# Lightweight Furniture Design Enabled by Folding Technology; Development and Proof of Suitability of New Solutions for Lightweight Design

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Cooperation Partner: Karl W. Niemann GmbH + Co. KG

**Initial Situation**

The cooperation partner Karl W. Niemann GmbH + Co . KG has established in this industry as a manufacturer of furniture parts (preferrably front faces). It has at its disposal the technology and knowhow to process a high-strength, biaxially oriented, coextruded foil of polyethylene terephthalate (PET) of excellent mechanical and optical properties with high-gloss or matt surfaces. From the mechanical properties of the foil, they derived the desire to explore and open up the performance potential of this type of foil coating for use in folding technology.

**Objective**

The approach of the project is based on further developing the long-known folding principle. This principle is also called the mitred-corner or folding approach. Thereby, grooves are milled into one side of the plane surfaces, and the plates are folded or wound along these milled lines to become three-dimensional elements. As part of the project, the following further developments of the procedure were to be investigated, thus developing new innovative products and solutions and materialise them:

- application of high-strength and flexible coating materials (hinge) for implementing infinitely foldable corner solutions for collapsible solutions, such as fair stands;
- development of new solutions required thereby, for mechanically fixing the folds;
- development of an industrially applicable technology for highly precise milling on both sides in order to be able to allow "folding back", which was previously not implemented, thereby generating complex spatial structures;
- development of solutions to protect the milled grooves during use and transport.

**Approach and Results**

The mechanical performance capability of the coating was determined by establishing parameters, such as stretch, the gluing strength of the foil by means of tensile and pressure tests and a pressure test of the corner solution (Fig. 1). 8-mm-thick chip, fibre and compact boards were used. Furthermore, "hingeability" was investigated in a permanent folding test (Fig. 2). As a result of the investigations, it was established that the foil showed sufficient strength regarding both mechanical properties and gluing. With a view to the hinge properties, the test was aborted after 50,000 folding cycles, as no significant changes

*Fig. 1: Pressure test on a corner element*


*Fig. 2: Folding durability test*

could be observed. At a relative humidity of > 65 %, significant signs of swelling were identified in the unprotected grooves, which required to seal them off. Kleiberit 555.6 could be proven to sufficiently protect the unprotected V-grooves in the chip and fibreboards. Kleiberit 555.6 is a single-component reactive sealant that, by reacting with moisture, changes from its liquid (its viscosity is almost that of water) to a solid state.

Cavities and the wood-based material structures are filled and solidified in that way. An impairment of the corner geometry of the V-joint due to swelling, when Kleiberit 555.6 was used, could not be observed. The treatment resulted in a slight discolouration (darkening) of the joint surface. Also the suitability of adhesive foil (tesafix 4965) could be proven for protecting open grooves during transport.

A calculation tool was developed to support potential users in planning foldable bottoms. Calculation rules were set up for a web-based tool with the help of analytical and numerical methods (FEM), with which potential users can compare several folding variants on the web pages of the project partners (Fig. 3). What is shown here is the respective sagging of a certain folding variant, considering the selected material and geometry conditions. Such sagging is contrasted to the thickness and mass of a flat and plane (not folded) bottom. This shows the user immediately the saving potential of his variant (material savings) at the same performance (bending). A small corpus system consisting of a folded corpus frame with a rear, grooved wall and, optionally, with a flap or door (turnable) as a closing solution that can be used depending on the position of the corpus (turned) was produced as a master series. There, the coating foil acted as a hinge. This system was presented at the BMWi Innovation Day in Berlin on 22 May 2014.

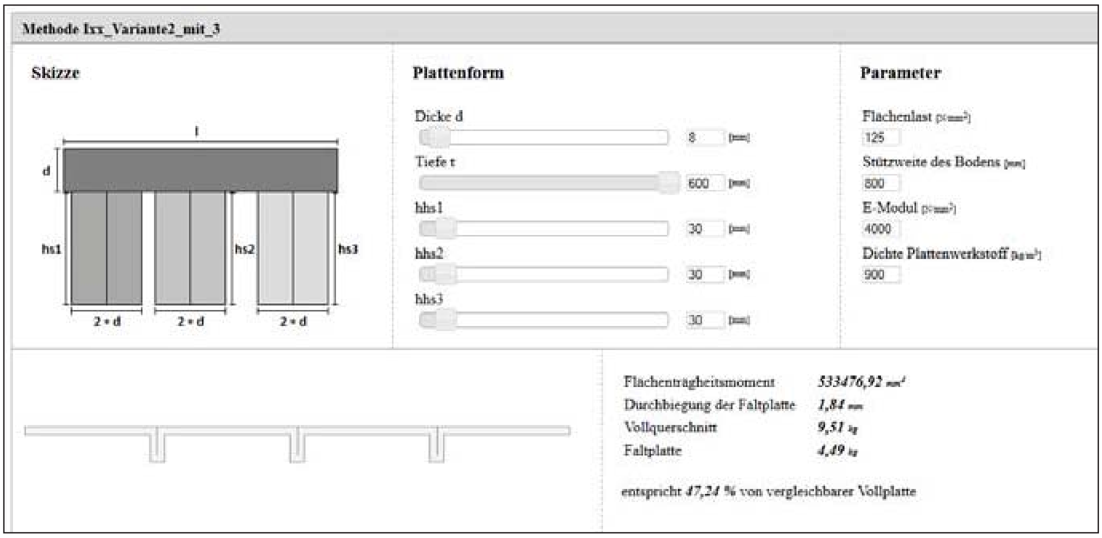


*Fig. 3: Web tool for the design of foldable shelves*