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Fast design of medical ultrasound probes with Simcenter Flotherm

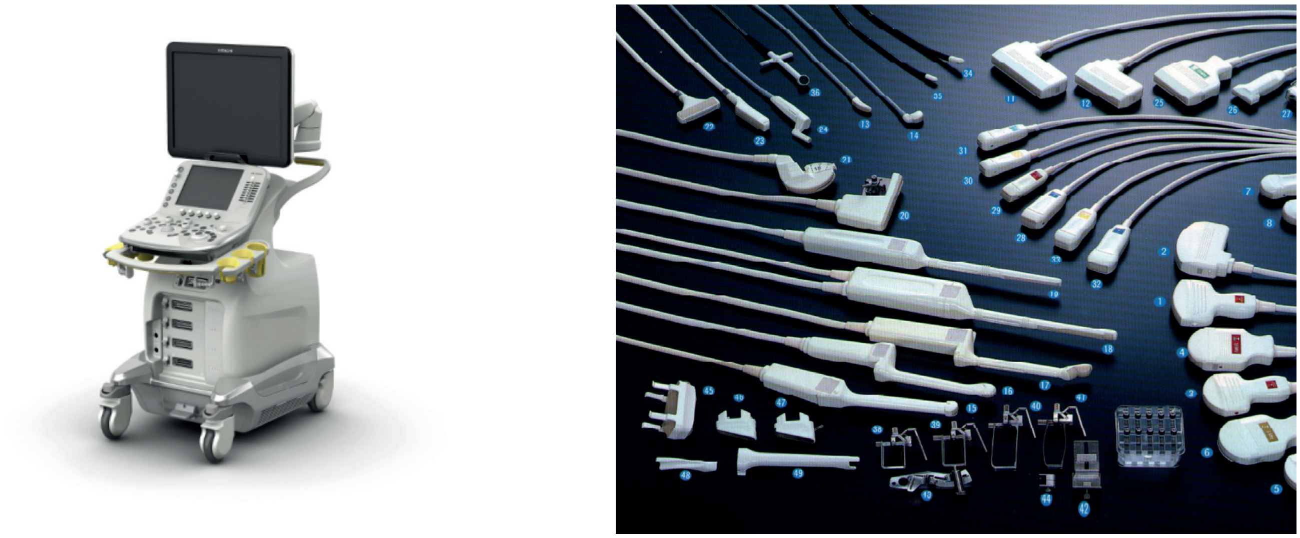
Changing to Simcenter Flotherm enables Hitachi to accelerate design process

Executive summary

Upon deploying Simcenter™ Flotherm™ software, Hitachi found a design process for its medical ultrasound probes that meets the company's manufacturing needs. With Simcenter Flotherm, Hitachi's simulations were significantly faster and extremely accurate.

Kazuya Motoki
Hitachi, Ltd., Japan

Abstract



(a) (b)

Figure 1: Hitachi ultrasound scanning system (a); Assortment of Hitachi ultrasound probes (b).

To accurately assess the design of its medical ultrasound probes and meet strict international regulations, Hitachi chose the Simcenter Flotherm software thermal analysis tool from Siemens Digital Industries Software to perform a transient thermal simulation. After years of using a competitor's tool, Hitachi transitioned to Simcenter Flotherm and immediately received simulation results faster while significantly improving the overall design process.

Ultrasound systems (figure 1a) for diagnostic images have advanced in the last 20 years and include more sophisticated electronics. Currently, they encounter higher quality scan images on much larger screens but in smaller, more compact systems that draw higher power consumptions to manage.

Hitachi supplies ultrasound scanner systems and a wide range of probes (figure 1b). Each probe includes piezoelectric transducers, as an imaging sensor, which generates heat during a scan. Recently, more of the electronics associated with the probe have been used inside the probe to improve image quality. As the performance of probes increases, heat generation is becoming a bigger issue compared to our previous designs.

Test state	Body surface applications	Invasive applications
Tissue-mimicking material	Initial temperature: 33°C or more **T < 43°c**	Initial temperature: 37°C or more **T < 43°c**
Left in air	Initial temperature: 23°C ± 3°C T < 50°C	

Table 1: Temperature standards for ultrasound probes.

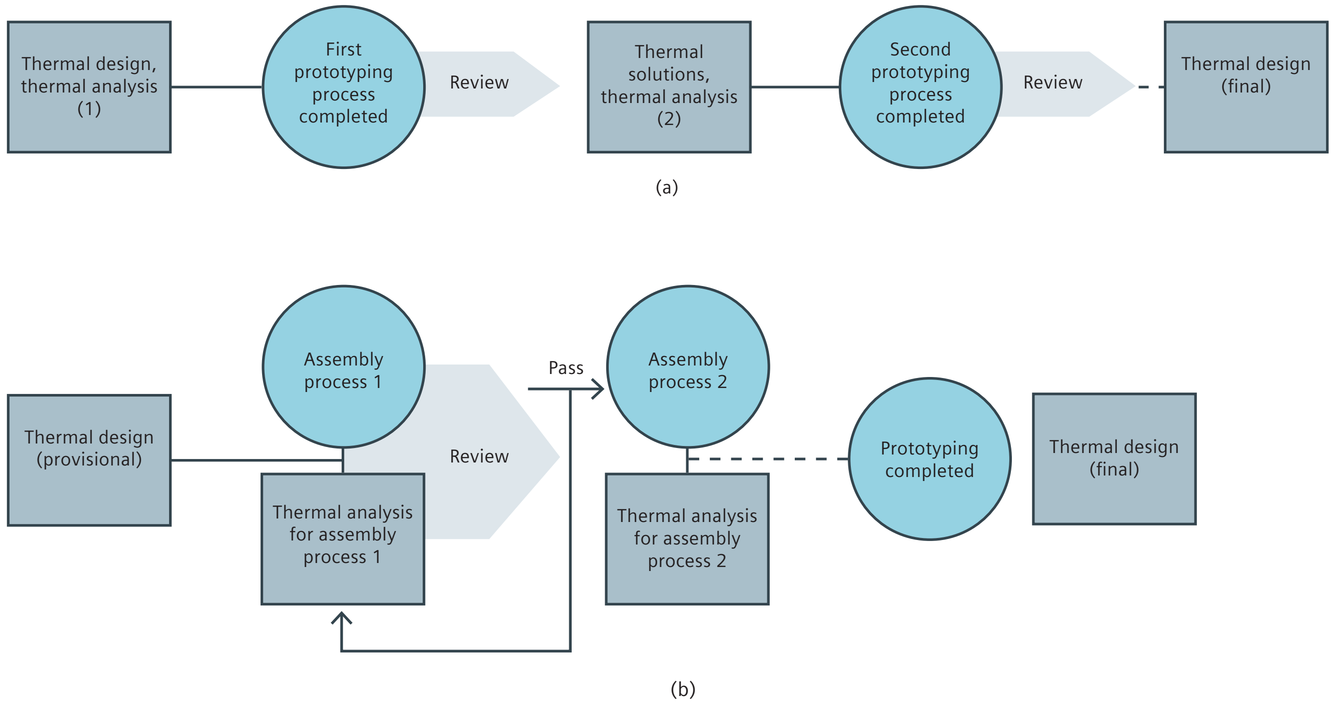


Figure 2: Hitachi CFD simulation workflow before Simcenter Flotherm (a); and today (b).

Manufacturers must comply with existing international safety standards (IEC 60601-2-37) for the thermal limits for ultrasound probes (table 1). These temperature limits must not be exceeded while the equipment is powered continuously for up to 30 minutes to prevent burns. Real-world probe situations such as on/off usage, variations in ambient conditions, and body temperature variations in patients also need to be considered. Predicting transient surface temperature rise, rather than the equilibrium temperature, is a key measure for assessing probes; any computational fluid dynamics (CFD) code must perform a transient thermal simulation correctly. We chose the Simcenter Flotherm software thermal analysis tool from Siemens previously because it was faster at receiving simulation results than our existing tool, easy to mesh, had a good interface with our mechanical computer-aided design (MCAD) software, and it was easy to pass our CFD predictions to our finite element analysis (FEA) tool.

We typically have two to three weeks to influence the design of a probe. Our typical workflow before using Simcenter Flotherm is shown in figure 2 (a). We finalized the product design after several rounds of prototyping, but we found difficulties with the CFD tool we were using at the time, making it difficult to know what the problems were in the final assembled product. Figure 2 (b) shows the process workflow we have iterated to since using Simcenter Flotherm because of its capabilities to shift design to the left and an earlier stage that has allowed us to have significantly fewer prototypes and doubled our cost savings. In this instance, the result achieved after reviewing the thermal analysis predictions versus actual measurements early on, identifying and rectifying problems for each assembly process, and then moving to the next part of the process.

Material	Thermal conductivity [W/mK]	
	Manufacturer catalog value	Measured value
Material A	0.3	0.3
Material B	15	5
Plastic A	0.2	0.2
Adhesive A	0.2	0.2

Material	Emissivity	
	Manufacturer catalog value	Measured value
Material A	0.86	0.96
Material B	0.8	0.15 (gold-plated surface)
Material C	0.9	0.96

Material	Specific heat [J/kg]	
	Manufacturer catalog value	Measured value
Material 1	900	850
Material 2	1,900	1,500
Material 3	1,000	650

Table 2: Ultrasound probe constituent material thermal property measurement results.

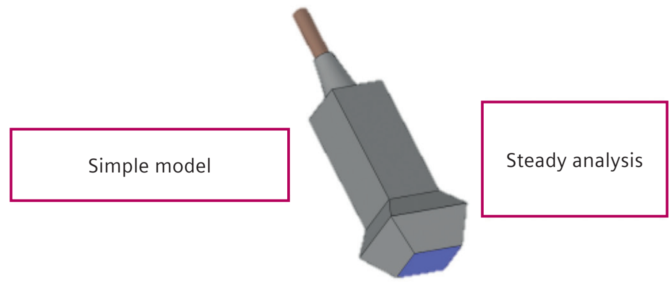


Figure 3: Simple Simcenter Flotherm model geometry of a Hitachi probe.

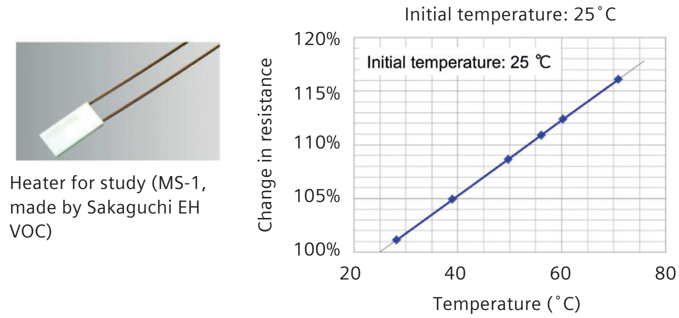


Figure 4: Ceramic heater characteristics.

From a product design perspective, we require a CFD tool that has high analysis precision and low prediction errors. To achieve this, we made sure our probe constituent material properties were correct, such as thermal conductivity, emissivity, specific heat and density. To ensure high precision, we carried out rigorous test measurements on all supplier materials (table 2) and found that certain materials (for example, materials B that was composites) had big variations (in red font) than those shown in manufacturer datasheets.

The next step in the thermal simulation process for improving our transient thermal analysis predictions was simulating a simple probe inside Simcenter Flotherm (figure 3) at steady state. We then performed a more detailed probe model (with each component part accurately modeled), reviewing each process transiently. At this stage, the ceramic heater's temperature dependence should be taken into account via measurement of its resistance at a fixed voltage (figure 4) when the heater was used in the simple mock-up in experiment. These heater temperature characteristics needed to be input into Simcenter Flotherm and controlled to maintain constant power during the simulation process, otherwise the CFD simulation would overestimate or underestimate the actual measurement results. Through these

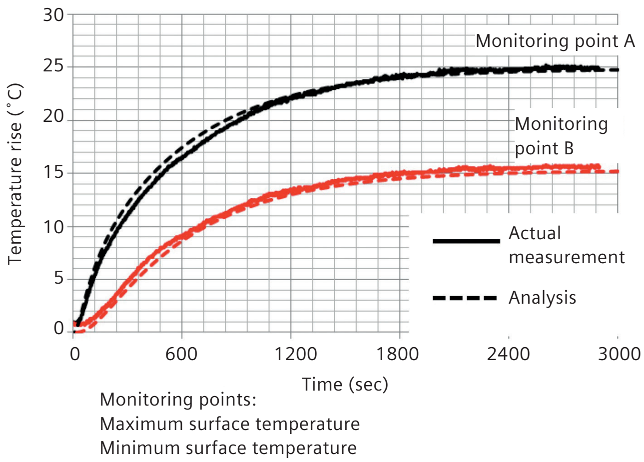


Figure 5: Transient thermal measurements versus Simcenter Flotherm predictions of a simple probe.

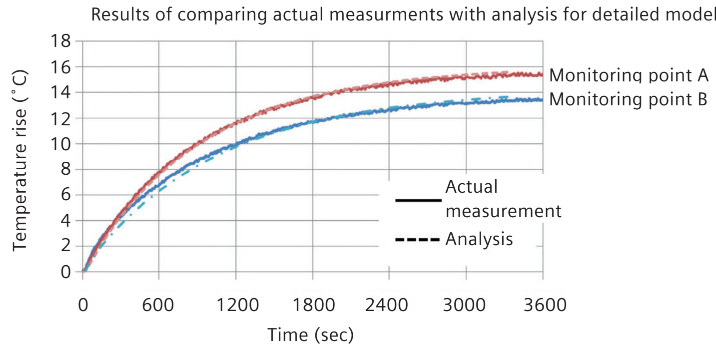


Figure 6: Transient thermal measurements versus Simcenter Flotherm predictions of a detailed model probe.

processes, we found that using Cartesian meshes inside Simcenter Flotherm provided the most accurate CFD predictions (figure 5) for the probe assembly when compared with actual measurements, especially when using measured material properties in the detailed probe model (figure 6). We also used the Simcenter Flotherm command center capability for multiple early design of experiment analysis.

In summary, we found that our simulations are very accurate, 10 times faster than before, and we have a design process that fits our manufacturing needs; we use Simcenter Flotherm 100 percent of the time on our four-core machine. Simcenter Flotherm has helped us invent several patents for our probes.

Siemens Digital Industries Software

Headquarters
Granite Park One
5800 Granite Parkway
Suite 600
Plano, TX 75024
USA
+1 972 987 3000

Americas
Granite Park One
5800 Granite Parkway
Suite 600
Plano, TX 75024
USA
+1 314 264 8499

Europe
Stephenson House
Sir William Siemens Square
Frimley, Camberley
Surrey, GU16 8QD
+44 (0) 1276 413200

Asia-Pacific
Unit 901-902, 9/F
Tower B, Manulife Financial Centre
223-231 Wai Yip Street, Kwun Tong
Kowloon, Hong Kong
+852 2230 3333

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