Thermal Design Tool for Vehicle Electric Parts

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ABSTRACT This paper proposes a software tool utilizing CAE, and a method for parts design. Progress in vehicle electronics has been remarkable, and electronic circuit design now has a significant influence on car performance. Hence, it is desirable to link analysis and circuit design directly. Commercial design software allows approximate calculation of heat transfer in circuit boards, but the distribution of heat generation and differences of heat transfer coefficients are not taken into account. This paper addresses these issues and reports on an advantageous circuitry technique. The main feature of this development is the specially made component library that can be used with commercial analysis software. Information stored in the component library includes the shape and heat transfer coefficient of each surface, the heat generated, and the terminal connecting structure. Even if the shape and heat transfer coefficients can be defined with commercial software, residual parameters are hard to define due to the limitations of the software. A CAD-based geometry file is combined with component data, and the combined file is applicable for computer analysis. As a result of utilizing the above-mentioned technique, the cost of designing a new circuit board or a junction block, etc. can be halved compared to conventional techniques.

1. INTRODUCTION

Vehicle electric parts made up of several circuit boards and electrical joints are the target of this development. One of these is the junction block (JB), which typically has relays, fuses and circuit patterns as components. Its main function is to distribute signals and power to the proper devices. However, preparation for analysis can be an arduous and time-consuming process, and due to the increase in the scale of circuits, the situation is becoming even more serious.

This paper introduces a solution to this problem, and the software tool developed here proves effective in practical application with reduced labor.

2. TOOL CONSTRUCTION

Figure 1 shows the data flow in the software developed here. Its basic concept is to use a customized pre-processor with a commercial solver and post-processor. The customized pre-processor, which is main focus of this paper, includes three principle elements. The first element is a CAD process, which constructs geometric data for analysis. Library editors are included in this process. The second element is an automatic mesh generator. The last element is a boundary condition generator.

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In conventional methods, the most time-consuming process is defining boundary conditions, generally followed by automatic mesh generation. The heat generated and the heat transfer coefficient are the two most important aspects of boundary conditions in this type of analysis.

In this development, the heat generated from a circuit pattern is calculated with a Joule heat calculator, while the heat generated from the components is calculated with the component's boundary condition generator, which can also calculate the heat transfer coefficient.

The automatic mesh generation process is based on the original CAD tool which contains library editors. The library editors enable us to construct an outline structure for the automatic mesh generator, and, using component data created by the library editors, the original line drawing tool creates an outline drawing for analysis.

Finally as a pre-process, the analysis data generator provides data for sending to the solver program. The analysis data generator requires geometrical data and boundary conditions. These are delivered from the above-mentioned tools.

3. UTILIZATION OF THE CAD SOFTWARE

Only with difficulty can commercial CAD software be applied directly to this type of analysis. For example, automatic recognition of a structure with a narrow crevice or a laminated structure is very hard to do. If there is neither a narrow crevice nor an overlap structure (as

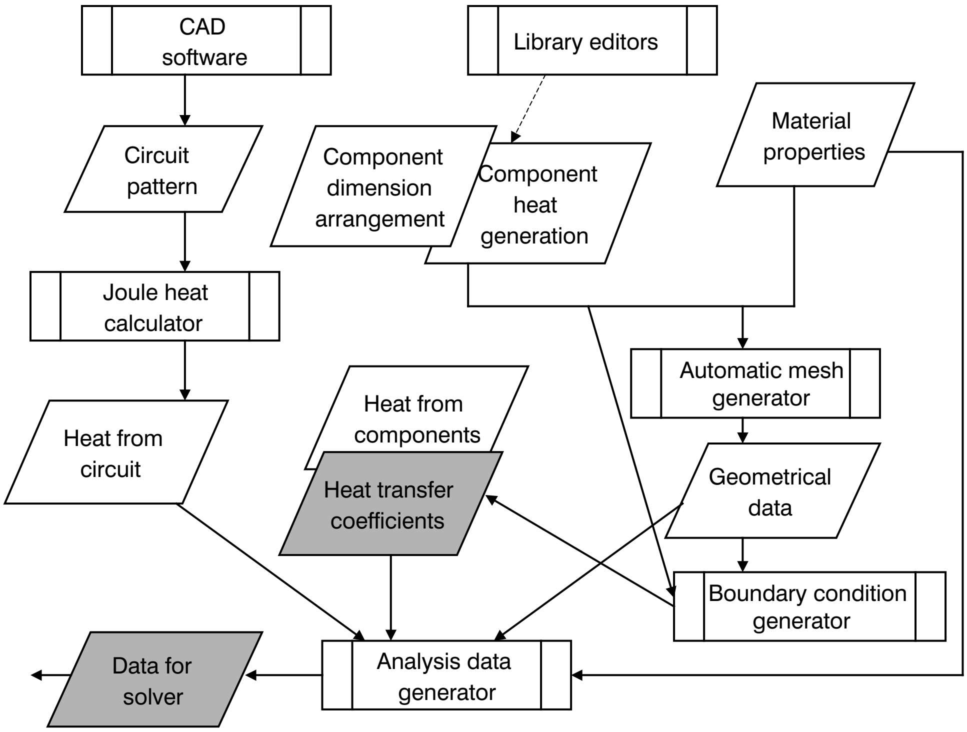

Figure 1 Data flow.

when a lid is put on a box), we can use commercial software capable of automatic generation of a mesh from a quite complicated CAD drawing, which has come on to the market recently. However, this is not entirely satisfactory, in that commercial automatic mesh generation software fundamentally deals with tetrahedral mesh generation. There are, however, disadvantages with a finite element method using a tetrahedral mesh. At least, a hexahedral mesh enables us to make a model with fewer nodes, and in some types of analysis a tetrahedral mesh cannot provide sufficient accuracy. Automatic generation of a hexahedral mesh is still being developed by several groups and has not yet been completed.

In this development, geometrical data and boundary conditions are given from libraries. That means the boundary conditions for each position are prepared automatically and precisely. Data from commercial software are only for circuit pattern drawing. Other geometrical data are also from the libraries. There are numerous types of library editors, while their basic functions are the same. They provide geometrical data and the value of heat generated. Typically, editors are applied for circuit boards, relays and terminals. The geometrical data provided by library editors become the basis of mesh generation.

Information on only a few coordinates is enough to create line drawings, and no complicated data is necessary. Figure 2 is a typical line drawing generated by the tool developed here. It has a layered structure as if sliced into shells. The extracted data are treated as in the case of CT scan, and a three-dimensional figure is then reconstructed.

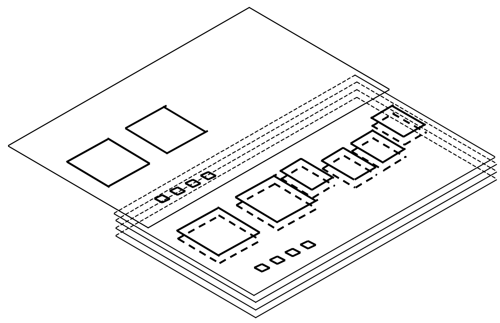

Figure 2 Layered line drawing.

4. AUTOMATIC MESH GENERATOR

Figure 3 shows how an actual model is represented as a line drawing by the automatic mesh generator.

A two-dimensional line drawing is provided from each layer. This data set of a line drawing is defined here as a “CAD,” and from the CAD file a filtering tool can provide the minimum geometrical information, which can be defined using “corner points.” Mesh generation software can then generate a calculation mesh from the corner points. The filtering and mesh generation software are of a proprietary design. The role of filtering software is to purge unused information and to provide useful geometrical information from each layer of the line drawing. The automatic mesh generation software reconstructs a three-dimensional structure from the vertices and generates a hexahedral mesh using a structured method, which is suitable for a rectangle-based object. In spite of limited applicable objects, this method is suitable for many types of JB since the components used in them are mostly rectangular.

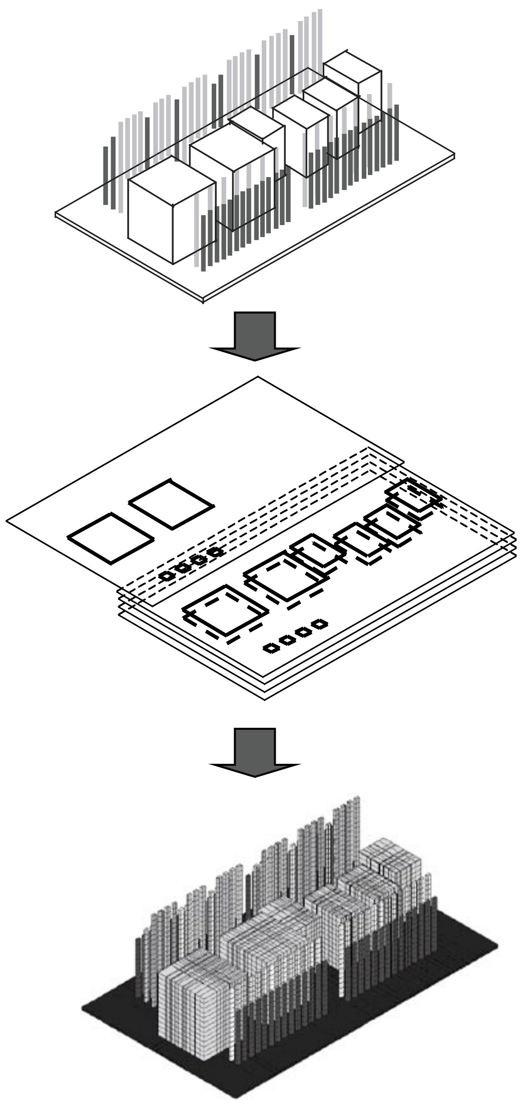

Figure 3 Automatic mesh generation.

5. BOUNDARY CONDITION GENERATOR

The boundary condition generator can output two types of data: heat generated from components and heat transfer coefficients for each portion of the surface. Source data for both types of boundary conditions are supplied from the libraries.

Heat from the circuit is calculated with a Joule heat calculator. Hence, the objectives are relays and terminals. The heat generation data are stored in libraries as volume flux. The boundary condition editor acquires these data and assigns each of them to corresponding coordinates of a fully constructed analysis model.

The Joule heat calculator requires drawing data of a circuit pattern. Also, it requires the input of electrical current data. In the first step, Joule heat distribution on the circuit board is calculated, and in next step, these data are combined with data for another boundary condition and exported to the solver.

Heat transfer coefficients for each portion of the surface of the components should be calculated using this boundary condition generator. In this case, the dimensions of each component are required, and the dimension data are also obtained from libraries.

6. RESULTS AND DISCUSSION

6.1 Heat Transfer Analysis

The temperatures at several points located on the board surface are compared between measured and calculated values. Figure 4 takes calculated values along the horizontal axis and actual measured values along the vertical axis, and plots various points on the board. Also in the figure, ΔT expresses the temperature rise in the Kelvin scale. In this example, the maximum error between measurement and calculation is approximately ±2K, which is sufficient for practical purposes.

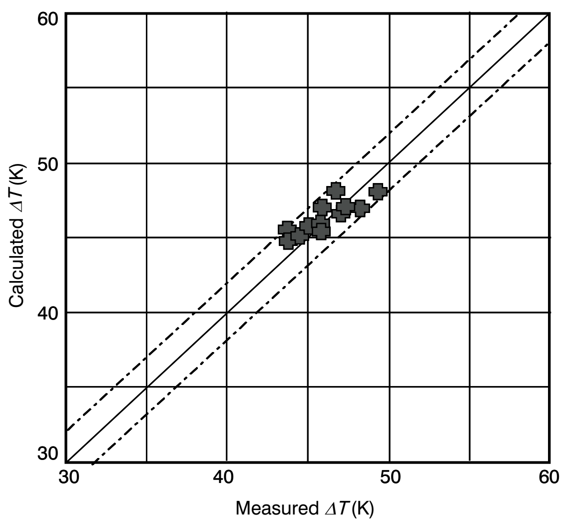

Figure 4 Calculated and measured data.

6.2 Calculation Time

Analysis time can roughly be divided into model creation time and calculation time. Among commercial solvers, calculation times do not differ by much in normal cases. Preparing boundary conditions is the most time-consuming process. The developed boundary condition generator can dramatically reduce the preparation time. As a result, total simulation time is less than 50 % of the conventional method.

7. CONCLUSION

In this paper, we have presented a new design method for vehicle parts considering thermal properties. This simulation tool is constructed of a library editor, automatic mesh generator and boundary condition generator. This development induces the enough accuracy for design and the reduction of simulation time by 50 % or less.

In the future, more generally used software tool should be developed which realizes virtual trial production.

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