content of main and impurity elements, having a limited solubility in solid solution and determining the solidification temperature range;
- value and rate of the growth of strain in solidification of the weld and its subsequent cooling;
- presence of conditions for redistribution of impurity elements, such as carbon, sulphur, oxygen etc., characterised by a high diffusivity under the thermal-force impact on metal by the fusion welding process;
- formation of the fine weld structure in one- and multi-pass welding, which determines the process of plastic deformation in metal of the polycrystalline welds;
- cohesive strength of grain boundaries in the welds with a stable austenitic structure, which determines conditions for initiation of hot cracks.

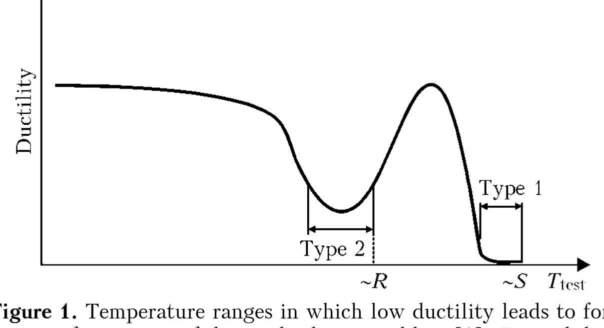

Figure 1. Temperature ranges in which low ductility leads to formation of two types of the cracks during welding [1]: S — solidus; R — recrystallisation

The purpose of this study was to perform comparative evaluation and investigation of the sensitivity of welds and welded joints on alloy Inconel 690 made by using welding wires Inconel 52 and Inconel 52MSS to hot cracking.

Special specimens are available for simulation of conditions of deformation of the deposited metal in multi-pass welding of real structures. Evaluation of the sensitivity to hot cracking, including in the multi-pass welds, is performed on the test specimens simulating the thermal-force impact exerted by the welding process on formation of the weld structure and initiation of hot cracks. Also, the use is made of the machine testing methods with the graduated forced deformation. In this case the most efficient methods are Varestraint-Test and PVR-Test (Programmierter Verformungs-Riss Test) [9]. So, these methods were employed to evaluate the sensitivity to solidification cracking, as well as to ductility-dip cracking in multi-pass welding of nickel alloy Inconel 690 by using welding wire Inconel 52MSS characterised, according to the preliminary data, by high crack resistance in the low-temperature ductility dip range. Investiga-