ACCURACY–TIME TRADE-OFF IN RECONSTRUCTION OF THE HEAT TRANSFER COEFFICIENT K USING ABC AND ACO ALGORITHMS

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Keywords: **swarm algorithms, artificial intelligence, time-varying thermal conductivity coefficient, thermal conductivity modeling, optimization of computational parameters**

The accurate reconstruction of the heat transfer coefficient κ under the fourth-kind boundary condition remains one of the key inverse problems in heat conduction modeling, especially in applications related to the cooling of castings and imperfect thermal contact between the casting and the mold [1,2,3,4]. In engineering practice, however, high solution accuracy alone is not sufficient. Equally important is the computational cost incurred to achieve such accuracy. This very problem serves as the starting point of this work. Instead of another classic comparison of optimization algorithm effectiveness, an assessment of their utility from the perspective of the trade-off between reconstruction error and computation time was proposed [5,6].

In the study, two swarm algorithms, Artificial Bee Colony (ABC) and Ant Colony Optimization (ACO) [7,8], were considered and applied to the identification of the κ coefficient in the inverse heat conduction problem using temperature data. The calculations were performed in an original numerical environment based on the finite element method. As a quality criterion, the L2 error functional and the reconstruction error of the parameter κ relative to the reference value were adopted. The analysis was conducted for different population sizes, numbers of iterations, and levels of noise in the reference data. A key element of the work is the comparison of reconstruction quality with the time required to obtain a solution, and the determination of computational configurations that are most cost-effective from a practical standpoint.

The adopted approach allows moving away from the simplified criterion of "minimum error" and toward a more realistic approach to identifying the parameter κ. In many industrial tasks, a solution that is slightly less accurate but significantly faster can be more valuable than the numerically best result, even if computationally expensive. It is expected that the conducted analysis will identify the parameter ranges in which increasing the number of iterations or population size ceases to yield a proportional improvement in quality, and will also show which of the analyzed algorithms more frequently lead to solutions that dominate in the accuracy-time trade-off. In this context, the work contributes not only a comparison of two metaheuristics but, more importantly, a practical criterion for their conscious selection for tasks involving the reconstruction of thermal contact conditions [9].

References

[1] Zych M., Dyja R., Gawrońska E., Sczygiol N., Domek G., Estimation of the heat transfer coefficient for three ranges of reference values under fourth-kind boundary conditions using swarm algorithms, Journal of Applied Mathematics and Computational Mechanics 2025, 24(4), 119–131, DOI: 10.17512/jamcm.2025.4.08.

[2] Gawrońska E., Dyja R., Zych M., Domek G., Selection of the Heat Transfer Coefficient Using Swarming Algorithms, Acta Mechanica et Automatica 2022, 16(4), DOI: 10.2478/ama-2022-0039.

[3] Hetmaniok E., Solution of the two-dimensional inverse problem of the binary alloy solidification by applying the ant colony optimization algorithm, International Communications in Heat and Mass Transfer 2015, 67, 39–45, DOI: 10.1016/j.icheatmasstransfer.2015.05.029.

[4] Hetmaniok E., Słota D., Zielonka A., Using the swarm intelligence algorithms in solution of the two-dimensional inverse Stefan problem, Computers & Mathematics with Applications 2015, 69(4), 347–361, DOI: 10.1016/j.camwa.2014.12.013.

[5] Gawrońska E., Zych M., Dyja R., Domek G., Using artificial intelligence algorithms to reconstruct the heat transfer coefficient during heat conduction modeling, Scientific Reports 2023, 13, 15343, DOI: 10.1038/s41598-023-42536-w.

[6] Dyja R., Gawrońska E., Zych M., Influence of the Control Points Position on the Accuracy of Heat Transfer Coefficient Selection, Acta Physica Polonica A 2024, 146(6), 794, DOI: 10.12693/APhysPolA.146.794.

[7] Karaboga D., An Idea Based on Honey Bee Swarm for Numerical Optimization, Technical Report TR06, Erciyes University, Engineering Faculty, Computer Engineering Department, Kayseri, Türkiye 2005.

[8] Karaboga D., Basturk B., On the performance of artificial bee colony (ABC) algorithm, Applied Soft Computing 2008, 8(1), 687–697, DOI: 10.1016/j.asoc.2007.05.007.

[9] Chen Y., Liu K., Liao D., Ji Z., Zhang J., Simplified inverse heat conduction method for interfacial heat transfer coefficient of casting process based on simulated feedback, Thermal Science and Engineering Progress 2025, DOI: 10.1016/j.tsep.2025.103506.