

IMPROVING SURFACE SIZING OPERATIONS FOR AN EDUCATIONAL PAPER MACHINE

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Abstract <p>The objectives for this thesis were to improve the starch application process for the educational paper machine to allow continuous application at a controlled rate. The work was done for University of Wisconsin Stevens-Points educational paper machine.</p> <p>When the work was started the size press was not in operating condition. There had been attempts to improve the original design by adding spray bars for starch application. With this design there had been major problems in keeping the starch hot and with the nozzles clogging</p> <p>Because the objective was to be able to have a better control for the amounts of starch applied, the basic pond size press did not feel like the best alternative. It was decided to build a starch application box over the press roll to achieve the objective. During the work the starch kitchen was also improved.</p> <p>After the work was finished there was a trial run to observe possible improvements. It turned out that continuous starch application was possible. The surface sized paper had better tensile strength and grammage increased compared to the base paper from the same run.</p> <p>If this design will be selected for active use in UWSP some future improvement should be made. The prototype application box was made out of polycarbonate and it should be replaced with stronger material as well as the box support bracket, which was made out of scrap metal. Some of the starch tubes still remained flexible tubes and those should also be replaced with hard piping.</p>		
Keywords Surface sizing, coating, paper machine, starch		
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Tiivistelmä <p>Opinnäytetyön tarkoituksena oli kehittää opetuspaperikoneen pintaliimauslaitteistoa siten, että mahdollistetaan tärkkelyksen jatkuva applikointi paperirainaan halutulla tasolla. Työ toteutettiin opetuspaperikoneeseen University of Wisconsin Stevens-Pointissa.</p> <p>Lähtötilanne pintaliimauslaitteiston suhteen oli se, että alkuperäistä lammikkoliimapuristinta oli alettu kehittämään lisäämällä siihen suutinpalkki, jolla applikoinnin oli tarkoitus tapahtua. Tässä oli kuitenkin ilmennyt ongelmia mm. liiman jäähtymisen, sekä suutinten tukkiutumisen muodossa. Näistä syistä pintaliimauslaite ei työn alkuketkillä ollut käyttökuntoinen.</p> <p>Koska työn tavoitteena oli mahdollistaa alkuperäistä rakennetta parempi annosteltavan tärkkelyksen määrän säätö, ei lammikkoliimapuristin enää ollut varteenotettava vaihtoehto. Myös suutinapplikoinnin ongelmien vuoksi rakenteen jatkokehittäminen ei tuntunut järkevältä. Ratkaisuksi valittiin rakennettavaksi pintaliimalle applikointilaatikko puristinrullan päälle, jotta saataisiin mahdollistettua parempi liiman määrän säätö. Tässä yhteydessä myös tärkein käsittelylaitteistoa kehitettiin paremman lopputuloksen saavuttamiseksi.</p> <p>Työn valmistuttua suoritettiin koeajoa, jossa kävi ilmi että uudella laitteistolla pystytään jatkuvaan applikointitapahtumaan. Pintaliimatun paperin vetolujuus koheni huomattavasti sekä grammapaino kasvoi samassa ajassa valmistettuun liimaamattomaan paperiin verrattuna.</p> <p>Jatkokehiteltävää työssä kuitenkin jäi, mikäli tämä applikointimenetelmä otetaan varsinaisesti käyttöön opetuspaperikoneella. Applikointilaatikon prototyyppi tehtiin polykarbonaatista ja se olisi suotavaa korvata jämerämmällä valmisteella, kuten myös laatikon teline. Myös osa tärkein käsittelyn putkistosta jäi vielä tässä vaiheessa epäsiisteiksi letkuiksi.</p>		
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1. INTRODUCTION

The subject for this thesis originated from my year as an exchange student in University of Wisconsin, Stevens Point, USA. These studies included group work to improve schools educational paper machine functions. All graduating paper-science seniors will go through similar design project of their own subject. Problem statement for our group was to optimize the size press and all related operations on the PS&E department paper machine to allow continuous application of surface size at a controlled rate.

Sizing is a process which is used mainly to improve paper or cardboard strength properties. Starch is applied to paper surface at the point of paper machine line where paper is dry enough not to break in the process. Starch works as a glue between the ponds in the paper improving the strength properties of the final product.

Current size press at the UWSP papermachine had not been used for several years and starch kitchen was not fully functioning. There have been other students before with similar projects and the situation with machinery was unfinished at the time we started our work.

These modifications were needed to improve the flexibility of the UWSP paper machine. For educational papermachine it is very desired that machine can run great variety of paper grades. UWSP offers services for industry, one of these services is “hands on classes” where people can produce paper on their own with real paper machine. There are also test runs arranged for different new inventions and trials which paper corporations want to run on small scale. Paper machine is also used for producing paper for art students and others. Being able to apply desired surface size opens many new possibilities and could pay improvement costs itself with later usage.

2. OBJECTIVES

Objectives for this work were to be able to control the rate of starch application and to optimize all the other operations related to surface sizing at this paper machine. One of the main duties besides the actual press modification was to improve starch cooking and delivery system.

3. MAIN PROCESSES IN THE PAPERMAKING

Before entering to the paper sizing person should have some knowledge about basic papermachine functions. These main processes are briefly explained in this section. Person should also understand the fact that there are many other active functions running at the mill than just the visible papermachine line. Without stock preparation, stock and water circulations and other vital functions paper machine could not operate.

3.1 Headbox

The headbox is basically the first part of actual paper machine line. Before the headbox is the stock preparation where the pulp is produced. The function for the headbox is to feed the stock on the wire with the desired consistency, usually between 0.5-1,0 % at this point. The headbox is also supposed to create even stock distribution in the cross direction and also to control the pressure changes in the feed flow to maintain even stock distribution in the machine direction. (Knowpap 2013)

There are always fiber flocs in the feed stock and the headbox is supposed to break these flocks mainly with hydrodynamic forces. When there is too much and too big flocks in the stock paper quality will be poor. That is one reason why the headbox design plays a major role in the paper quality. (Knowpap 2013)

3.2 Wire section

Wire section is the part of the machine where most of the water is removed. Wire is acting like a sieve cloth and the water goes through it to exit. In the wire section there are also hydrodynamic forces created to break remaining fiber flocs for improving the paper quality. Water in this section has to be removed in the right way so fiber retention will stay as desired. Enough water has to be removed to achieve good runnability in the press section. After this section consistency is usually 17-20%. (Knowpap 2013)

3.3 Press section

Main functions for the press section are to remove the water and compress the paper to achieve higher wet strength to get good runnability in the later processes. Pressing happens between the felt and a smooth roll or between two felts. Pressing starts with lower compression first for not breaking the paper structure. Later in this section pressing force can be increased to remove more water. After this section consistency is 35-50 % depending on the paper grade. (Knowpap 2013)

3.4 Drying

In the drying section water is removed from the paper by evaporation. There are three different ways for removing water:

- Contact drying with cylinders
- Blow drying
- Infra-red drying

Main things to consider about drying are to remove the water without affecting the paper quality and to remove water with as low energy costs as possible. (Knowpap 2013)

4. SIZING AS A PAPER PROCESS

Sizing is a process which is mainly used for improving the strength properties. Sizing is also used for reducing penetration of the aqueous solutions to the finished product. There are two different types of sizing: internal sizing and surface sizing. (Smook 1994, 283)

Internal sizing's basic principle is to apply sizing agent in the pulp to achieve reduction to the rate of penetration of the water or other aqueous liquids into the paper. Internal sizing does not have such a powerful increase of the strength properties than surface sizing. In the early years of paper making rice starch and later animal glue have been used for this application. Today's papermakers use different kinds of rosin size for internal sizing. (Smook 1994, 283) (Holik 2006, 83)

In this thesis we concentrate on the surface sizing. Many important paper qualities can be improved with the surface treatment. Surface sizing is commonly used for the fine papers, coated base papers and paper boards. Suitable sizing agent and the sizing equipment are selected regarding to the final product. Usually for the surface sizing paper machines use the film size press and paper board machines use the size press because of differences in z-directional penetration and speed limitations between these press types. (Knowpap 2013)

Besides the important increase in the surface strength, many other paper properties can be improved with the sizing. Most common of these are:

- Reduced dusting
- Desired absorption properties
- Reduced porosity
- Reduced dimensional variation
- Improved smoothness

Being able to alter these properties as wanted is very vital to produce good quality products in the categories as fine paper, coated base paper and paper boards. (Hägglom-Ahnger 2000, 174-175) (Knowpap 2013)

5. MATERIALS USED FOR SIZING

Starch is the most common material used in the surface sizing. Other binders than the starch are used mainly for special paper grades, when there is a need for specific surface properties. Starch is also very cheap material compared to other binders like CMC (carboxy methyl cellulose) or PVA (poly vinyl alcohol). (Knowpap 2013)

5.1 Starch

Basically the starch from any source can be used in the surface sizing. The most common sources for the starch are corn, potato, wheat and tapioca. Different locations around the world have different plants which are easily available for industrial use. For example the corn starch exists in a very large amount of all kinds of products. This is also the reason that 75% of all starch produced is made out of corn. Rest of the starch produced basically divides between potato (7 %), wheat (8 %), and Tapioca (10 %). USA makes 52 % of all the starch produced in the world. EU has the share of 17 % and rest of the world remaining 31 %. (Holik 2006, 68-69)

Paper industry uses a significant amount of all the starch produced. In 2002 48.5 million tons of starch was produced. Paper industry used 5.5 million tons in the year 2004. This means that the paper industry consumes around 10 % of all produced starch and most of it goes to the surface applications like surface sizing and coating. (Holik 2006, 68-69)

From all the starch consumed in the paper production in 2004 North America, Asia and Europe used 94 %. The remaining 6 % were used in the rest of the world. Differences in the usage between these three were small, North America used 35 %, Europe 30 % and Asia 29 %. (Holik 2006, 68-69)

Starch has to be modified before using in the surface sizing. Unmodified starch has very high viscosity which will limit the possible consistency of the sizing agent. Modifying the starch will lower the viscosity of sizing slurry and also improve its temperature stability. (Knowpap 2013)

Even the modified starch has to be cooked before use. This means that the aqueous suspension is heated until it will become “gelatinized” solution. This is done either as a batch cooking or a continuous cooking. (Smook 1994)

When time goes by after the cooking and the starch slurry gets colder it could get thickened which is called setback. This “gelling” will make the starch unusable. Unmodified starch has tendency for this setback even without cooling. Besides the lower viscosity achieved by modifying the starch setback resistance is very vital factor for working sizing process. (Smook 1994, 285-286)

5.2 CMC

CMC (carboxy methyl cellulose) is a synthetic, water solvable material, which is derived from cellulose. CMC can be dispersed in the cold water but dispersion time is much shorter when hot water is used. In sizing and pigment coating CMC is used as a thickener and a binder. CMC is also good water retention agent because it is strongly hydrophilic. (Lehtinen 2000, 265-267)

5.3 PVA

PVA (poly vinyl alcohol) is used in the surface sizing because it has many desired properties to create good quality special papers. PVA is fully soluble with water, it has great film-forming properties and a good adhesion to fibers and fillers. (Lehtinen 2000, 282-283)

Using PVA as a binder it can improve the surface strength, decrease the oil absorption and improve the water retention value. PVA can be used with the starch or just PVA alone. When using the PVA and the starch, increasing viscosity might cause problems in the process. (Knowpap 2013)

5.4 Sizing agent properties affecting the process

Viscosity plays a major role in the sizing agent penetration to the paper. When the viscosity is increased more size is applied to the paper surface. This means that the penetration depth can be altered with the viscosity changes in the sizing slurry. Besides the temperature changes viscosity is also related to shear forces and the surface tension of the solution. (Mäkitalo 2013, 21)

Consistency has also straight effect to the penetration of the sizing agent. High consistencies do increase viscosity of the slurry and low consistency will limit the amount which can be applied. Using relatively high consistencies is very desirable because it has major effect on afterdrying expenses. Very high consistency slurry might result as a layer of size on the paper surface which might not stay intact with the paper, or it can stick on the roll surface ruining the paper. (Mäkitalo 2013, 20-21)

The produced paper and also the sizing agent are slightly electrically charged. By optimizing electric charge of sizing slurry can help to get the final product stable and increase penetration and therefor decrease coverage. (Mäkitalo 2013, 21)

6 SIZING EQUIPMENT

The conventional size press was in use for most purposes until the 1980's when there started to be real need for faster press types, because the size press was limiting factor in the paper machine. In 1960's Gate-roll type press was established. This type of the press could achieve faster speeds than the pond size press, but it also had own problems as much lower z-directional penetration than the pond size press and speed limitations around 1200-1300 m/min with higher size amounts. In the 1980's the film size press was discovered and even with today's fast paper machines the film size press is not the limiting factor. Still the press type has to be carefully selected for the right application. For example the film size press cannot achieve as high z-directional penetration than the pond size press. (Lehtinen 2000, 489-490)

6.3 Pond size press

In today's paper manufacturing the pond size press is still used mainly for the paperboard machines. The pond size press has excellent z-directional penetration which is vital property for the paperboard. With high starch penetration the final product will have good stiffness and internal strength. Another commonly used application for the pond size press is precoating technique for coated woodfree papers. Figure 1 explains the operating principle of the conventional pond size (Lehtinen 2000, 491)

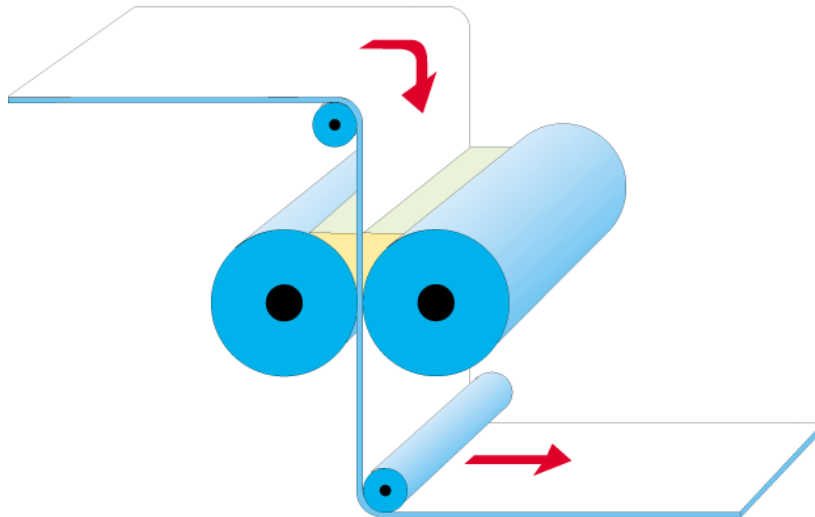


FIGURE 1. Pond size press (Knowpap 2013.)

In the pond size press the paper goes through a flooded nip where starch is applied straight to the paper. Concentration in the pond type press is usually 5-6 % and amount of starch applied less than 4 g/m². Higher concentrations usually results as runnability problems. (Hägglom-Ahnger 2000, 174-175)

Biggest issue in the pond size press is speed limitation. When running faster than 1000 m/min there usually will be problems with splashing. The speed where problems usually starts depends on many different things, but the starch viscosity and the roll diameter are the main factors when this problem occurs. Problems have been tried to be solved by increasing the roll size to create deeper pond for bigger hydrostatic pressure and also with the symroll application where the one roll is larger than the other. The probability for web breaks in the pond size press is also considerably big, because of massive wetting of the paper in the nip. Defects in the paper usually will cause web breaking. (Hägglom-Ahnger 2000, 174-175)

When using the pond size press, the concentration of the sizing agent is limited. The amount of the starch pick up and the penetration depth is a result of capillary action in the pond and the nip pressure. Higher concentration and viscosity means more pick up. Paper properties like porosity, moisture content and temperature also have an effect to the amount of pick up. (Hägglom-Ahnger 2000, 174-175) (Holik 2006, 290-291)

6.4 Film size press

The film size press (Figure 2) was discovered in the 1980's to answer for the demand of faster size press. The film size press operates little different than the pond size press. In this type of press sizing agent is first applied to the application roll and then transferred to the paper surface. In the surface sizing application to the roll surface happens with the grooved rod. Rod diameter is between 10-12 mm and there is a variety of rods with different size grooves in them. Amount of the applied starch is adjusted with the volume of these grooves in the rod and the pressure of the rod against the roll. Also the dry concentration of the applied starch is more flexible than in the pond size press. (Hägglom-Ahnger 2000, 175-176)



FIGURE 2. Film size press (Knowpap 2013.)

Film press technique has many other advantages over the pond size press than just being able to run higher machine speeds. When using the film press technology there is not a pond that paper has to go through. Sizing agent is applied to the paper surface as a film with the transfer roll. This combined with the fact that the film press can operate with significantly higher solids content than the pond size press gives it great advantage when afterdrying costs are considered. (Hägglom-Ahnger 2000, 175-176)

In today's market competition is tough and the papermachine efficiency has a big role in it. Drying of the paper takes a big role in the total steam usage at the paper machine. The drying section is also very long part of the papermachine and when the need for drying decreases lesser number of drying cylinders is needed and the factory size can be slightly smaller.

Biggest advantages compared to the pond size press are:

- Superior runnability even with high machine speeds
- Moisture content of entering paper can be 1-3 % more than with pond size press
- Major savings in after drying expenses
- Dry contents of starch can be up to 15 %
- Base paper has no major effect in starch pick up

Basically only advantages the pond size press has compared to the film size press is its fairly simple construction and the fact that film size press cannot always achieve such a great z-directional penetration to the paper.

(Hägglom-Ahnger 2000, 175-176)

6.5 Coating of paper

Coating does improve mechanical, visual and runnability properties of the paper or paperboard. Usually coating is done mainly to improve visual properties of the paper, such as printability, gloss, smoothness and brightness. (Knowpap 2013)

Coating has a major effect in the paper printability because after coating ink does not penetrate deep into the paper like it commonly does when printing on the uncoated paper. High grade papers can be coated up to three times to maximize the printability. Smoothness of the paper also increases when coating layer is filling the pores on the surface of the paper. Gloss does correlate with the smoothness, which means that high gloss can be achieved by coating and calendering the paper. (Knowpap 2013)

There are three different groups of surface coating methods. Surface sizing, which is the main subject of this thesis, pigmentation and pigment coating. Differences between these groups becomes whether pigment is added or not, consistency of the surface finishing agent and coat weight. Surface sizing does not contain any pigment. Differences between the surface sizing, pigmentation and pigment coating can be seen from the picture below (Figure 3). (Knowpap 2013)

Film press operational windows

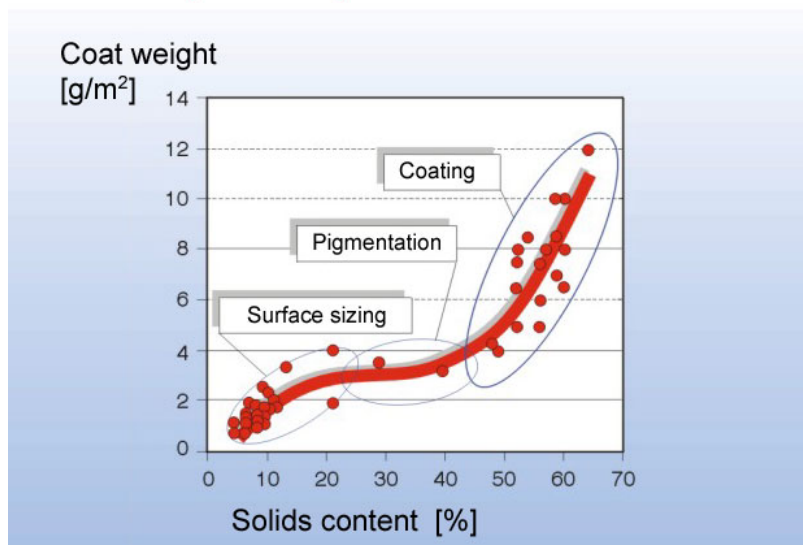


FIGURE 3. Differences between sizing, pigmentation and pigment coating (Knowpap 2013.)

6.5.1 Materials used for paper coating

Coating color contains pigment, binding agents, thickeners and additives. Pigment is the most important material in the coating color and usually 80–95 % of dry weight of the coating color consists out of the pigment. Volume fraction of the pigment is also very important factor and it is usually around 70 % of the coating color. (Welling 2012, 5) (Smook 1994, 287)

Sometimes the pigments are divided into the groups as main pigments, special pigments and accessory pigments. Main pigments will take the biggest share in the color. Special and accessory pigments are used mainly to improve some certain properties in the final paper. Most commonly used pigments are Kaolin, Ground calcium carbonate (GCC) and talc . (Welling 2012, 5)

In the coating color binders are supposed to bind pigments to each other and to the paper. Binders can also partly fill pores between pigments. There is usually a mixture of binders in the coating color. Task for the main binder is to bind pigments and the co-binder is there mainly to change rheology of the coating color. (Welling 2012, 14-15)

Thickeners are supposed to adjust the viscosity of the coating color to the desired level. Water retention of the coating color can also be controlled with thickeners. CMC (Carboxy methyl cellulose) is widely used thickener which also works partially as the binder. (Knowpap 2013)

There are many available additives for coating colors. These additives are being used for improving certain properties or to avoid unwanted phenomenon's in the coating process. Some of the desired functions are such as foaming control (anti-foaming agents), slime-control, adjusting optical properties, pH, viscosity etc. (Hägglom-Ahnger 2000, 183-184)

6.5.2 Blade coater

The blade coating is the most used pigment coating technique. There are a few different types of blade coaters, such as blade coater with jet applicator, blade coater with short-dwell applicator and applicator roll equipped blade coater. (Hägglom-Ahnger 2000, 185)

The applicator roll is the most used coating head in the paper industry. This method has been proven to work for most of the paper and paperboard grades from the paperboard coating, speeds less than 500 m/min to the lightweight coated paper speeds higher than 1500 m/min. The operating principle is fairly simple. The applicator roll locates partly in the tub where the coating color is picked up. Then the applicator roll moves the coating color to the paper surface at the backing roll. Distance to the doctor blade can be up to 600 mm. This is why the applicator roll is also called long-dwell applicator. Operating principle of the applicator roll is shown in Figure 4. (Welling 2012, 19-20)(Lehtinen 2000, 416-417)

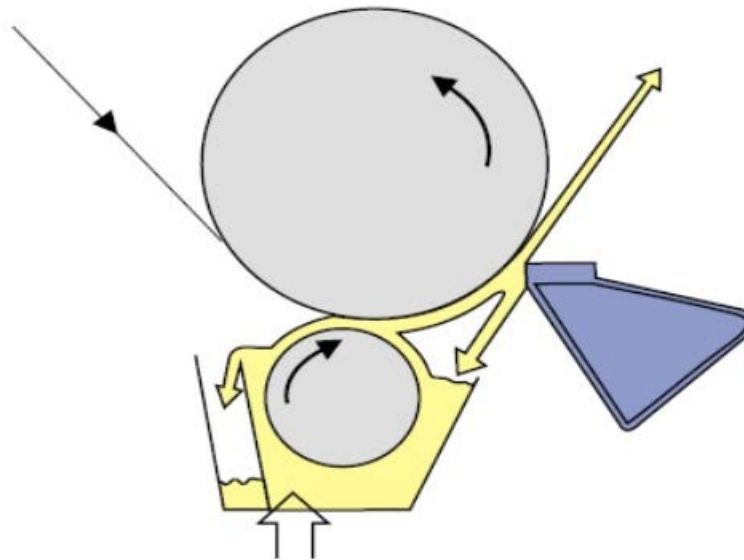


FIGURE 4. Principle of roll applicator (Lehtinen 2000, 417.)

The jet-applicator structure is very similar to the applicator roll equipped blade coater. Instead of the applicator roll, the coating color is applied straight to the paper surface using a spray nozzle. The amount of the coating color is finally set as desired with the doctor blade. The advantages in this design are that the roll is not needed which makes the jet application suitable for considerably high speeds and smaller pulsation in application pressure. Also the amount of excess coating color applied is much smaller than with the application roll. This means that the doctor blade load can also be smaller which also decreases the wear of the doctor blade and improves runnability. The structure of jet application coater can be seen from Figure 5. (Hägglom-Ahnger 2000, 187-188)

Principle of free jet application coater

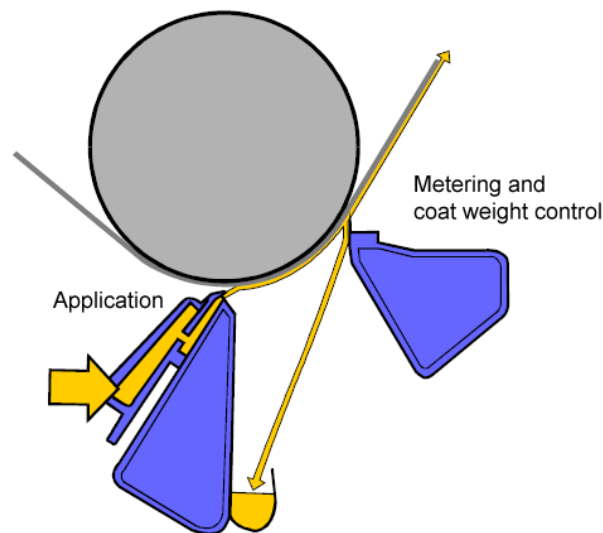


FIGURE 5. Principle of Jet applicator (Knowpap 2013.)

The blade coater with short-dwell applicator has significantly smaller application area than the application roll and the jet application, being just between 25-40 mm. In short dwell applicator there is a chamber for coating color just behind the doctor blade, as can be seen from Figure 6. (Knowpap 2013)

Operating principle of OptiBlade

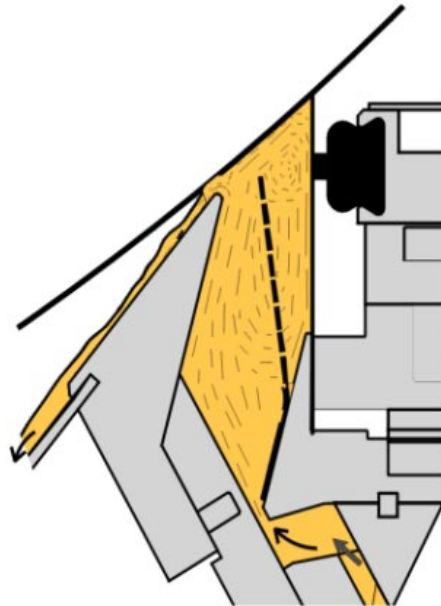


FIGURE 6. Principle of short-dwell applicator (Knowpap 2013.)

In the short-dwell applicator the coating color application happens the following way. The paper web is the one wall in the coating color chamber. When the paper web moves, it also creates movement in the chamber of coating color. Finally the amount of applied coating color will be adjusted with the doctor blade. Because of the short application time and low application pressure, maximum amount of the coating color applied remains 2-3 g/m² smaller than with the application roll. Typical amounts applied with the short-dwell applicator are 6-11 g/m² (Hägglom-Ahnger 2000, 186-187) (Welling 2012, 20-22)

6.5.3 Film transfer coater

The film transfer technique was introduced first for the size press use in the 1980s and later on also for pigmentation and pigment coating. Film transfer coating has some desired characters like simultaneous coating on the both sides of the paper, low investing costs and relatively small size. (Hägglom-Ahnger 2000, 190)

When using the film transfer coater the coating color is applied first to the applicator roll and then to the paper surface, much like in the film size press. In the coating process the film splitting from the applicator roll to the paper surface is critical. Usually 70 – 80 % of the coating color splits to the paper surface and the rest 20 – 30 % stays on the applicator roll. The film transfer coater has rather good runnability, but with high speeds fogging and “orange peel” texture might become a problem. (Hägglom-Ahnger 2000, 190-191)

Differences between the film transfer coating and blade coating result as very different coating color coverage in the final product. As person can see from Figure 7, the film transfer coater has uniform coverage of the coating color to the paper and the blade coater coating color amount can vary in different places on the paper surface.

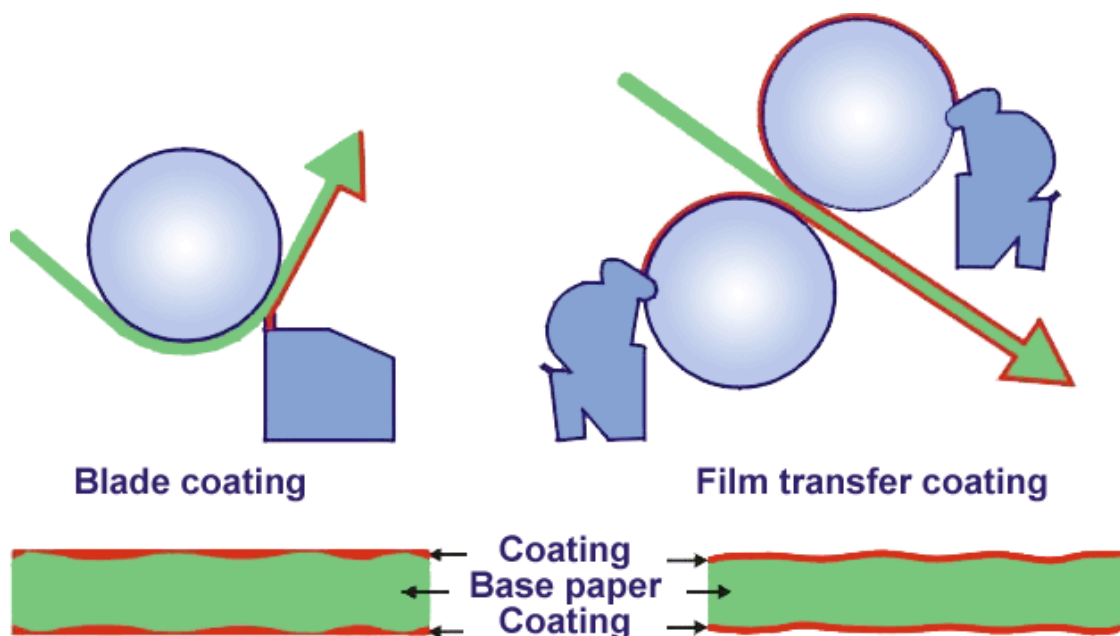


FIGURE 7. Coating layer differences between blade and film applications (Knowpap 2013.)

6.5.4 Rod coater

Basically only difference between the blade coating and the rod coating is the method used for adjusting the amount of the coating color. As the blade coater uses the doctor blade, rod coater has a rotating rod to remove the excess coating color. (Welling 2012, 26)

The rod coating is still used for some of the paperboard and special paper grades. Biggest advantage of the rod coater over the blade coater is the fact that the rotating rod will remove some of the dirt or separate fibers if those exists in the coating process. In the case where dirt gets to the blade it usually stays there and will cause damage to the coating. (Welling 2012, 28)

7 DESIGN AND PRODUCT METERING SIZE PRESS FOR UWSP PAPER MACHINE

7.1 Current press and problems

Current equipment at the paper machine is the old pond size press which has not been in active use for several years. There were also some parts like most of the piping disassembled by the previous project groups who had not finished their construction work. The group before us tried to use spray bars for starch application. It turned out to be challenging to keep starch warm and nozzles clean and not plugging.

One option for us would have been to replace all the spray bar related stuff with the original pond size piping and run the press like that. This solution would not have given very good opportunity to alter the application rate which was one of our main goals with the project. That is why we started to figure new design for application method. Picture of the original pond size press is shown in Figure 8.



FIGURE 8. Original pond size press design at UWSP paper machine

Second problem was the starch kitchen and keeping the cooked starch hot. First of all there was no hot water available for cooking the starch. It takes a lot more energy and time for cooking the batch of starch with cold water. Lack of hot water was also problem for tank cleanup, especially combined with the fact that there was no drain in the day tank. Other big problem was inadequate insulation in both tanks of the starch preparation. Cooked starch has to be maintained warm enough to be usable in the process.

The piping between the tanks and the press was lying on the floor and created a major tripping hazard. There also was not any kind of return flow system from the pond back to the day tank which of course has a major role in starch loss at the process. Figure 9 shows the cooking tank with original insulation .



FIGURE 9. Starch cooking tank

7.2 Goals in new design

Our main goal with the new design was to be able to control the rate of size applied to the paper. We were also supposed to optimize all the functions related to the size press. With these new improvements the papermachine should be more flexible for the running parameters. With larger variety of paper products the papermachine could not only produce more paper for student use but also the University could advertise more possibilities in trial runs and education for paper companies.

With new design we were also supposed to be able to run with higher solids concentration, which should result as fewer web breaks and decrease the need for afterdrying.

7.3 Design and producing the prototype

The first problem for us was to decide which type of the application method we were going to use. The original pond size press is still used for some paper and cardboard grades and the structure has been proved to work. In this case we still wanted to be able to control the applied size more than it is possible with the pond type press.

The previous group worked with the spray bar construction for application method. The idea is to spray the sizing agent to the roll cover, from where it is applied to the paper surface. Main problems with this construction were keeping the starch hot enough and the constant plugging of the nozzles in the spray bars.

Because of these facts and previous attempts we wanted to create construction more like the actual metering size press. We decided to create a size box to deliver controlled amount of starch to the profile.

We started designing the box with basic drafts (Figure 10) to get some idea about the measures it should have. The box had to big enough to hold the starch solution even with the faster flow rates but it also had to fit between the rolls at the paper machine.

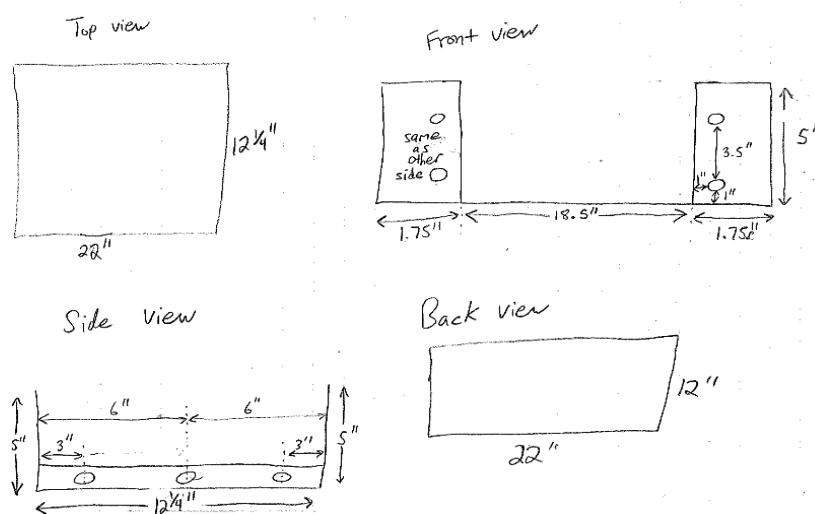


FIGURE 10. Rough drafts for size box

After some drafts we wanted to create 3D model (Figure 11) for better chance to see how it looks like and how it could possibly fit to the paper machine line. I used the Autodesk software for modeling the concept. This turned out to be the final design and we could start the actual fabrication.

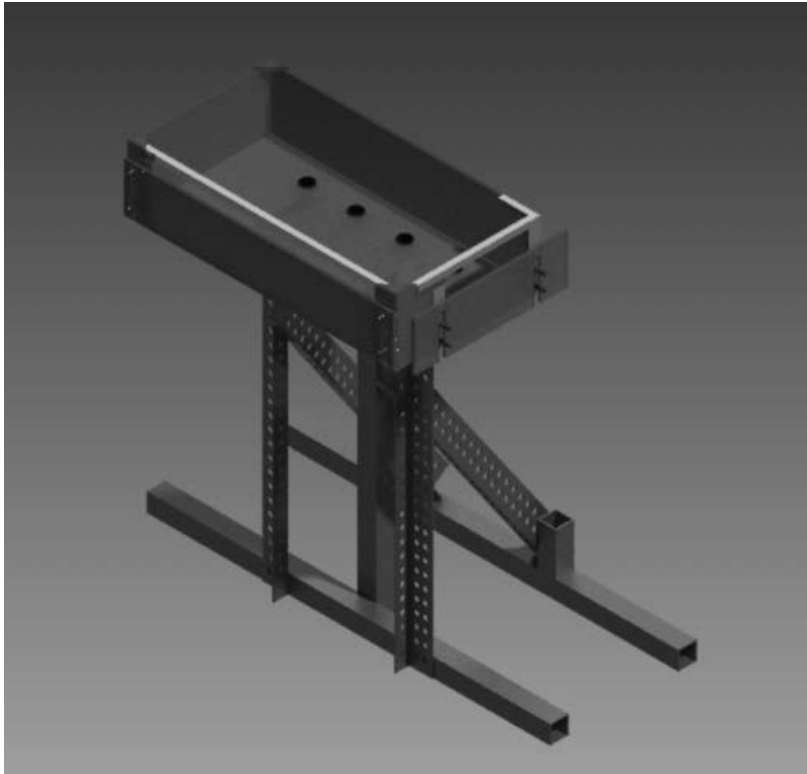


FIGURE 11. 3D model of size box

Budget for this project was just few hundred dollars so we tried to use recycled material as much as possible. The prototype box (Figure 12) was made out of polycarbonate. It is strong enough and it gives us possibility to see well what is happening inside of it.



FIGURE 12. Size box construction

We could alter the flow rates in the box by raising and lowering the gate in the front side of the box, next to the roll. The flow rate to the box could also be changed by the feed pump pressure. We drilled four inlet holes to the box to get even flow distribution in the box. Support bracket (Figure 13) was fabricated from the scratch material what we found from the lab.



FIGURE 13. Size box and bracket installed

7.4 Other improvements

For the cook tank we installed two layers of new insulation. Big improvement for the cooking was adding a hot water line which makes a big difference in the cooking efficiency. Also the cleaning of the tank became much easier. The new hot water line can be seen from the figure 14. Cook tank insulation is shown in the figure 15.



FIGURE 14. New hot water line

FIGURE 15. Insulated cook tank

The day tank also got its share of new insulation. Keeping the starch in day tank hot is very important for avoiding the starch gelling. Starch slurry can sit in the day tank for considerably long time and this combined with the temperature decrease creates a major threat for gelling. We also created a drain to the tank to aid the cleaning. The drain is located at the bottom of the tank and makes the cleaning easier when person does not have to take the starch slurry out with a bucket. Drawdown tube was installed to the tank to help to observe flow rates to the size box. The drawdown tube and the new layer of the insulation can be seen from the figure 16.



FIGURE 16. Insulated day tank with drain and drawdown tube

We also created return system for the overflow starch. There was not existing system so we had to start for the beginning. We added a temporary tote to catch the overflow starch. We did also connect a level sensor in the tote to start the return pump when needed.

There are pictures below this which explains the structure of the support bracket of the size box. The catch pan for overflow starch can also be seen from the figure 17.

Return pump assembly was not final. As the person can see from the figure 18, the pump is located on the temporary desk.



FIGURE 17. Catch pan for overflow starch



FIGURE 18. Return pump for starch recycling

7.5 Results

Our objectives in this project were to be able to apply continuous surface size with the controlled rate and to improve all the functions related to the size press.

In the test run we were able to apply the continuous surface size. Controlling the amount of the applied starch turned out to be more challenging than we thought. The press started to create little pond between the rolls with smaller flow rates than we thought. Because of this fact increasing the flow rate up to 60 lbs/min did not have a major effect on the amount of starch applied.

Basis weight and tensile strength testing gave positive results. There was a good improvement in tensile strength of the surface sized paper compared to the paper from the same run which was not sized. Tensile strength increased up to 108 kN/m, compared to tensile strength of 97-100 kN/m for base paper from the same run without size.

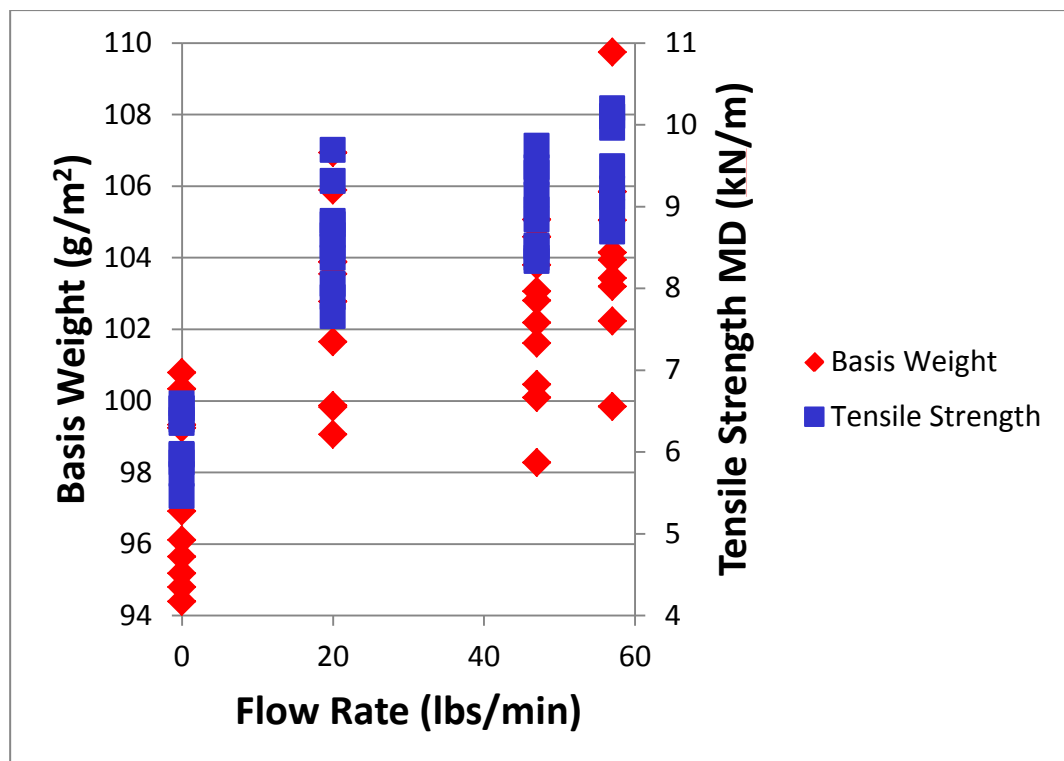


FIGURE 19. Test run results

Consistency of the sizing slurry during the test run was 7 %. In future runs this could possibly be increased to avoid unnecessary re-wetting at this point. In our trial run paper at the reel felt little moist. Before testing basis weight and tensile strength paper was dried overnight in the paperlabs “oven” to get reliable results.

After modifications the starch kitchen definitely became more user-friendly. Being able to start cooking with warm water has a major effect on cooking time and efficiency. New insulation in tanks lowers the risk for starch gelling which makes the starch slurry unusable.

With newly installed return flow system user could achieve major savings when overflowed starch does not go to waste. This installation of ours was not final and the catch pan should be upgraded for the permanent design. Also all the remaining flexible tubes should be replaced with hard pipes when continuing the project. With new hot water line and other piping modifications we improved user safety on the machine by decreasing the tripping hazard.

8 SUMMARY

Overall this project was really interesting and it gave me better understanding of the surface sizing of paper. Our group in this design project worked well together and also we got good guidance from the UWSP faculty staff when needed.

I hope that our design will be useful for future use and there will be other people interested enough to finish and possible even improve this design.

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