Influence of brazing process conditions on the microstructure and mechanical properties of joints of aircraft engine structure components

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ABSTRACT
In this study, research was carried out on the analysis of the effect of changes in key parameters of the furnace brazing process of sheet metal components made of nickel superalloys on the microstructure and properties of produced joints. Two nickel superalloys were adopted for the study – Hastelloy X and Inconel 718 – brazed with nickel based filler metals – Vitta-Braze 1996 (Ni-13Cr-4.5Fe-4.5Si-2.7B) and Palnicro 36M (Ni-36Pd-10.5Cr-3B-0.5Si), respectively. The brazing process was carried out under industrial conditions. Three most crucial factors that could disrupt its proper course were investigated: interruption of the heating operation at its various stages, a change in the soak time at the brazing temperature and a change in the width of the brazing clearance. The research plan was divided into three segments, each dedicated to one of the mentioned factors. A standardized package of specimens, assembled from the sheet metal samples in accordance with developed assumptions for lap joints, was used.
In the first segment of the study, brazing processes were interrupted at selected stages of heating, subsequently load was cooled to the room temperature and then subjected to rebrazing. The joints were tested after process interruption and after rebrazing. Next part of the research plan was aimed at evaluating the effect of soak time at brazing temperature (in the range of 1-60 minutes) on the process of joints microstructure and physical properties evolution for both analyzed materials configurations. In the third segment of the study, the impact analysis of the brazing clearance change in range of 0,05-0,5 mm on selected joints characteristics was done. In each segment of the study, in the case of Inconel 718 superalloy, properties after precipitation hardening was taken into consideration. Conducted tests included observations of macro- and microstructure (SEM), chemical composition analysis in micro-areas (SEM/EDS), shear and peel tests of the joints, as well as filler metal spreadability tests. Attempts of phase analysis using X-ray diffraction (XRD) and evaluation of thermal phenomena occurring during the heating of the filler metals and filler/base metal couples by differential scanning calorimetry (DSC) were made.
The conducted research allowed to obtain data to evaluate changes in the microstructure and functional properties of vacuum brazed joints of sheet metal components made of Hastelloy X and Inconel 718 superalloys, under varying process conditions. A characterization of the joints microstructure evolution, depending on the change of key parameters and the course of brazing cycle, including a description of the phase components in the particular zones of the base metal and the joint (diffusion, iso- and athermal crystallization zones), was done. An evaluation of the effect of process parameters on liquid filler metal flow conditions and mechanical properties of the joints was also carried out. Results were used as a basis for developing the quality and technological procedures dedicated for industrial usage.
Keywords: superalloys, vacuum brazing, precipitation hardening, microstructure, aircraft engines