Quantifying Results and Improving Performance Using Advanced Instrumentation

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INTRODUCTION

For more than 20 years, instruments have been available to measure the moisture content of press felts. This technology utilised a microwave resonance chamber to produce an analogue signal that could correlate to the gsm of water in a press fabric. These resonance chamber units wer sensitive to thermal expansion and contraction and had relatively low sampling rates.

In recent years, however, a planar sensor has been developed to provide a digital signal at extremely high (1024 Hz) sampling rate. New instrumentation can measure sheet consistency in the forming and press section, as well as fabric moisture content for diagnostics. This high sampling rate allows for data manipulation to provide analysis such as FFT (Fast Fourier Transform) and 3D fabric mapping. These tools will show sources of pulsation/vibration and fabric or process variations, that could not be seen in 2D line graphs.

The accuracy of these planar sensors now can provide sheet and fabric water content in the forming and press sections, and consistency of the sheet itself in open draws.

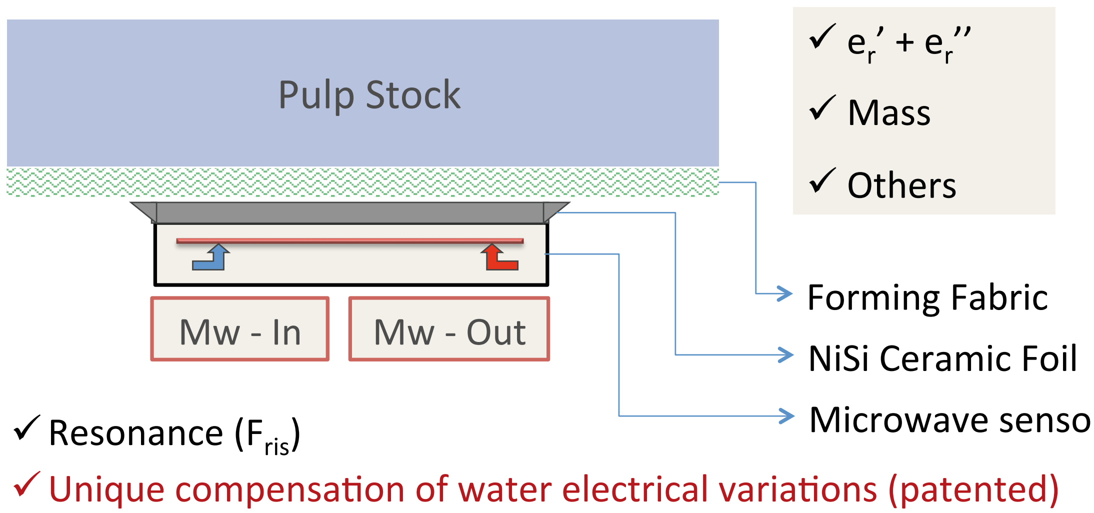

Figure 1. *New planar sensor operates without a resonance chamber*

THE INSTRUMENTS

A. Principles of Operation

Older technology relied upon nuclear radiation from so-called “back-scatter” gauges. There were numerous issues with nuclear technology, not the least of which were inherent radiation risk, governmental regulation, having a separate radiation officer, and disposal of the radioactive source material after its useful life.

A new generation of instruments have been developed using microwave technology. These units use less radiation than that produced by a cell phone, and is safe to the touch.

Figure 1 demonstrates that a fabric or a fabric/sheet passing over the head will cause a change in the flux of the microwave field set up between the incoming source (antenna) and the receiver. That microwaves cause resonance in water molecules above the sensor, means that all the sensor perceives is the water itself, not the fibre, the fabric, or the surrounding machinery.

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B. The Instruments

In the forming section the FibreScanFIX can be mounted anywhere that the roughly 10 x 12cm head can fit. Since the instrument does not see the machine framing in its measurements, tight fitting spaces can be accommodated between table elements.

FORMING SECTION MICROWAVE MOISTURE-MEASURING UNITS

The instrument is available in both portable and fixed versions. The fixed version comes with a control box that is usually mounted in the control room. It is equipped with 8 inputs for sensor heads at various locations. It also has 8 analogue outputs with a 4-20 ma signal used for controlling whatever strategy is employed, and one digital output for interface with the machine’s DCS.

Figure 2. *The head for measuring felt moisture and/or felt and sheet moisture.*

The control box is the same unit used for all machine-mounted instruments for the forming, press, and other applications.

MACHINE MOUNTED FORMING UNIT

In the press section, there are two instruments used. The first, the PresScan, is used to measure felt moisture, and felt/sheet moisture combined. Standard applications involve determining the efficiency of uhle boxes and doing water balances to determine the relative contribution of each dewatering element. The most common application is in reducing vacuum consumption for uhle boxes and suction rolls.

These instruments are also available with traversing scanning capability. These units measure felt moisture, permeability and temperature. These EasyScan units are equipped with 3D felt mapping capability and can be interfaced with the machine's DCS.

THE FIXED HEAD FOR MEASURING FELT AND FLET/SHEET MOISTURE

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SHEET CONSISTENCY MEASURING SENSOR

In the past, only heavy weight sheets could be measured in open draws because the sensor head had to be in contact with the sheet, and only special cases could tolerate this without the risk of sheet breaks. Our "new generation" technology now allows the sheet to be as far as several millimeters away from the sensor head, and still achieve +/- 1 gsm accuracy.

All the instruments described will provide an analogue output for controlling, and a digital output for interface with the papermachine's DCS.

CASE STUDY 1

In this case, assistance was requested to convert machine operations from newsprint/LWC production, to 100% OCC corrugating medium. The gap former section (figure 5) was designed for completely different sheet formation and sheet properties, than would be required with the new paper grades. From this work, a desired set of running conditions could be presented to mill management that had the projected outcomes for sheet properties and/or energy savings; the

Our "new generation" technology now allows the sheet to be as far as several millimeters away from the sensor head, and still achieve +/- 1 gsm accuracy.

Figure 3. *The traversing and fully programmable felt scanner*

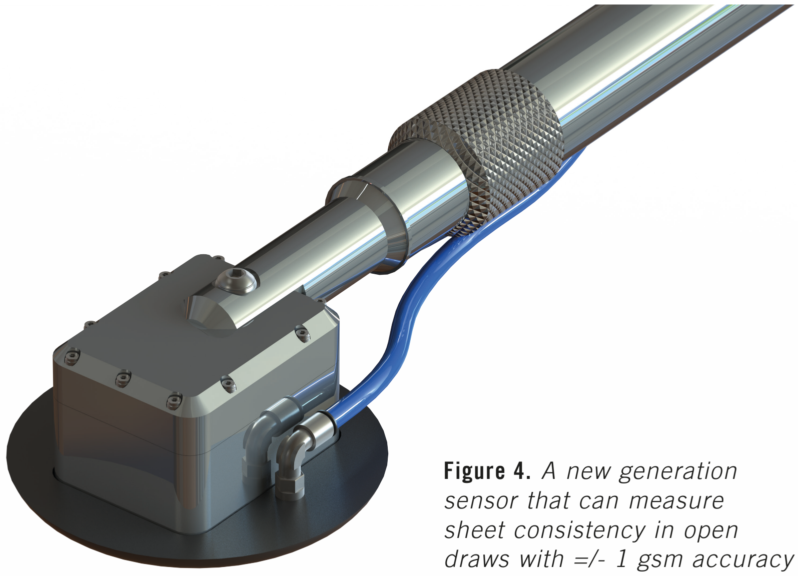

Figure 4. *A new generation sensor that can measure sheet consistency in open draws with =/- 1 gsm accuracy*

people running the machine could then make informed decisions about the set-up that would produce the best overall results. As a follow-up, recommendations were also made that would allow the instruments to control – rather than simply monitor – the water being removed. This eliminates day to day variables such as stock differences, refining, temperature, or any other incoming issues.

FORMING SECTION WITH ZONES IDENTIFIED

The drainage curve measured was typical of what is seen on gap formers, with much dewatering happening early in the process, and relatively less done in the "high vacuum" areas.

DRAINAGE CURVE IN "STANDARD MODE"

Our experiment design consisted of changing practices to reflect lower vacuums in the early drainage elements and higher/lower vacuum in the last (or high vacuum) areas, as seen in Fig. 6. Standard operating conditions are shown in Fig. 7.

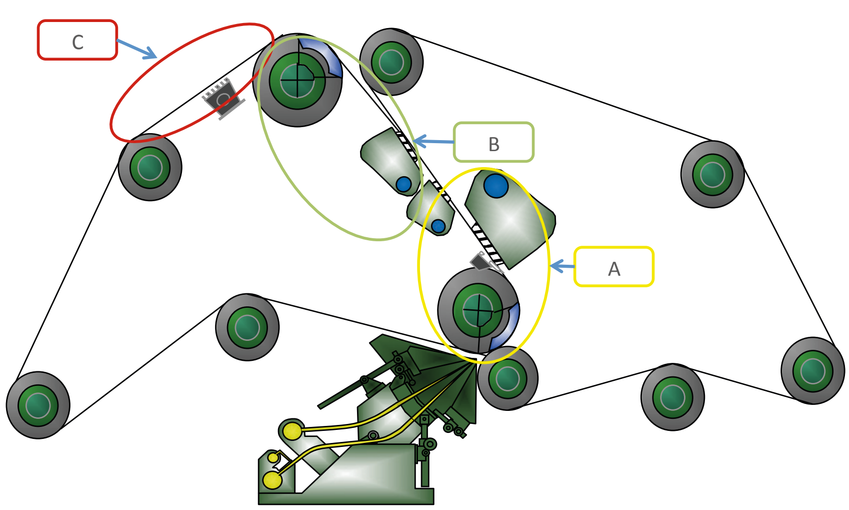

Figure 5. *A side elevation drawing of the forming section. To simplify analysis the section has been divided into 3 zones.*

		ZONE A				ZONE B				ZONE C	
Conditions	N°	Forming roll kPa	Shoe 2nd kPa	Shoe 1st kPa	Shoe 3rd kPa	suction box kPa	Duovac 1 kPa	Duovac 2 kPa	CR Low kPa	CR High kPa	Hivac kPa
Base cond	1	10	5	10	15	15	20	25	37	49	43
Zone A low	2	5	0	5	10	15	20	25	37	49	43
Zone A+B low	3	5	0	5	10	10	15	25	27	49	43
Zone A+C low	4	5	0	5	10	15	20	25	37	49	10
Zone A+B+C low	5	5	0	5	10	10	15	25	27	49	10
Zone C +B Low	6	10	5	10	15	10	15	25	27	49	10
Zone C low	7	10	5	10	15	15	20	25	37	49	10
Zoen B Low	8	10	5	10	15	10	15	25	27	49	43
Base repetead	9	10	5	10	15	15	20	25	37	49	43
Best	10	5	0	5	10	5	10	25	20	49	10

Figure 6. *The plan shows lower vacuums in zone 1, lower vacuums in zone 2, and lower/higher vacuums in zone 3*

STANDARD CONDITIONS

Paper Machine Parameters

Stock system		**Stock system**	
Stock	100% OCC	**Stock**	100% OCC
Basis weight	85 gr/m2	**Basis weight**	85 gr/m2
Machine speed	964 m/min @ reel 940 m/min @wire	**Machine speed**	964 m/min @ reel 940 m/min @wire
WW system	0,301%	**WW system**	0,301%
Jet ratio	1,031		
HB flow	79510 l/min		
Forming section			
Configuration	Valmet Forming roll+ 3 zone shoe		
Fabrics	....		
Vacuum			
Forming roll (bottom)	5 kPa	**DUOVAC (bot)**	20 / 25kPa
Shoe (top box)	5-10-15 kPa	**COUCH 1-2**	<u>37/49</u> kPa
Suction (bottom box)	<u>15 kPa</u>	**HIVAC**	<u>43</u> kPa
Press Section			
Press loadings	**1° nip: 200 kN/m - 2° nip shoe Press: 1100 kN/m**		
Draws	2,5%		

Figure 7. *Documentation of "starting conditions", i.e. settings from previous newsprint/lwc runs*

TRIAL PLAN

It has been seen in numerous other installations that the strategy of lower vacuums early in the process can significantly reduce the drive load in the forming section without negatively impacting sheet properties or steam consumption in the dryer section, so this is the strategy that was being evaluated.

The actual tests were carried out over roughly one hour spans, allowing jumbo rolls to be produced for testing. Simultaneously, drive loads in the forming section were being observed and recorded. Test results for each condition were summarised and put into spreadsheet form. These results will be discussed later in the paper, but all conditions produced "in spec" paper.

Date		28-May	28-May	28-May	28-May	28-May	28-May	28-May	28-May	28-May	28-May
Time		10.00	10.13	11.09	12.02	13.30	13.55	14.45	15.40	16.30	17.40
Jumbo out		10.11	11.55	11.58	12.52	13.50	14.40	15.35	16.26	17.20	
		4011791	4011792	4011793	4011794	4011795	4011796	4011797	4011798	4011799	4011800
Run		1	1	1	1	1	1	1	1	1	
Sample		1	2	3	4	5	6	7	8	9	
Description		Base cond	Zone A low	Zone A+B low	Zone A+C low	Zone A+B+C low	Zone C +B Low	Zone C low	Zone B Low	Base repetead	Best
Laboratory											
Basis weight		99.6	99.6	98.5	99.7	100.2	99.4	98.4	98.1	98.5	98.8
Burst	kPa	257	271	268	266	262	256	251	261	261	261
Burst Index		2.58	2.73	2.78	2.67	2.61	2.58	2.55	2.66	2.65	2.64
Elongation CD	%L	2.53	2.48	2.18	2.34	2.8	2.51	2.27	2.66	2.23	2.56
Elongation MD	%L	2.06	2.05	1.98	1.94	2.05	1.93	2.04	1.99	2.02	2.02
Porosity	ml/min	149	180	213	233	209	212	205	217	239	232
Ratio SCT MD/CD		2.1	1.99	2.02	2.04		2.04	2.01	2.01	1.98	2
Ratio Tensile MD/CD		3.35	3.28	3.29	3.16	3.18	3.13	3.17	3.14	3.2	3.17
Ratio TSI md/CD		2.61	2.55	2.49	2.48	2.51	2.49	2.48	2.48	2.51	2.5
Roughness bs	ml/min	1534	1440	1538	1390	1564	1530	1548	1448	1558	1562
Roughness ts	ml/min	1596	1540	1581	1432	1601	1531	1527	1595	1576	1576
SCT CD	kN/m	1.49	1.62	1.66	1.61	1.55	1.55	1.59	1.59	1.57	1.57
SCT MD	kN/m	3.11	3.2	3.35	3.26	3.09	3.15	3.17	3.21	3.1	3.12
Tensile strenght CD	kN/m	1.81	1.91	1.93	1.9	1.88	1.86	1.87	1.92	1.89	1.91
Tensile strenght MD	kN/m	6.05	6.23	6.33	6.13	4.88	5.8	5.92	6.01	6.05	6.05
Tickness	µm	151	153	150	152	152	153	151	149	152	151
TSO avg	°	1	0.9	0.4	1.5	-0.6	1.1	1.2	1.2	0.1	0.7
TSO min	°	-1.8	-2.3	-2.3	-2.5	-7.8	-4.2	-4.2	-3.2	-4	-4.2
TSO Max	°	4.5	4.6	2.9	4.3	3.6	6.1	5.4	5.4	3.1	4.2
CMT (30) calc	N	150	155	165	160	149	152	154	156	149	150
CMT Manual measurement		**155**	159	169	159	158	160	153	**152**	**151**	**158**

Figure 9. *Actual test Results*

PERCENTAGE CHANGE IN TEST VALUES

	Base cond	Zone A low	Zone A+B low	Zone A+C low	Zone A+B+C low	Zone C +B Low	Zone C low	Zone B Low	Base repetead	Best
Basis weight	0.6	0.6	-0.6	0.7	1.2	0.4	-0.7	-1.0	-0.6	-0.3
Burst	-0.8	4.6	3.5	2.7	1.2	-1.2	-3.1	0.8	0.8	0.8
Burst Index	-1.3	4.4	6.3	2.1	-0.2	-1.3	-2.5	1.7	1.3	1.0
Elongation CD	6.3	4.2	-8.4	-1.7	17.6	5.5	-4.6	11.8	-6.3	7.6
Elongation MD	1.0	0.5	-2.9	-4.9	0.5	-5.4	0.0	-2.5	-1.0	-1.0
Porosity	-23.2	-7.2	9.8	20.1	7.7	9.3	5.7	11.9	23.2	19.6
Ratio SCT MD/CD	2.9	-2.5	-1.0	0.0	-100.0	0.0	-1.5	-1.5	-2.9	-2.0
Ratio Tensile MD/CD	2.3	0.2	0.5	-3.5	-2.9	-4.4	-3.2	-4.1	-2.3	-3.2
Ratio TSI md/CD	2.0	-0.4	-2.7	-3.1	-2.0	-2.7	-3.1	-3.1	-2.0	-2.3
Roughness bs	-0.8	-6.9	-0.5	-10.1	1.2	-1.0	0.1	-6.3	0.8	1.0
Roughness ts	0.6	-2.9	-0.3	-9.7	0.9	-3.5	-3.7	0.6	-0.6	-0.6
SCT CD	-2.6	5.9	8.5	5.2	1.3	1.3	3.9	3.9	2.6	2.6
SCT MD	0.2	3.1	7.9	5.0	-0.5	1.4	2.1	3.4	-0.2	0.5
Tensile strenght CD	-2.2	3.2	4.3	2.7	1.6	0.5	1.1	3.8	2.2	3.2
Tensile strenght MD	0.0	3.0	4.6	1.3	-19.3	-4.1	-2.1	-0.7	0.0	0.0
Tickness	-0.3	1.0	-1.0	0.3	0.3	1.0	-0.3	-1.7	0.3	-0.3
TSO avg	81.8	63.6	-27.3	172.7	-209.1	100.0	118.2	118.2	-81.8	27.3
TSO min	-37.9	-20.7	-20.7	-13.8	169.0	44.8	44.8	10.3	37.9	44.8
TSO Max	18.4	21.1	-23.7	13.2	-5.3	60.5	42.1	42.1	-18.4	10.5
CMT (30) calc	0.3	3.7	10.4	7.0	-0.3	1.7	3.0	4.3	-0.3	0.3
CMT Manual measurement	1.3	3.9	10.5	3.9	3.3	4.6	0.0	-0.7	-1.3	3.3

Figure 10. *△ in test values from standard, as a percentage*

SEVEN TRIAL CONDITIONS PLUS STANDARD

Date		28-May	28-May	28-May	28-May	28-May	28-May	28-May	28-May	28-May	28-May
Time		10.00	10.13	11.09	12.02	13.30	13.55	14.45	15.40	16.30	17.40
Jumbo out		10.11	11.55	11.58	12.52	13.50	14.40	15.35	16.26	17.20	
		4011791	4011792	4011793	4011794	4011795	4011796	4011797	4011798	4011799	4011800
Run		1	1	1	1	1	1	1	1	1	
Sample		1	2	3	4	5	6	7	8	9	
Description		Base cond	Zone A low	Zone A+B low	Zone A+C low	Zone A+B+C low	Zone C +B Low	Zone C low	Zoen B Low	Base repetead	Best
FiberscanONE											
Shoe	gr/m2	1748	1770	1748	1840	1870	1880	1880	1812	1812	
Suction box	gr/m2	1158	1234	1338	1250	1402	1320	1204	1278	1210	
Duovac	gr/m2	820	820	882	860	890	860	860	870	860	
CR	gr/m2	468	460	472	460	480	480	475	480	470	
Hivac	gr/m2	450	430	415	460	475	475	475	470	450	450
Press solids	gr/m2	782	790	790	790	810	810	810	810	810	
2nd Press felt	gr/m2	690	700	700	700	720	720	720	720	720	720
Hivac water flow (net)	l/min	2296	2143	2028	2373	2488	2488	2488	2449	2296	2296
Shoe	%	5.59	5.52	5.59	5.31	5.22	5.19	5.19	5.39	5.39	-171.25
Suction box	%	8.59	8.03	7.38	7.93	7.03	7.49	8.24	7.75	8.20	-171.25
Duovac	%	12.38	12.38	11.46	11.77	11.35	11.77	11.77	11.62	11.77	-171.25
CR	%	22.95	23.40	22.73	23.40	22.30	22.30	22.56	22.30	22.84	-171.25
Hivac	%	23.99	25.27	26.33	23.40	22.56	22.56	22.56	22.84	23.99	23.99
Press solids	%	50.72	51.27	51.27	51.27	51.27	51.27	51.27	51.27	51.27	-15.14
Delta Hivac/Ecoflow	l/min	472.29	441.20	509.39	480.83	565.64	543.64	566.64	595.37	496.29	480.29
Press solids(ecoflow+fsfix)		51.88	53.06	50.54	51.57	48.63	49.36	48.60	47.68	51.01	51.59
Drainage Shoe	L/min	10749	10750	10742	10767	10773	10775	10774	10761	10760	10505
Drainage Suction box	L/min	4516.0	4102.7	3138.3	4516.0	3582.2	4286.4	5174.3	4087.4	4607.9	0.0
Drainage Duovac	L/min	2587.2	3168.9	3490.4	2985.2	3919.0	3521.0	2633.1	3123.0	2679.0	0.0
Drainage CR	L/min	2694.3	2755.5	3138.3	3061.7	3138.3	2908.6	2946.9	2985.2	2985.2	0.0
Drainage HV	L/min	137.8	229.6	436.3	0.0	38.3	38.3	0.0	76.5	153.1	-3444.4
FiberscanFix 1	%	14.2	14.6	14.1	15.2	13.9	14.0	14.0	13.8	14.8	13.2
FiberscanFix 2	%	23.9	25.2	27.0	22.1	21.1	21.5	21.5	23.3	23.3	21.8

Figure 8. *Test conditions*

SHEET PROPERTY MEASUREMENTS

Rolls from each trial were tested per the mill's criteria. The results of these tests are shown in Fig. 9, and the percentage change is shown in Fig. 10.

Taking the analysis of the test data one step further, we summed the △ percentages for each test condition which resulted in the chart shown as Fig. 11.

As can be seen in Fig. 11, the best sheet quality readings come from running zones a. and b. at lower vacuums, allowing the later dewatering elements to compensate.

DRIVE LOAD REDUCTION AND RUNNABLILITY

Fig. 12. shows that zone a. has the potential of providing the greatest potential for drive load reduction, since 42% of the total drive is consumed in that area. The forming roll, being a rotating element, will have significantly less impact on the total load than does the shoe – which, of course, is stationary; this results in high drag and consequent forming fabric wear.

It was noted that the machine could also run well with vacuum lowered in zones a, b, and c. In fact, the press section could accommodate higher water loads when all 3 zones were lowered and the Hi-vac was completely turned off. When turned off, however, the trim tail became unstable and wavered on the table, so a low (10 kPa) vacuum needed to be applied at the Hi-vac for runnability purposes.

the press section could accommodate higher water loads when all 3 zones were lowered and the Hi-vac was completely turned off.

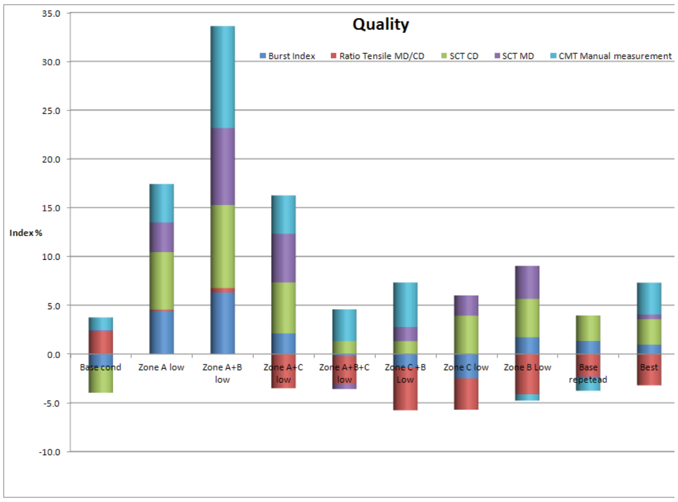

Figure 11. *The "Quality Index" is compiled by summing the percentage change in properties from the standard settings*

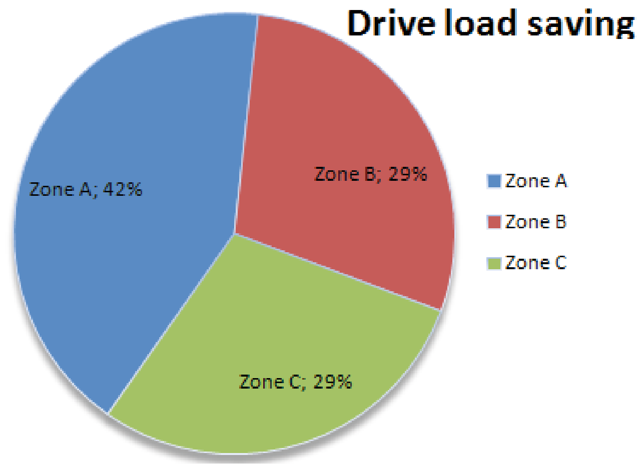

Figure 12. *The percentage of total forming section drive in each zone*

Obviously, the highest drive load savings occurred when vacuum was lowered in all 3 zones. ***Total drive savings when vacuums were lowered in all 3 zones was 363 kWh.*** As can be noted in the results tables, the total consistency delivered to the press section decreased by 2.5%. Steam pressure decreased during the run with all 3 zones lowered, from 41.2 t/h, to 40 t/h. It is unclear whether changes in stock occurred during that time, or perhaps the increased porosity measured during the trial allowed the sheet to dry more easily. ***Vacuum load requirements also dropped by 67 kWh, resulting in total savings of 430 kWh for the "best" drives setting.***

CASE STUDY 2

In this case study, the mill had two objectives: firstly, to obtain energy savings from reduction of vacuum pump and drive load requirements in the forming section, and secondly, to establish a control loop before the top wire unit to control incoming consistency.

MACHINE SIDE ELEVATION OF THE FORMING SECTION

In this study the variables to be observed are

a) the microwave water content readings (g/sqm and l/min.)
b) vacuum levels (mbar)
c) drive load
d) paper properties

The study was conducted in 2 phases; firstly, a varying vacuum on the suction boxes pre-top wire, and secondly, with the operation in closed control loop to the 3rd suction box, immediately before the top wire unit. It was anticipated that several grade changes would occur over the life of the study. In the benchmark mode, it was observed that the couch roll had a 22% loadshare, the wire turning roll had a 48% loadshare, and the top wire drive roll had a 30% loadshare for a total of 426 kW.

the highest drive load savings occurred when vacuum was lowered in all 3 zones.

DRAINING CURVE IN INITIAL MODE

These measurements indicate an incoming consistency to the top wire of 3.7%, the consistency of the bottom ply after the vacufoils being 7.1%, and an estimated consistency of more than 10% at the bonding point – a level considered to be quite high for good ply bond. The water removed by the top wire was 1,330 l/min/m, compared to what is considered good industry practice of 1,600 l/min/m. It was hypothesized that the top wire unit could do more work and help the z-direction uniformity of the sheet, which had shown to be a positive impact on sheet properties. In the initial settings, pre-couch consistency was 16.3%.

In a series of steps, vacuum to the first 3 suction boxes was reduced from 140 to 80mbar in box 1, from 140 to 100mbar in box 2, and from140 to 100mbar in box 3. Consequently, the higher incoming consistency (to the top wire) forced the top wire to remove more water; this produced a 17.6% pre-couch consistency, and an 8% improvement in overall solids. Measured amperage was 383 kW – a 10% reduction in drive load. The load share percentages did not change.

It is theorised that the bottom ply was at least partially sealed in the initial measurement, and sending a wetter overall sheet into the secondary headbox, allowed greater overall water removal.

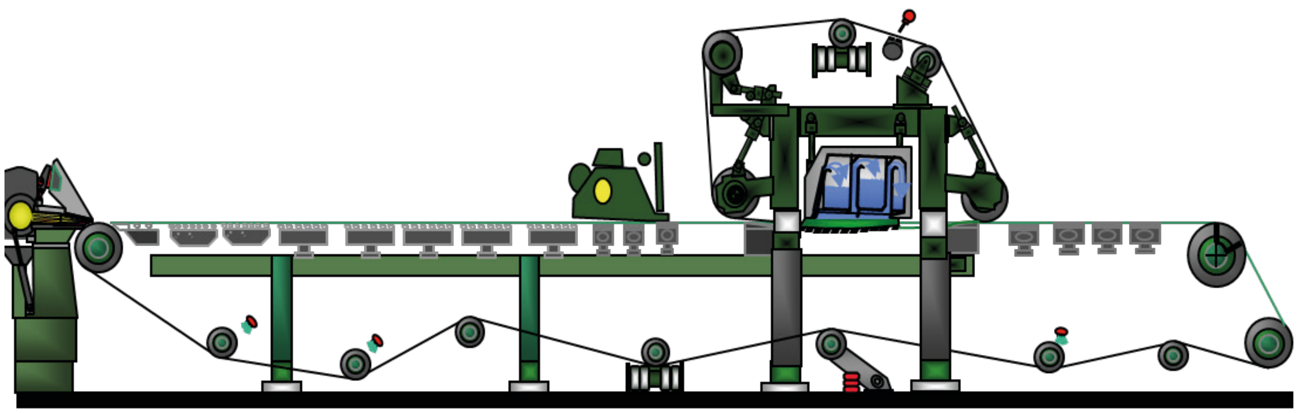

Figure 13. *The dewatering units*

Cost savings… can be achieved by the scientific application of vacuum in the forming and press sections.

The 2nd phase of this trial involved putting suction box 3 in “control mode” by using the 4-20ma output from the microwave device. Water content measurements of the incoming sheet (to the top wire) were made first, allowing the operators to use their “normal” operating methods, and then putting the 3rd suction box into “control” mode, allowing an approach valve to open and close, proportionate to the signal. Incoming variables such a temperature, refining, raw material, and pH were accommodated. Fig. 14 shows a time domain during which the trial was run. Reduction in variability is visually obvious on the run chart.

CONCLUSIONS

- New microwave instrumentation allows measurement of fabric and/or sheet water content in the press and forming sections, as well as sheet consistency in open draws.
- Process parameters can be benchmarked and controlled using sheet water content as a measurement target.
- Sheet properties can be benchmarked and controlled using water content measurements at critical points on the forming table.
- Cost savings in vacuum reduction and drive load reduction can be achieved by the scientific application of vacuum in the forming and press sections.

Water inlet value vs basis weight.

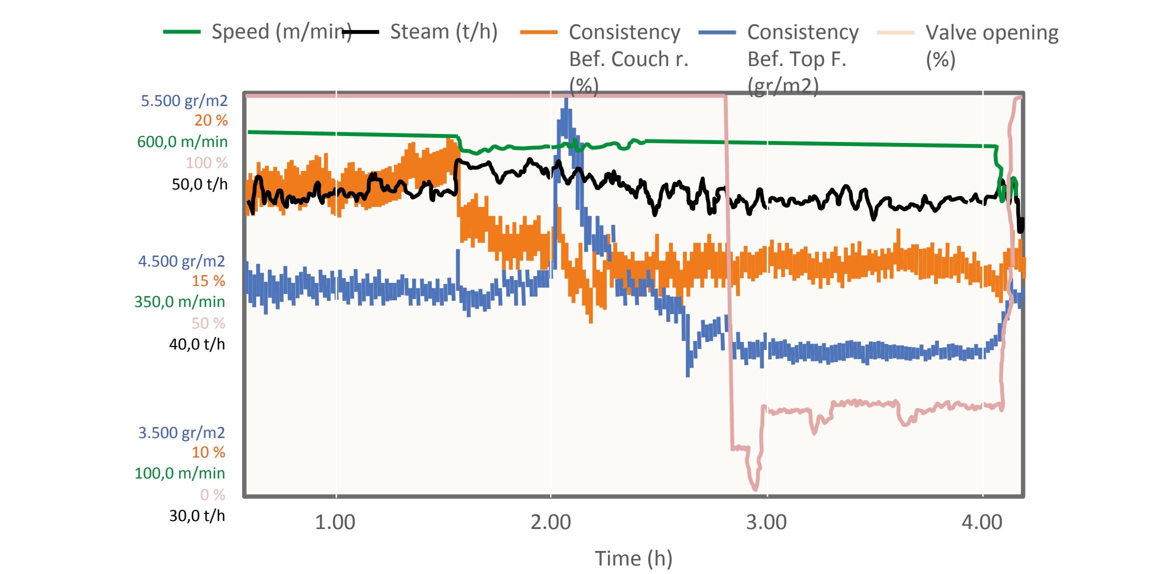

Figure 14. *Water content (blue) without control mode (left and center right) vs. in control mode (lower right). Variability is greatly reduced.*