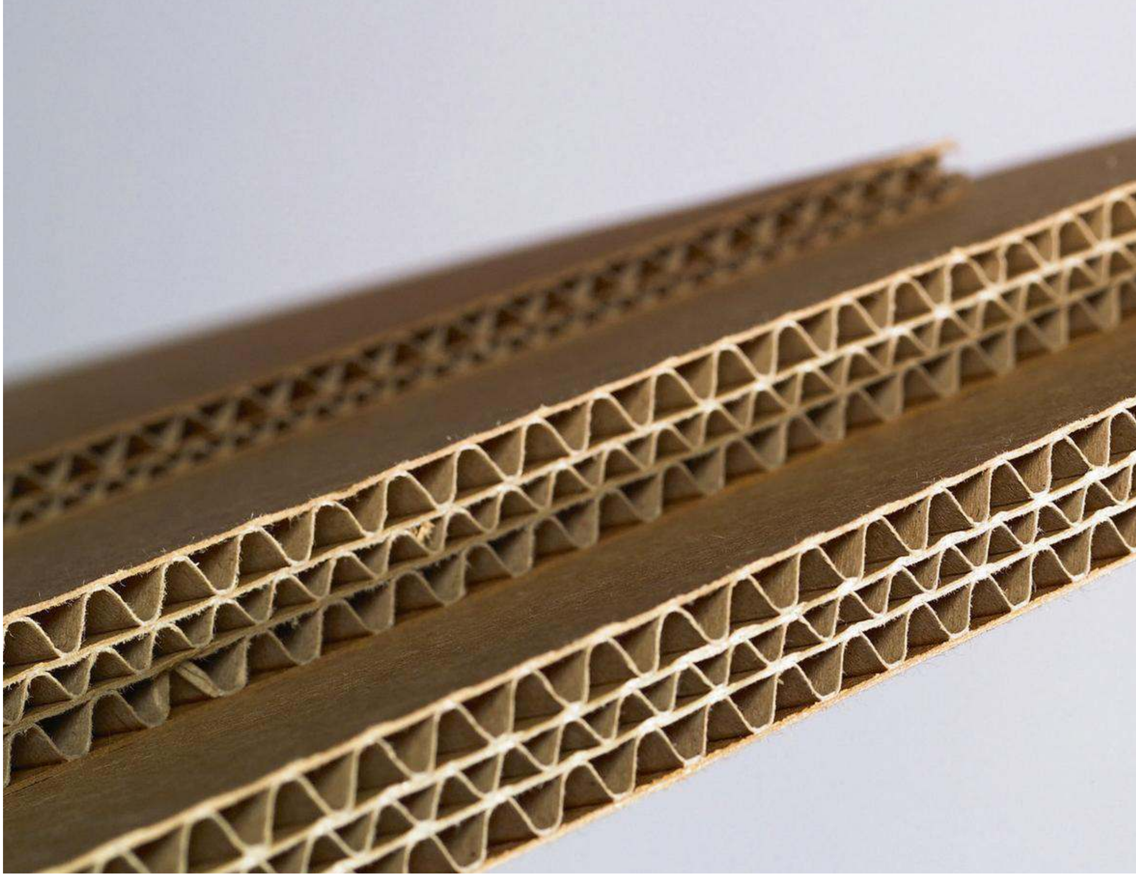
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Improved testing to enhance corrugated board mechanics

PTS provides advanced testing facilities and comprehensive know how

In some cases the conventional testing methods are not suited to assess the packaging behaviour observed in practice. For example creeping effects that are crucial for the long-term mechanical stability of transport packaging are not addressed adequately. To provide a solution for such questions comprehensive research work is conducted at PTS. One current project aims at the prediction of the long-term stability of corrugated cardboard packaging. A broad range of state-of-the-art testing setups and new developed methods emphasize mechanical material characteristics as a major issue in corrugated board production, converting and usage. However, a comprehensive quality assurance to be aspired has to cover much more aspects such as surface and optical characteristics, printability, protection and barrier properties beside others.

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Introduction

The special, multifunctional properties at reasonable costs make corrugated board more and more attractive in the growing market of packaging solutions. The current developments in this field towards lower grammages, new fluting types or new lightweight products necessitates assuring a sufficient level of mechanical characteristics such as stiffness or strength under external loading. Beside a broad range of conventional testing setups PTS provides new approaches and solutions well directed to the special customer needs e.g. to evaluate the effect of converting, transport and storage processes on the mechanical packaging stability with special emphasis to material damages and subsequent loading capacity reductions. In practice not only a total failure at a corresponding maximal bearing load is critical but also irreversible deformations and stiffness losses at lower stress levels might degrade the packaging usability significantly. In some cases the conventional testing methods are not suited to assess the packaging behaviour observed in practice. For example creeping effects that are crucial for the long-term mechanical stability of transport packaging are not addressed adequately. To provide a solution for such questions comprehensive research work is conducted at PTS. One current project aims at the prediction of the long-term stability of corrugated cardboard packaging. A broad range of state-of-the-art testing setups and new developed methods emphasize mechanical material characteristics as a major issue in corrugated board production, converting and usage.
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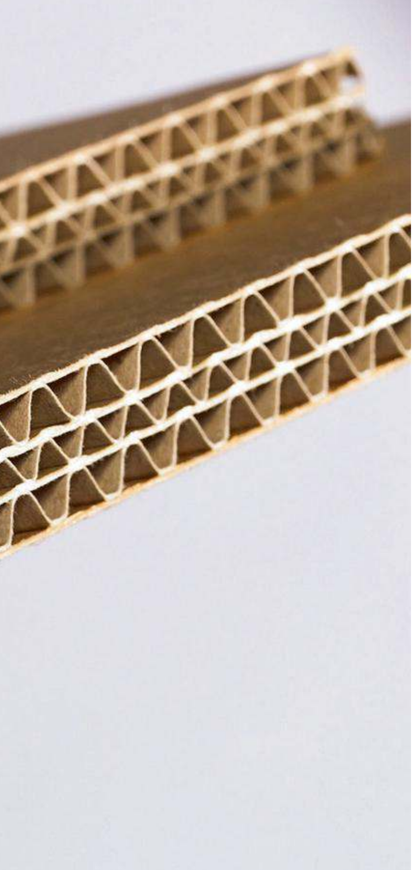

Material	Mechanical testing methods
Base paper (Liner, Fluting)	
	• Short-span compression test SCT • Tensile stiffness • Bursting strength • Concora Medium Test (CMT)
Corrugated board	
	• Edge Crush Test (ECT) • Flat Crush Test (FCT) • 4-point-Bending stiffness • Puncture Energy Test (PET) • Bursting strength • Pin adhesion test
Packaging	
	• Box Compression Test (BCT)

Tab. 1: Important mechanical testing methods of base paper, corrugated board and packaging materials.

Ensuring mechanic stability of corrugated board and packaging materials

The most important strength requirements of corrugated board result from the stackability and containability[1] of corrugated containers. Stackability is the ability of a container to resist compressive forces during transport and storage and is often evaluated by applying a box compression test between two flat, parallel pressure plates. For stackability, good edgewise compression resistance and bending stiffness are necessary in terms of the corrugated fibreboard. Containability is the ability of a container to resist external or internal mechanical stresses. For containability, bursting strength and puncture resistance are important. Flat crush resistance is also relevant as a routine measurement. If base papers are considered, then tensile stiffness and their behaviour during the short span compression test have to be considered. Table 1 gives an overview of available tests to determine mechanical characteristics of packaging, corrugated board and base papers using standardized methods *(Table 1)*. Samples of base papers and corrugated board grades are usually evaluated on the basis of ideal, virgin specimen whereas corrugated board undergoes a series of treatments during converting and transport steps. That might lead to a reduction of mechanical strength and stiffness. Often not only a total failure at a corresponding maximal bearing load is critical but also irreversible deformations and stiffness losses at lower stress levels might degrade the packaging usability significantly.

A further elucidation of these effects makes it necessary to better describe and distinguish structure and material related effects such as deformation of fluting structures (e.g. irreversible change into a nonsinusoidal curve), bending, buckling, break of glued joints etc. For this purpose standard testing methods have to be complemented by appropriate mechanical tests, e.g. involving loading/reloading cycles to analyse elastic and inelastic deformations, material degradation and damage or material failure. A promising approach seems to be an optical strain field analysis accompanying the mechanical tests, a technique that is already applied to different tasks concerning material characterization and to determine characteristic material parameters *(Fig. 1)*[2].

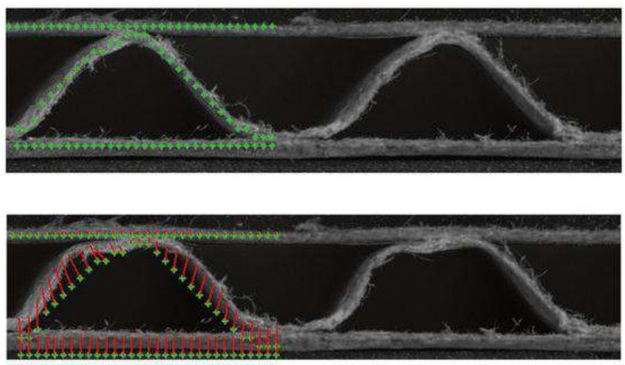

Fig. 1: Result of a corrugated board compression test in thickness direction (FCT): unstressed sample and grid points (left), deformed nonideal fluting structure and displacement vectors after loading (right).

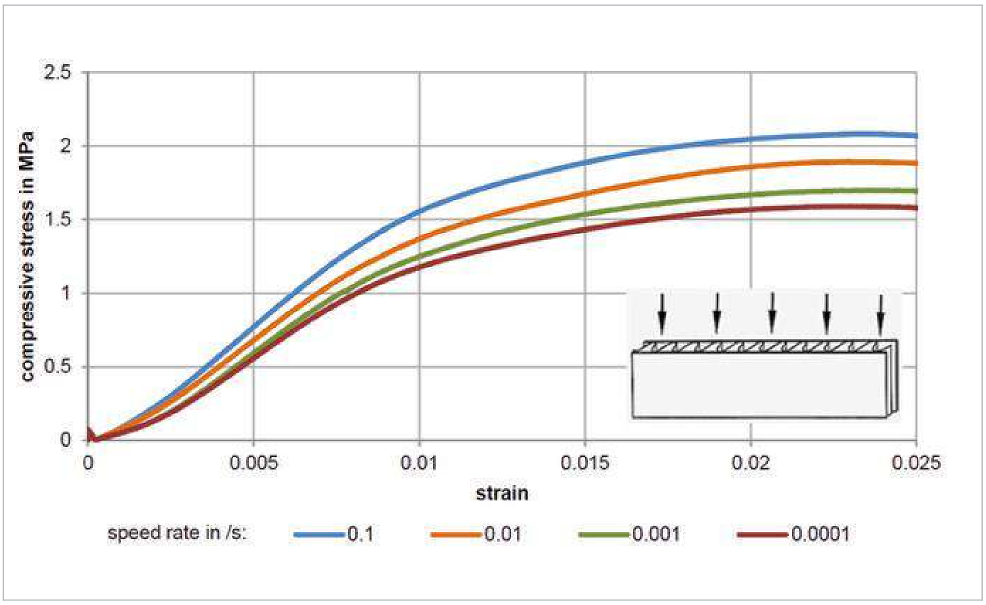

Fig. 2: Speed rate dependent stress-strain-characteristics from edge crush test measurements.

New approach to describe the long-term mechanical behaviour of corrugated cardboard packaging based on speed rate controlled short term tests

The long-term mechanical behaviour especially with regard to creeping effects is one of the main characteristics for the application of corrugated cardboard in transport packaging. Several influencing factors, such as loading or climate conditions, are important and have to be taken into account. In standard testing the test pieces are loaded so that failure occurs instantaneously or at least within a few seconds from the start of the test. In actual situations, many packages undergo static loads for long periods, where viscoelastic behaviour of the material plays an important role. Consequently the long-time behaviour can hardly be described by the available standard test methods.

On the other hand currently used endurance tests are cost- and also time-intensive and therefore cannot be carried out in large numbers or when fast decisions are required.

One current research project therefore aims at the prediction of the long-term stability of corrugated cardboard packaging based on speed rate controlled short term tests. The new approach is focused on short-term tests applying tensile, bending or crushing load conditions. Examinations with various speed rates of the respective load types allow the determination of continuum mechanic material constants. Fig. 1 shows the speed rate dependent stress-strain characteristics measured during edge crush tests for a double wall corrugated cardboard sample (strain rate as indicated from 0,0001/s to 0,1/s) *(Fig. 2)*.

The viscoelastic part of the material behaviour is described by a multiple Maxwell-model comprising a setup of parallel spring and damper components *(Fig. 3, left)*. For each speed rate spring and damper constants are determined directly *(Fig. 3, right)*. In the following it is possible to develop a corresponding relaxation model by means of a so-called Prony analysis. Describing the time-dependent behaviour of the elastic modulus allows to predict the (viscoelastic) creep behaviour of the corrugated board and therefore the packaging *(Fig. 4)*.

Currently the method is to be extended and validated by carrying out additional long-term studies under defined climatic conditions that make it possible to identify the overall viscoplastic material behaviour and to

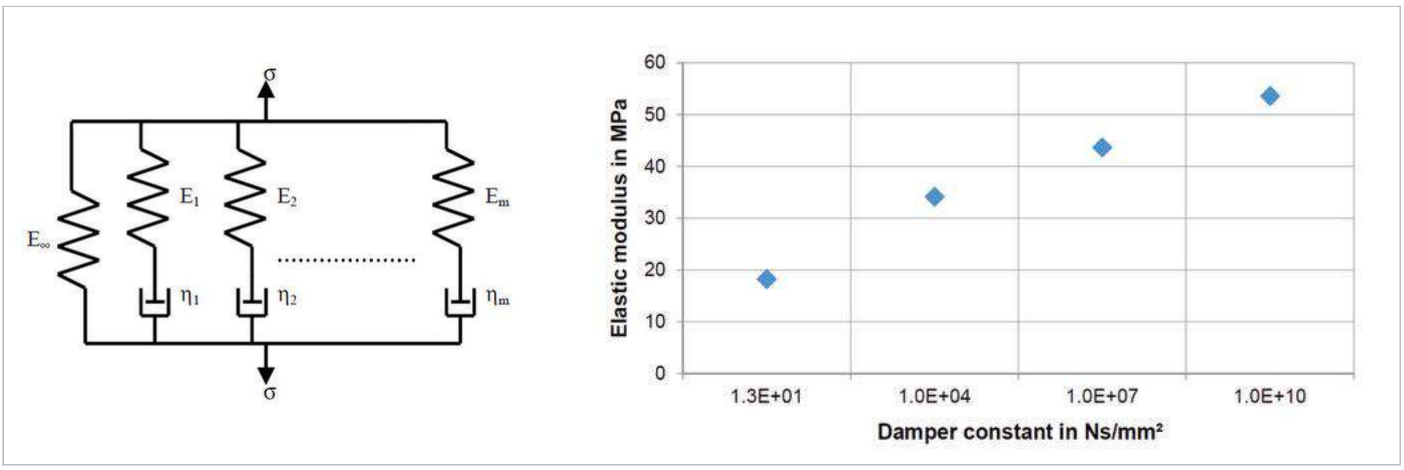

Fig. 3: Scheme of a multiple Maxwell model to describe the viscoelastic material behaviour (left), Spectrum of spring (Ei) and damper (ηi)constants from the experiments in Fig. 2 (right).

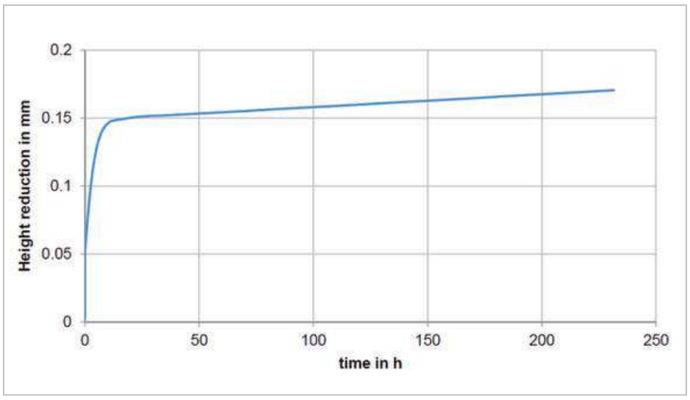

Fig. 4: Calculated long-term height reduction of a corrugated cardboard sample during a long term edge crush test.

specify the effect of differing moisture contents due to changing climatic conditions using a so-called shifter function.

The improved modelling approach makes it possible to relate short term test data to the expected long term failure of corrugated packaging and thus supporting a fast, reliable and cost effective development and design of new packaging.

Comprehensive quality assurance of paper and board packaging materials in production and design

The previous chapters underline an elaborate mechanical material characterisation and optimization as a major concern in corrugated board production, converting and usage in transport packaging. However, a comprehensive cost-effective quality assurance to be aspired has to cover much more aspects such as surface and optical characteristics, printability, protection and barrier properties and others. Many different properties and impact factors must be analysed systematically in order to identify specific differences in product performance or to detect possible causes of differences in quality. PTS relies on the experience gained from numerous consultancy projects for renowned clients and are constantly developing new methods to maintain our competitive edge. Examples from the range of topics that have to be taken into consideration:

- Chemical composition and product structure
  - Furnish and paper constituents e. g. fibre composition, ash, moisture, coating binder etc.
  - Identification of corrugating base papers e. g. semichemical fluting, kraft/test liner or fluting
  - Identification of spots, deposits and impurities
  - Chemical mapping in the micrometre range
- Surface properties and optics
  - Microscopy, Topography analysis
  - Wetting and penetration, Porosity
  - Optics like brightness, opacity, gloss; light fastness and light-induced ageing
- Printing and converting quality
  - Printability using digital and analogue printing technologies
  - Evaluation and optimization of converting processes e. g. creasing, folding and cutting
- Compliance with food safety requirements
  - Analysing the content and migration of critical substances like mineral oils or phthalates
  - Development of barrier coatings
  - Environmental compatibility
  - Transfer of antimicrobial constituents
- Testing services
  - Safety packages
  - CEPI Comparative Testing Service *(Fig. 5).*

References

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2 Kühnöl, K.; Kuntzsch, T.: Bestimmung werkstoffmechanischer Kennwerte an faserbasierten Werkstoffen aus optisch ermittelten Dehnungsfeldern. PTS Forschungsvorhaben IK-VF 130044

Fig. 5: Overview on services provided by PTS Material Testing & Analytics.