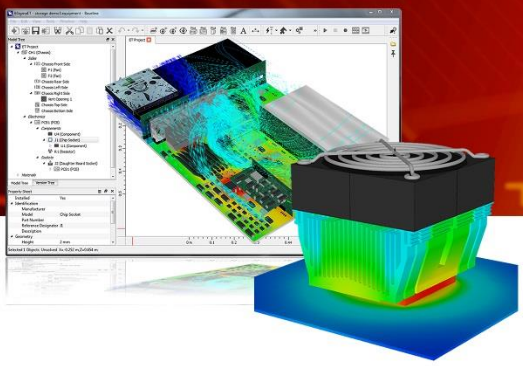

Thermal Simulation in the Engineering Design Process

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Do thermal issues increase your time to market? In recent years, thermal simulation has been used to identify thermal issues during the design process. This ensures that products are released on time, are less likely to be recalled, and that lifetime product costs are reduced.

Our previous paper, "Electronics Cooling Trends – Past, Present and Future"[1], discussed the history of computational fluid dynamics (CFD) in the electronics industry. This paper specifically describes its application in the engineering design process for electronic equipment. It looks at the advantages of including thermal simulation early and throughout the design process, as well as how to manage the flow of data between the thermal engineer and the engineering design team.

Engineering Design Process

Across the electronics industry, the requirement for shorter design and development cycles is increasing. Companies must keep to product release deadlines for fear of being beaten to the market by the competition and missing the key advantage of being first to the market.

The result of this is that engineering management must reduce and manage the risk of design mistakes in every aspect of the product design. Historically, detailed thermal design of a product has often been neglected and 'rules of thumb' have been used to ensure the components operate below their maximum operating temperature.

Mistakes in the thermal design of the equipment would only be found at the prototype stage or even later. Engineers would have to rush to find a solution at a very late stage in the design process. This often resulted in missed deadlines and increased costs. This can no longer be acceptable in today's competitive market place.

In order to ensure an error in the thermal design of the product does not result in missed deadlines or increased product cost, the thermal design of the equipment must be considered from the very start of the product design cycle.

[1] To read this paper please visit www.futurefacilities.com/media/info.php?id=197

Thermal simulation should be used at multiple stages in the design process so that any mistakes can be identified and rectified sooner. A design process that includes thermal simulation can be seen below in Figure 1. Each stage in the process is explained in more detail through the paper.

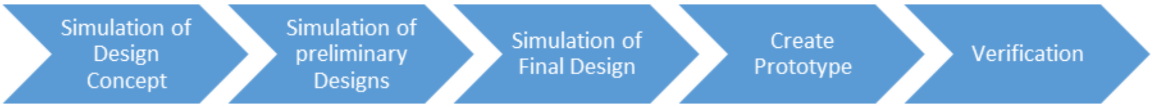

Figure 1 - Thermal simulation process throughout the engineering design cycle

Concept Simulation

Before the specification of the product is signed off, it may be necessary to create a simple thermal model of the equipment to verify that it is possible to cool the equipment within the constraints of the product specification. This is particularly important if the equipment is to be cooled by natural convection.

However, a concept thermal model may be important for equipment cooled by forced convection if there is a limit on the number of fans or fan speed, due to the maximum noise output, for example.

The simulation can be used to determine whether the device can be cooled given the specified power dissipation, form, size, weight and environmental conditions. An example of this type of model is shown in Figure 2. The electronic components in this type of model are represented by a lumped block of heat. The enclosure and any heat sinks or fans are represented simply, as the detail has yet to be defined.

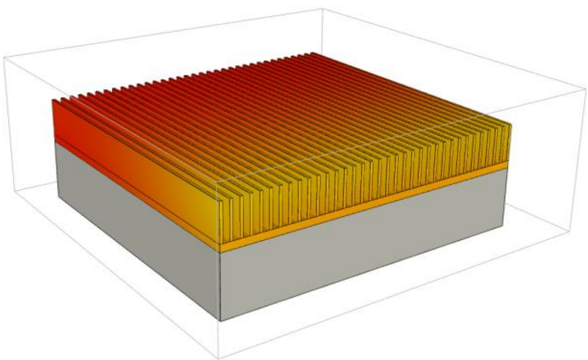

Figure 2 - Concept Thermal Simulation

At this stage the engineer should ensure that the temperature inside of the equipment model does not exceed the maximum operating temperature of typical components which will be used in the equipment, for example 85 °C. If this is not the case, the product specification may need to be modified or a more detailed thermal simulation will need to be created before the project can continue.

Preliminary Design Simulation

If thermal simulation is only performed when the electronic and mechanical design is complete, it is very difficult to make any significant changes to the design. This is because any change will significantly affect all the other aspects of the design.

The earlier a problem is found, the simpler, quicker and cheaper it is to rectify. Thermal simulation of the equipment should therefore be performed in tandem with the electronics and mechanical designs.

"Thermal simulation of the equipment should be performed in tandem with the electronics and mechanical designs"

The PCB designer should share key information with the thermal engineers: the components that are expected to be on the board; their approximate location; and an estimate of the power consumption of any significant components.

This information should enable the thermal engineer to create a thermal simulation, which may in turn identify cooling issues with the board layout. Should the model identify any concerns related to cooling, these can be communicated to the PCB designer before the time consuming task of designing the routes on the board. Thereafter, thermal simulation can be used to experiment with improvements to PCB design and to identify the optimum solution to resolve any cooling issues.

The initial mechanical design should also be communicated to the thermal engineer as early as possible so that they can start simulating the design. At this stage it does not necessarily need to be a complete 3D model of the enclosure, as this is time consuming to create. Instead, simple sketches with key dimensions indicated will be enough information to create a simulation that can identify any major thermal design flaws and identify regions where there is a risk of a thermal issue. However, the more detail about the enclosure design, the more accurate the simulation of the electronics will be.

At this preliminary stage in the design cycle, the aim is to identify any areas or components that might have a thermal issue in the equipment – it is not to predict definitive component temperatures or to approve the thermal design of the equipment. This is because there is simply not enough information available to do this. For now, the focus must be on advising the PCB designer and mechanical designer on how to improve the design to reduce the risk of excessive design changes in the future, and to cool the equipment effectively.

Simulation of the Final Design

When the design of the equipment is complete, a thermal simulation should be created to verify it. This should be done before any prototypes are created.

The purpose of this simulation is to ensure that, when the equipment is running at maximum load and maximum ambient temperature, all the components are below their stated maximum operating temperature.

At the final design stage, it is important to include all thermally-relevant information including PCB design, component thermal models, 3D CAD models and material characteristics. This is discussed in more detail later in this paper.

Once the simulation has been created and analysed, a decision can be made on whether the equipment is ready for manufacture from a thermal point of view. If any thermal issues are found, the model can be used to investigate possible solutions. However, the expectation is that the majority of issues will be found in the previous round of simulations.

Verification

Once a prototype of the equipment has been created, it is important to take physical measurements to verify that the thermal simulation is accurate.

There are many methods to measure the temperature inside the equipment, including thermocouples, on-chip temperature sensors and IR temperature measurements. The choice of sensor will depend on the application and there are advantages and disadvantages of each measurement method.

The accuracy and limitations of the sensor should be considered when analysing the results. It is also important to correctly model in the simulation the environment in which the equipment is being measured. For example, if measurements are being taken in a forced flow test chamber, this needs to be accurately modelled in the simulation in order to make accurate comparisons.

There will always be some discrepancy between the simulation results and measured results due to: experimental accuracy, input data accuracy and numerical accuracy. As long as the discrepancy is not significant, the insight and understanding the simulation gives will still be valid and useful conclusions can be drawn.

Data Flow

A thermal engineer needs a vast amount of data to create an accurate thermal simulation of a piece of electronic equipment. They must also be able to effectively communicate any design changes to the mechanical and electronic design engineers. Figure 3 shows the flow of data that is required for a thermal simulation and the outputs of the simulation.

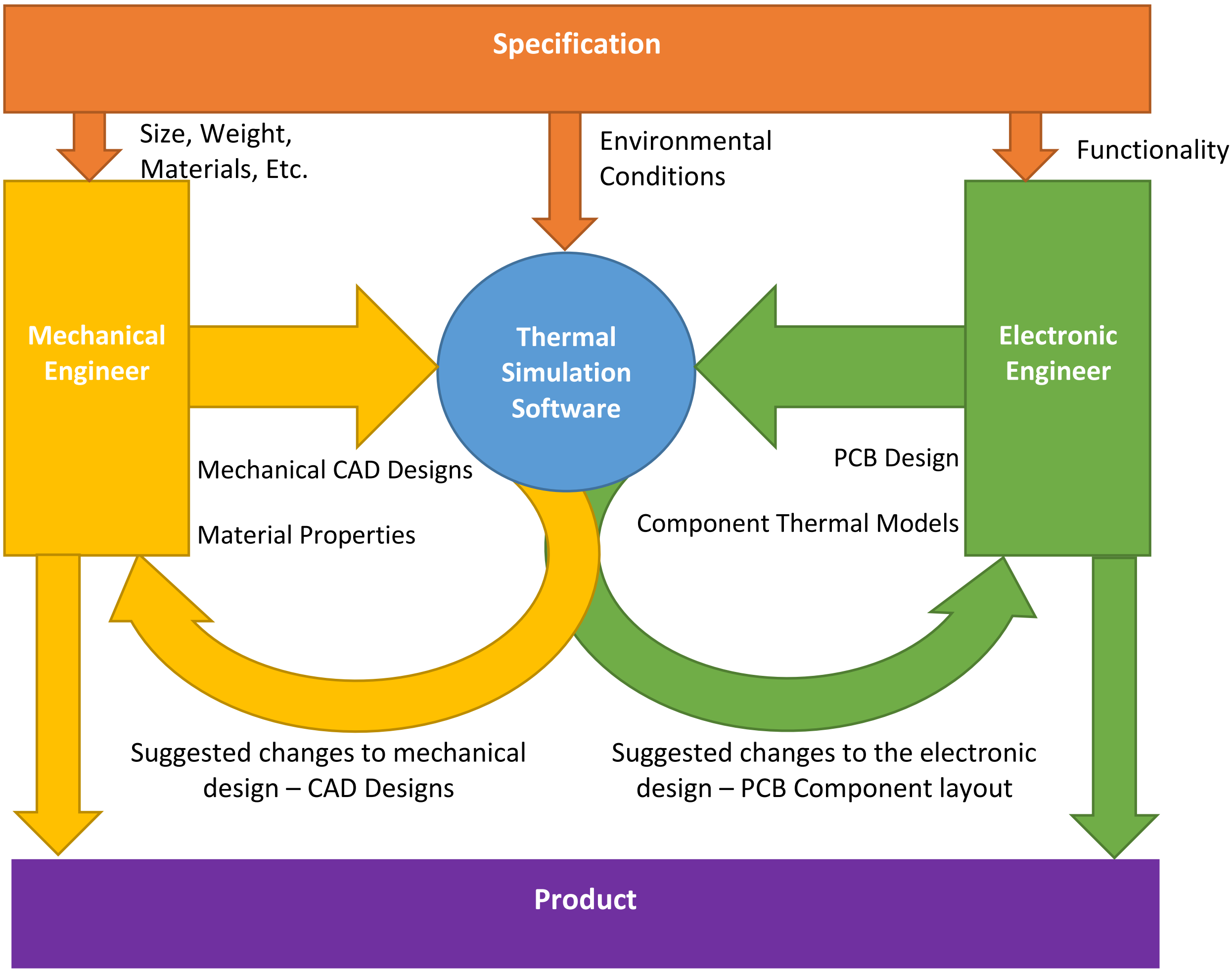

Figure 3 - Thermal Simulation Data Flow

Mechanical Data

Increasingly, thermal design engineers create thermal models direct from a 3D CAD model. Thermal simulation software such 6SigmaET allows the direct import of 3D CAD into the thermal model, and the complete 3D model can then be used in the thermal simulation. This enables faster model creation because the thermal engineer no longer has to recreate the geometry in the thermal model.

"Maintaining a comprehensive library will significantly reduce the amount of the time that is required to create a thermal model."

It is sometimes necessary for the mechanical engineer to simplify the CAD geometry and remove any unnecessary detail, such as the detail on a screw head, before it can be used in the thermal simulation. This reduces the computational complexity of the model and enables the results to be calculated in a reasonable amount of time, without compromising accuracy.

With a direct CAD import into the thermal model, the mechanical engineer can very quickly exchange any design changes with the thermal engineer. A process should be put in place so that if any thermally-significant change is made to the mechanical design, an updated CAD model is given to the thermal engineer.

Data about the thermal characteristics of all the material used in the equipment is required for an accurate thermal model. A library of materials and their thermal characteristics should be created and maintained by the thermal engineer. The thermal simulation software should contain a populated library of materials, which can be used across multiple projects. A library can also be used to store fan characteristics of commonly used fans as well as CAD models of parts which are used across multiple products. Maintaining a comprehensive library will significantly reduce the amount of the time that is required to create a thermal model.

Electronic Data

A modern PCB is immensely complicated. It will have hundreds, if not thousands, of components, many conductor layers and thousands of connections. This makes creating a thermal model of a PCB challenging.

Modern thermal simulation software such as 6SigmaET has many tools to make creation of a thermal model of a PCB simple. The design of the PCB, including the components' location, size, and reference designator, can be quickly imported into the model through a range of PCB file exchange formats.

Detail of the traces on each PCB layer can also be imported. Detailed trace information can often be too complicated to solve in a thermal model so options are available to approximate what percentage of copper trace there is in each area.

In order to accurately predict the component temperature, a thermal model that represents the internal structure of the component is required. There are two standards for thermal models of electronic component: 2-resistor and Delphi Compact:

- The 2-resistor specification is the most commonly supplied information by manufacturers, but is also the most simplistic.
- Delphi compact models are more detailed and can be used to better predict component temperature.

Engineering teams need to request the most accurate component model from component manufacturers. The thermal engineer should create and maintain a library of thermal models of components used within the organisation.

A thermal model will be useless without accurate information about the power dissipation of the components in the equipment. The power dissipation will need to be calculated by the electronics engineer who designed the circuit, as the power dissipation of a component will vary depending on the application.

The ability to import a list of component power dissipations matched to the component reference designators is key to accelerating future edits to the model as the design evolves.

Reporting

Once a thermal simulation has been solved, the results should be communicated to the relevant engineers. These results must be presented simply and clearly: it should not require an expert thermal engineer to understand them.

Component overheat plots shown in figure 4 simply show whether the components are operating below the maximum operating temperature. Streamline plots (figure 5) are a clear and simple way of showing the airflow through the equipment. The ability to plot the surface temperature directly on imported CAD geometry makes identifying the hot spots in the equipment simple (Figure 6).

Subsequent to analysing the results, any suggested changes to the mechanical and electronic design must be effectively communicated to the mechanical or electronic design engineer. The ability to export mechanical and electronics designs from the thermal simulation software is important because it ensures the detail of the design change is not lost.

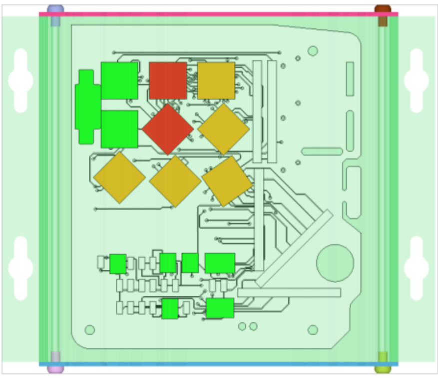

Figure 4 - Component Overheat Plot

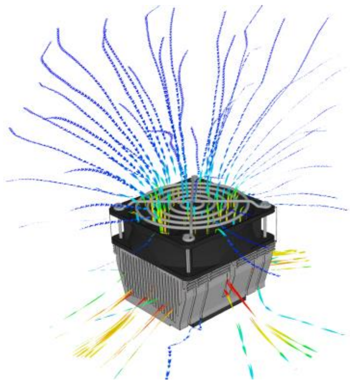

Figure 5 - Streamlines showing the flow through a CPU Cooler

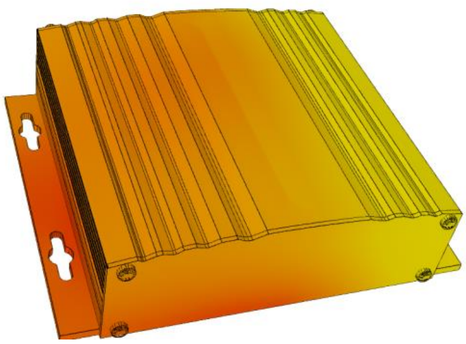

Figure 6 - Surface Temperature plot

Conclusion

Thermal simulation of electronic equipment is becoming an increasingly important part of the engineering design process. Using thermal simulation reduces the risk that a thermal design issue will only be found once a prototype is built, ensuring that project deadlines are met and cost increases are avoided.

"It is important that thermal simulation does not become a bottleneck."

Thermal simulation should become an integrated part of the engineering design process. Accordingly, it is important that thermal simulation does not become a bottleneck in the design process. This means that both model creation and solving must be as quick as possible.

Thermal simulation of the equipment must be scheduled in the project plan at appropriate stages throughout the project. This ensures that any issues are identified as early as possible, reducing the impact on the project.

A significant amount of data is required to create a thermal simulation, so it is important that data can be effectively shared with the mechanical and electronics CAD design tools. The thermal simulation tool must be able to quickly and easily import this data and represent the data effectively in the thermal model. A process should be put in place to ensure that any thermally significant changes to the mechanical or electronic design are communicated to the thermal engineer.

For many products, thermal simulation is an important part of the design cycle and a key part of the final sign off the design. Future Facilities is committed to the continuing development of 6SigmaET to ensure it fits the demands of the modern engineering design process.

For more information about thermal simulation using 6SigmaET please visit:

www.6SigmaET.info

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