Performance Evaluation and Prediction for Quenching Oils in Production Using JMP® Pro

2020-EU-EPO-436

| 11/03/2020 | JMP Discovery Summit 2020 | GUILLER Victor

LUBRICANTS. TECHNOLOGY. PEOPLE. FUCHS

Agenda

1 | Abstract

2 | Objectives & Method

3 | Results

4 | Conclusion

5 | Opening

01. Abstract

- Quenching is a very common method in the heat treatment of materials. In this process, a heated workpiece is rapidly cooled within a fluid to obtain certain material properties, i.e. specific hardness of metals.

- In the production of quenching oils, a time-consuming performance test evaluating the cooling speed and characteristics of the fluid is used to assess if the product meets the specifications.

- To test the performance, an Inconel quenchprobe is heated up to 850° C, and immersed in the test liquid for 60s. The temperature of the quenchprobe is recorded during the 60s.

- The evaluation and comparison of performances is realized through the analysis of six parameters obtained from the cooling curves.

FIG. 1. Parts in production after tempering furnace and before quenching process

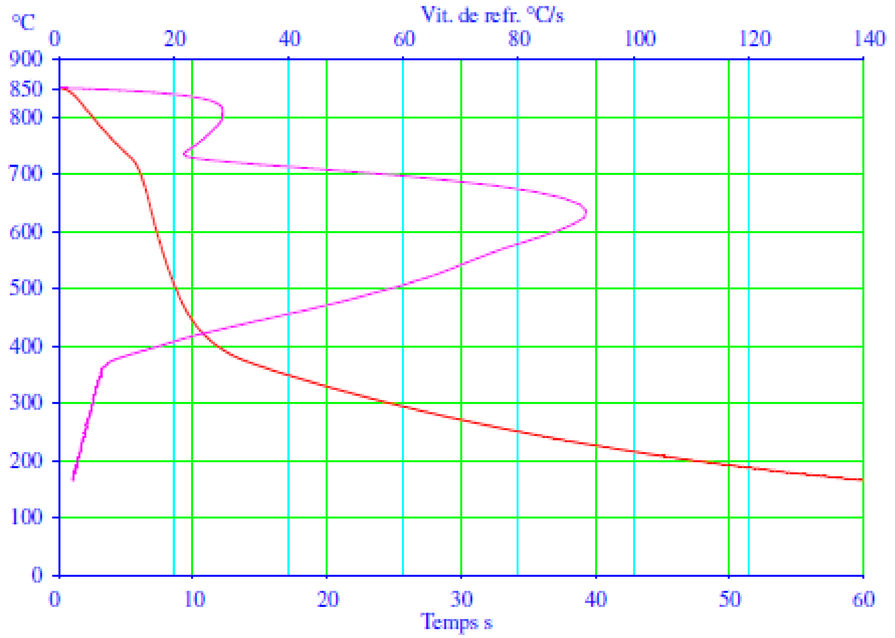
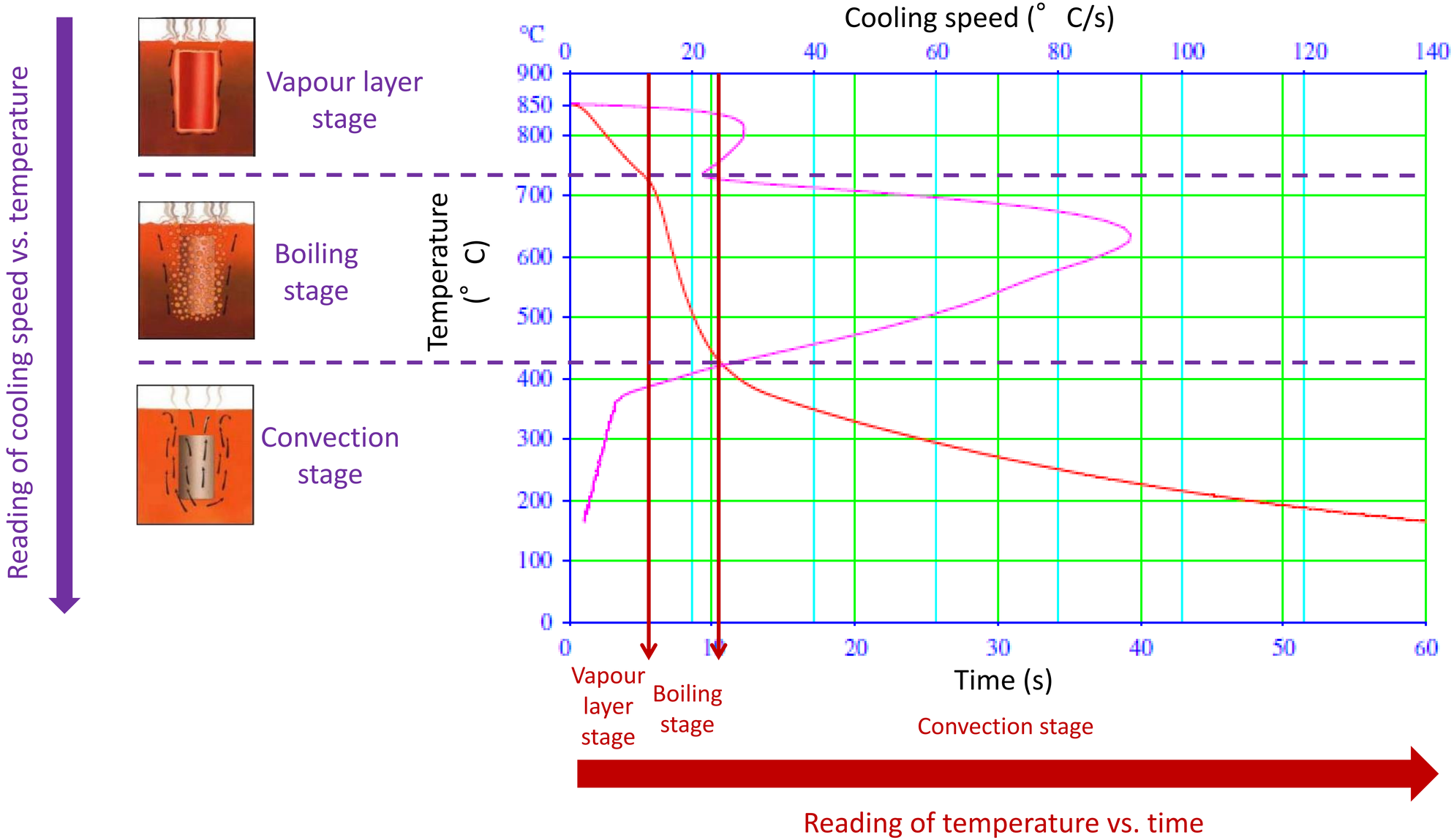
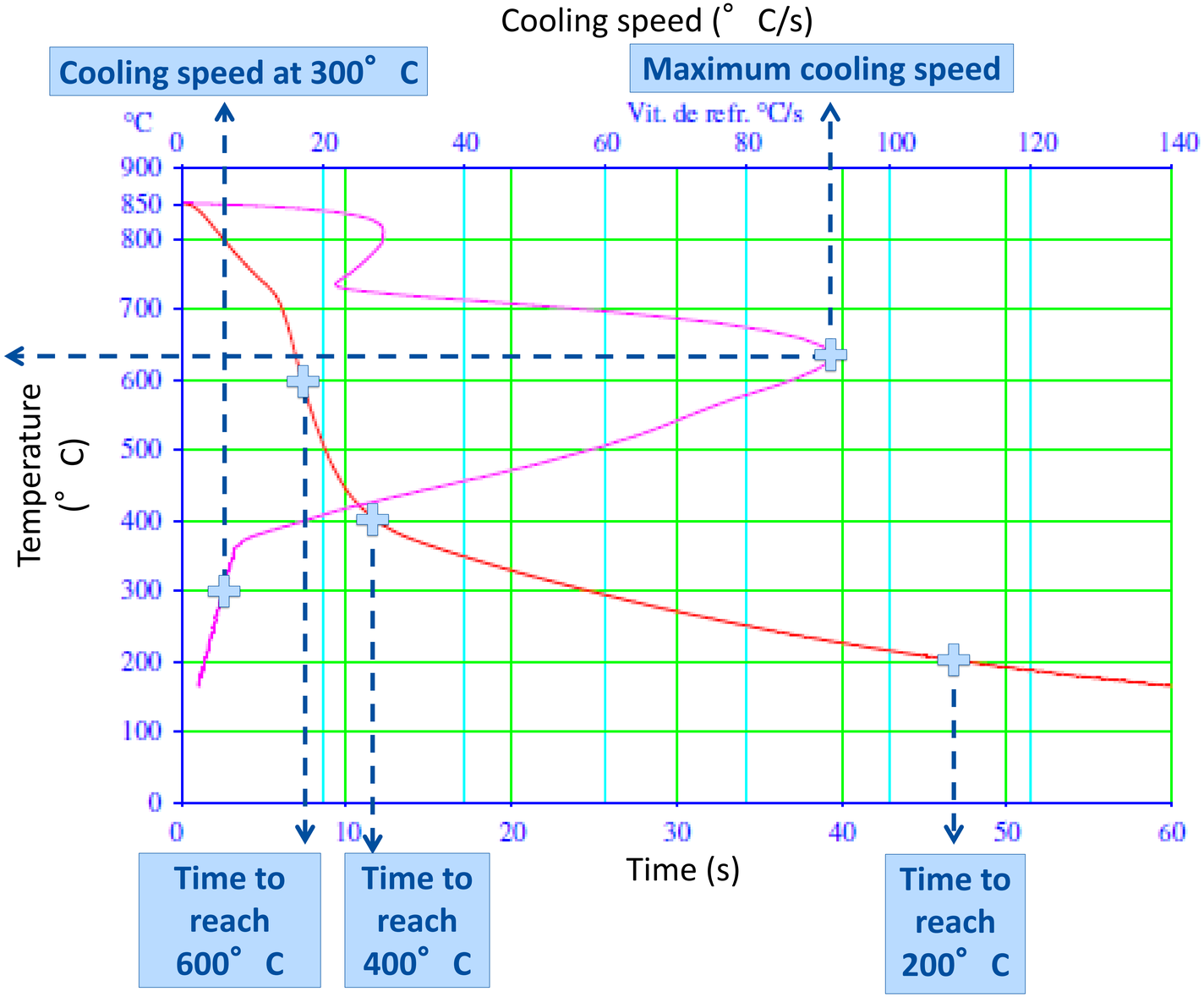


FIG. 2. Cooling curves (in red: temperature vs. time, in pink; cooling rate vs. temperature).

01. Abstract


Reading of cooling speed vs. temperature
Vapour layer stage
Boiling stage
Convection stage
Cooling speed (° C/s)
°C
0
20
40
60
80
100
120
140
900
850
800
700
600
500
400
300
200
100
0
Temperature (° C)
0
10
20
30
40
50
60
Time (s)
Vapour layer stage
Boiling stage
Convection stage
Reading of temperature vs. time

01. Abstract



These 6 parameters comes from 5 points and 2 curves (each with 481 points).

We use 5/962e of the information, so around **0,5%** of the informations contained in one test !

02. Objectives & Dataset

Objectives

- Create a mathematical model of the cooling curves with the Functional Data Explorer on JMP® Pro,
- Predict conformity or non-conformity of the production batches,
- Identify and classify the different products (type A / type B).

FIG. 3. Quenching test

Dataset

- 32 batches (2018-2019),
- 2 product type (A/B),
- 2 conformity status (conform/non-conform),
- 5 quenchprobes used (same geometry, but different number of tests done with each, different suppliers, different electric connexions quality…),
- 5 unknown batches to be determined: type A/B and conformity status.

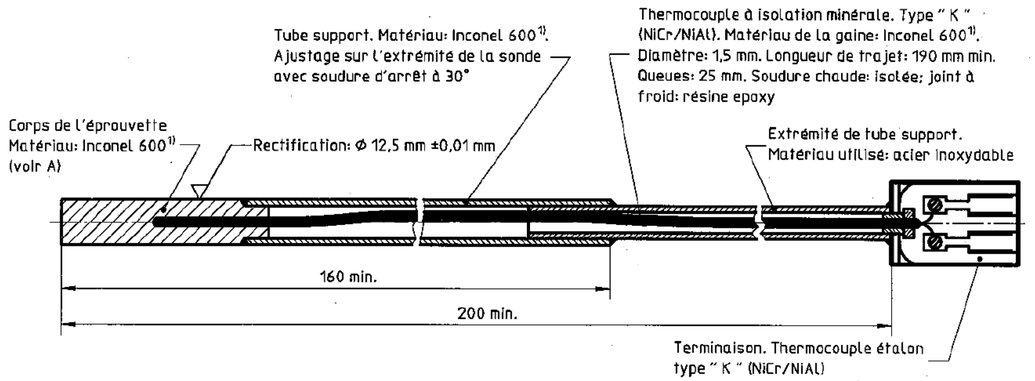
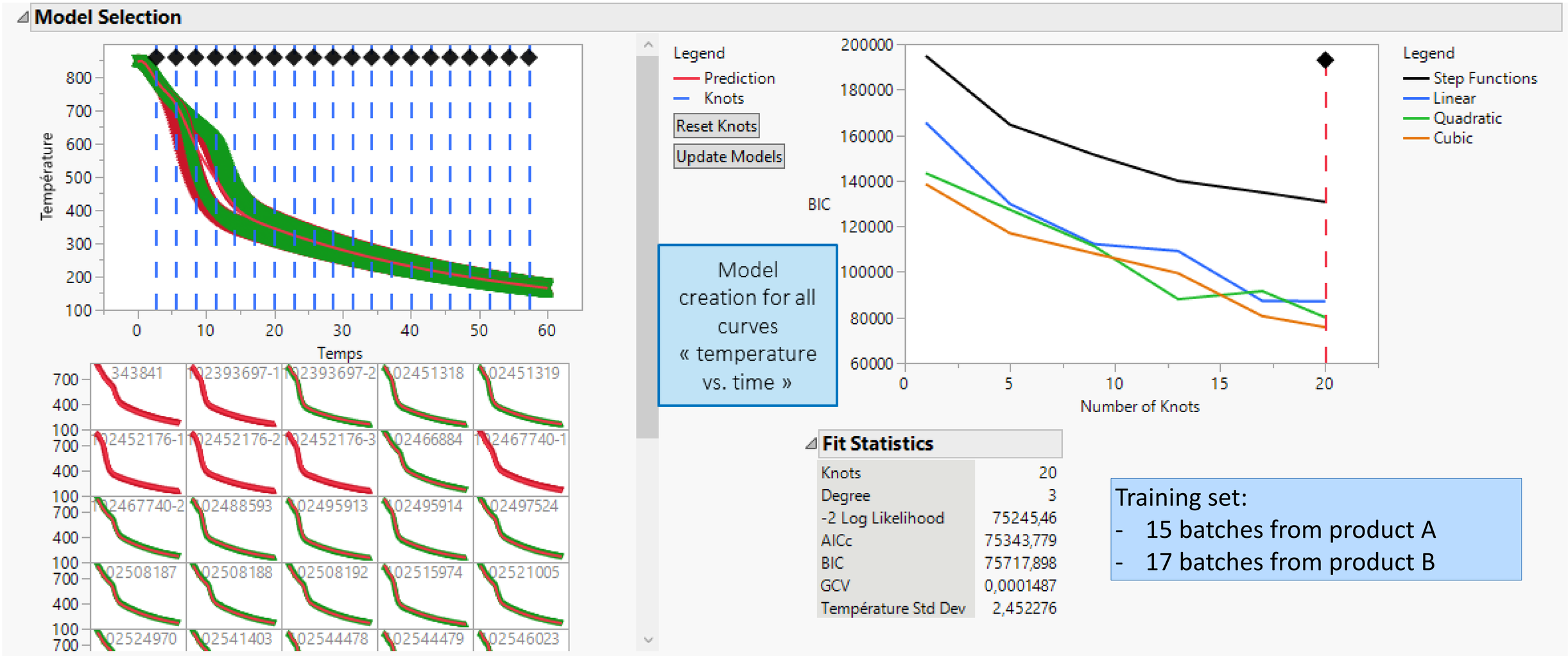
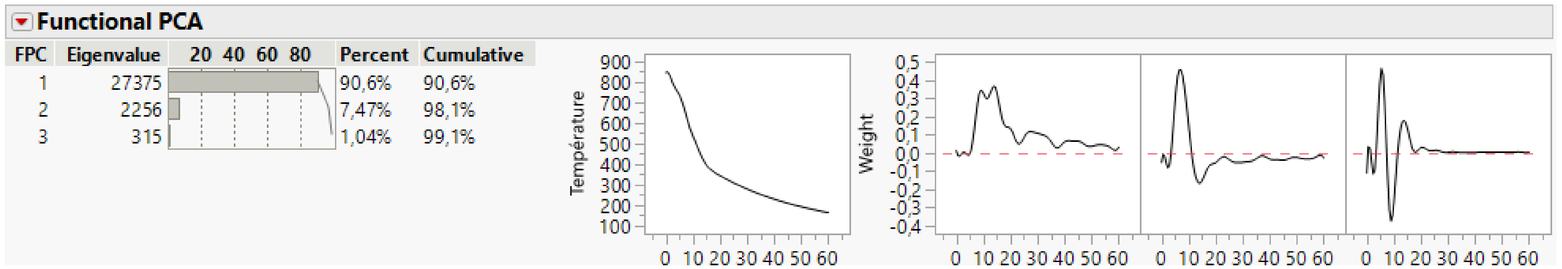


FIG. 4. Quenching probe technical description

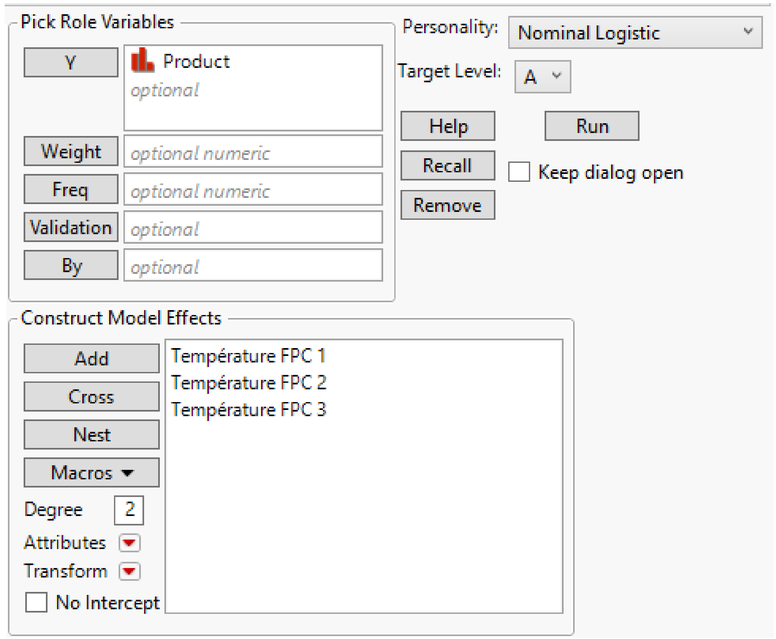
03. Results – Signal modelisation

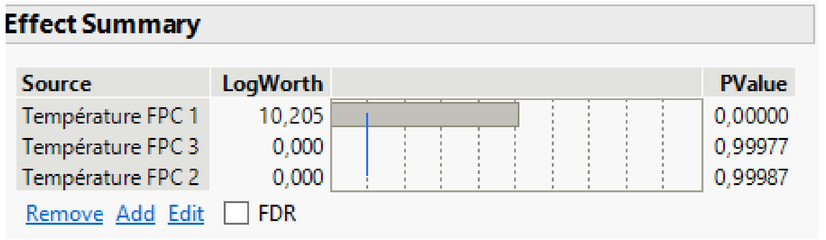


03. Results – Product identification

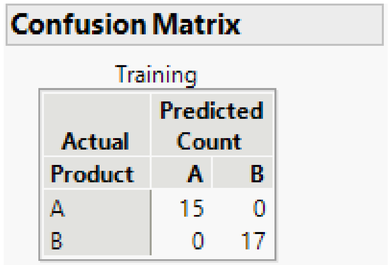


Determination of product type for samples 1, 2, 3, 4, 5 with FPCs scores and nominal logistic platform (Fit Model)

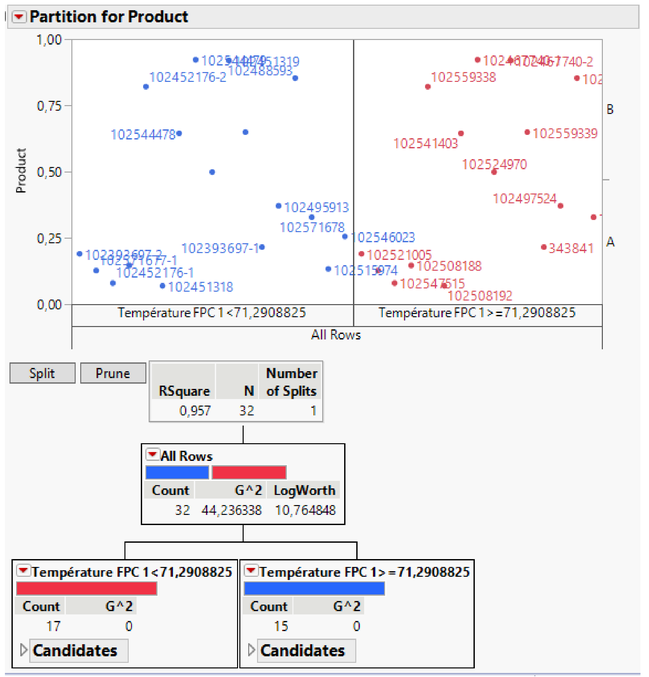




FPC 1 is the only significant FPCs for explaining the product type in the model



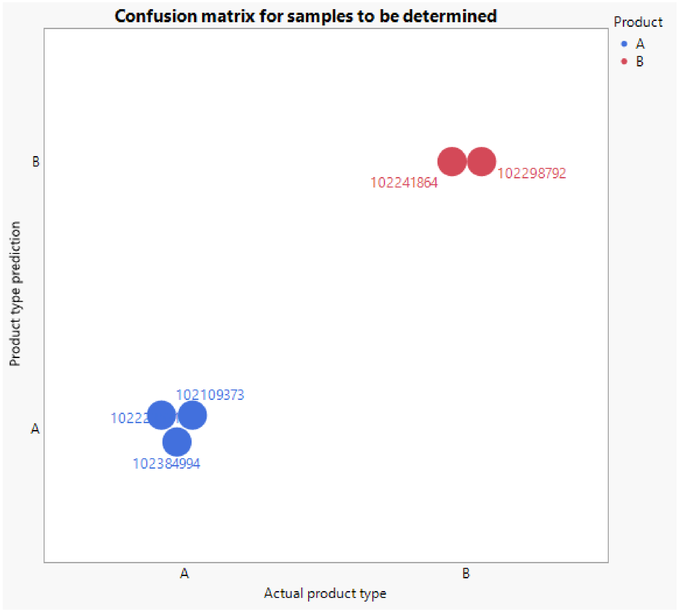
On the 32 batches used for the training, no classification errors.



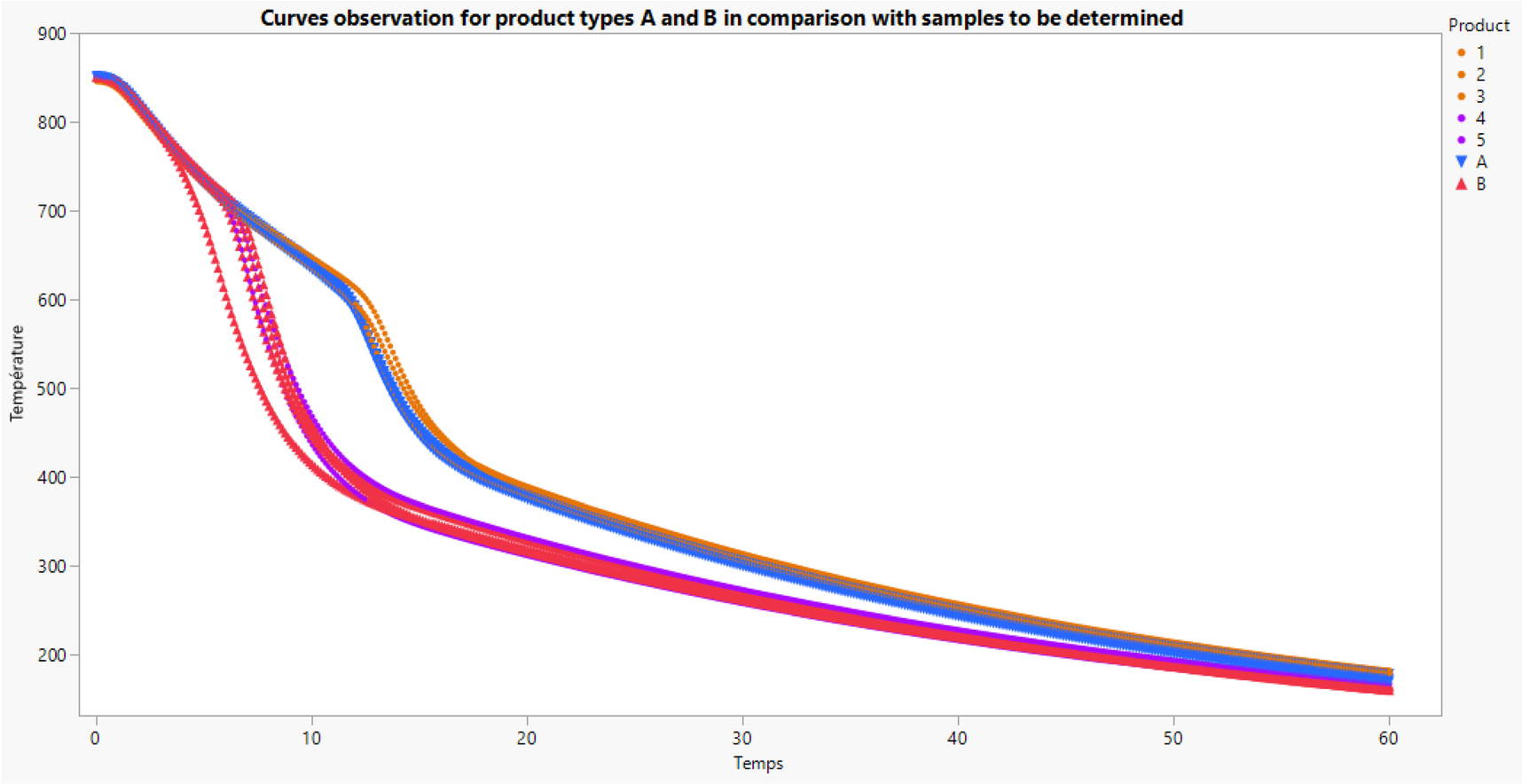
Same results from a decision tree :

03. Results – Product identification (validation)

Determination of product type for samples 1, 2, 3, 4, 5 with FPCs scores and nominal logistic platform (Fit Model)



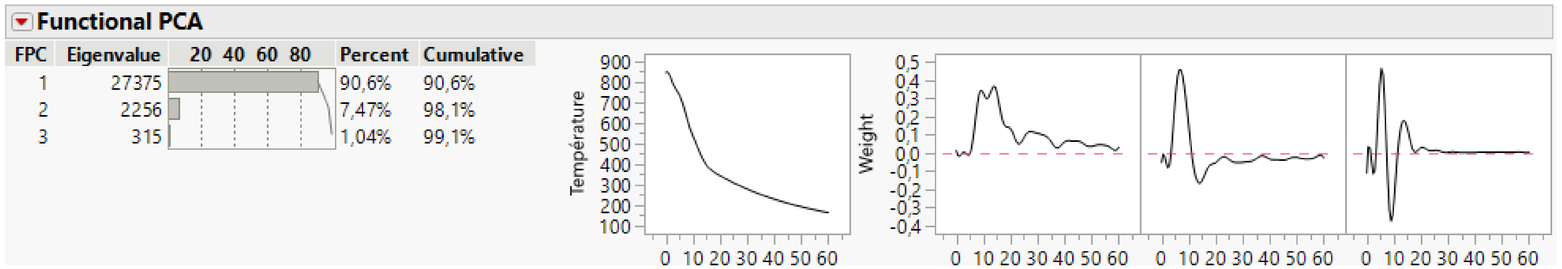
On the 5 samples to be determined, no classification errors found.



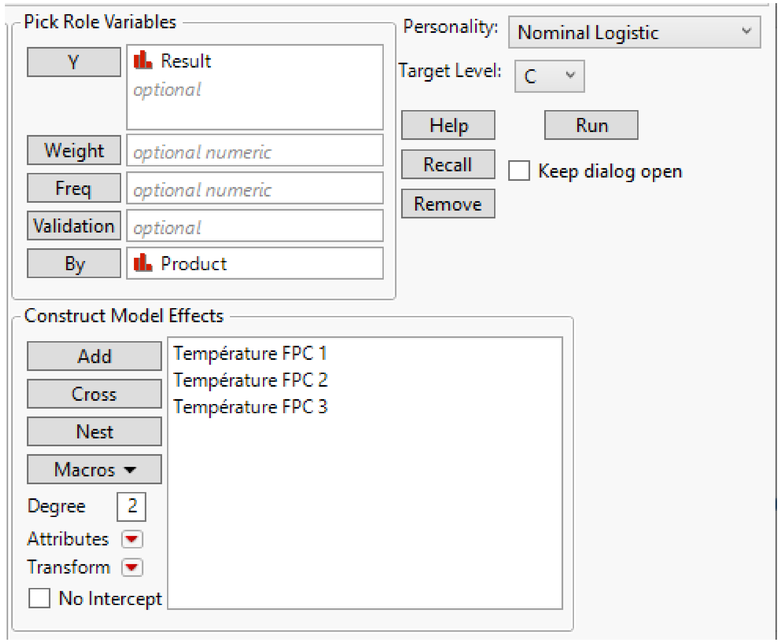
Visualization of the curves of the samples to be determined with the graph Builder

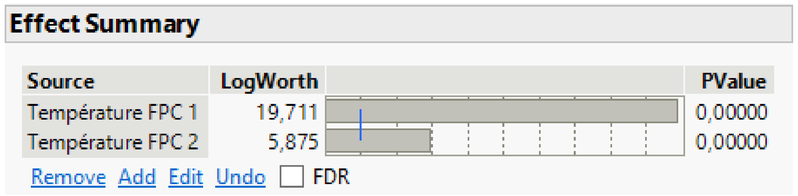
Correct product identification ! 1,2,3 = Product A / 4,5 = Product B

03. Results – Conformity identification

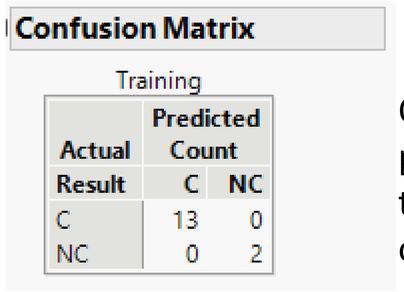


Determination of conformity status for samples 1, 2, 3, 4, 5 with FPCs scores and nominal logistic platform (Fit Model)

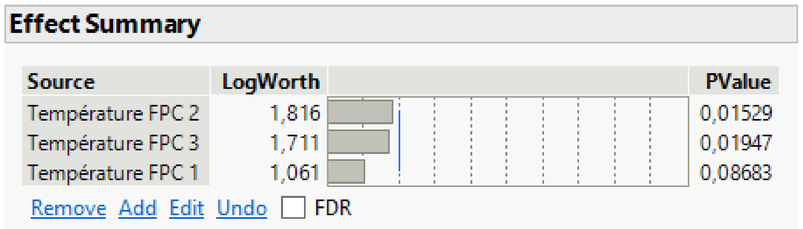




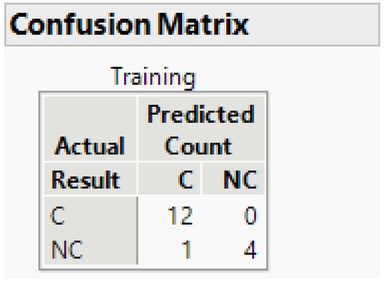
FPC 1 and 2 are the only significant FPCs for explaining the conformity in the model for product A



On the 15 batches of product A used for the training, no classification errors.



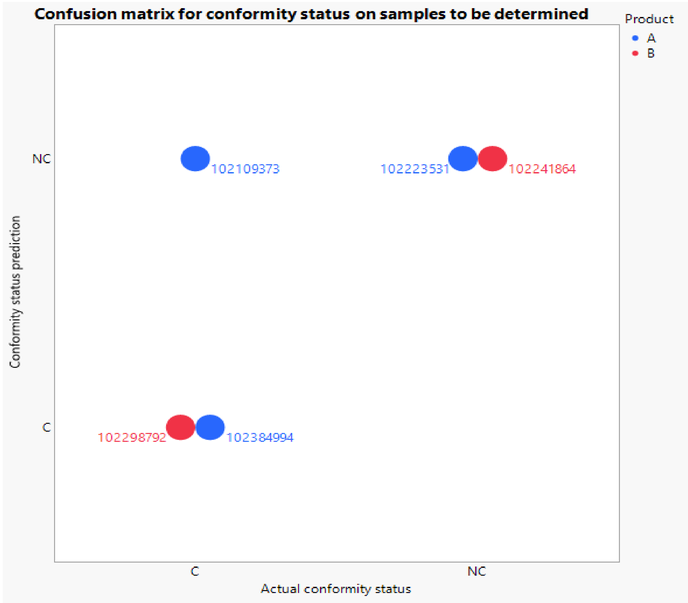
All FPCs are similar for explaining the conformity in the model for product B



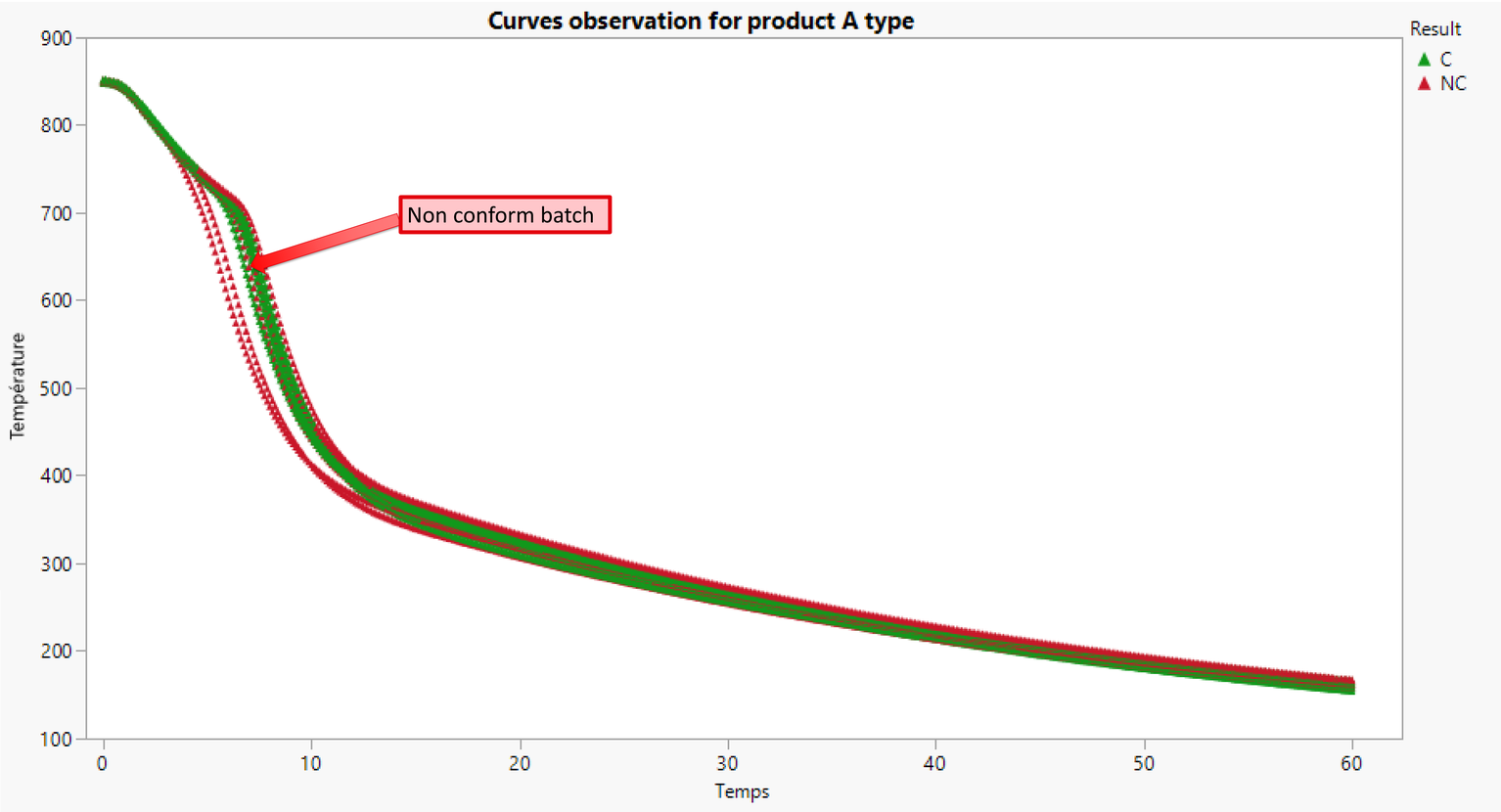
On the 17 batches of product B used for the training, only 1 classification error.

03. Results – Conformity identification (validation)

Determination of product type for samples 1, 2, 3, 4, 5 with FPCs scores and nominal logistic platform (Fit Model)



On the 5 samples to be determined, 1 classification error found.



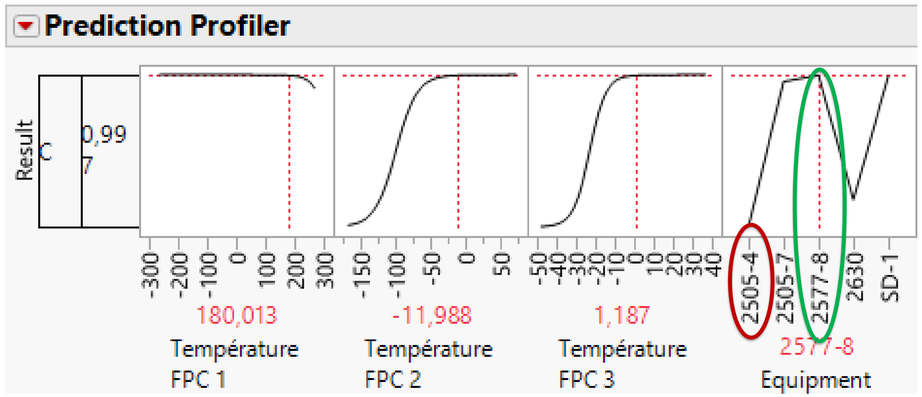
One curve for a non-conform batch among conform batches

Good product identification ! But improvement of the model needs to be done (especially for product B), with more data and inputs from the production. Method change for the validation of product to be considered.

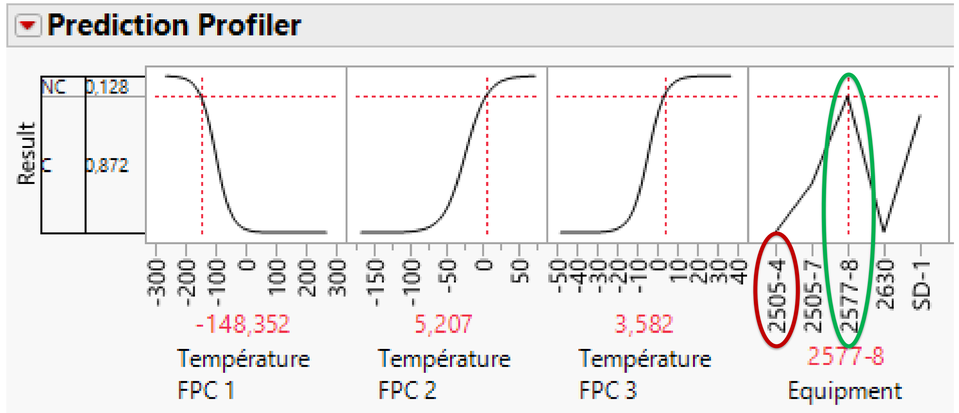
03. Results – Comparison of equipment

Comparison of equipment (quenchprobes)

FPCs with mean values from product A batches



FPCs with mean values from product B batches



With product A and B, quenchprobes 2577-8 and 2505-4 show high level of conformity results.

Equipment	2577-8		2505-4	
Product	A	B	A	B
%Conformity (profiler)	99,7%	87,2%	0%	0%
Conform	6	3	0	1
Non-conform	0	1	2	1

	2577-8	2505-4
Number of tests	236	203

Problem detected with quenchprobe 2505-4 (low level of conformity batches).

Logistic profiler with FPCs from product type shows differences between equipment. Investigation to be done, as number of tests with the quenchprobes may not be the root cause for behaviour differences.

04. Conclusions

Results

- Correct product identification,
- Correct conformity prediction, possibility to use the model for a more precise conformity determination (compared to existing method),
- Detection of a problem for one equipment (quenchprobe 2505-4 with a high level of non-conformity in the prediction profiler),
- Cost and time-saving modelisation and prediction (instead of using trials and errors method),
- Possibility to add a reference to the Functional Data Explorer for each product and use it to predict the optimal amount of additive to use to have the lowest non-conform batches.

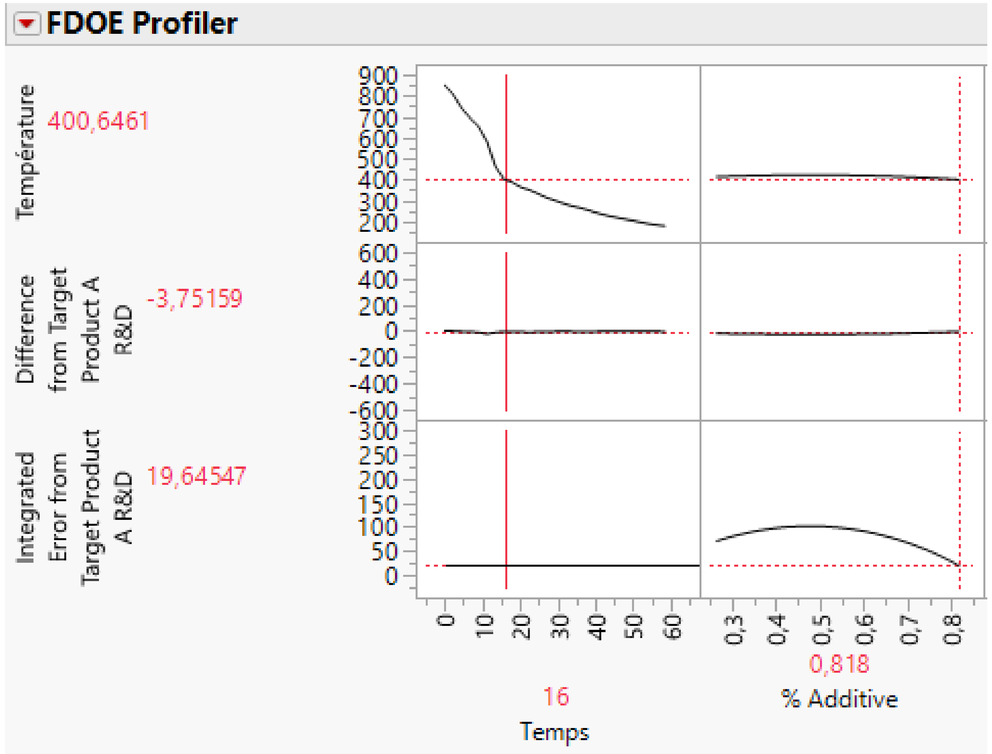
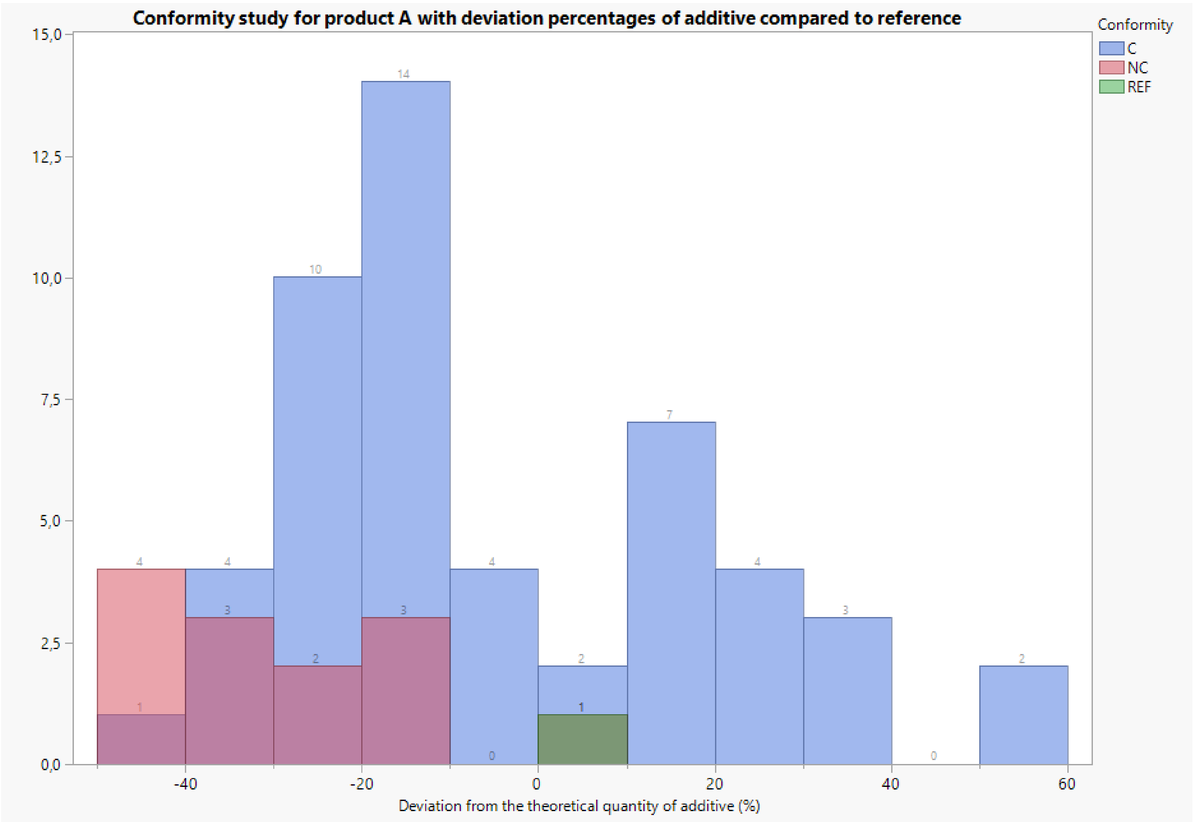


FIG. 5. FDOE profiler for product type A, with %additive as a factor

05. Opening

Opening

- Study is now made with a larger set of batches from the two products A and B (326 batches).
- Model will be tested and updated with these new datas.
- Possibility to set safe domain variation for the quantity of additive to get conform products, based on historical data.
- **Estimation of saved time with automatic curves analysis:** 30 to 50% less time required.
- **First step for a broader application range:** new product types will be added to create a library of results for determining the product type for unknown batches (around 17 product types).



Thank you very much for your attention.

LUBRICANTS.
TECHNOLOGY.
PEOPLE.

FUCHS