Answer to REVIEWER – 3

We have proofread the paper and we have found a few grammatical mistakes that have been corrected.

Subject of the manuscript is suitable for publication in your Journal, however the results and presentation is not convincing. In the manuscript innovative thermal conductivity constitutive matrix is proposed. The beginning of the manuscript is interesting, but total results are not convincing.

The main advantage of the method proposed in this article is its simplicity. The constitutive matrices developed by previous methods presented complex calculations, while the new constitutive matrix, proposed in this work, depends exclusively on the coordinates of the vertices of the tetrahedra which constitutes the mesh.

In addition, the errors are much smaller with the new matrix and this allows meshes of smaller number of elements, obtaining the same precision with lower temporal cost.

As it is underlined before, the simplicity of the method and its greater precision mean that the new methodology can be applied to more complex problems, such as the calculation of the thermal heating of the rotor and the stator of an electrical machine of much more complex geometry and with more complex physical properties and boundary conditions, even convective type. This is critical in the problems in transitory regime.

Mathematical formulation is innovative, however the simulation results are similar comparing with standard methods results.

You are right.

The numerical results are similar to those obtained with other methods. We have demonstrated this by comparing our results with the results obtained with the FEM in the verification process in section 3.

In our case, the main contribution of this article is the formulation and verification of a new thermal-conductivity constitutive matrix using the CM, which is a numerical method different from standard methods such as the FEM, the Finite Differences Method, etc. that start from the differential equation and from field magnitudes such as the heat flow. These standard methods need a preliminary step of discretization of these equations before solving them. The CM, which is the numerical method associated with the Finite Formulation, has the advantage of not needing this prior discretization.

The main issue here is that the advantage of the new method is not convincingly explained. The application also. The difference of 0.0025% is not really important. The calculation time/cost is not adequately addressed.

Three methodologies have been formulated previously to obtain the constitutive thermal matrix. These methods are those by Tonti [16], Bullo [21–22], and the method proposed by Specogna [14] for problems of electrical conduction which we have adapted to thermal conduction [10–13].

These three methods use projections of edges and surfaces from dual to primal space. They also use local coordinate systems with subsequent transformations to global coordinates. Calculate the barycenters of the dual surfaces and then obtain a weighted dual barycenter from those previously found.

In [16], Tonti presents a new 2D numerical method for the solution of temperature field equations using CM. The essence of the method is to directly provide a discrete formulation of field laws. It is proved that, for linear interpolation, the stiffness matrix so obtained coincides with the one of the FEM. For quadratic interpolation, however, the present stiffness matrix differs from that of FEM; moreover, it is unsymmetric. It is shown that by using a parabolic interpolation, a convergence of the fourth order is obtained. This is greater than the one obtained with FEM, using the same interpolation.

In [21] Bullo calculates through CM the 2D fields applied to a coupled computation of electric and thermal conduction using a linear interpolation of both the electric and temperature fields and uses a quadratic interpolation for thermal analysis approach. In [22] Bullo uses CM for the solution of coupled problems of steady-state electric and transient thermal conductions in 3D regions. Dual barycentric cell complexes are used for both space and time domains, the latter inducing a Crank–Nicolson time integration scheme.

In [14], Specogna, by using a CM formulation for eddy currents, presents a geometric approach to construct approximations of the discrete magnetic and Ohm's constitutive matrices. In the case of Ohm's matrix, he also shows how to make it symmetric. He compares the impact on the solution of the proposed Ohm's matrices, and an iterative technique to obtain a consistent right-hand-side term in the final system is described.

In [12–13], González develops a new constitutive matrix, [Mλ], for thermal conduction in transient thermal regime is using CM. He demonstrates that this matrix is equivalent to the electrical conduction constitutive matrix in steady state and applies this constitutive matrix to thermal analysis of asynchronous electric machines in transient regime.

In [10–11], Monzón-Verona analyses the temperature distribution in a conductor disk in transitory regime. The disk is in motion in a stationary magnetic field generated by a permanent magnet and so, the electric currents induced inside it generate heat. The system acts as a magnetic brake and is analysed using infrared sensor techniques. In addition, for the simulation and analysis of the magnetic brake, a new thermal convective matrix for the 3D Cell Method (CM) is proposed.

These methods use projections of edges and surfaces from dual to primal, they use local coordinate systems with subsequent transformations to global coordinates and they calculate the barycenters of the dual surfaces and then obtain a weighted dual barycenter from those previously calculated.

The main advantage of the method proposed in this article is its simplicity. The constitutive matrices developed by previous methods presented complex calculations, however, the new constitutive matrix depends exclusively on the coordinates of the vertices of the tetrahedra which constitute the mesh.

As we said before, the simplicity of the method and its greater precision means that the new methodology can be applied to more complex problems, such as the calculation of the thermal heating of the rotor and the stator of an electrical machine of much more complex geometry and with more complex physical properties and contour conditions, even of convective type.

The calculation time is comparable, but the fact that the errors are much smaller with the new matrix, as can be seen in Table 7, allows meshes with a smaller number of elements, obtaining the same precision and with a lower time cost, as it is necessary in transitory regime problems.

An example of calculation is really not connected with real case shown in the figure 1. In fact, figure 1 is not addressed in the calculation.

You are right.

Figure 1 shows a real rotor and stator to which the conclusions of this work could be applied in the future. Here, we present a simplification of these electromechanical converters to facilitate the verification of the proposed constituent matrix.

Besides for such a simple tube (used in calculation) case an analytical solution is known therefore analytical results shall be shown for comparison.

You are right.

We have added the section 3.1 explaining that we have verified the FEM through the analytical solution of a simple problem for a single thermal conductivity. Then, the FEM has been applied as a reference tool in sections 3.2 and 3.3 to verify a more complex problem of two thermal conductivities and we have compared with FEM the results obtained by means of the two thermal conductivity matrices analysed with the CM.