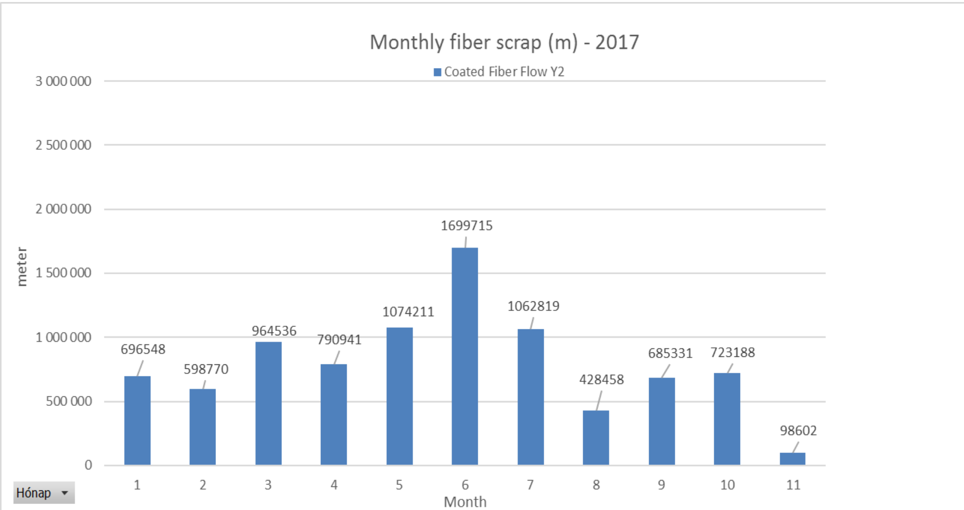
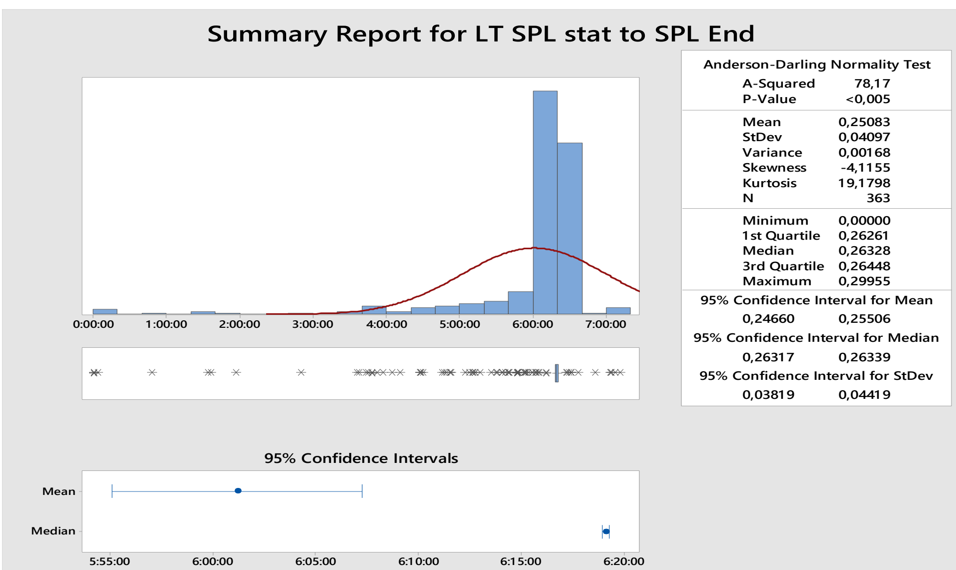
Technical project - using Minitab

A short summary related to

- **Predictive maintenance, and**
- **Time series analysis**

Business case and context





Business case

2017 data confirmed that large and greatly varying amount of fiber scrap

Summary report of production runs also confirmed that 24% of production runs – which should take 6 hours 19 to 23 minutes – did get finished a lot earlier, and so those runs were disturbed.

The expectation was to reduce **scrap** and improve production **equipment availability**.

Context

The graphs are related to a product that represents 80% of the overall factory output.

Its production process has two main sections. First fiber is produced and rolled onto spools. This is the semi finished product.

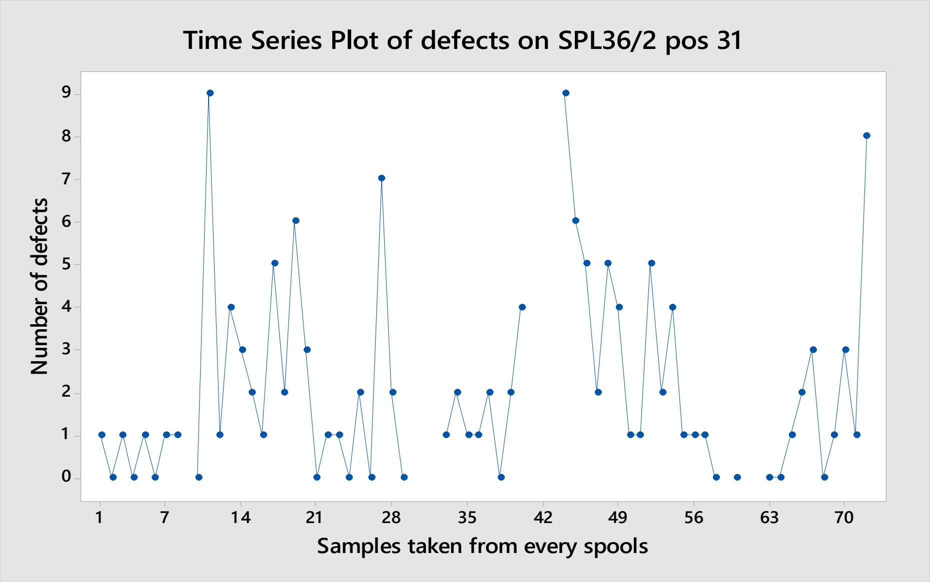
The spools are than taken to module production where the finished product is made.

The fiber is produced on two lines. The two lines has equal capacity, and they are identical.

Problem and goal statement

Problem statement:

During 2018 wk32 – 35, a measurement series revealed that SPL36/2's position 31 had an unexpected number of defects on ZW500 FLOW polymer membrane samples taken for a quality analysis.



Goal statement:

The project intended to find some of the root causes of the large number of defects as well as some of the root causes of the large variation to reach a statistically significant performance change, improvement. This is meant on SPL36/2 position 31-36 only.

The statistically significant performance change should be seen on

Primarily:

- defect rate by sampling of spools right after production,

Secondarily

- module quality of sampled spools.

Project timescale and risks

Miles stones	Schedule
1, Problem selection and project definition	10.09.2018
2, Creating the understanding of the current situation	21.09.18
3, Identification and checking of possible reasons and causes	28.09.18
4, Generating possible solutions	05.10.18
5, Select the solution	15.12.18
6, Plan and test/pilot the solution	31.01.19
7, Implement, standardize and control	31.05.19
8, Assess and validate achievements	15.12.19

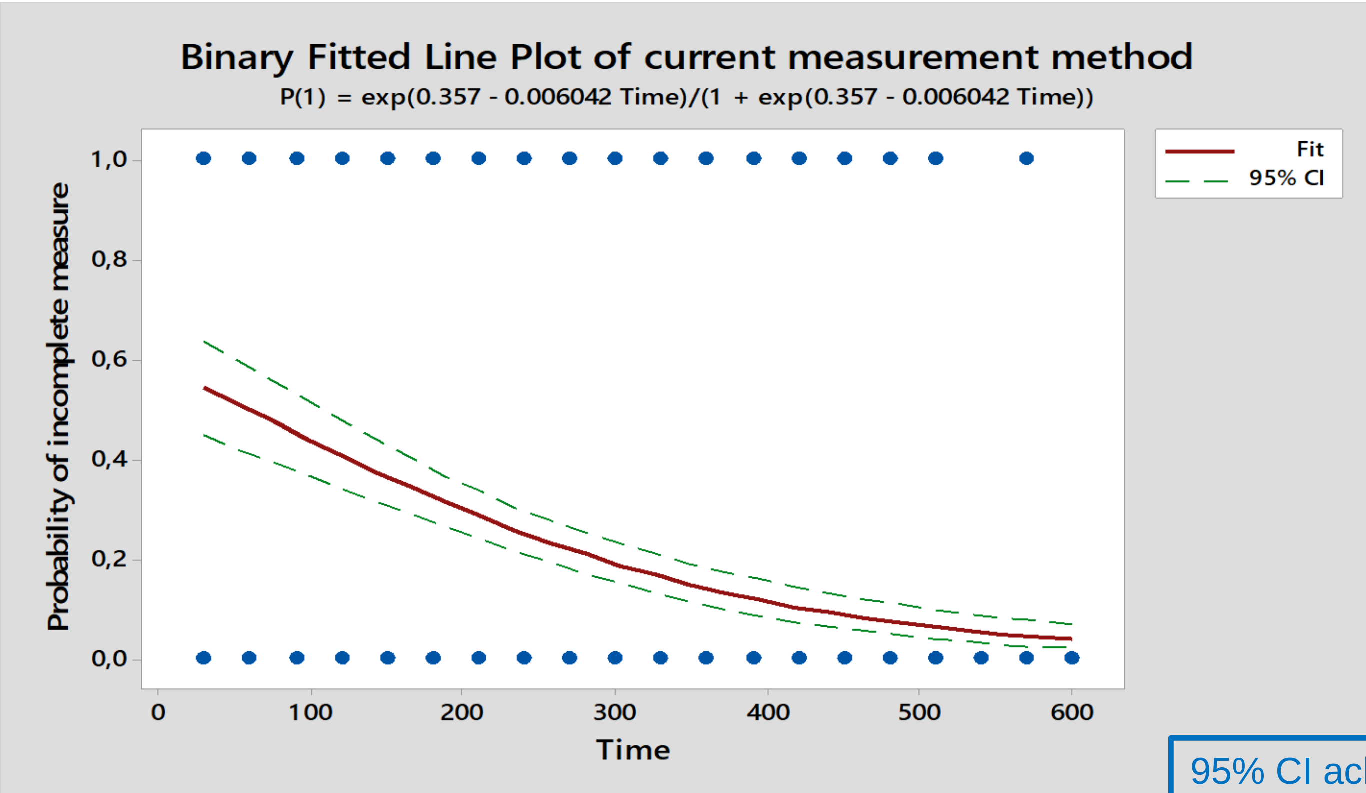
Risks

1. Unknown change in the standards of operation that can be technical and/or process oriented; this would influence the measurement results without knowing its background, so it would lead to wrong conclusions
2. Sickness of team members
3. Many days of holidays taken by any of the team members
4. Unknown approach(es) or tool(s) for the team members used during the project
5. Hectic workload of team members that makes the completion of project work difficult or impossible
6. Unsolved arguments on results/conclusions
7. Change in production method on the production line due to e.g. trials.

How to handle the risks

1. Daily / weekly review to confirm the standard way of operation
2. Case by case
3. Holiday plans are reviewed till the end of November; in case of changes, everyone is responsible to communicate it at least by the weekly project meeting
4. MS Team and special statistical methods are trained
5. Weekly task review
6. Weekly follow up and discussion; in addition, R&D)is an initial approver, so any senior leader can be shown results if it agrees to do so
7. such type of operation cannot happen during the project, if it is needed then it happens on 36/1 machine.

Defect measurement process validation



Predict Seconds	CI - high	Prediction	CI - low
30	0,447208	0,543771	0,637151
60	0,411779	0,498567	0,585441
90	0,376572	0,453386	0,532484
120	0,341756	0,408960	0,479747
150	0,307464	0,365973	0,428723
180	0,273831	0,325019	0,380759
210	0,241066	0,286577	0,336866
240	0,209533	0,250991	0,297565
270	0,179753	0,218471	0,262856
300	0,152296	0,189100	0,232361
330	0,127610	0,162856	0,205542
360	0,105922	0,139626	0,181873
390	0,087236	0,119238	0,160911
420	0,071389	0,101476	0,142300
450	0,058119	0,086101	0,125757
480	0,047117	0,072867	0,111049
510	0,038068	0,061530	0,097977
540	0,030673	0,051858	0,086370
570	0,024660	0,043636	0,076075
600	0,019790	0,036667	0,066954
630	0,015858	0,030775	0,058884
660	0,012693	0,025804	0,051751
690	0,010149	0,021619	0,045455
720	0,008109	0,018100	0,039903
750	0,006475	0,015144	0,035012
780	0,005167	0,012665	0,030707
810	0,004122	0,010588	0,026921
840	0,003287	0,008848	0,023594
870	0,002621	0,007392	0,020672
900	0,002089	0,006174	0,018107
930	0,001664	0,005156	0,015856
960	0,001326	0,004305	0,013882
990	0,001056	0,003594	0,012152

95% CI achieved

Purpose and conclusions:

It was assessed if the current measurement process is capable to reveal the defects. The measurement process was based on pressurized gas. The larger size defects were visible as bubbling points by that.

However, it did take some time until the defects could get visible. The current testing time was 30 seconds at the time of the assessment. The assessment confirmed it had to be longer in order to provide reliable results. 95% CI could be reached by 11.5 minutes testing time.

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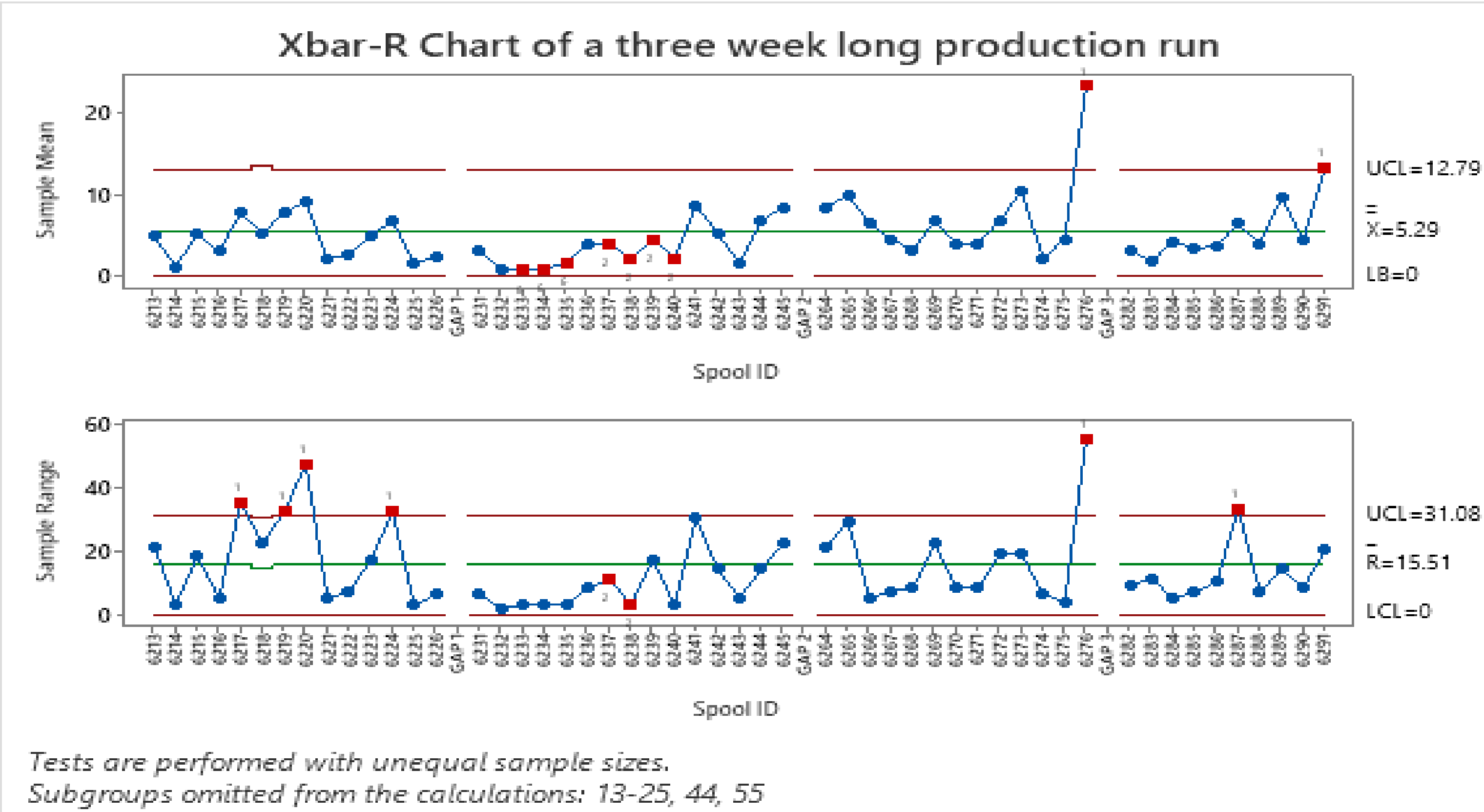
Process behavior



Operational definition of Y measure: the average number of defects on 6 pcs of 30 meter long fiber samples kept under 4 psi pressure for 10 minutes.

To set the base line, the process behaviour was reviewed by the above Y measure data and its evaluation.

The data describe a three week long period. The process was not stable.

Sampling

For the base line setting, our sampling approach was established as introduced below. This was then used during the project work.

Our approach was a standard process sampling. A predefined length (30 m) of fiber was taken from each spools of the six positions. Positions are meant as parallel fiber runs produced at the same on the same machine.

In this way, samples were taken once in each 6 hours during working days, and one sample subgroup consisted of 6 times 30 m long samples.

The data we collected while base line setting was also used to validate our sampling strategy. Based on the below result, it was accepted as suitable.

Method

Parameter	Mean
Distribution	Normal
Standard deviation	2.5 (estimate)
Confidence level	95%
Confidence interval	Two-sided

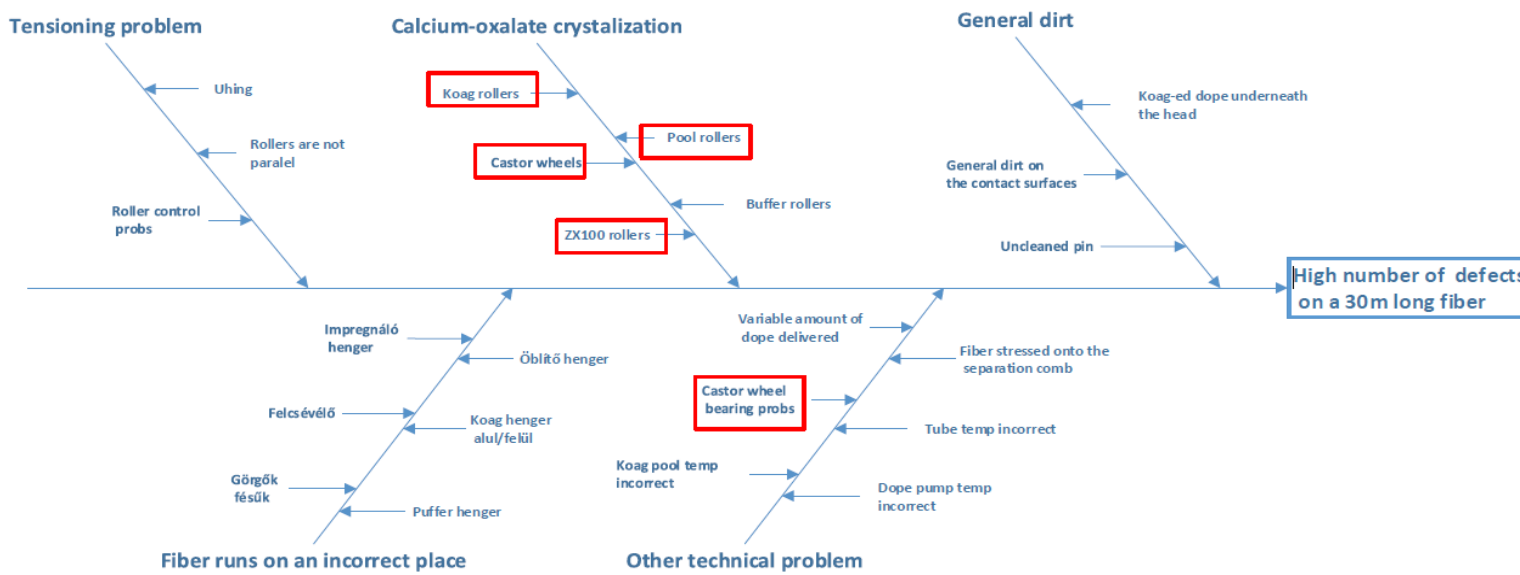
Results

Sample Size	Margin of Error
30	0.933515

Root cause identification

During a workshop, possible root causes were collected and prioritized by the project team. The important ones are highlighted below by red.

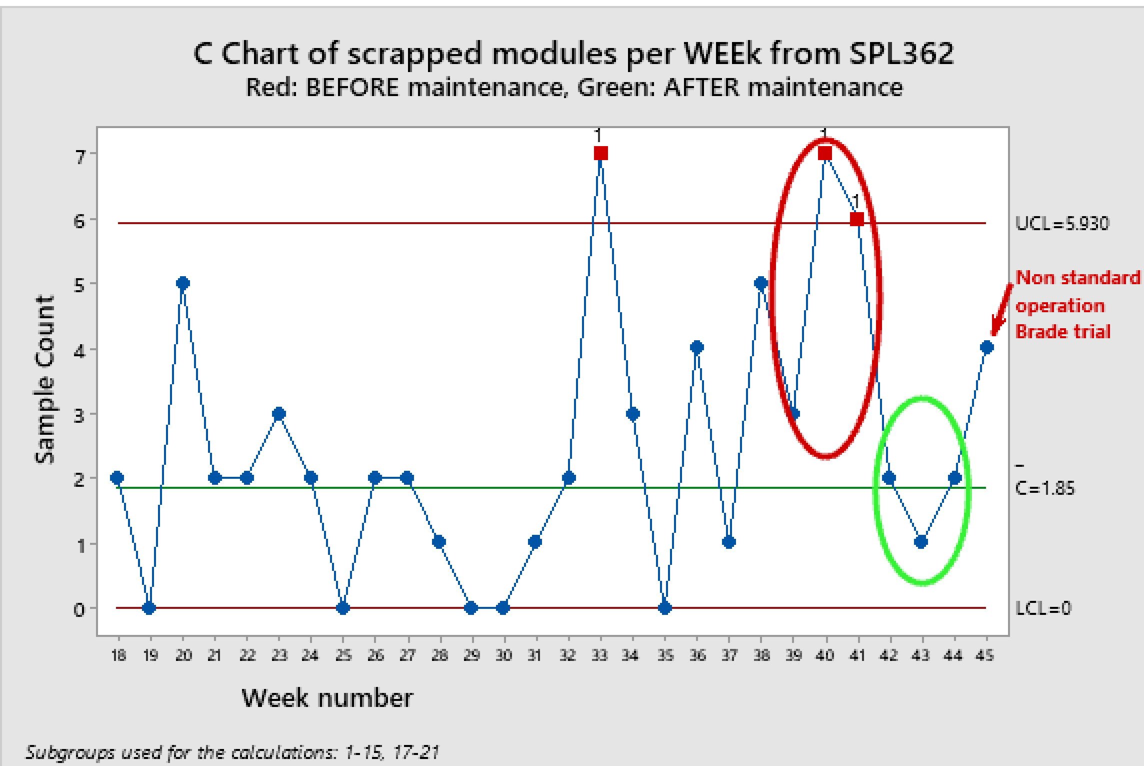
The findings were verified afterwards e.g. by external lab's chemical analysis.



Root cause verification results I.

Utilizing further what was discovered, a verification was prepared to see if **imitating** a process without calcium-oxalate would improve the process behaviour.
The chart below shows the weekly scrapped modules. The hypothesis test used daily scrap data, so 21 data values in each group.

The below supports the verification, though this is a weak support. Further results are on the next page.



Two sample T test - Method

μ_1: population mean of daily scrap SPL362 wk39-41
μ_2: population mean of daily scrap SPL362 wk42-44
Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

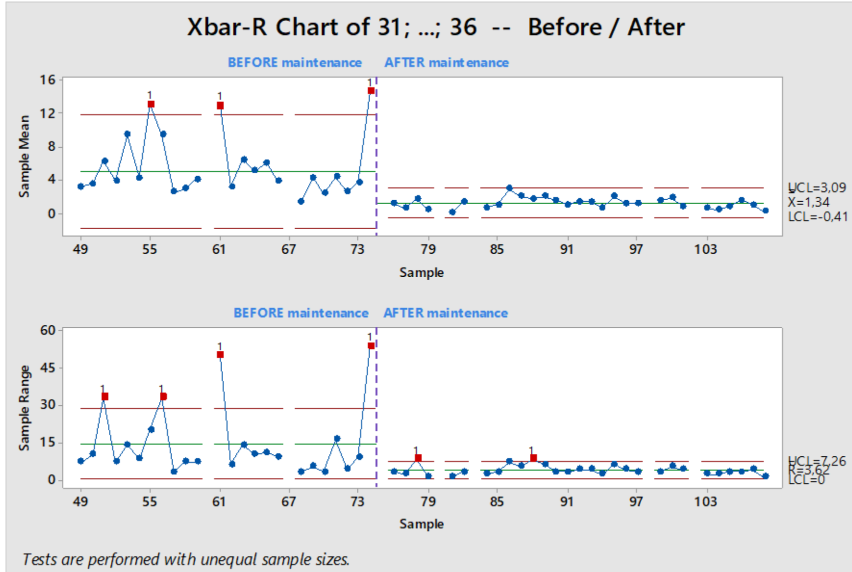
Sample	N	Mean	StDev	SE Mean
daily scrap SPL362 wk39-41	21	0.762	0.995	0.22
daily scrap SPL362 wk42-44	21	0.238	0.436	0.095

Test

Null hypothesis	$H_0: \mu_1 - \mu_2 = 0$
Alternative hypothesis	$H_1: \mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
2.21	27	0.036

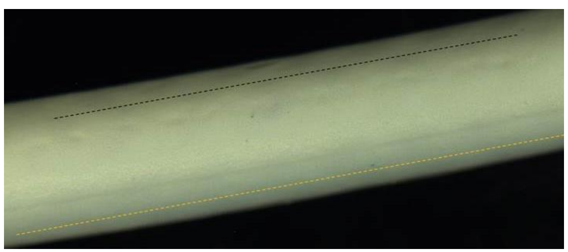
Root cause verification results II.

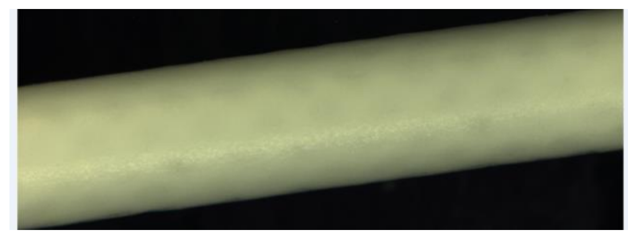


Before
on product

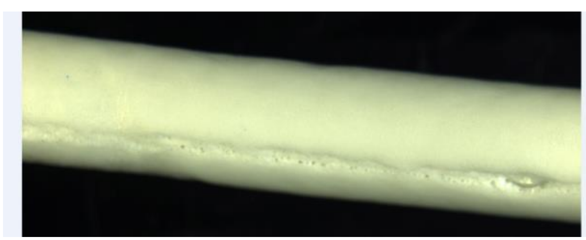
After
on product

On fiber





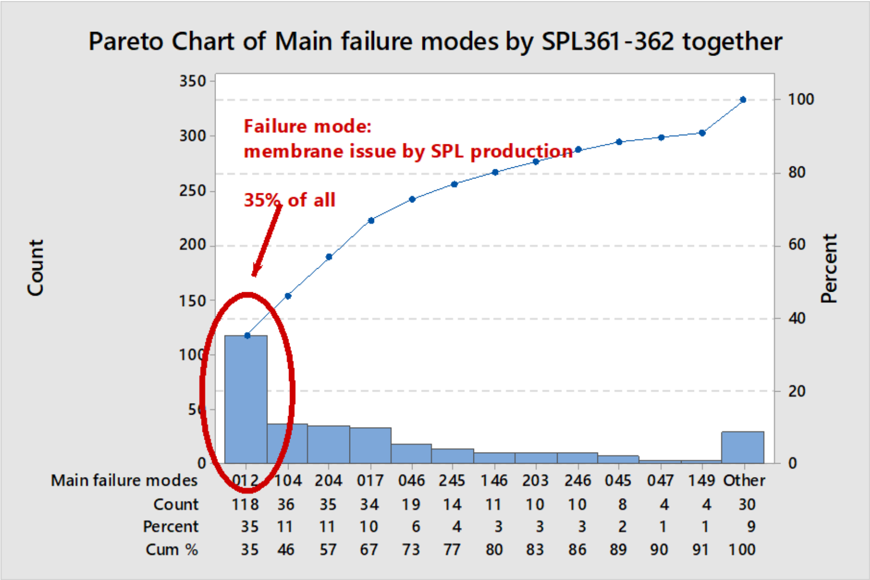
In scrapped module

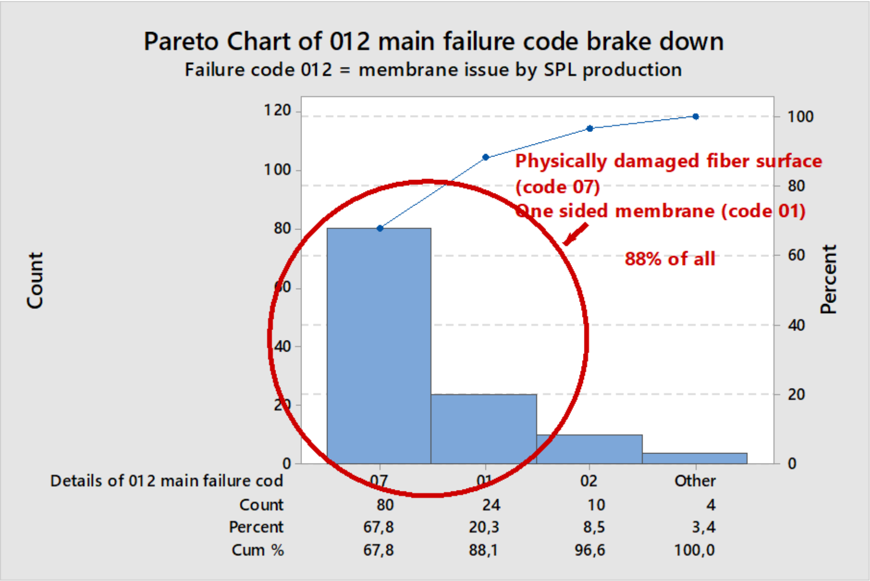


Hypothesis test supports the reduction of scrapped modules (slide 9)

Overall, the verification was considered as successful.

Quantifying the root cause's effects





Conclusion:

~ 30% of the scrapped modules could be saved in case there is a well controllable solution for a process change.

The solution

Water softener

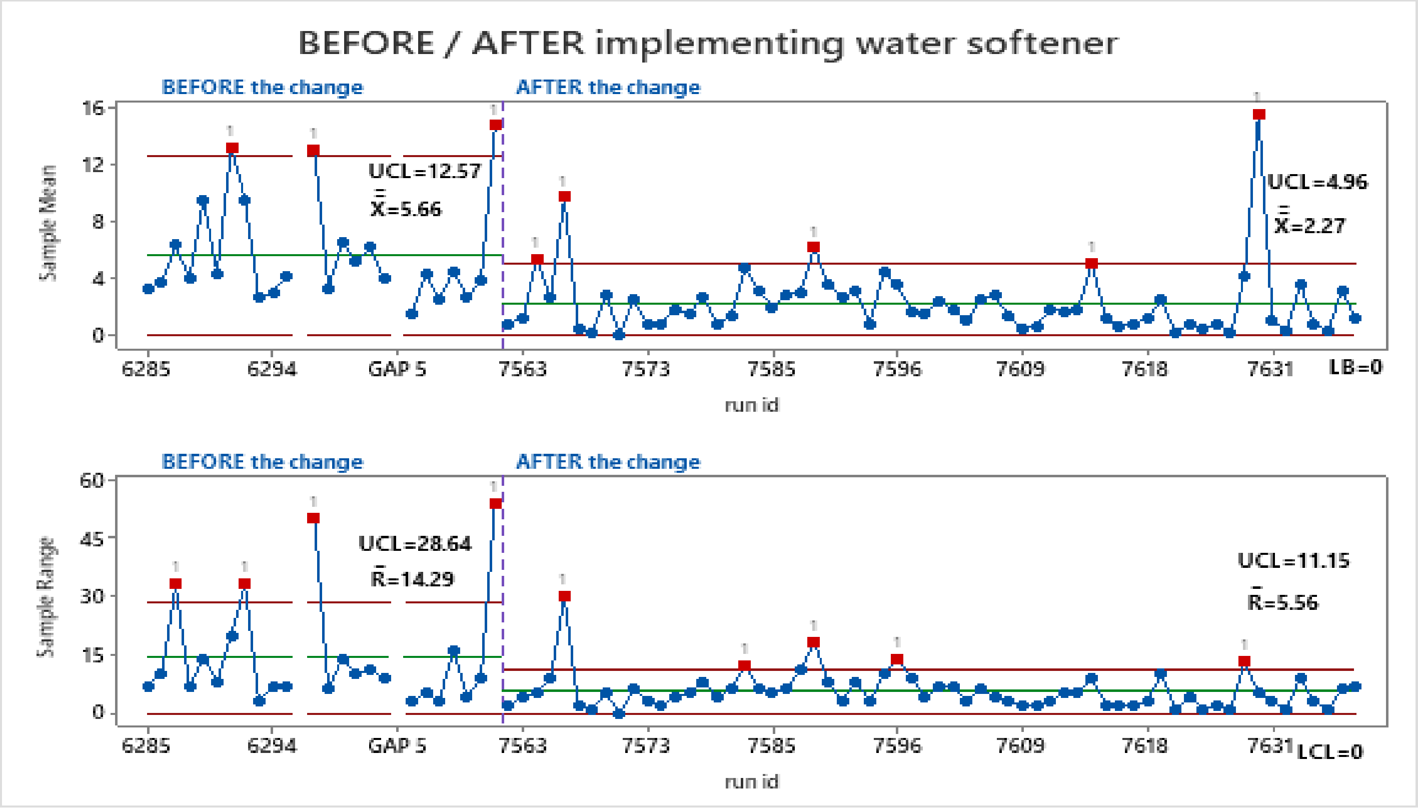
The solution the project team concluded on was to build a water softener into the technology line. In other words, production process design change was proposed.

This was to:
- serve as a inadvertent error prevention,
- by producing calcium free RO water with 8 m3 per hour capacity.

Since the solution does not allow calcium-oxalate creation it prevents

- all possible membrane surface damage as well that was caused by the calcium-oxalate,
- any equipment maintenance need / line stop due calcium-oxalate crystallisation.

Before / after data comparison I.



Description:

The above chart introduces the performance change that was realized by the water softener implementation.

Length of validation period was defined according to business requirements and results of data analysis of process behaviour.

Root causes of all out of control points of ’AFTER the change’ were successfully investigated. None was caused by calcium-oxalate on contact surfaces.

Before / after data comparison II.

Two sample T test - Method

μ_1: population mean of BEFORE the change
μ_2: population mean of AFTER the change
Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
BEFORE the change	24	5.66	3.64	0.74
AFTER the change	62	2.27	2.42	0.31

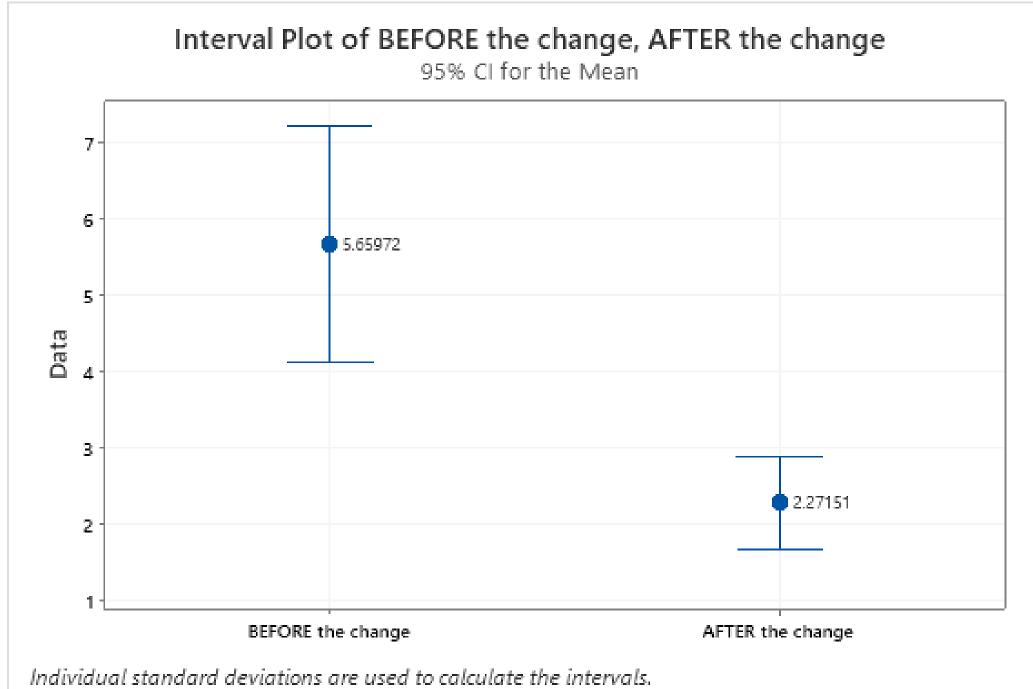
Estimation for Difference

Difference	95% CI for Difference
3.388	(1.747, 5.030)

Test

Null hypothesis H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
4.21	31	0.000



Evaluation:

’AFTER the change’ data set proves that the water softener implementation resulted a statistically significant change in the process behaviour.