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Intensification of Press Felt Dewatering for Tissue Machines

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Abstract
This article describes a method of dewatering press felts using a blow-through device. The essence of this method is pressing out free water contained in the felt with unheated air at a slight overpressure. The usefulness of this method for various types of felt used in tissue machines was tested. The results showed that the effectiveness of this process depends mainly on the proper selection of the pressure difference on both sides of the dewatering felt and of the blow-through time (dwell time). The increase in the dryness of felts dewatered by means of the air blow-through method is closely related to the structure and contamination of the felt. In the second part of the study, the felts were additionally dewatered using a suction chamber with a vacuum of 20 kPa. Unfortunately, the increase in the dryness of the felts by means of a vacuum was not very high, only up to 2.8%.

Key words: *fibrous materials, press felt dewatering, air blow-through, paper machine.*

Introduction

Press felts must be cleaned, dewatered, and lubricated to maintain the void volume and caliper, as well as to prevent wear. After intensive cleaning of the press felt by mechanical (low and high pressure showers) and chemical means, it should be optimally dewatered before entering the press section. The dewatering efficiency of the paper web in the press section of the paper machine mainly depends on the degree of dryness of the felt [1].

The water content of the felt influences the total dewatering performance of the press through the change in the hydraulic pressure. The higher the felt water content, the higher the hydraulic pressure [1].

The resulting dryness of the felt depends largely on the type of felt and drainage equipment used. Traditionally, water removal from the web in the press section tissue machine has been carried out with felts, which mainly remove water with the help of suction boxes (typical vacuum level 20 ÷ 40 kPa) – known as Uhle box dewatering. Current paper machines work at a speed much higher than that of air flowing through felt using a suction box. The typical operating speed is 10-30 m/s.

Many observations have been made on how much of a vacuum a felt needs during its life – and when. Practical experience shows that the total dewatering remains constant or even decreases when the vacuum level is increased to over 50 kPa. This means that a high vacuum has no positive influence on an old felt [2, 3].

The cross-directional movement of a fast moving felt versus airflow leads to a deflection of the air jet in the direction of the running felt and therefore causes a considerable reduction in the working surface of the suction box. In this way, the drainage efficiency of the felt decreases [4].

In the case of very fast paper machines, this can lead to a total cancellation of the open air flow surface and consequently hinder felt conditioning. The deflection of suction box air flow is a result of Bernouli's Principle and Darcy Law. This phenomenon occurs in every paper machine.

An alternative solution to the drainage of felt may be air blow-through equipment. The equipment works on the principle of air blow-through felt. In this case, airflow through the felt is similar to that in the suction box, with the only difference being that the blow-through occurs with a greater difference in pressure and air density.

Although felt suction slot-boxes [5] are still the most widely used felt water separators for press felt dewatering and cleaning processes, the new through-air techniques for press felt conditioning are gaining more of a foothold in the papermaking industry [6]. The conditioning of the press felt consists of cleaning the felt by means of high-pressure showers and further dewatering. The advantages of the blow-through are the possibility of increasing paper machine productivity (by increasing the speed), as well as savings in construction materials and space in the machine room. It seems possible and justified to use this type of equipment on fourdrinier machines and twin-wire machines in order to increase their dewatering efficiency. In order to conduct a study of the suitability of the air blow-through method for dewatering various types of press felts for tissue machines, an experimental stand was designed.

Experimental

Characteristics of the blow-through process of felt dewatering

The process of the blow-through dewatering of press felt consists in pressing out free water contained in the felt with unheated air at a slight overpressure. The air flows from the pressure chamber through the felt into a space where there is atmospheric pressure and presses out water from the felt. Only free water is eliminated from felt. The remaining water is in micro-pores and on the walls of inter-fibre ducts in the form of an absorbed layer. Prolonged blowing of air through the felt causes, among others, the evaporation of water, but such a process is not economical when unheated air is used. Thus, the blow-through dewatering process is terminated when the felt reaches theoretical dryness (s_t). Upon the further blowing of air through the felt, we are dealing with a drying process in which different phenomena take place. Blow-through dewatering consists in the mechanical elimination of free water from the felt: it is a process of filtration of water and air in a deformable porous medium. The process is characterised by varying the water (n_w) and air (n_p) modu-

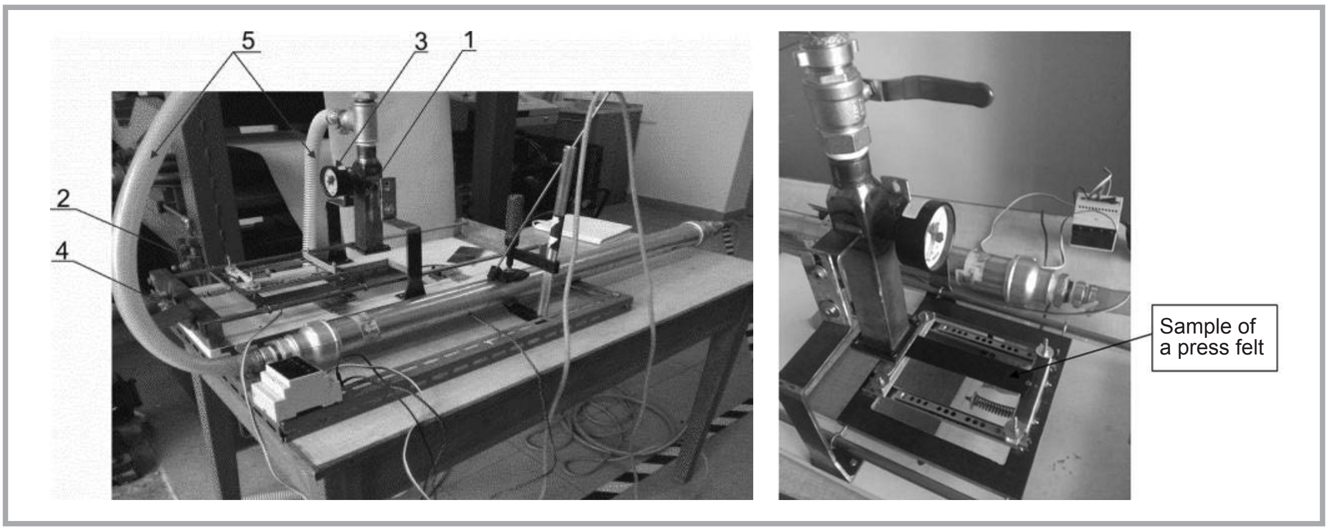

Figure 1. *Photo of the research stand with through-blowing device: 1 – slotted through-blowing header, 2 – trolley with press felt, 3 – manometers, 4 – driving system, 5 – pipeline.*

lus. During the dewatering of felt by air flow, the initial dryness increases to theoretical dryness (s_t), the (n_w) modulus decreases from 1 to 0, and the (n_p) modulus increases correspondingly, according to the relation:

$$n_w + n_p = 1 \qquad (1)$$

Where, n_w is the modulus for water and n_p the modulus for air.

The thickness of the felt decreases during this process as a result of deformation. Investigations have shown that within the range of parameters used ($s_i \geq 50\%$, s_t, $P_1 \leq 110$ kPa), the deformation of the felt is closely related to the outflow of water (s_i – initial dryness, s_f – final dryness, P_1 – air pressure in the blow chamber). The flow of air affects it much less. After the elimination of free water (after reaching the theoretical dryness s_t) the thickness of the felt becomes stabilised and further flow of air causes no significant changes in thickness up to the moment when the process of evaporation of bound water begins. The amount of water removed by the felt-through-drying box, with slot width (l), from the felt surface can be described as [7]:

$$|Q| = -k_w \frac{H_0 \cdot l}{b} + e \cdot V_c \cdot l \qquad (2)$$

The formula above contains the main design parameters of the felt-through-drying box:
- air pressure in the through-air chamber (H_0),
- width of the felt-through-drying box slot (l) and parameters describing the felt being dewatered,
- coefficient of water filtration through the felt (k_w),
- felt thickness (b),
- coefficient of felt porosity (e),
- felt deformation velocity (V_c).

Equation (2) contains a modified Darcy equation that provides the water velocity along the y axis perpendicular to the felt run and takes into account the deformation of the felt during the drainage process. In the case of the removal of free water with non-heated air, the pressure difference on the sides of the felt being dewatered has a decisive effect on dewatering. The effectiveness of the process will depend mainly on the suitable selection of the parameter above and of the blow-through time (dwell time). The dwell time is the amount of time during which the felt is positioned in the active area of the blow chamber slot. Experimental studies were aimed at determining the optimal values of these parameters.

Material and methods

To study air blown through the felt, an experimental stand was developed. The equipment used in this work is shown in ***Figure 1***. By means of the adjustable driving spring system, the speed of the felt could be regulated to provide different times for the through blow. A sample of felt 30 mm wide was placed on the trolley and driven by means of a spring system (***Figure 1***) at a constant speed of 5.0, 4.0 and 3.3 m/s. The speed of the felt was measured by means of a timer connected to motion sensors. The design and drive in the testing device allowed to obtain only such felt speeds.

The new and worn felts, removed from the paper machine after 30 days of operation, were tested. The air permeability index for old felts was 83%. A double-layer press fabric with one single-base fabric (felt number 1) (***Figure 2***) and a double-layer press fabric with double-base press fabric (felt number 2) (***Figure 3***) were tested. The basis weight of the felts was 1153 g/m^2 and 1270 g/m^2, respectively. All felts were 100% synthetic. Double-layer papermaking felt no.1 is of a double warp structure (***Figure 2***). In felt number 2 a "laminated" structure of double-base fabric is used to increase durability for high load positions and provide good compaction resistance. Conventional woven structures tend to compact during operation, which deteriorates paper quality. Both felts are used for the production of tissue paper. The press felts tested are composed of a base woven layer with nonwoven layers on either side, which are assembled by the needling process. Spinning technologies and weave design significantly affect fabric mechanical, thermal and surface properties [8-10]. The felt samples were tensioned before the measuring test by the spring system with a constant force of 3.5 kN/m. The slotted through-blowing header was set in such a way that the jet air hit the surface of the felt at a 90° angle. During the test, the bottom surface of the header touched the surface of the felt.

The research was divided into two parts. In the first part, the felts were dewatered only by an air blow-through device. In the second part, the felts were dewatered using the air blow-through device and a suction chamber. In both studies dif-

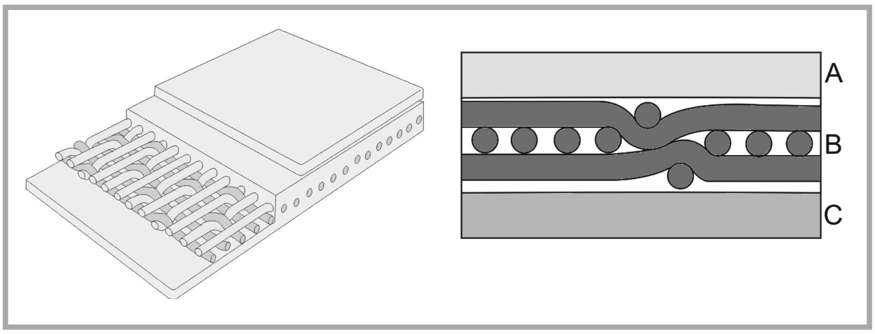

Figure 2. *Principal structure of double-layer press felt number 1. A – paper side fibre layer, B – base weave (double warp structure) C – roll side fibre layer.*

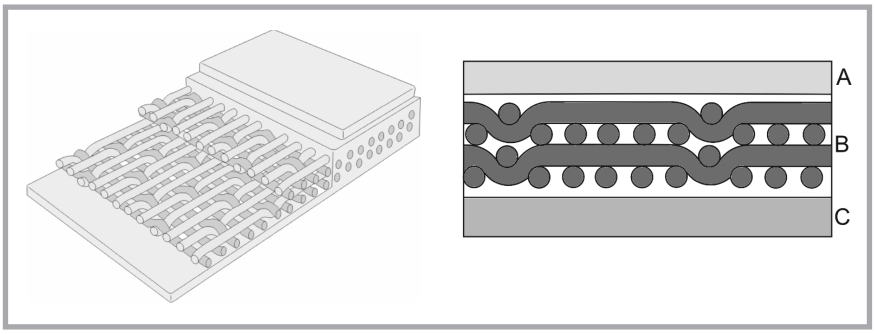

Figure 3. *Principal structure of double-layer press felt number 2. A – paper side fibre layer, B – first and second base weave, C – roll side fibre layer.*

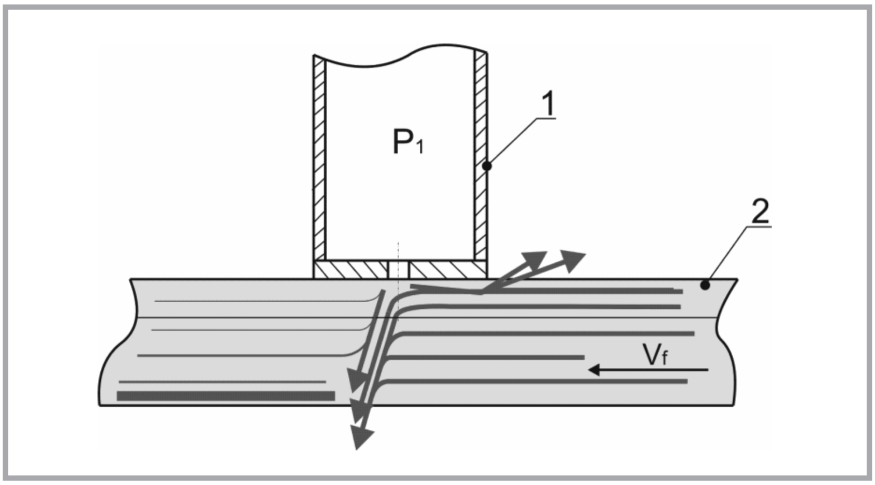

Figure 4. *Two-directional removal of water from felts. 1 – slotted through-blowing header, 2 – press felt.*

ferent flow rates of the air jet were used. The air jet flowed out from the nozzle of the equipment through a slot width of 1 mm, 2 mm and 3 mm. The temperature of air blow-through was 20 °C. The felts were dewatered at air pressure in the blow chamber from 10 to 110 kPa. The air pressure in the chamber was measured using a technical manometer with an accuracy class of 1.6 in the range of 0 ÷ 400 kPa. The vacuum level in the suction chamber was 20 kPa. The underpressure in the suction chamber was measured by means of a technical vacuometer with an accuracy class of 1.6 in the range of -50 ÷ 0 kPa. The moisture content of the felt was measured by the weight method. The press felt was tested at an initial moisture content of 50%.

Based on the measurements carried out, the following were calculated:

- the increase in the dryness of the felt after air blow-through – Δs_1, %
- the increase in the dryness of the felt after air blow-through and the suction box – Δs_2, %

Through- blowing and dewatering procedures

In the first part of the study, felt samples with an initial moisture content of 50% were installed in the device and dewatered by means of air flow. During the tests, the felt speed as well as the air pressure and slot width in the chamber were changed. Before and after through-blowing, the samples were weighed to determine their moisture content.

In the second part of the study, the samples were additionally dewatered using a suction box with a vacuum level of 20 kPa. In the first and second parts of the study, the air jet hit the surface of the felt from the side of contact with the paper. During suction chamber dewatering, the lower part of the felt (side roll) was in contact with the surface of the suction box.

The moisture content of the felt was determined from ***Equation (3)***:

$$W = \frac{m - m_s}{m} \cdot 100, \% \qquad (3)$$

Where, m is the sample weight before drying, g and m_s the sample weight after drying, g.

The weighed samples were put into the dryer and dried at a temperature of 103 ÷ 105 °C to a constant weight. The drying time was dependent on the moisture of the sample. The drying of samples was completed when the difference between successive weightings of the sample was less than 0.002 g.

The blow-through time was determined by the felt speed and the width of the slot in the nozzle. The dwell time of the felt in the open area of the nozzle is crucial because it directly impacts water and contaminant removal from the felt. On machines with higher production speeds (> 5.0 m/s), the blow-through time will be shorter than those used during the tests. In order to obtain the same increases in the dryness of felts, it will be necessary to apply higher air pressures or a higher temperature, respectively. The increase in the dryness of felts dewatered by means of blowing-through is closely related to the structure and contamination of the felt. During the blow-through, the water contained in the felt was removed in two directions (***Figure 4***). This confirms that there is a factor suppressing the flow of air and water through the felt structure. The side water flow was smaller when the felt was new and the air pressure in the chamber smaller, i.e its *air* flow *velocity* was lower.

When dewatering the old felt with high air pressure in the blowing-through chamber, a significant amount of water was removed in the lateral direction. This was caused by the deformation of the felt sample during the blow-through rather than by the deformation of the felt structure itself. In addition, a water film was created on the bottom of the felt, which proves the rapid reduction in kinetic energy of the air jet through the felt. Too little air flow at the bottom of the felt decreases the dewatering of the felt. In this case, there was a relatively large difference in pressure across the felt. The test results above formed the basis of the second part of tests carried out with a vacuum chamber.

Results and discussions

Press felts are in direct contact with the paper surface and strongly influence both the quality of the paper and the economy of the papermaking process. During its lifetime, the press felt runs through the press nip several million times, which causes a decrease in the thickness of the felt, as well as in its abrasion and contamination. Fillers, fibres or adhesives, for example, from recovered paper deposited in the press felt structure impede or even locally prevent water flow. These are important reasons why a press felt has to be replaced.

Average moisture results of the felts (average of five samples tested) that were obtained after part 1 of the tests are shown in ***Figures 5-8***.

Figures 5-8 show the influence of air pressure in the blow-through chamber (P_1) on the final moisture content of old and new felts (no. 1 and 2).

Measurements were carried out at three slot widths of the chamber, i.e 1, 2 and 3 mm, with an initial moisture content of the felts tested of 50%, at a velocity of 3.3, 4.0 and 5.0 m/s. In ***Figures 5-8***, the acceptable moisture of the felts is marked in the dark area (acceptable moisture of the felt before the nip in the press section).

Felt no. 1 was the most susceptible to dewatering by the air blow-through method. Initially, the amount of water

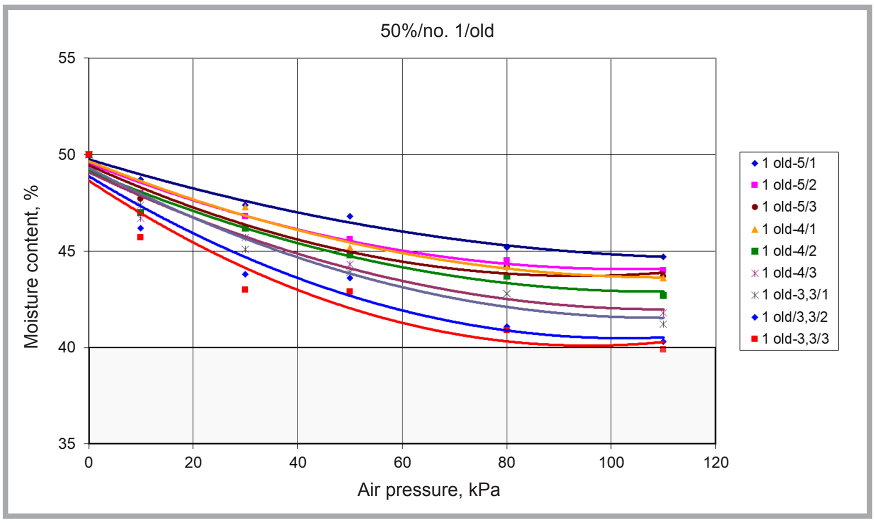

Figure 5. *Influence of air pressure in the blow-through chamber (P_1) on the final moisture content of felt no. 1 – old (after blow-through) for W_p = 50%, V_f = 5.0; 4.0; 3.3 m/s, l = 1, 2, 3 mm.*

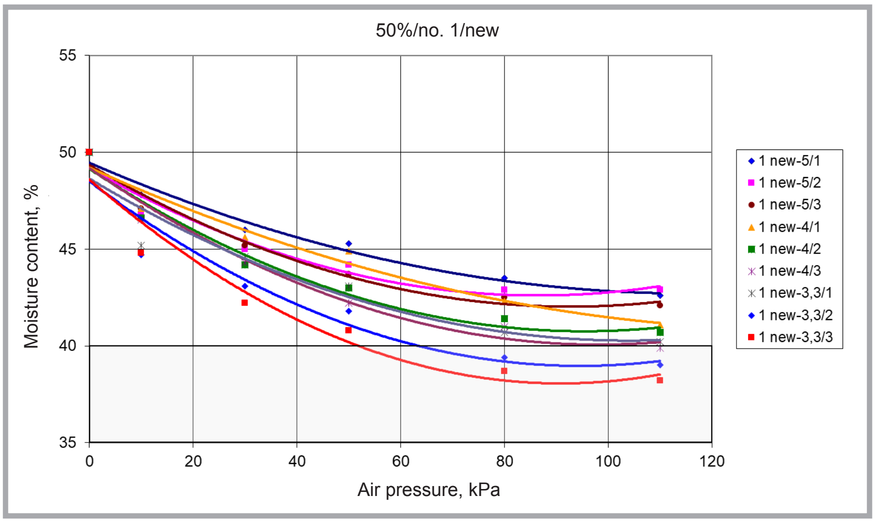

Figure 6. *Influence of air pressure in the blow-through chamber (P_1) on the final moisture content of felt no. 1 – new (after blow-through) for W_p = 50%, V_f = 5.0; 4.0; 3.3 m/s, l = 1, 2, 3 mm.*

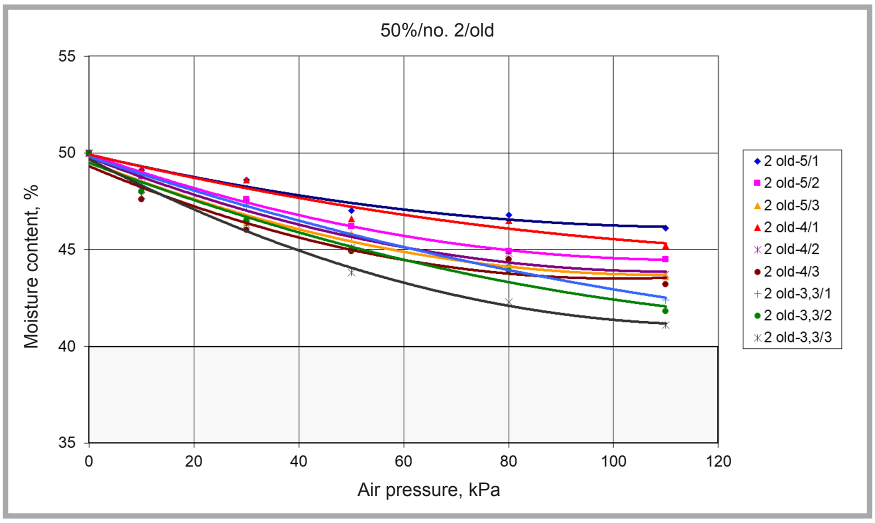

Figure 7. *Influence of air pressure in the blow-through chamber (P_1) on the final moisture content of felt no. 2 – old (after blow-through) for W_p = 50%, V_f = 5.0; 4.0; 3.3 m/s, l = 1, 2, 3 mm.*

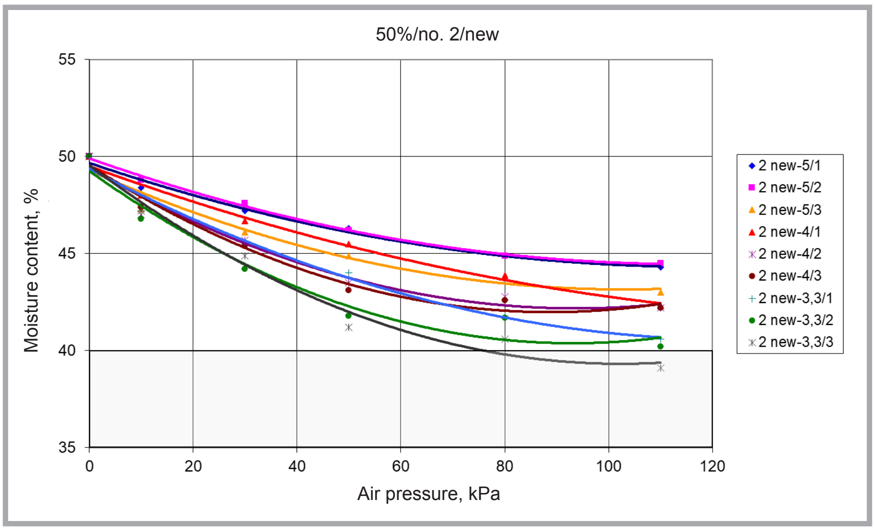

Figure 8. *Influence of air pressure in the blow-through chamber (P_1) on the final moisture content of felt no. 2 – new (after blow-through) for W_p = 50%, V_f = 5.0; 4.0; 3.3 m/s, l = 1, 2, 3 mm.*

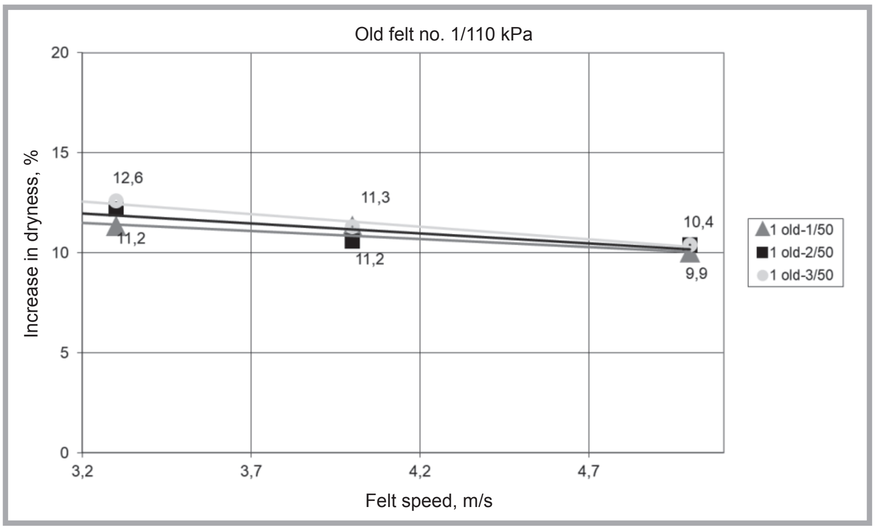

Figure 9. *Increase in dryness of old felt no. 1 for 110 kPa, W_p = 50%, V_f = 5.0; 4.0; 3.3 m/s, l = 1, 2, 3 mm.*

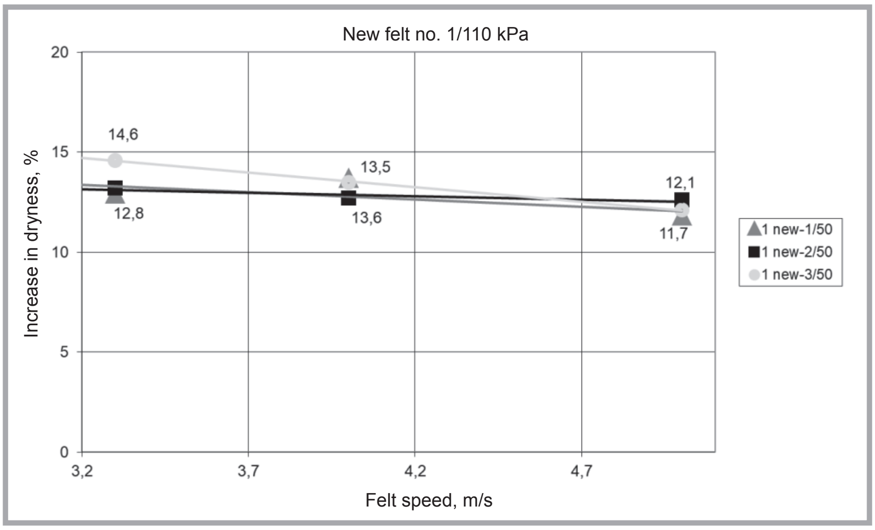

Figure 10. *Increase in dryness of new felt no. 1 for 110 kPa, W_p = 50%, V_f = 5.0; 4.0; 3.3 m/s, l = 1, 2, 3 mm.*

removed significantly increases with an increase in the dwell time and pressure in the chamber. The drainage efficiency of the felt drops significantly when the air pressure in the chamber is approximately 80 kPa. The dryness of felt number 1 was increased by air blow-through to 15% depending on the condition of the felt, the air pressure in the blow chamber, and the dwell time of the felt in the open area of the nozzle of the equipment (blow-through time) (***Figures 9*** and ***10***). For laminated felt, it was to approx. 9.8% (***Figures 11*** and ***12***), which is due to the occurrence of significant air flow resistance through felt structure no. 2.

Press fabric no. 2 is laminated and has a higher basis weight with an additional layer in the structure.

The difference in dryness between new and old felt after air blow-through was approx. 2.0%. The highest increase in dryness for felts no. 1 and 2 was obtained with air pressure in the chamber equal to 110 kPa, at a felt speed of 3.3 m/s and slot width of 3 mm. During the increase air pressure in the blow chamber, the dryness of the felt increased significantly. At the same time, the volume of air blow-through increased. From an economic point of view, the ratio of air consumption to drainage of the felt to achieve an increase in dryness Δs_1 is most important. The most economical is the drainage of felts with a width of the slot in the nozzle of 1 mm. In the case of a wide slot (3 mm), the felt is dewatered mainly in the initial part of the slot. In the final part of the slot, flowing air takes only single drops of water.

In the second part of the study, the felt was dewatered by two methods. In the beginning, the felt was dewatered by blow-through and then by means of the suction chamber. The speed of the felt during dewatering by means the blowing-through device and suction chamber was the same. The slot in the suction chamber was 15 mm. Both felts increased in dryness after dewatering using the suction chamber. Unfortunately, the increases in dryness of the felts were not very high, especially those contaminated. The felts dewatered by air-blowing through were later dewatered using a suction box. The dryness of new felts no. 1 and 2 increased to a maximum of 2.8 and 2.0%, respectively. The dryness of old felts was lower than for new felts by 0.3 ÷ 0.8%. The suction air flow produced by a vacuum of 20 kPa is on its own not capable of pulling the water out of the felt and into the suction box slot, which is the reason why with older felts very poor or even no suction box dewatering is obtained. It should also be borne in mind in this context that the air velocity over the suction box slot decreases with an increasing vacuum. Air is less dense when the vacuum is higher.

The pressure difference between the atmospheric pressure and the vacuum in the chamber box compresses the felt structure somewhat. This reduction in the volume of the felt pushes the water, to a certain extent, into the lower part of the felt as far as the roll side and from there into the chamber box slot, thus achieving chamber box dewatering. Therefore, ***Equation (2)*** is particularly useful for conditioning new felts of various designs that have not been over-compacted.

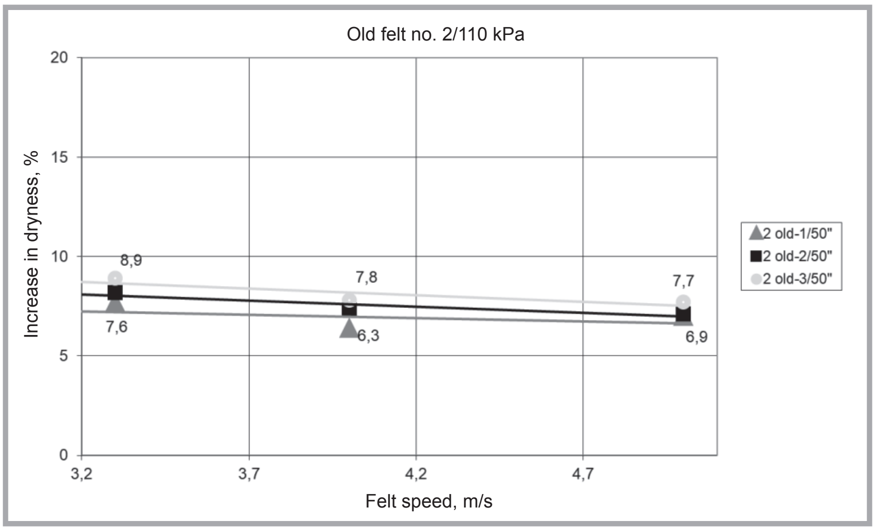

Figure 11. *Increase in dryness of old felt no. 2 for 110 kPa, W_p = 50%, V_f = 5.0; 4.0; 3.3 m/s, l = 1, 2, 3 mm.*

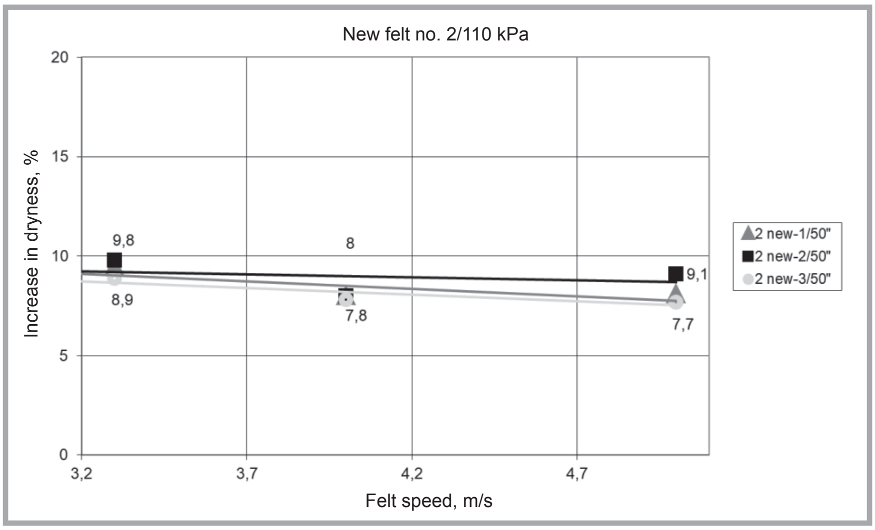

Figure 12. *Increase in dryness of new felt no. 2 for 110 kPa, W_p = 50%, V_f = 5.0; 4.0; 3.3 m/s, l = 1, 2, 3 mm.*

Conclusions

From measurements and observations it is possible to draw the following conclusions: The through blow method can be applied for dewatering wet felt, imparting to it high air permeability. It was more economical to use narrower slots in the nozzle and higher air pressures in the blow chamber than to use wide slots and lower air pressure in the equipment. The dynamic effect of the air jet issuing from the slotted box is advantageous for good penetration of the structure and for removing water particles from the smaller pores. The additional dewatering of old felts by the suction chamber did not significantly increase the dryness of the felts. Based on the results of the tests, it seems reasonable to assume that air blow-through equipment can be a good way of dewatering press felts. The main advantage of felt dewatering by the through – blow method is the great intensity of this process. To obtain the highest possible device efficiency, it seems purposeful to divide the area of the through-blow devices into several zones and gradually change the air parameters as the felt dryness increases. In addition, by increasing the air temperature and number of slots in the equipment, the drainage efficiency of the felt can be increased.

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