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Multi-objective Bayesian optimization for intumescent coatings

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Aims/objectives

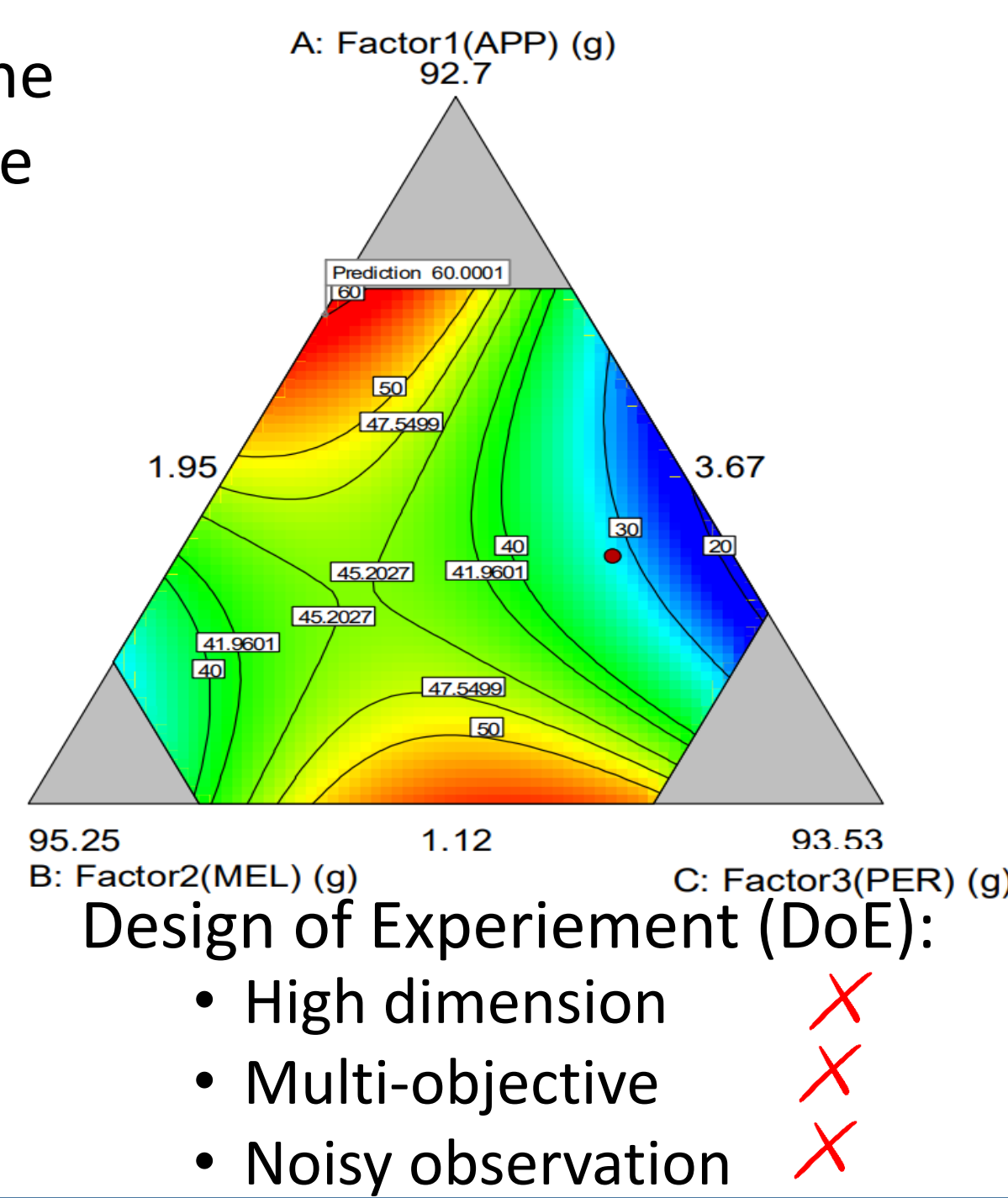


Wood is more and more used in buildings = sustainable materials compared to concrete and steel

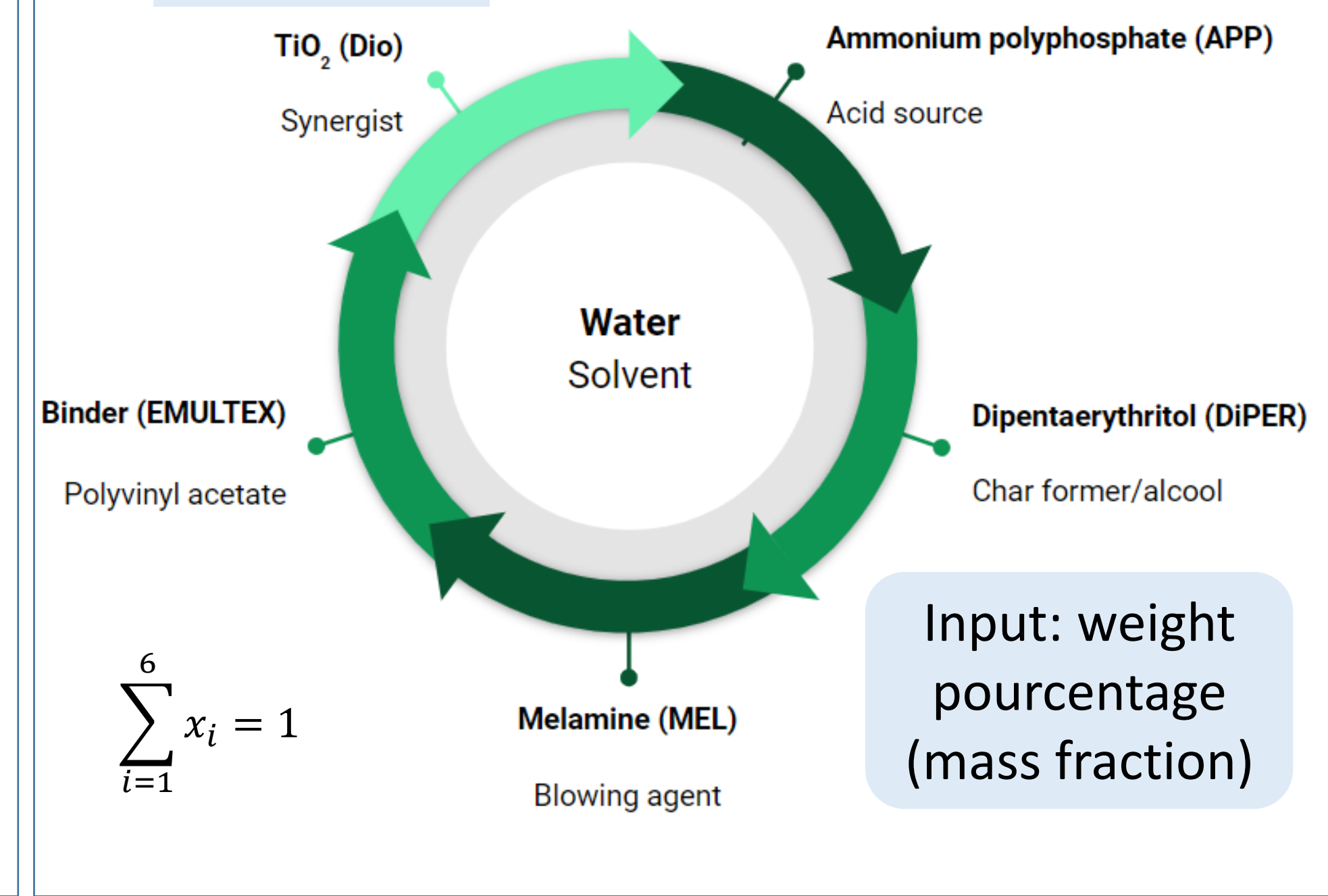
Intumescent coating most commune system to protect wood against fire



Intumescent coatings in case of fire => expanded structure limiting heat and mass transfer



Input

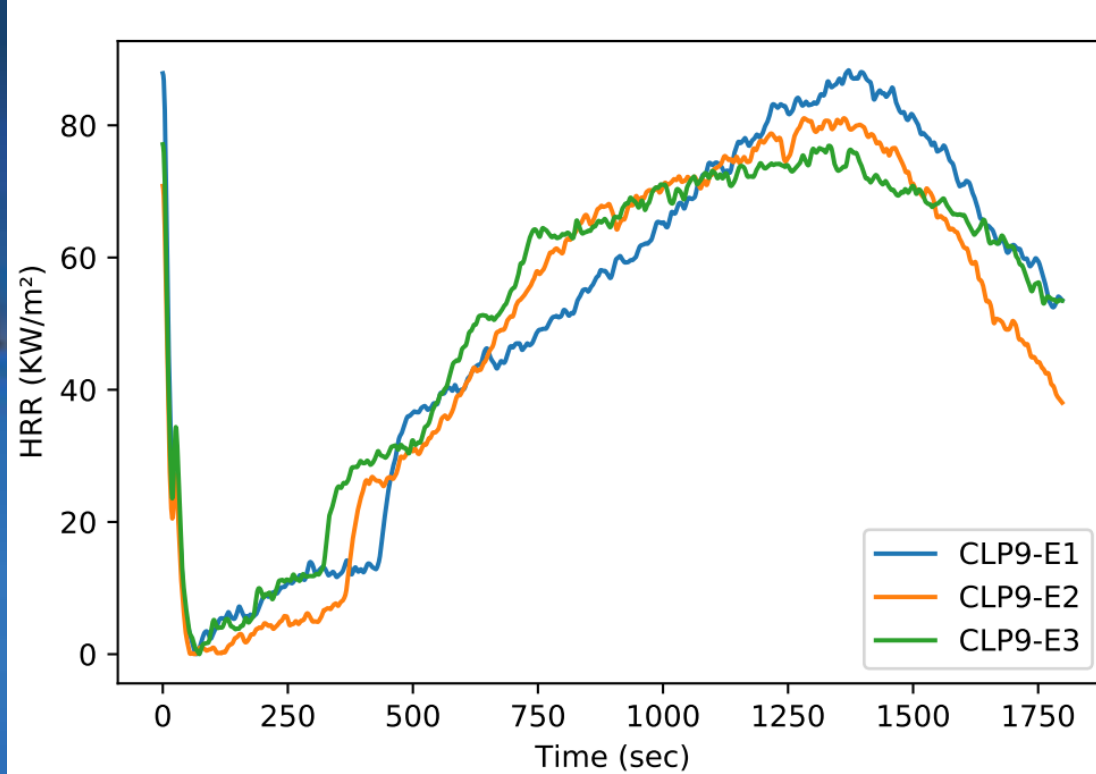


Output



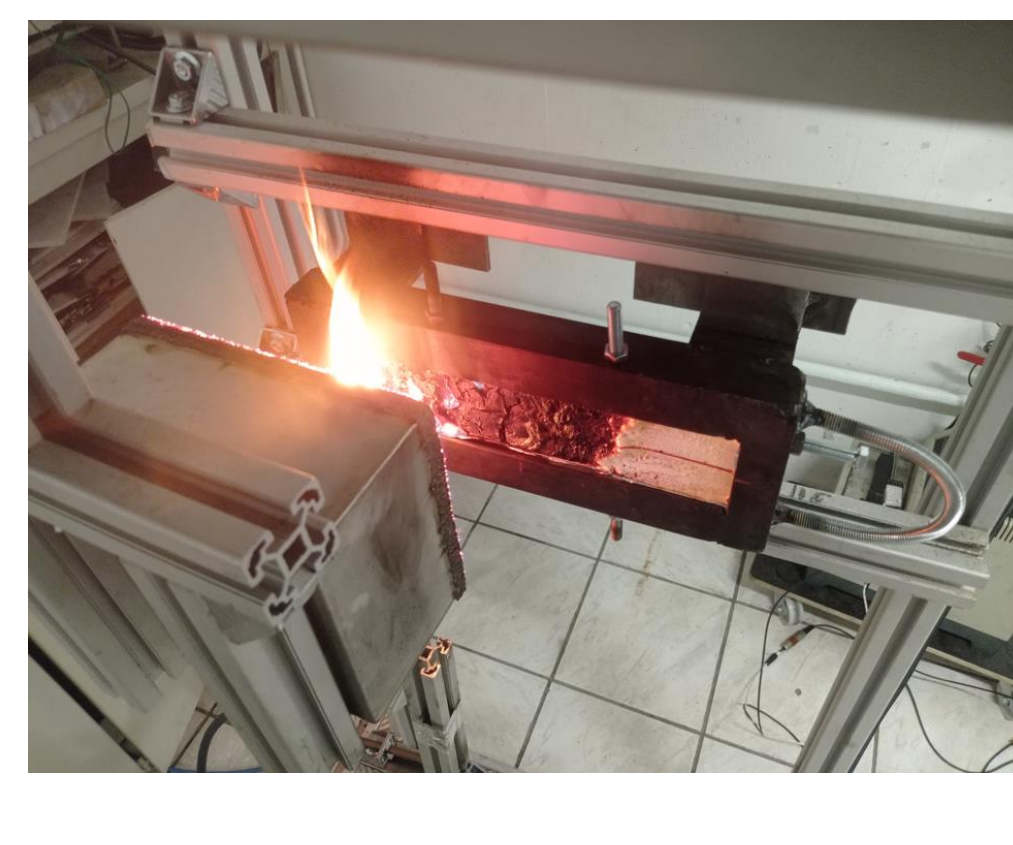
- Heat flux: 50 KW/m²
- Test time: 30 min

Horizontal mass loss cone



- Total heat released (THR)
- Time of ignition (ti)

3 Fire tests → 4 performance outcome



CFE 1/3 scale

The flame propagation is evaluated using a lab-made CFE radiant panel test (similar to the ISO5658-2)

3 - distance of degradation

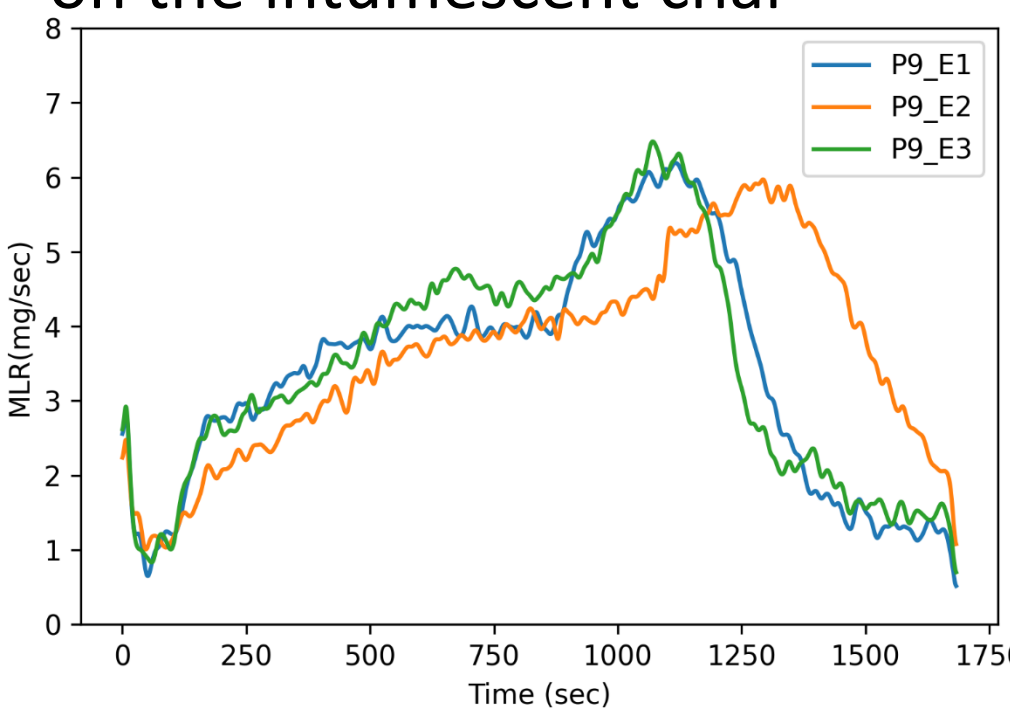


Determination of distance of degradation *via* image segmentation (K-means clustering)

Vertical mass loss cone



Vertical → more representative of fire in a building and impact gravity on the intumescent char

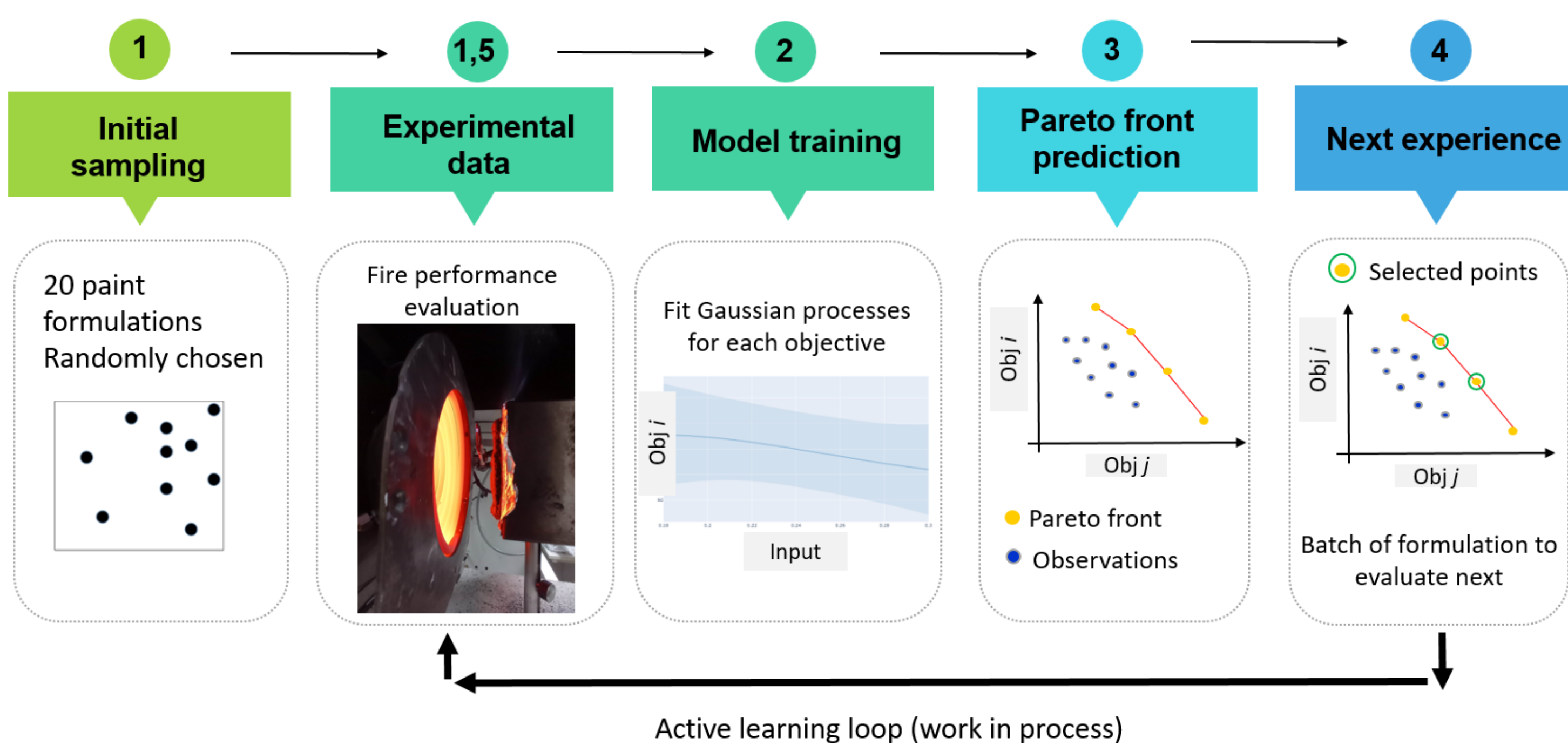


- Median of the mass loss rate

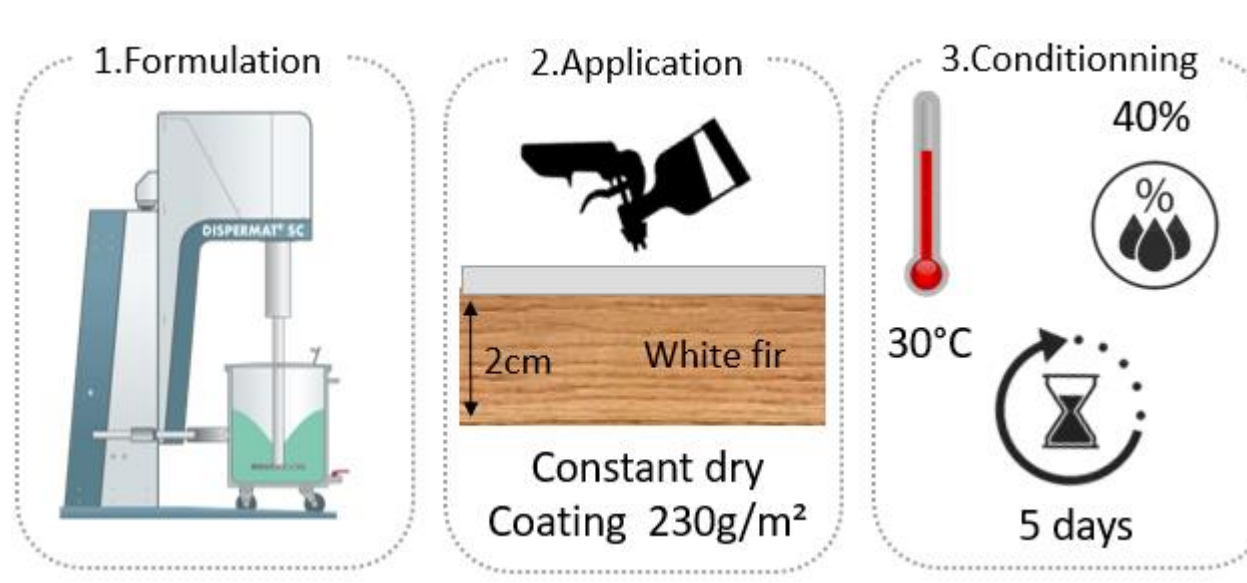
- Heat flux: 50 KW/m²
- Test time: 30 min

Pipeline

Bayesian optimization (BO) is a sequential model-based approach that efficiently explores and exploits the search space to find the optimal solution of a black-box function with limited evaluations. BO can be used for noisy and small dataset.



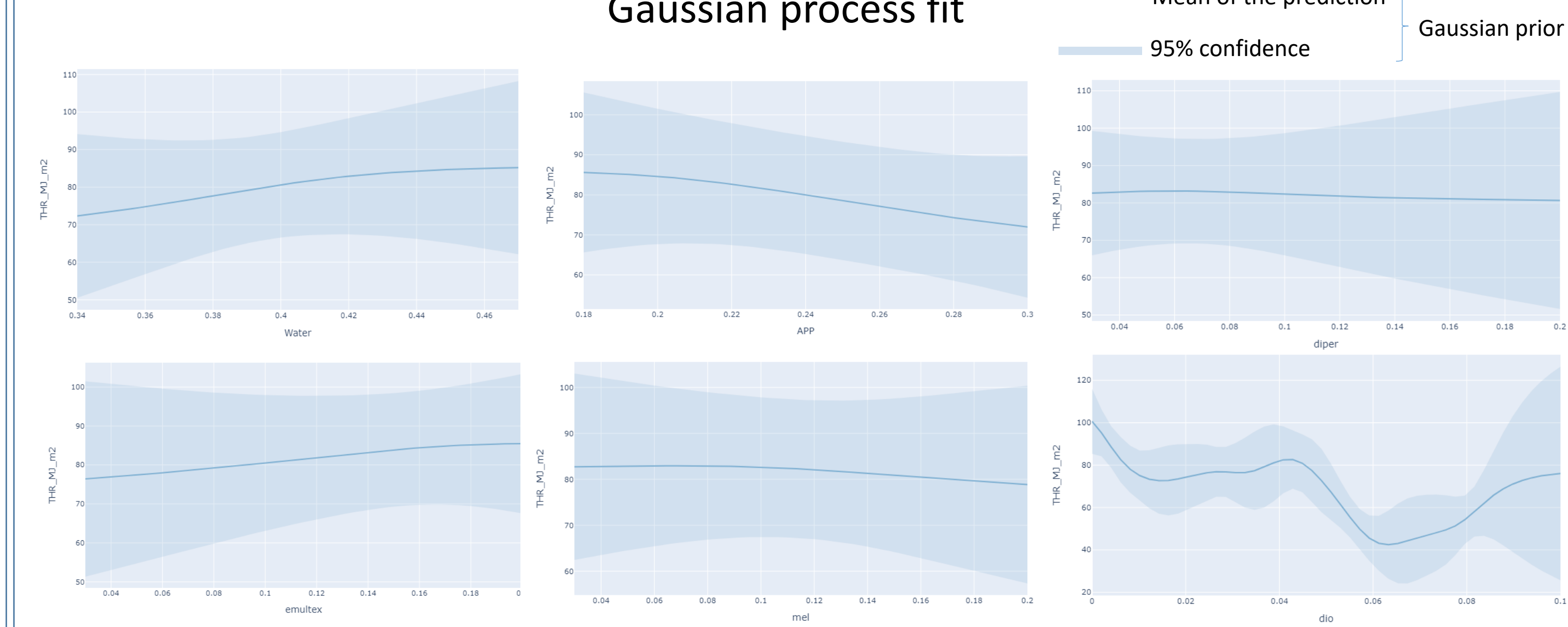
In Multi-objective optimisation there is typically no single best solution. The Pareto front is the set of solutions where no other solution can improve one objective without sacrificing another. It represents the optimal trade-off between conflicting objectives, providing a range of solutions, to guide decision-making.



Experimental protocol

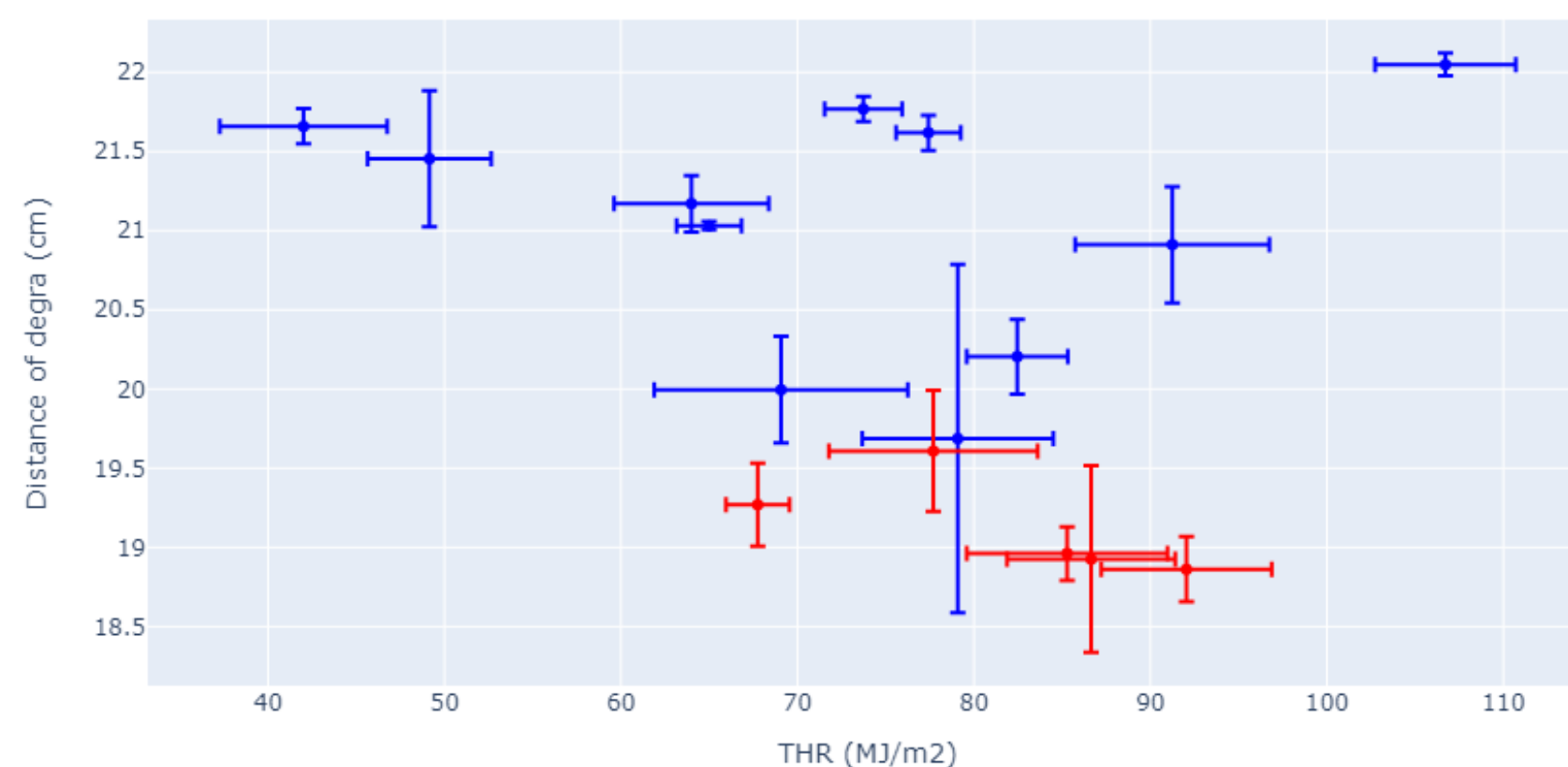
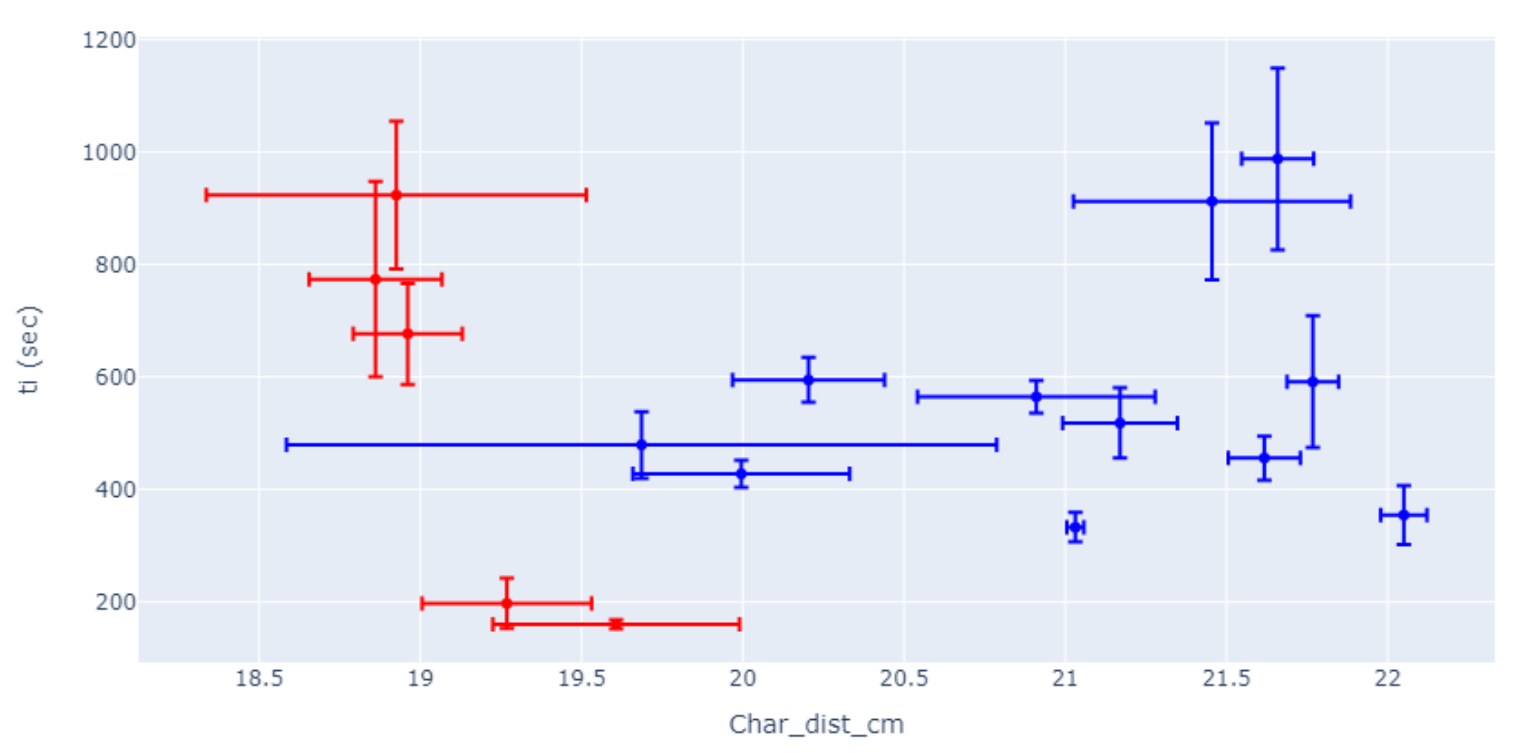
- The coating formulations were prepared using a high-speed disperser
- A constant dry mass is applied on white fir
- The sample is conditioned at 30°C, 40% RH before the fire testing

Prediction



First results

Based on the trade-off plot, it's relatively easy to achieve formulation with high time to ignition and low distance of degradation.



Based on the trade-off plot, it's challenging to achieve a formulation that simultaneously offers a low degradation distance and THR.

Conclusion/perspective

- Intumescent is an efficient method to protect wood against fire in a building
- Designs of experiment are efficient but require high amount of data
- Multi-objective Bayesian Optimisation has been chosen to find the optimum configuration of the paint (pareto front) and minimize the number of samples
- The performance of the coating is evaluate by 3 fire tests giving 4 parameters

Outlooks

- Number evaluation until a satisfactory approximation of the Pareto front is obtained
- Comparison between different sampling for initial points

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