Hydromechanical paper forming

New paper products through hydromechanical paper forming

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Abstract

It is known from the project „Application of media-based processes for deep drawing of paper and board“ that hydrostatic pressure superposition during media-based deep drawing of paper causes an extension of the process limits. However, the previous process designs showed a significantly slower process speed compared to conventional deep drawing. Therefore, the aim of this project was to combine the advantages of media-based pressure superposition with regard to the forming limits using the increased process speed of conventional deep drawing in the hydromechanical deep drawing process.

Project description

The research project tests the working hypothesis that hydromechanical forming of paper enables the advantages of material support in the forming process with shortened process times through the use of a rigid punch. In combination with the intended extension of existing design strategies, based on adapted material data acquisition and numerical simulations, this offers advantages through shorter product development times and possible new product classes for paper as semi-finished product. The investigation of hydromechanical forming concepts for paper promises to extend existing forming limits of conventional deep drawing processes with rigid tools. This will enable paper to compete with existing packaging products as a renewable raw material, but also as a production commodity. In addition, an expansion of the design possibilities and thus the variety of shapes makes it possible to address new markets. As a favorable starting material, new product classes for products made of paper can thus be created, especially in the innovative environment of SMEs. This is also the point of departure for the expansion of existing design strategies. The possibility of recording material behavior during forming by means of numerical modeling in conjunction with adapted material data extraction offers potential for material, process and product optimization. This makes it possible for SMEs to easily check product ideas or have them checked without having to invest directly in plant technology and experimental test series. The results obtained can be summarized in recommendations for action for material selection and product and process optimization and, as shown, simplify the future design of products and processes.

Results

To achieve this goal, a die concept consisting of a rigid deep-drawing die and a fluid pad was initially constructed. By controlling the pressure, it is possible to monitor the counter pressure in the fluid cushion and adjust it if necessary. The process limits were then determined in test series. In order to be able to lay the foundations for the industrial establishment of the process, design strategies for the development of new paper products were also established with the aid of numerical simulations. For the numerical modeling of materials, material data that describe the material behavior in an abstract way are required. To accomplish this, targeted material characterizations as well as tests on frictional behavior could be carried out, based on the findings of previous research projects. In this context, similarities and differences between the two types of material chosen by the project committee (recycled fiber-based board and virgin fiber-based board) were revealed, particularly in terms of strength. A pronounced directional dependence of the properties was observed in the tensile test. The virgin fiber board proved to be stronger in terms of its maximum bearable loads but only minimally better in elongation.

The data obtained were used to build numerical simulation models suitable for die design and feasibility analyses. A two-dimensional approach proved to be the most effective way of making fundamental statements about geometric tool design, process parameters and process control. In comparison with experimental forming tests, the models were extended to three dimensions, checked and further optimized. It was found that in particular the representation of anisotropy and the behavior under overstressing (damage) lead to an increase in the effort required for data generation, modeling and calculation.

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