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Numerical Approach for the Modelling of a Sheet Metal Folding Process

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Abstract

Folding is a process of forming cellular structures out of a flat raw material. Through this technology it is possible to create sharp-edged structures with high depths and multiple bending axes and for this reason it is part of the technical origami.
Current research work at the IFU focuses on applying this technique to sheet metals with thicknesses between 0.5 – 2mm. These kinds of structures can be used for optically appealing claddings, heat exchangers or sandwich panel core materials. In previous projects, it was shown that it is necessary to pre-crease the bending axis on the flat raw material to achieve a defined folding process. For sheet metals, in particular the embossing of grooves is a promising approach. The general challenges for folding sheet metals are the forming of radii, the hardening effects emerging in the bending axis, and well-ordered design of appropriate tool concept. Also appropriate FEA models are necessary for a sufficient development of this process. The embossing of grooves itself is a bulk metal forming process and, therefore requires volume elements. Folding itself, however, is a forming process of large blanks, which is why simulations based on tetrahedral elements are extremely time-consuming. For this reason, two different models are necessary. The first model, which has integrated volume elements, simulates the folding of single folding cells targeting to detect the interaction of the embossing and the subsequent bending process. In the second model, shell elements are used, with a focus on the effect of the grooves' run rather than the effects of the embossing itself.
In this paper, a FEA model for the folding of a mono cell is presented, which shows that a defined folding with small radii for sheet metals with blank thicknesses larger than 0.5 mm is possible as well.

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Keywords: Folding, bending, embossing

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1. Introduction

Folding is a process of shaping cellular structures out of a flat raw material just by local bending at defined, multiple folding axes. This technology makes it possible to create sharp structures with high depths. Such cellular structures are part of technical origami which is characterized by:

- Its geometry, which is defined through folding and, therefore, requires a folding algorithm.
- An initial material having a negligible thickness.
- Only local forming at the bending axis, no global plastic deformation over the workpiece [1]

Current research work of the Institute for Metal Forming Technology focuses on applying this technique to metallic materials with non-negligible thicknesses. Such structures can be used for optically appealing claddings, heat exchangers or as core materials of sandwich panels. Folded structures are suitable for the use as core structures of sandwich panels due to their shape. The high depths and multiple folding axes make it possible to achieve high levels of stiffness with a planar isotropic behavior, comparable to honeycomb structures. Additionally, these cores reveal open structures, and therefore, features like ventilation or functional integration can be applied without further machining operations. In Fig. 1 different folding structures with different numbers of major bending axes (MBA) are shown [2].

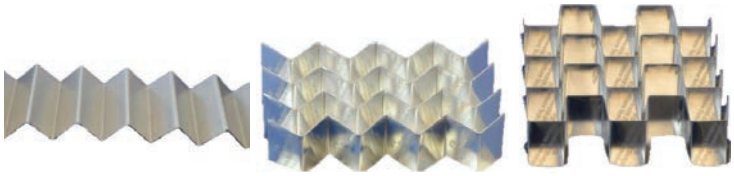

Fig. 1. Different folding structures and their numbers of major bending axes [2]

Nomenclature

V	length of the front rectangular of a 2-MBA cell
S	width of half a 2-MBA cell
L	length of half a cell
B	width of the centre part of a 3-MBA cell
H	height of cell
p_a	length of the pre-crease between flank and addendum
f_trans	degree of freedom for translation
f_rot	degree of freedom for rotation

2. State of the Art of folding processes

Today, most research projects in the field of folding focus on initial materials with low levels of thickness and strength. Most applications are suitable for non-metallic materials like polymers, aramid paper, cardboard, and fiber composites. Only few investigations are focused on sheet metal applications like pure aluminum with a maximum thickness of 0.2 mm [3] or 0.5 mm [4] and steel alloys with thicknesses below 0.1 mm. In [3] Gattes et al. different dies are used for gradually processing a 2-MBA structure. However, this procedure is not a real folding process, because there is not only a bending at the bending axis, but also a forming on the plane area of the cell.

Schenk et al. [4] perforated two blanks along their bending axis (Fig. 2 (a)). Between the two blanks, spacers were aligned along the bending axis (Fig. 2 (b)). In a vacuum (Fig. 2 (c)), both blanks are then folding themselves by twisting the aligned spacers (Fig. 2 (d)). This approach shows good results with regard to the folding process, but only materials with low yield strength levels are suitable to be folded that way.