

Flexible power management through IR deep drying

Bivalent operation of paper drying in preparation for purely electric drying

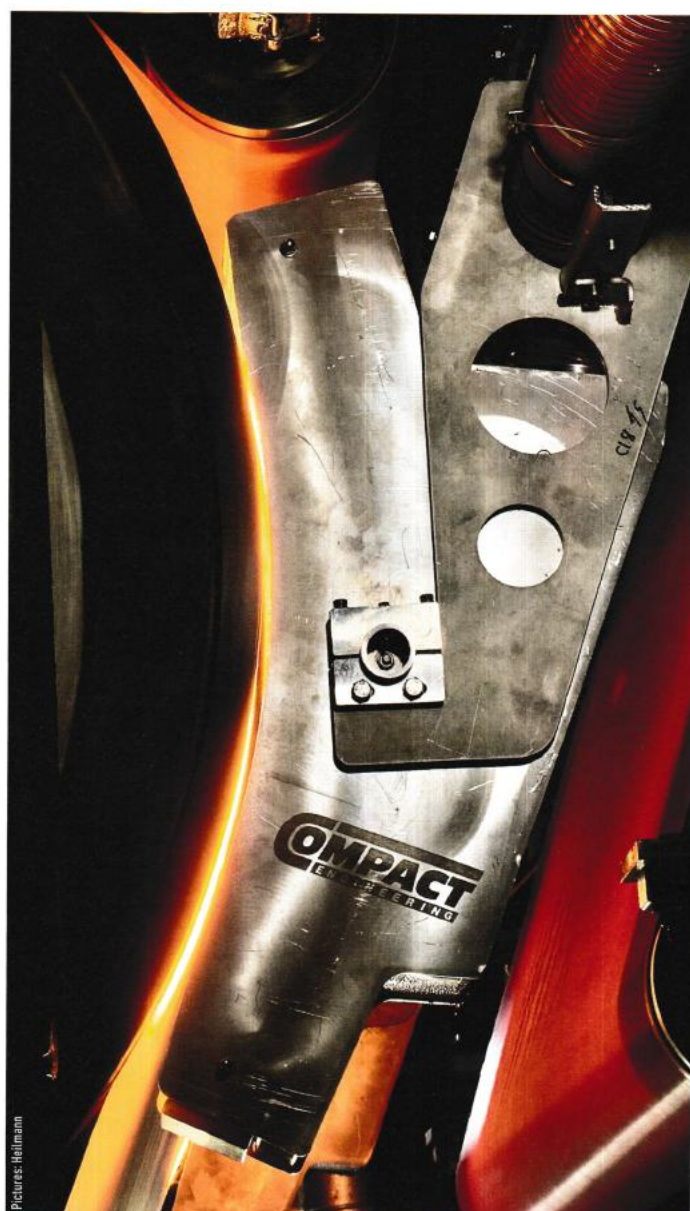


Fig. 1 Infrared deep drying with eNIR Corona as edge dryer

Paper production is energy intensive. In paper manufacturing, around two-thirds of the total energy is used in the drying process for paper and coating. In the vast majority of cases, paper is currently dried using fossil fuels.

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Reducing the amount of energy required for drying significantly lowers overall energy costs. Today, existing technologies could replace 15 % to 25 % of fossil fuels. Ideally, a bivalent operation should be achieved, whereby the most cost-effective energy source is selected based on the current costs of the various energy sources. A solution for this is already available today.

There are various tools currently available to paper makers that can significantly reduce drying requirements and thus enable decarbonizing the drying.

Infrared Deep Drying

An essential aspect of paper production is infrared deep drying. In this process, energy is introduced into the deep layers of the substrate at the speed of light. This goal can be achieved by using NIR (near infrared) emitters and eNIR (enhanced near infrared) emitters. The latter typically evaporate twice as much water as the former.¹

The key advantages are manifold:

1. The coating is dried from the initial sediment layer. This means that much less liquid phase penetrates the substrate. Otherwise, this would have to be released from the fibres again later and accelerated to the surface – two energy-intensive processes that can be avoided. At the same time, excellent coating hold-out is achieved with very low losses of binder and fine particles.
2. Paper and cardboard are dried from the inside out. Cylinders only heat the surface. The speed at which heat flows into the paper is limited. This means that a relatively large number of cylinders are required to heat the paper through and bring it to a constant temperature. At this point, energy supply and evaporation are in balance. However, if the paper machine runs too fast, it is impossible to prevent the centre from remaining too moist in the z-direction, which later leads to layer separation. Infrared deep radiation, on the other hand, heats the substrate to its full depth at the speed of light and drives

the water to the surface, thus making the work of the cylinders or hot air hoods easier. These are not designed to bring the water to the surface. Here, expensive infrared is the tool of choice – it acts as a catalyst.

3. The deep penetration of infrared radiation means that less energy is required for drying. With coat drying, the energy required to remove water from the fibres is eliminated. Preheating and profiling require much less time than is normally needed to transfer heat deep into the substrate. The machine can run much faster.

Enhanced NIR dryers from Compact Engineering typically evaporate twice as much water as standard NIR dryers due to their optimised wavelength.² They consume only half the energy for the same performance. They have minimal energy losses thanks to energy optimisation. For this reason, eNIR dryers are still a very expensive tool for the paper maker. However, they are the only ones that are so energy-efficient for deep drying.

Deep drying of the substrate and coating can reduce overall energy consumption. This involves replacing some of the fossil energy with potentially renewable energy. In coating drying, fossil gases are replaced by renewable energies. In some cases, this also reduces overall energy costs.

Application Cases

Using various application examples, we explain how decarbonization of drying can already be implemented today, or has been implemented, while reducing energy costs.

Application 1 – Film press drying on a speciality paper machine

This is a speciality paper machine that produces everything from high-quality packaging papers to papers with functional, sometimes highly complex PVA coatings. Drying was previously carried out using hot air, which was generated using gas. A post-drying section is attached downstream.

This is perfectly adequate for simple starch application. The same applies to simple pigmented coatings with latex. However, this is suboptimal for certain coatings. The production speed must therefore be adjusted depending on the coating. With light papers, this only achieves an insufficient contribution margin.

The basis weights of the finished products range from 60 g/m² to 400 g/m². The coatings can be simple starch applications, a starch-latex combination, PVA, PVA with starch, and PVA with starch and pigment. With a dry content between 10 % and 18 % and a coating weight between 3 g/m² and 10 g/m², a large amount of water has to be dried. (Fig. 2)

Drying was limited due to the restricted installation space. It was also not possible to increase the energy input into the surface, as heat transfer into the deeper layers of the coating and substrate is physically limited. Increasing the energy input would have led to premature film formation on the surface.

This was particularly critical when drying PVA-based coatings, as it leads to typical surface damage such as pinholes at reasonable production speeds. These occur when a large proportion of the liquid phase migrates into the substrate. It then finds its way back to the surface in the post-drying section and through the PVA film.

The hot air hoods were replaced by a series of eNIR Apollo emitters on the top and reverse sides and by opposing reflectors. These are the smallest dryers from Compact Engineering, but they always prove to be the best choice for very lightweight substrates. To allow sufficient ventilation for the water evaporated during irradiation, the emitters and reflectors were separated from each other. Instead of the originally planned 920 mm installation space, 1,250 mm was planned. The installed power is 160 kW/m per side. With a maximum of 230 kW/m, i.e. just under two-thirds of this power, all coatings could be immobilised and some of the water evaporated.

The special feature of eNIR dryers is that the initial sediment layer is immobilized immediately. This prevents the liquid phase – and thus also valuable coating components – from penetrating into the substrate. The energy required for drying is significantly reduced as water no longer needs to be dissolved from the fibres of the substrate and accelerated to the surface. This means that considerably more water is evaporated with the same amount of energy.

For the paper mill, this results in a very welcome reduction in the steam pressure of the post-drying section by a good third. This will enable the use of a highly efficient heat pump for steam generation in the post-drying section in the future.

By potentially profiling at the end of the pre-drying section, it will also be possible to reduce the required steam pressure there and consider the use of energy-efficient heat pumps in the future.

Typically, such an installation pays for itself within 12 to 24 months, and in certain cases in less than 6 months.

Application 2 – Profile control of a cardboard machine

A paper machine is used to manufacture packaging paper. Until now, the profile was adjusted using a remoistening spray bar. To do this, the substrate first had to be over-dried and then remoistened with water in the areas that were too dry.

Before the size press, the moisture content in md and cd should be kept as constant as possible. However, it can also be regulated very quickly in order to achieve uniform hold-out of the starch coating. (Fig. 3, 4)

Each paper side is equipped with eNIR Titan, which provides 100 % more drying performance than Apollo with around 75 % more installation space. These radiators can reduce moisture fluctuations from +/- 0.8 % to +/- 0.1 % during normal operation. This typically allows a machine to be run 3 % to 8 % faster.

Profile regulations typically pay for themselves within 6 to 18 months, depending on the extent of moisture variation.

By adding a preload, the dryers can reduce the moisture content by up to 3 %. This allows the production speed to be increased by 10 to 12 % while maintaining the same steam consumption. Alternatively, steam consumption can be reduced accordingly while maintaining the same production speed.

Application 3 – Preheating a cardboard machine

With cardboard with high grammages, the energy input into the depth is a time-consuming process. The heat transfer from the cylinder to the surface, on the other hand, is very fast. However, the transfer into the depth is slow. On the one hand, this causes the surface to dry out prematurely, thus becoming a thermal

insulator. On the other hand, it promotes layer separation, as the centre of the web does not dry sufficiently in the z-direction. At the same time, the surface must continue to dry at the end of the machine to achieve the required dry content in the depth of the substrate.

By installing an impingement drying system between the press and the drying section, the entire thickness of the web is brought to evaporation temperature at the speed of light.³

With 320 kW/m on the top (eNIR Titan) and reverse side (eNIR Corona) of the paper web, the web can be heated to temperatures between 60 °C and 85 °C. The first radiator is installed between the press and the pre-dryer section, the second against the lower dryer cylinder.

With an energy input of around 24 kWh per tonne of cardboard, it was heated to 60 °C across the entire thickness of the substrate. Since the surface is cooler than the centre due to the removal of the evaporation enthalpy, the water now flows to the surface, making the drying cylinders' work easier. Although these are excellent for evaporation, they are not very efficient at moving the water within the substrate to the surface. (Fig. 5)

Sheet temperature normally at 57.7 °C at entry and 60.5 °C at exit is having 63.9 °C on reverse side when heated on top side and 84.2 °C at exit when heated on top and reverse side

With an energy input of around 72 kWh/t, the cardboard was heated to 85 °C. Evaporation already occurred under the eNIR dryers. However, this is not advantageous in terms of energy, as the electric eNIR dryers take over the work of the cylinders here. This is only interesting if electricity costs are extremely low.

With an output of around 72 kWh/t, impingement drying achieved more than 7.5% of the paper machine's total drying capacity. 840 g of water per kWh were evaporated from the cardboard. This is close to the theoretically possible 860.4 g when evaporating pure water. This demonstrates the catalytic effect of the eNIR dryers: they heat the substrate completely in the Z direction. The water moves to the surface of the substrate, as this is the coldest point - thus the wellness oasis for the water in the substrate. This makes the cylinders' work easier, as the water flows towards them.

In the case of increased production, preheating pays for itself within 6 to 18 months; without increased production, it can take up to 36 months for the project to pay for itself through steam savings.

Digital twin for further reduction of steam pressure

Based on CF ProcSim's drying algorithms, AutomationX has developed a digital twin that reduces steam consumption by 4 to 8 percent while maintaining production and quality. These savings have also been confirmed by paper mills.⁴ This results in payback periods of six to twelve months. Depending on the machine's performance, the investment can pay for itself in as little as three months. No downtime is required to implement this digital twin.

Automatic bivalent mode operation of the paper machine

This digital twin has now been expanded to take into account the current prices of all types of energy. If a paper mill has a flexible electricity tariff, the paper machine is regulated in such



Fig. 2 Film press drying with eNIR Apollo

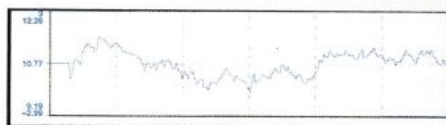


Fig. 3: Humidity profile without profiling with moistening spray bar

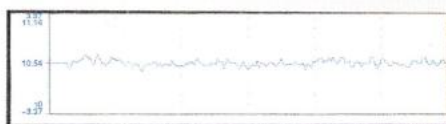


Fig. 4: Moisture profile with eNIR

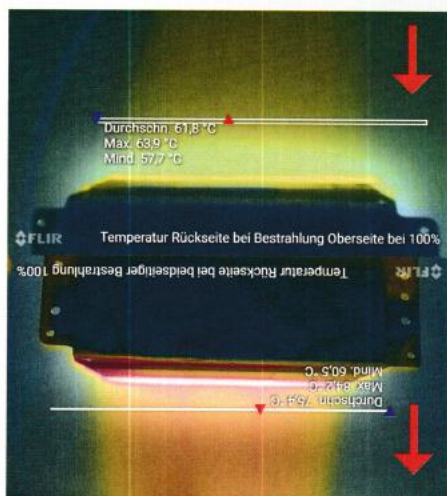


Fig. 5: Impingement preheating a cardboard box with 72 kWh/t and increasing the temperature to 84 °C

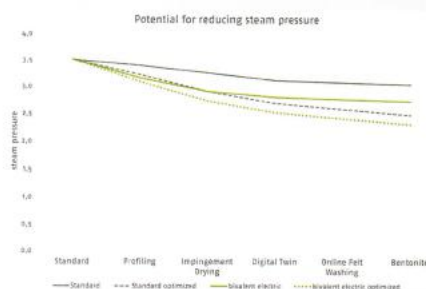


Fig. 6: Potential for reducing the required steam pressure in normal operation and in electrically optimized operation

a way that not only is energy saved, but part of the dry load is shifted to electrical energy at night and on weekends.

In the above example, impingement drying would only heat the substrate to 60 °C to 65 °C due to high electricity costs resulting from bivalent operation. In addition, profile control is operated without preload. If the electricity price decreases, preheating is increased to the maximum, in the above case to 85 °C. In profile control, a preload is also specified. This allows 15 % to over 30 % of the steam to be replaced by electricity without changing the quality or production.

Further possibilities for reducing the steam pressure

Additional components for reducing vapour pressure can be used to make heat pump operation even more efficient.

With NCR Biochemical's online felt washing, dry matter increases of 0.25 to 1 % are achieved after pressing. The special bentonites from Aquatan achieve the same level. They mask the impurities so that their intrinsic water retention capacity no longer comes into play during dewatering. Together, these two factors lead to a reduction in steam consumption of 2 % to 6 % and thus to lower steam pressure. And neither measure requires any investment; both can be implemented immediately during on-going operation.

Further measures will lead to a further reduction in drying requirements. First and foremost is press optimization, although this measure will represent the largest investment. (Fig. 6)

Heat pumps for complete decarbonization

In this bivalent mode, the vapour pressure can be reduced by a third or more. This enables highly efficient operation of BM GreenCooling's heat pumps with a high COP thanks to reduced thermal stroke.⁵ The payback period depends on the achievable COP and the current prices for renewable and fossil fuels.

eNIR dryers are only used where they are technologically superior to heat pumps and energetically equivalent, i.e. when completely heating the substrate in the Z direction.

Summary

The decarbonization of paper drying is already possible today with existing solutions. Ideally, this is done in bivalent operation, in which the economically ideal operating condition is automatically selected based on current energy costs. In view of rising costs for CO₂ certificates, this will lead to an increasing emphasis on electric operation from 2027 onwards. This will significantly reduce CO₂ emissions from paper mills.

Sources:

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