**EUROMECH Colloquium 592**

**"Deformation and damage mechanisms of wood-fibre network-based materials and structures"**

*7 – 9 June 2017, Stockholm, Sweden*

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Wood-fibre network-based materials and structures, such as paper and paperboard, have a long tradition in society as carriers of information and as packaging material. However, recent concerns regarding the environment and sustainability, as well as industrial requirements for increased efficiency, have created a demand for a deeper understanding of the mechanics of such materials, reaching a level considerably beyond current industrial practice. This also includes the use of wood fibre network-based materials in non-traditional applications.

The objective of EUROMECH Colloquium 592 was to share and discuss recent advances in experimental characterisation and modelling of the deformation and damage mechanisms of wood fibre network-based materials and structures in manufacturing, converting and end use at all relevant length scales. There were altogether 61 participants and about 37 presentations including a key-note lecture given by Daniel Söderberg, KTH, Stockholm. Extended abstracts of all presentations were included in the Book of Abstracts. The relatively large number of participants from research institutes and industry should be acknowledged. There was extensive interaction between the participants during breaks and session chairmen had to work hard to reassemble participants in the lecture hall.

The presentations covered a wide range of topics related to the major challenges in the field, such as paper-moisture interaction during conversion and end-use, paper-fluid interaction during papermaking and printing, and the multiscale and stochastic nature of paper damage. Recurring issues addressed in the talks and discussion were:

- **The true bonded contact area in fibre-fibre joints**

The mechanical properties of the fibre-fibre joint play an important role in the strength and stiffness properties of fibre network materials. Detailed understanding of the physics, chemistry and mechanics of the fibre-fibre joint is far from complete. A key concept here is to understand the area in real contact between two fibres and the chemical bonds acting between the surfaces. At the colloquium, contributions addressing these issues were presented in the form of X-ray microtomography analyses of the joint and analysis of the dominating bonding mechanisms at different length scales.

- **Modelling of the fibre-fibre joint**

The mechanical properties of fibre-fibre joints, both from physical and modelling points of view, were also heavily discussed. Here, issues related to combined loading of the fibre-fibre joint and to how to capture the physics of the fibre-fibre joint in modelling at different scales were addressed. The mechanics of fibre-fibre joints under combined modes of loading and aspects related to network modelling were addressed by several groups, and issues related to the important problem of dimensional stability, such as hygroexpansion, were also heavily discussed. An important issue in this context is not only to capture the continuum behaviour, but also local variations in properties and to include parameters that make it possible for material producers and end-users to benefit from the results.

- **Statistical effects**

The mechanisms that control stiffness and strength of fibre-based materials originate from the structure at the microscale, where the fibre mechanical properties, fibre morphology and orientation, the number of inter-fibre contacts, bonding properties and disordered nature of the fibre network play crucial roles. Therefore, statistical effects play a significant role in understanding the mechanical properties of these materials. Important issues addressed at the colloquium are the applicability of weakest links concepts and Weibull theory. This was discussed by several groups. Statistical effects constitute a relatively novel research area for the community, where major advancements are needed and expected in the near future. This is also related to the homogenization of materials at different length scales in multiscale modelling.

- **Moisture effects**

Understanding and modelling the influence of moisture on the mechanical properties of paper materials is one of the grand challenges in the mechanics of paperboard. This topic was addressed by several speakers at different structural levels, including continuum-based mixture theory, build-up of stiffness and strength during drying and modelling of hygroexpansion. The inclusion of moisture and temperature effects in 3D continuum models is a relatively unexplored research area, although some recent advances were presented at the colloquium.

- **Capturing micro- and meso-mechanical phenomena in continuum models**

The mechanisms that control stiffness and strength of fibre-based materials originate from the structure at the microscale, where the fibre mechanical properties, fibre morphology and orientation, the number of inter-fibre contacts, bonding properties and disordered nature of the fibre network play crucial roles. Therefore, it is natural to tackle the questions related to the mechanics of the fibre network structures at the length scale where the essential components can be taken into consideration. At the same time, bringing the information from the microscale upwards to the product scale at the appropriate climate conditions is the only way to make the scientific findings both relevant and applicable. Failure is often initiated at the scale of a few fibres, whereas quality parameters, in general, are defined in a continuum mechanics setting that results in essentially size-independent properties.

Issues related to these aspects were addressed frequently in many of the talks. It can be concluded that both continuum and network models have made major advances in recent years, but there are still many important issues to be resolved, particularly regarding the coupling between different length scales. In continuum models, issues arising at the colloquium included, for example, damage in the form of delamination and deformation and damage in load cases characterized by significant contributions from in-plane compression. In network modelling, issues related to both characterization of the network structure and modelling of fibre-fibre joints were addressed. In network modelling, the important issues of multi-axial loading, particularly in the case of substantial compression and shear, are still in the very early stages.

- **Parameter identification in multi-scale models**

While being touched upon in many talks, this is still an unresolved area. It is particularly important to define reliable and robust parameters that capture the underlying deformation and damage mechanisms, while still allowing their measurement in an industrial setting where statistical effects also play a significant role.

It is clear that many critical questions are far from being answered and the community has agreed to plan for a new meeting in about 5 years. Many participants have expressed their strong appreciation for the colloquium; we would like to quote one of the participants “Frankly, this EUROMECH conference was one of the most enjoyable meetings I experienced. Engaged, dynamic, and interesting!” This is what we wanted to achieve. The colloquium has also strengthened the ties between the paper mechanics and material mechanics communities and this was also one of the objectives. Finally, we would like to thank EUROMECH for the financial and especially organisational support.