Universitatea "Lucian Blaga" din Sibiu

FACULTY OF ENGINEERING

DOCTORAL THESIS

Studies and research on thin-walled hydroformed blanks

- Abstract -

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Contents

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Abstract

The theoretical, numerical and experimental research discussed in this thesis, aim to study, analyze and deepen international knowledge with regard to the unconventional method of cold plastic forming of thin-walled hydroformed blanks. The need to address this technology resulted from the high costs and low access of researchers from small and medium companies and also university research centers. Gaining access could facilitate the achievement of future product prototypes. Conventional forming and the high adaptation costs of new tools on existing machinery in order to maintain the current standards for producing small or unique series are technically and economically inefficient.

To address the current aim of the thesis, the author has developed and implemented a unique hydroforming equipment concept, with simple and modular design. This was the result of combining design knowledge with researching other concepts from known field specialists, but also meeting the research goals.

After following a broad study, as exemplified in references chapter with books, magazines and current works of field specialists, hydroforming thin-walled literature review has been written down. The first chapter discusses the current economical - political context around global fight towards energy. Afterwards followed the presentation of hydroforming technology and its application areas, differences from conventional technologies and its advantages and disadvantages, that resulted in a comprehensive classification of all branches of the process. The typical materials, their limitations under hydroforming on specialized equipment was also discussed. Positioning this technology in the current market and desire to continue the development and research dissemination created the thesis objectives.

To meet the objectives outlined in the first chapter theoretical research has been carried out on deepening hydroforming knowledge regarding solid mechanics, linear elastostatics equations, finite element method and time discretization. Key focus on material properties, how to determine and analyze important material characteristics, criterions and laws that govern these properties.

Following the grounding of theoretical research, in chapter three numerical research on hydroforming blanks were discussed. For the most accurate mathematical modeling of the behavior of materials during hydroforming process the finite element method should be applied. Therefore, the possibilities and how to analyze hydroforming with finite elements was approached. The investigated geometric model has been defined, by specifying the size, shape and hydroforming process parameters. To conduct numerical and experimental research the materials subject of research and analysis steps to track the performance of these materials on cold plastic deformation by hydroforming have been defined. Specialized sources were studied to define more precisely chemical and physical properties for each material brand. These properties were compared with those determined by tests performed on equipment machines from the Centre for Studies and Research for Metal Forming from "Lucian Blaga" University.

The experimental research evaluates the ability of plastic forming of five different materials, with two thicknesses, for which the main physical properties, deformation limits and other inherent properties are determined. By conducting the uniaxial tensile tests on standardized specimens, the following mechanical properties have been determined such as yield point, true strain, true stress, Young's modulus etc., as well as parameters related to intrinsic material properties such as work-hardening coefficient, strain hardening coefficient, strength coefficient and plastic anisotropy coefficients. These data have been determined using a tensile testing machine - Instron 5587 and GOM Aramis optical measuring deformation system.

In assessing the subject materials limits forming limit curves have been determined using a modular deep-drawing device and GOM Aramis system, from the same research center. Comparative presentation of determined material forming limit curves and the preceding material data have completed the hydroforming research model. Thus the device hydroforming concept was born. It has been developed and executed by the author, for use by universities and small or medium companies. Produced using universal lathe by qualified personnel in machining and assembling, therefore not so expensive, the biggest acquisition costs are for research materials and a hydraulic power-pack. Besides the unique and

simple design, the most important feature is the modularity, offering the possibility for change or adaptation of new active elements. Different material thicknesses for producing highly complex parts (caps, flanges etc.) in a single operation, which can be used in various branches of automotive industry or consumer goods. Using fluid work environment that formed parts have a high surface quality and a pleasing aesthetic, an important advantage for the final product.

The device is designed to withstand pressures of up to 700 [bar], so with the appropriate hydraulics it should reach a clamping force of 215 [tf]. But for the present research this pressure was inadequate for some subject materials, therefore the hydraulic generated pressure used was up to 400 [bar], a clamping force of 125 [tf] and maximum hydroforming force in the current configuration is 40 [tf]. These forces are considered very high considering the current device configuration, but this is possible through good design, execution and ensuring proper sealing.

Model validation results, required for comparison between numerical and experimental research are major strain ε_1, minor strain ε_2, blank thickness reduction and forming limit diagram. For measuring these parameters, the unformed blanks have undergone an electrochemical etching process of a dot grid. After hydroforming, these dots have been studied and evaluated with GOM Argus an optical measuring deformation system. The main hydroforming pressure for clamping and forming was monitored during the tests using a pressure transducer. All experimental results are compared and analyzed extensively with those obtained by numerical simulation and the resulted error percentage is less than 5 [%]. In this way the accuracy of the experimental results was evaluated and the finite element model was validated. For all the studied materials, both major and minor strains and the thickness reduction have the same tendency of variation for the die radius and the hydroforming pressure, that is, the results increase with decreasing radius and increasing hydroforming pressure.

Comparing the results obtained for both numerical and experimental research, the hydroforming behavior of W1.4301 austenitic stainless steel is superior to the other materials studied, proven by formation behavior by the strain values

incurred, but also presenting a good corrosion resistance and aesthetics when electrochemically etched and hydroformed.