Soft roll covers for Janus™ calenders

Voith Paper Service (formerly Scapa Kern) has been producing soft calender roll covers for more than a decade. A new cover generation has now been developed to take account of the special demands on soft roll covers in multi-nip calenders.

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Development history of soft roll covers

The first two Janus™ calenders with soft roll covers went into service in 1996, including the first Janus™ online calender.

Modern calender roll covers are made of composite fibre materials, either with cast or fibre-reinforced surface layers.

The advantage of cast surface layers is the high isotropy and the very smooth and homogeneous surface. At the cost, however, of brittleness and a tendency to form cracks propagating in all directions (**Fig. 1**).

That is why Voith Paper only uses cover materials with fibre-reinforced base and surface layers (**Fig. 2**). The fracture characteristics of the fibre-reinforced surface layer are shown in **Fig. 3**.

Cover design principles

The TopTec™, Rubin™ and Safir™ calender roll covers manufactured by Voith Paper Service mainly comprise a fibreglass-reinforced base layer and a surface layer strengthened with aramide fibres.

The multi layered base construction is built up by winding fibreglass textile with fillers and resin around a metal core. It forms a dynamically strong composite, bonded both with the metal core and with the surface layer. To this purpose, the physical characteristics of the base layer such as mechanical strength, Young's modulus, deformation characteristics and bonding must comply on the inner side with the metal core material, and on the outside with the surface layer used for calendering.

In the first multi-nip calenders, hot-spot problems increasingly arose due to the high nip frequencies. They were caused by the thermal energy released during repeated local overloading of the cover material.

Due to the intrinsically low thermal conductivity of polymer material, this heat cannot be dissipated quickly enough, and

Fig. 1: *Cracks extending over the entire roll cover, mainly in the axial direction.*

Fig. 2: *Crack growth limitation by fiber reinforcement.*

Fig. 3: *Crack growth mechanism*
a Fiber fracture
b Fiber pull-out
c Crack bridging
d Matrix deformation.

Fig. 4: *Roll damage due to deposits.*

Fig. 5: *Mechanical overload due to deposits. Thickness of deposit*
- *200 μm*
- *100 μm*
- *70 μm*

Fig. 6: *Loss factor tan delta for various calender roll covers.*


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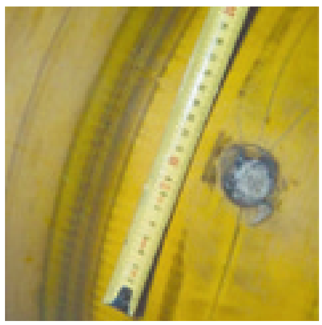
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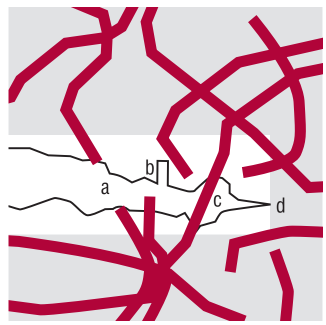

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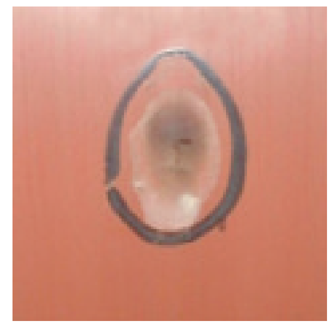
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the temperature rise causes cover expansion mainly in the radial direction. This process is repeated with every nip pass. The sum effect of periodic overloading and thermal expansion is a self-energizing cycle, which even might continue after the initial pulse due to roll deposits ceases.

On high-speed calenders, this effect can lead within minutes to hot-spot burning of polymer covers **(Fig. 4)**.

With heavy deposits or edge overloading, even the latest cover materials cannot stand up to this self-energizing effect **(Fig. 5)**. However, they are considerably more resistant to smaller nip fluctuations such as in pressure or temperature. The amount of deformation energy converted into heat during each nip pass depends on the material properties **(Fig. 6)**.

Critical for this is the none-dimensional “tan δ” parameter, which can be influenced by an appropriate molecular structure, as well as by interaction between the polymer matrix and fillers or fibres.

By optimizing the material composition, heat generation in the Rubin™ and Safir™ covers was nearly halved. As a result, the damage caused by these effects has been greatly reduced.

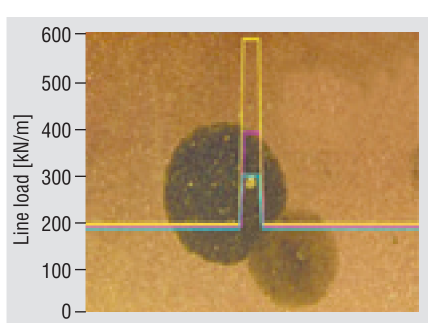
Surface quality of polymer covers

The outstanding feature of cast covers is their extremely homogeneous and smooth surface. To attain such quality with fibre-reinforced covers, enormous technological and development effort is required. It was found that roll cover service life could only be optimized by compromising with surface quality. For this reason, Voith Paper roll covers have been optimized in two directions.

Rubin™ covers were optimized for use with coated papers **(Fig. 7)**, where the smoothest possible surface is required. This was attained by particularly fine fillers distribution but with a reduced fillers quantity.

The resultant hardness is somewhat lower, i.e. 90 Shore D, thus compromising abrasion resistance and therefore service life to a certain extent **(Fig. 8)**.

Rubin™ covers are ideal for calendering grades where the most important requirement is high gloss.



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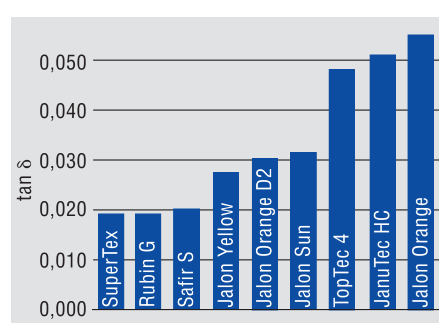

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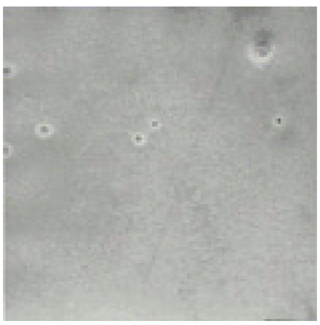
Fig. 7: *Coated paper surface.*

Fig. 8: *Fillers distribution in Rubin™ G cover.*

Fig. 9: *SC paper surface.*

Fig. 10: *Fillers distribution in Safir S cover.*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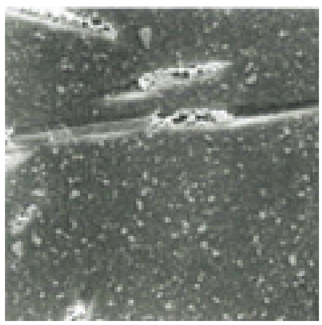
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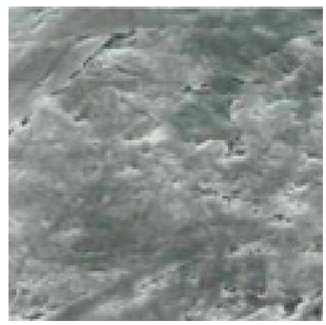
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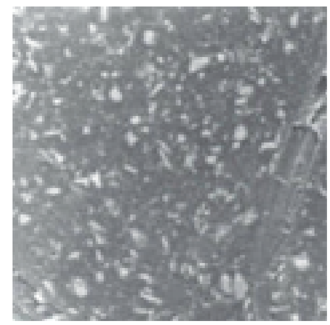
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On the other hand, for magazine papers in particular **(Fig. 9)**, roll covers with high availability and service life are indispensable for cost-effective paper machine operation.

Safir™ covers are therefore optimized for best possible resistance to abrasion, which makes them particularly proof against barring. The very hard fillers used to this purpose result in a cover surface hardness of 92 Shore D **(Fig. 10)**.

Due to these outstanding qualities, Safir™ roll covers are the most frequently used in multi-nip calenders.

Isolated cases of mechanical overloading often occur in practice. In contrast to the continuous dynamic overloading described above, which causes hot-spot damage due to heat development, sporadic mechanical overloading can cause damage which may take weeks to develop due to high cover elasticity.

Until recently, this kind of damage mechanism was not known in detail. To analyze the material stresses caused by such overloading, a finite-element simulation model was developed which reproduces the nip mechanisms very realistically within certain limits.

On the hard steel roll of a nip with polymer-covered counter-roll, a surface deposit was modelled **(Fig. 11)**. In the dynamic simulation model, this represents a foreign material accidentally passing through the nip.

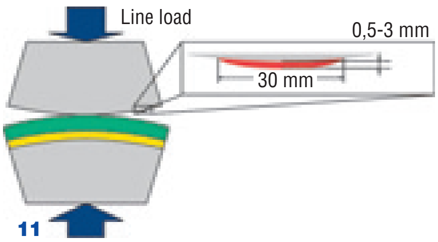
Simulation results revealed mechanical stresses and strains due to deformation caused by the surface deposit. To get results quickly, simulation was subject to the following limitations as against reality:

- Linear stress-strain characteristic assumed for the polymer cover material
- Surface deposit material characteristics assumed the same as steel
- Deformation of the steel roll not taken into account
- Prestressing of the reference model not taken into account

Despite these limitations, the simulation reproduces relatively well the physical processes taking place when a foreign material passes through the nip.

Results

● In the first simulation a line load of 550 kN/m was assumed as roll loading. As the surface deposit passed through the nip, simulation showed that beyond a certain pressure due to the roll mass and inertia, the nip opened, and the resultant stresses in the cover corresponded approximately to those which would occur at ten times the line load. This is roughly the same as the conditions occurring in single-nip calenders or with the top and bottom rolls in multi-nip calenders. The same behaviour has been observed on test calenders, where the intermediate rolls can evade due to their relatively low mass.



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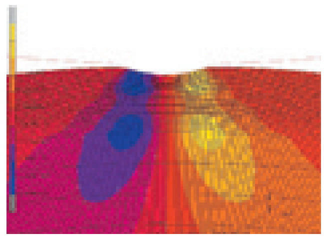

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Fig. 11: *Finite element method (FEM) simulation model design Line load.*

Fig. 12: *Compressive stress as a function of deformation.*

Fig. 13: *Shear stress in the tangential direction with 3 mm deformation.*

Fig. 14: *Operating experience with calender roll covers in a number of Janus™ calenders.*
- *Normal [%]*
- *Damage [%]*
- *Barring [%]*

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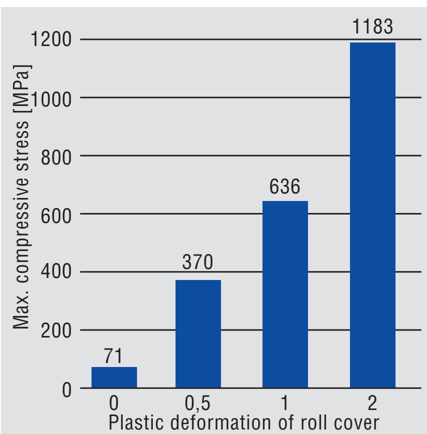

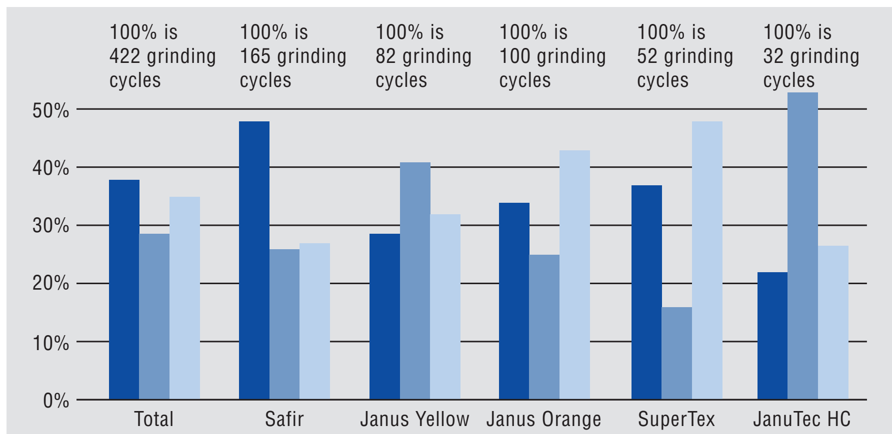

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In practice, however, the very heavy intermediate rolls of multi-nip calenders cannot deflect so easily. The simulation model was, therefore, adjusted by locking-in the roll centres accordingly. Due to the resultant deformation, this revised model revealed significantly higher stresses than the previous one.

● Surprisingly, the comparatively high deformation rates when a foreign material passes through the nip at 1,500 m/min, seemed to have relatively little effect. The reason is that despite the high peripheral speed, the deformation rate is still well below the sonic velocity in the polymer cover material, so that the shock waves, which can cause serious damage at unexpected points, do not occur in the simulation model.

The only identifiable effect in the dynamic simulation model is slightly asymmetric stresses in the nip as the surface deposit passes through.

● Since linear material parameters are assumed in the model, the resultant stresses are, of course, a linear function of the surface deposit thickness. They reach the equivalent of the stresses occurring at about 50 times the line load **(Fig. 12)**.

Already at relatively small deformations of only 0.5 mm, peak shear stresses exceeding the material strength occur in the cover cross-section **(Fig. 13)**.

● Secondary peak shear stresses occur tangentially in the transition zone between the cover and the metal core. These secondary peak stresses are due to the different Young's moduli of the cover and metal core materials, and can critically affect bonding of the cover to the core. In practice, this is often where damage due to mechanical overload first occurs. Such damage to the bonding layer is not immediately critical, but due to dynamic loading during ongoing roll operation it can spread until the cover is destroyed in the end. Since final destruction may not occur until some weeks afterwards, troubleshooting can be a very difficult task.

Ultrasonic inspection is a well-proven way of detecting damage due to mechanical deformation. It shows up any damage at a relatively early stage, thus avoiding further damage due to cover bursting and flying particles.

Summary and conclusions

All in all, there has been a significant reduction of damage to soft roll covers **(Fig. 14)**.

The type of damage has also changed. Barring is the most frequent reason for roll replacement, with mechanical damage in second place. Safir™ covers offer better running behaviour and longer grinding intervals than any other synthetic cover currently on the market.