Prediction of Transient Slab Heating Characteristics in a Walking Beam Type of Reheating Furnace

Sang Heon Han*, Seung Wook Baek

Division of Aerospace Engineering, Mechanical Engineering Department
Korea Advanced Institute of Science and Technology(KAIST)
373-1 Guseong-dong, Yuseong-gu, Daejeon, 305-701 Republic of Korea
E-mail:freezia @kaist.ac.kr

Key Words: Heat Transfer, Heating Characteristic, Reheating furnace, Parallel Computing

ABSTRACT

A full-scale simulation of steel mill reheating furnace was performed by using parallel computing technology. Turbulent flow as well as chemical reaction is considered and solved in a coupled manner while radiation is also calculated. The movement of slab is taken into account so that a more precise observation of its heating characteristics becomes possible through this numerical analysis.

INTRODUCTION

An analysis of thermal efficiency of a reheating furnace requires a precise investigation of combustion and flow characteristics. Especially, the hot gas flow field exercises a deterministic role in heating slabs. In real-scale furnace, the burners are positioned slightly slanted with respect to axial direction to have more hot gas flow reach the slabs. Sometimes, some walls, so-called dam, are inserted to the furnace to block the main flow and to control the main flow in the furnace. But these are not all the factors in determining heating efficiency. There exist other factors such as type of fuel, location of slabs, thermal properties of slabs, and geometry of slab supporting system. Skid posts and skid beams play a role of obstacles to hot gas flow and disturb the flow reaching slabs. In addition, they intercept radiation between hot gas and slabs. It is well known that slabs are mostly heated by radiation in reheating furnace so that heating efficiency is decreased by the reduction of radiation from hot gas to slabs due to existence of the structures.

Full-scale simulation of a furnace has been restricted because many structures and the scale of a reheating furnace demand a huge computing power to perform its numerical analysis. But nowadays, there has been such a great development in computing technology that we can attain a relatively high computing power through clustering many PCs. Computationally, an entire computational domain is subdivided into several zones and these zones are allotted each PC clustered. Present work is to simulate the transient heating characteristics of slabs in a POSCO furnace by using MPI parallel computing technology.

RESULTS

Figure 1 shows a half section of the reheating furnace. The furnace is symmetric along the z=0 plane so that calculation is performed on the half section of the furnace. The furnace has the dimension of 5.4m x 10.7m x 36.0m. Usually, a furnace is divided into three zones - preheating, heating, and soaking zones. Slabs are mostly heated in the preheating and heating zones. The role of soaking zone is to reduce the slab temperature. 29 slabs are simultaneously heated in the furnace in about 2 hours. The slabs have the dimension of 0.23m x 4.8m x 1.02m and are located at the elevation of 0.21m from the furnace bottom.

The size of entire grid is $44 \times 48 \times 266$ while slabs have the grid size of $5 \times 44 \times 9$. N_θ and N_ϕ which are solid angles split number for radiation, have the value of 4 and 12, respectively. The slabs move every 256 seconds so that they reside in the furnace for 7424 seconds. Total computational time is equal to the slab residence time. The time step size for calculation is 32 seconds. Computation is performed on a 16 clustered PCs (3GHz CPU) while it takes about 4 days to complete the calculation.

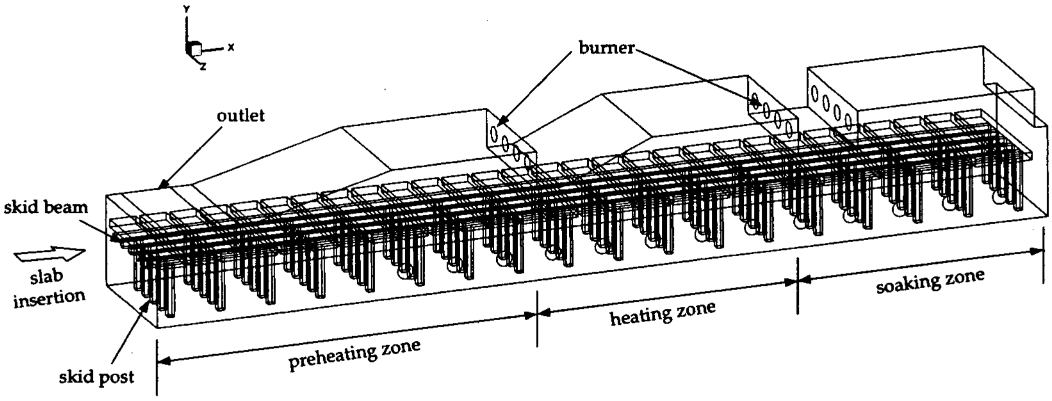


Figure 1. Configuration of the furnace

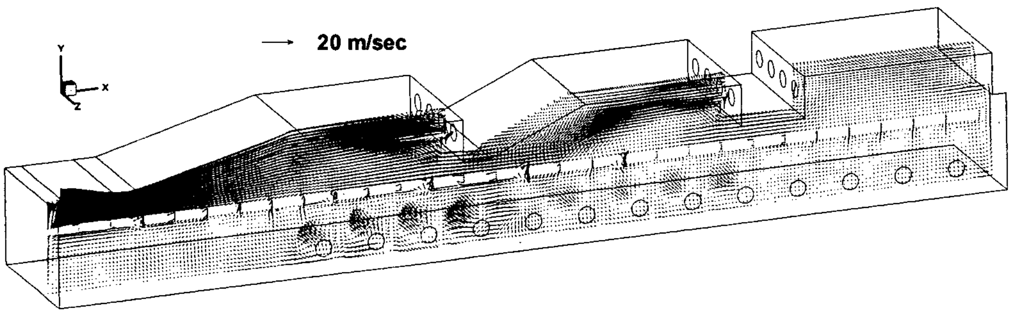
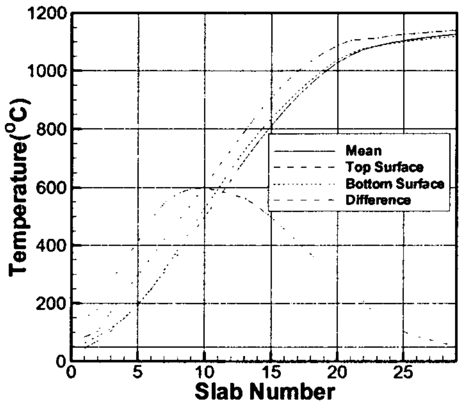
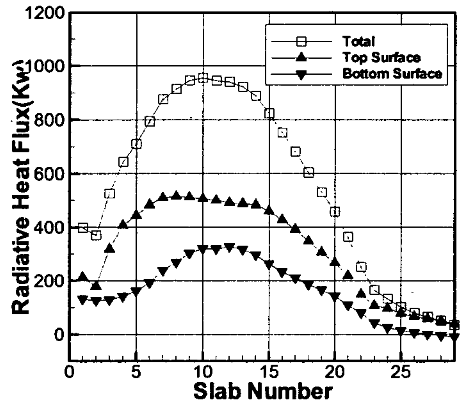


Figure 2. Velocity vector on constant z-plane



(a) temperature



(b) radiative heat flux

Figure 3. Temperature and radiative heat flux of the slabs

As seen in Fig. 2 the velocity vector in the soaking zone is relatively weak because the mass flow rate of burners in the zone is small compared to the other zones. Figure 3(a) shows the volume averaged temperature, area averaged temperature on the bottom and top surfaces, and maximum temperature difference inside a slab. The slabs exit to rolling mill with around 1100 °C. In the soaking zone, slabs experience a little temperature change and the temperature difference continuously decreases. The temperature difference is reduced to 50 °C before exit to rolling mill. Figure 3(b) shows three integrated incident radiative heat fluxes into the slabs– on all the surfaces, on the top surface, and on the bottom surface of each slab. The slabs in the preheating and heating zones are recieving a large portion of radiative heat flux. Among the slabs, 10^{th} slab receives the largest radiative heat flux. Radiative heat flux again becomes weaker in the soaking zone. It is beacuae the slabs aleady have experienced enough heating in previous zones and the temperature difference becomes very small. Moreover, small radiative heat flux is observed to come out from the bottom of the slabs in the soaking zone.

REFERENCES

[1] Zongyu Li, P. V. Barr, and J. K. Brimacombe, Computer Simulation of the Slab Reheating Furnace, *Canadian Metallurgical Quarterly*, vol. 27, no. 3, pp. 187-196, 1988.

[2] Peric, M., A Finite Volume Method for the Prediction of Three Dimensional Fluid Flow in Complex Ducts, Ph. D dissertation, Imperial College , 1985.

[3] Ferziger, J. H. and Peric, M., Computational Methods for Fluid Dynamics, Springer, 1996.