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Doctoral School

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Summary of the Doctoral Dissertation titled: "*Application of the FSW Method in Joining Metal Components of Car Seats"* supervised by Prof. Dr Krzysztof Gaska, Eng.

The objective of this doctoral dissertation is to select appropriate parameters for the friction stir welding (FSW) process (welding speed and tool rotational speed) to achieve satisfactory mechanical properties of the joint and to analyze the influence of the tilt angle of the tool shoulder on the quality of the weld. Due to increasing weight restrictions on car seats, an attempt was made to use aluminum alloys in the construction of seat frames to potentially optimize their weight. Additionally, a research gap was identified, focusing on the influence of tool parameters on the final weld quality. For this purpose, two types of welding tools were designed from powder steel with a 0° shoulder tilt angle and a -10° tilt angle.

The dissertation addresses the research problem of achieving a joint efficiency of at least 70%. To accomplish this, a series of trials were conducted using various welding process parameters with two proprietary welding tools made from Vanadis 23 steel.

Furthermore, the dissertation has two research goals: the first is to enhance the efficiency of joining metal components in car seat structures by replacing the current process with a new method of welding aluminum (friction stir welding), with current methods being MAG and TIG welding. The second research goal involves designing proprietary FSW tools (Vanadis 23 steel) and analyzing the impact of the tool shoulder tilt angle on weld quality.

The research part of the doctoral dissertation was carried out based on a research agenda, where the input data included FSW tool parameters and various process parameter combinations. A series of tests were defined, such as tensile strength, weld hardness testing, metallographic, radiological examinations, and surface roughness measurements of the weld. The final outcome of the research was the selection of the most advantageous tool and process parameters.

The dissertation includes an introduction, a summary, and five chapters. The first chapter discusses the characteristics of the FSW process, process parameters, and tools. Additionally, the advantages and disadvantages of the process and the construction of joints made using the FSW method are presented. Apart from the above-mentioned topics, an overview of aluminum alloys used in the automotive industry and an analysis of other methods of joining aluminum alloys are provided.

The next chapter formulates the research problem and methodology. The third chapter contains a detailed description of the research methodology, divided into six subsections: preparation of samples for friction stir welding, tensile strength testing, hardness testing, radiographic testing, metallographic testing, and roughness testing. The first subsection characterizes the aluminum alloy used in the research, the parameters of the two designed FSW tools, and the combinations of FSW process parameters. Moreover, each subsection includes a description of the testing parameters, sample preparation methods, and general characteristics of the tools and materials used.

In the fourth chapter, the results of the conducted tests for all process parameter combinations and designed FSW tools are presented. Given that the research problem of the doctoral dissertation was achieving a joint efficiency of 70%, special attention was paid to this issue.

The fifth chapter provides an analysis and discussion of the research results based on the current state of knowledge. It was found, based on microscopic analysis, that at lower rotational and welding speeds, the joints have fewer defects, indicating proper metal flow during the welding process. At a welding speed of 1400 rpm and 70 mm/min, porosity was observed on the trailing side. Lower welding speeds resulted in higher heat input, promoting proper material flow and resulting in a weld with fewer defects. Additionally, tensile strength tests showed that the results were consistent regardless of the tool used. The average tensile strengths ranged from approximately 4.28 kN (at 1000 rpm and 50 mm/min) to the best values obtained at 1400 rpm and 70 mm/min, averaging 4.83 kN. These values are about 24% lower than the tensile strength of the base material for the worst samples and about 15% lower for the best-performing samples.

In conclusion, laboratory tests confirmed the feasibility of using the FSW method for welding car seat structure components with the proposed tools. Better joint quality was achieved with a tool having a zero tilt angle of the shoulder to the welded surface. Based on the conducted tests, the optimal parameters for the friction stir welding process were determined to be 1200 rpm with a feed rate of 50-70 mm/min. The results of this research, particularly the FSW process model, provide a foundation for potential technical-scale implementation.