Optimized Coat Drying on a Board Machine

Creating the right drying regime for drying aqueous coatings on paper and board is a critical part of the quality control process. The very first stages of drying are arguably the most important, especially on heavier substrates where the opportunities for the liquid phase and the fine solids of the coating color to migrate into the sheet are the highest. Rapid removal of water from the coating to the gel point is important as this minimizes the risk of binder migration and associated print mottle as the coating passes through the dryers following the infrared. Taking the coating to the gel point also removes the risk of the coating color sticking to backing rolls when the machine speed and coat weight is increased.

1. Introduction

Infrared dryers are commonly used to provide the first phase of the drying process, where the dryers remove sufficient water from the coating to immobilize the coat on the sheet surface. This helps with the control of binder migration and so eliminates print mottle.

Ningbo Zhonghua Paper planned increasing the capacity of their board machines PM2 and PM3 to cope with the board demand in China. This goal is supposed to be achieved by speed increase from 700 m/min to 1,000 m/min. At the same time it was planned to allow increased coat weight by substituting expensive fiber with low cost pre-coating. Both goals could not be achieved with the present equipment, as the coaters were lacking drying capacity.

Ningbo Zhonghua was looking for alternatives to the existing coat drying system. This project is described in the paper. *(Fig. 1)*

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About Ningbo Zhonghua Paper

Ningbo Zhonghua Paper belongs to APP's industrial papers division, APP being the Chinese branch of the Indonesian group Sinar Mas, and is located on China's east coast about 200 km south of Shanghai.

The mill has three board machines and produces 700,000 tons/year of double-coated board, mainly in the range of 200 to 300g/m^2, with maximum weight of 400 g/m^2.

PM3 at Ningbo Zhonghua Paper, Ningbo/China is a multi-layer board machine with four coating stations installed on it, two coating the top side of the sheet and two coating the reverse side of the sheet. The drying after the coating stations is undertaken using a combination of electric short wave infrared dryers followed by hot air dryers. The hot air dryers typically run with an air temperature of between 168 and 174 °C.

Fig. 1: Compact Engineering's IRE Impact Replacement Emitter with perforated protective glass, gold reflectors and special high efficiency lamps

2. Project overview

2.1 Project alternatives

Ningbo Zhonghua evaluated four alternatives:

- Keeping the existing equipment – therefore postponing the coater rebuild until final decisions on other project parts were taken.
- Substituting the existing electric emitters by gas fired ones. Even though this appeared to be a good choice, the alternative could not be chosen: gas-fired emitters require more space which leads to hefty rebuild costs.
- Substituting the emitters by hot air dryers. This should be even more attractive from a theoretical point of view, but an even bigger machine rebuild would be required.
- Install more efficient electrical infrared dryers. This alternative was selected, as most components of the existing system could be used in the future, allowing the capital expenditure to be lowered as much as the promised reduction in energy cost.

2.2 Project implementation

In early 2013, the management of the mill decided to increase the drying capacity and the energy efficiency of the infrared dryers following coater stations 1 and 2 by changing only the emitters in the existing infrared dryer frames. The existing TAPS units with a nominal capacity of 30 kW delivered from ten 3 kW lamps were to be replaced with Compact Engineering's Impact Replacement Emitters (IRE) with a nominal capacity of 24 kW each, delivered from eight 3kW lamps.

The rationale behind changing the emitters was twofold. Firstly, lamp consumption in the existing units was high and this contributed to high running costs. The lamp life guarantee was more than doubled with the new emitters. Secondly, it is the ambition of the mill to substitute coat weight for fiber and to be able to achieve this, the coating stations require additional drying capacity. At top coat, speed increase was the only goal of the expansion program, whereas for the pre-coating the increase in coat weight, allowing the mentioned reduction of fibers, was an additional challenge – thus the upgrading of the pre-coating dryers was selected as the first step.

The mill management team decided that the most cost-effective solution was to retain the existing dryer layout and the majority of the hardware and just change the emitters in the infrared dryers to Compact Engineering emitters. With the given guarantee of 40 % reduction in energy cost, the reduced downtime and the possibility to significantly increase the drying capacity, alternative four gave the best results.

Fig. 2: Compact Engineering's IRE at the 1st and 2nd coater head in the foreground, Impact's emitter on the top coating in the background

2.3 Technology

Compact Engineering has been manufacturing short wave infrared dryers for over 25 years and has continually improved the design and performance of the dryers through a process of research and development. The main differences in the Compact Engineering emitter to the Impact TAPS units are

- the lamps,
- the reflectors,
- the quartz plate and
- the use of air on the sheet surface.

Compact Engineering manufactures lamps that are designed and made specifically to heat paper and board. The lamps run at a lower temperature and so a longer wavelength to ordinary infrared lamps, resulting in a near doubling of heat transfer efficiency.

Compact use gold-plated reflector blades to direct the primary infrared towards the sheet and any infrared that is reflected by the coating is re-reflected until absorption takes place. The reflector design also allows for special ventilation facilities to deliver cooling air to both the reflector elements and the lamps. *(Fig. 2)*

Compact uses a hydroxyl-free quartz plate between the lamps and the coated sheet for protection. This means that the plate is practically invisible to the wavelengths of infrared that are generated by the lamps. This results in the plate absorbing very little infrared, which is useful from an energy efficiency point of view and also means that the plate does not get hot and pose a fire risk. In fact, Compact's emitters cool to hand-touchable from full power in a matter of seconds. The quartz plates also have special ventilation facilities that allow the cooling air to scour the boundary layer and provide the means of mass transfer needed for drying to take place.

2.4 Results

The emitters were changed on June 7, 2013 in the infrared dryers following coater number one and coater number two. The changeover of just the emitters in both infrared frames took in the region of four hours.

To compare the performance of the existing dryers and the replacement emitters from Compact, data was collected before the changeover on the June 6, 2013 and after the changeover on the June 8, 2013.

The visual difference can clearly be seen in Fig. 2, which shows the coating section of PM3. It is obvious that Compact Engineering's emitters waste less energy in the visible spectrum of light, having a significant higher ratio of invisible infrared light. (Fig. 1)

2.4.1 Evaluation method

A useful method to compare the performance of the different dryers is to measure the change in moisture content of the coating and the sheet between two different power settings. This allows the mass of water removed from the sheet and coating to be calculated and the power consumption can be read from the meters on the power control cabinets. The results can then be expressed in terms of kilograms of water removed per kilowatt consumed or kg/kW.

To provide the data, before the changeover the infrared dryers were run at 10 % and 80 % power, and the difference in moisture removed from the coating and power consumed was noted.

Following the changeover, the trials we run at 20 % and 80 %, and the change in power and moisture in the coating and the sheet noted.

The results of the measurements can be seen in *Tabs. 1* and *2* as well as *Figs. 3* and *4*.

	Coater	Low Power	Water Removed	High Power	Water Removed	Power Difference	Change in Water Removal	**Average Water Removal Rate**
		[kW/m]	[kg/m/hr]	[kW/m]	[kg/m/hr]	[kW/m]	[kg/m/hr]	[kg/kW]
Before	CS#1	9.66	208.93	61.87	209.33	52.21	0.40	0.0077
After	CS#1	28.12	185.77	120.58	196.55	92.46	10.78	0.1166
							Improvement	1,514 %
Before	CS#2	9.66	217.50	61.87	218.31	52.21	0.81	0.0155
After	CS#2	28.12	188.20	120.58	203.86	92.46	15.66	0.1694
							Improvement	1,093 %

Tab. 1: Water removal at different power settings before the rebuild, for calculating the effective removal rate, and the over 15-fold and 11-fold removal of water per kW installed power respectively

	Sheet Moisture before coating	Sheet moisture after drying	**Change in Sheet Moisture**	**Effective evaporation rate**
	[%]	[%]	[kg/m/hr]	[kg/kW]
Before rebuilt	5.3	5.4	+7.39	-6.18
After rebuilt	5.5	5.0	-65.04	0.34

Tab. 2: The effective evaporation rate was negative before the rebuild, meaning migration of binder and fines into the substrate; after the rebuild the effective evaporation rate turned positive, meaning migration into the substrate is prevented

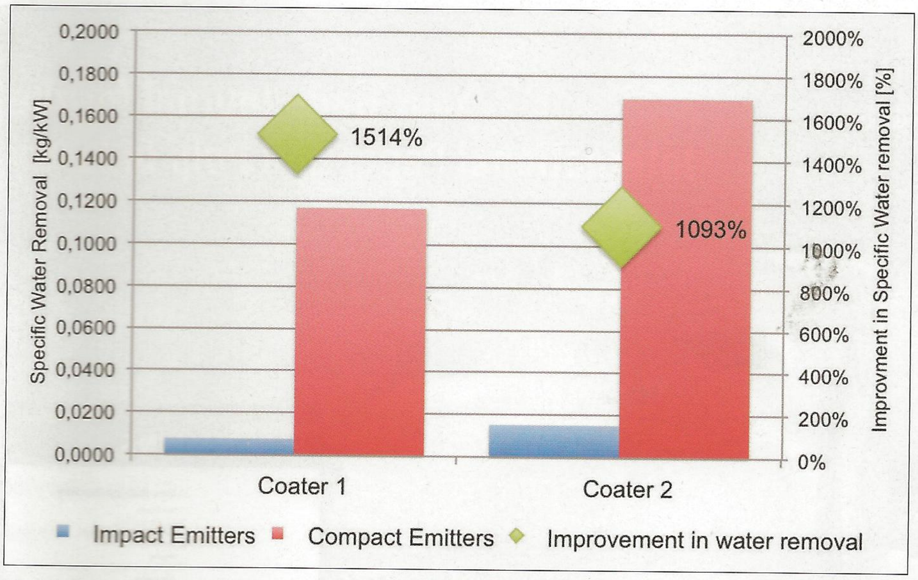

Fig. 3: Improvement in Specific Water removal [kg/kW]; compacts emitters respectively evaporate 15 and 11 times as much water as the previous emitters

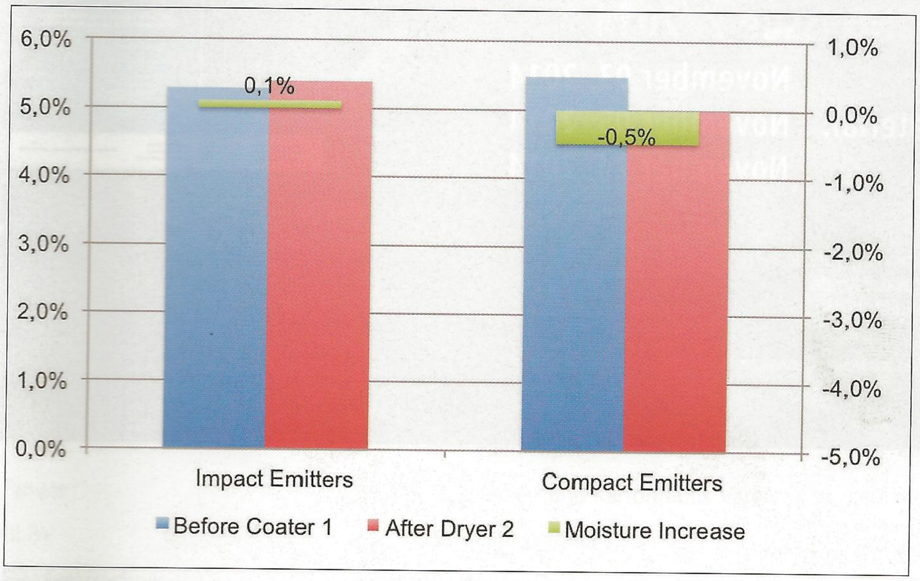

Fig. 4: Change in moisture content of the full sheet before Coater 1 and after Hot Air Dryers 2 before rebuild (impact emitters) and after (compact emitters)

2.4.2 Discussion of results

From the analysis of the data collected, it can be seen that the change from the existing modules in the Impact frames to the Compact Engineering IRE's has resulted in more energy efficient moisture removal from the coating by the infrared dryers.

Ignoring the moisture removed from the base sheet and looking only at the moisture removed from the coating, it can be seen that the Compact emitters appear to remove 15 times the mass of water per kilowatt than the Impact emitters on coater #1 and 11 times the mass of water per kilowatt on coater #2.

The reason for this lack of performance in the existing emitters is due to insufficient energy being transferred from the Impact emitters to the sheet to have any influence on the drying. This is due to the peak wavelength of the infrared at 1.17 µm emitted by the lamps used in the existing infrared dryers being too short, therefore it is transmitted through the sheet with only a small proportion of the total output being absorbed by the sheet.

Due to the design of the Compact lamps, the Compact emitters are able to transfer more of the total energy to the sheet and start the evaporation process. The nature of the way the sheet absorbs the infrared emitted by the Compact dryers means that a positive vapor pressure is created in the sheet structure and this pressure serves to push the water from the coating to atmosphere.

Further, the energy absorbed by the sheet is still resident in the sheet as the sheet enters the hot air dryers and this reduces the amount of work the hot air dryers are required to perform. This reduction in workload, due to the improved performance of the infrared dryers allows the energy consumed by the hot air dryers to undertake more drying. It is probable that the residual energy is resulting in the reduction of moisture in the base sheet.

The air impingement in the Compact Engineering modules also starts the evaporation before the sheet enters the hot air dryers and this assists the hot air dryers in their operation, allowing the hot air to remove more water from the sheet and the coating which will allow a production increase in the future.

The extreme short time for installing the emitters – less than four hours downtime – delivers a payback period measured rather in weeks than months – but even the total exchange for a completely new system would have paid back in much less than a year.

3. Outlook

With the potential for future production increases where each 1 % reduction in total moisture represents a 3 %+ production increase, the desired increase in production speed can be achieved. The desired pre-coat weight increase appears realistic even with increased machine speed, guaranteeing thus fiber savings in addition to the energy savings. Also, as on the other coaters, existing infrastructure can be used as well, the same short pay back period can be achieved.

4. Summary

Despite the high cost of electric energy vs. hot air dryers or gas fired infrared dryers, the selection of the ideal emitters with optimum wavelength guarantees a significant reduction in energy cost, as Ningbo Zhonghua Paper could see on their recent rebuild of the pre-coating stations on their PM3 manufacturing coated board. This paper shows that not the apparently cheapest energy delivers the lowest production cost per ton of paper, but in this specific case the apparently most expensive energy.

The main profit of the Compact Engineering's technology is the possibility reducing raw material cost and increasing significantly the production of the paper machine, with very little capital expenditure for the coaters, and extremely fast payback, which is measured in weeks and not years.