Process simulation –
Virtual papermaking

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With growing demands on paper machine efficiency as well as product quality, a deeper knowledge of all papermaking processes is essential. In order to identify the effects of each machine component on product characteristics, increasingly complex testing is required. However, the high costs involved often preclude carrying out enough tests to eliminate statistical error. Furthermore, some machine sections are inaccessible to measuring devices.

Today's vastly more powerful computers enable a new discipline for tackling these problems: process simulation. Given a computer model, extensive research can be done at comparatively low cost. For example, the effects of varying individual input parameters can be studied, design parameters and machine settings can be optimized, and a deeper knowledge can be gained of the physical processes involved. In fact simulation results often deliver more detailed data than test measurements.

In this connection Voith Paper has formed a team for compiling simulation models of papermaking processes. This provides other departments with valuable support in optimizing existing concepts and developing new ones, as well as in identifying and overcoming technical limitations. By applying the accumulated know-how gained from individual projects to new developments, increasingly sophisticated simulation models can be developed with spending less and less time.

Mill operators benefit directly from simulation technique (**Fig. 1**): it enables machine concepts to be tailored to their individual requirements, thus optimizing product quality. Furthermore, early simulation minimizes development risks both for new installations and rebuilds. And by knowing in advance the effects of machine settings on process stability and product quality, commissioning times can be significantly shortened.

As shown in **Fig. 2**, the simulation procedure is based on the laws of physics. In papermaking these are primarily the laws of thermodynamics, fluid flow and materials mechanics. The mathematical simulation model is established by combining

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Fig. 1: *Customer benefits of simulation techniques.*

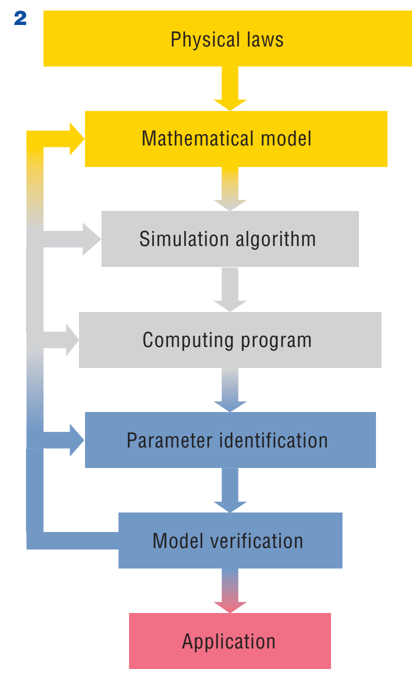


Fig. 2: *Simulation procedures.*

Fig. 3: *Aspects for further study in individual papermaking processes.*

the respective equations, but only seldomly is a purely analytical solution possible; in most cases numerical methods have to be applied. Apart from converting the simulation algorithm into a computer program, the system parameters also have to be defined, for example by laboratory measurements. Before it can be applied by the user, the simulation model has to be verified by comparison with test results and adapted as necessary. In other words, simulation only partially replaces research on the test-bed. Only by combining the two, an efficient R&D tool can be developed.

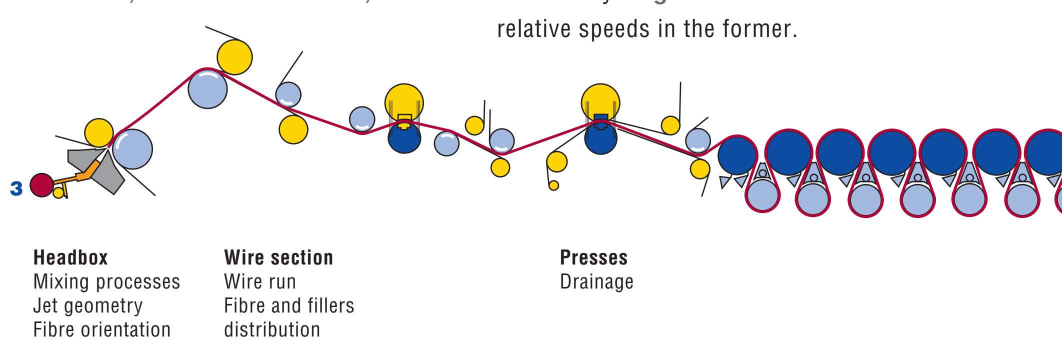
Typical of papermaking technology is the wide variety of tasks in each process stage **(Fig. 3)**. In the headbox, for example, simulation can provide information on stock mixing efficiency with the dilution water, on jet geometry and on fiber orientation. Simulation of the drainage process in the former shows how the fibers and fillers are redistributed by the vacuum elements. Particularly interesting is also a simulation of the drainage mechanisms in presses, showing the effect of various machine parameters on attainable dry content. It also indicates the flow velocity between web and felt, which influences the paper surface quality. The main information derived in the drying section, apart from evaporation efficiency, concerns the web run behaviour and web shrinkage characteristics. Among the coating information obtainable by simulation are the flow characteristics, while winding technology simulation helps to optimize the paper roll structure and roll changing procedure.

The common features of individual processes are so important, that a single simulation group for the entire papermaking process is very worthwhile. Various points in the process are governed by the same laws of physics, as follows:

- The **laws of materials mechanics** apply to nearly all process simulations. They define elasticity, viscous or plastic behaviour, and stock characteristics such as viscosity and permeability.
- **Fluid dynamics** simulation is required above all in the approach flow section, headbox and former, as well as in the presses and for the various coating technology methods.
- **Press nip** analysis is required at several points in the paper machine, including the press section and calender.
- Apart from the web itself, the felts and wires also travel through the paper machine at high speed. **Web run simulation** is therefore an important core competence of the simulation team.

As a typical simulation project, we analyzed the top and bottom wire speeds in a former. Since the tensions in wire loop sections vary widely, the wire stretch and the speeds also vary accordingly. Ideally, both wires should run at the same speed when in direct contact with each other. This not only avoids shear stress in the web, but also minimizes wire wear in the edge zones.

The simulation model converts the vacua on the suction elements into friction forces, using the coefficients of friction measured between bars and wires on our test facility. **Fig. 4** shows the simulated relative speeds in the former.



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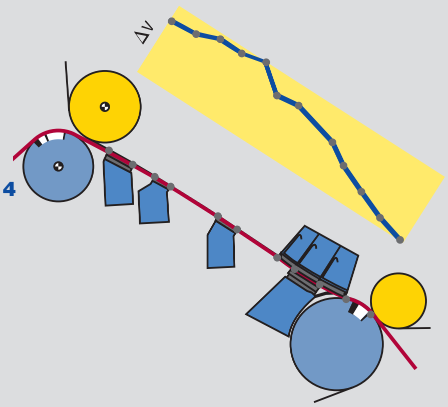

Fig. 4: *Aspects for further study in individual papermaking processes.*

Fig. 5: *Sheet water drainage velocity in the z-axis direction on a shoe type first press.*

Fig. 6: *Sheet dry content distribution in the first press.*

Fig. 7: *Dry content in the second press.*

Another example is press drainage simulation. For that material characteristics such as rheology as well as paper and felt permeability are required, which can be measured in the laboratory. By iterative computation, the simulation program works out a solution complying both with Darcy's law and mass retention for the water and air phases.

Simulation results are shown in the following for a tandem shoe press. Fig. 5 shows water flow velocity in the z-axis direction as the web passes through the first press. Drainage is at first restricted to the two paper surfaces, but extends deeper on the way through the nip. As seen at the outer contour of the cross-section, the web expands elastically again to some extent after leaving the press.

The respective dry content is shown in Fig. 6. On the paper surface quite high values are already attained after leaving the press nip, while the water content in the center remains relatively high.

Dry content distribution after passing through the first press serves as ingoing profile for the second press, where, as shown by the dry content distribution in Fig. 7, compression now extends right into the sheet. No further water is removed from the outer layers except near the nip centre, since only in this zone is the pressure higher than that attained in the first press.

It becomes apparent from both examples that simulations may provide more insight than could be obtained from measurements. Once the numerical results have been validated against data measured at experimental paper machines, the computer programs can be run inexpensively to study the effects of extensive parameter variations.

Based on current and future projects, the Voith Paper simulation group is going to build up expertise in the modelling of a wide range of sub-processes. In the long term, the individual models will be combined to form a complete model of the entire papermaking process.

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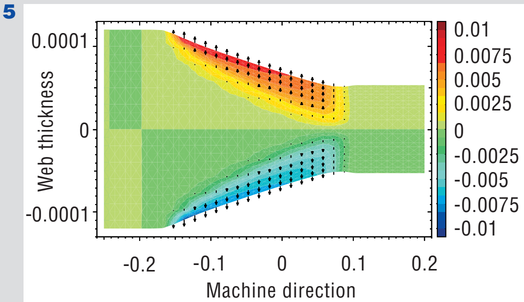

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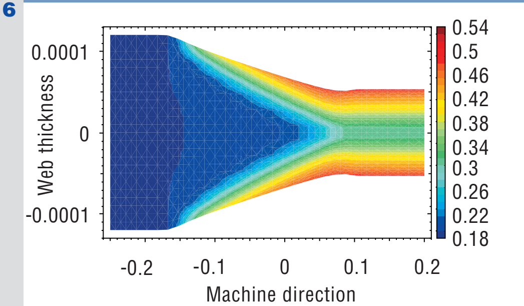

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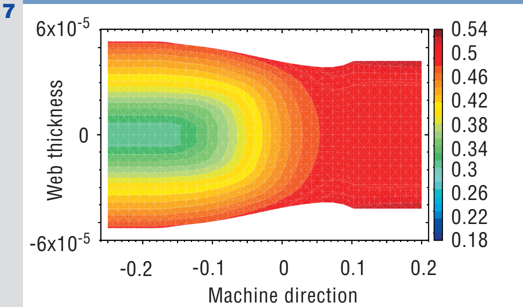

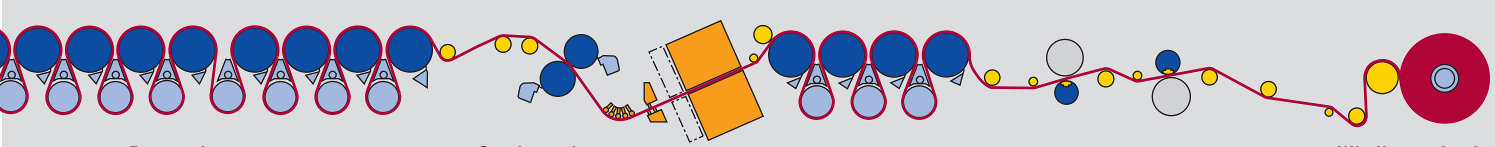

Dry section
Heat flow
Web run
Shrinkage

Coating unit
Sizing flow
Contact vibrations

Winding technology
Paper roll structure
Reel change