

Quality as driver for Integrated Intelligent Manufacturing



**Distributed, autonomous
control solutions**

F. Marchiori
F. Avellino

"Integrated Intelligent Manufacturing for Steel Industries"

(I2MSTEEL)

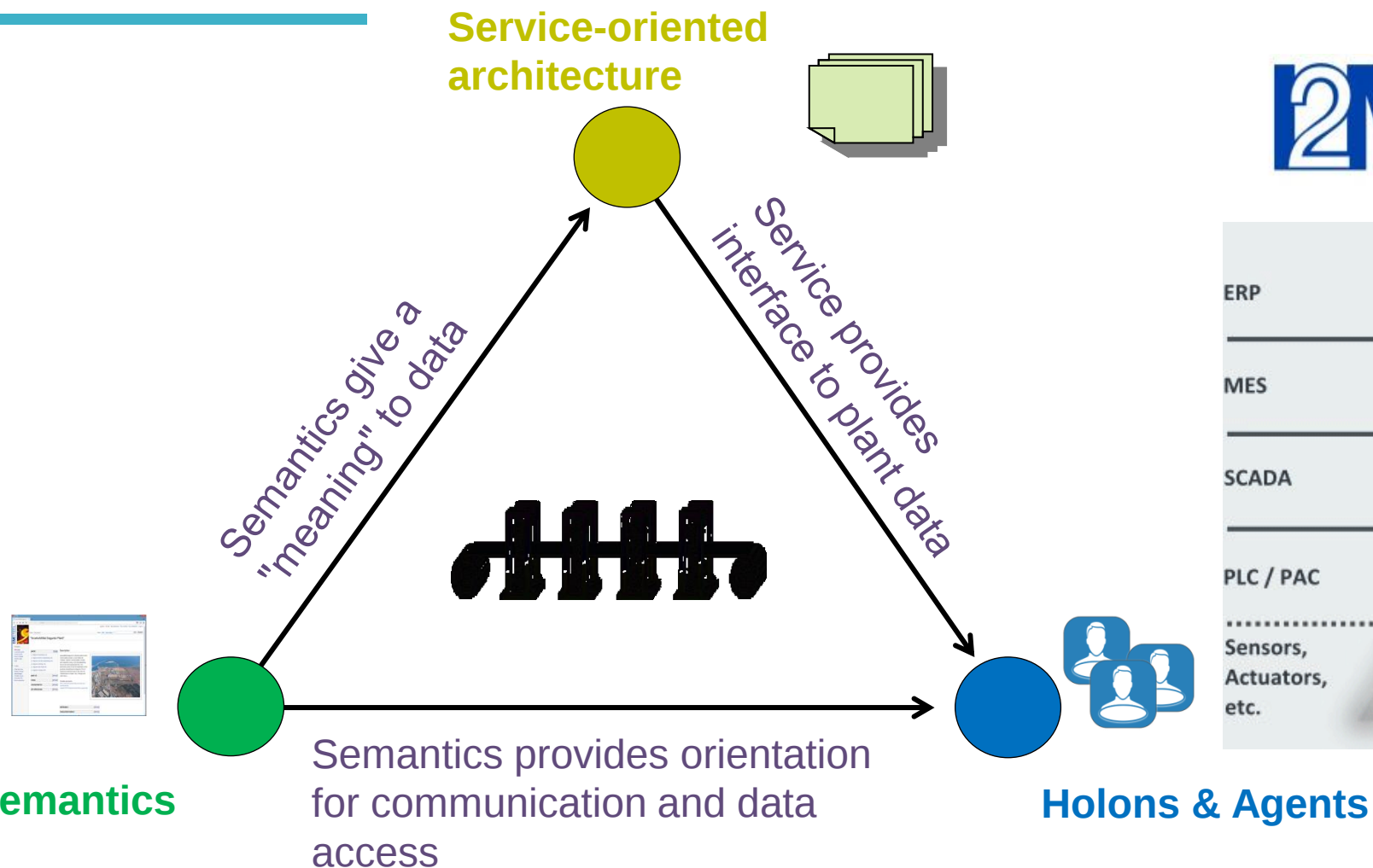
I2MSTEEL



SIEMENS



Object: Develop New paradigm



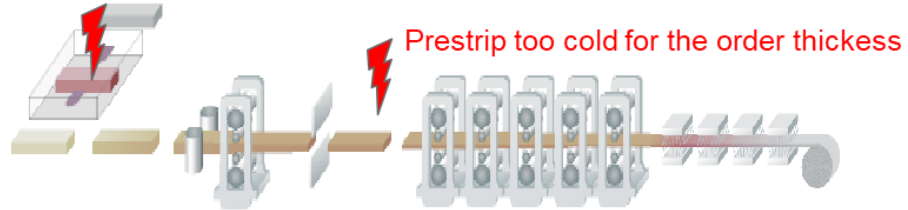
2MSTEEL



Use Case 1

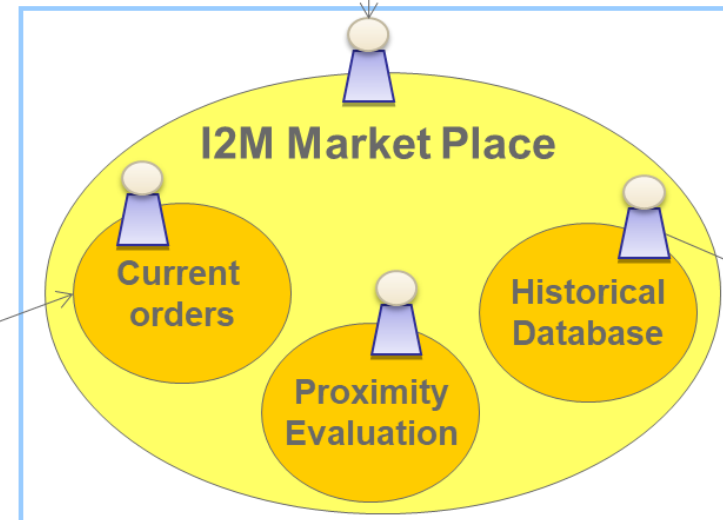
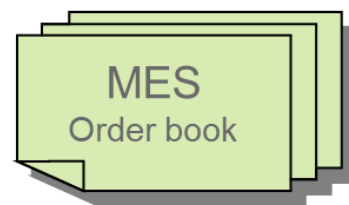


slab over heated



HSM L2

Request alternative thickness

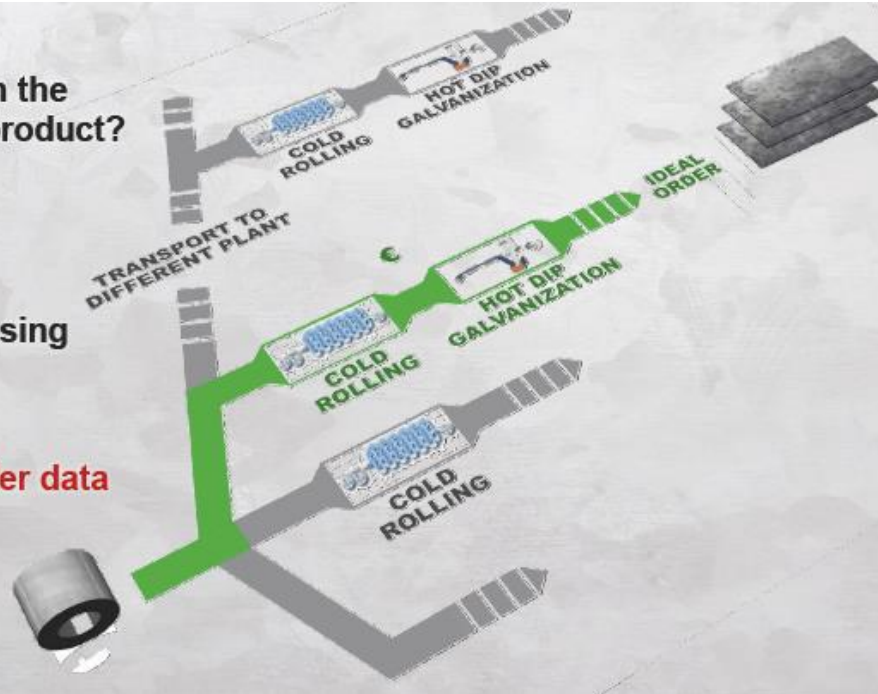


Use Case 2

What can we do with the off-spec hot rolled product?

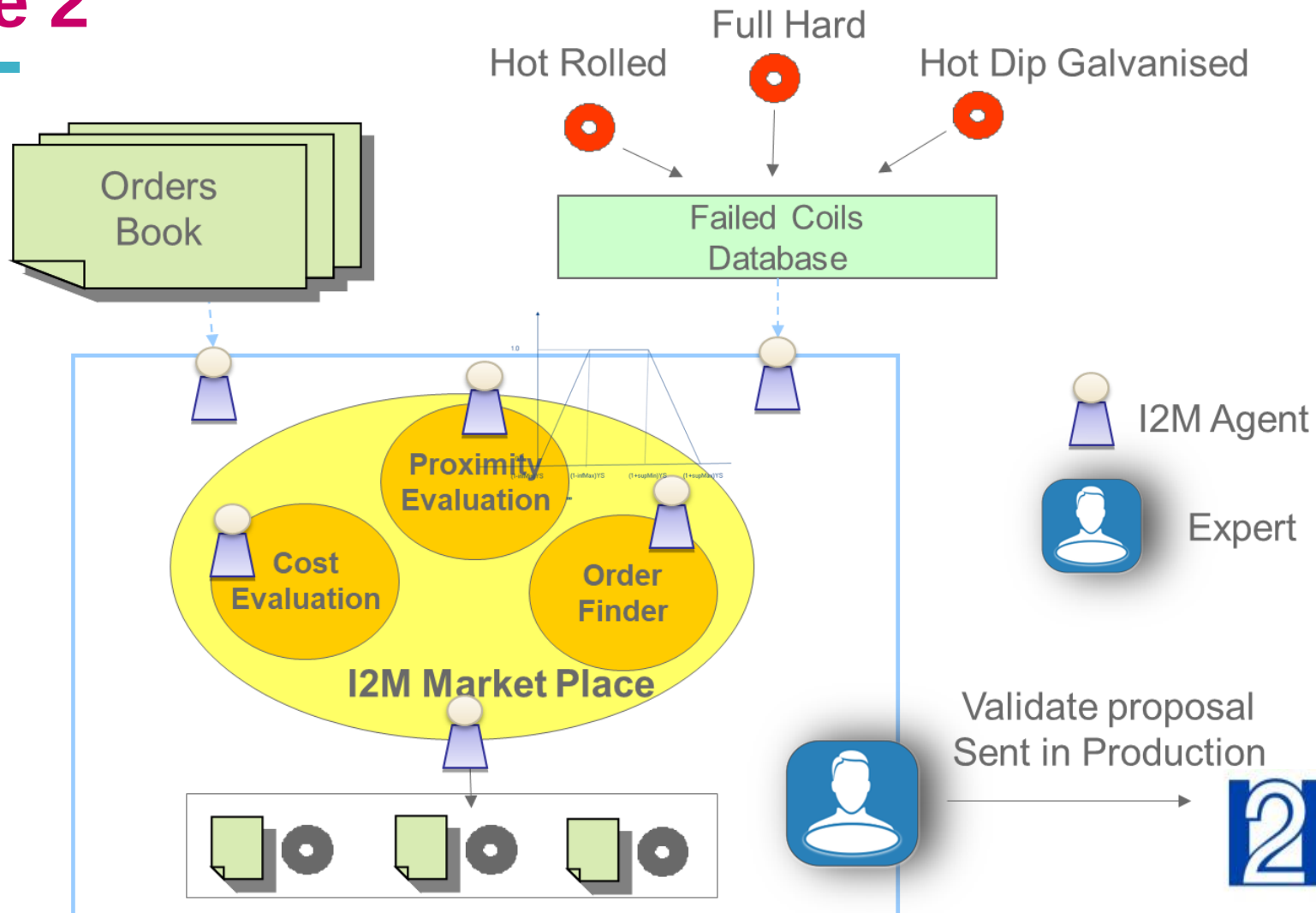
- Keep it as it is
- Goto post-processing

Central problem:
Product data vs Order data

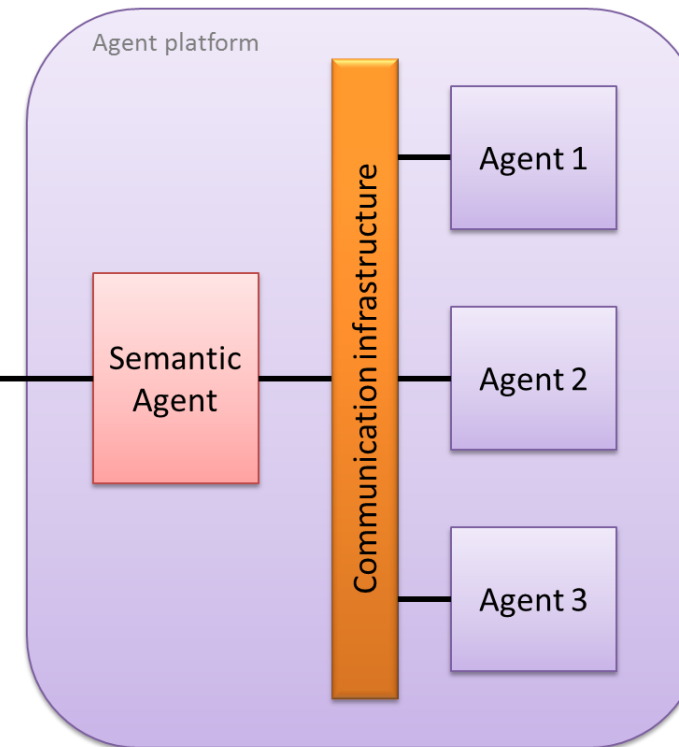
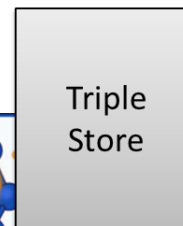
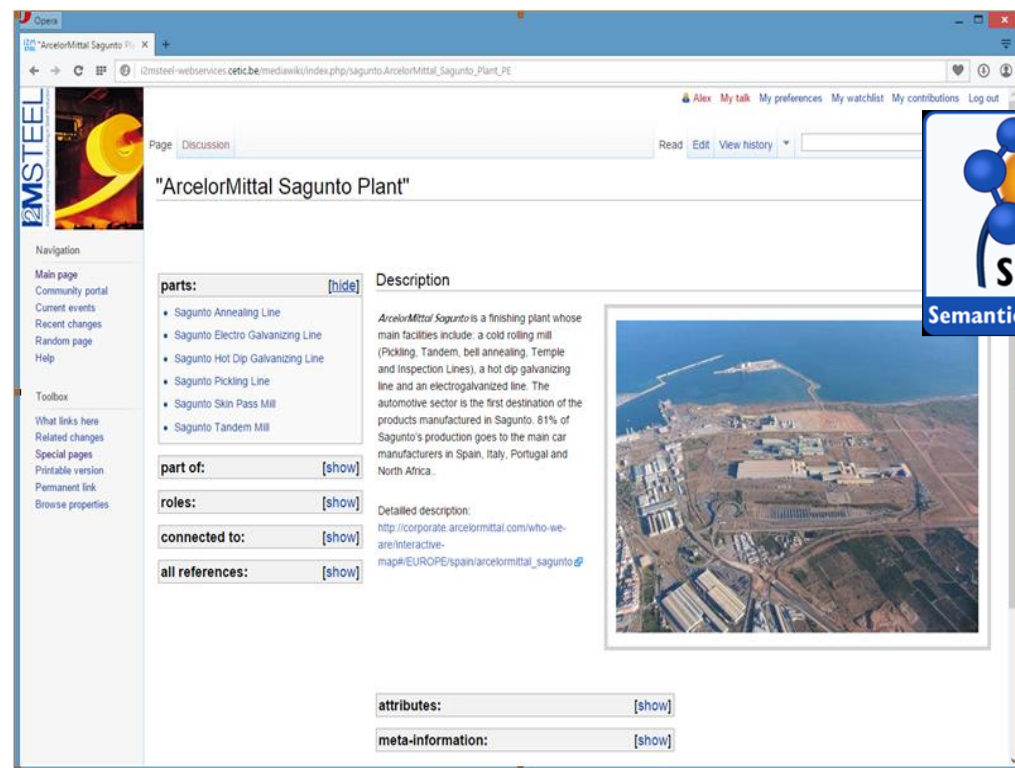


- **Off-spec products**
 - Example: product misses target thickness
- **Blind products**
 - Slabs being processed to coils, without having a specific order
- **Current solution**
 - Sell steel-product at a secondary market
 - **Lower profit**
- **Better: sell product on prime market**
 - Find a matching order = reallocate **during** processing
 - **Higher profit**

Use Case 2

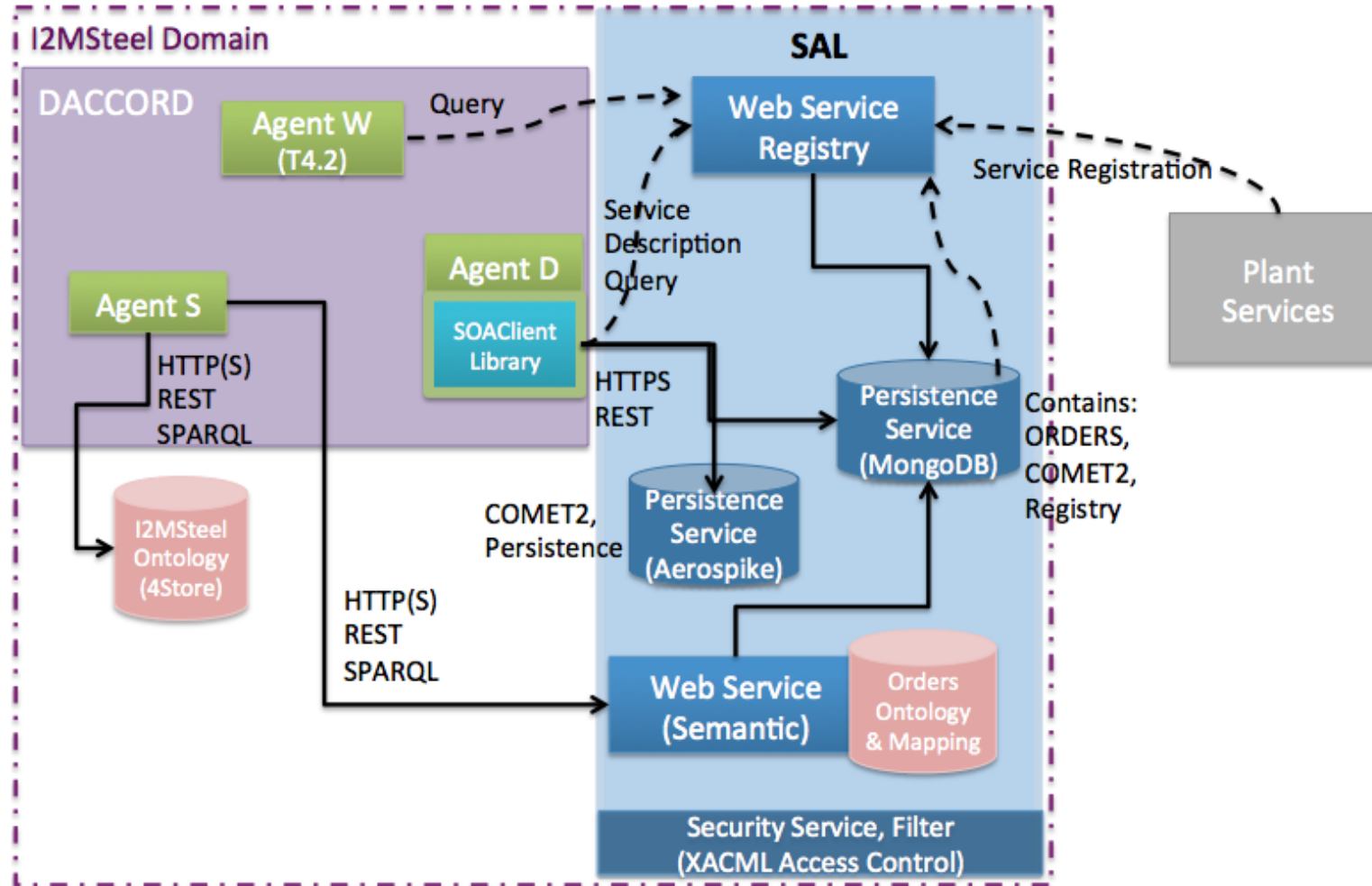


Implementation of semantics



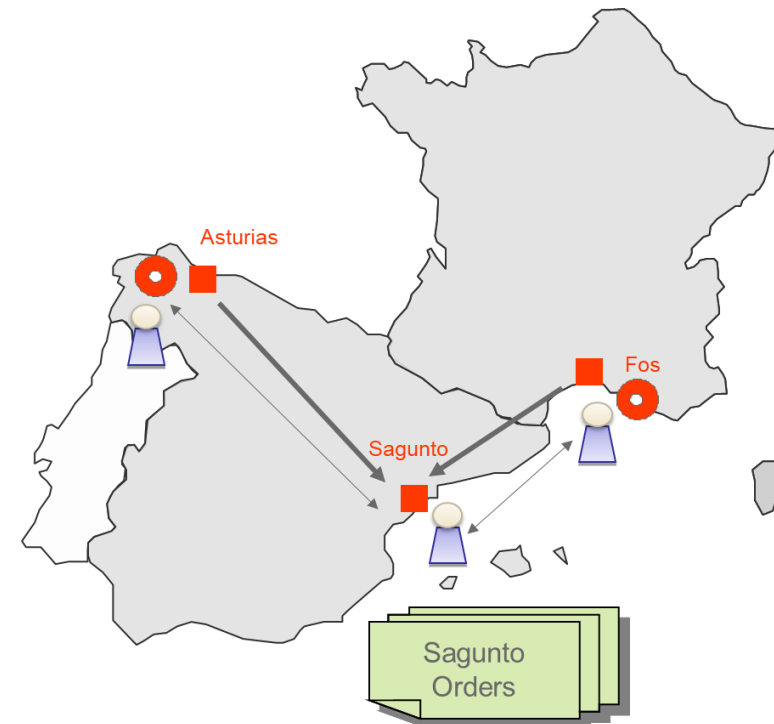
2MSTEEL

Implementation of service oriented architecture



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Implemented system



19

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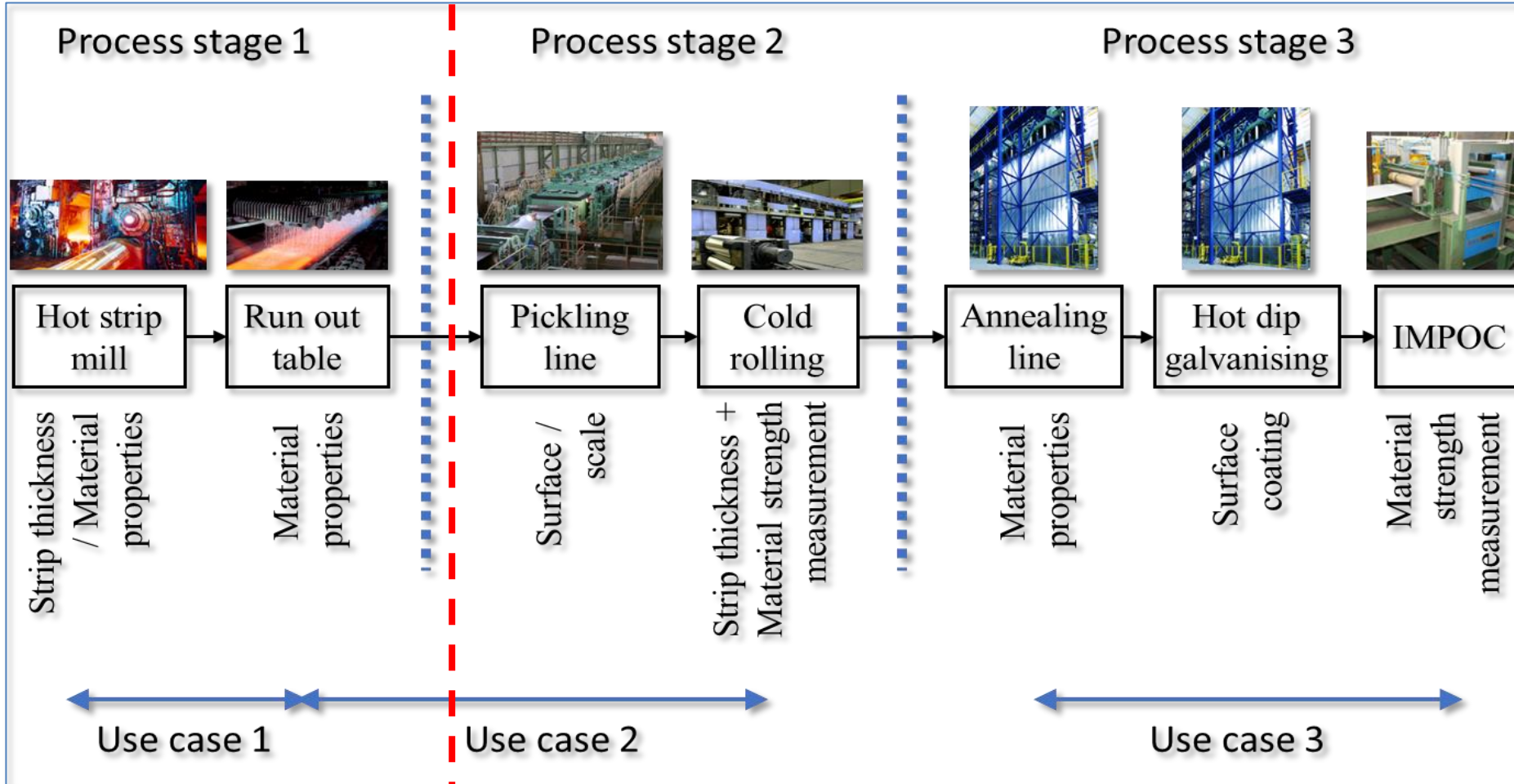


"Novel automatic model identification
and online parameter adaption for
supporting the industrial deployment of
model-based material property process
control “

(AutoAdapt)



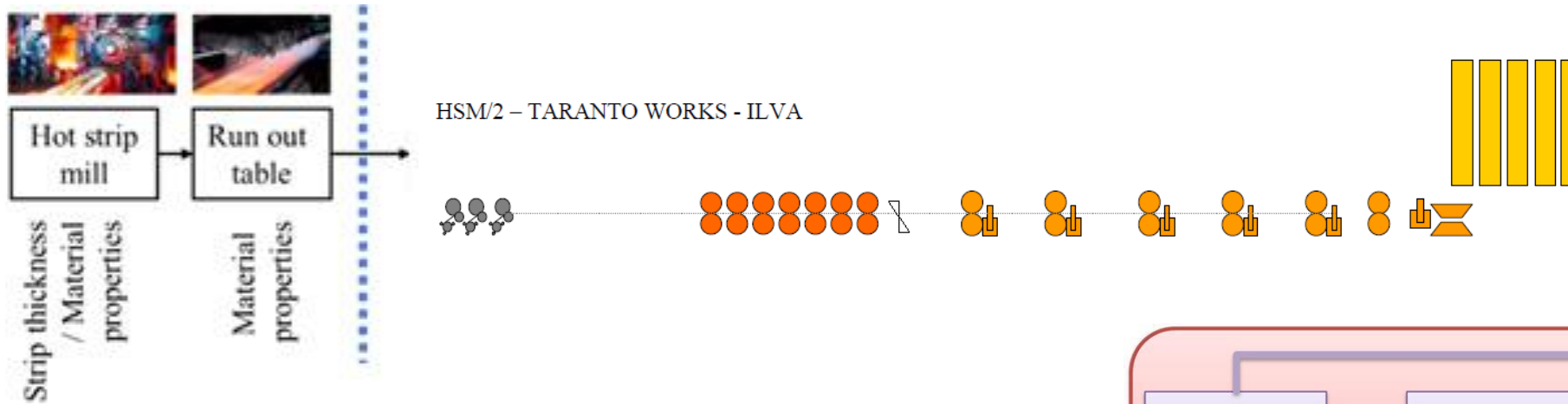
AutoAdapt project Objectives



- The aim of this project is to improve the *homogeneity* of material properties from *coil to coil* and *over coil length* throughout the whole process chain.
- Concerning the process route of steel making, the algorithms, models and concepts which were developed and industrially tested are separated in three use cases.
- *Use case 1* is intended to be shown.

Use case 1

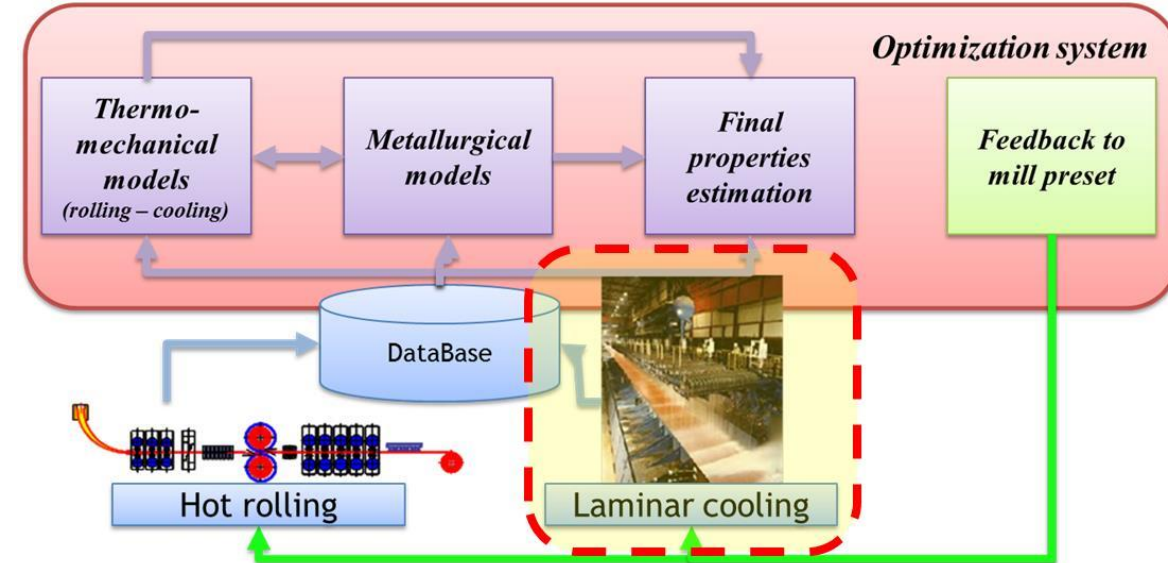
Hot Strip Mill and Run-Out Table



The work of use case 2 was carried out at the Hot Strip Mill (HSM) TN2 at ILVA Taranto (Italy)

“CSM microView” is a system allowing:

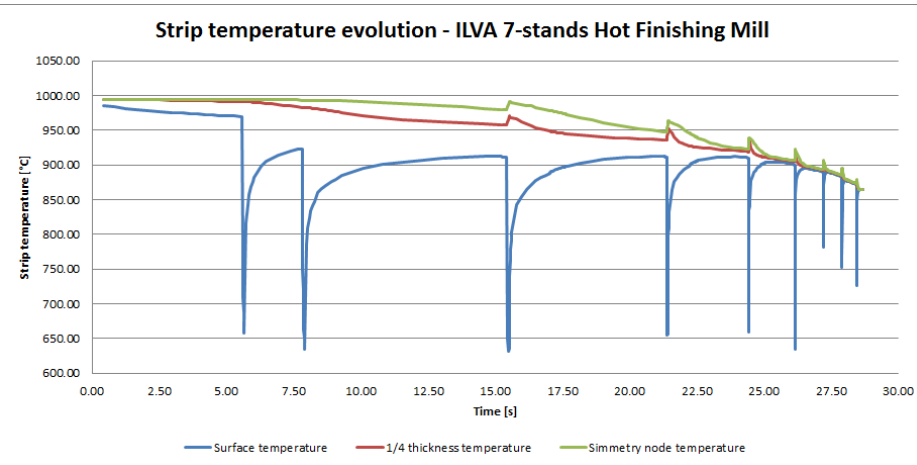
- online calculation of strip thermal evolution, microstructure parameters and mechanical properties
- creation of quality reports
- optimization of the main control parameter (the coiling temperature) with reference to mechanical and micro-structural targets



Calculation modules included in the microView

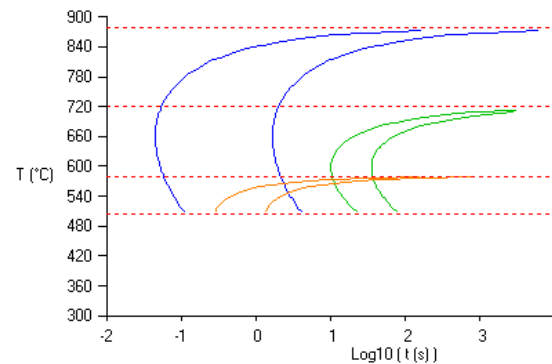


Strip thermal model



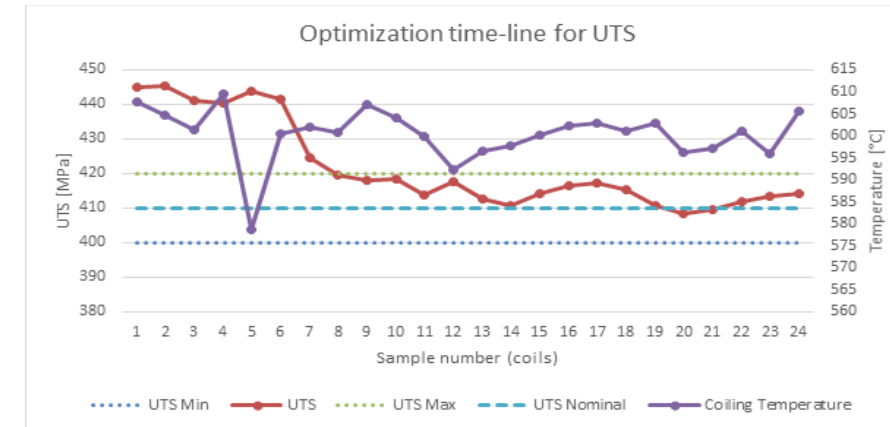
Finite difference based
strip thermal evolution

Metallurgical model



Physical-empirical based
approach and
Artificial Neural Network

Optimization module



Nonlinear constrained multi-
target optimization procedure

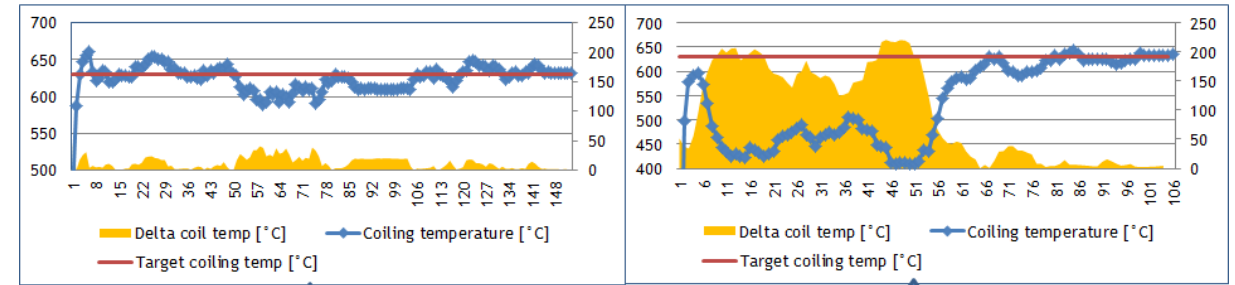
Selection and organization of main information



- List of materials (chemical compositions from the industrial partner) and plant characteristics
- Properly filtered on-field signals

List of selected materials

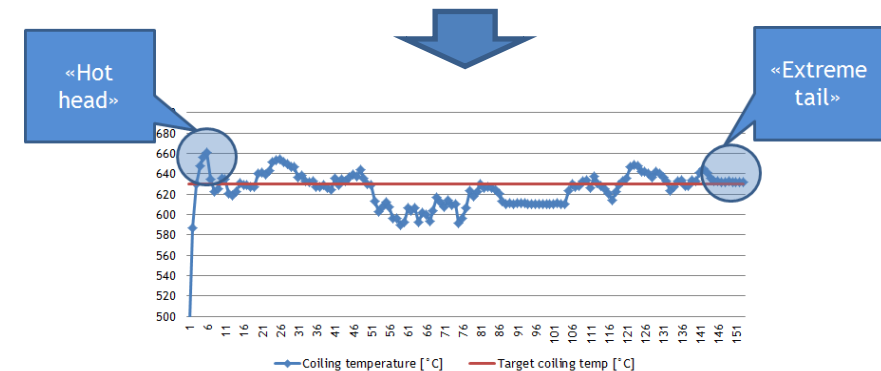
Chemical range [%]	Thickness level	Steel name	Width [mm]	Thickness [mm]
0,035<C<0,1 0,18<Mn<0,75	Low	S235JR+M	1500	2.00
		DD11	1500	2.00
	Medium	S235JR+M	1500	4.00
		CS TYPE B	1676	4.55
	High	CS TYPE B	1828	6.35
		DD11	1000	6.00
0,13<C<0,17 0,5<Mn<1,2	Low	S275JR+M	1500	2.00
		S235J2+M	1160	2.10
	Medium	S235J2+M	1180	4.70
		SS GR.36 TYPE 1	1524	4.80
	High	SS GR.36 TYPE 1	1524	6.41
		SS GR.36 TYPE 1	1828	6.45
0,18<C<0,2 1,3<Mn<1,4	Low	S355J2+M	1350	2.70
	Medium	S355JR+M	975	2.00
HSLA	Low	S315 MC	1005	1.80
		S315 MC	1005	1.80
	Medium	S355J2C+M	1680	4.51
		S355J2C+M	1680	4.51
	High	S275JR+M	1500	8.00
		S355J2+M	1500	8.00



Coil OK
Moderate delta temperature (<50 °C)

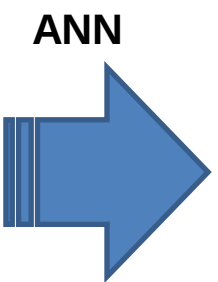
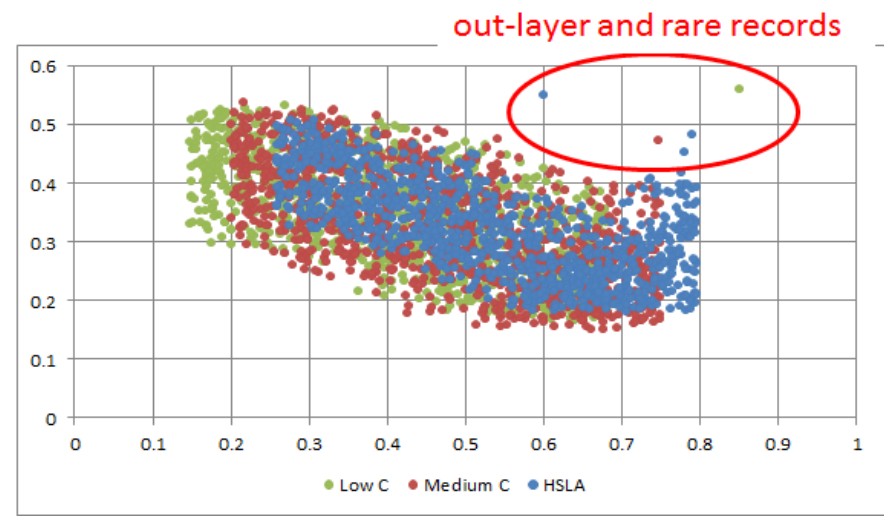
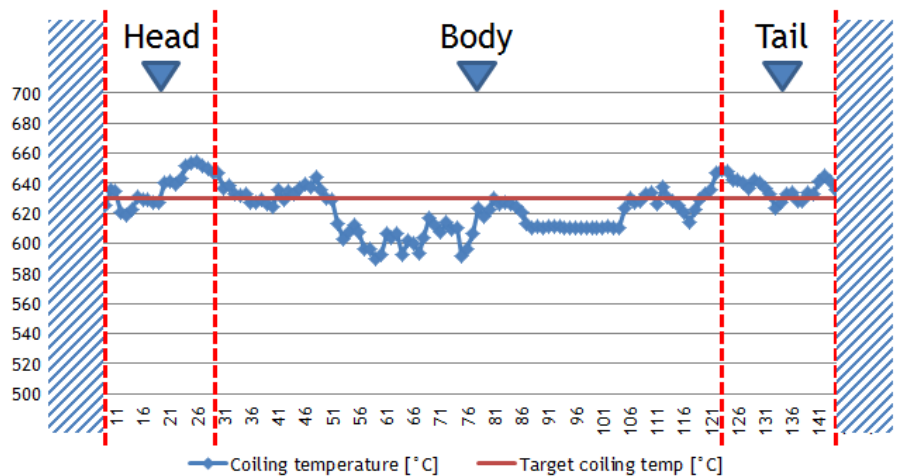
Coil not OK
Considerable delta temperature (>50 °C)

**Direct level data filtering examples:
comparison with max values and extremes cut-off**





Out-layers discarding and reporting



Strip	Id Slab	Thickn	Width	Cast	Order	Quality	Chemical
4G84999	1U30065	3,45	1.220,00	U64984	45923.4	SEMW06	DLS545

Steel	%
CARBON	0,0820
MANGANESE	0,8410
PHOSPHORUS	0,0540
SULPHUR	0,0080
SILICON	0,2170
ALUMINIUM	0,0280
CALCIUM	0,0030
COPPER	0,0670
NICKEL	0,0560
CHROMIUM	0,7560
MOLYBDENUM	0,0090
TIN	0,0120
NIObIUM	0,0030
VANADIUM	0,0030
TITANIUM	0,0030
BORON	0,0008
NITROGEN	0,0087
OXYGEN	0,0000

Average estimated						
	Hea		Bod		Ta	
	av.	dev.	av.	dev.	av.	dev.
Ferri	94,30	2,62	55,51	20,76	90,63	0,82
Grain	6,11	1,04	3,89	0,10	4,10	0,41
Perli	5,70	2,62	1,95	3,51	7,73	1,35
Marten	0,00	0,00	0,10	0,18	0,42	0,41
Bainit	0,00	0,00	43,04	24,56	1,26	1,71

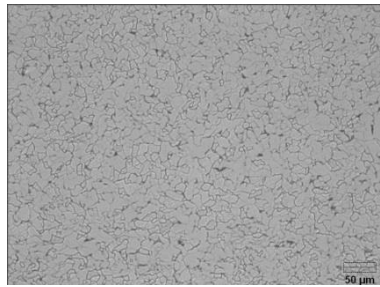
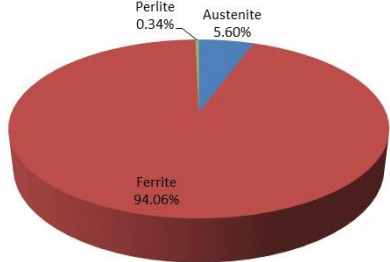
Run out table						
	Hea		Bod		Ta	
	av.	dev.	av.	dev.	av.	dev.
Speed(m/s)	5,60		5,62		6,77	
Fin.	836,25	14,55	850,47	5,70	827,49	18,81
UFC exit	729,16	30,71	664,76	23,24	704,50	4,59
Interm.	597,97	119,14	323,75	31,34	385,31	16,20
Coling	449,38	170,01	102,74	5,20	131,22	13,19

Average estimated mechanical properties												
Head					Body				Tail			
	Av.	min	max.	StdDe	Av.	min.	max.	StdDe	Av.	min.	max.	StdDe
YS	430,72	412,27	455,44	18,56	460,59	453,07	467,04	4,60	458,40	455,95	463,13	2,95
UTS	517,66	502,90	536,87	14,19	548,16	534,60	558,50	8,29	536,73	534,78	539,82	1,95
EI%	26,00	25,78	26,33	0,20	24,90	23,33	26,81	1,12	24,95	23,70	25,78	0,85
HV10	164,26	158,69	166,83	3,46	204,06	169,56	226,06	19,74	171,24	169,18	173,46	1,80

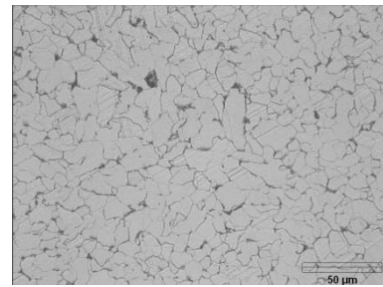
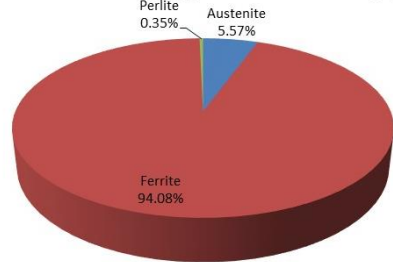
Microstructure forecasting



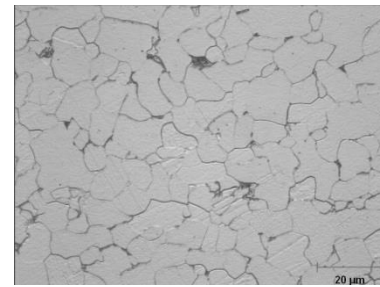
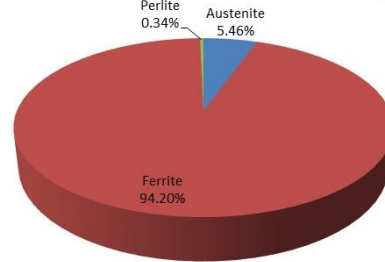
Phase fractions (simmetry node) [%]



Phase fractions (upper surface node) [%]



Phase fractions (bottom surface node) [%]



Composition (wt%)

C	0.060	Mn	0.224
P	0.008	S	0.008
Si	0.015	Al	0.028
Cu	0.245		

Final rolling temperature [°C]

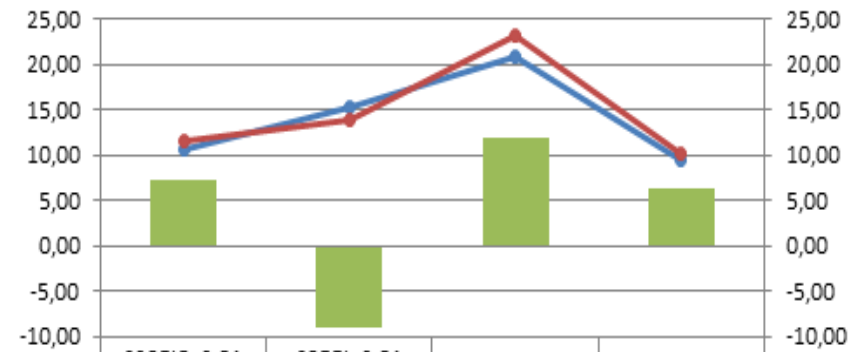
870

Coiling temperature [°C]

655

Slab reheating temperature [°C]

1164



Relative perc. error [%]	7,29	-9,14	12,02	6,32
Ferrite Grain Size [μm]	10,70	15,20	20,80	9,50
Calc. Ferr. Grain Size [μm]	11,48	13,81	23,30	10,10

Relative perc. error [%] Ferrite Grain Size [μm] Calc. Ferr. Grain Size [μm]

Pearlite [%]

8.3

Ferrite Grain Size [μm]

10.7

Calc. Ferr. Grain Size [μm]

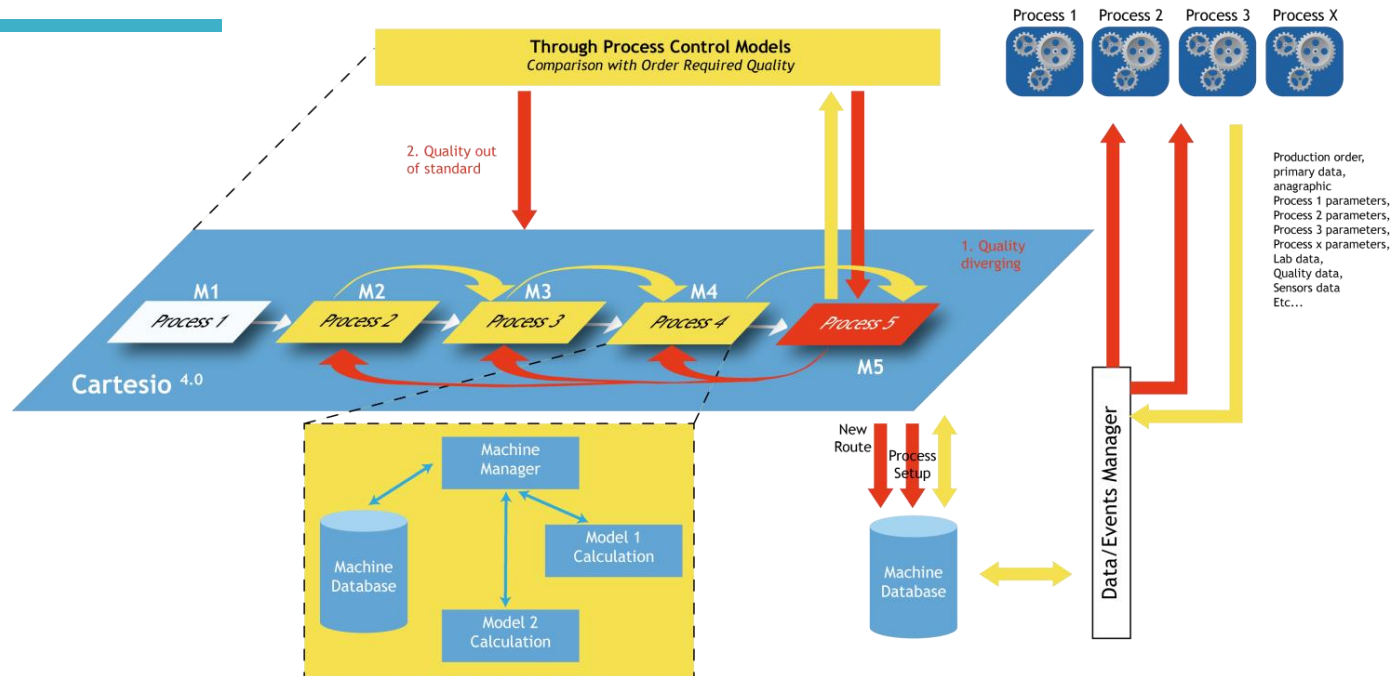
11.48

Relative perc. error [%]

7.3

CONTROL^{IN}STEEL

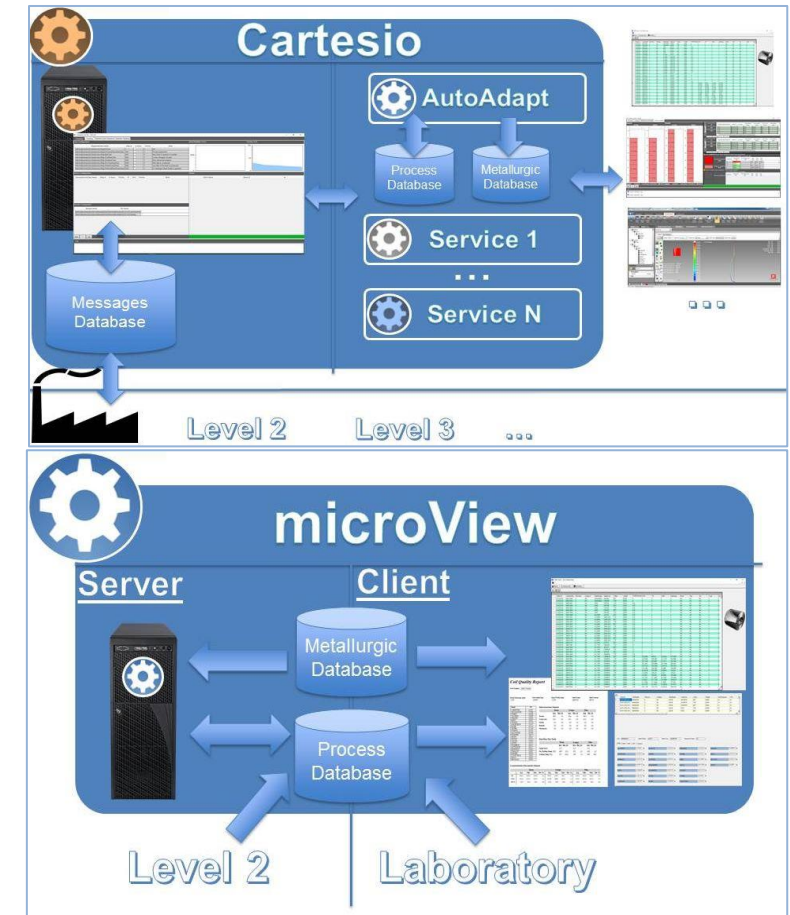
Cartesio platform



Cartesio System entities:

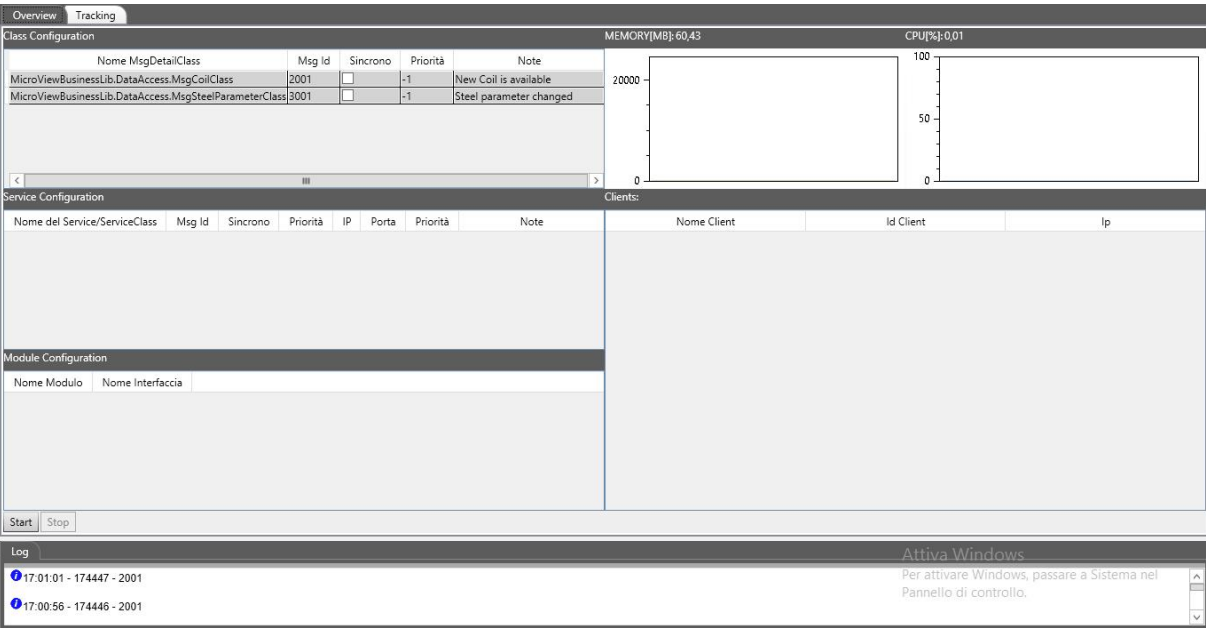
- Service
- Communicating with the plant through interface tables
- Module
- DLL that deals with launching mathematical models.
- Message

Entity used to notify a service to perform certain operation

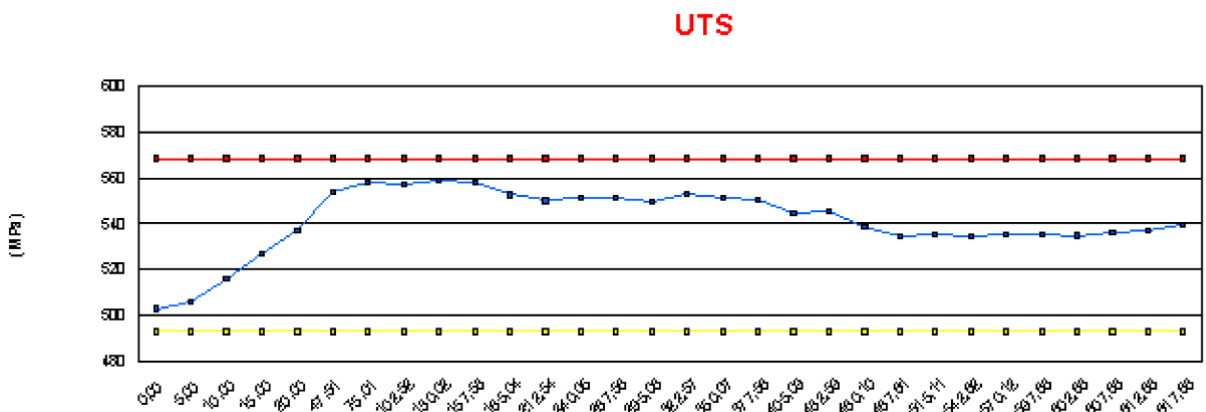
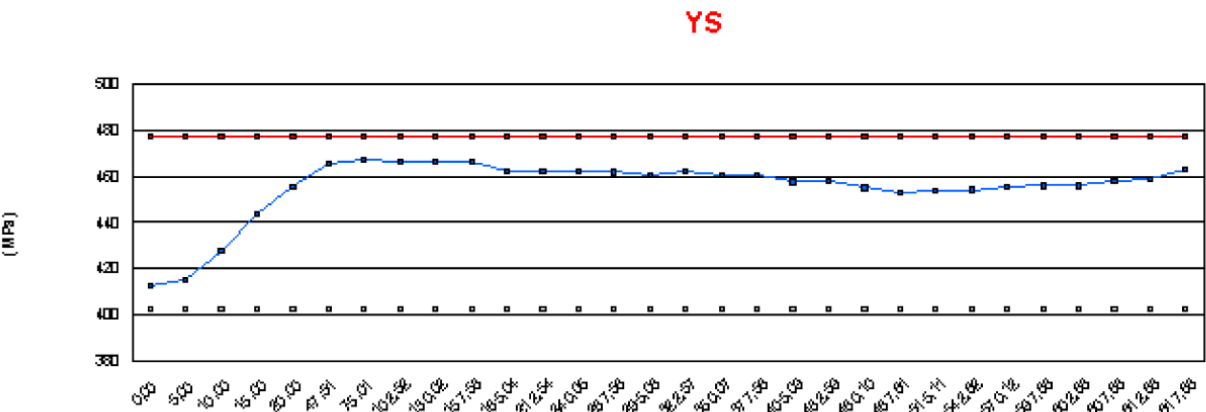


microView

Overview/tracking section



Overview/tracking section GUI



microView Simulation section



Col	Row	Analys	SteelCust	CfBox	Weight	FinalThickness	UTS	YS	TotB	Hardness	Exam	Poa	Dr	Type	Rp02	Rel	Relh	Re
680038106	0	OK	S235JRC	TOP	23000	1.48	411.1	344.0	26.9	132.6	NO	NA	NA	0	0	0	0	0
680038201	0	OK	S235JRC	BOT	23000	1.48	403.7	337.0	27.6	130.2	NO	NA	NA	0	0	0	0	0
680038202	0	OK	S235JRC	TOP	23000	1.48	400.1	334.0	27.8	129.1	NO	NA	NA	0	0	0	0	0
680038203	0	OK	S235JRC	BOT	23000	1.48	402.0	335.5	27.8	129.7	NO	NA	NA	0	0	0	0	0
680038205	0	OK	S235	BOT	25000	1.42	396.4	332.2	28.1	127.9	NO	NA	NA	0	0	0	0	0
680038306	0	OK	S235	TOP	25000	1.4	396.6	332.3	28.1	127.9	NO	NA	NA	0	0	0	0	0
680038502	0	OK	S235JR	TOP	25000	1.38	402.6	335.7	27.6	129.9	NO	NA	NA	0	0	0	0	0
680038503	0	OK	S235JR	BOT	25000	1.38	400.3	333.7	27.7	129.1	NO	NA	NA	0	0	0	0	0
680038504	0	OK	S235JR	TOP	25000	1.38	398.2	331.9	27.8	128.4	NO	NA	NA	0	0	0	0	0
680038506	0	OK	S235JR	TOP	25000	3.9	398.9	333.7	30.6	128.7	NO	NA	NA	0	0	0	0	0
680038507	0	OK	S235JR	TOP	25000	3.9	399.6	334.4	30.6	128.9	NO	NA	NA	0	0	0	0	0
680038701	0	NO	S235JR	TOP	24000	4	0.0	0.0	0.0	0.0	NO	NA	NA	0	0	0	0	0
680040201	0	NO	S235JR	TOP	24000	4	0.0	0.0	0.0	0.0	NO	NA	NA	0	0	0	0	0
680042704	0	OK	S235JR	TOP	25000	2.4	403.3	338.5	29.1	130.1	NO	NA	NA	0	0	0	0	0
680042901	0	NO	S235JR	BOT	25000	3.5	0.0	0.0	0.0	0.0	NO	NA	NA	0	0	0	0	0
680042903	0	OK	S235JR	BOT	25000	2.7	402.0	336.6	30.1	129.7	NO	NA	NA	0	0	0	0	0
680043101	0	OK	S235JR	TOP	25000	1.93	409.4	342.0	27.8	132.1	NO	NA	NA	0	0	0	0	0
680043102	0	OK	S235JR	BOT	25000	1.93	406.9	339.7	27.8	131.3	NO	NA	NA	0	0	0	0	0
680043103	0	OK	S235JR	TOP	25000	1.93	407.0	339.6	27.9	131.3	NO	NA	NA	0	0	0	0	0
680043104	0	OK	S235JR	BOT	25000	1.93	409.8	342.3	27.9	132.2	NO	NA	NA	0	0	0	0	0
680043105	0	OK	S235JR	TOP	25000	1.93	407.7	340.3	27.9	131.5	NO	NA	NA	0	0	0	0	0
680043106	0	OK	S235JR	BOT	25000	1.93	408.8	341.1	28.0	131.9	NO	NA	NA	0	0	0	0	0
680043201	0	OK	S235JR	TOP	25000	1.93	405.3	338.6	28.8	130.7	NO	NA	NA	0	0	0	0	0
680043205	0	OK	S235JR	TOP	17000	2.7	406.7	340.7	29.7	131.2	NO	NA	NA	0	0	0	0	0

Col: 680040201

Steel Grade: A5012

Steel Cust: S235JR

Spessore Finale: 4

STEEL | HRM | HFM | ROT | Output

ALLUMINIO

0.045304 %

COBALTO

0.006122 %

OSSIGENO

0.002188 %

NIODIO

0.001448 %

ANTIMONIO

0.004117 %

CROMO

0.048075 %

POMBO

0.001313 %

ZINCO

0.017101 %

ARSENICO

0.005459 %

FOSFORO

0.005116 %

RAME

0.23284 %

ZIRCONIO

0.000165 %

AZOTO

0.004854 %

MANGANESE

0.317481 %

SLICIO

0.017517 %

ZOLFO

0.002981 %

BORO

0.000143 %

MOLIBDENO

0.021485 %

STAGNO

0.012205 %

CALCIO

0.003345 %

NICHEL

0.098405 %

TITANIO

0.002183 %

CARBONIO

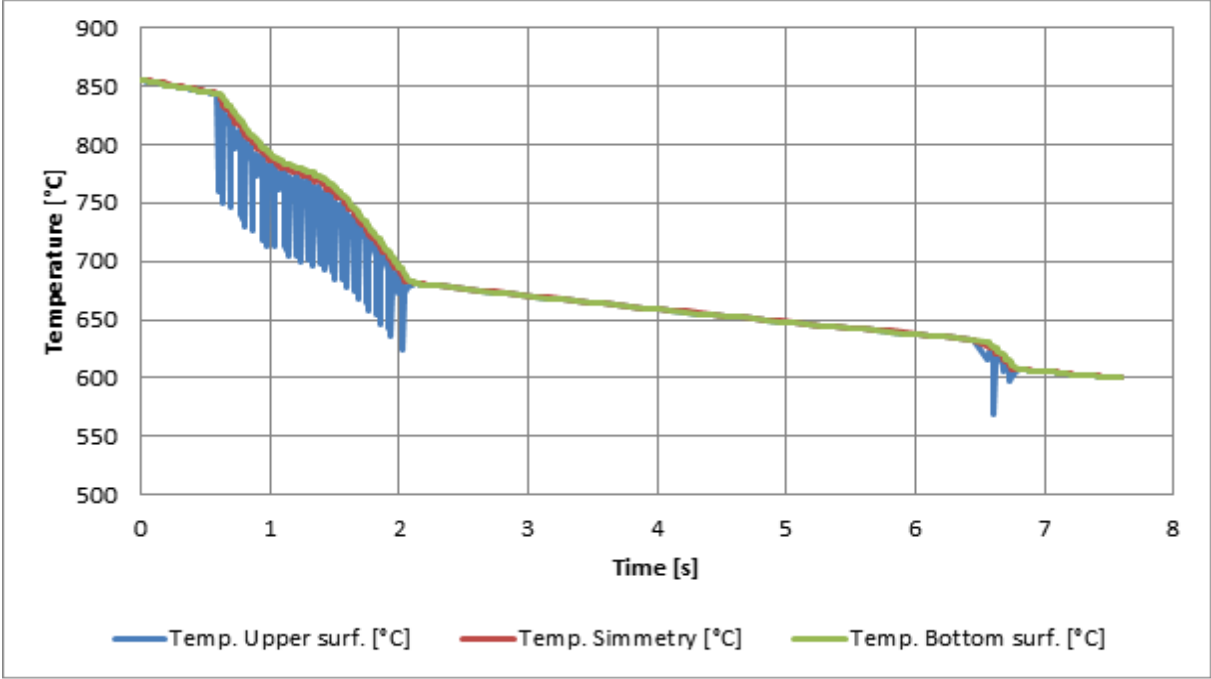
0.034947 %

NIOBIO

0.001145 %

TUNGSTENO

0.000581 %



Simulation section GUI

Example:
Re-calculated thermal evolution
on the run-out table

microView Optimization section



Report | Analisi Dati | Simulazione

Criteri di Selezione

Da 01/01/2018 A 31/01/2018 Coil Number Spessore Min Spessore Max Cerca

Steel Grade Steel Custom: S235 Posizione Testa Corpo Fine Completo Analisi Modello Completa Analisi Laboratorio Completa

Variabili da Analizzare

Cal

Spessore Finale

Peso

Steel Customer

Steel Grade

Stato analisi Modello

Larghezza

Composizione Chimica

Uscolo HFM

Spessore

Temperatura

Uscolo HFM

Spessore

Temperatura

Proprietà Meccaniche & Microstrutturali

UTS Av

UTS Max

UTS Min

UTS dev. st.

YS Av

YS Max

YS Min

YS dev. st.

E% Av

E% Max

E% Min

E% dev. st.

HV10 Av

HV10 Max

HV10 Min

HV10 dev. st.

Data Lab.

Fenite

Perlite

Bainite

Grain Size

Martensite

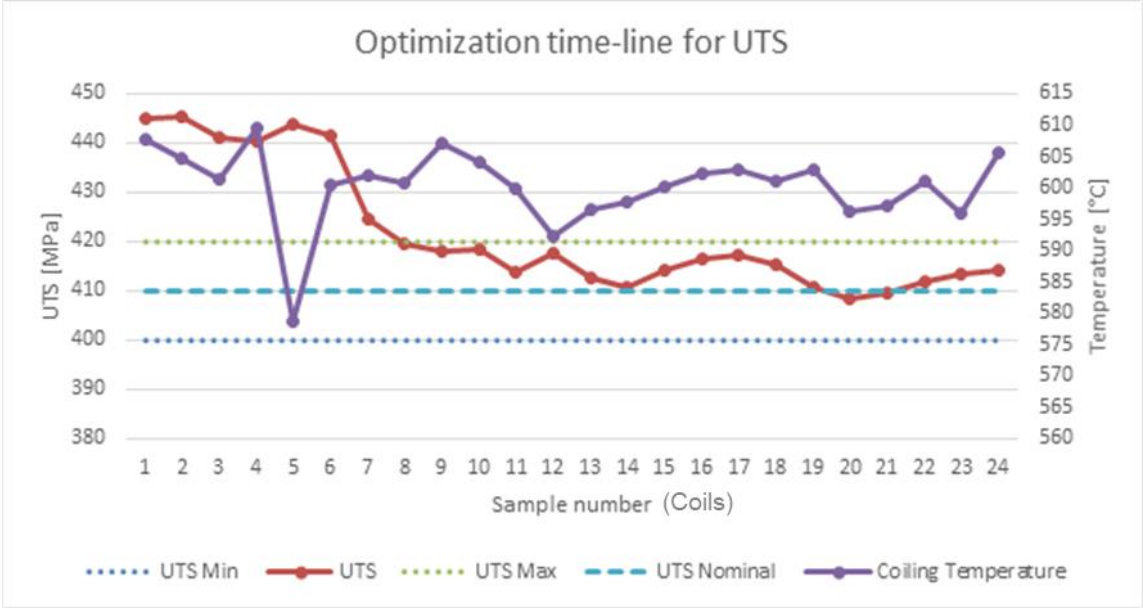
Temperatura Arricchimento

Selezione Tutto

Risultati

Col Trovati: 138

Col Number	Pos	Final Thick	Custom	HFM Ext. Thick	HFM Ext. Temp	HFM Ext. Temp	HFM Ext. Thick	UTS Av	UTS Max	UTS Min	UTS DevStd	YS Av	YS Max	YS Min	YS DevStd	B Av	B Max
600001205	C	1.75	S235JR	15.00	976.9	852.1	1.75	415.4	415.7	414.9	0.19	346.0	346.3	345.7	0.16	27.83	27.85
600001404	C	1.75	S235JR	15.00	978.1	852.4	1.75	413.9	413.4	413.4	0.15	344.6	344.8	344.3	0.13	27.87	27.88
600001405	C	1.50	S235JR	13.50	975.8	834.9	1.49	402.2	403.5	403.0	0.14	333.8	334.3	333.4	0.24	27.98	27.99
600001501	C	1.50	S235JR	13.50	967.8	834.8	1.50	402.5	403.1	401.8	0.26	333.4	334.0	332.9	0.23	28.04	28.07
600001502	C	1.50	S235JR	13.50	971.1	834.5	1.50	408.3	408.8	408.0	0.20	340.6	341.1	340.1	0.26	27.70	27.72
600002005	C	1.50	S235JR	13.50	973.2	837.2	1.50	408.2	408.5	408.0	0.14	340.8	341.0	340.6	0.11	27.72	27.73
600005302	C	3.90	S235JR	16.00	941.3	855.2	4.12	390.2	390.4	389.9	0.11	324.1	324.3	323.7	0.12	31.60	31.60
600005302	C	2.40	S235JR	16.00	1008.0	856.1	2.39	403.0	403.3	402.7	0.15	337.5	337.8	337.3	0.13	28.89	28.89
600005303	C	2.40	S235JR	16.00	1006.3	857.9	2.39	402.7	402.9	402.3	0.18	337.3	337.5	337.0	0.15	28.89	28.89
600005904	C	2.70	S235JR	16.00	988.6	846.0	2.70	405.9	406.1	405.6	0.11	340.0	340.1	339.7	0.09	29.20	29.20
600006005	C	2.70	S235JR	16.00	963.2	849.5	2.70	405.7	405.5	405.3	0.34	319.5	320.4	319.0	0.37	31.32	31.34
600011801	C	5.03	S235JR	13.50	974.9	845.1	5.29	403.8	403.9	403.7	0.05	401.5	401.8	401.3	0.12	31.84	31.91
600013401	C	2.00	S235JR	15.00	940.1	844.4	2.00	396.6	396.9	396.4	0.16	331.2	331.4	331.0	0.13	28.72	28.75
600013605	C	1.48	S235JR	13.50	935.1	843.4	1.47	399.1	400.1	398.5	0.37	332.7	333.5	332.3	0.30	27.67	27.76
600013606	C	1.48	S235JR	13.50	937.6	843.3	1.48	398.0	398.2	397.5	0.18	331.6	331.8	331.3	0.14	27.83	27.86
600013701	C	1.48	S235JR	13.50	939.1	841.2	1.48	404.4	404.8	404.2	0.17	335.8	336.2	335.5	0.20	27.80	27.84
600013702	C	1.48	S235JR	13.50	939.3	841.6	1.48	403.5	403.8	403.3	0.17	334.9	335.2	334.7	0.14	27.91	27.92
600013703	C	1.48	S235JR	13.50	938.9	840.9	1.48	404.1	404.3	403.8	0.16	335.5	335.7	335.2	0.13	27.83	27.84
600013704	C	1.48	S235JR	13.50	939.7	843.2	1.48	403.3	403.5	403.1	0.12	334.7	334.9	334.6	0.09	27.89	27.90
600013705	C	1.48	S235JR	13.50	939.1	844.0	1.48	403.3	403.6	403.0	0.18	334.8	335.0	334.5	0.14	27.89	27.90
600013706	C	1.48	S235JR	13.50	938.2	844.1	1.48	403.5	403.8	403.2	0.18	335.0	335.3	334.7	0.18	27.84	27.90
600013801	C	1.48	S235JR	13.50	936.9	842.8	1.48	402.4	402.7	402.2	0.16	335.8	337.0	336.7	0.12	27.28	27.29
600013802	C	1.48	S235JR	13.50	937.8	844.1	1.48	402.2	402.5	401.9	0.14	336.7	337.0	336.5	0.11	27.28	27.29
600013802	C	1.48	S235JR	13.50	952.0	842.8	1.48	411.2	411.5	410.8	0.18	341.4	341.6	341.0	0.14	27.15	27.16
600013903	C	1.48	S235JR	13.50	955.4	841.8	1.47	412.0	412.3	411.6	0.19	342.1	342.3	341.8	0.17	27.10	27.12



Optimization section GUI

Example:
Optimization time-line for a selected
mechanical property (UTS)

Thank you for the attention:

Francesca Marchiori: francesca.marchiori@rina.org

Filippo Avellino: filippo.avellino@rina.org