LINTING OF FILLER IN THE OFFSET PRINTING PROCESS

This Minor Thesis is submitted as a requirement for the degree of Masters of Engineering Science in Pulp and Paper Technology at the Australian Pulp and Paper Institute, Department of Chemical Engineering, Monash University, Clayton, Victoria, Australia

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SUMMARY

The aim of this project is to predict the filler linting propensity of newsprint by the following process :

a. Design printing experiments to artificially remove filler from the surface of machine made newsprint

b. Investigate novel methods of determining filler size distribution in paper

c. Compare the material removed in the laboratory printing experiments with the filler size distributions measured in the surface of the paper

Norske Skog Boyer Mill supplied samples of newsprint for analysis. These were chosen as they had a known propensity to lint, from quality and audit testing conducted at the paper mill. The quality testing included running 7,000 sheets through a small sheet fed offset press and measuring the mass of material removed.

Printing experiments were designed to artificially remove filler from the surface of the newsprint using an IGT Printability Tester. This test was able to demonstrate the linting propensity of a series of newsprint samples.

Image Analysis was used to quantify the lint removed from the newsprint in the printing experiments.

Several methods of determining filler size distribution in paper were investigated including:

a. Scanning electron Microscopy (SEM) with backscatter detection

b. Scanning electron Microscopy (SEM) with x-ray detection

c. Scanning electron Microprobe with x-ray detection

d. X-Ray Tomography with Phase contrast

e. FTIR Spectroscopy

Scanning electron Microscopy (SEM) with backscatter detection was the most successful method for determining the size distribution of filler particles in the newsprint surface.

No correlation could be found between the material removed in the laboratory printing experiments and the filler size distributions measured in the surface of the paper.

Correlations were found between the Treeline result in the offset printing test run by Norske Skog, and the degree of linting of the IGT test print.

Correlations were found between the Treeline result, and the amount of filler measured in the surface of the sheet by SEM and backscatter detection.

Recommendations for future work include the following:

a. Investigate the ability of FTIR Spectroscopy quantify filler size distribution on newsprint surfaces.

b. Repeat the IGT experimental set, including the addition of water / fountain solution as a variable.

c. Obtain more data for treeline results to confirm correlations obtained.

DECLARATION

I, Sonya Rand hereby declare that this minor thesis contains no material which has been accepted for the award of any other degree or diploma in any university and that, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference is made.

Signed…………………………………………

Date……………………………………………

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1.0 INTRODUCTION

In the offset printing of newsprint, linting is described as the tendency of paper to shed loosely bound fibres and fines during printing.[1] This material subsequently adheres to the offset printing blanket and disrupts the transfer of ink from the inking system to the blanket. The result is a deterioration of print quality to the point where the press must be stopped and cleaned.[2]

The international industry trend has been an increase in offset printing of newsprint and hence linting is a major source of customer complaints to paper manufacturers.[2-5] All newspapers in Australia are printed using the offset process.

The mechanism of linting is generally described as a combined effect on the ink film splitting forces and the inter fibre bonding energy of the paper surface.[2],[4] Linting is also related to the flow of ink in the press nip under pressure. There are two types of ink flows : a porous ink flow, penetrating the paper surface pores and a free ink flow at the surface of the ink-saturated pores. Theoretical analysis by Mangin and Silvy [6] shows that the ink flows induce sufficient drag on the fibre to cause lint by disturbing the bonding of weakly bound fibres on the surface.

Researchers [2],[7] suggest that different levels of force applied to the surface of paper generate different types of linting. At low forces, unbonded material, often referred to as dust, is removed. At medium forces, weak or loosely bound material, often referred to as lint is removed. At higher forces, well bonded surface fibres are removed, often referred to as picking.

The lint removed from an offset blanket ranges in size from very fine fibre and filler fragments, ray cells, whole fibres to mini shives and other debris.[4],[8-9] Ray cells are the predominant component of lint, followed by fibre fragments, poorly fibrillated fibres and fillers.[2]

Whilst paper manufacturers are investing substantial effort into understanding and preventing linting of papers, it is not only due to paper issues. Linting arises from a complex interaction between paper properties and printing press parameters.

Some studies have suggested that the printing press variables have a greater effect on the linting propensity of paper than the paper itself.[2]

Norske Skog, manufacturers of newsprint have initiated a technical study of linting in relation to offset printing of newsprint. This study is a collaborative effort between Norske Skog paper mills in Europe, Australia and New Zealand and external research providers.

The work reported in this thesis is part of the collaborative work between the CRC for Functional Communication Surfaces, Australian Pulp and Paper Institute and Norske Skog. The work reported is part of a broader linting project. Other researchers in the project are studying the linting of fibre.

The aim of this project is to predict the filler linting propensity of newsprint by the following process :

1. Design printing experiments to artificially remove filler from the surface of machine made newsprint

2. Investigate novel methods of determining filler size distribution in paper

3. Compare the material removed in the laboratory printing experiments with the filler size distributions measured in the surface of the paper

Paper from Norske Skog, Boyer Mill, Tasmania forms the basis for this study. Norske Skog Boyer Mill, employs 450 people and manufactures a range of newsprint and publishing related grades. The 290,000 tonnes of paper produced represents 40 % of the Australian market

Raw materials for the mill are plantation radiata pine, regrowth eucalypt and recycled fibre, which is produced at Norske Skog, Albury Mill, NSW.

There are 2 paper machines on site, PM2 and PM3 with production capacities of 125 000 tpa and 165 000 tpa respectively.

The paper grade used for the study is named Image / Norstar and is a 52 gsm improved newsprint grade manufactured on PM2. The specifications for Image / Norstar are given in Appendix H. The furnish is 67 % TMP radiata pine, 28 % chemi-mechanical eucalypt (cold caustic soda) and a filler component of 5 % calcined clay (supplied by Imerys as Alphatex).

This paper grade was chosen for analysis as it has been subject to linting in the past, according to customer feedback and in house quality and audit checks.

It is anticipated that further research in the topic of linting, will provide a more detailed understanding of the mechanism and assist in determining ways to minimise its occurrence.

2.0 LITERATURE REVIEW

This literature review addresses the linting of fibre and fillers from newsprint and offset printed papers. The published literature pertaining to linting focuses on fibre linting as it is perceived to be greater in impact and magnitude. Generally, where fibre linting occurs, filler will also be present in the lint removed. There is a general lack of research and literature on the specific linting of filler from newsprint and hence this body of work is aimed at improving the understanding of this phenomena.

Filler is added to the sheet for a variety of reasons : [10]

- Increase of brightness and opacity
- Improve sheet formation
- Improve print characteristics
- Replacement of expensive fibre material.

These aims can only be achieved if the filler is retained in the sheet with a uniform filler distribution. It is when filler separates from the sheet structure that linting and dusting problems start to occur. [10]

Retention aids are added in the papermaking process to improve filler retention in the sheet. Typically, cationic synthetic polymers, two component soluble polymer systems or micro-particulate systems are used to achieve the filler retention. [11] The measurement of filler retention on the paper machine does not however necessarily take into account the filler distribution throughout the sheet.

All retention aid systems based on high molecular weight polymers such as polyacrylamides have a tendency to flocculate the filler particles into large aggregates, but do not provide a uniform filler distribution throughout the sheet. [11]

Studies have been conducted [10],[11] that suggest that filler linting propensity increases where there is a high degree of agglomeration of the filler as opposed to a uniform filler distribution in the sheet.

Alternative methods such as treating the filler with high charge density low molecular weight polyethylene enables the filler to link as small particles to the fibre structure. [11]

The propensity of filler to lint out of the sheet is also based on its location in the thickness of the sheet. Filler particles on the surface of the sheet are more likely to be lint candidates. The distribution of filler in the thickness of the sheet is a function of the forming and dewatering conditions on the paper machine. Vacuum and forming conditions should be optimized to ensure that the filler distribution is even and not localised on the sheet surface. For these reasons, paper made in a gap former is less likely to lint than that made on a fourdrinier machine. [2],[3]

The overall amount of filler in the sheet is also linked to the filler linting propensity. The higher the filler content, the more likely the filler will deposit as lint. [10]

Printing Tests

There has been significant research in the field of designing printing experiments to artificially remove fibre and filler from the surface of machine made newsprint or paper. Traditional laboratory based tests such as the IGT pick test and Prüfbau wet pick have been used extensively. [5],[7],[9]

Mangin and Dalphond [7] evaluated three force intensities corresponding to dusting, linting and picking, using an IGT printability tester at constant (2.5 ms^{-1}) speed.

Lindem and Moller [9] report that no relationship could be found between the IGT test result and the quantity of lint accumulated on the commercial printing press blanket. The IGT is proposed as being more suited to measuring internal bond strength than it is in assessing loosely bound material on the paper surface.

Similarly, no relationship could be found between the Prüfbau wet pick test and the quantity of lint accumulated on the commercial printing press blanket.[9]

Heintze and Ravary [8] warn that laboratory tests that print only a small area of the paper should be used with caution since the actual material removed in these tests may be very different from the material that builds up on the blanket of the commercial offset press.

Ionides [3] warns that in laboratory tests, due to the small sample area, in order to get a significant amount of lint to measure, the stress applied to the sheet surface must be greater than that encountered on a commercial offset press. This may make the test procedure un-representative. [3]

Most linting studies concentrate on the lint accumulated on the offset blanket, but linting is a problem that affects the entire press, including the ink train and rollers [8]. This is an area where it is difficult to replicate real world conditions on a laboratory scale printing test.

Some linting studies have been conducted on commercial printing presses to examine the conditions that produce linting. [9],[12].

Lindem and Moller [9] carried out a series of 27 printing trials under standardised full scale production conditions on a four-colour offset press in Norway. The principle aims were to :

- Evaluate the effect of blanket lint deposits on print quality
- Establish the nature of the lint and where it deposited on the blanket
- Measure the quantity of lint deposited
- Identify simple laboratory methods that could predict quantities of lint deposited on the blanket with reasonable accuracy.

Lindem and Moller [9] found that the majority of lint consisted of ray cells and fibre fragments from reaction wood. This lint did not result in any marked deterioration in print quality after 100,000 copies were printed and so could not be regarded as being a problem. For those samples that showed the highest amount of linting, the lint consisted of fibrillated fibrous material in addition to the ray cells and fibre fragments. Generally, linting occurred more in unprinted regions than printed regions. Lindem and Moller [9] were unable to find a lint predicting method that corresponded to the amount of lint deposited on the actual offset blanket.

Wood et al [12] found that commercial scale printing trials could be used to demonstrate significant differences in the linting of a series of newsprint sheets. A correlation was found between the linting in cold set offset and heat set offset. Press variables were found to have a major effect on the linting propensity of the newsprint.

Whilst the commercial printing trials are able to give an indication of linting in the pressroom, conducting trials is often difficult due to competition between production and research based priorities.[3],[13]

As a proactive measure, paper mills began conducting their own version of commercial print trials by evaluating linting propensity on small pilot offset presses for audit or quality assurance purposes. For example, the Apollo lint test is performed on a small web fed offset press and is commonly used in the Canadian newsprint industry.[7]

Norske Skog, Boyer Mill uses a Heidelberg GTO-52 offset press as a laboratory test to measure the linting tendency of newsprint and to study the factors affecting print quality.[14]

It was found that for every ink setting studied, the more excess fountain solution that was available, the lower the linting tendency. Unfortunately optimum print density was associated with high levels of linting.[14] Increasing fountain solution is believed to decrease linting due to emulsification within the ink, which decreases viscosity and tack.[2]

Earlier theories that the fountain solution weakens hydrogen bonds in the paper and subsequently increases linting do not appear to be valid.[9]

Despite the attempt to replicate the commercial print environment, researchers believe that that pilot press testing is not satisfactory. Mangin and Dalphond [15] have noted that the linting propensity of paper is the result of an interaction between the paper linting propensity and the press parameters. It is concluded from this that measuring lint accumulation on the blankets of a pilot offset press is not a good test to evaluate the linting propensity of paper, since it can not replicate the conditions in a large commercial press room.

It has also been concluded by Mangin and Dalphond [7] that a group of papers tested on two different offset presses, or on the same offset press, but under different conditions may not rank in the same order for linting propensity. It is suggested that testing the paper linting propensity on an offset press is limited to the type of press and printing conditions used.

Mangin and Dalphond [7] suggest that the linting propensity of paper should be considered as the response of the paper surface to different forces. These forces will be different on any given press, run under any given condition. Similarly researchers [2],[4] propose that fibres are removed from the surface of the paper when the external forces exceed the forces holding the fibres together in the network.

Ionides [3] proposes further that the force that removes lint in the offset press nip is a force perpendicular to the sheet surface, compared to the frictional forces that loosen up the lint which are parallel to the sheet surface and scuff the paper in the nip.

Printing press variables that have been assessed for their effect on linting include [1],[2],[16]

- Printing Speed
- Pressure
- Temperature and Humidity
- Length of printing run
- Nip / Blanket packing
- Take-off geometry
- Plate to Blanket
- Blanket age
- Cleaning solvents
- Hard vs compressible blankets
- Printing Form / Density
- Ink weight
- Ink Tack / Rheology
- Fountain solution
- Wetting agents
- Hydrophilic correctors

Some of these variable are discussed below.

Printing Speed

It is generally accepted that linting increases with printing speed. [1],[2] This increase in lint accumulation varies inversely to the diameter of the blanket cylinder.[1] The printing speed also affects the size of particles removed.[1],[2] An increase in speed increases the size of lint particles.[1]

Pressure

There are conflicting reports on the effects of pressure. Some research indicates that linting increases with increasing pressure and the opposite findings are reported in other research work. [2] There is a lack of comprehensive models of ink-paper-press interactions to predict the effects of printing pressure. [1],[2]

Temperature

As temperature increases, the tack and viscosity of the ink decreases. This causes the ink transfer to be smoother and thus decreases linting. [2]

Length of Printing Run

The accumulation of lint in a press is not uniform between printing units. There is more linting in the first unit of the press and the lint consists of particles that are not bonded to the surface. [2] Subsequent printing units have lint that is weakly bound into the sheet. The stronger the binding force of the lint, the later in the printing process it is removed. [2]

Bonding can also be adversely affected due to moistening of the sheet. This is sometimes referred to as water induced linting.[2] The longer the printing run, the more the total lint quantity increases. Because a large quantity of the lint travels back up the process to the ink train, the ink quality will decrease during the printing run.[2]

Blanket Effects

The ideal set up of the press has the two cylinders which form the nip packed evenly. Mis-matching the packing increases the likelihood of linting. [2] Mis-matching is common because press operators routinely change individual blankets when necessary, instead of changing them together, which results in an inevitable mis-match because the new blanket has not packed down as much as the older one. [2] Overpressure has been reported to reduce linting, however as overpressure also decreases print quality and reduces the life of blankets and plates, it is not often used to reduce linting. [13]

Older press blankets cause more linting than new press blankets due to a layer that has accumulated during it working life despite being routinely cleaned to remove such buildups. [2]

Cleaning solvents can make the blanket swell and increase in roughness and thickness. This subsequently can increase linting. [2]

Lint accumulation differs between hard and compressible blankets. On a compressible blanket, lint decreases with decreasing print density. On a hard blanket, lint does not vary significantly with density. [2] There are conflicting reports of which blanket types create more linting. [2]

Take-off Geometry

In normal offset printing, the nominal take off angle is 15^{O}. In general, the paper side printed at the nominal take-off angle, partially wrapped up on the blanket cylinder causes less lint accumulation than the opposite side. [1][2]

Web feed, web tension

Web tension affects the linting propensity as if affects the true take-off angle of the paper. [2]

Printing Form

Linting increases with print density, due to more ink coverage and more ink film to surround and grip the fibres. [2] The highest lint accumulation is usually in the halftone areas. The lint is considerably less in the solids and non-image areas of the print. [1],[2]

Ink Weight

The effect of ink film thickness on deposit of lint on the blanket seems negligible. [1],[2]

Ink Tack and Viscosity

In general terms, the literature states that an increase in ink tack increases linting. An increase in ink viscosity increases linting. [1],[2]

Fountain Solution and additives

In offset printing, fountain solution is not only transferred in non image areas , but also in image areas as it is emulsified with the ink. [1],[2] The fountain solution thus decreases the tack and viscosity of the ink and thus causes the linting to decrease. Mangin [1] found that increased dampening decreased linting in the first station, but had no affect on succeeding printing units. The addition of alcohol to the fountain solution decreases lint. However, most newsprint presses currently work without alcohol.

The addition of hydrophilic correctors, which prevent corrosion in the printing plates, decreases accumulation of lint on the blanket. [2],[13] However, the dislodged lint still travels around the press. [2] Increasing the hydrophilic corrector content forms a slip layer on the blanket which prevents the lint from leaving the paper surface or inhibits its deposition. [13] The hydrophilic corrector does not evaporate ;it forms a moist lubricating layer on the blanket surface. [13]

Paper variables

Paper machine variables are also an obvious influence on the linting propensity of paper. Stock preparation, furnish, forming, wet end chemistry, pressing, drying, calendaring and slitting can all potentially affect the propensity of a paper to lint.[2] When traditional fourdrinier machines were upgraded to twin wire assemblies, the linting tendency decreased.[3],[8] When the press sections were upgraded, the linting tendency also decreased.[9],[12],[16]

Fractionating the pulp using hydrocyclones and then refining the rejects reduces linting and improves the surface properties. [2] Generally screening has little effect on linting as the fibres are separated based on size / length, not on specific surface. Centricleaners or hydrocyclones do a more effective job of removing fibres with a low specific surface because this is the basis on which they separate. [2] The reject rate can be controlled to improve the linting propensity of a paper grade.

It is proposed that the presence of filler in the sheet can increase the linting tendency because the filler particles settle between the particles and prevent the hydrogen bonding that connects the fibre matrix. [2] Filler particles are likely lint candidates as they are poorly bound in the sheet.

The use of de-inked stock can induce the linting of the filler from the de-inked pulp. The filler is attracted to the resin on the resin rich ray cells and then travels to the blanket with the ray cells. [2],[13]

As the printing run proceeds, the amount of filler as a percentage of the overall lint actually decreases, because the filler is the first to deposit on the blanket. [2]

Newsprints with a high waste percentage are reported to lint less. This may be attributed to less ray cells in the furnish, as ray cells are the predominant constituent of fibrous linting. [2] The higher proportion of kraft fibres from magazines also contributes to fibre bonding.

Pulp coarseness, defined as weight per unit length of fibre affects linting. The higher the fibre coarseness, the higher the linting propensity of the paper, due to less overall sheet bonding. [3] Refining of pulps to produce well developed fibres decreases the linting propensity of paper. [3]

For paper made on a Fourdrinier, the linting propensity of the top side of the sheet is 20–60% more than the wire side of the sheet. [3] This is due to the fines distribution in the sheet, with more fines trapped on the wire side of the sheet. The fines provide multiple bonding sites in the paper structure. Also, potential lint candidates such as ray cells and stiff fibres or shives are removed during drainage on the bottom side of the fourdrinier. [3] The conclusion therefore is that gap forming produces a paper with decreased linting propensity on the top side of the sheet as compared to a fourdrinier. [2],[3] Since the material collected at press roll doctor blades closely resembles that collected from offset printing blankets, any efforts to reduce press section picking, would also decrease the linting propensity of paper. [2] Higher press loads and a gentle transfer out of the press section decrease the linting propensity of a paper. [2],[3] Suction presses which remove water and loose surface fines also decrease linting, by removing the linting candidates from the surface of the sheet. [3]

As in the press section, picking can also occur in the dryer section of a paper machine. Having the drying cylinders too hot is a common problem that results in picking and hence increases the linting propensity of papers. [2] A steady increase in temperature though the early stages of the drying train are preferred for reducing linting. [3] Whilst calendering consolidates the sheet structure, it does not necessarily decrease linting. Hard nip calendering at low temperature actually increases linting, while temperature soft nip calendaring can decrease linting. [2] Calendering at too high a load can increase linting by weakening the sheet. [3]

Offset blankets sometimes have a line of linting on the edge of the paper path. This can often be attributed to slitter dust. This can be eliminated at the paper machine winder / sheeter by vacuum extraction of edge / knife dust. [2]

The linting tendency of papers themselves should have decreased as technology has improved with paper machine upgrades and the manufacture of new paper machines throughout the world. This may be the case, but the increase of offset printing in the newsprint industry [2-5] and higher quality expectations than ever before have resulted in linting being an important problem in the printing industry. This is magnified by the change from black to multi-colour printing of newspapers and the dramatic increase of printing press speeds over time.[12] The use of multi-colour printing has increased linting due to the addition of ink and fountain solution in multiple consecutive stations which weakens the fibre bonding of the paper surface.

Characterisation and quantification of lint

There have been numerous approaches to quantify lint accumulation during printing which include [5],[8] :

- Lint removed from press blanket with adhesive tape and fibres counted visually or by image analysis
- Molten wax poured on offset blankets and cooled to trap the lint and ink. Subsequent filtration of the molten wax and treatment with a solvent separates the lint from the carrier.
- Lint removed from the press blanket with adhesive tape and quantified with caliper measurements
- Lint removed with the Domtar lint collector and then filtered. The Domtar lint collector is a tray, which is held firmly against a stationary offset blanket area to be sampled. Using dilute isopropanol and a brush the lint and ink is washed off the blanket into the tray and bottled. These bottled samples are then screened to determine the mass fractions retained on each mesh and may also be subjected to visual analysis. [17]
- Lint characterized by Kajaani fibre length detector.
- Colour / Brightness measurement taken of offset press blanket after passing paper sheets through and compared to the clean blanket

The lint removed from an offset blanket ranges in size from very fine fibre and filler fragments, ray cells, whole fibres to mini shives and other debris.[4],[8-9] Whilst image analysis can be used to quantify the produced lint [16], it is important to note that the single large particles often cause more printing problems than an equivalent area of small ones. [3]

In years gone by, newsprint lint consisted mainly of large mechanical pulp fibres, which were loosely bonded into the paper surface. Advances in fibre development within the pulping process have been able to solve this issue.[12]

The current trend is more towards lint deposits of small ray cells, other fines and fillers.[2],[4-5],[13] The common feature of these particles is that they are short, stiff and have a low specific area which means that they have low bonding potential into the sheet of paper.[3-5],[9],[12] Nearly all lint particles are shorter than 1mm with over 90% reported as being less than 0.3 mm long, including ray cells which are typically about 0.1 – 0.2 mm long.[9],[13] The disadvantage of the smaller lint particles is their mobility in the printing press, traveling up into the ink train or fountain solution unit.[15]

Going back to the source, researchers [4-5] suggest that the linting propensity of paper be controlled by decreasing the linting propensity of the base pulp by optimizing the mechanical pulping process. Processes such as screening, centri-cleaning, reject refining, chemical treatment were considered in order to deliver a pulp with decreased linting tendency to the paper machine.

Measurement of filler distribution in paper

The use of scanning electron microscopes to determine filler content in paper structures has been reported[10],[18-20]. Cross-sections are prepared by microtoming and embedding the paper into an epoxy resin block for examination. [10],[18] Surface samples are simply placed on a stub and then into the microscope.

Elemental analysis has been conducted with energy dispersive spectroscopy to produce elemental maps of the paper, using a scanning electron microscope (SEM).[18-20]

Alternatively back scattered electron imaging can be employed, which takes advantage of the atomic number differences of the material.[18] The details of this method are explained in Section 3.2.1.2.

Failings of these types of methods is that only small areas are measured and these may not fully represent significant structural features in the paper such as sheet density distribution, microformation, pores and wire marks. [18]

Other issues include the length of time required to prepare the samples by microtome and the limit of SEM technology to 1000X magnification.[18]

The need for more information on how to quantify filler in paper samples is one of the main drivers for this project and body of work.