

Tutorial

Application of meshless methods for thermal analyses

ORGANIZER



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ABSTRACT:

In numerical analysis, the most popular method is the finite element method (FEM). However, more and more researchers pay attention to meshless methods. The methods have been applied for the analysis of many scientific and engineering problems in the literature. A special group of these meshless methods is the collocation-based methods. In these methods, the initial or boundary conditions and, sometimes, the governing equations can be satisfied by enforcing them at selected points in the domain, called collocation points. In such a way, the unknown coefficients of the assumed approximate solution are determined. When the boundary value problem is considered, the governing equation is satisfied by the trial function in the approximate solution, and only the boundary conditions are satisfied by collocation, then this approach is called the boundary collocation technique in the literature.

The Trefftz method was proposed in 1926 by Erich Trefftz at a conference in Zurich. The approximate solution takes the form of a linear combination of trial functions that satisfy the governing equation describing the considered problem exactly. In special cases, the test functions in the Trefftz method (Trefftz functions) also satisfy some of the boundary conditions. This variant of the Trefftz method is referred to in the literature as the Trefftz method with special-purpose Trefftz functions.

Another example of a collocation-based meshless method is the method of fundamental solutions (MFS), which is a special kind of the Trefftz method. In the MFS, the approximate solution is a linear combination of fundamental solutions, which are functions of the distance between any point inside the considered domain and the source point located outside the domain, on a so-called pseudo-boundary (or fictitious boundary). The unknown coefficients are determined using the boundary collocation technique. The MFS is quite easy to implement, and the main question in the method is how to distribute the source points (i.e., what should be the shape of the pseudo-boundary and the distance between the pseudo-boundary and the considered domain). The MFS was proposed in 1964 by Kupradze and Aleksidze.

The Kansa method (or the global radial basis function collocation method) is the newest method among the meshless methods considered. It was proposed in the early 1990s by Edward J. Kansa. In this method, the approximate solution is expressed as a linear combination of radial basis functions. This method differs slightly from the two previously described methods because the test functions (radial basis functions) used in it do not satisfy the differential equation describing the problem. Therefore, the unknown coefficients of the approximate solution are calculated by collocation of both the differential equation (at a finite number of points within the area under consideration) and the boundary conditions (at a finite number of points located at the boundary of the area).

During this tutorial, some selected examples of the MFS and RBF application for solving thermal problems will be presented. The first problem concerns fluid flow and heat transfer through a straight tube with smooth and sharp fins. The other example is an inverse problem. Application of this method for the identification of the blood perfusion coefficient. The examples presented will include a mathematical description of the problem under consideration, an algorithm for solving it using meshless methods, and some numerical examples.

ABOUT ORGANIZER:

JAKUB KRZYSZTOF GRABSKI, Ph.D., Eng., is employed as an assistant professor at the Institute of Applied Mechanics, Poznan University of Technology, Poznań, Poland. Since September 2024 he is a vice-dean for full-time studies at the Faculty of Mechanical Engineering. He holds a Ph.D. in mechanical engineering, which he was awarded in 2016. His research interests include computational mechanics, meshless methods, corrugated cardboard, fluid mechanics, heat transfer, bioengineering, and inverse problems. He has published more than 35 papers in peer-reviewed journals and around 20 conference papers. Among the awards he has won, one can distinguish the Scholarship of the Minister of Science and Higher Education (Poland) for outstanding young scientists 2020 and START 2018 - stipend for young researchers below 30 from the Foundation for Polish Science. Furthermore, he is a member of the following scientific associations: Sigma Xi, GAMM, Polish Society of Theoretical and Applied Mechanics, Polish Society for Biomedical Engineering, and Polish Association for Computational Mechanics.