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Research area: Product aims

Paper, paperboard and board // Packaging papers and paperboard

Key words:

Mechanical properties, material parameters, experimental mechanics, load-bearing capacity, numerical simulation, computational mechanics, constitutive law, flow rule

TITLE:

Material parameters for the efficient evaluation of the mechanical properties of multilayer materials and the subsequent design of adapted products

Background/Problem area

In the context of lightweight construction, semi-finished products, especially resource-efficient and recyclable multilayer materials, continue to grow in importance. In order to achieve specific properties, thin layers with low stiffness are often integrated into the lamination. The various materials resulting from paper technological production can often meet many requirements for chemical resistance, stiffness, strength and creep strength in a laminate or sandwich, but must be able to be characterized adequately, especially in mechanical terms, so that they can be included in the design process. There is a lack of measuring procedures, however, designed to determine the required material parameters in constitutive laws as part of a continuum mechanical approach. Here a particular challenge is to overcome stability problems of the thin sample material associated with its relatively low stiffness and, at the same time, to resolve the problems associated with thermal and hygroscopic properties and inhomogeneity. The measuring procedures that exist in the paper sector are only suitable for comparison amongst themselves in trade.

Objectives/Research results

Based on the example of paperboard in the sense of a semi-finished product, measurement techniques affiliated with calculation rules were developed for the optimal design of paper-composite cross sections that are generally usable and available as design tools in the development of adapted or new products from multilayer composites; for example, to determine the out-of-plane shear behaviour a shear test equipment for use in universal testing machine was constructed and buildt.

For this general purpose, tension, compression, shear and strike-off tests has been made, as well as optical deformation analyses with regard to local mechanical stresses and cross direction strain. For instance, an indirect measure procedure to determine the elastic in-plane shear modulus was successfully developed on the base of common tension tests and a computational mechanical theory.

Moreover, in particular the existing in-house laboratory standard measuring procedures for paper, which in some cases operate with fairly complex mechanical stress states, have been identified as a suitable complement to basic experiments in answering questions of workability with the help of reconstruction methods using mechanical modeling in reverse engineering. In order to provide a compact but adequate basis for numerical simulations, the approach is based on identifying important parameters in adapted simplified constitutive laws for paper in a methodical material modeling framework. Fundamental statements about the suitability of starting materials, concerning the properties of the individual layers, are made in creasing folding boxboard, as a complex processing operation.

The differentiation of tension and compression flow rules, which is important for constitutive laws for natural fiber materials without any matrix, was implemented together with a modified associated yield surface with tension/compression-dependent linear isotropic hardening for the explicit solution method with a rapid rear-projection process, at the accessible interface of the LS-Dyna finite element software as the user defined material in the FORTRAN programming source code.

Application/Economic benefits

The requirements related to the design and construction of lightweight structures are currently - and to an even greater extent will be in future - the key driver to the development of high technologies along the entire chain of production processes of flat materials. Especially in the paper sector, the link between the production of a new fiber material and its use in innovative products often fails since the semi-finished products that emerge from paper manufacturing technology are still too infrequently understood as engineering materials. The building and construction industry as well as the mechanical engineering sector need materials which can be produced over a large area in a short time.

A significant improvement for the marketability of paper-like materials can be achieved by adapting the characterization in terms of their mechanical, chemical and other properties to the requirements for structural design in context with the verification of load-bearing capacity, long-term durability and verification of suitability and serviceability. The necessary parameters that are measured on the finished paper itself should be taken into account in a selective production process and can also be used to assess converting processes.

Period of time: 01.08.2012 – 31.03.2015

Remarks

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