

Technical development over the last 20 years and new technologies

Sensors and control (level 1), standards, regulations

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Topic classification

Number	Name	Main Partner
1	Heating and burner technology; alternative heating methods; electrical heating	BFI
2	Modelling of entire furnace, model based predictive control (level 2)	RINA
3	Measurement and sensors, measurement-based furnace control (level 1); standards, regulations	RWTH
4	Materials in the furnace and product quality	CRM
5	Heat transfer, heat recovery, productivity, economy	SWE



Main KPIs for furnace measurement technologies over the last 20 years:

Energy consumption

e.g. GJ/t

Fuel consumption can be reduced by proper temperature and atmosphere control.

CO₂ emission

e.g. kg/t

For level 1 measurement technologies, the reduction of CO₂ emissions is mainly linked to the reduction of energy consumption.

Furnace productivity

e.g. t/h

Homogeneity and repeatability of the furnace temperature and atmosphere help to ensure constant product quality, reducing product waste. This in turn increases furnace productivity.

Scale loss

e.g. g/m²

Scale loss can be reduced by optimising the oxygen content in the furnace through correct oxygen measurement.



The key technologies reviewed in topic 3 focus on **improving the energy efficiency of furnaces** and **enhancing product quality** using advanced measurement and control technologies.

Main parameters recorded in a furnace:

- Furnace and charge temperature



↑ Furnace productivity
↓ Energy consumption & CO₂ emissions

- Furnace atmosphere composition (O₂, CO)



↓ Energy consumption & CO₂ emissions
↓ Scale loss

- Air and fuel flows
- Off-gas composition
- Furnace pressure



Measurement of charge temperature

Aim of research: Improve accuracy of the methods used to determine the charge temperature during the process to ensure optimum reheating conditions.



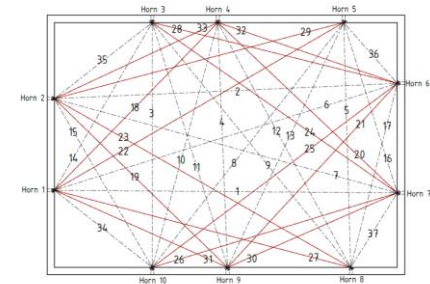
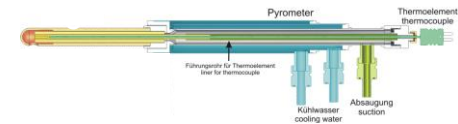
- Charge temperature controlled by measuring temperature of the furnace atmosphere using thermocouples and calculating the charge temperature using level 2 heating models.
- Thermal Imaging and IR pyrometry enable direct and contactless measurement of the surface of the product^{1,2}
 - **IR Pyrometers:** single spot or line measurement.
 - **Thermal imaging:** measurement over large areas. Whole temperature mapping of the stock and furnace possible.

1: European Commission, Directorate-General for Research and Innovation, Powell, J., Casajus, A., Muilwijk, F., New method for contactless measurement of true temperature of hot steel strips and control of the thermal process by in situ spectroscopy : final report, Publications Office, 2002

2: European Commission, Directorate-General for Research and Innovation, Niska, J., Steimer, C., Broughton, J., et al., Advanced measurements and dynamic modelling for improved furnace operation and control (DYNAMO) : final report, Publications Office, 2017

Measurement of gas temperature

- Two thermocouple extrapolation method²
- IR gas pyrometer²
- Suction pyrometer²
- Ultrasonic gas temperature measurement system^{2,3}



2: European Commission, Directorate-General for Research and Innovation, Niska, J., Steimer, C., Broughton, J., et al., Advanced measurements and dynamic modelling for improved furnace operation and control (DYNAMO) : final report, Publications Office, 2017

3: Ouk Hwang, Min Chul Lee, Wubin Weng, Yuhe Zhang, Zhongshan Li, Development of novel ultrasonic temperature measurement technology for combustion gas as a potential indicator of combustion instability diagnostics, Applied Thermal Engineering, Volume 159, 2019

Control of temperature

Aim of research: Optimization of the process control to achieve uniform temperature profile of the charge



- On-Off burner control⁴
- Control algorithm considering position of the product in the furnace, desired width-wise temperature distribution and the type of product⁴
- Optimization of slab distance to reduce the temperature difference across the slab width⁵



4: European Commission, Directorate-General for Research and Innovation, Stubbs, J., Quintiliani, G., Sanfilippo, F., Integration of reheating furnaces with rolling conditions at roughing mill (Improheat) : final report, Publications Office, 2002.

5: G. Fink, D. Nelli, M. Fantuzzi, M. Tomolillo, Optimisation of the beam blanks' reheating conditions in the reheating furnace, EUR (2002)

Furnace atmosphere measurement

Measurement of O₂ and CO measurement to minimize fuel consumption and scale formation.



- Equilibrium between sufficient O₂ to ensure complete combustion and minimum O₂ to avoid heat loss and scale formation and reduce variability of O₂



- Regulation of the air-to-fuel ratio:
 - Using air and gas flow measurements → further processed in PLC
 - Measurement of oxygen content (ZrO₂ probes)⁶
 - Pneumatical (EN 12067-1 or EN 12078) and electronic (EN 12067-2) gas/air ratio controllers



Off-gas composition measurement

- Continuous and portable off-gas analysis equipment²
- For the measurement of off-gas composition emitted in off-gas duct, the Standard Reference Methods (SRM) are defined in the following European Standard:
 - EN 14789: Determination of volume concentration of oxygen – Standard reference method: paramagnetism
 - EN 14792: Determination of mass concentration of nitrogen oxides – Standard reference method: chemiluminescence
 - EN 15058: Determination of the mass concentration of carbon monoxide – Standard reference method: non-dispersive infrared spectrometry



² European Commission, Directorate-General for Research and Innovation, Niska, J., Steimer, C., Broughton, J., et al., Advanced measurements and dynamic modelling for improved furnace operation and control (DYNAMO) : final report, Publications Office, 2017

Further measurement devices

- **Acid Dew Point (ADP) Sensor**

- Measurement and dynamical adjustment of the off-gas temperature to improve waste heat recovery⁷

- **Gas and air flow measurement:**

- Many different types of sensors are available on the market: vortex, ultrasonic, thermal flow meters or vane wheel anemometer
- Orifice meters are still typically used to measure flow rate using the Differential Pressure Measurement principle



7: Ivashechkin, P., Kozariszczuk, M., de la Fuente, D., Lapp, T., & Ramirez, J. J. A. Novel acid dew point sensor and corrosion probes for dynamic waste heat recovery from steel mill flue gases.

Research gaps for alternative heating systems

- Influence of fuel blends on **flow measurement**⁸
- Influence on **fuel quality measurements**⁸
- Influence on **off-gas composition** and **pollutant emission** measurements
 - Revision of NO_x limit definitions
 - Alternative off-gas analyzers equipment
- Temperature measurement for electrical and hybrid heating systems



8: Hydrogen technologies for decarbonization of industrial heating processes (HyInHeat), Horizon Europe, DOI: 10.3030/101091456



Thank you for the attention!

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