Using Analysis to Innovate with New Materials

Analysis and optimization tools enable Samsung engineers to reduce the cost of appliances without sacrificing performance.

By Beverly A. Beckert

The Korean-Chinese Suzhou Samsung Electronics Co. joint venture develops and produces major home appliances, including refrigerators and washing machines. The company constantly seeks ways to lead the competition by reducing the volume of material in its products without sacrificing top-rate performance.

The household appliances sector is an exceptionally competitive arena, so appliance manufacturers across the globe place particular emphasis on technical innovation and cost effectiveness when creating designs. While streamlining products and controlling the production process are important factors in cost control, the selection of materials also plays a major role in keeping production costs down.

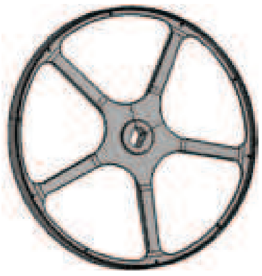
Simulation plays a key role in achieving these objectives at Samsung as it explores lightweighting opportunities and alternative material choices for its commercial product line.

Lightweighting Leads to Optimized Belt Pulley

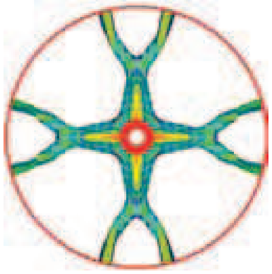
Cheng Fuping, Suzhou Samsung manager, explains that the company optimized the design of a belt pulley for one of its washing machines. The belt pulley connects the motor to the drum and drives the drum during operation.

Conventionally, the belt pulley is constructed from cast aluminum. With cost pressures increasing, Suzhou Samsung was interested in reducing the pulley's weight by optimizing its design and/or using new materials for its production. When considering alternative materials, both their performance and cost become primary factors – so Suzhou Samsung employs topology optimization to meet the challenges relating to design and materials.

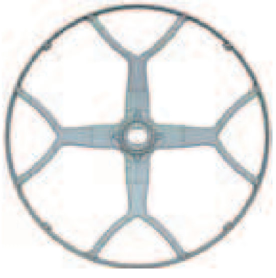
To carry out optimization on the pulley, Suzhou Samsung chose OptiStruct®, a structural analysis and optimization solver and a key component of Altair's HyperWorks® suite of computer-aided engineering (CAE) tools. "OptiStruct provided us with important optimization capabilities," says Cheng, "such as topology, size and shape optimization. We were particularly interested in topology optimization to obtain the most efficient structure or distribution of material used in the structure."



Original five-spoke aluminum belt pulley design



Topology optimization results from Altair OptiStruct



CAD model of optimized four-spoke aluminum-based belt pulley

The optimized four-spoke aluminum belt pulley is now in mass production

"Topology optimization with OptiStruct helped reduce the weight of the structure reasonably and enabled us to find the optimum material distribution without numerous tests, while satisfying mechanical performance requirements"

— Cheng Fuping, Engineering Manager, Suzhou Samsung Electronics Co.

The aluminum pulley that Suzhou Samsung wanted to optimize incorporated five spokes. Engineers sought to find the optimal material distribution or the minimum volume for the spokes area of the pulley.

The topology optimization resulted in the creation of a four-spoke pulley. Further, shape optimization enabled the engineers to determine the optimal divergence angle of the outer edge of the spoke. The reconstructed CAD model reflected a 6% reduction in the total volume of the pulley, compared with the five-spoke version.

Today, the four-spoke aluminum belt pulley has been running smoothly in mass production, and the company has applied for a patent on its redesigned pulley. Continuing to leverage OptiStruct and the HyperWorks CAE suite, Samsung is now exploring the use of alternative materials to further reduce the cost and enhance the performance of the pulley.

Designing for Material Substitution

With a focus on keeping production costs down, Suzhou Samsung considered changing the composition of its refrigerator door covers on certain models. The door itself is composed of an upper and lower door cover, steel panel, interior lining and foam materials. Conventionally, ABS engineering plastic, formed through injection molding, is used to create the upper and lower door covers, which are fitted on the ends of the door and fix the door's position.

Exploring opportunities for cost reduction, the company wanted to use HIPS instead of ABS for the injection-molded covers. Unfortunately, during initial feasibility evaluations, the HIPS covers exhibited cracking during Samsung's temperature cycling testing process.

Engineers sought to verify their physical test results through simulation to virtually explore ways to modify the door cover design for HIPS to eliminate the cracking phenomena.

Zhao Shouzhen, CAE engineer, explains that during the physical reliability testing process, the door is placed in a chamber, where the temperature is initially lowered to a chilling level, then elevated to a high temperature and finally lowered to a chill point again. During the low-temperature cycle of this testing process, the refrigerator's upper and lower door covers made with HIPS material exhibited cracking in the middle of the door cover's top surface, beginning at the front edge of the door cover.

Suzhou Samsung engineers performed an analysis of the material, structure and injection-molding process to look for the cause of the cracking. They knew that the strength and toughness of HIPS is inherently lower to that of ABS, and HIPS has a large thermal expansion coefficient resulting in a large amount of deformation when undergoing drastic temperature change. Clearly, the change in material was one factor contributing to the cracking issue.

Additionally, the door cover's front edges used a flat chamfer (beveled) form for aesthetic reasons, which resulted in a reduction in the strength of the front edge. As for the injection-molding process, the upper door cover underwent three-point injection with the sprue (opening) positioned in the middle. The lower door cover was made with a two-point injection process, producing a weld line in the middle. The result was residual stress near the sprue and weld lines, which also increased the risk of cracking near the middle of the door cover.

Simulation Yields a Solution

To qualitatively and quantitatively analyze the stress on the door cover during thermal expansion and contraction, the engineers used HyperMesh®, a high-performance finite-element pre-processor, and RADIOSS®, a structural analysis and optimization solver, both of which are part of Altair's HyperWorks suite of CAE software. With these tools, engineers developed a computerized simulation of the refrigerator door cover temperature field employing HyperMesh. Shell elements were used to mesh the steel plate and interior lining while solid elements were used for the foaming material.

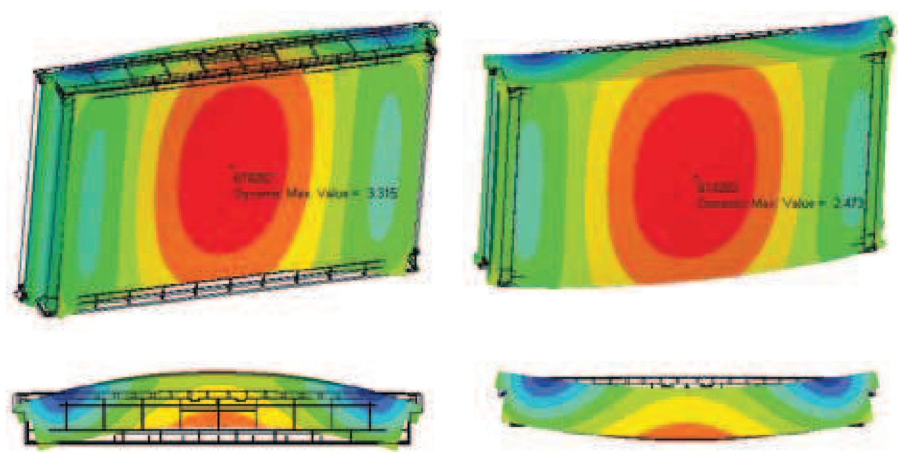
Since the material parameters for each part of the door are measured at room temperature, the simulation was separated into two conditions: a drop from room temperature to low temperature (condition 1), and an increase from room temperature to high temperature (condition 2).

The simulation analysis showed that, under condition 1, the door cover stress and deformation were comparatively large and that the fracture, therefore, stemmed from contraction during the low-temperature cycle, a finding consistent with the experimental results. The maximum stress appeared at the upper and lower door cover middle front edge, a finding also consistent with the actual fracture site.

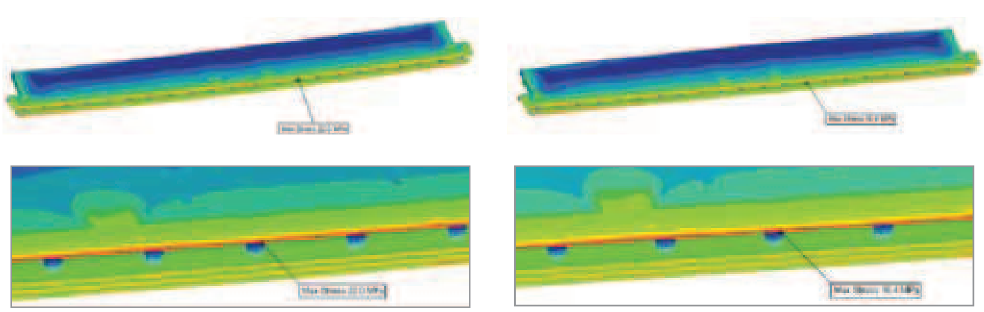
After changing the material from ABS to HIPS, the safety coefficient declined from an initial 2.0 to 1.3 because of the lower stress limit of HIPS. The maximum deformation increased from the original 2.8 mm to 3.3 mm.

With the cumulative stress effects of temperature cycling, the door cover cracked. Engineers next evaluated ways to prevent the cracking, beginning with increasing the thickness of the door cover's top surface and adding stiffeners in the form of vertical and horizontal ribs.

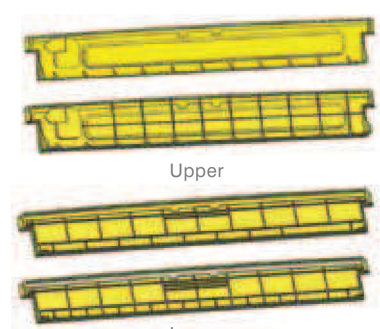
Refrigerator door cover crack failure after temperature cycle



Whole door deformation contours (HIPS) for condition 1 (left) and condition 2 (right)



Upper door cover stress contour for condition 1 (left) and condition 2 (right)



Original and proposed optimization section for the upper cover (top) and the lower cover (bottom)

> *"HyperWorks enhanced our quality and cost competitiveness while strengthening our research and development goals."*
>
> — Zhao Shouzhen, CAE Engineer, Suzhou Samsung Electronics Co.

"We examined two proposals on methods to carry this out and used HyperMesh to analyze each method," says Shouzhen. "The second proposal, which extended the rib length and height suggested in the first plan, proved to increase the door cover safety coefficient to 2.0, which was equal to that of ABS material." Further, the overall deformation of the door body was reduced from 3.3 mm to just 2.3 mm (an improvement over ABS).

Although the weight of the upper and lower covers increased by 27.6 g and 17.5 g respectively, HIPS costs significantly less than ABS; so even with the slightly additional weight (material), HIPS could reduce overall material costs.

Improved Strength with Lower-Cost Materials

Using HyperWorks CAE tools for finite-element analysis, Suzhou Samsung clearly verified the reasons behind the door cover fractures. With solutions derived from the simulation, engineers were able to improve the covers' structural strength while replacing ABS with HIPS material to meet a more cost-effective target.

"This application of HyperWorks tools to analyze temperature fields and enhance the quality and cost competitiveness while strengthening research and development goals is a household-appliance industry success story," says Shouzhen. "HyperWorks was instrumental in enabling us to innovate with new materials to remain competitive while preserving our reputation for high-quality products." C2R

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For more information on OptiStruct, RADIOSS and HyperMesh, visit www.C2Rmagazine.com/2013