DOMTFCALT 1.0 - A 3D Heat Transfer Software for isotropic or anisotropic medium, in steady state or transient regime with or without internal heat generation

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This work is a spin-off from a research aiming at the performance of structural analysis and safety assessment of the advanced nuclear reactors by the Design by Analysis (DBA) route, for pressure vessel and piping [1]. As one of the steps for this purpose, the knowledge of the temperature field in each point of an analyzed component is necessary to allow for the calculation of the thermal stresses generated. This requires the use of a software to for determine the temperature fields. For engineering design application, a tridimensional analysis is mandatory. For our research, we needed a software that is usually available only commercially, at a high price and without a source code. Considering that the heat equation is a prototypical parabolic differential equation, we decided to develop a code that can also be useful for the students and researchers of IEN when dealing with heat transfer problems or with various other fields in physics and engineering with analogous differential equation. This way, our aim is to make a software that could be easily adapted and enhanced. We initially developed a 3D software called DOMTRFCAL in Fortran 90 for steady state heat transfer (Poisson's equation), for any type of irreducible finite element [2] [3]. The software was developed using 10 nodes quadratic tetrahedron, which are more comprehensive, but was designed bearing in mind that the addition of new elements can be easily done with a minimum of localized changes at the original source code. The inclusion of elements such as quadratic or linear cubic three-dimensional elements, as well as simpler elements in 2D or 1D, can be easily done. The software is as general as possible, and was developed considering a number of different materials. It can accommodate different thermal conductivity coefficients in each direction for dealing with anisotropic materials. The prescribed boundary conditions are temperatures and flows of heat by conduction and convection. Internal heat generation was also taken into account. The material properties were considered as temperature independent. Radiation flow was not considered, even though its subsequent inclusion in the software's structure is very simple [4]. As a natural second step, we extended the software to the non-stationary case. Although this is not really necessary for our research, this was done to allow anyone interested with the possibility of conducting other analysis such as that of heat shock, for example. The new generated code is called DOMTFCALT. We suppose that all boundary conditions, as well as the heat generating rate and material properties, do not vary with time. For this to be possible, a complete heat equation was considered and a partial discretization was used. The spatial domain was discretized using the same quadratic 10 nodes tetrahedron finite element. For the time domain, we used a finite difference scheme with time varying linearly and time steps defined by a relation that takes into account a square of a typical element dimension. An Euler implicit scheme was used and it showed good results. Both codes were conceived to be used (but not exclusively) in conjunction with a commercial software GiD as its pre and postprocessor. Currently an IEN a Technical Note is being prepared which will contain the theory that underpins the development of the software, as well as details of its implementation, such as the method used to impose the boundary conditions and the algorithm used for linear system solution in addition to the commented source code to allow anyone to be able to make corrections, improve it and make adaptations and extensions introducing new finite elements.

References

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