Theoretical Elaboration of Design Requirements, Especially of the Choice of Materials, Analysis and Development of Suitable Hinge Systems for a Foldable Piece of Furniture

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Initial Situation

A high degree of mobility and flexibility is reached if furniture can be folded. The folding mechanisms have previously been facilitated by fittings of metal or plastics. The few hinging solutions involving a textile component in use so far are based on the principle of gluing plate-like wood material onto a layer of fabric. This principle is unfavourable from a static point of view and results in furniture being heavy-weight, as much material must be arranged at a neutral level where it hardly contributes to the required stability. Also, the transfer of forces in the hinges can, due to being double-mitred, be effected via half of the plate's cross-section only. Therefore, it was the principal idea of the project to attach the fabric layers to the outside of the wood-based materials. Thereby, the forces can, for there is only one mitre then, be transferred via the entire cross-section, which allows applying thicker, yet lighter sandwich plates. The idea of mobility of foldable furniture is supported by lower weight. The outside layer of fabric is not only able to transfer forces, but can, at the same time, serve as a decorative layer by using printed-on textiles.

Material and Methods

The main task consisted in finding a suitable combination of fabrics, lightweight plate material and appropriate jointing or adhesives. For their nature of use and frequency of folding, tables and chairs are especially suited for the folding design.

Substrate panels: The project investigated several sandwich and solid-core materials as well as design solutions for force transfer, such as frame design, bar design and concealed edge bands. By way of the FEM, stiffnesses of the variants were calculated, evaluated and compared in view of the mass of the panel materials. A frame design appeared to show the most favourable ratio of bending stiffness versus mass. As manufacture is very elaborate though, a novel panel design was developed in the project (Fig. 1). It consists of two 8-mm-thick plywood panels glued to each other, provided with pocket millings of a reversely mirrored shape. This allows to partially remove material to address design requirements and necessary points of load introduction. Still, a significant reduction in weight, as compared to solid-wood material is achieved.

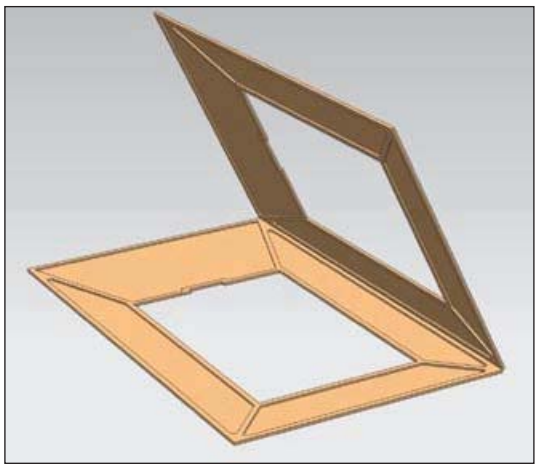

Fig. 1: Pocket sandwich

Fabrics: Several fabrics (cloth and fleece materials) and some kraft papers were investigated. A specification of the materials for textile joints by merely adopting the usual parameters, such as maximum tensile force and maximum tensile force elongation, is impossible, as they represent one part of the load only. With the help of an especially developed clamping jig with a double-sided mitre, fabrics can, initially without any influence by any gluing, but under actual load situations as prevailing in the hinge, be characterised.

The elongation-rupture test establishes the elongation behaviour in the form of a force-elongation graph. A large number of fabrics could be investigated after which the appropriate variants were subjected to a second test. The tumble test (Fig. 2) is expected to show durability during the use of the hinge. For that reason, the clamping device is fixed to the rotating drive. Thereby, the rotating axis is in line with the joint axle. The rotating drive performs a turn of ±135°. The second part of the clamping device tumbles, for reasons of gravity, around its vertical position. This does not only test the alternative bending of the fabric, but also slight elongation and a dynamic load, as they may appear during setup or removal and in the course of use.

In the tests, double calendered spunbonds revealed the best properties and are thus best suited as hinges. Also, they can very well be printed on.

Adhesives: For gluing the fabric to the substrate plate, an initial preselection was made. After an evaluation regarding the time when open, gluing compatibility, processing effort, properties of gluing and costs per m², the adhesives PVAc, phenolic resin (used as a film) and PUR were looked at in a peel test. An appropriate connection could be made by applying PVAc, as, apart from its adhesive effect, mechanical jointing is achieved, thanks to the fabric being soaked by the adhesive.

Tests of assemblies at the Furniture Test Lab

The various hinge types were initially and individually tested on special jigs in the test laboratory. In order to guarantee the durability of the fabric hinge, there was also a test on a sample hinge, consisting of a vertical substrate plate and a flap, which was equivalent to its use as a seating surface. The test was aborted after 1,000,000 cycles.

Conclusion

Based on the manufacture of the sample and experimental testing of the fabric hinges and foldable furniture assemblies, design requirements and technological manufacturing stages were derived for the manufacture of foldable furniture. As a result, a seating group including a table (Fig. 3) could be made that combined the technological developments of the project and demonstrated the benefits of the fabric hinge in conjunction with the pocket sandwich.

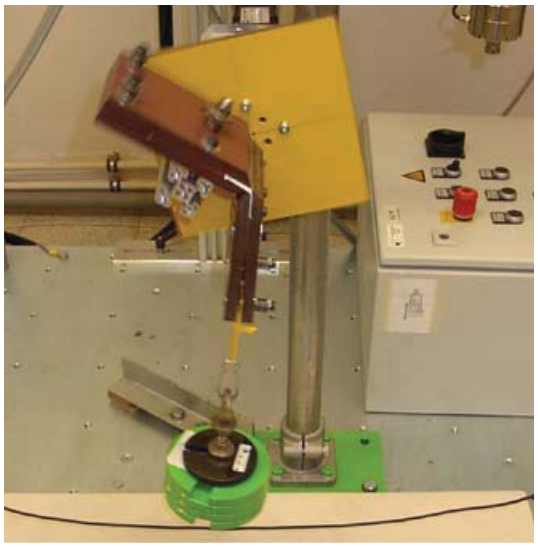

Fig. 2: Tumble test with an additional weight

Fig. 3: Foldable stool during stability testing