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Pocket Ventilation System In Dryer Section Of Paper Machine: A Review

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ABSTRACT: In paper industry, dryer section of paper machine consumes large amount of energy. It also leads in terms of capital investment as compared with other sections and most of the paper properties are influenced by dryer section, so any improvement in dryer section of paper machine can significantly reduce cost as well as improve paper quality. This paper deals with study of the pocket ventilation in the dryer section of the paper machine. Also it shows the various factors which influence the paper drying process. In the conventional paper machine, the reason for the uneven drying of paper was the uneven pocket air humidity distribution along the cross direction of paper web. This problem can be overcome by improving the pocket ventilation system in the dryer section of the paper machine. This improvement in the pocket ventilation would increase the drying rate of paper web which ultimately reduce the operating cost and energy consumption. Improved pocket ventilation also helps to maintain the uniform humidity profile.

Keywords: Paper machine; Pocket ventilation; Dryer pocket; Paper drying; Humidity profile.

1 INTRODUCTION

A paper machine consists of three sections. These three sections are forming/wire section, press section and drying section. In forming section, sheet is formed by suspension of pulp slurry evenly across forming fiber. The dewatering takes place mainly due to gravitational force. The process is carried out till the appropriate dryness is achieved. In the forming section nearly 20% of water content is removed from the slurry [2]. As the water is removed, fibers adhere to one another and paper web is formed. This newly formed paper web is passed to press section where it is mechanically compressed between rollers in one or more press nip.

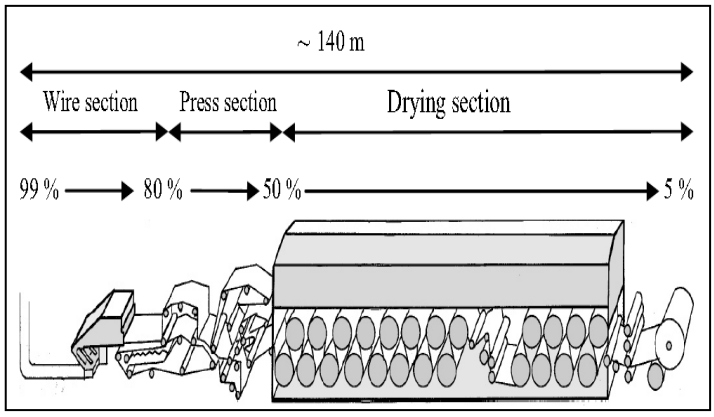

Figure 1: *Systematic layout of Paper Machine with different section.*

When the web reaches in the dryer section the dry content is in the order of 40 – 50% which is shown in above figure [2]. In dryer section, the remaining water is removed by vaporization. The main purpose of the drying process in paper manufacturing is to remove the water content in the paper web and to give the sufficient amount of heat to individual dryer cylinder to maintain the desired moisture level in the wet paper web. The dryer section consists of series of internally steam heated cast-iron rotating cylinders. Heat is transferred to the wet web from the heated cylinder as the web passes on the outer surface of the cylinder. The steam gets condense inside the dryer cylinder. If this condensate is not removed then it would increase the weight of roller thereby decreasing the speed of roller and hence increasing the energy consumption. Again this condensate would form a thin layer on the inner surface of cylinder and it can acts as barrier to heat transfer. Hence condensate is removed from the cylinder with the help of siphon or similar arrangement. After the dryer section 5% to 6% moisture content is present in the paper web [1]. The dryer section of paper machine has nearly 1/3rd part of investment and operating cost and it is responsible for approximately 2/3rd of total energy consumption [3], [8]. Usually dryer section can be directly related to the paper machine energy consumption. Therefore for larger production of paper the energy consumption should be reduced so as to increase the efficiency of paper machine. This can be achieved by optimizing pocket ventilation system to reduce cost and improve paper quality. Pocket air ventilation, hood balance and dew point have significant influence on the paper machine efficiency [4]. Thus any improvement in pocket ventilation system can significantly minimize paper making operation cost [5]

2 DRYING PROCESS

The purpose of drying process is to remove the water content present in the wet paper web up to certain desired level by evaporation. The basic mechanism behind drying process is heat and mass transfer. The heat is transferred from hot steam inside dryer cylinder to the dryer cylinder and in turn to the paper web moving over outer surface of the cylinder. This heat energy is absorbed by wet paper web and the water vapours are released in the dryer pocket. Thus the mass is transferred from the paper web to the dryer pocket in the form of water vapours. The steam gets condense inside the dryer cylinder after loosing its heat energy. Liquid water content in the wet paper web changes its phase to vapour due to heat transfer from cylinder to paper web. The drying process is typically carried out by following methods – Contact drying (multi-cylinder and Yankee cylinder drying), Convective drying (nozzle and through air drying), Radiation drying (Electric and gas drying) [6]. The most commonly used drying arrangement in the paper industry is multi-cylinder drying which generally consists of series of 20-120 number of cylinders having diameter of 0.75-2 meter [3].Figure 2 shows the schematic representation of two-tier drying having the four phases of the

drying process for each dryer cylinder [3]. These phases are as following:

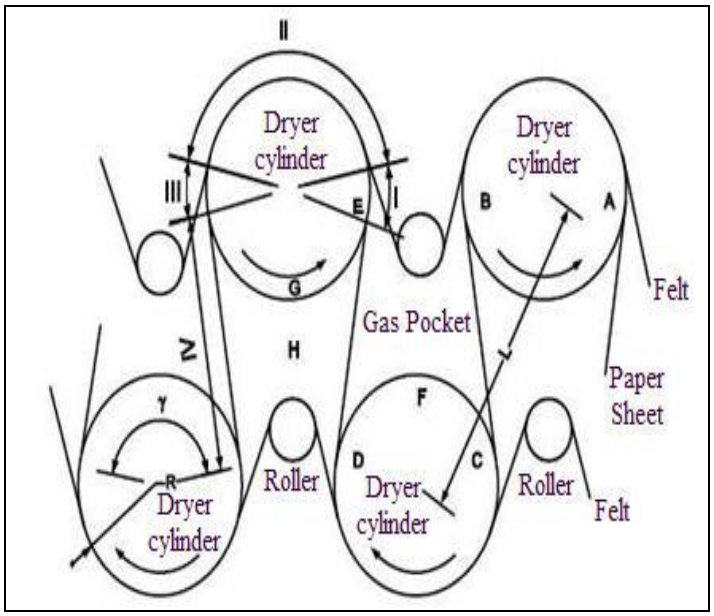

Figure 2: *Schematic of multi-cylinder paper drying system in a paper dryer section.*

- Phase I: In this phase the paper sheet comes in contact with the cylinder but it is not covered with the felt.
- Phase II: The paper sheet continues to be in contact with the dryer cylinder which is supported by the felt on the outer surface of cylinder.
- Phase III: This phase is also similar to the phase I which shows that the paper sheet is in contact with the dryer cylinder without the backing of the felt.
- Phase IV: In this phase the paper sheet is free from the contact of dryer cylinder and felt. It is open from both side and maximum amount of evaporation takes place in this region.

The phase I and III are combined with the phase II to form the contact region AB as shown in figure while phase IV which forms the free draw region BC. According to Shaun Reardon et al. (Sept. 2000) the 35% of drying occurs when the sheet is in contact with the heated dryer cylinder and 65% of the drying occurs in the free draw region [7]. This statistics shows that for efficient drying it is essential to make the sufficient and proper ventilation in the dryer pocket.

3 Dryer Pocket Ventilation

Dryer pocket is a space bounded between two adjacent cylinders in case of single-tier system or between three cylinders in case of two-tier system of dryer section as shown in figure 3[9].

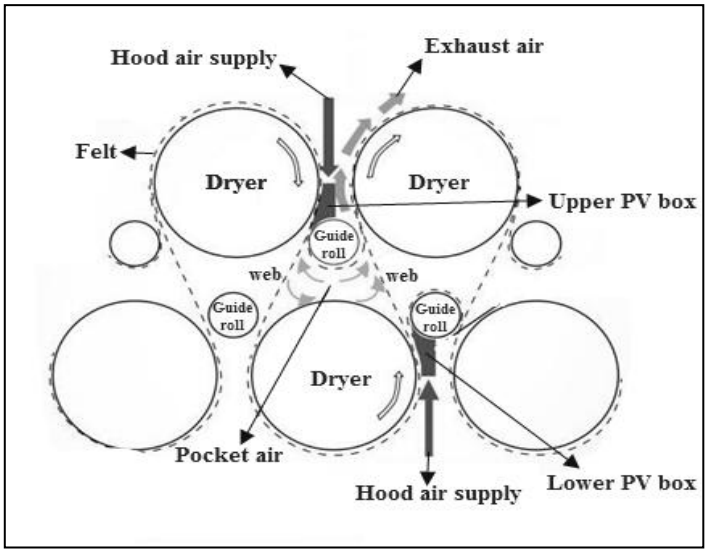

Figure 3: *Pocket ventilation for two tier dryer section.*

Each dryer pocket is separated by paper web and felt. In the dryer pocket higher evaporation of water content occur from the web. Paper web receives heat energy carried by hot steam in dryer cylinder. When wet web gets sufficient amount of heat energy water present in it gets evaporated. Paper web moves further in between the cylinders where web is open on both the sides. The amount of water content evaporated from the paper web in the air around the web increases as paper web moves continuously. For the efficient drying process it is necessary to increase the vapour removal rate in the dryer pocket. The increased cylinder surface temperature may not improve the drying process but the evaporated water from paper web must be removed by even supply of hot and dry air. As the air movement from the dryer pocket is very low or nearly equal to the stagnation. Therefore it should be ensured that the airflow is sufficient and evenly distributed through the dryer pocket. The pocket ventilation system must be able to perform the following functions [1]:

- Remove the water vapour from the dryer pocket of the dryer section.
- Improve the utilization of the energy in the dryer section of the paper machine.
- Maintain good working conditions in the machine room in terms of heat, humidity and noise.

Figure 4 illustrate the importance of the ventilation in the drying process [1]. Humidity profile of paper web for paper machine without pocket ventilation is non-uniform i.e. the moisture content at the middle of paper web across the deckle length is higher as compared to edges because of poor ventilation. Also the amount of moisture content is higher across the cross direction. Whereas the humidity profile for paper machine incorporated with pocket ventilation is almost uniform across the deckle length of paper machine with lower moisture content in the web as compare to the previous arrangement.

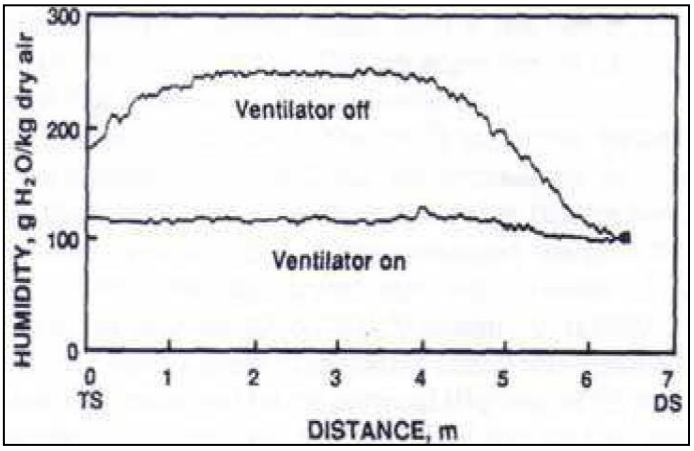

Figure 4: *Effect of pocket ventilation.*

Modern paper machine are equipped with pocket ventilation (PV) box in dryer section through which hot air at a temperature about 100-120^{0}c is passed into the pocket [7]. The paper passes over the hot cylinder due to heat transfer from dryer cylinder to paper web water content in paper web evaporates and this moisture gets accumulate in pocket resulting in formation of stagnant pockets of air. This stagnant pocket of air reduces the paper drying rate. Increasing the cylinder temperature is not sufficient to control humidity content in paper web. To overcome this problem a device known as Pocket Ventilation (PV) box i.e blow box is used in the dryer section of the paper machine. The function of PV box is to remove the moisture from dryer pocket and thereby preventing water vapour accumulating in the dryer pocket and also to prevent the moist atmospheric air being drawn in the pocket.

4 Case Study

This case study is reviewed from Bharat Patil et al. [9], [10]. The case study shows the various effects on the humidity and velocity of air in the dryer pocket without and with use of PV box. The different parameters used in this analysis are listed as follows.

Table 1:
Parameter details used in the modeling of paper drying process

Parameters	Value	Unit
Paper thickness (t)	0.1	mm
Machine speed (v)	500	m/min
Cylinder diameter (D)	1.5	m
Distance between two dryer axes (L)	1.8	m
Water evaporation from paper (m_{evp})	0.05	Kg/s
Width of slot for PV box (w)	5	mm
Temperature of dry air (T)	110	˚c
Length of PV box across machine direction (l)	3.6	m
Density of dry air (p)	1.22	Kg/m^3
Total number of cylinders (N)	43	

For the computational analysis of flow simulation, FLUENT software is used. Flow turbulence, energy and species transport models were used for defining the physics of the problem. Air and water vapour were considered as species. In the dryer pocket the evaporation rate was taken as 50gm/s. The following figure shows moisture content (Relative humidity) inside the dryer pocket.

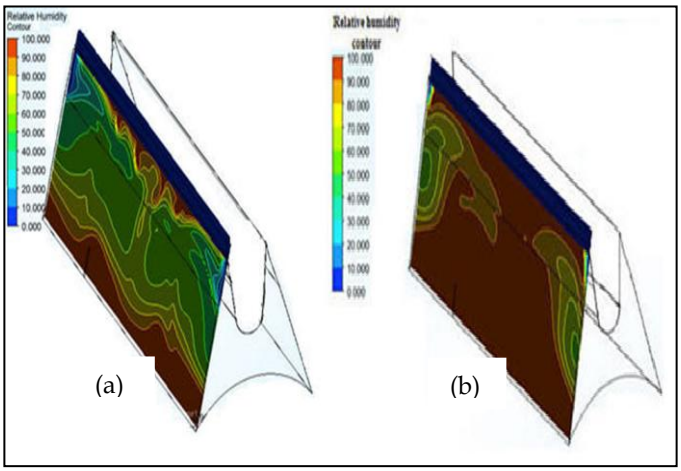

Figure 5: *Variation of humidity inside the Dryer Pocket before and after saturation.*

From figure 5(a), it can be observed that the relative humidity near the bottom of dryer pocket is comparatively high. This is mainly due to the continuous accumulation of moisture vapour evaporated from the paper web. Figure 5(b) shows the relative humidity after complete saturation of air inside the pocket. The edges of dryer pocket were open to the surrounding air due to this reason the humidity at the middle section of dryer pocket is comparatively more than the edges of dryer pocket across the deckle length of machine In the modeling, the contour is considered at 10 mm from paper surface as shown in below figure 6. From the figure it is seen that there is less amount of saturation in pocket as compared with the dryer pocket where pocket ventilation box was not used.

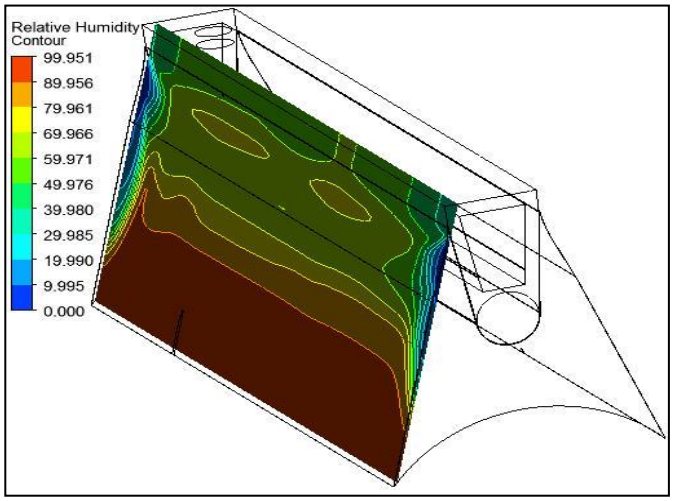

Figure 6: *Relative Humidity contour near paper surface.*

From above contour it is seen that the humidity is higher at the bottom of paper where it separates from felt. It is also seen that the upper portion of pocket has lower level of humidity as compared to the bottom portion of pocket.

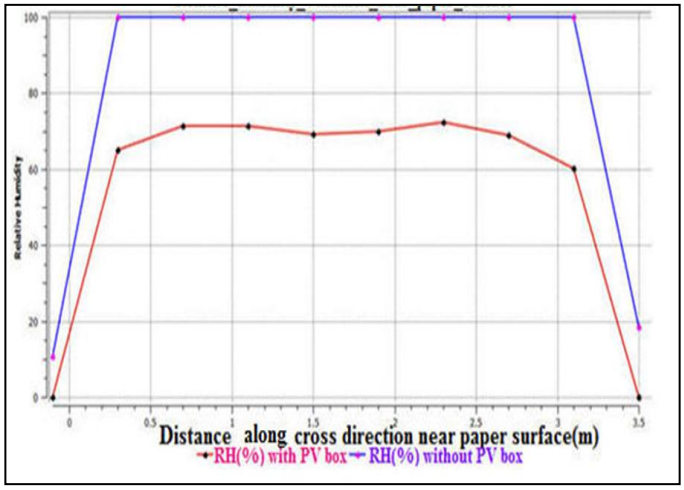

Figure 7: *Relative humidity variation near paper surface.*

From figure it can be noticed that there is large difference in the relative humidity of air in the dryer pocket. Ultimately the relative humidity was reduced by using the pocket ventilation box [9].

5 Conclusion

By providing proper pocket ventilation the vaporization of water content from paper web can be increased. The moist air trapped inside pocket is replaced by hot air. This hot air also breaks the vapour layer from paper web formed during water vaporization process. Pocket ventilation helps to maintain uniform humidity profile across the deckle length of paper. The conditions of the dryer section has important role in the paper quality. It seems that there is scope for the improvement of pocket ventilation system so that more uniform moisture profile can be obtained and it will also increase the paper drying process, which ultimately reduces energy consumption. From the case study, it is seen that the moisture saturation inside the pocket was reduced in the dryer pocket with the incorporation of pocket ventilation box. But still the humidity is higher in the region near the separation of paper from the felt. Therefore there is scope for improvement of the pocket ventilation box due to which the higher humidity can be controlled which indirectly results on the drying rate.

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References

[1] Ajit K Ghosh, “Fundamentals of Paper Drying – Theory and Application from Industrial Perspective, Evaporation, Condensation and Heat transfer”, Dr. Amimul Ahsan (Ed.), (2011) p 535-582.

[2] Ola Slatteke, “Modeling and Control of the Paper Machine Drying Section”, Department of Automatic Control, Lund University, January 2006, p 15-17.

[3] T. Lu, S.Q. Shen, “Numerical and experimental investigation of paper drying: Heat and mass transfer with phase change in porous media”, Applied Thermal Engineering 27 (2007), p 1248-1258.

[4] Naveen Bhutani, Carl-Fredrik Lindberg, Kevin Starr, Robert Horton, “Energy assessment of paper machine”, Energy Procedia 14 (2012), p 955-963.

[5] Jianyao Mou, G. Randall Straley, Xiaodong Wang, “Study of the spontaneous air flow through a moving porous medium”, Advances in Engineering Software 34 (2003), p 507-514.

[6] Gouni Paltakari, “Drying of paper”, Spring 2013, unpublished.

[7] Shaun A. Reardon, Michael R. Davis, P. E. Doe, “Computational modeling of paper drying machines”, TAPPI journal peer reviewed paper, September 2000.

[8] Jenny Ekvall, Tore hagglund, “Improved web break strategy using a new approach for steam pressure control in paper machines”, Control Engineerig Practice 16 (2008), p 1151-1160.

[9] Bharat Patil et al., “Study of Pocket Ventilation System in Dryer Section of Paper Machine”, International Conference on Advances in Mechanical Engineering, May 29-31, 2013.

[10] Bharat Patil et al., “Analysis of Humidity inside pocket in dryer section of Paper Machine”,International Conference on Advances in Mechanical Engineering, May 29-31, 2013.