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On the issue of assessing the probability and preventing the occurrence of "ductility dip cracking" mechanism under conditions of multi-layer welding arc 3D-overlaying process on nickel and cobalt alloys

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It is proposed to estimate the multi-layer nickel and cobalt alloy deposited metal's "ductility dip cracking" mechanism (ISO 17641-1 classification) hot cracking susceptibility by the ε critical rupture strain criterion, defined with longitudinal static tensile testing of "as built" (ISO/ASTM 52900 terminology) deposited metal at 20-1100 °C temperature range.

8 nickel (Inconel 625, Hastelloy C22, Inconel 718, EP367, EP 648, ChS 40, EI 698, Reñe 80) and 4 cobalt alloys (Ultimet, Stellite 6, Stellite 12, Stellite 190) had been analyzed. The nickel alloy chemical composition was chosen to vary from heat resistant alloys to ~50 vol. % γ′-phase content superalloy. Cobalt alloys – with carbon content gradually varying from 0,06 to 3,2 wt. % to estimate the carbide strengthening effect on the deformation. From the upper-mentioned materials, "vertical wall"-type weld workpieces had been produced with multi-layer TIG and micro-plasma welding deposition processes. After workpieces side polishing, miniature-sized proportional samples were cut from them by electrical discharge machining, for further static tensile tests on MTS-810 servo-hydraulic machine.

The analysis of obtained experimental data had shown, that in nickel and cobalt alloys "as bult" deposited metal, the next temperature ranges of reduced deformation capacity can be observed: up to 650-700°C – in carbide-strengthened cobalt alloys (e.g. Stellite 6 and Stellite 12), due to the preservation of its hot hardness property; 600-800°C – in nickel alloys with more than 3% molybdenum content (e.g Inconel 625, EP 367, ChS 40), or in nickel superalloy, strengthened with over 20 vol. % γ′-phase (EI 698); 1000-1100°C – caused by increased average oxygen and nitrogen content ([O] > 0,025 wt. % and [N] > 0,025 wt. %). Considering the previously defined low-ductility state in "as built" nickel superalloy deposited metal (e.g. ε = 0,8-4,8 % at 20-1100°C for deposited metal Reñe 80), and their renown hot cracking high susceptibility, it was concluded that crack appearance according to "ductility dip cracking" mechanism is possible under certain stiffness conditions, when at T = 600-1100°C critical longitudinal rupture strain values are ε < 5-10 %. The resource-saving assessment method for multi-layer deposited metal's hot cracking susceptibility according to "ductility dip cracking" mechanism, introduced by the Paton EWI, besides from testing different nickel and cobalt alloys, can also be used for comparative analysis on the deformation capacity of similar deposited metal obtained with filler materials (wire, powder) from alternative manufacturers and to evaluate their suitability for 3D arc additive manufacturing.