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THE OPTIMIZATION OF THE PAPER MACHINE DEWATERING PROCESS BY USING THE NEW POLYURETHANE SUCTION PRESS ROLL COVER

Dejan Brankovic[1], Boris Latinovic[2], Zdravko N.Milovanovic[3]

Summary: *This paper provides an analysis of the condition of real industrial system after the implementation of new technical and technological solution of the paper machine dewatering system in the production industry system SHP Celex a.d. Banja Luka. The new technical and technological solution is the use of new type of polyurethane cover of the paper machine suction press roll. Compared to the previously used rubber coat, the dewatering performance is significantly positively changing. The measure of change of the condition of system is the increase of dryness of paper which unambiguously determines a lower specific energy consumption per ton of paper produced. Another important value is the increase of lifetime of new coat since the new type of material bears much higher workloads without compromising the performance. From the aspect of maintenance, the new technical and technological solution enables an increase in the interval between two consecutive cycles of grinding of suction press roll cover. Since those are the planned annual cycles of grinding and significant costs of grinding of the coat, the significant economic effects have been achieved within the maintenance plan. The end result is a significant economic benefit of the business production system.*
Key words: energy saving, production efficiency, maintenance costs, water evaporation

1. INTRODUCTION

In modern times the operation and existence of industrial systems depends on the continuous process of upgrading and improving of the working performances of parts of the system. The final result of processes of upgrading and improving of the performances should be the fulfilment of the expectations in terms of increasing the level of production system efficiency and thereby achieving positive business results.

Production, as a basic element of profit making, is an activity that has to be acted on positively. The conditions for the smooth functioning of production have to be created as well as the conditions for its growth. The growth of production provides the creation of positive economic developments enabling the development of business systems as well as of the society as a whole. Maintenance, unscheduled downtime, and energy costs are three of the highest budget item for any facility [1]. One of the ways of active work on the production is the investment activity. The specific results of investment activities are represented through effectiveness and reliability of the production process, i.e. business

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[1] Mr.sc. Dejan Brankovic, SHP Celex Banja Luka, dejan.brankovic@sfpgroup.eu
[2] Mr.sc. Boris Latinovic, SHP Celex Banja Luka, boris.latinovic@shpgroup.eu
[3] PhD Zdravko N.Milovanovic, Faculty of Mechaical Engineering Banja Luka, zdravko.milovanovic@unibl.rs

operations of the business system. The correct evaluation of reliability for the system or components is very important for high quality and security [2].

This paper presents the analysis of the impact of implementation of new technical and technological solution on the production process results of the real industrial system SHP Celex, Banja Luka. In particular, this paper is concerned with the process of optimization of paper machines dewatering system in the cycle of production of paper.

2. THE OPTIMIZATION OF THE PAPER MACHINE DEWATERING PROCESS

The process of dewatering of paper on the paper machine is a complex technological cycle which includes several key and interconnected input elements:

- system of headbox and handing over of the flow of paper stock to the sieve system (primary dewatering process);
- suction press roll system (vacuum system generated by operation of vacuum system - two parallel connected turbo blowers that generate a constant level of vacuum and a constant air flow);
- blind hole press roll system (pressure and vacuum generation based on passing of felt over the blind holes).

After the dewatering process the paper passes through the Yankee dryer where the drying process of paper stock begins.

2.1 ANALYSIS OF THE WORK OF SUCTION PRESS ROLL WITH RUBBER COVER

When analyzing the dewatering process, suction press roll system is one of the main elements significantly affecting the technological parameters such as dryness of the produced paper, the percentage of moisture, moisture profile and specific energy consumption (energy per tonne of heavy oil consumption - GJ/t). Suction press roll is composed of two functional parts: suction chamber (where the vacuum from the vacuum system is generated) and shell (cylindrical roller which rotates under its own power) which through rubber coat and felt with paper stock is in contact with dryer.

Fig. 1 Suction press roll

Fig. 2 Suction press roll and dryer

The quality of rubber cover has a significant impact on the technological conditions of production. Since the rubber cover wears out over time, the conditions of technological production impose the need of grinding the rubber cover every 6 months or putting a new rubber cover after three full cycles of grinding. This is the main planned repair/service that is implemented as part of the activities and costs of maintenance service. By constant monitoring and analysis of work and behaviour of rubber cover, certain problems are identified which over a long period of time cause significant maintenance costs. The most important problems related to the rubber cover are the following:

- sensitivity to mechanical damage and chemical effects;
- it requires the work with a smaller line pressures because of softness compared to other types of cover and therefore with wider nip (shown in Figures 3 and 4);
- relatively short lifetime compared to the price of the new rubber cover.

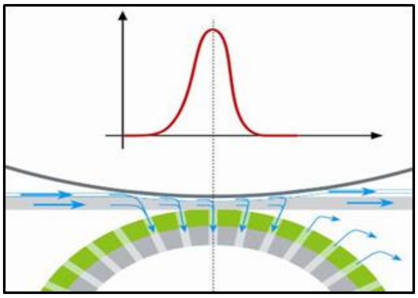

Fig. 3 Dynamic nip of polyurethane cover

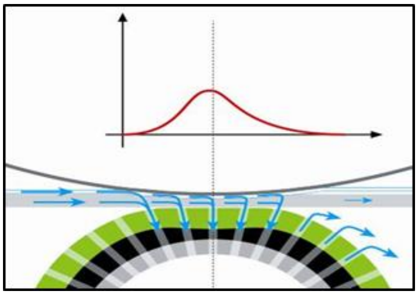

Fig. 4 Dynamic nip of rubber cover

All the disadvantages made us thinking about the possibility of using an alternative that could with its characteristics improve the operational and technological conditions. The process of draining and handing over of the paper stock is shown in Figure 5.

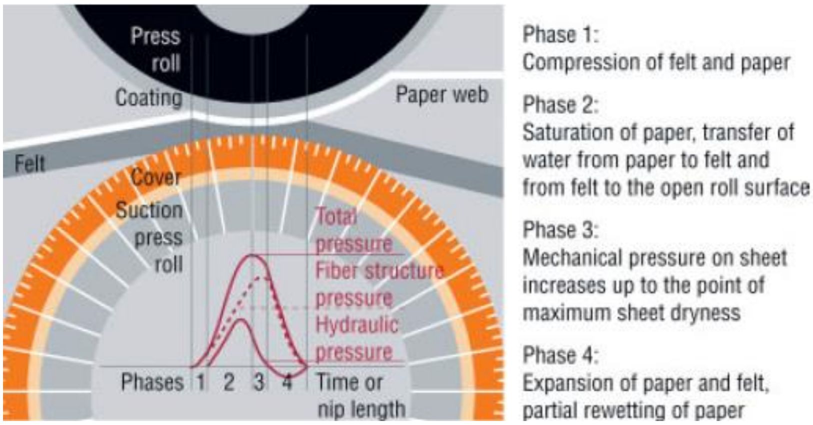

Fig. 5 *Process in the nip [3]*

The main aim is to act on reducing of percentage of paper stock moisture by using a new solution. In this sense, the next step was the analysis of the behaviour of suction press operation with the new cover made of polyurethane. The experiences of other paper manufacturers were also collected, whose assessments were from extremely positive to negligible improvement. The main characteristic of working with polyurethane cover is the ability to use much higher line pressure resulting in better dewatering process.

Taking into account the large investments (the difference in price of rubber cover and polyurethane cover is almost 1:2 in favour of polyurethane) and the sensitivity to technological process and the characteristics of each individual paper machine, the task of change of the cover material showed to be extremely complex.

2.1.1 ASSESSMENT OF BENEFITS WHEN USING NEW POLYURETHANE COVER

The economic benefits that can be expected in case of using the suction press roll with polyurethane cover are primarily connected with saving of energy necessary for drying of paper and saving of maintenance costs relating to the cost of grinding of suction press roll.

Starting base for predicting energy saving for drying are purely physical - higher drynes after presses enables lower thermal energy consumption for drying. Only evaporation of water has been taken into analysys.

Energy necessery for water evaporation can be calculated [4], [5] as:

$$Q_e = \dot{W}_e \cdot \left(h_{dp} - h_w\right) \tag{1}$$

$$Q_e = \dot{W}_e \cdot \left(r_0 + c_{dp} \cdot t_2 - c_w \cdot t_1\right) \tag{2}$$

where is:

$\dot{Q}_e$ - energy exchanged for evaporating water from the web during drying from inlet dryness x_{in} to outlet dryness x_{out};

$\dot{W}_e$ - evaporated water;

h_{dp} - specific enthalpy of superheated steam at outlet temperature;

h_w - specific enthalpy of water at inlet temperature;

r_0 - enthalpy of evaporation;

c_{dp} - specific heat capacity of steam;

c_w - specific heat capacity of water;

t_1 - temperature after presses (inlet temperature);

t_2 - outlet temperature (at outlet drynes).

If dry matter is considered as constant in process than evaporated water can be defined as:

$$\dot{W}_e = \dot{m}_{dm} \cdot \frac{1 - x_{1in}}{x_{1in}} \tag{3}$$

while evaporated water after replacing suction press roll rubber cover and installation of PU cover can be defined as:

$$\dot{W}_{e+0.01} = \dot{m}_{dm} \cdot \frac{1 - x_{2in}}{x_{2in}} \tag{4}$$

where is:

$\dot{W}_e$ - evaporated water (before cover replacement, with x_{1in} dry content after presses);

$\dot{W}_{e+0.01}$ - evaporated water (after cover replacement, with x_{2in} dry content after presses);

x_{1in} - dry content after presses before cover replacement (rubber cover)

x_{2in} - dry content after presses after cover replacement (PU cover)

$\dot{m}_{dm}$ - dry matter

Relation between energy used for water evaporation before and after cover replacement can be expressed as:

$$\dot{Q}_{e+0.01} = \dot{Q}_e \cdot \frac{x_{1in} \cdot (1 - x_{2in})}{x_{2in} \cdot (1 - x_{1in})} \quad (5)$$

where is:

$\dot{Q}_e$ - energy exchanged for evaporating water from the web during drying (before cover replacement, with x_{1in} dry content after presses);

$\dot{Q}_{e+0,01}$ - energy exchanged for evaporating water from web during drying (after cover replacement, with x_{2in} dry content after presses);

Measured dry content after presses on standard rubber cover had values around 0.45 (or 45%). Guaranteed increase in dry content after installation of PU cover was 0.01. For mentioned values, relation between energy used for water evaporation before and after cover replacement becomes approximately:

$$\dot{Q}_{e+0.01} = \dot{Q}_e \cdot 0{,}96 \quad (6)$$

Calculation shows that energy savings can be estimated to 4%.

Energy saving:

- estimated/guaranteed increasing of the dryness after press rolls for 1,0%;
- estimated decreasing of the specific energy consuption about 4%;
- monthly specific consumption 30days x 20t = 600t heavy oil/month;
- monthly saving 4% of 600t = 24t/month;
- average heavy oil price 482€/t 24t/month = 11.568€/month;
- Yearly saving of energy: 138.816 €/year.

Maintenance costs savig Energy saving:

- estimated/guaranteed increasing of the dryness after press rolls for 1,0%;
- estimated decreasing of the specific energy consuption about 4%;
- increasing of intervals between two grindigs – less maintenance costs;
- price for the old cover = about 34.000€;
- price of the new PU cover = about 55.000€;
- number of grindings of the old cover: 2 x per year; about 7.500€;
- number of grindings of the new cover: 1 x per year;
- lifetime of the old cover: 3 years;
- lifetime of the new PU cover: 9 years;
- Yearly saving of grindings: 7.500€;
- saving for 9 years for 2 rubberings: 2x34.000€= 68.000€; per year 7.555€;
- total maintenance costs saving: about 15.055€/year.

Based on previous analyses, the total estimated costs saving (TECS) is:

TECS=138.816€+15.055€=153.871€/year.

2.2 ANALYSIS OF THE WORK OF SUCTION PRESS ROLL WITH POLYURETHANE COVER

In order to analyze the work of the suction press roll with a new polyurethane cover we will compare the work of the same time cycle of rubber cover (January 2014) with the operation of polyurethane cover (January 2015).

Table 1 *Specific steam consumption for the period January 2014 - January 2015*

Day	January 2014				January 2015			
	Paper production(t)	Heavy oil(t)	Steam (GJ)	PM (GJ/t)	Paper production(t)	Heavy oil(t)	Steam (GJ)	PM (GJ/t)
17	92,28	16,89	685,73	5,85	131,17	21,08	853,74	5,18
18	126,49	21,06	855,04	5,39	116,06	20,59	833,90	5,65
19	90,09	16,07	652,44	5,62	118,46	21,49	870,35	5,53
20	23,06	7,58	307,75	9,30	122,03	21,41	867,11	5,41
21	111,68	19,67	798,60	5,69	107,40	20,24	819,72	5,80
22	79,08	16,29	661,37	6,37	112,51	19,79	801,50	5,54
23	113,97	18,74	760,84	5,49	123,07	21,44	868,32	5,44
24	126,05	21,17	859,50	5,56	109,28	19,55	791,78	5,48
25	130,22	22,67	920,40	5,64	119,21	20,16	816,48	5,19
26	114,47	21,53	874,12	5,98	112,64	19,95	807,98	5,37
27	83,63	18,46	749,48	6,45	116,65	21	850,50	5,33
28	104,62	21,2	860,72	5,83	91,14	18,51	749,66	6,03
29	76,42	15,79	641,07	6,07	105,99	19,80	801,90	5,56
30	102,06	19,47	790,48	5,77	121,09	21,19	858,20	5,47
31	104,70	19,5	791,70	5,92	121,93	22,17	897,89	5,38
	January average 2014			**6,06**	January average 2015			**5,49**

Based on the seventeen days of work in January 2015 the average specific steam consumption of the paper machine was 5,49GJ/t. Compared to the same period in January 2014, when the specific steam consumption of the paper machine was 6,06GJ/t, there is a clearly distinguishable reduction in energy consumption for drying of paper by 0,57GJ/t. Compared to the planned 1%, the obtained result indicates an increase in the degree of drying by 2.5% which represents a reduction of consumption of energy for drying by 11%. It should be noted that this was a shorter period of monitoring with normal operating conditions of the paper machine but that this was a winter period. It is reasonable to expect an even better final annual result since the periods without the need for additional heating (low outside temperature will be also included.

There is also a significant positive change in the uniformity of moisture profile, which significantly affects the quality characteristics of the final product. Figures 6 and 7 show the profile of moisture and grammage. By analyzing the graph of the profile of moisture with rubber cover and polyurethane cover, a positive change and uniformity is easily noticeable in case of work with polyurethane cover.

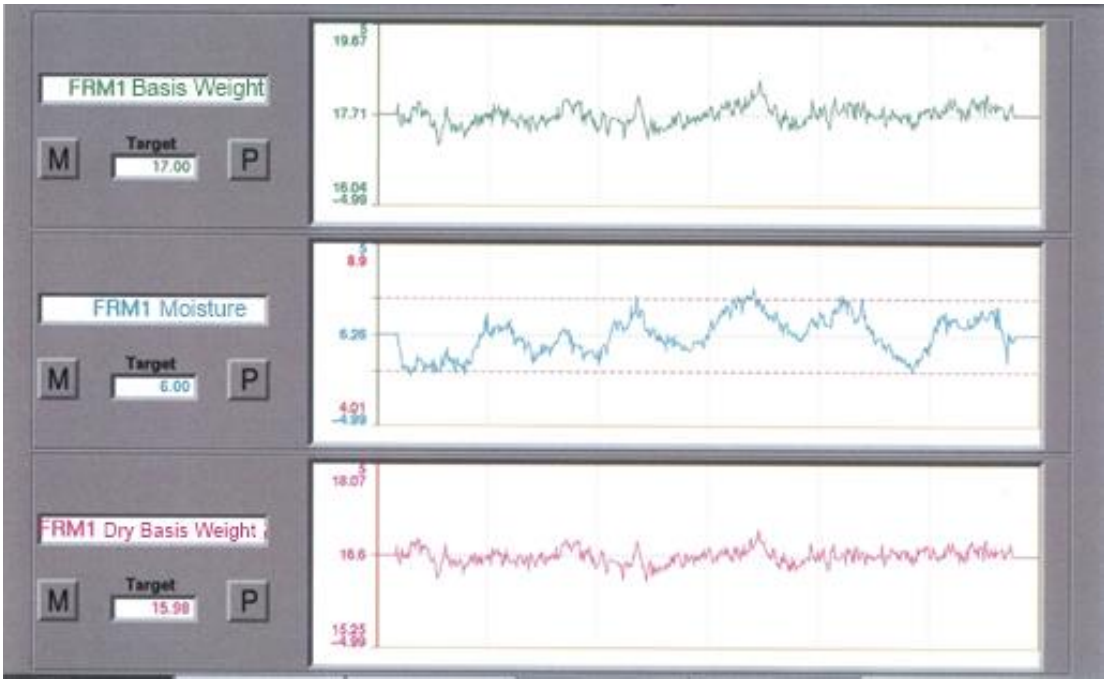

Fig. 6 Profile of moisture when working with rubber cover

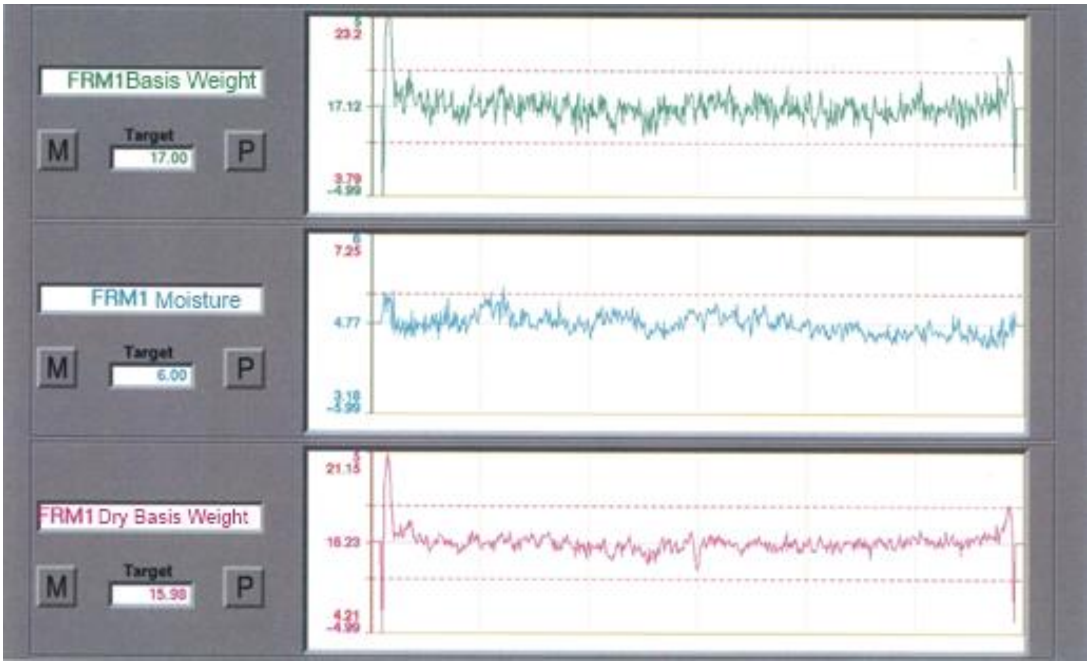

Fig. 7 Profile of moisture when working with polyurethane cover

3. CONCLUSION

A new technological solution (replacing of the rubber cover with polyurethane cover) achieved a number of positive technological effects resulting in significant economic benefits of the production system:

- a lower specific steam consumption per unit of produced paper was achieved (the result of reducing the percentage of moisture in the paper after passing of the paper stock through the system of suction press roll);
- a more balanced cross-section profile of moisture in the paper was achieved;
- an increase of the lifetime of felt is expected (based on already achieved three working cycles of 45 days of work);
- increase of the time between two successive grindings of the cover (based on control of the surface condition of polyurethane cover for two planned paper machine downtime).

These positive results confirm the best link between investment in new technology solutions and the impact on the effectiveness of manufacturing system. The progress of manufacturing industrial system and society as a whole can be expected only by developing of new technologies and technological systems.

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