

HEATS: Thermal Analysis with Fast Boundary Elements

SURFACE-BASED ANALYSIS

In many industrial applications, only the surface data are of interest. If, furthermore, the creation of a three-dimensional domain mesh is a bottleneck in the overall modelling costs, surface-based methods become an attractive alternative. The boundary element method (BEM) operates only on the surface by finding an approximate solution to equivalent boundary integral equations. In case of linear problems such as the heat equation, the BEM is a well-known alternative, but commonly suffers from its inherent quadratic complexity in storage and computation time.

We provide a symmetric Galerkin BEM with a Multilevel Fast Multipole Method. Together with optimal preconditioning techniques, this approach is distinguished by a linear complexity: **twice the number of degrees of freedom take twice the time to compute.**

FEATURES

The software tool HEATS provides the following functionality:

- computation of matrix coefficients with robust integration schemes
- octree-based adaptive geometric clustering
- multilevel fast multipole acceleration of matrix-vector products
- operator preconditioning techniques with optimal scaling

TECHNICAL DETAILS

The starting point of a direct BEM analysis is the representation of the solution in terms of its boundary data, here the temperature u and the heat flux q ,

$$u(\mathbf{x}) = \int_{\Gamma} G(\mathbf{x}, \mathbf{y}) u(\mathbf{y}) d\mathbf{s}_{\mathbf{y}} - \int_{\Gamma} \partial_{\mathbf{n}_{\mathbf{y}}} G(\mathbf{x}, \mathbf{y}) q(\mathbf{y}) d\mathbf{s}_{\mathbf{y}}. \quad (1)$$

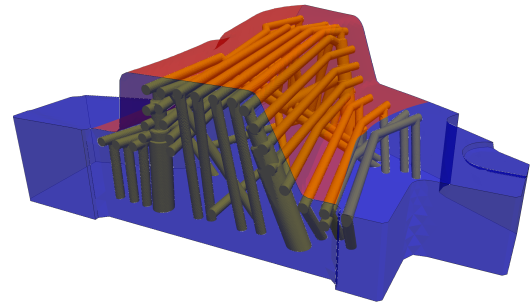
The integrals are over the surface Γ and $G(\mathbf{x}, \mathbf{y})$ is the fundamental solution. For heat conduction problems, a typical boundary condition is Newton's law of cooling

$$q(\mathbf{x}) = \kappa(u(\mathbf{x}) - u_{\infty}), \quad (2)$$

which relates the heat flux to the surface temperature by means of a far-field value u_{∞} and the heat transfer coefficient κ . The combination of Eqs. (1) and (2) yields a set of boundary integral equations in the unknown functions u and q . Using a discretisation based **only on a surface mesh**, a linear system of equations is obtained. This system is fully populated leading to a quadratic complexity in the number of unknowns such that the limits of computer resources are quickly reached.

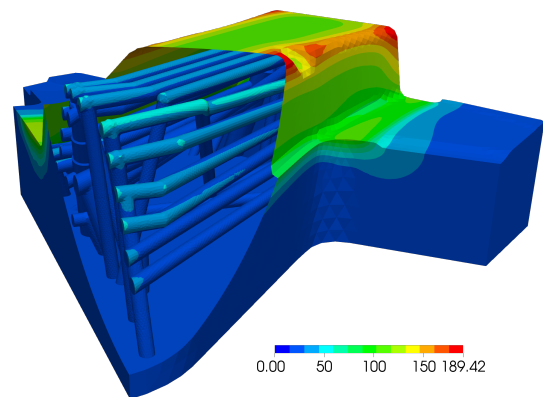
Using a hierarchic subdivision of the geometry and a series expansion of the function G , the matrix-vector product of the final system of equations can be realised with a linear complexity. Together with state-of-the-art preconditioning techniques, the iteration number in the solution process is virtually independent of the system size, thus rendering an optimal complexity of the overall approach.

INDUSTRIAL EXAMPLE



Hot forming tool with cooling channels (geometry by courtesy of weba Werkzeugbau Betriebs GmbH)

For a demonstration of the performance of this software tool, we applied it to the heat conduction in a hot forming tool pervaded by multiple cooling channels. The surface of the tool consists of its outer part, partially in contact with the hot metal, and the interior channel surfaces. Different boundary conditions are applied to this surface regions.



Surface temperature in °C

The simulation result shows the surface temperature on all surfaces and the hottest parts are easily identified.

Mesh	original	refined
#surface DoFs	250K	1000K
CPU time	20 min	80 min
storage	10GB	40GB

Computational costs

The comparison of the computational costs after mesh refinement clearly indicate the optimal complexity of the method.

TAILSIT GmbH
Nikolaipplatz 4
8010 Graz, Austria
www.tailsit.com
info@tailsit.com
+43 676 974 6416

Contact Person:
Dr L. Kielhorn

**TAIL
SIT**
tailored
simulation
tools