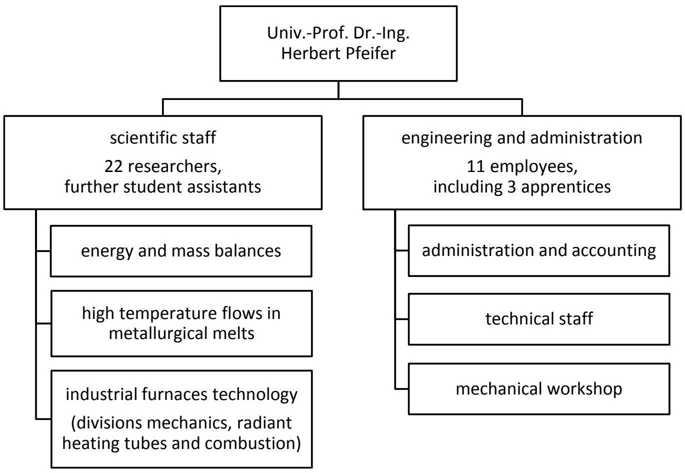
# Department for Industrial Furnaces and Heat Engineering at RWTH Aachen University

The Department for Industrial Furnaces and Heat Engineering (German abbr. IOB) at RWTH Aachen University, headed by Univ.-Prof. Dr.-Ing. Herbert Pfeifer, is an internationally recognized research department with the mission to optimize processes and plants in the fields of manufacturing, processing and recycling of iron and steel, non-ferrous metals, glass and ceramics. The department is part of the Division of Materials Science and Engineering in the Faculty of Georesources and Materials Engineering.

## Structure

Currently (November 2016), there are - in addition to the professor - 22 scientific staff members and 11 technical and administrative staff members employed at the department. The scientists are working in 3 research groups. The organizational structure of the IOB is as follows:




## Energy and Mass Balances

The preparation of energy and mass balances used for plant and process optimization, is the main objective of this research group. Electric arc furnaces for steelmaking are of special interest. The research areas cover the fields of process technology, environmental engineering and heat treatment.

*Process and Environmental Engineering*

Basis for the calculation of any energy and mass balance are valid measured furnace data. With these data, the modeling and simulation of the process is possible by using Computational Fluid Dynamics (CFD) or other numerical and analytical methods. For this, the IOB applies wide experiences in installation and operation of off gas analysis systems in high temperature industrial units, such as the electric arc furnace, and in modeling and simulation.

In addition to the process technology, the aspect of environmental measurements becomes more important. To identify environmentally relevant mass flows (dust, $NO_x$, $CO_2$) measurement systems are implemented in industrial dedusting plants. Apart from determining the current state, fundamentals of their formation are investigated and process control strategies to reduce or avoid environmentally relevant emissions are developed and investigated in pilot scale as well as in industrial plants.

Another important field of research is the investigation of replacing fossil carbon carriers by biomass, e.g. in the electric steelmaking process. Here again the investigations are conducted at laboratory and pilot-scale as well as in cooperation with industry at industrial plants.

Furthermore, the research group operates a 600 kW pilot electric arc furnace at the location Herzogenrath.

*Heat Treatment*

There are a series of heat treatment furnaces available, where experimental investigations for heat treatment and sintering in a wide temperature range (1600 °C max) and under different atmospheres can be performed. The heat treatment of various components and materials is offered as a service.

## High Temperature Flows in Metallurgical Melts

Knowing the flow during refining and continuous casting of steel, copper and aluminum in metallurgical reactors (converter, ladle, tundish and mould) is crucial for the optimization of the product quality of semi-finished and finished products. Since the possibility of flow measurements inside metallurgical melts is limited due to the high temperatures, the fluid flow and heat transfer processes

Figure 1: Water model of a thin strip caster

are examined on the basis of physical and numerical models.

*Water Models of Metallurgical Reactors*
Since the kinematic viscosities of molten metals and water are quite similar, the flow characteristics of both fluids are almost equal. Therefore, a study of melts in water models is possible. At the IOB, there are several water models for experimental investigations, e.g. of converters, ladles, tundishes and casting moulds (see Fig. 1).

Various laser-based methods for flow field measurements are available. Furthermore, the IOB disposes of measurement systems for mixing times and particle deposition rates.

*Numeric Modeling*
In addition to experimental investigations, numerical simulations using CFD are conducted. The accuracy of the calculations is increased by simulating the water flow and using data from highly-accurate measurements for validation first. Subsequent, the simulations for multiphase, non-isothermal metal melts are performed. Especially when interacting physical effects need to be considered, e.g. magneto-hydrodynamic and thermo-technical phenomena in electro-slag remelting (ESR), the CFD simulation is applied successfully.

## Industrial Furnaces
The focus of this working group is the investigation of reheating and heat treatment furnaces of the metal producing and processing industry. The aim is to increase the durability of furnace components, the process stability, the product quality, the energy and resource efficiency, and the reduction of pollutant emissions. A wide variety of furnace types is covered in research activities.

*Mechanics*
This team is researching mainly on structural mechanics, fluid dynamics and heat transfer in heat treatment furnaces with forced convection. This includes the investigation and optimization of the furnace atmosphere flowing inside an industrial furnace using fans, flow ducts, diffusors and nozzles used for the circulation and guidance of the furnace atmosphere to be considered. For surveillance and process control, a continuous volume flow rate measurement device and several model-based sensors ("soft sensors") were developed especially for high temperature applications. On the other hand the effects on charges and high temperature flow guidance systems caused by forced convection are of interest. The team has a special focus on continuous strip treatment lines, like continuous annealing lines, galvanizing plants, strip floatation furnaces or rapid cooling lines.

*Combustion*
In this team combustion processes in industrial furnaces are investigated using numerical simulation and experimental techniques. These include non-invasive methods such as OH*-visualization as well as temperature measurements and the measurement of the local gas composition. Due to scale formation significant material losses occur in metal heating processes. One goal is to reduce scale formation during the reheating of metal goods (such as copper) while achieving low $NO_X$ emissions. To increase the heat flux to the item being heated, direct flame impingement is investigated. Flameless oxidation is implemented in numerous furnaces. A further aim is to increase the limits of use of flameless oxidation towards low burner capacities and bio fuels.

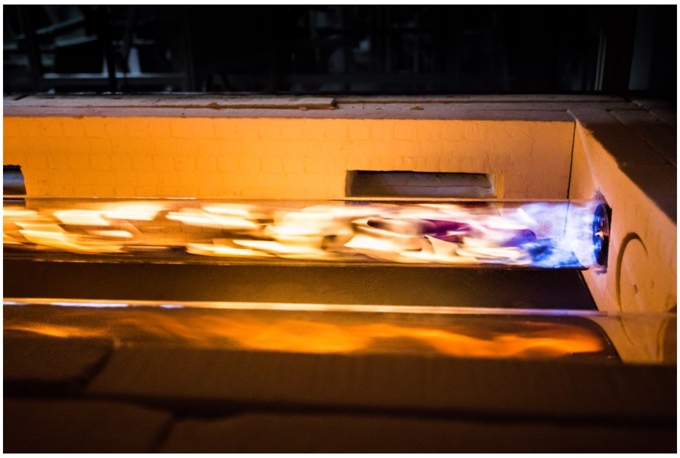


Figure 2: Combustion in a radiant heating tube

*Radiant Heating Tube Technology*
Gas-fired radiant heating tubes made of steel or ceramic material allow the indirect heating of a furnace in order to avoid undesirable reactions of the material surface of the loaded goods with the exhaust gas. Because of their importance for hot-dip galvanizing furnaces, strip flotation furnaces for the recrystallization annealing of copper strips or in furnaces for the heat treatment of aluminum, research on this topic has the aim of optimizing radiant heating tubes with regard to service life etc. Not only are experimental studies carried out on a test stand (Fig. 2), numerical simulations of the thermal fluid dynamics and structural mechanics are also done. One of the main research objectives is to increase the durability by reducing thermal stresses. This can primarily be accomplished by achieving a homogeneous surface temperature and an optimized flow within the radiant tube. A further research focus is to extend the application of the use of radiant heating tubes to small diameters to reduce the space requirement of suitably equipped facilities.

## Expertise and Funding
The IOB looks back on numerous, successfully completed research and development projects in cooperation with international companies and research departments of all sizes. The application for funds and the participation in many publicly funded projects on national and European level and its project management belong to the expertise of the IOB.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