Proceedings of the 7th World Congress on Mechanical, Chemical, and Material Engineering (MCM'21)
~~Prague, Czech Republic~~ Virtual Conference – August, 2021
Paper No. HTFF 140
DOI: 10.11159/htff21.140

Heat Transfer in High-Temperature Contact Processes with the Participation of the Oxidized Layer

Aleksandra Przyłucka[1], Marcin Rywotycki[1]
[1] Department of Heat Engineering and Environment Protection, Faculty of Metals Engineering and Industrial Computer Science, AGH University of Science and Technology
Czarnowiejska 66, 30 - 059 Krakow, Poland
aprzylucka@agh.edu.pl; rywotyc@agh.edu.pl

Extended Abstract

The heat transfer mechanism at the contact of two solids surfaces is common in technological processes related to the metallurgical and processing industries. It can be found in devices that use waste heat, such as thermoelectric generators [1]. The heat transfer between the generator surface and the exhaust collector surface requires the determination of the heat flux flowing among them. Its value depends on: the type of materials used, the pressure force, the roughness and the presence of the intermediary medium. The correct description of the process requires the knowledge of the value of the above-mentioned flux or the value of the heat transfer coefficient as a function of the pressure force and temperature function. The heat transport mechanism at the contact also occurs in high-temperature processes, i.e., forging, hot rolling and continuous casting of steel. Their characteristic feature is a large temperature difference between working tools. Changing the surface temperature of the tools involved in the contact has a significant effect on the value of the heat transfer coefficient through the contact [2]. The heat flux between the tool and the workpiece depends on factors such as: temperature, pressure, contact time, surface roughness and oxide scale thickness. Determining the boundary conditions in the above-mentioned processes is necessary to obtain an accurate and unambiguous solution of the heat conduction equation. Their direct identification and designation are complicated to implement. The problem can be solved by building a process model.

The available literature [3-6] allows to divide the models describing heat transfer in contact into two groups. The first one covers the issues defining the constant, average value of the heat transfer coefficient. On the other hand, the models of the second group describe the variable value of this coefficient in functions of the surface temperature at constant pressure or variable pressure at a constant temperature. Due to the omission in numerical calculations of the pressures influence on a constant heat transfer coefficient value, there are no precise results of the temperature field in high-temperature processes.

The main research objective of this work is to determine the dependence of the heat transfer coefficient at the contact as a function of surface temperature and pressure, taking into account the oxidized layer. This should be a form of mathematical relationships that can be easily implemented in numerical calculations. The presented work covers the realization of several partial research tasks. The experimental part consists in measuring temperature changes at specific points in two steel samples in contact. One of the cylindrical samples is heated at temperature above 1000ºC using an electric furnace. Then the hydraulic press subtends it with a given force against the cold sample. Thermocouples mounted in the axis of the samples allow to record the temperature changes during the experiment. The obtained results constitute a reference point for the numerical simulation of the two-dimensional model of the oxidation layer growth and numerical calculations of the heat flux on the contact surface using the inverse method to determine the heat flux and heat transfer coefficient. The developed dependencies of changes in the heat transfer coefficient can be used during numerical calculations of industrial processes in which contact mechanisms occur.

References

[1] L.S. Hewawasam, A.S. Jayasena, M.M.M. Afnan, R.A.C.P. Ranasinghe, M.A. Wijewardane, "Waste heat recovery from thermo-electric generators (TEGs)," *Energy Rep.,* vol. 6, supp. 2, pp. 474-479, 2020.
[2] M. Rosochowska, K. Chodnikiewicz, R. Balendra, "A new method of measuring thermal contact conductance," *J. Mater. Process. Technol.*, vol. 145, no. 2, pp. 207-214, 2004.

[3] F. Biao, T. Jing, Z. Yu-Hong, F. Li-Wu, Y. Zi-Tao, “An improved steady-state method for measuring the thermal contact resistance and bulk thermal conductivity of thin-walled materials having a sub-millimeter thickness,” *Appl. Therm. Eng.*, vol. 171, 114931, 2020.
[4] S. Mosayebidorcheh, M. Gorji-Bandpy, “Local and averaged-area analysis of steel slab heat transfer and phase change in continuous casting process,” *Appl. Therm. Eng.*, vol. 118, pp. 724-733, 2017.
[5] O.K. Panagouli, K. Margaronis, V. Tsotoulidou, “A multiscale model for thermal contact conductance of rough surfaces under low applied pressure,” *Int. J. Solids Struct.*, vol. 200-201, pp. 106-118, 2020.
[6] F. Wen-Zhen, G. Jian-Jun, C. Li, T.A. Wen-Quan, “A multi-block lattice Boltzmann method for the thermal contact resistance at the interface of two solids,” *Appl. Therm. Eng.*, vol. 138, pp. 122-132, 2018.