

# **OPINION**

## **on a dissertation**

**for the award of the educational and scientific degree of "Doctor" in**

**Field of higher education – 5. Technical Sciences**

**Professional field – 5.1. Mechanical engineering**

**Doctoral program - "Construction Mechanics, Strength of Materials"**

**Author:** Eng. Petya Hristoforva Daskalova, MSc

**Topic:** „Enhancement of the fatigue life of fastener holes in D16AT aluminum alloy using a modified Split Mandrel Cold Working method“

**Member of the Scientific Jury:** Prof. Eng. Angel Petrov Anchev, Ph.D.

### **1. Topic and Relevance of the Dissertation**

The relevance of the dissertation is determined by its focus on one of the most significant problems in modern mechanical engineering and aeronautical engineering - namely, the enhancement of the fatigue durability of structural elements with fastener holes made of high-strength aluminium alloys. These alloys are widely used due to their favourable strength-to-weight ratio; however, they are also highly susceptible to fatigue failure initiated in stress concentration zones around holes. In this regard, the issues addressed in the dissertation are directly related to the reliability, safety, and service life of components with cylindrical holes subjected to variable loading.

Of particular relevance is the choice of the method used to enhance fatigue durability—cold expansion of holes, which is a proven and widely applied industrial technique for introducing beneficial compressive residual stresses. The dissertation investigates a modified cold expansion method developed by the doctoral candidate’s supervisors (Prof. DSc Yordan Maksimov and Prof. DSc Galya Duncheva), which overcomes several limitations of conventional technologies, such as the strict tolerances required for pre-machined holes and the complexity of technological cycles. This endows the research with not only scientific merit but also clear practical significance.

It should be emphasized that the doctoral candidate has conducted an in-depth and critical analysis of a substantial body of contemporary scientific literature (128 references, predominantly in Latin script, 59 of which are scientific publications from the last 10 years), covering both established and the most recent studies in the fields of material fatigue, cold plastic deformation methods, and their influence on surface integrity parameters. This enables a clear positioning of the research within the global state of the art and supports a well-substantiated formulation of the aims and objectives of the dissertation.

In summary, it can be concluded that the dissertation addresses a relevant scientific and applied problem, proposes an innovative technological solution, and provides convincing experimental evidence of its effectiveness, thereby fully justifying its significance and topicality at the present time.

### **2. Research Methodology**

The dissertation employs a consistent and well-structured research methodology combining theoretical analysis, experimental investigations, and synthesis of the results in the context of the

fatigue behavior of aluminum alloys with fastener holes. The applied methods are purposefully selected and aligned with the stated aims and objectives of the study.

The primary focus of the experimental investigations is on specimens made of high-strength aluminum alloy D16AT (2024-T3) containing fastener holes and subjected to a modified cold expansion method (MSMCW). To evaluate the effectiveness of the proposed method, a variety of modern experimental approaches are employed. The distribution of residual circumferential stresses around the holes is examined using X-ray diffraction, with subsequent stress calculation performed using the  $\sin^2\psi$  method. The condition of the surface and subsurface layers is characterized through microstructural analysis (using scanning electron microscopy and optical microscopy) and microhardness measurements, enabling a comprehensive assessment of the changes in surface integrity induced by the cold expansion process.

The fatigue performance of the treated specimens is determined through systematic fatigue testing under pulsating tensile loading, with the experimental data summarized in S–N curves. The repeatability and reliability of the results are analyzed and compared with those obtained for conventionally processed holes.

### **3. Contributions of the Dissertation**

I accept the contributions as presented in the dissertation, which can be summarized as follows:

#### **Scientific and Applied Contributions**

- A morphological classification scheme of the main approaches and corresponding methods for enhancing the fatigue life of metallic structural elements with fastener holes has been developed.
- It has been demonstrated that under conditions of excessively large scatter in the diameters of pre-machined holes, the MSMCW method ensures the formation of an intensive and deep zone of beneficial compressive circumferential residual stresses on both end faces of bushing-type specimens made of aluminum alloy 2024-T3 after cold expansion and subsequent final reaming of the holes.
- The grain refinement effect in the vicinity of the hole surface in aluminum alloy 2024-T3 after cold expansion using the MSMCW method has been established under conditions of varying initial hole diameters.
- It has been established that the microhardness on the end surfaces of aluminum alloy 2024-T3 specimens subjected to cold expansion with different initial diameters is approximately 25% higher compared to the as-received condition.
- Based on microhardness profiles in axial sections, the presence of a circumferential gradient has been identified, resulting from differences in equivalent plastic deformation in axial sections corresponding to the symmetry planes of the segment and the slot of the tool implementing the MSMCW method.
- It has been demonstrated that the removal of a plastically deformed layer of appropriate thickness around the cold-expanded holes during final reaming provides a homogenizing effect on the axial distribution of circumferential residual stresses, leading to improved fatigue behavior under pulsating loading of sheet components made of aluminum alloy 2024-T3.

- Fatigue S–N curves under pulsating loading have been obtained, proving the effectiveness of the MSMCW method under conditions of excessively large scatter in the diameters of pre-machined holes, achieving more than a sixfold increase in fatigue durability (based on fatigue strength at  $10^6$  cycles) of aluminum alloy 2024-T3 compared to the conventional hole processing case.

#### **Applied Contributions**

- An economically efficient cold expansion process ensuring constant interference under conditions of excessively large scatter in the diameters of pre-machined holes.
- A database of surface integrity characteristics (residual stresses, microhardness, microstructure) of bushing-type specimens made of aluminum alloy 2024-T3 subjected to cold expansion using the MSMCW method, correlated with the degree of cold expansion (DCE) and the thickness of the metal layer removed during final reaming.
- A database of fatigue durability under pulsating loading of flat specimens with fastener holes made of aluminum alloy 2024-T3, processed either by cutting only or by the MSMCW method, correlated with the degree of cold expansion (DCE) and the thickness of the metal layer removed during final reaming.

#### **4. Publications and Citations Related to the Dissertation**

The presented publications, in terms of both quality and quantity, meet the requirements of the Development of Academic Staff in the Republic of Bulgaria Act, its implementing regulations, and the regulations for the acquisition of scientific degrees and academic positions at the Technical University of Gabrovo. Particularly noteworthy is the presence of a publication in the Web of Science - indexed journal *Metals*, which, at the time of the preliminary defence, had already received seven citations in other internationally indexed and peer-reviewed journals.

The remaining articles and conference papers were presented at two international conferences held in the city of Gabrovo, as well as published in The Journal of the Technical University of Gabrovo.

#### **5. Authorship of the Results obtained**

I have no doubts whatsoever that Eng Petya Hristoforova Daskalova MSc is, to a sufficient extent, the author of the results presented in the dissertation. Her scientific supervisors are proven and internationally recognized scholars in the field of the dissertation topic, with a significant number of successfully supervised doctoral candidates, numerous publications in journals indexed and peer-reviewed in the international databases Scopus and Web of Science, as well as national and international patents.

#### **6. Evaluation of the abstract**

I consider that the presented dissertation abstract fully corresponds to the content of the dissertation and is of sufficient length, comprising 33 pages.

#### **7. Critical remarks**

I have no comments or reservations regarding the conclusions drawn, the experimental results obtained, or the contributions presented in the dissertation.

#### **8. Information on Compliance with Legal Requirements**

