Drying performance and fabric tension: Mill trials

By I. Lang

Abstract: A recent laboratory study showed the positive effect on drying rate of operation at elevated dryer fabric tension. In this paper, the results from mill trials on different paper grades (news, fine and linerboard) are presented, which support the findings of the lab trials and show that significant improvements in drying capacity can be achieved by operating dryer fabrics at tensions higher than those commonly used by industry.

Paper and board is generally dried on a series of steam-heated cylinders. Heat transfer from the condensing steam to the web is limited by a number of factors, namely, thickness of the condensate layer, dryer scale, cylinder resistance and contact resistance between the web and cylinder. This can be represented by the following simplified equation;

\[ R_{\text{total}} = R_{\text{steam}} + R_{\text{shell}} + R_{\text{contact}} \]

According to some researchers, the contact resistance accounts for 35 to 70% of the overall heat transfer resistance [1].

The role of the dryer fabric is to convey the web through the dryer section and maintain intimate contact between the web and cylinder. Fabric tension acts on the paper web through contact pressure at the fabric-web-cylinder interface and has a direct influence on contact resistance.

The contact pressure \( (P) \) is determined by the following equation;

\[ P = \frac{T}{r} \]

where \( T \) is the fabric tension and \( r \) the radius of curvature of the cylinder.

Little exists in the way of recent mill data on the effect of dryer fabric tension on drying rates. One study done by Belanger and Anderson [2] in the 1960s reported on condensing rate measurements on two commercial newsprint machines. This work is frequently cited in the TAPPI technical information paper (TIP) on recommended dryer fabric tensions [3], which proposes that the main reason for operation at higher fabric tension is to overcome boundary layer air entrained between the web and cylinder.

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The goal of this study was to measure actual field performance as a means to check the validity of the previous lab study, with a view to providing guidelines for dryer fabric operation.

Background

Previously the author reported on drying rate measurements carried out at AstenJohnson’s facility in Kanata, ON.

The drying rig used in the lab study shown in Fig. 1 was a bench-top platen dryer (described in more detail in reference 7), which operated at industrial temperatures and contact pressures.

In its current set-up the drying rig simulates the one-sided drying found on a modern single-felted dryer section, with one side of the web in contact with the hot dryer and the other supported by a dryer fabric.

The tests were carried out on three grades of paper: news (48-g), fine (75-g copy paper) and linerboard (205-g), over two ranges of sheet solids, 50 to 70% and 70 to 90%, to simulate the drying process on a conventional machine in the warm-up and constant rate zones, as well as in the falling rate zone. This was done to determine whether, in practice, increased fabric tensions should be used preferentially in different parts of the dryer section.

Platen temperatures used were similar to the average cylinder temperature normally found in practice, i.e., 105, 120 and 150°C for news, fine and linerboard respectively.

Contact times of 400 ms were used for all tests, corresponding to a machine speed of 350 to 400 m/min. A 100 ft³/m dryer fabric was used to support the web for all tests.

The results of the drying rate tests are reported as a function of contact pressure rather than fabric tension. Although fabric tension is the more common parameter, its use occasionally leads to errors in interpretation when different dryer diameters are involved. Most paper machines operate with fabric contact pressures from 1.8 to 2.8 kPa (1.4 to 2.1 kN/m). Contact pressures used in the lab study ranged from 1.4 kPa to 5.7 kPa (i.e., nearly twice the level commonly used in industry). The corresponding fabric tension for 1.5- and 1.8-m diameter cylinders, the most common sizes found in industry, are list-
For the mill trials, modern machines were selected allowing a range of measurements from 2.0 to 4.0 kPa.

Drying rates from the lab tests were determined by measuring the moisture loss, and dividing by the area of the sample and the total time the sample was in contact with the heated platen. Drying rates for the mill trials were calculated from the condensate flow by assuming a 10% heat loss to the surroundings and ignoring sensible heating of the web. All drying rates are reported on a contact area basis (sheet wrap).

## RESULTS

### Lab Trials:

The drying rates as measured in the lab for newsprint, fine and liner are shown in Figs. 2 to 4. • The drying rate of newsprint increased by 6.7 and 7.0% for 50 to 70% and 70 to 90% solids respectively; • For fine paper, the increase in drying rate was 30.7 and 19.8% for 50 to 70% and 70 to 90% solids, respectively; and • For linerboard, the increase in drying rate was 42 and 46% for 50 to 70% and 70 to 90% solids, respectively.

We observed that for all grades studied the drying rate increased with increasing fabric tension, the rate of change being high initially, gradually levelling out and then tending towards an upper limit. We also observed that, with the exception of the fine paper test, the increase in drying rate was comparable for both ranges of sheet solids studied. Further, we noted that the increase in drying rate was more substantial for the higher temperature conditions. This was reported in the author’s previous work [7].

### Mill Trials:

The drying rates obtained on the AstenJohnson laboratory-drying rig at a conventional fabric tension (contact pressure) are, in general, similar to those quoted in the TAPPI TIPS for the grades tested [8,9,10]. Since the TAPPI TIPS make no distinction for fabric tension, a series of mill trials was planned to determine if the lab results were representative of what happens on an actual paper machine. In total, four mill trials were carried out, one on newsprint, two on linerboard and one on fine (copy) paper.

The procedure used for the mill tests was straightforward. Condensing rates, sheet and shell temperatures were measured for the dryer group under consideration. To simplify the procedure and to limit interference with the operation of the machine, one dryer group was studied during a test. The selection criteria for the dryer group was that it: a) be in the constant rate zone (approx. 50 to 70% solids), and b) preferably operate at constant steam pressure during the test (i.e., not as a control group for reel moisture content). The first set of measurements was taken at the “as found” operating condition. Dryer fabric tension was then reduced to the lowest limit acceptable to mill personnel. Once steady-state was reached, usually in 20 to 30 minutes, new measurements were taken. The tension was then increased, in steps, to the design maximum of the machine. In total, four or five measurements were taken per test, requiring four to eight hours to complete.

### Newsprint:

One set of trials was conducted on a modern, high-
speed newsprint machine. The dryer section consists of six sections, the first three single-felted and the last three double-felted. The dryers are 1.8-m diameter and are equipped with spoiler bars and stationary siphons. During the test, the machine operated at 1,250 m/min, making 48 g/m² news. Furnish was TMP with a small percentage of kraft.

Condensate drawdown tests were carried out on the fourth section (double-felted) at five levels of fabric tension, from 1.8 to 2.8 kN/m (1.9 to 3.1 kPa contact pressure). The estimated solids content in and out of the fourth section was from 55 to 65%, which fell within the 50 to 70% range of the lab trials. Average dryer temperature in the fourth group was 109°C.

The results of the field trials are compared to the lab results for 113°C in Fig. 5. The calculated drying rate is similar to the lab drying rate. Of greater importance, however, is that the field data shows the same trend as the lab data, suggesting a more pronounced effect of increasing drying rate when tension is increased. From the field data, we observed an increase in drying rate of nearly 15% as compared to only 4.4% from the lab data over the same range of contact pressure.

Fine Paper: Measurements were carried out on a modern, high speed, fine paper machine. The main dryer section consists of seven top-felted dryer groups followed by a size press, with three top-felted dryer groups in the after-dryer section. The dryers are 1.8-m diameter and are equipped with spoiler bars and stationary siphons. During the test the machine was producing 75 g/m² copy paper at 1,255 m/min. Furnish is bleached kraft.

The fabric tension was varied in the fourth section from 2.1 to 3.7 kN/m (2.3 to 4.1 kPa contact pressure). The estimated solids content in and out of the fourth section was 59 to 65%, which falls within the 50 to 70% range of the lab trials. Cylinder temperature in the fourth group varied from 115 to 121°C.

The results of the field trials are compared to the lab results for fine paper in Fig. 6. There is a reasonably good agreement both in terms of the magnitude of the drying rate and, more importantly, the trend of increasing drying rate with contact pressure. Drying rate increased by 15.1% and 11.5% for the field and lab trials respectively, over the range of fabric tensions tested on the machine.

Linerboard: Measurements were made on two linerboard machines, referred to as machines A and B.

Machine A was a modern machine producing linerboard from 100% recycled fibre. The dryer section consists of one single-felted dryer group followed by three double-felted groups, or a total of 45 drying cylinders. The dryers are 1.8-m diameter and are equipped with spoiler bars and stationary siphons. For the test the machine was operating at 650 m/min, making 170 g/m² linerboard from 100% OCC.

Measurements were made on the second (13 dryers) and third (14 dryers) dryer groups on separate days. Tensions were varied from 1.4 to 3.0 kN/m (1.6 to 3.3 kPa). The third and fourth dryer groups are used as the control groups. With a cascade steam and condensate system, the pressure in the second group varies with the third and fourth (generally 0.75 to 1.0 bar below the third group). This meant that steam pressure changed in the groups under investigation during the test. As the machine was run at constant speed (constant drying load), the condensing rate did not change significantly.

An indication of the effect of felt tension on drying performance can be seen from the overall and contact heat transfer coefficients, which were calculated from the condensing rate data and measurements.
of shell and sheet temperature. The results of the calculations for the third group are shown in Fig. 7.

The contact coefficient was observed to increase by approx. 12%, and the overall coefficient by 7.7% over the range of tensions tested.

An interesting deduction from the data is that fully 55% of heat-transfer resistance is attributed to the contact resistance.

The average steam pressure in the entire dryer section was reduced from 9.7 to 8.5 bar (140 psig to 124 psig), and from 9.6 to 9.2 bar (139 psig to 133 psig) over the range of tensions tested on the second and third dryer groups respectively. This suggests that the effect of fabric tension on drying rate was more pronounced in the earlier drying phase. However this conclusion is clouded by the fact that over the course of the tests on the third dryer group, base ply primary refiner power increased significantly, which suggested possible changes on the run affecting furnish and drainage.

Machine B is a large, modern machine producing linerboard from 100% recycled fibre. The main dryer section consists of four single-felted dryers, two double-felted groups, four single-felted groups followed by a size press with four single-felted dryer groups, four single-felted groups of four single-felted dryers, two double-felted dryer groups respectively. This produces linerboard from 100% recycled furnish to increase by approx. 12%, and the overall group increased by 10% over the range of tension tested, with most of the increase observed from 1.75 to 3.2 kN/m (10 to 18 pli). From 3.2 to 3.9 kN/m (18 to 22 pli), the increase in drying rate was small. This indicates that the effect of the steam pressure run during the test there would be little benefit at running fabric tension above 18 pli, although lab tests at this and higher temperatures indicate that drying rate should continue to rise.

**CONCLUSIONS**

Measurements were carried out on four paper machines on three different paper grades. Drying rates were calculated from condensing rate data, and then compared to drying rate data from lab tests for similar paper grades and at similar solids content (50-70%). Time limitations prevented a more detailed analysis over a broader range of sheet solids.

Drying rates increased with increasing fabric tension, the rate of increase dropping off as a maximum drying rate was approached. The trend of increased drying rate with increased dryer fabric tension for newsprint and fine paper was similar or slightly greater than that observed in the lab - at similar shell temperatures. Measurements on one machine (i.e., B) producing linerboard showed a maximum drying rate at a lower tension than observed in the lab, support the concept that temperature has a significant influence on dryer fabric tension effect, as has been shown in previous work by the author.

The results indicate that operation with elevated dryer fabric tension (above those levels typically used in industry today) is beneficial to drying performance. This supports the need for machine builders to design roll, bearings and other fabric loaded components to withstand higher loads than used in the past.

The machines tested in this study were operated at fabric tensions within the limits established by the machine builder. Mills would be well advised to verify and respect the felt tension rating of their paper machine equipment before operating at elevated fabric tension to avoid equipment failure or damage to dryer clothing.

The results of the mill trials validate the lab-drying rig as a viable tool to predict the influence of dryer fabrics on drying rates.

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**LITERATURE**


Résumé: Une récente étude en laboratoire a démontré l’effet positif de la vitesse de séchage lorsqu’on élève la tension de la toile sécheuse. Dans la présente communication, les résultats des essais en usine avec diverses catégories de papier (papier journal, papier fin et carton couverture) sont présentés à l’appui des résultats des essais en laboratoire, et montrent qu’il est possible d’améliorer considérablement la capacité de séchage en utilisant des toiles sécheuses à des degrés de tension plus élevés que ceux qui sont couramment utilisés dans l’industrie.


Keywords: DRYER FELTS, TENSION, DRYER SECTIONS, DRYERS, PERFORMANCE, PAPER GRADES.