Smart furnace design through TECSIGLASS physics-based simulation

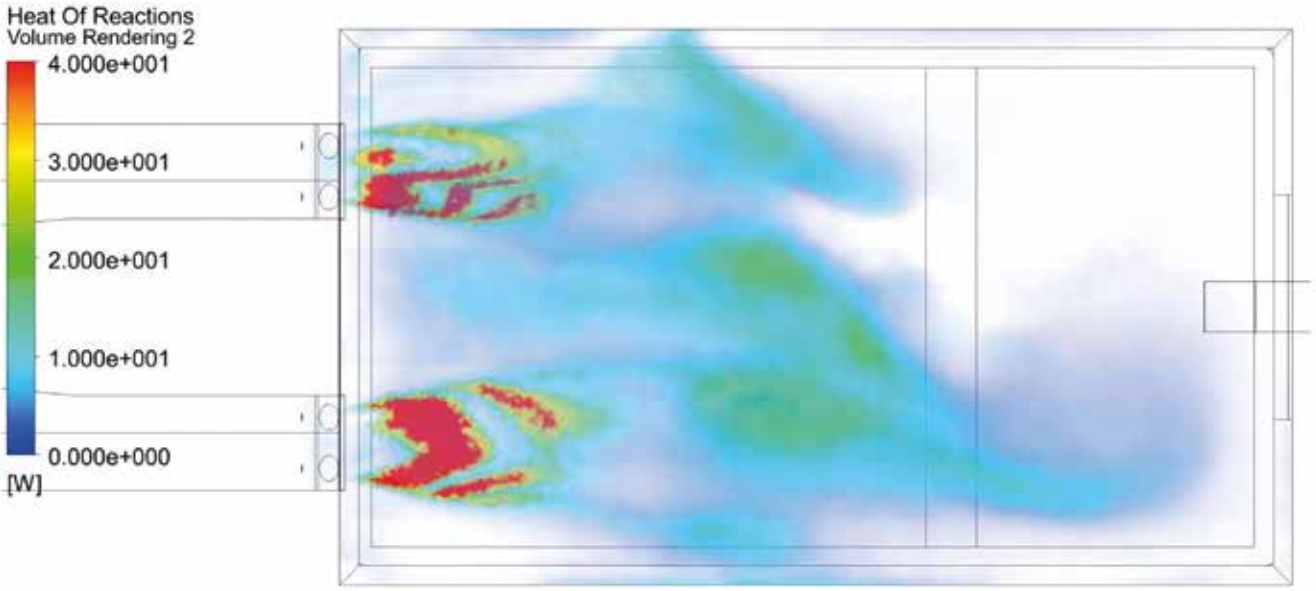
A rising leader in glass furnace innovation, TECSIGLASS blends deep technical expertise with cutting-edge research. Through advanced CFD modeling and strategic partnerships, the company is redefining furnace design, simulation and diagnostics – offering efficient, sustainable solutions for today's challenges and tomorrow's glassmaking demands.

SIMULATION FROM THE FURNACE DESIGNER AND THE END-USER PERSPECTIVE

A cutting-edge company in the design and supply of glass furnaces, Tecsiglass S.r.l. is headquartered in Genoa, Italy. Despite its recent establishment, the company has quickly emerged as a market leader, thanks to the extensive experience of its technicians and the enthusiasm and innovative vision of new generations. This blend of expertise and energy has enabled Tecsiglass to achieve significant milestones in a short period. One of the distinctive features of Tecsiglass is its strong commitment to research and development (R&D). Recently, the company created a Ph.D. position to further strengthen its team, which already includes the collaboration of about ten researchers from the University of Genoa and SIRELAB S.r.l.. These researchers work in synergy to develop advanced models and applications to support the design, monitoring and management of glass furnaces.

PIONEERING SIMULATION FOR ADVANCED FURNACE DESIGN

Several R&D projects have been completed over the last decade receiving fundings from regional, national or European institutions resulting in a strong competence acquired on numerical simulation of the main aspects related to the glass furnace system design and operation. The main achievement recently is that of an innovative, fully-coupled CFD (Computational Fluid Dynamics) numerical model for the simultaneous simulation of combustion and melted glass flows with superior characteristics of stability, accuracy and applicability with respect to existing commercial codes for glass furnace simulation. The model is based on basic reacting fluid flow physics with advanced and general chemical kinetic schemes or multiphysics setup (i.e. electric field). As such it is an effective tool to conceive and develop truly innovative solutions. On the contrary, existing simulation approaches with simplified modelling, highly tuned on current state of the art furnaces, cannot certainly be trusted as valuable tools to drive innovation for new and peculiar configurations.



INNOVATIVE APPLICATIONS OF CFD IN OPERATIONAL SUPPORT

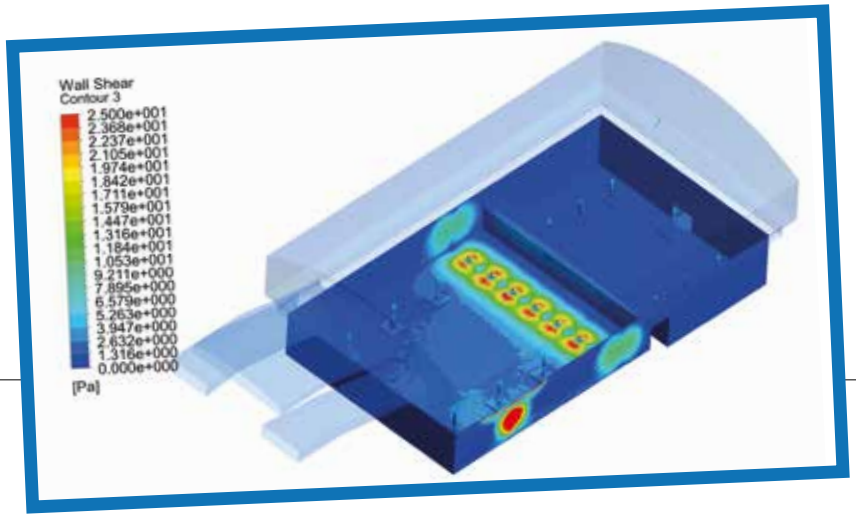
Tecsiglass is determined in introducing the use of the above simulation approach for a wide range of purposes:

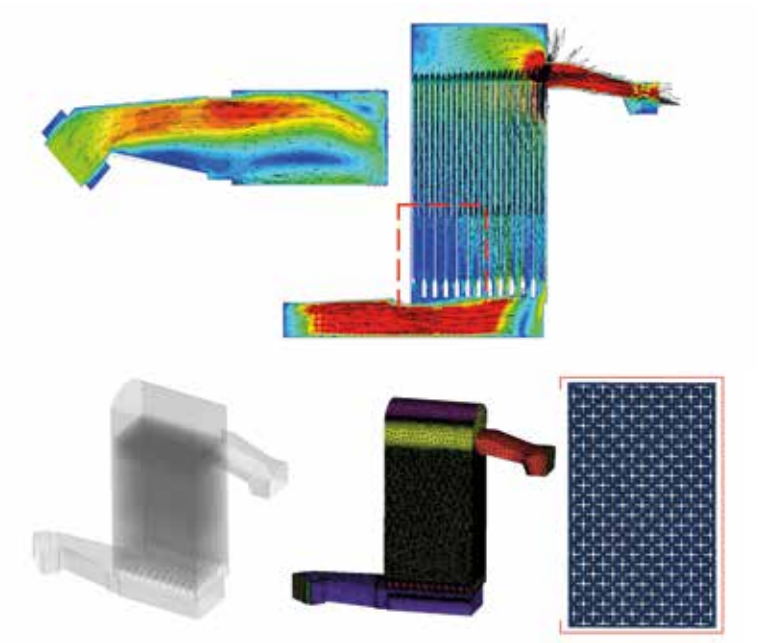
- Supporting the design of efficient and innovative solutions;
- Allowing for the critical analysis of existing solutions with detailed investigation and physical interpretation for troubleshooting of fault and malfunction in operation;
- Developing advanced monitoring and diagnostic platforms with the joint use of numerical simulation, data acquisition and artificial intelligence;
- Innovative training systems using virtual or augmented reality platforms with embedded results from simulation to support the teaching of difficult topics (i.e. the complex melted glass flow paths and the effects of electric boosting or mixing enhancers like boilers).

In the context of decarbonizing the sector, the CFD model represents a fundamental tool for evaluating the impact of introducing hydrogen as a fuel and increasing the share of melting energy obtained using boosters. The model allows for a detailed analysis of the effect on the glass bath due to the positioning of the electrodes and/or the increase in the power delivered. The following figures show a simulation of the combustion flames with reaction heat of 30 percent from H2 and the presence of boilers and electrodes activated. The model enables analysis of the stress on refractories caused by glass movements and temperature variations, providing insights into their potential erosion. In this way, it offers an additional tool for optimizing design and process management. An example of CFD use for troubleshooting is described in the following pictures. In a standard end-port furnace both regenerative chambers, during furnace reconstruction phase, showed a peculiar damage of the refractories into the core flow in a region close to the external walls with perfect symmetry into the right and left chambers. The flow inside the regenerative chamber has been simulated using the actual 3D layout and details of the internal checkers. It emerged that the design of the feeding channel of the camber, due to its excessive section variation, in air phase, induces a large flow recirculation that causes a bad feeding of the refractories in the corresponding lower part. As a consequence, the upper part of the refractories are not adequately fed with combustion air; they do not follow the correct air-fumes cycle with enhanced thermal stress and pollution with erosion from the fumes. If the original configuration and layout of the regenerative chamber system had been designed using CFD the above problem would have never occurred.

DIGITAL TWIN TECHNOLOGY AND FOREHEARTH OPTIMIZATION

The forehearth is a complex system that must deliver melted glass to the forming machines with a prescribed temperature profile

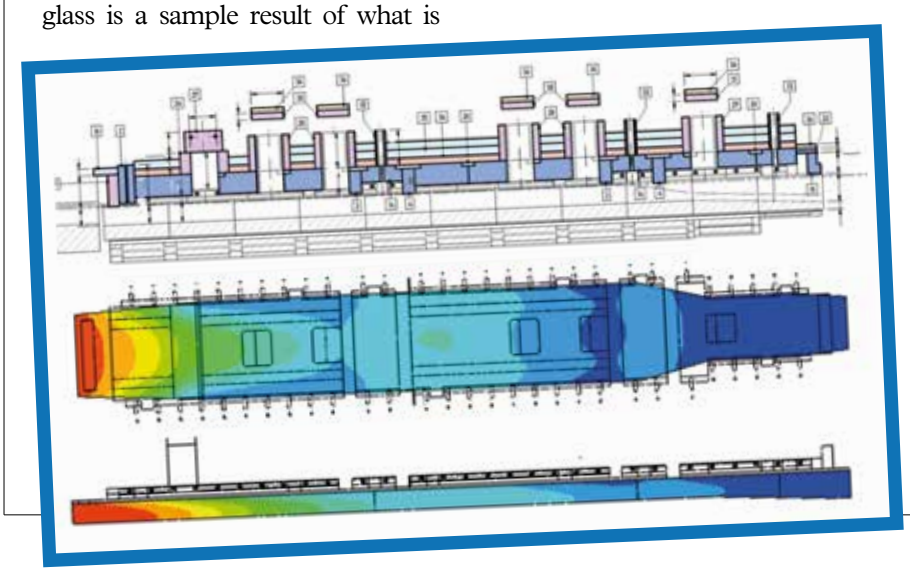


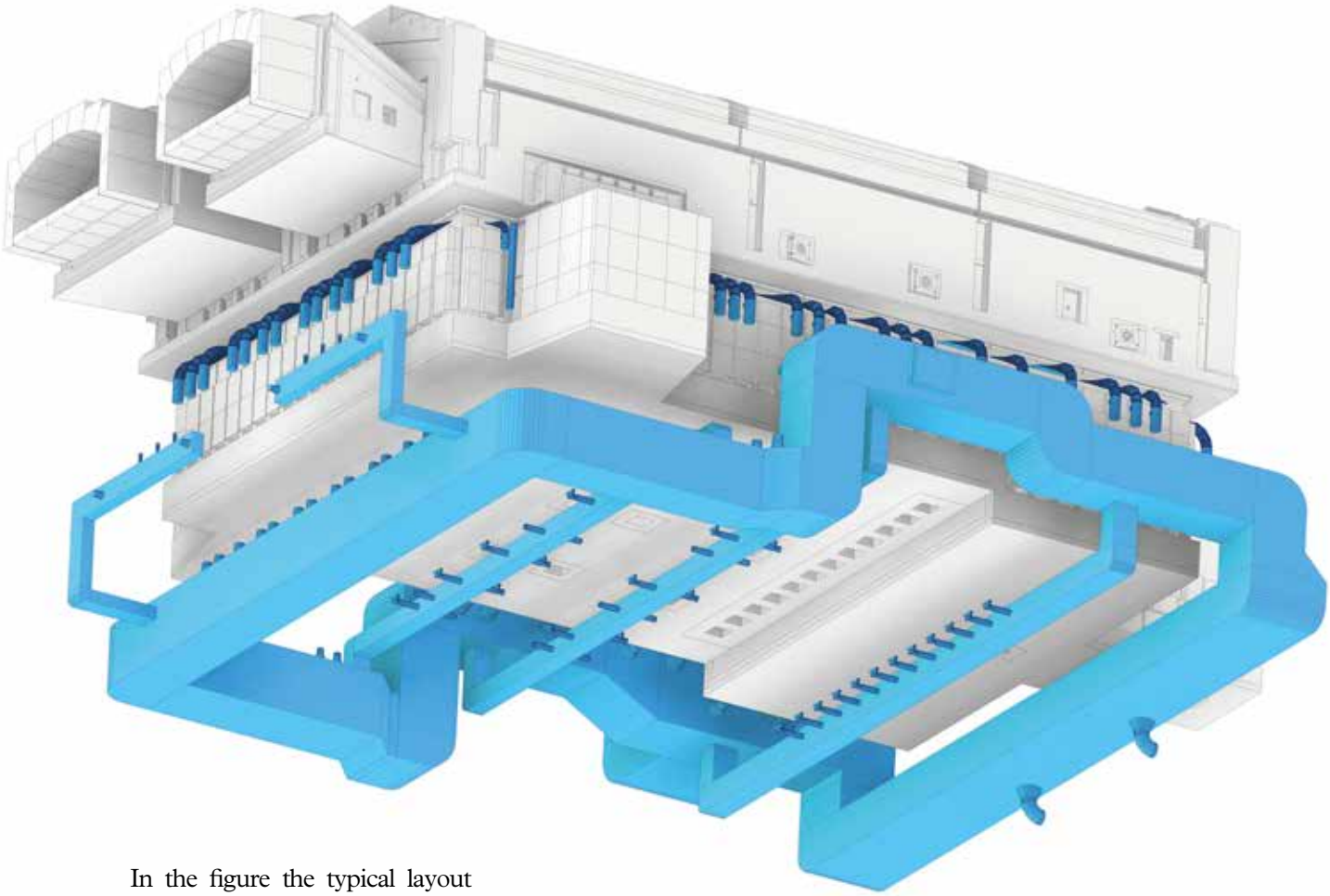


to guarantee final product quality; its thermal setup during production change is a crucial phase that tends to give production waste with related financial and environmental costs. Tecsiglass with its technological partners, is developing a digital twin of the system able to support the decisions of the personnel for the forehearth setup and useful for maintenance, diagnostic and also training purposes. CFD models, data acquisition and artificial intelligence are the combined ingredients that form the digital twin platform. The CFD simulation is the central core of the strategy to support artificial intelligence and data mining tools with the underlying physics. In the following figures the temperature distribution in the melted glass is a sample result of what is obtained from the abovementioned combined combustion and melted glass coupled 3D CFD approach, specifically set for forehearths simulations. The flames from all the burners in the three sections of the channel are numerically solved and the thermal effects of heat fluxes through the walls and the ventilation from chimneys are also considered. The model is validated against several data available from actual operation campaigns.

COOLING SYSTEMS AND INTEGRATED DESIGN PLATFORMS

The furnace tank and throat cooling is a crucial aspect to extend refractory life and it is also a source of high energy consumption due to the continuous forced ventilation process from specific blowing systems. The thermal control is obtained with a slot impingement flow mechanism that needs to be well-tuned and optimized to reduce energy costs and to maximize heat transfer effects. Tecsiglass has a long-term design practice of the above ventilation system and it is effectively using CFD to optimize the above slot impingement process. The accurate quantitative simulation of the heat transfer process from slot impingement, especially with several slots interacting, is not an easy task. Tecsiglass can rely upon the appropriate models and CFD procedures developed by its partners University of Genoa and SIRELAB to design the most efficient thermal control system and layout for a given furnace.





In the figure the typical layout for the tank and throat ventilation is shown The forced ventilation heat transfer effectiveness depends on the complex thermal fluid-dynamic interaction of several slots (as shown in the figure). In the figure the turbulent kinetic energy for two or three slot interaction is shown from the validated CFD model in use that gives an idea of the flow complexity.

Tecsiglass, in partnership with SIRELAB, is also developing an advanced software platform that integrates all the information derived from various numerical simulations with the surveys conducted on furnaces at the end of their campaign using high-accuracy laser scanning and photogrammetry technologies. This platform, based on a Client-Server logic, can also use the data collected within a dedicated database, facilitating the reprocessing of field data. The above platform can be effectively used with virtual or augmented reality hardware for training purposes or for advanced revision of furnace design and maintenance. ■