

Heating Ramp Control in a Modular Furnace with Rotating ON/OFF Burners

A reduced COMSOL workflow coupling transient heat transfer, radiation, precomputed flow fields, and temperature-feedback control.

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Abstract

Repeated burner switching makes fully coupled transient CFD, heat transfer, and radiation simulations computationally demanding. This work presents a reduced, physics-based COMSOL workflow for analysing **heating-ramp control** in a **modular furnace with rotating ON/OFF burners**.

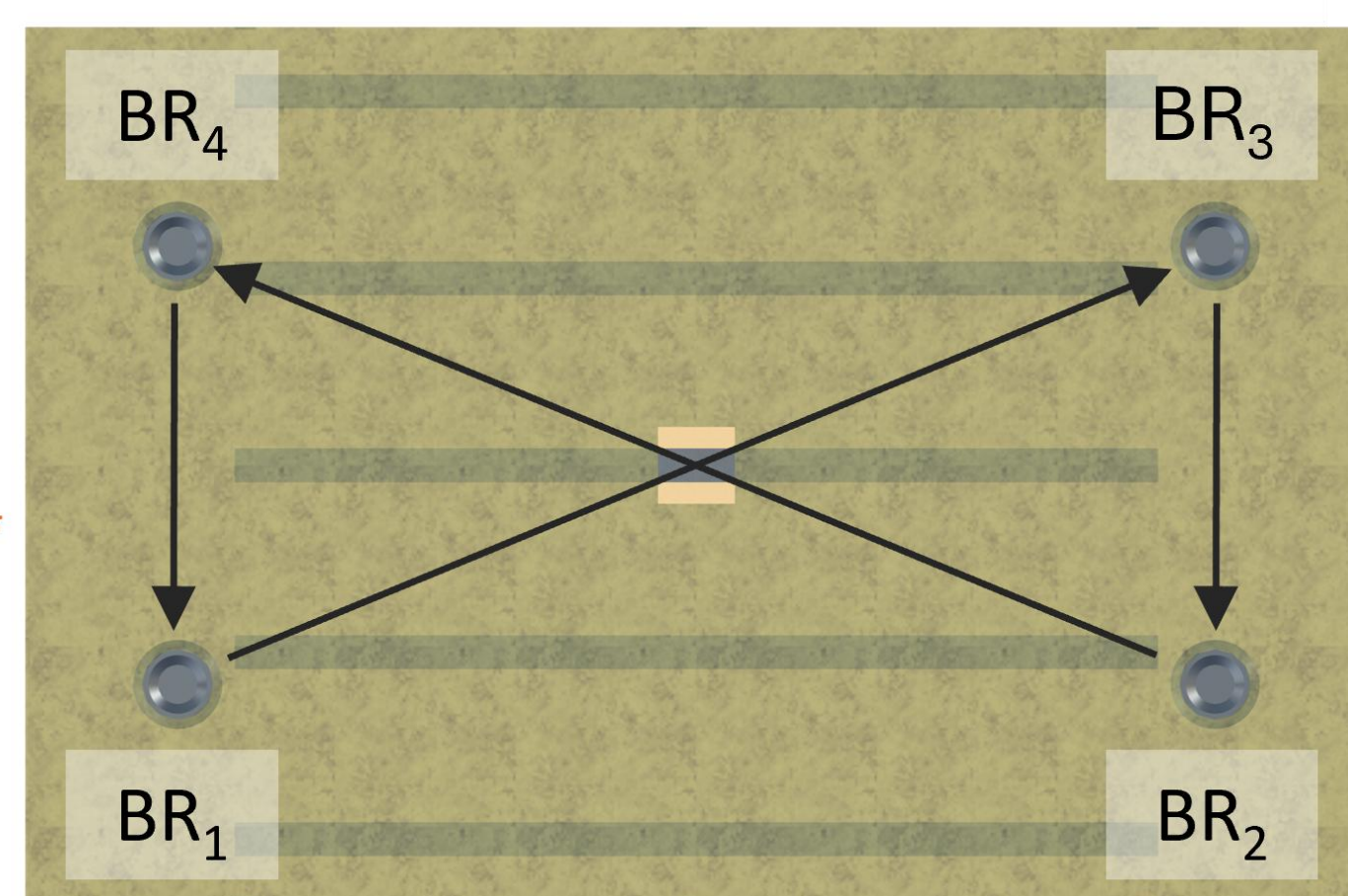
The model solves **time-dependent heat transfer** with **surface-to-surface radiation**. Combustion is represented by an **equivalent flame-temperature boundary condition** modulated through a

smooth activation gate. **Steady velocity fields** are precomputed for representative burner states and reused in the thermal model.

Feedback from a single control thermocouple adjusts the **effective ON-time**, while the remaining thermocouples are used to verify compliance with the prescribed temperature limits. This allows ramp-up and stabilization to be investigated without resolving the full transient flow at each switching event.

$$\begin{cases} \theta = \text{mod}(t, T_{rot}) \\ u(x, t) = \sum_i s_i(\theta, \tau_{on})^* u_i^{CFD}(x) \\ T_{BC, i} = T_{roof} + (T_{flame} - T_{roof}) g_i(t)^* \end{cases}$$

* active burner state
* smoothing gate



Methodology

The burners follow a periodic sequence over a rotation period T_{rot} . A temperature-feedback signal based on the control thermocouple T_C determines the **effective ON-time** τ_{on} and the corresponding **burner activation state** $s_i(\theta, \tau_{on})$.

$$\begin{aligned} e_T &= T_{ref} - TC \\ \tau_{on} &= u_C \tau_{max} \\ u_C &= C(e_T) \\ g_i(t) &= s_i(\theta, \tau_{on}) f_{sm}(t) \end{aligned}$$

A **smooth gate** $g_i(t)$ modulates the equivalent flame temperature, while the rotation state selects the corresponding precomputed velocity field. Periodic conditions represent a central module under synchronized operation of adjacent modules.

Results

The calculated response **follows the prescribed heating ramp and approaches stabilization**, with the temperatures at **all verification thermocouples remaining within the prescribed limits** despite the periodic fluctuations induced by burner cycling.

Smooth activation improves numerical robustness near switching instants, allowing nonlinear radiation and repeated changes of burner state to be handled within a **computationally manageable transient simulation**.

The normalized control signal shows how the firing demand adapts throughout ramp-up and stabilization.

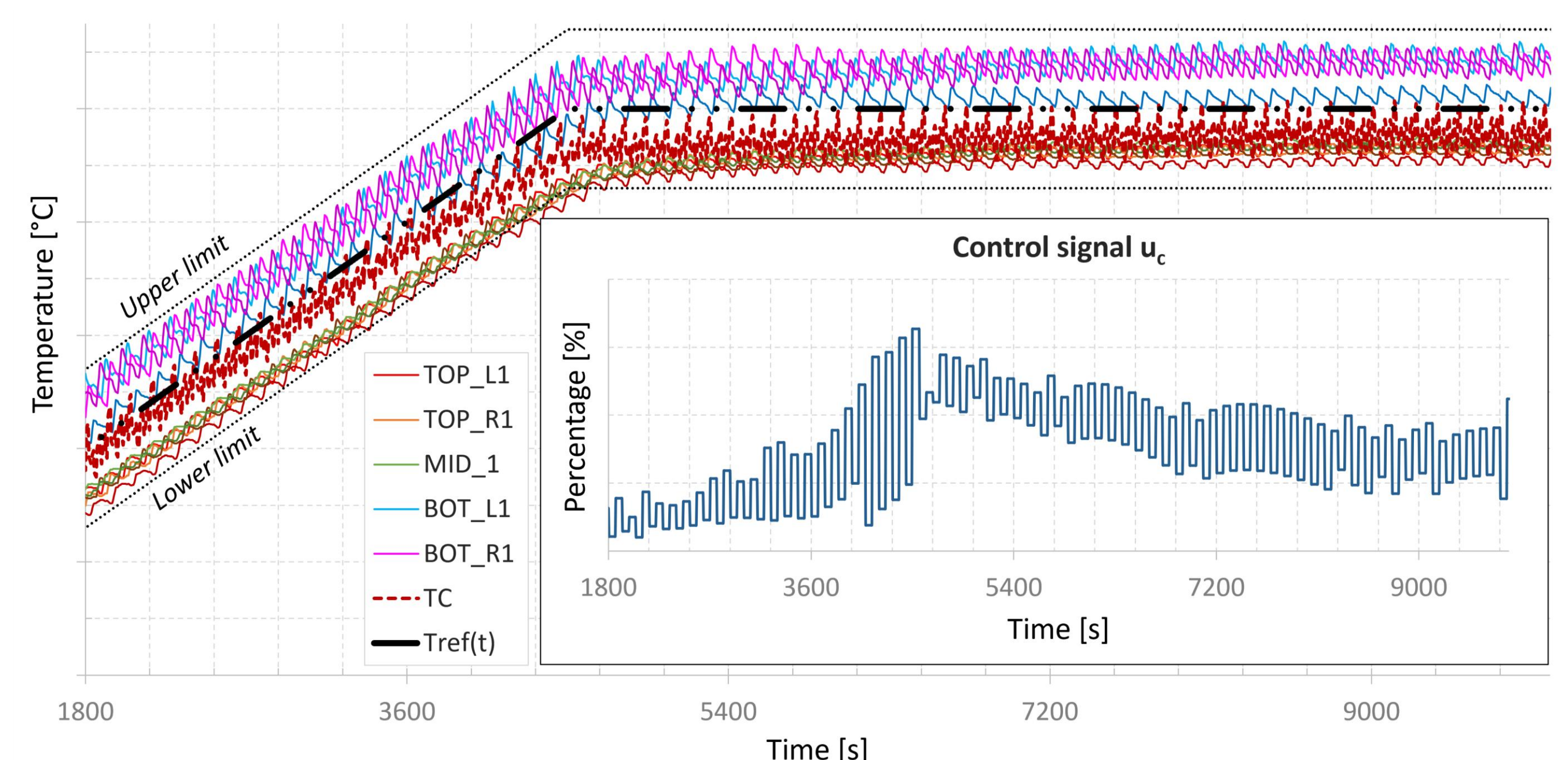


FIGURE 2. Control and verification thermocouple trends during ramp-up and stabilization. The inset reports the normalized control signal generated from T_C .

REFERENCES

1. COMSOL 6.4, CFD Module User's Guide
2. COMSOL 6.4, Heat Transfer Module User's Guide
3. COMSOL 6.4, Events Interface User's Guide

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