

# OPINION

for dissertation work  
for the acquisition of the educational and scientific degree "Doctor" in

**Field of Higher Education – 5. Technical sciences**  
**Professional Field – 5.1. Mechanical engineering**  
**Doctoral Program – „Structural Mechanics and Strength of Materials“**

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**Topic: Increasing the fatigue life of fastening holes in aluminum alloy D 16 AT, by a modified cold expansion method**

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## 1. Topic and relevance of the dissertation

The topic of the dissertation is dedicated to the task of experimentally evaluating the effectiveness of a modified Split Mandrel Cold Working method for improving the complex state of the surface and subsurface layers (Surface integrity, - "SI") around cold-expanded holes, in order to increase the fatigue life of structural elements made of aluminum alloy 2024-T3, in conditions of relatively large tolerance of the pre-machined holes.

When creating relatively fixed connections between metal components of mechanical structures, screw and rivet joints are most often used. Their implementation is carried out with the help of fastening holes, which are natural concentrators of stresses and deformations in the material of the assembled elements. When operating in dynamic conditions, the strength resource of the elements is determined by the destruction due to the occurrence and development of fatigue cracks in the materials in the areas around the holes. This process is typical for products of transport, aviation and space technology and often leads to material and immaterial losses, which determines the efforts of engineers from the world's leading laboratories to conduct research to study this phenomenon.

Solving the task formulated in the topic of the dissertation is another step in preventing material fatigue, which allows me to believe that the presented dissertation meets the requirement for topicality of the dissertation.

## 2. General characteristics of the dissertation work and research methodology

The dissertation work contains - Table of Contents, Accepted Notations and Abbreviations, Introduction, four chapters, Classification of Contributions, Publications on the Dissertation and Literature. The total volume is 95 pages with text, formulas, 46 figures and 4 tables. The cited literature includes 128 titles (articles, reports, books and websites), of which 41 with a reflected digital identifier and 17 patents.

**CHAPTER 1. Current status of the problem of increasing the fatigue life of structural elements with fastening holes.** This part of the dissertation is a review of the state of the art. The essence of the phenomenon of "material fatigue" and the role of fastening holes in industry are examined, with an emphasis on the field of aircraft construction. A classification scheme of methods for increasing the fatigue life of structural elements with fastening holes is summarized. Based on the proposed scheme, an analysis of modern dynamic and static methods for introducing useful circumferential residual compressive stresses to increase the fatigue life of parts with fastening holes has been made.

The chapter ends with conclusions from the overview information and based on them, the purpose of the work and the tasks to be performed are formulated.

**CHAPTER 2. Essence and implementation of a modified method for cold expansion of fastening holes.** Here, an analysis of the technological cycles of the basic Split Mandrel Cold Working (SMCW) method, which builds on the competitive Split Sleeve Cold Expansion (SSCE) method, has been conducted. From the summaries made, the Modified Split Mandrel Cold Working (MSMCW) method has been presented, based on the idea of transforming the cold expansion process of holes from dimensional to non-dimensional.

For this purpose, the created tool and device with hydraulic drive, providing constant tightness in the conditions of a wider tolerance of the hole diameter size and the stages of the technological cycle in the proposed MSMCW method, are described, accompanied by the necessary geometric conditions for implementation. The presented information is summarized in conclusions motivating the conduct of research and experimental evaluation of the effectiveness of the MSMCW method.

**CHAPTER 3. Effectiveness of MSMCW method for improving surface integrity in sleeve-type specimens of 2024-T3 aluminum alloy.** This chapter presents the results of an experimental evaluation of the effectiveness of the MSMCW method with respect to the main characteristics of the state of the surface and subsurface layers with a decisive importance for the fatigue behavior of parts with fastening holes - the distribution of circumferential residual stresses, the microstructure and the microhardness profile of the material around the holes.

In conducting the individual experiments, appropriate research methods and corresponding computational procedures were applied. With the selected material, axisymmetric specimens with well-selected sections for microstructural analysis were prepared and used. The measuring equipment and the settings of the operating modes are in accordance with the tasks set. The results obtained are appropriately presented and visualized, and the analysis has led to generalized conclusions that allow the formulation of scientific and applied contributions.

**CHAPTER 4. Effectiveness of the modified SMCW method for improving the fatigue behavior of 2024-T3 aluminum alloy specimens with fastening holes.** Chapter 4 presents an experimental study to evaluate the effectiveness of the MSMCW method for increasing the fatigue life of sheet structural elements with fastening holes made of 2024-T3 aluminum alloy with a view to their application in aircraft construction. To investigate the influence of the initial clearance between the surface of the pre-machined holes and the tool, the experiments were conducted under conditions of relatively large dispersion of the diameters of the pre-machined holes, with emphasis on the repeatability of the results.

The fatigue tests were conducted on four groups of specimens (one of which was a reference), with the same geometry and differing in the way the holes were machined. The fatigue behavior of the specimens from each group was investigated on a Zwick/Roell Vibrophore 100 testing machine with a pulsating tensile cycle and with the natural frequencies of the fatigue specimen (52.2 – 52.5 Hz).

The fatigue behavior of the sample groups was evaluated using  $S - N$  curves obtained based on tests up to  $10^6$  cycles. The results were analyzed and summarized in four conclusions formulated in scientific-applied and applied contributions.

The experimental research presented in the dissertation, such as structuring, volume and content, shows that the doctoral student has the necessary skills and competencies to work on scientific research in the applied field.

### **3. Contributions of the dissertation work**

I accept the 7 scientific-applied and 3 applied contributions requested by the doctoral student. They reflect the main results of the scientific research in the dissertation.

### **4. Publications and citations of publications on the dissertation work**

On the topic of the dissertation, the doctoral student has presented five publications. One scientific article was published in a national journal from the national reference list (magazine "Proceedings of TU-Gabrovo"), three scientific reports in international scientific conferences with scientific review, and one article in the international journal "Metals" and, according to the

