How can you evaluate your Paper Machine with the TSO Tester?

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Introduction

Many paper makers around the world are happy with the way their Paper Machine is operating. Some smaller adjustments made to the Jet/Wire ratio, to the Fiber Furnish, Dewatering on the Forming section etc.

But are you satisfied with the end result, the Paper you are making? Can the quality become better? Are you running the Furnish on the high side, i.e. putting too many good fibers in, instead of adjusting the Paper machine?

I am going to go thru the steps how to evaluate the Production using a TSO Tester. It will be shown in steps, and also with comments for different Headboxes, Press sections, Furnish etc.

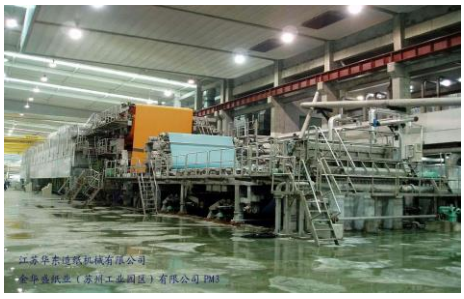
The TSO Tester

Fourdrinier

Let's start with the basics, with a one layer Fourdrinier Machine. The first thing to do is to take a sample from the Machine Reel across the web, and run it in a TSO tester.

The results will tell you if the TSO Angle is as it should be across the machine, i.e. +/- 3-5 degrees variation and crossing the Center of the Web/Paper Machine at 0 degrees. If it does not meet these criteria's there will be a need to make adjustments.

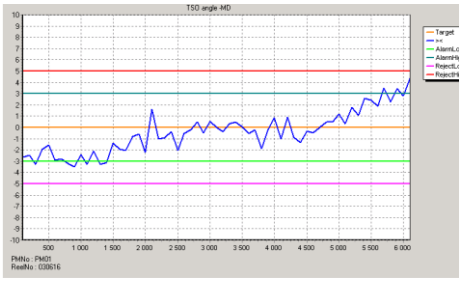
A Fourdrinier Paper Machine



Track your settings of the Paper Machine, in this case the Headbox settings:

- Jet/wire ratio – Rush or Drag
- L/b value – Pressure Forming or Velocity Forming
- Wire speed – total Capacity as well as actual speed
- Total Head – Total Capacity as well as current volume
- Type of Headbox – Open, Hydraulic, with or without Dilution Control
- Manual adjustments or Automatic adjustments
- Edge Flow valves/Bleeders
- Re-circulation Valve
- Furnish composition
- Wet End Chemistry

TSO Angle Ideal profile

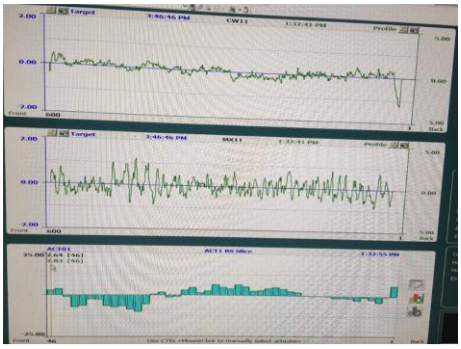


Quality parameters

Different type of Grades needs to be adjusted differently. This will be discussed further in this paper.

- Caliper Profile – from your On-line system
- Basis Weight Profile – from your On-line system
- Moisture Profile – from your On-line system
- Lab data
    - Which Paper Property are you adjusting against?
    - Are you close to set point
    - Variations within specifications, i.e. International Standards (TAPPI, ISO, DIN)

Typical Online profile



Lab Data

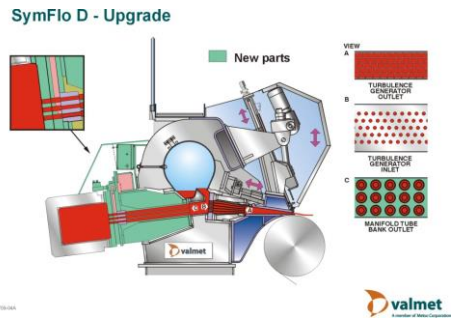
PMNo		PM8		GradeID		Kondopoga		OrderID		12345			
ReelNo		221007		Grammage		42		Date		05/12/2007 10:54:00			
PropertyName	Unit	Mean	StdDev	Min	Max	OK	Errors	Target	AlarmLow	AlarmHigh	RejectLow	RejectHigh	
Roughness 98 TS	ml/min	161	12.2	135	190	26	0	160	130	200	125	225	
Roughness 98 BS	ml/min	256	24.7	207	303	26	0	160	130	200	125	225	
Thickness	µm	68.62	1.061	66	71	26	0	68	65	73	60	75	
T9I MD	kNm/g	9.6	0.129	9.38	9.88	26	0	9.5	9.35	9.95	9	10	
T9I CD	kNm/g	2.11	0.083	1.93	2.23	26	0	2.1	1.9	2.3	1.75	2.45	
T9I MD/CD	--	4.56	0.157	4.29	4.92	26	0	5	4.5	5.5	4	6	
T3O Angle +L	Degrees	1.37	0.962	-1.56	3.2	26	0	0	-3	3	-5	5	
Scale 0.6	--	49.6	0.9	47.9	51.5	26	0	50	47	53	40	80	
Scale 0.8	--	31.9	0.63	30.7	33.1	26	0	30	25	35	20	40	
Scale 1.25	--	23.1	0.56	21.9	24	26	0	23	18	28	15	30	
Scale 2.0	--	17.8	0.51	16.6	18.6	26	0	18	16	20	13	23	
Scale 3.0	--	15.7	0.51	14.7	16.7	26	0	15.5	14.5	16.5	13	18	
Scale 5.0	--	16.4	0.82	15.3	18	26	0	16.5	14.5	18.5	13	20	
Scale 8.0	--	19.2	1.32	16.9	22	26	0	19	16.5	22.5	15	25	
Scale 14.0	--	26.5	3.22	21.7	34.1	26	0	25	20	30	15	35	
Scale 22.0	--	33	5.68	21	49.1	26	0	33	20	50	18	55	
Scale 37.0	--	43	10.11	27.9	64.2	26	0	45	27	65	20	70	
L&W Tensile Strength MD	kN/m	2.34	0.232	1.93	2.74	26	0	2.35	1.9	2.8	1.5	3	
L&W Tensile Stretch MD	%	0.83	0.108	0.63	0.98	26	0	0.8	0.6	1.2	0.4	1.4	
L&W TEA MD	J/m²	11.42	2.681	6.9	16.18	26	0	11	6	16	5	17	
L&W Tensile Strength CD	kN/m	0.61	0.056	0.52	0.69	26	0	0.6	0.5	0.7	0.4	0.8	
L&W Tensile Stretch CD	%	1.81	0.252	1.31	2.22	26	0	1.8	1.3	2.3	1.1	2.5	
L&W TEA CD	J/m²	7.26	1.536	4.64	9.74	26	0	7.25	4.6	9.8	4	10	
Grammage	g/m²	41.7	0.58	40.7	43.1	26	0	42	41	43	40	44	

Problems areas

Typical Problems that you find when starting to evaluate the situation at a Mill with a Fourdriner, a one Layer Paper Machine are the following:

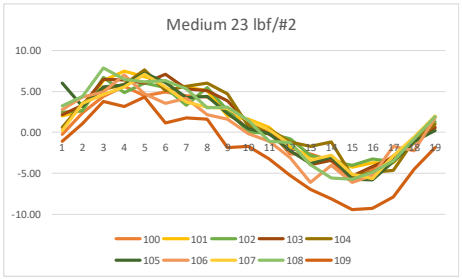
- The TSO Angle has a much higher variation then what it should be.
    - Will it be possible to adjust the Jet/Wire Speed to get a bigger or smaller difference?
    - If answer is Yes! Go step by step by changing the Jet Speed in small steps to avoid Paper Breaks and other disturbances in the Production. Take a new sample for each setting and compare the information.
      If we are getting improvements in the TSO Angle, how does it affect your production and Paper properties? If Positive, continue step by step until you reach a good TSO Angle profile.
      If you are not getting a positive results, change to lower the Jet Speed and see what happens when the Jet/Wire Speed difference changes.

Example of Headbox



- The TSO Angle is showing uneven profiles, i.e. the crossing of the TSO Angle is not in the Center of the Machine.
    - Adjust you Re-circulation valve in small steps, open or close depending on your true Jet/Wire Speed difference.

TSO Trial



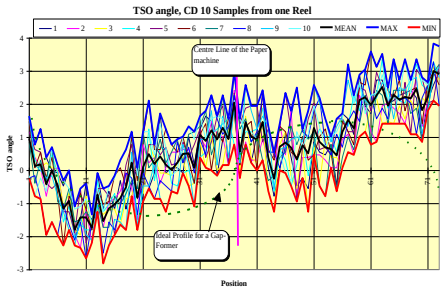
By opening or closing the re-circulation valve you will see with each sample taken if the Cross point is moving to where you want it to go, i.e. crossing the center.

Most machine operators look at the sight glass to establish if the machine is correctly adjusted. This might be a good way to check the re-circulation, but it doesn't include clogged tubes or other disturbances.

- If your machine shows pulsations or vibrations, try to find out the origin of these disturbances.
    - The reasons can be:
        - White water pump running at to high volume i.e. the Pumps are making the flow instable and thus pulsations. Check the Short Circuit of your Paper Machine.
        - Breast roll shaker – can be good to get improved Formation, but with too high Frequency or Amplitude it causes Vibrations/pulsation in the sheet forming
          Check with taking 10 samples across the machine from the same Machine Reel and compare the Profiles in a Spread Sheet. Additionally it is good to take a Machine Directional sample approx., same length as the Forming wire. Her you will immediately detect if there are Pulsations/Vibrations in the Forming of the Paper Web.

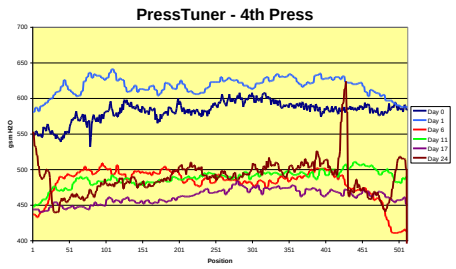
Breast Roll Shaker

Example with 10 profiles from the same machine Reel



Disturbances can derivate from other parts of the Paper Machine, such as Press Section, Dryer Section, Winder, Re-Winder and addition Size Press, Coating Section, Calendar etc.

Felt Moisture Profiles

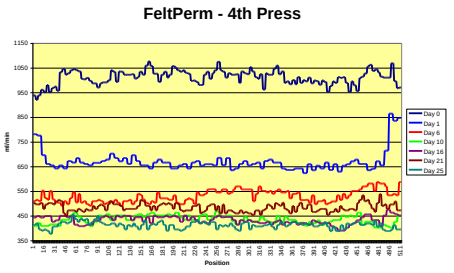


Important values and tests to compare your TSO/TSI data with are:

- Moisture Profile(On-line profiles and lab data)
- Caliper Profile (On-line profile and lab data)
- Basis Weight Profile (On-line profile and lab data)
- Press section information:
    - Felt Moisture Profiles

    - Felt Permeability Profiles
    - Nip Pressure Profiles
    - Felt age and History, wear and Tear
    - Showers
    - Cleaning
- Paper Machine Alignment
    - Has to be done on a regular schedule if not there be a mis-alignment that shows up in an un-even Quality profile

Felt Permeability Profiles

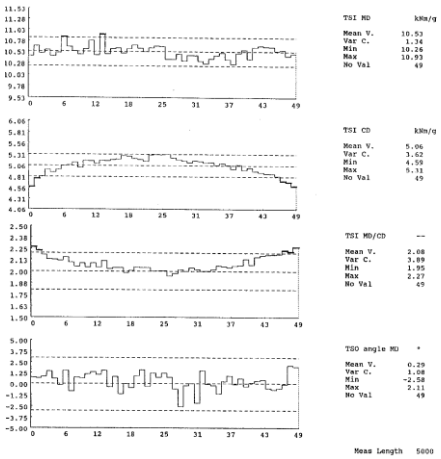


When the TSO Angle Profile is as per the experience from over 500 of Paper Machines World Wide, i.e. Crossing the Machine at 0 degrees in the middle of the machine and the variation is between +/- 3-5 degrees, then we can look at our TSI Profiles.

TSI –Profiles are

- TSI-MD – the variation of our TSI number in the Machine direction. Should be +/-5% across the web, to avoid runnability issues in the Converting Process
- TSI-CD – the variation of our TSI number in the Cross direction. Should be +/-10% across the web, to avoid shrinkage and as it is comparable with many Quality Parameters, such as bending Stiffness, SCT(STFI), RCT etc. we need to keep an eye on the results.
- TSI-MD/CD ratio is the result of how the TSI-MD and TSI-CD Profiles turns out. Different Grades of Paper have different thresholds.
    - Newsprint 3.0 – 5.0
    - Linerboard 1.8 – 2.2 (Strength related)
    - Linerboard 2.0 – 2.4 (Burst related)
    - Sack Kraft 1.8 -2.2 (Standard sack)
    - Sack Kraft 1.0 (Clupack)
    - Copy Paper 1.8 – 2.2 (sheeted)
    - Printing Grades 2.0 – 2.5 (roll-to-roll)

Typical TSI profiles



Multi-layer Machines

Are these machines very different to a Single layer Fourdrinier Machine? Not really but the approach is a little more complicated as we need to know from where the disturbances are coming.

Unfortunately we cannot turn of one or several layers and run the layers separately. We have to use other methods to establish the factual settings.

Multi Layer Machine

To split the sheet would be ideal, but is not very easy to do.

One important thing to take in to consideration, and that is that 2 or more layers have to be set in more or less the same way as the base ply. If not the sheet might curl and even twist even if the TSO Angle profile looks perfect as per our expectations.

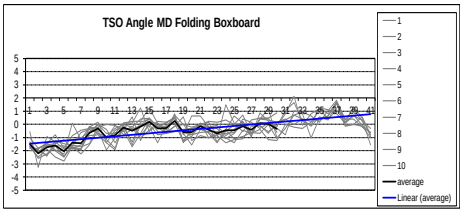
Track your settings of the Paper Machine, in this case the Headbox settings:

- Jet/wire ratio – Rush or Drag (especially Main ply and each additional headbox)
- L/b value – Pressure Forming or Velocity Forming (are you able to change on all headboxes or only the base ply?)
- Wire speed – total Capacity as well as actual speed (for each Headbox)
- Total Head – Total Capacity as well as current volume (same system for all headboxes or separate ones?)
- Type of Headbox – Open, Hydraulic, with or without Dilution Control (different set-ups are common)
- Manual adjustments or Automatic adjustments
- Edge Flow valves/Bleeders (on Base ply only or does the other layers also have this function?)
- Re-circulation Valve (Has to be checked for each Headbox and set correctly)
- Furnish composition (Depending on Grade)
- Wet End Chemistry (Depending on Grade)

Quality parameters

Different type of Grades needs to be adjusted differently. This will be discussed further in this paper.

TSO Angle Profile – Board



- Caliper Profile – from your On-line system
- Basis Weight Profile – from your On-line system
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    - Variations within specifications, i.e. International Standards (TAPPI, ISO, DIN)

Additional Tests to be made

We have seen the advantage of also testing samples taken in the machine direction as well. With a sample taken from the edge or the center of the machine, with a length of approximately one Wire length, any machine directional variation will show up.

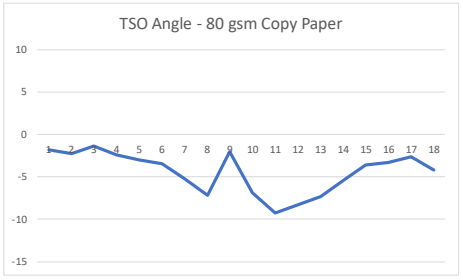
It can be for example how much the Breast Roll shaker effects the results.

It can be for example how the Heat control of a Dilution control Headbox might change the results.

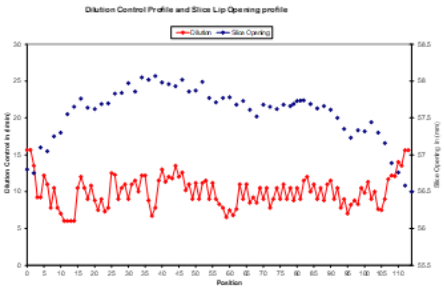
By analyzing the Frequencies and Amplitudes, you will be able to determine which part of the Paper Machine is effecting the variations.

When doing a Trial it can be good to compare the lab data from the most important Quality Parameters and see if you can improve or if they deteriorate.

Old Copy Paper Machine



Dilution Control Paper Machine



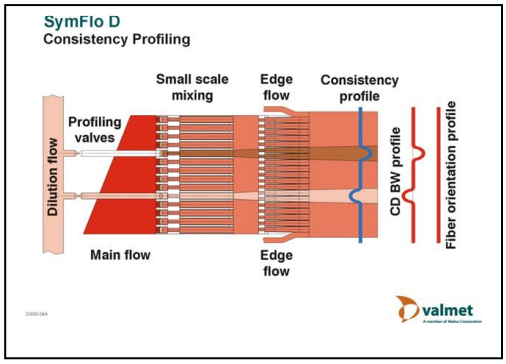
Summary

To plan the adjustments to be made we need approximately one week and a lot of testing and comparing data. Normally you will reach an acceptable result relatively easily.

We believe that the TSO Tester is a great tool to help to get the evaluation the Paper Machine setting done in a faster way and it is also good to monitor the production on a daily basis.

For example several of the Paper machine Suppliers are using the TSO tester to facilitate the start-up of a New paper Machine or after a mayor re-built.

Consistency Profiling (Valmet Concept)

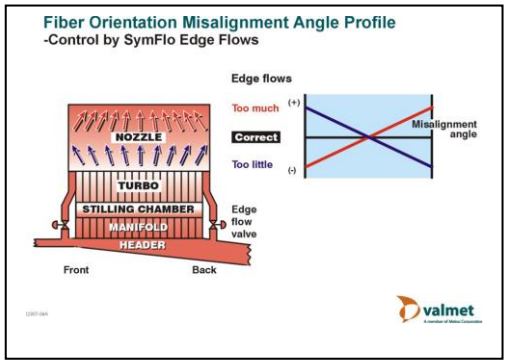


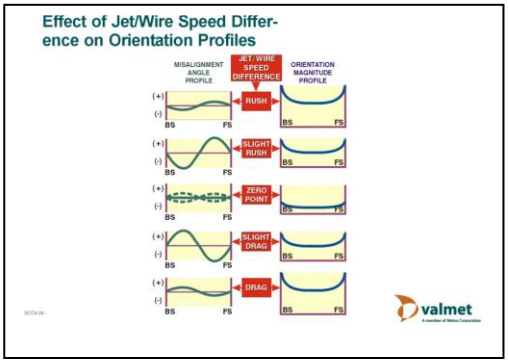
In order to be able to adjust both the Grammage Profile and the Fiber Orientation Profile the control is independent from each other. The dilution control adjusts the Consistency Profile i.e. Grammage Profile while the Fiber Orientation Profile can be adjusted separately. The Valmet Concept also includes Edge Flow Valves, which can be very useful to adjust the Fiber Orientation, without loosing Grammage.

Fiber Orientation Mis-Alignment Angle Profile

More or less all modern Headboxes are built in the same way. I.e. a Tapered Header to facilitate the even pressure across the Paper Machine, a Manifold with Stilling Chamber and a Turbo Chamber to accelerate the Fibers when released thru the Nozzles.

With a Higher Pressure in the Headbox, you will achieve the Higher velocity of the Jet when hitting the Wire. With the edge Flow valves you are able to change the Velocity from each edge towards the Center of the Paper Machine.





Jet/Wire Speed Difference

When the Jet Speed and the Wire Speed are equal, the Speed difference is 0. This is not a very stable situation and should be avoided.

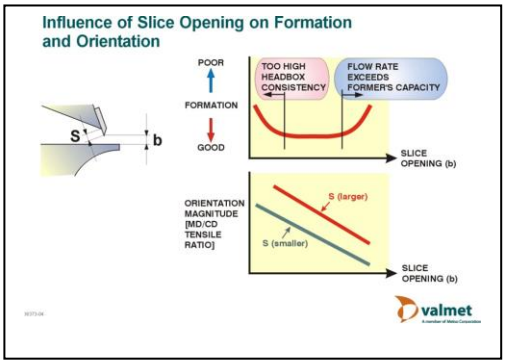
When the Jet Speed is higher then the Wire speed you will Rush the sheet and when the Wire speed is higher you will be Dragging the sheet

Influence of the slice Opening on Formation and Orientation

Most Paper Machine Headboxes have a fixed setting between the Slice Lip Opening (L) and the Slice Lip (s)

By changing (L) you are able to influence the Formation which will be better with a moderate Slice Opening.

By changing the Lip (s) you will influence the Magnitude of MD/CD Ratio

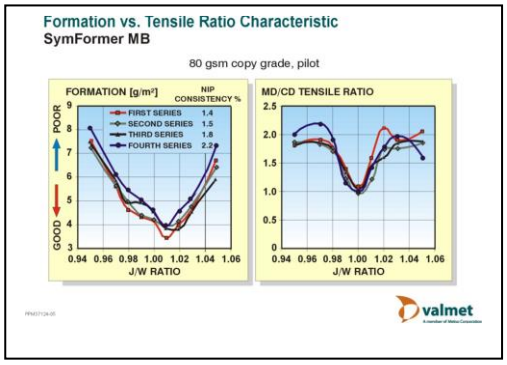


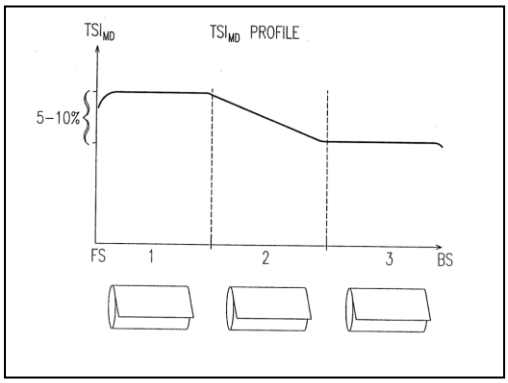
Formation and Tensile Ratio on a Symformer (Valmet)

The picture to the right shows what happens with the

Formation when changing the Jet/Wire Ratio. A lower number indicates better Formation.

MD/CD Tensile Ratio shown as a function to the Jet/Wire Ratio. Here is more a question to find the ideal setting for the Grade of Paper Produced.





The Variation allowed on the TSI-MD Profile

As indicated earlier the variation allowed depends on the Grade, but should not exceed +/-10%

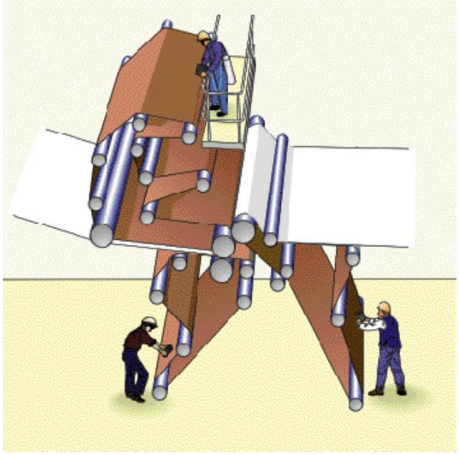
In case of a Printing Grade a larger variation would indicate:

- Mis-register problems
- Roll hardness problems
- Wrinkles
- Pipes, Cockling etc.

A Typical Press section

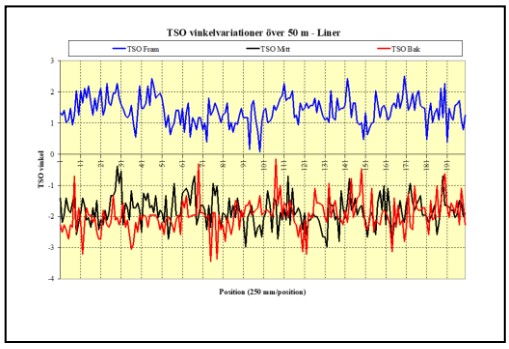
The persons shown on the picture indicates where You should measure the Press Felt Moisture and/or Press Felt Water Permeability.

A well adjusted and Maintained Press section allows The Paper Machine to have longer runs, better and equal Quality and better economics.



A Machine Directional Sample tested with a TSO Tester

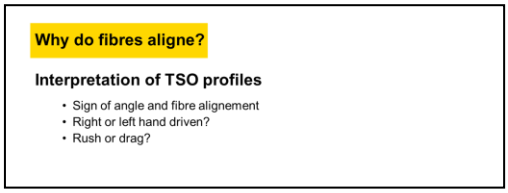
A sample 50 m long was taken in the center position and at each edge of the Reel. It was tested with 25 cm step length to be able to evaluate the variation in the MD direction.



We can clearly see a variation of max +/- 2 degrees which is considered very good.

Why do Fibers align?

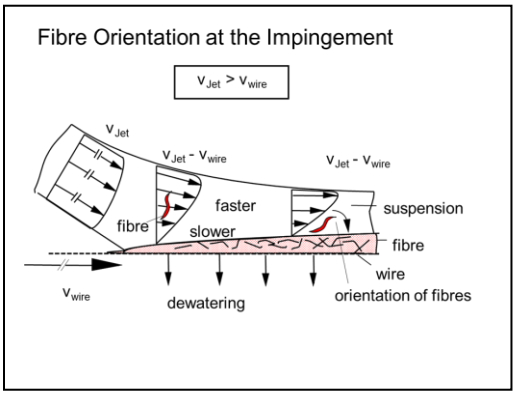
Important questions, that needs to be addressed. We will below, try to do this in a good way.



Fiber Orientation at the Impingement

Inside the Headbox we are trying to have the fibers free from each other and easy to control. The Manifold with its Turbulator achieves this, but as soon as the Fiber has left the Slice and is prepared to land on the Wire, we have an issue.

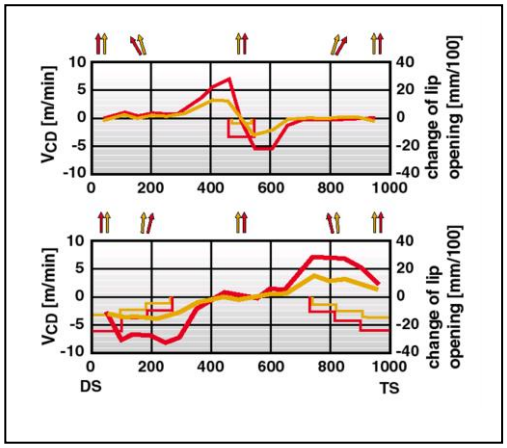
The Wire it self advances with a set speed, decided by the Control System of the Paper Machine.

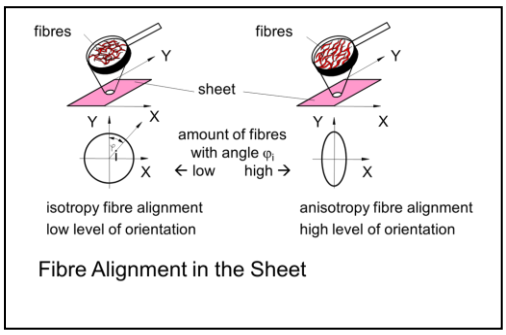


As you can see from the picture to the right, we assume same Jet Speed (vJet) at the exit, and due to the suspension thickness the Jet Speed changes. I.e. higher speed on top and lower closer to the Wire. Eventually the Fibers land on the Wire and are dragged down by the dewatering sequence.

Jet Speed changes across the web

The Picture to the right describes the Jet Speed variation across the web as well as what happens when the Lip Opening changes.
The top Graph shows what happens at the Center of the Head Box.
And the lower Graph shows what happens when Lip opening is changed at the edges.
Consequently the Slice Lip Opening effects the Jet Speed, and thus also the Fiber Orientation.

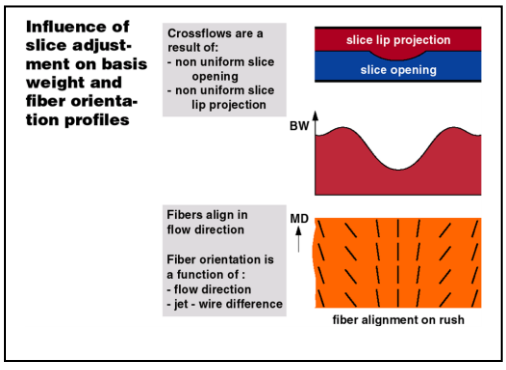




Fiber Alignment in the Sheet

When you have a perfect Isotropy, i.e. the TSI-MD = TSI-CD or TSI-MD/CD Ratio = 1. This happens theoretically in a Hand sheet Former or when you produce Sack Kraft with a Clu-Pack Unit.

In all other cases the TSI-MD>TSI-CD, thus we have a Fiber Orientation or the sheet is Anisotrop.



The Influence of Slice adjustment on Basis Weight and Fiber Orientation Profiles

By changing the Slice Lip Opening, you change the Jet

Speed. Smaller Opening means higher Jet Speed, and Bigger Opening means slower Jet Speed.

By changing the Jet Speed you also change the Fiber Orientation. We would like to have a consistent Jet Speed/ Wire Speed difference across the sheet (Headbox). Due to Cross flows this is only achieved in theory. In reality there are many influences to the Cross flow, and thus an uneven Fiber Orientation. The Basis weight changes also when the Slice Lip Opening is changed. A bigger opening means more flow and thus more fibers, higher Basis Weight is achieved. In case of Dilution Control the Basis Weight can be controlled independently to the Slice Opening and thus being able to Control the Fiber Orientation at the same time.

TSI/MD/CD Ration versus RCT and Burst Strength

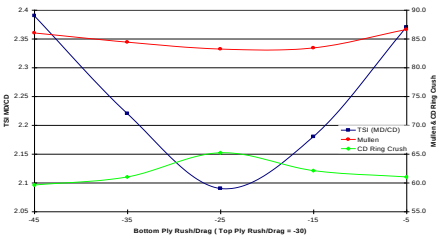
On very good trial to make is when changing the Jet/Wire Ratio also log the values for RCT(SCT) and Bursting Strength. Typically for a Liner Grade.

To the right we see the three Graphs,

- TSI-MD/CD versus Speed Difference between Jet Speed and Wire Speed.
- RCT-CD versus Jet-Wire Speed Difference
- Bursting Strength versus Jet-Wire Speed Difference

The TSI-MD/CD Ratio reaches its lowest point at no Speed Difference (Theoretically) in reality at minus 25 Feet/Min.

TSI-MD/CD versus RCT and Burst Strength



At this point the RCT-CD is at its highest while the Burst is almost at its lowest point.

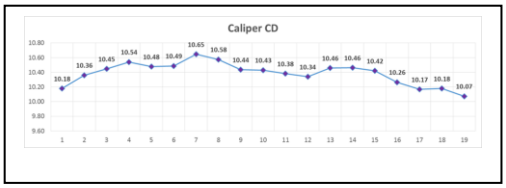
We need to decide which of the properties are the most important for each Grade.

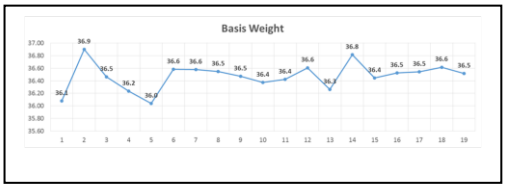
Re-circulation Valve Setting

The regulator for the Re/circlulation at a typical Tampella Head Box.

Caliper and Basis Weight Profiles

Besides the TSO&TSI Profiles it is also important to monitor the Caliper and the Basis Weight Profiles.
To the right we have one Caliper Profile And one Basis Weight Profile.





All the above information have been collected during almost 30 years of working with the TSO Tester. It gives the non-experienced user an idea what needs to be done to achieve perfect Profiles for the TSO

Angle, TSI-MD, TSI-CD, TSI-MD/CD Ratio and of course all other important properties in the Paper Sheet Produced.

For additional information Please contact:

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