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Evaluation of drawability of tailor-welded blanks made of titanium alloys Grade 2 || Grade 5 ☆

Julita Winowiecka [a,*], Wojciech Więckowski [a], Marcin Zawadzki [b]

[a] Częstochowa University of Technology, Faculty of the Mechanical Engineering and Computer Sciences, 21 Armii Krajowej Ave, 42-200 Częstochowa, Poland
[b] WSK "PZL-Rzeszów" S.A., 120 Hetmańska Str, 35-078 Rzeszów, Poland

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ABSTRACT

Titanium materials are becoming increasingly popular in modern applications. They are used whenever parts with low weight and high strength properties are required. Titanium and its alloys have been successfully used in many industrial branches especially in the automotive and aerospace industries. Titanium blanks are used to produce various parts of aircraft such as engine parts, wings or fuselages.

In the paper, the numerical modeling and experimental results of the forming process for tailor-welded blanks were presented. This technology consists in joining elements that are made of different materials or have different thicknesses using welding. The blank analyzed in the work was a combination of two different titanium sheets – commercially pure titanium Grade 2 and titanium alloy Grade 5. In the paper, different properties of fusion and heat affected zone were taken into account.

The sheets were joined using electron beam welding (EBW) technology. EBW is a high power density method and consequently produces a small fusion and heat affected zone (HAZ). The properties of the welded material change to a smaller extent compared to arc welding technologies. EBW is performed in vacuum which prevents the titanium from absorbing gases.

The mechanical properties of the materials, the weld and HAZ were determined based on experiments. The limit curves for the analyzed titanium sheets, necessary for crack formation analysis, were determined experimentally.

The titanium blanks joined using EBW technology underwent the stamping process using a hemispherical punch in order to observe the phenomena occurring during the formation of welded sheets with different mechanical properties. For comparative purposes, numerical analysis was performed using PAM-STAMP 2G, based on the finite element method. The numerical simulations included selection of the friction coefficient and blank holder force to ensure the best forming results.

The aim of the experiment and numerical simulations was to determine the plastic deformation occurring in the material during the stamping process. Based on the obtained results, drawability analysis of the used titanium sheets was done. The studies have shown that proper selection of the process parameters enables forming of titanium TWB sheets made of titanium and its alloys.

1. Introduction

Titanium and its alloys have become more popular in industrial applications, especially in a wide range of products used in the automotive and aircraft industry. These materials have become in recent years technically superior and very cost effective [16]. Titanium, especially its alloys, such as Ti–6Al–4V, have an excellent combination of mechanical properties and specific strength. Additionally, they have good corrosion and high erosion resistance, and stiffness [16]. Titanium and its alloys have been used in all industrial sectors where the reduction of weight and production costs is required [1,3].

Lightweight elements are desirable, especially in aircraft applications. Many airplane components and bodies are composed of titanium and its alloys [6]. Ti–6Al–4V is used to produce structures and edges of the wing, fuselage elements and engine components. Commercially pure titanium Grade 2 has good drawablility but low strength [1]. Titanium alloy Grade 5 in comparison to Grade 2 possesses very high mechanical properties (yield strength and tensile strength) but simultaneously poorer drawablility [6,16]. During the forming of titanium sheets, some technological problems arise. Titanium alloys have a strong springback tendency that causes low dimensional accuracy of parts, plastic instability followed by necking and failure during sheet-metal forming [1,2]. The poor

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* Corresponding author. Tel.: +48 792663019.
E-mail address: julita.winowiecka@gmail.com (J. Winowiecka).

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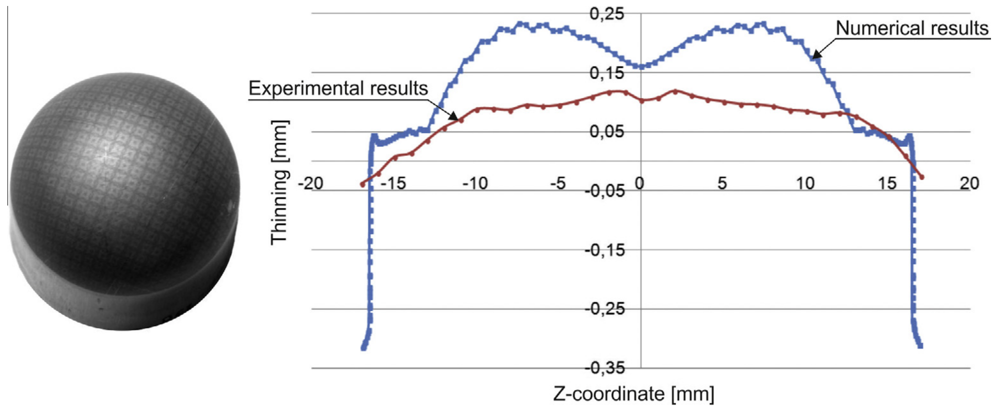

Fig. 1. Thickness distribution for drawn-part made of uniform Grade 2 sheet – experimental and numerical results.

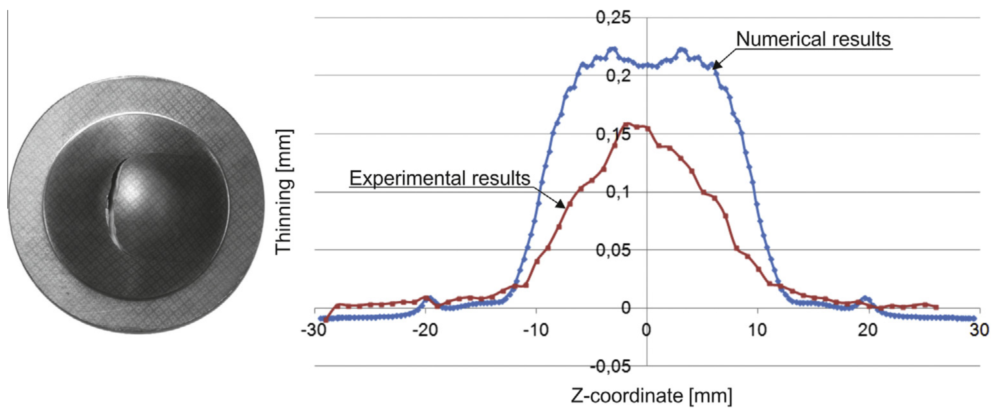

Fig. 2. Thickness distribution for drawn-part made of uniform Grade 5 sheet – experimental and numerical results.

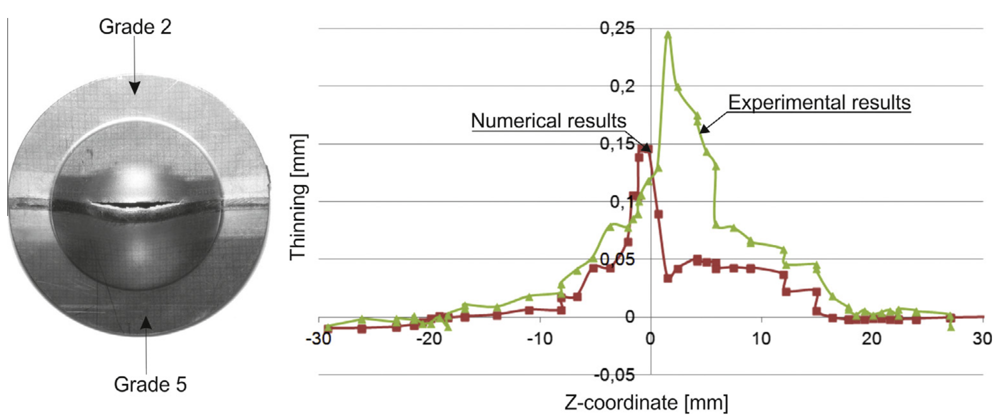

Fig. 3. Thickness distribution for drawn-part made of welded Grade 2 || Grade 5 – experimental and numerical results.

drawability of titanium alloys in ambient temperature, using a traditional sheet-metal forming process, causes many application limitations [2,4,20]. Part of these problems can be solved using unconventional or modern forming techniques e.g. hydroforming, the hot stamping process and using elastic tools (e.g. elastic, rubber die) [1–4,20]. Additionally, proper selection of the process parameters such as friction conditions and holding-down force could improve the dimensional accuracy of parts, should be also taken into account [13]. Friction plays an important role in titanium-sheet forming. The lubrication layer facilitates uniform flow and plastic strain distribution in the drawn-part. Often in titanium-sheet forming, "build-ups" are created on the tool surface. On part of the surface, small scratches and dents occur which reduce the quality and dimensional accuracy of the parts. Elimination of this problem is possible by the use proper lubrication or adhesive layers [5].

Tailor-Welded Blanks (TWBs) technology allows for joining different materials with completely different mechanical properties and even thicknesses, usually joined using high-tech welding methods [7,17,21,22] The welded blanks are joined using laser or electron beam welding and friction stir welding [14]. All the methods have several advantages. Laser beam joining offers a precise