Sumitomo Calls on SIMULIA for Answers to Cell Phone Cable Design Challenges

Realistic simulation with Abaqus FEA provides solutions down to the wire

So many people feel they can't live without their cellular telephones these days, but how do cell phones survive all that use – and abuse – from people? These days the devices have to provide ever-greater functionality fitted into an increasingly smaller package. One solution has been to add a flip/twist or sliding panel that opens up to provide more surface area. Yet the laws of physics are constant: electricity can only travel along an unbroken path. This means that the wires keeping everything inside a cell phone running smoothly have to stay intact no matter what.

The solution? Coaxial cables. Made up of hundreds of bundled fine wires, and of less than 0.3 mm in diameter, they are highly compact and particularly well suited to use inside cell phones because a protective layer around each signal wire shields it from electromagnetic noise. The individual wires within a coaxial cable, each measuring just dozens of microns in diameter, stand up well against all the bending and twisting of a typical cell phone panel – at least for a while.

Although coaxial cables are made to withstand tens of thousands of opening/closing cycles, the recent trend towards even thinner products has limited cable routing options, and increased the loads on the cables themselves. So, as specialists in electronic wire products, engineers at Sumitomo Electric Industries saw a further need to enhance cell phone cable durability and decrease wire breakage from fatigue.

"Cell phone product design must include an evaluation of the lifetime of the phone's cables," says Shigeki Shimada, a member of the team at the Analysis Technology Research Center at Sumitomo. "Since the optimum layout of the cables ensures that their lifetime exceeds that of the product, we need this information at the earliest design stages."

In the past, the Sumitomo team evaluated cable lifetime using fatigue test equipment that physically stressed the wires over long periods of time. But the highly competitive electronics industry is demanding ever-shorter design cycles, while advances in cell phone durability are producing longer-lasting, more complex phones whose cables must stay functional for the duration.

Computer-aided engineering solutions from SIMULIA, the Dassault Systèmes brand for realistic simulation, provided Sumitomo with a strong response to these pressures: Using Abaqus Unified Finite Element Analysis (FEA) software, the group created computer models to simulate the behavior of everything from a single wire to a full bundle of coaxial cables. The models provided an inside view of many of the stresses and strains arising in the dynamic environment of a cell phone body. The results of their analyses provided engineers with a cause-and-effect vocabulary with which to examine design and material modifications resulting in improved performance.

The Sumitomo research group started with FEA models of a single cylinder-shaped wire rod, similar to an electrical cable (Figure 2). Simulating the response of the model to deformation caused by extension, bending and twisting (using Abaqus/Explicit for a quasi-static analysis), they measured the number of virtual wire breakages. These results helped them quantify the relationship between strain amplitude and lifetime.

Moving up to more complex FEA models of a coaxial cable with detailed internal structures (Figure 3), the Sumitomo engineers researched the relationship between the wires and the insulating layer under different degrees of strain and deformation. They used elastic material

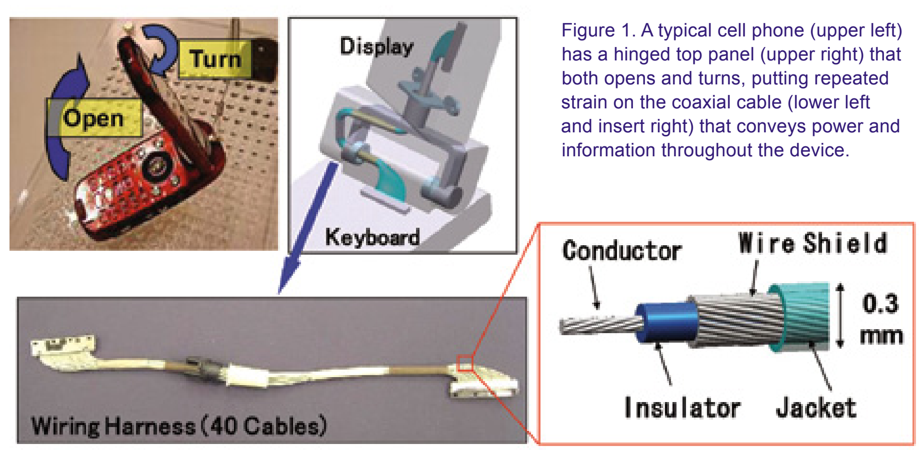

Figure 1. A typical cell phone (upper left) has a hinged top panel (upper right) that both opens and turns, putting repeated strain on the coaxial cable (lower left and insert right) that conveys power and information throughout the device.

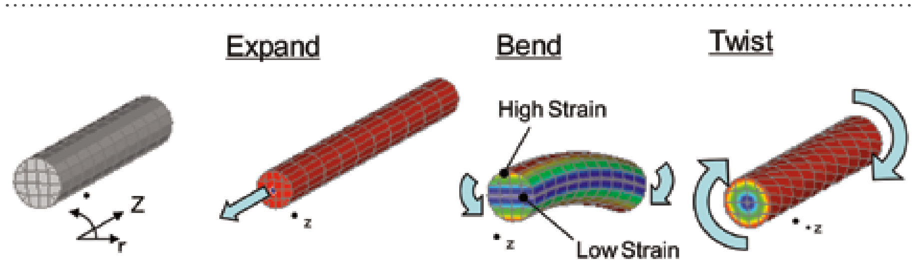

Figure 2. Deformation modes and main states of stress in a wire rod in Abaqus FEA.

models for the copper alloy of the wires composing the conductor and shield, and the Teflon resin of the insulating layers; the more than 100,000-cycle lifetime needed for the wires required a small strain (below 1%), meaning plasticity could be neglected. Combining these results with the data from the first models imparted deeper insight into the lifetime of an entire cable under fatigue tests that included left/right bending and other deformations. Real-world fatigue testing plus measurements of actual cable behavior validated the FEA predictions.

Finally, in order to look at the behavior of coaxial cables in the context of their actual layout inside a cell phone, the group modeled the cable and its insulation jacket as a macro beam with specific tensile, bending and torsional stiffness, and calculated the deformation at specific points in time at each area during the simulated movement of the cable. They next modeled the wall and cable bundle in the vicinity of the hinge – where the majority of problems occur in actual cable layouts of cell phones.

Simulating the behavior of the cable during opening/closing cycles that included a 180-degree rotation, they compared their Abaqus FEA results with X-ray images of actual cable cycles under fatigue testing (Figure 4). "We can now make qualitative evaluations of the lifetime of an actual layout of electrical cables," said Ken Manabe, another member of the research team. "In the future we plan to work on modeling kink-initiated breakages as well as cable breaks caused by wear."

With the lifetime evaluation methodology they developed using Abaqus Unified FEA, the engineers could then turn to even more complex design challenges, such as the effects of cable layout on lifetime in the newest thin, slide-type cell phones. They discovered that the sliding action of the phone caused the cables to meander both sideways and axially, extremely shortening lifetime. The design solution was a protective tape sheath that kept loose cables aligned together (Figure 5), but did not restrain their flexibility as the phone slide moved.

"Our CAE expertise is now helping us develop applications for similar types of cables, such as those used in robots," says Shimada. "As demands for cable performance become more diverse and rigorous, realistic simulation will help us develop responses to the various design challenges that arise."

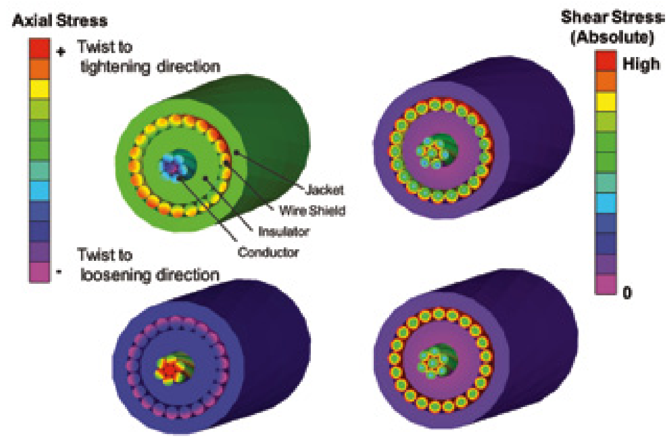

Figure 3. Distribution of axial and shear stress in full cable model under twisting (18 degrees/mm).

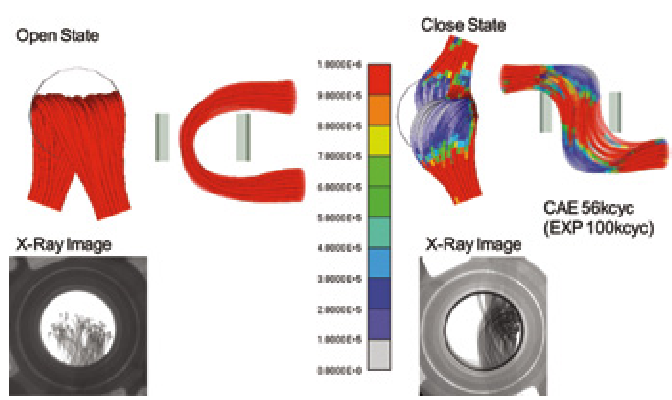

Figure 4. Results of lifetime evaluation and X-ray image of opening/closing cycle.

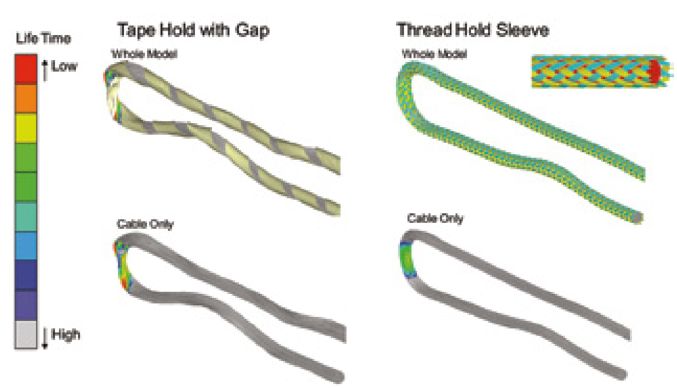

Figure 5. Design evolution of the cell-phone slide motion harness: Previous iterations of protective tape used an overlapping tape hold (not shown) that stacked the co-axial cables, increasing strain and shortening lifespan. The first improvement (left, top and bottom) was to change the way the tape was wound, opening a gap to release the cables. But cables could flow out the gap so lifespan did not increase much. Next, thread hold protection was tested (right, top and bottom). The friction of the threads is low enough not to stack the cables and the gap is too small for the cables to flow out. CAE and experimental testing confirmed that a long cable lifetime resulted from this design.

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