ABSTRACT

The aim of this dissertation is to develop and implement the manufacturing and welding technology of steel pipes with wear-resistant composite liners for applications in hydraulic or pneumatic transport of media that cause abrasion and corrosion. The work directly addresses the real needs of the energy, mining, and food industries in joining steel pipes containing liners made of modern composite materials resistant to corrosion and wear.

The aim of the research is to develop scientific and technological foundations for the welding of materials that have so far been considered unweldable. Achieving this goal requires an analysis of the influence of heat input on the joining process, in order to obtain joints with stable structural, mechanical, and chemical properties, including resistance to wear and corrosion. The dissertation aims not only to provide a new technological solution, but also to broaden theoretical knowledge regarding the phenomena occurring in the welding zone of materials characterized by increased welding difficulty.

The dissertation consists of two parts. The first part presents a literature review describing technological challenges in pneumatic and hydraulic transport related to abrasive and corrosive wear, the current state of knowledge on wear-resistant steels, steel materials with liners, coating application methods, wear-resistant composite coatings resistant to corrosion, weldability of wear-resistant steels, joining of wear-resistant steels and steel materials containing liners, as well as welding challenges of steel materials with liners.

The second, research-focused part presents the thesis and objectives of the dissertation, detailing the research methodology, results, and conclusions drawn from each completed research stage. Initially, welding tests were conducted on carbon steel pipes without liners, with laboratory thermocouples attached on the root side to measure thermal cycles of heating and cooling. The MMA welding method was used to weld pipes with different edge preparations to determine the optimal beveling method before welding. Subsequently, for the selected edge preparation method, arc welding technology tests were conducted using TIG, MMA, and MAG welding in the PH position and additionally MAG in the PJ position, employing the same measuring equipment as before. The goal was to determine the welding method with the lowest heat input and the most favorable temperature distribution, heating, and cooling times in the range from 120°C to the maximum temperature and from the maximum temperature to 120°C. The next step involved comparing the arc welding method identified as the most favorable in

the previous task with manual LBW welding of carbon steel plates without liners, using the same measurement equipment as in previous cases. For each task, non-destructive testing was performed, including visual, penetrant, ultrasonic, or radiographic testing, as well as destructive testing, such as macro and microstructure examination and hardness measurements.

Based on the results of individual research tasks, manual LBW welding of plates with liners was performed. After conducting tests similar to the previous tasks, welding of steel pipes with liners was carried out. A welding technology for lined pipes was developed, followed by a series of tests to evaluate their mechanical properties and corrosion resistance. Non-destructive testing of joints was conducted, along with liner adhesion tests using the pull-off method and mechanical property testing, including hardness measurements and tensile tests. The results of these tests allowed for a clear determination of the impact of welding technology on the properties of the welded joint and the composite liner. Additionally, a transient 3D thermo-metallurgical FEM simulation was performed in ESI VisualWeld 2023.5 to generate a model of the welded joint containing liners.

In conclusion, it was determined that welding of pipes with composite liners, depending on their diameters, can be performed while achieving the required weld quality and ensuring the necessary sealing between the composite liners without causing damage.

Keywords: **development of welding technology, pipe welding, welding of pipes with composite lining, hydraulic transport, pneumatic transport, pipes**