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Title:

ANALYSIS OF THE IMPACT OF CHANGES IN THE GEOMETRY OF JOINED ELEMENTS ON THE STATIC AND FATIGUE PROPERTIES OF STRUCTURAL ADHESIVE JOINTS OF ALUMINUM ALLOY SHEETS EN AW -2024-T3 AND S235JR STEEL

Summary:

The doctoral dissertation addresses the issue of analyzing the impact of geometric changes at the leading edge of joined elements on the static and fatigue properties of structural adhesive joints of S235JR steel sheets and EN AW-2024-T3 aluminum alloy. The topic of the dissertation was chosen in response to the need to develop a simple, effective method that would ensure an effective increase in strength properties, particularly fatigue properties.

In order to preliminarily confirm the hypothesis that load-bearing capacity can be improved by modifying the structural connections, a numerical analysis was performed using the finite element method (FEM). The simulations were carried out using NX Simcenter software. It was shown that although the considered geometric modifications do not lead to a reduction in maximum stress values, they do cause a change in the nature of stress distribution in the adhesive joint area. Local stress concentrations are shifted away from the leading edge of the joint due to the influence of the geometry of the notches and holes.

As part of the experimental research, samples of single-layer adhesive joints were prepared in the base variant, i.e., without modifications, and in variants with geometric modifications. The modifications consisted of making indentations or holes of various sizes at the front edge of the joined sheets. Immediately before making the joints, an analysis of the bonded surfaces was carried out to determine the roughness parameters and the surface energy. The joints were made using Araldite 2014-2 chemically curable epoxy adhesive for metals.

The samples were first subjected to static strength tests under shear conditions, with a comparative analysis performed for each variant. The possibility of improving the static properties for selected variants was demonstrated. For steel sheet joints, in the case of the variant with 3 mm wide and 1 mm long notches, there was a 13.48% increase in strength compared to the base variant. In turn, the largest increase in strength for aluminum alloy connections was recorded for the variant with 2 mm wide and 2 mm long notches. Compared to the base variant, the increase was 8.77%. At the same time, it should be noted that in the case of most variants with modifications, no significant improvement in static strength was observed.

In addition, statistical methods (single-factor analysis of variance and regression analysis) were used to analyze the relationships between the load-bearing capacity of adhesive joints in the basic version and those subjected to structural modifications. Statistical analyses showed that the modifications had no significant effect on static strength.

In the next stage of work, fatigue strength tests were carried out, performing a comparative analysis for selected connection variants. It was shown that all the structural modifications considered have a very positive effect on the fatigue life of the connections.

In the area of high-cycle fatigue for steel connection samples at a maximum variable load of 9 MPa, an increase in average fatigue life of 275% was demonstrated for the variant with 1 mm wide notches. In this case, the average fatigue life was 1539.576×103 cycles, while for the base variant it was 410.516×103 cycles. The variant with holes at the edge also showed an increase in average fatigue life to 1162.916×103, which is an increase of 83.3% compared to the base variant. Moving on to the samples of EN AW-2024-T3 aluminum alloy connections, under high-cycle fatigue for the variant with 3 mm wide notches, at a maximum variable load level of 6.5 MPa, an increase in average fatigue life of 560.4% was demonstrated in relation to the base variant. For modified joints, the average fatigue life was 1209.089×103 cycles, while for the base variant it was 183.093×103 cycles.

The research results presented in the dissertation proved the hypothesis put forward in the thesis, according to which the use of perforations and indentations in the edge zone of a single-lap adhesive joint of S235JR steel sheets and EN AW 2024-T3 aluminum alloy in selected cases improves the static strength of the joints. However, with regard to the fatigue test results, it should be emphasized that each of the modifications applied contributes to a significant increase in fatigue life.