The International Journal of Engineering and Science (IJES)
|| Volume || 15 || Issue 6 || June || Pages || PP 23-26 || 2026 ||
ISSN (e): 2319 – 1813 ISSN (p): 2319 – 1805

Plywood as alternative material for bending die design

Peter Mulidrán[1], Emil Spišák[1], Janka Majerníková[1], František Ruda[1]
[1] *Technical University of Košice, Faculty of Mechanical Engineering, Department of Technology, Materials and Computer-Aided Technologies, Košice, Slovakia*
Corresponding Author: peter.mulidran@tuke.sk

----------ABSTRACT----------
The article presents information on unconventional production methods of forming tools with the use of laser techniques in combination with poplar plywood. The bending die was produced using 4 mm thick sheets of plywood cut by laser. The bending die was experimentally tested, as well as tested in a virtual environment using numerical simulation in the Solidworks 2022 program. The bender withstood 12 bending operations of thin steel sheets without failure, the largest load force was 1,560 N, and it could be used further.

KEYWORDS: *tool material, bending die, plywood, simulation*

Date of Submission: 26-05-2026 Date of acceptance: 05-06-2026

I. INTRODUCTION

There is currently a strong focus on minimizing costs, time and greenhouse gases in manufacturing. One way to minimize these today is through the use of renewable materials.
From an environmental perspective, the industry is starting to move beyond the classic lightweighting, strengthening and cheapening of products. It is looking at a broader picture of sustainable manufacturing methods for the future. This includes things like the circular economy, the use of smarter and renewable materials and alternative production methods. For manufacturing to be truly sustainable, these new technologies need to be combined with environmental friendliness. A big part of this is increasing the flexibility of manufacturing operations to handle a wider range of products, from mass production to the production of individual, custom-made items [1].

Sheet metal forming is a widely used technology for producing high-quality and precise metal parts. These parts, such as bodywork stampings, often require minimal post-press finishing [2]. Current sheet metal forming processes are geared towards high-volume, mass production. However, achieving a balance between flexibility in forming processes and economic viability is a significant challenge in the face of increasing globalization, price pressures, and changing geopolitical realities. New approaches are needed to reconcile these seemingly conflicting goals [2].

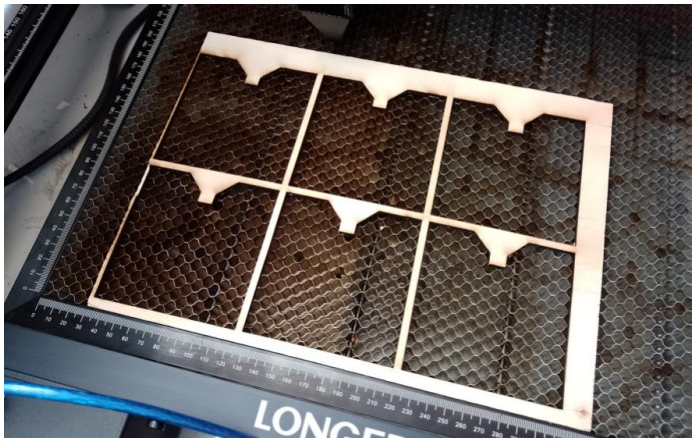
Research into deep drawing with conventional tools for high-volume production is substantial, including techniques for increasing tool life and reducing tool costs. However, research into alternative approaches to forming tools for low-volume, highly specialized, and one-off production remains relatively limited. Concrete-based deep drawing tools have been investigated by Holzer et al. and Guilleaume et al. for small-batch applications [3, 4]. Giorleo and Ceretti, Bergweiler et al. and Holzer et al. investigated the usability and mechanical load-bearing capacity of additively manufactured polymer tools for small-scale production of molded parts [3, 5, 6].

The presented article investigated the production and use of a poplar bending frame for performing “V” bending experiments. Three types of thin steel sheets were used in the experiment – high-strength steel, deep-drawing steel and microalloyed steel. Numerical simulation was used to simulate the loading of the bending frame, focusing on the prediction of stress and deformations of the bending frame made of poplar plywood. The bending frame made of wood plywood was able to withstand the load during the bending of 4 samples made of TRIP steel without breaking.

II. DIE MATERIAL AND PRODUCTION OF DIE

The experimental bending die was made of several pieces of poplar plywood. Individual segments, lamellas were cut using a 10 W LED laser (Fig. 1). The CAD model of die was imported to CAM program used for code generation of laser cutting sequence for each plywood lamella. The material for laser cutting was A4 format poplar plywood (297 x 210 mm) with a thickness of 4 mm. Individual wooden segments were connected using screws and nuts. The properties of poplar plywood are given in Table 1.

The bending machine made of poplar plywood consisted of 12 identical boards with screw holes. Individual segments, boards were connected using M5 screws and nuts (Fig. 2). The manufactured bending die was used for bending three types of sheets in a ZD-40 hydraulic press.



(a)

(b)

Fig. 1 Plywood used for laser cutting (a), Bending die made of plywood used in experiments

Density	Tensile Strength	Compressive Strength	Flexural Strength	Modulus of Elasticity
426 kg/m^3	30-34 MPa	31-41 MPa	44 MPa	6 500 MPa

Tab. 1 Mechanical and physical properties of poplar plywood

III. STATIC SIMULATION OF BENDING DIE

Numerical simulation is currently an integral part of structural design and technological processes. Using external load simulation, a designed bending die was investigated, consisting of 12 poplar plywood sheets connected by 4 M5 bolts and nuts. The Solidworks 2022 program was used to simulate the external load of the poplar plywood bending die (Fig. 3).

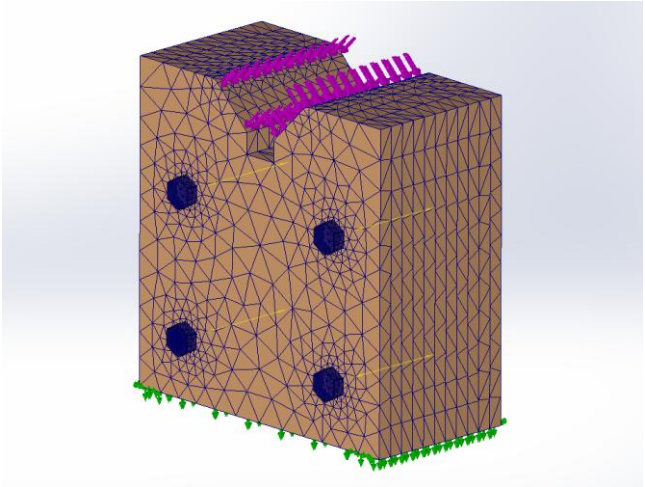
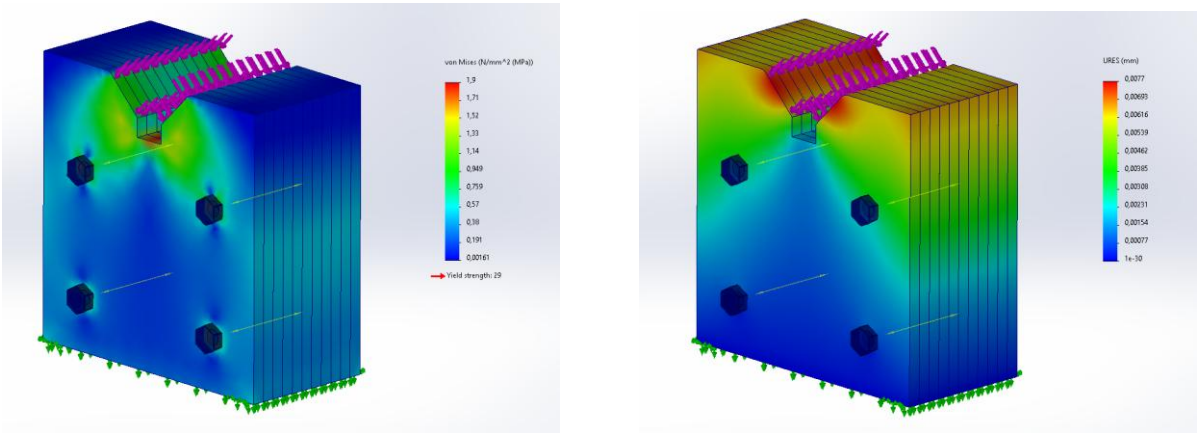


Fig. 3 Simulation setup of external load on plywood die made of 12 segments

The simulation settings in Solidworks 2022 software were as follows:

- Mesh element type: tetrahedral, volume element
- Maximum element size: es= 8 mm
- Integration scheme: implicit
- Solver: automatic
- External load: 1,560 N (max. force in the experiment)
- Clamping force derived from one bolt: 200 N

The results of the stress distribution (Fig. 4) and deformations (Fig. 5) indicate that the designed bending die is able to withstand external loads without permanent, plastic deformation, or failure. The results of the stress prediction indicate their concentration in the place of the so-called release, recess under the "V"-shaped cutout on the bending die. The max. value of the predicted stress reached 1.9 MPa, which is much lower than the yield strength of the material (29 MPa). The prediction of deformation, in this case displacements [mm] showed that when the bend is loaded with a force of 1,560 N, elastic deformation of the bending die occurs.



(a) (b)

Fig. 3 Stress distribution on poplar bending die (a), Predicted deformation of poplar bending die

The max. size of the predicted deformation, displacement reached 0.0077 mm, which, as a result, for real bending operations has a minimal impact on the accuracy of the shape and dimensions of the bent stampings. The largest displacements and deformations were measured in the area of the bend cutout, in which the bending operation itself takes place.

IV. EXPERIMENTAL RESULTS

Experimental verification of the plywood bending die was carried out using bending tests on high strength steel sheets – TRIP with a thickness of 0.75 mm. The aim was to determine whether the wooden bending die would be able to withstand external loads, bending of the sheets (Fig. 4) without failure.

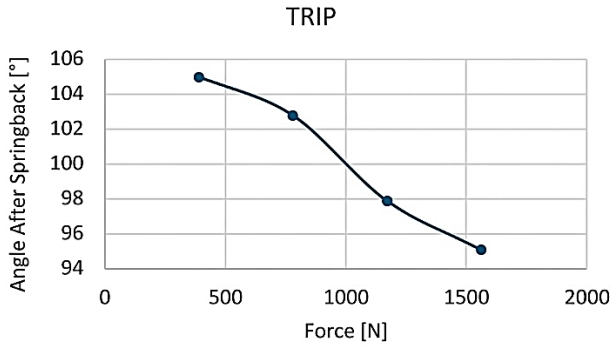


Fig. 4 Dependence of part angle after springback on calibration force

V. CONCLUSION

The paper contains information regarding the use of unconventional materials and technologies for the production of forming tools for low series production and experimental purposes. The work presents a designed bending die made of poplar plywood, which was made by laser cutting twelve wooden segments that were connected by screws. The bending die was experimentally tested, as well as tested in a virtual environment using numerical simulation in the Solidworks 2022 program. The bending frame withstood 4 bending operations without breaking, the highest load force was 1,560 N and it could be used further. The results of the springback on the stampings show a positive effect of the increasing calibration force on the reduction of the springback.

ACKNOWLEDGMENT

The authors are grateful for financial support by projects KEGA 018TUKE-4/2024, APVV-21-0418, VEGA 1/0330/24.

REFERENCE

[1]. M. Gude et al., FOREL-Wegweiser: Handlungsempfehlungen für den ressourceneffizienten Leichtbau. Dresden: Technische Uni Dresden, 2020. [Online]. Verfügbar unter: https://ris.unipaderborn.de/record/20318.

[2]. R. Sousa, "Incremental Sheet Forming Technologies," in Reference module in materials science and materials engineering, Elsevier, uuuu-uuuu. [Online]. Verfügbar unter: https:// www.sciencedirect.com/science/article/pii/B9780128035818040558.

[3]. K. Holzer, H. Schaal-Mulacek, E. Marker and W. Volk, "Kostenreduktion in der Prototypenfertigung," ZWF, Jg. 118, 7-8, S. 511–515, 2023. doi: 10.1515/zwf-2023-1097. [Online]. Verfügbar unter: https://www.degruyter.com/document/doi/10.1515/zwf-2023-1097.

[4]. C. Guilleaume, A. Mousavi und A. Brosius, "Hybrid deep drawing tool for lubricant free deep drawing," AIP Conf. Proc., Jg. 1896, Nr. 1, S. 140003, 2017. doi: 10.1063/1.5008159. [Online]. Verfügbar unter: ttps://pubs.aip.org/aip/acp/article/1896/1/140003/998831/Hybrid-deepdrawing-tool-for-lubricant-free-deep.

[5]. Geueke M., Steinheimer R., Lutz M., Engel B., "Sustainable tool technology: Wood-based forming tools," Materials Research Proceedings, Jg. 28, S. 1967–1976, 2023, doi: 10.21741/9781644902479-212.

[6]. P. Mulidrán, E. Spišák: nekonvečné spôsoby výroby tvárniacich nástrojov s využitím dreva: Transfer inovácií, 52, 2025. https://katedry.sjf.tuke.sk/transferinovacii/pages/archiv/transfer/52-2025/pdf/064-067.pdf