

**Smart consideration of actual ladle status monitored by novel sensors for secondary metallurgy process parameters and ladle maintenance strategies  
(SmartLadle)**

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**Partners:**

VDEh-Betriebsforschungsinstitut GmbH (BFI), Düsseldorf, Germany  
Schmiedewerke Gröditz GmbH (SWG), Gröditz, Germany  
Swerim AB (SWERIM), Lulea, Sweden  
Uddeholms AB (UAB), Hagfors, Sweden  
Sidenor Investigacion Y Desarrollosa SA (SID), Basauri, Spain

**Deliverable D1.1 Definition and collection of process parameters**

**Public**

Responsible Partner: SID

Due: 12/21

### **Deliverable D1.1 Definition and collection of process parameters**

Description of Deliverable:

Document that provides information about:

- which data is collected for models and layout of smart sensors, and
- the critical parameters for soft sensor approach and Advisory Tool

Industrial partner	Route	Ladle capacity	Relevant Steel Qualities and Products
SWG	EAF - LF - VD / VOD - Ingot casting	max. 40 t (VOD), max. 50 t (VD)	High alloyed / stainless steels
SID	EAF - LF - VD - CC	135 t	Special steel bars (SBQ) medium alloyed steels
UAB	EAF - LF - ASEA SKF - Ingot casting	70 t	Tool steel, medium to high alloyed steels

### **Content**

Tab name	Comment
heat_process_data	heat-based operational conditions
event_data	data of events e.g. steel temperature measurements
time_based_data_SM	cyclic process data of Secondary Metallurgy (SM)
time_based_data_burners	cyclic heating data
refractory	refractory data provided in additional documents
refractory_wear	wear data in different refractory parts of the ladle
ladle_temperature_data	thermocouple measurement data and thermographic data
critical_parameters	critical parameters for soft sensor

	Field	Unit	Description	Source (case
1	heat_number	int	unique number for each heat in steelmaking	
2	steel_grade	Text	steel grade descriptive name	
3	EAF_init_time	Timestamp	Electric Arc Furnace (EAF) start time	
4	EAF_finish_time	Timestamp	EAF finish time	
5	secondary_metallurgy_init_time	Timestamp	Secondary Metallurgy (SM) start time	
6	vacuum_init_time	Timestamp	vacuum start time	
7	vacuum_finish_time	Timestamp	vacuum finish time	
8	secondary_metallurgy_finish_time	Timestamp	Secondary Metallurgy finish time	
9	LF_init_time	Timestamp	Ladle Furnace (LF) start time	
10	LF_finish_time	Timestamp	LF finish time	
11	casting_init_time	Timestamp	casting start time	
12	casting_finish_time	Timestamp	casting finish time	
13	EAF_time	s	obtained from 3 - 4	
14	secondary_metallurgy_time	s	obtained from 5 - 8	
15	LF_time	s	obtained from 9 - 10	
16	vacuum_time	s	obtained from 6 - 7	
17	casting_machine_time	s	obtained from 11 - 12	
18	total_steel_contact_time	s	obtained from 4 - 12, total time of steel in ladle per cycle	
19	total_revamping_time	s	obtained from 12 - 4(next heat), total time of ladle revamping per cycle	
20	total_ar_volume	m3	Consumed Ar volume in secondary metallurgy	
21	ladle_number	int	unique number for each ladle in steelmaking	
22	ladle_number_of_heats	int	Number of heats that the ladle has worked	
23	time_in_burners_before	s	Time in burners for the ladle from previous heat	
24	EAF_kwh	KWh	Electric Consumption in EAF process	
25	LF_kwh	KWh	Electric Consumption in LF process	
26	total_amount_of_additions	kg	Secondary Metallurgy ferroalloy additions	
27	total_amount_of_slag_formers	kg	Secondary Metallurgy slag former additions	
28	total_weight	kg	Liquid steel weight	
29	carry-over slag	kg	It can be kgs (if measured) or an index	if available
30	slag thickness	m	It can be m (if measured or calculated from slag density and slag weight) or an index	if available

*heat\_process\_data*

Event data are time based but only happen in some concrete timestamps

These type of data are:

Temperature measurements of liquid steel melt

Alloy and slagformer additions

Start and end of LF heating (LF heating time)

Start and end of inductive stirring (inductive stirring time) (UAB)

Field	Unit	Description	Source (case dependent)
timestap	timestamp		
event_code	int		
value	depends on the event		

This also includes composition of:

steel (in EAF and SM stations)

slag (from EAF slag samples and from ladle slag samples)

*event\_data*

Field	Unit	Description	Source (case dependent)
timestamp	timestamp		
stirring_gas_volume	m3 in s. c.		
stirring_gas_pressure	Bar		
stirring_gas_type	binary		
atmospheric_pressure	Kpa		
inductive_stirring_current	A		(UAB)
vibration_sensor_value	index		if available

for ladle treatment and/or vacuum treatment

*time\_based\_data\_SM*

Field	Unit	Description	Source (case dependent)
timestamp	timestamp		
temp_burner1	°C		
temp_burner2	°C		
temp_burner3	°C		
temp_burner4	°C		
temp_burner5	°C		

entire ladle preheating programs

*time\_based\_data\_burners*

Ladle layout and lining from documents of the refractory suppliers: Number, type and thickness of different refractory layers

Refractory layout in tundish (SID)

Refractory layout in EAF (SWG)

at SWG and SID:

Material data of refractories from documents of refractory suppliers and literature including:

Thermal conductivity,

Density,

Specific heat capacity,

Young's modulus,

Coefficient of thermal expansion,

Poisson's ratio

if possible temperature dependent values

*refractory*

Depending on the measurement technique a size of the refractory in the measurement moment  
It can be measured in concrete bricks row by row or brick by brick

and/or in case of UAB:

Measurement with laser scanner: after relining before tapping of first heat into ladle, and after casting of each heat for all ladles in production

Including status of porous plugs and tap hole, side of stirrer and slag line.

Similar to refractory wear but with higher resolution. Sizes of the remaining brick size.

Any modifications during ladle repair (sliding gates, outer nozzles, inner nozzle)

Notations on condition of porous plug (normally lasts entire cycle)



at SWG:

Time series data of thermocouple measurements in ladle refractory

at Sidenor:

Thermographic temperature measurements of ladle shell from thermal cameras

*ladle\_temperature\_data*

### Task 1.3 (Swerim and UAB)

#### **Critical parameters for soft sensors** (sorted by importance)

The critical parameters can be categorized into three main parts:

- ladle status,
- heat characteristics,
- process parameters.

1. Laser contour measurement data including temperature and time
2. Ladle pre-heating: time, temperature
3. Total contact time of melt in ladle: ladle station, vacuum station, casting
4. Stirring data: gas flow, induction stirrer current density and direction
5. Process data: heating time, melt weight, carry-over slag, slag thickness, alloying additions, slag former additions
6. Steel composition: after de-slagging, after alloying, after vacuum treatment
7. Slag composition (when available): before and after vacuum treatment
8. Melt temperature: after de-slagging, after alloying, after vacuum treatment and from furnace process control model
9. Slag weight: after teeming
10. Total time of ladle revamping before ladle pre-heating
11. Ladle maintenance actions (e.g. changing sliding gate plates and/or nozzles, leakage test, visual inspection of ladle including porous plugs)
12. Additional information from operators (e.g. opening of porous plugs)