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ADVANCED MODELLING & SIMULATION – AMS

DATA-DRIVEN AND SYSTEM-SCALE MODELLING OF PULP PRODUCTION IN DIGESTERS

December 2019
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COOKING DIGESTOR EFFICIENCY

Use an in-house eDAP$^{©}$ data-driven prediction and system-scale model Pulpsim$^{©}$ to predict the cooking efficiency of the digester and output quality via the Kappa number

A- PHYSICS-BASED MODELLING: PULPSIM©

A System-scale Simulator of Cooking in Digestor Processes

- PlupSim© is a system code dedicated to the simulation of cooking in digester processes using first principles.
- The model consists of mass balances for the non-porous solid (wood chips) and the free liquor components.
- The model accounts for energy transfer between the phases within the reactor.

- PlupSim© can be deployed under Windows OS, and runs under Matlab.
- A tailored version can be prepared for other simulation tools, e.g. using Python.
- PlupSim© can be employed in various process engineering applications, incl. Kamyr Digestor technology.

Model Output

- Predicts degree of cooking at all locations of digester.
- Predicts concentration of all dominant chemicals of wood and liquor at all locations.
- Predicts temperature at all locations of digester.
- Predicts velocity of wood chips and liquor at all location of digester.
- Predict all of above for mixed wood scenario.
- Predict all of above for production rate change scenario.
- Can be used for various scenario analysis.
- Can predict the hanging or plugging of digester.

CASE STUDY: SUNILA PLANT FINLAND

Flow and operation simulated using PlupSim©
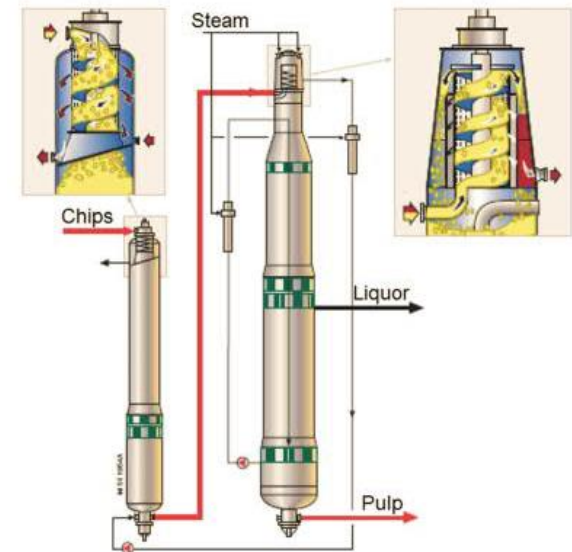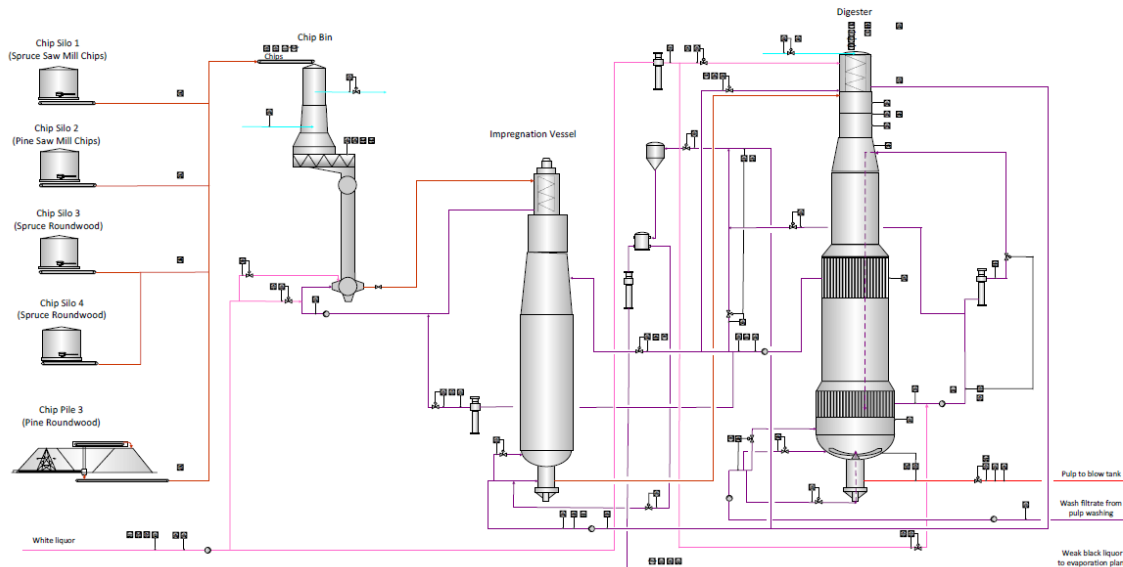
- The plant is located in Sunila Finland
- The digester is based on Compact Cooking G1 technology
- A reference case has been studied by S. Laakso: Modeling of chip bed packing in a continuous kraft cooking digester, PhD.

The digester is divided into 8 blocks in *Figure 51*. The figure shows an upflow-type (Counter-Current) Compact Cooking digester. Chips and liquor are added in *block 1* and the liquor is extracted in *block 4*. This first extraction position is called the extraction screen. After the extraction screen, the liquor flows in opposite direction relative to the chips. Washing liquor is added from the bottom of the digester (*block 8*). Part of the liquor is extracted in *block 6*. This second extraction screen is called the ITC screen (IsoThermalCooking). Part of the extracted liquor (from *block 6*) is recirculated back into *block 5*. Liquors flowing in opposite directions are extracted in *block 4*.
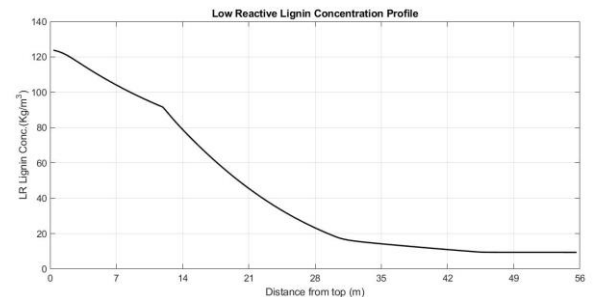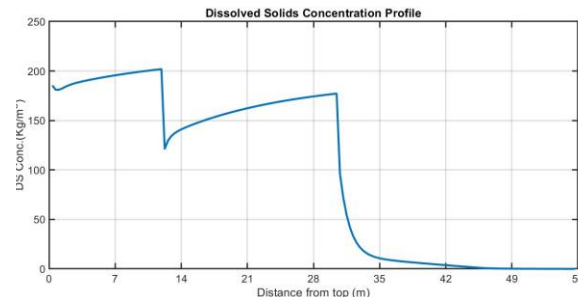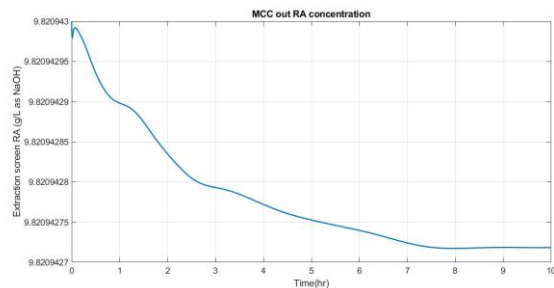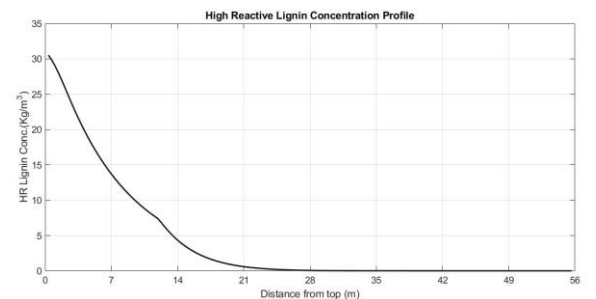
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CASE STUDY: SUNILA PLANT FINLAND

Flow and operation simulated using PulpSim©
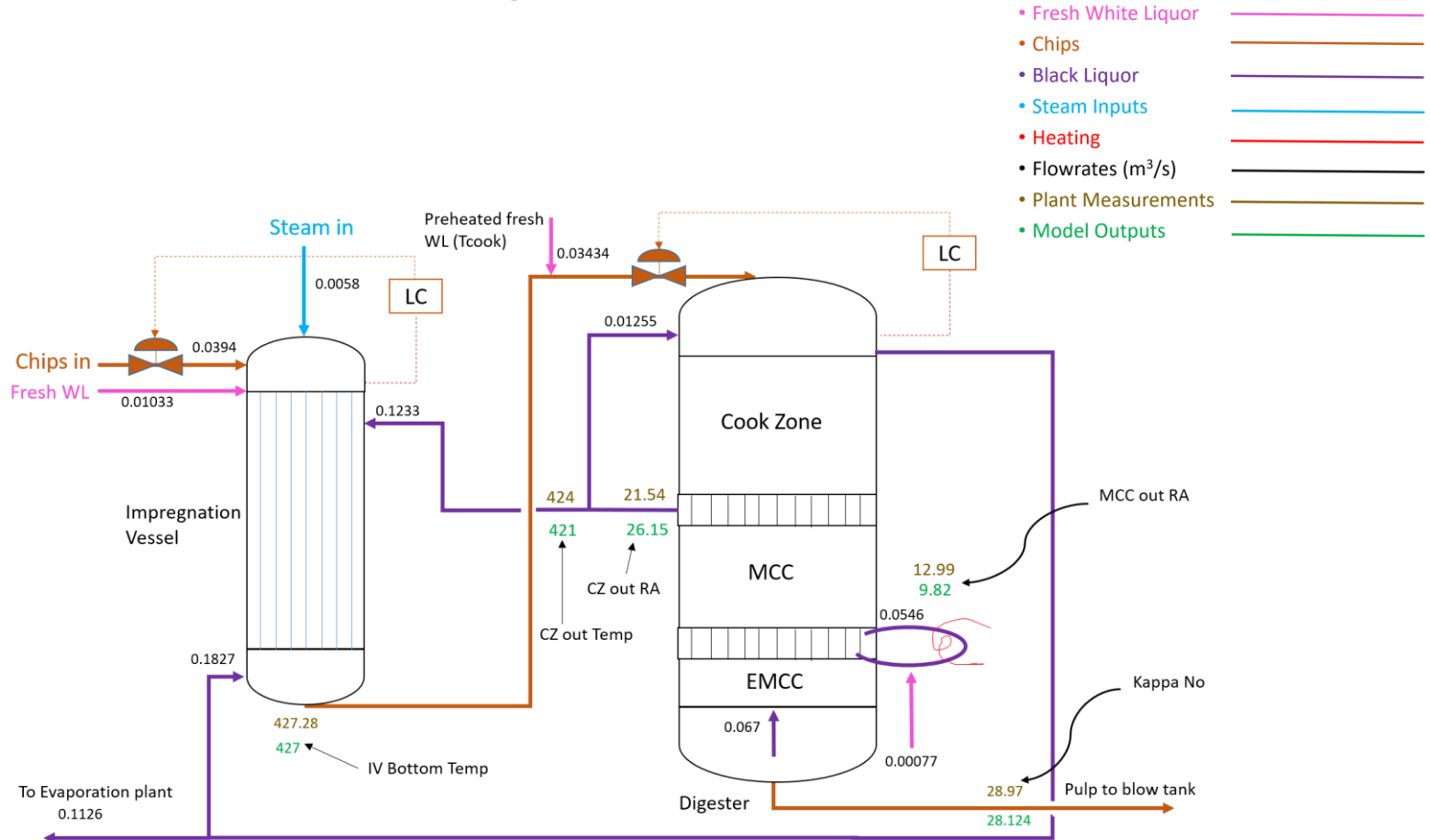
CASE STUDY: SUNILA PLANT FINLAND

Simulation results of PulpSim©
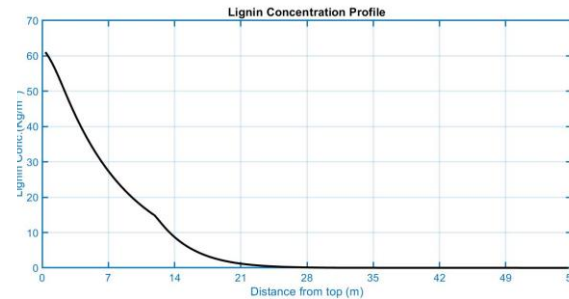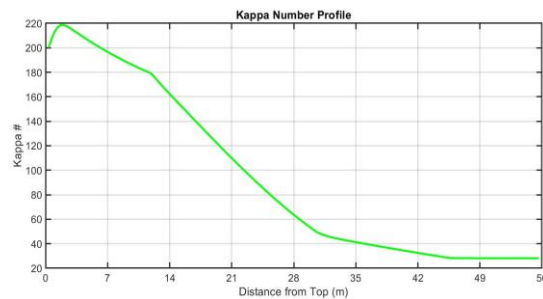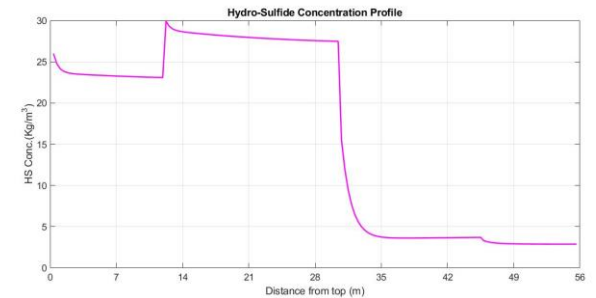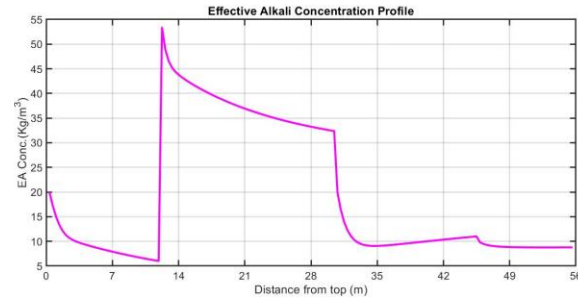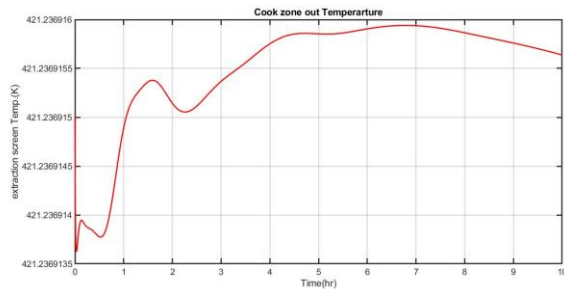
CASE STUDY: SUNILA PLANT FINLAND

Results validation: PulpSim© vs field data

Parameter	Plant Measurement	Model Output	Model Accuracy
Blow-line Kappa number	28.97	28.12	97%
Cook Zone out Extraction screen RA	21.54	26.15	83%
Cook Zone out temperature	424	421.24	99%
MCC out Extraction screen RA	12.99	9.82	76%
IV Bottom Temperature	427.28	427	99%

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B- DATA-DRIVEN MODELLING: DIGESTER DIGITAL TWIN

From plant data, through simulation and analytics towards the 'Digester Digital Twin'

Plant Data

Process Optimisation

Simulation Data	Data Analytics	Digital Twin	Insight
powered by **PULPSim**	powered by **eDAP**		

DIGESTER DIGITAL TWIN: USE OF E-DAP

eDAP

A data analytics platform for data analysis, statistics and predictive modelling

- **Integrated** : easily import a range of data types; visualize data trends in dashboard; perform predictive modelling using advanced mathematical algorithms
- **Versatile**: models a range of scenarios in industrial plants and environment, cross-correlate databases, enables building of Simulation Digital Twin (SDT)
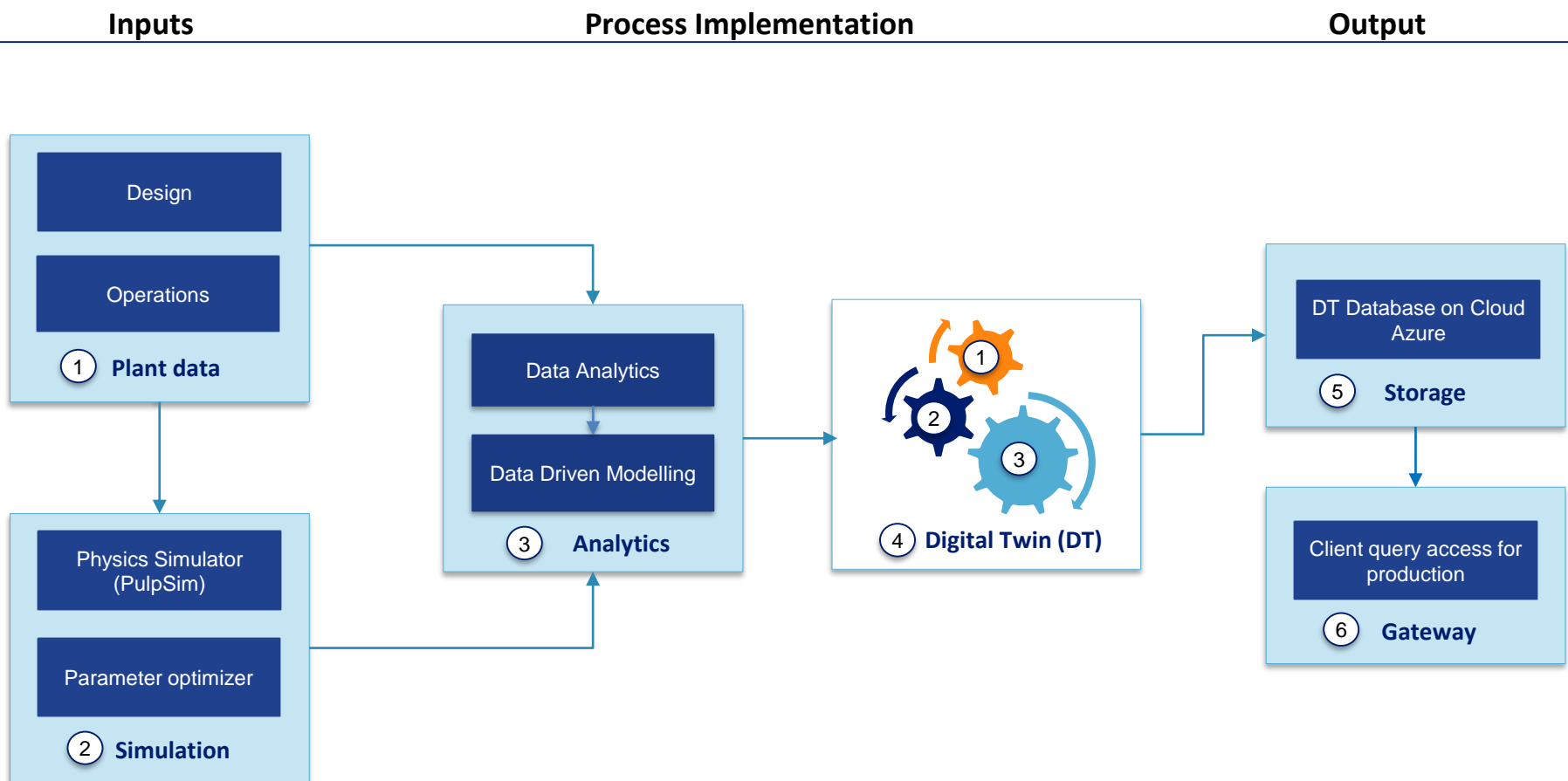
- Create a project database with different applications
- Insert, analyze data & perform statistics
- Visualize data on dashboard
- Perform Uncertainty Quantification (UQ)
- Conduct predictive modelling
- Interpret results and deploy

- **Interactive**: e-DAP helps make your analyses evolve and repeatable in time, capitalizing on former analyses and predictions of the scenarios
- **Broader impact**: identify more usable information through interactive analytics in various application areas

- Embedded with a variety of ML algorithms (for time and non-time series)
- Treats time- and space-dependent data
- Provides well-fitted data-driven models for various types of applications
- High convergence rate
- Excellent predictive performance

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DIGESTER DIGITAL TWIN: IMPLEMENTATION

From data acquisition and design through simulation & analytics to deployment

Inputs	Process Implementation	Output

Inputs

Design

Operations

① **Plant data**

Physics Simulator (PulpSim)

Parameter optimizer

② **Simulation**

Process Implementation

Data Analytics

Data Driven Modelling

③ **Analytics**

④ **Digital Twin (DT)**

Output

DT Database on Cloud Azure

⑤ **Storage**

Client query access for production

⑥ **Gateway**

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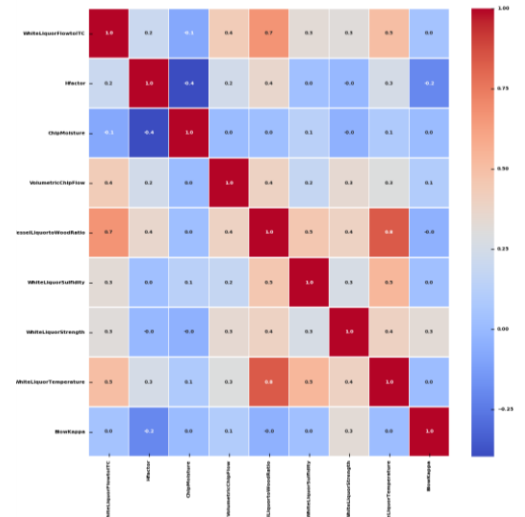# DIGESTER DIGITAL TWIN: CASE STUDY (SUNILA FINLAND)

Objective: predict using machine learning the blowup Kappa number

- Using historical data (here 3 months) including inflow properties and operational conditions, we train (using a portion of the data) our ML algorithms to create a data driven model (DDM) for the digester
- The DDM is then used to predict Kappa number for other inflow and operational conditions
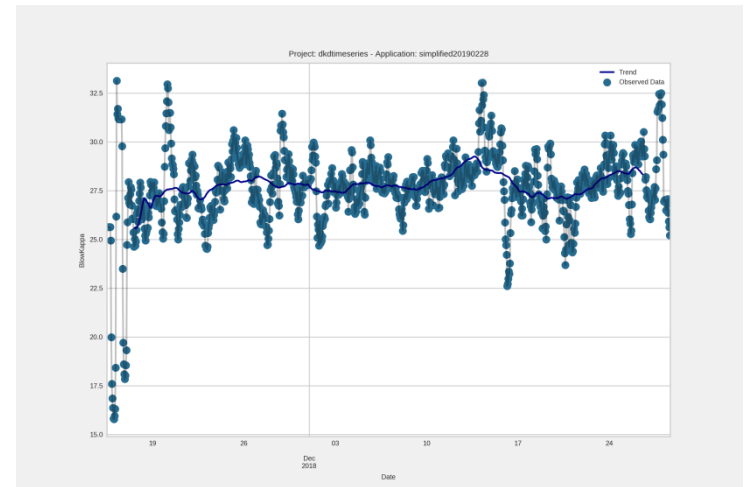

- A heat map is created, showing correlations between the various variables embedded in the data
- The heat map and other analytics results help infer useful insight into the production process through interactive analytics

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DIGESTER DIGITAL TWIN: CASE STUDY (SUNILA FINLAND)

Results : Kappa-number forecast, heat map

- Predictive modelling performance is tested for various ML algorithms
- In this case, tuning of the ML algorithms helps reach a very good prediction score.
- Our experts in ML can play with the different ML parameters in order to reach better scores.
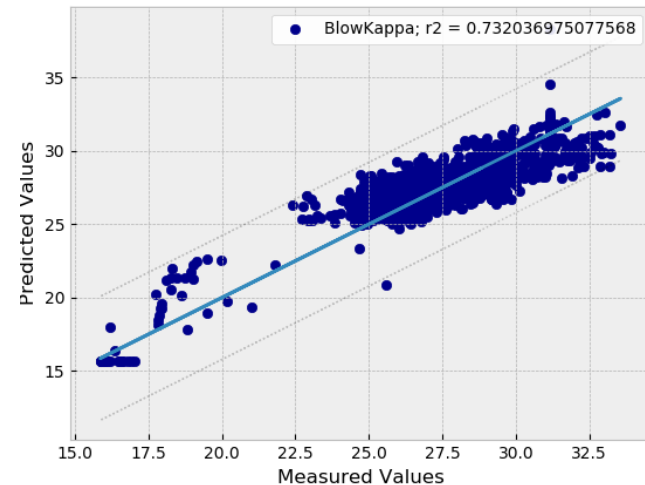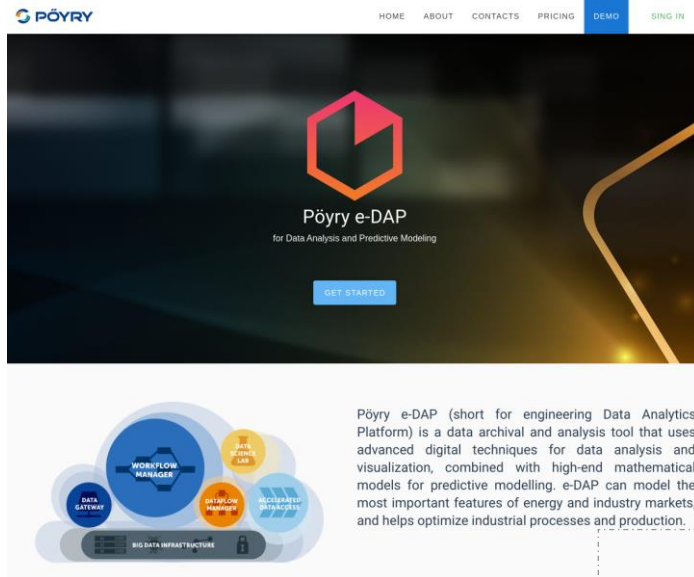

- The resulting DDM is shown to replicate the trend in kappa-number changes over two months.
- The model can forecast future trends.
- A new algorithm is being developed to sequence the historical data in useful portions, reflecting specific sequences of the cooking process.
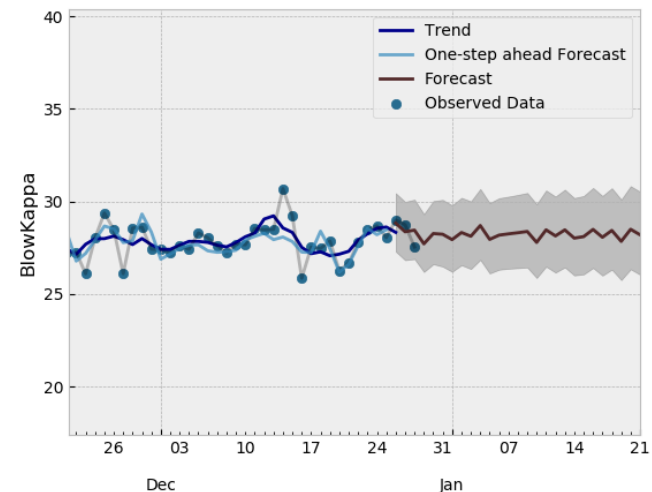
DIGESTER DIGITAL TWIN: FUTURE DEVELOPMENTS

Objective: Sensing live data from sensors and devices, through Azure Cloud IoT Edge and Hub, then predict using machine learning the blowup Kappa number