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info@ozeninc.com
(408) 732 4665
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AUTOMOTIVE

SEALING IN PROGRESS

Daikin's expertise in polymers helps to improve battery gasket designs for safer, longer-lasting automotive Li-ion batteries.

By Jihong Liu, Environmental Technology Laboratory, Daikin Industries, Ltd., Osaka, Japan

While Daikin Industries, Ltd. is best known as the world's leading manufacturer of air conditioners and refrigerators, it has also been a pioneer in the field of fluorochemicals, with a focus on products including fluoroelastomers, fluoropolymers and fluorocarbons. Leveraging its expertise in this field is leading to new markets for its products. Fluoropolymers, for example, are replacing rubber as the compound of choice for gaskets around electrodes of Li-ion batteries used in the

ANSYS software not only helped analyze the performance of gaskets, it is helping to design a better gasket.

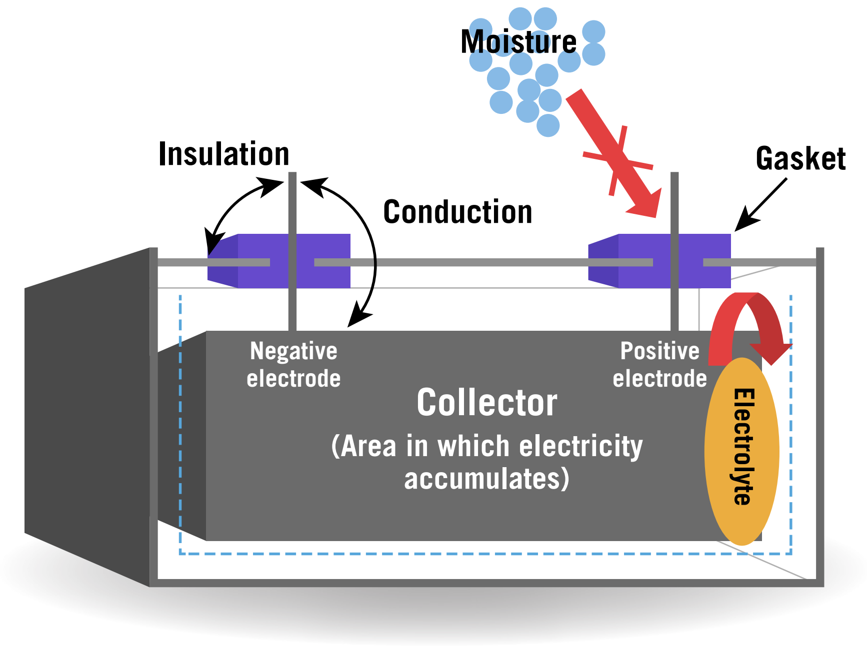
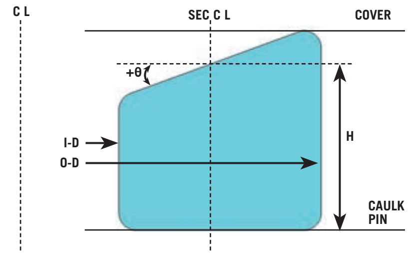
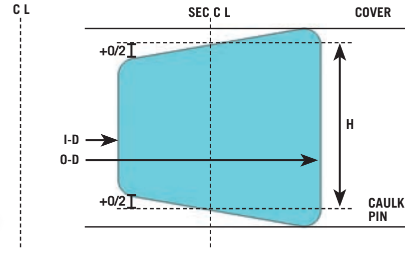


Diagram of Li-ion battery showing gaskets



Cross-sectional shape of circular gasket with axial symmetry when upper section is tilted in relation to horizontal plane



Cross-sectional shape of circular gasket with axial symmetry when both upper and lower sections are tilted in relation to horizontal plane

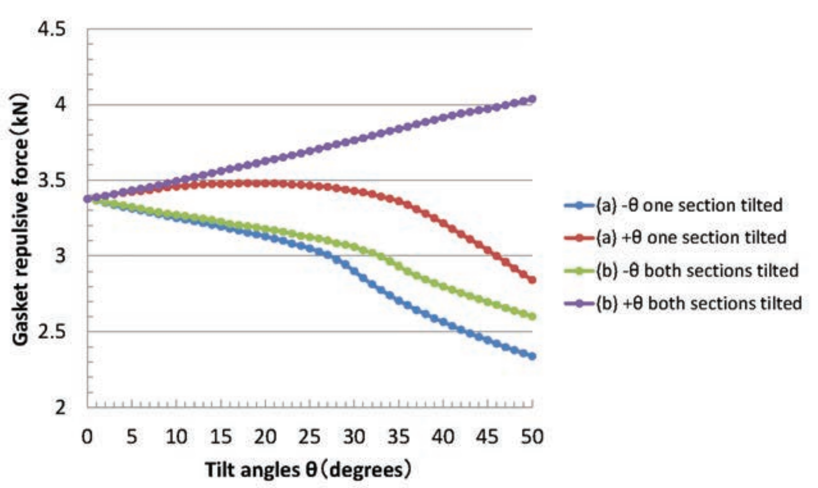
next generation of energy-efficient electric vehicles.

As the market for fluoropolymer gaskets increases in the automotive industry, the need to evaluate and improve seal performance has become an important issue for Daikin engineers. ANSYS software not only helped them analyze the performance of gaskets made from their NEOFLON™ PFA compound, it is helping them design a better gasket.

PERFORMANCE REQUIREMENTS FOR AUTOMOTIVE Li-ION BATTERY GASKETS

Gaskets used in Li-ion batteries act as seals to prevent electrolyte from leaking out and moisture in the air from infiltrating the battery. The gaskets also provide electrical insulation to prevent the positive and negative electrodes from making contact and causing short circuits. To ensure the safety and life-span of the batteries, sealing and insulation functions of automotive Li-ion battery gaskets must be guaranteed for 15 years or more. Battery gaskets must also possess restoring force to maintain the shape of the seal under adverse conditions, such as high temperatures and long-term stress, which can cause creep deformation. When a gasket is compressed, the restoring force that results creates a tight seal between the gasket and the metal surface. To achieve this, automotive Li-ion battery gaskets are designed with cross-sectional shapes to ensure that the overall thickness of the gasket is uniform over time.

Battery gaskets have traditionally been made of rubber. For many years, it was not considered possible to produce the gaskets from other polymers. Fluoropolymers like NEOFLON PFA, however, possess excellent electrolyte resistance, electrical insulation and climate resistance in addition to low moisture permeability. The material wedges into the concavities on metal surfaces, and can form a seal, even on rough surfaces, without the use of treatment agents or adhesives. Even at low temperatures (–40 C) or when exposed to long-term high temperatures (60 C), PFA retains its restoring force and maintains its seal performance. In addition, the amount of swelling of PFA in response to electrolyte contact is less than one-tenth that of rubber.



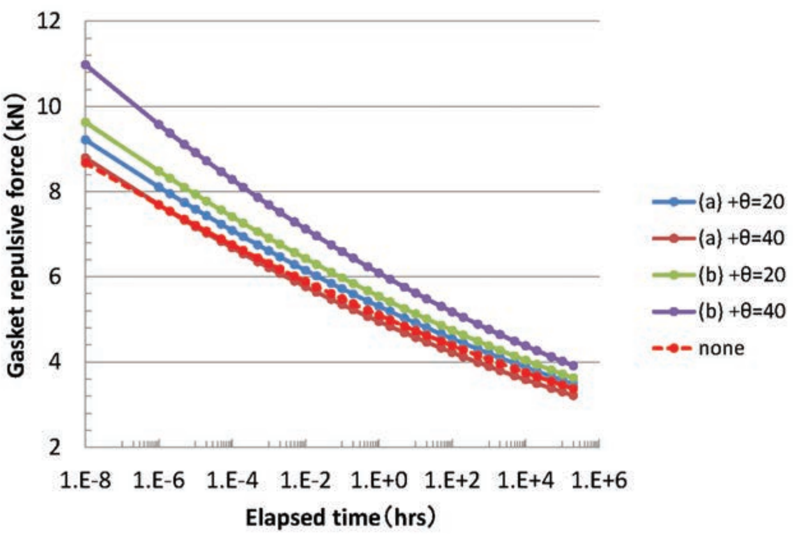
Changes in gasket repulsive force after 200,000 hours with one or two sections tilted and different tilt angles

SIMULATING GASKET PERFORMANCE

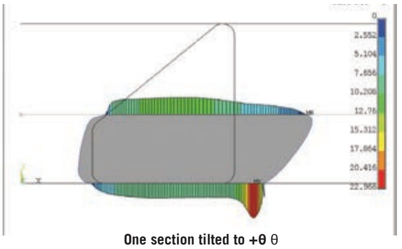
Conventionally, gaskets are used with an angle of tilt (θ) of 0 degrees, so there is no tilt and the thickness of the cross section is uniform. Because of the time typically necessary to create and test physical prototypes, little research had been done on the effects of changing the tilt of the gasket, and the limits of physical testing meant that engineers had to rely on trial-and-error methods to improve their designs. Daikin engineers hypothesized that they could use computer simulation to obtain a better understanding of the effects of age-related change, and to learn how changing the shape and tilt of their gaskets could improve efficiency and life expectancy of PFA gaskets.

To simulate the elastoplasticity and creep characteristics of PFA, Daikin engineers turned to ANSYS structural mechanics solutions to simulate the repulsive force produced by pressing an automotive Li-ion battery gasket into place in an extremely high-temperature environment (60 C, or 140 F). The gasket, caulk pin and cover are symmetrical around the axis, and the upper section (or the upper and lower sections together) are tilted in relation to the horizontal plane. The seal was simulated by pressing the caulk pin against the lower section of the gasket and the cover against the upper section of the gasket. Seal performance improves in proportion to the magnitude of the repulsive force against the seal.

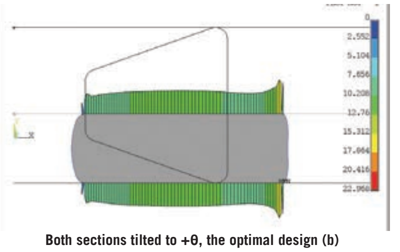
Daikin reduced the evaluation time from two months to only half a day.



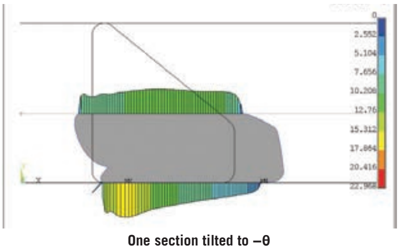
▲ Age-related change in gasket repulsive forces



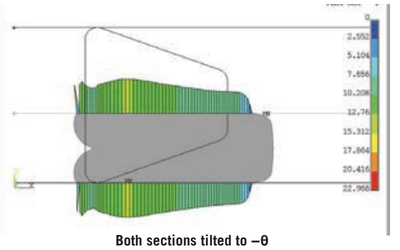
One section tilted to +θ θ



Both sections tilted to +θ, the optimal design (b)



One section tilted to –θ



Both sections tilted to –θ

▲ Distribution of seal surface pressure after 200,000 hours for gasket with tilt angle (θ) of 40 degrees

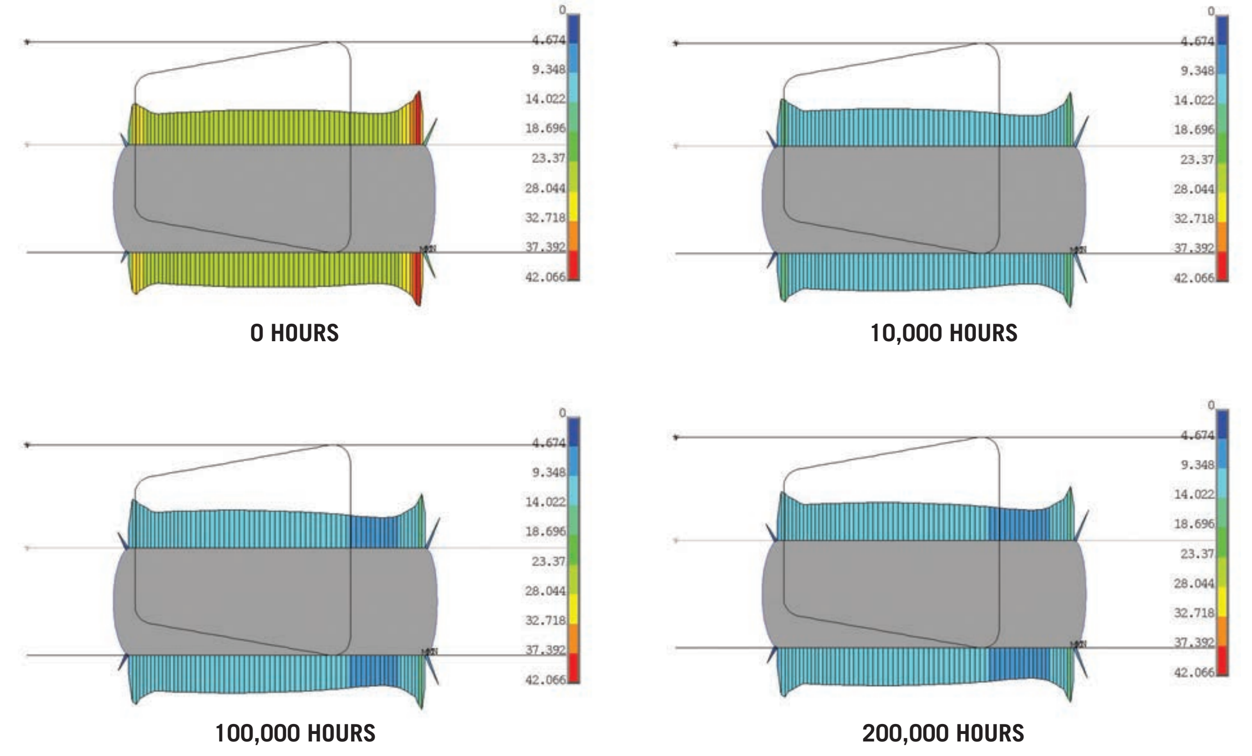
Daikin engineers modeled the material properties of PFA with a multilinear isotropic-hardening elastic–plastic model based on von Mises yield criteria; then they applied a modified time-hardening model to simulate creep characteristics after 200,000 hours at 60 C. They then virtually tested various cross-sectional gasket designs at different tilt angles and determined the repulsive force for each gasket design and tilt angle. They found that a gasket turned outward, and that an increased tilt angle for both sections of the gasket produced a higher repulsive force — and therefore a better seal — than the conventional shape with no tilt.

The team further analyzed the effects of time on the various tilt angles and confirmed that the optimal design was a gasket with both sections tilted to +θ because it maintained the strongest repulsive force over time. The simulations also indicated that other improvements could be made to the gaskets to prevent creep and increase repulsive force.

Using the information gained through ANSYS simulations, Daikin engineers developed a patent-pending cross-sectional design — a design that they had previously not even considered — that improved seal performance by 20 percent over the life of the gasket. They reduced the evaluation time from the two months it would require to manufacture and test physical models to only half a day.

By continuing to simulate new gasket designs, as well as other innovations in their fluoropolymer products, Daikin is positioning itself to expand its reach into new markets.

Daikin Industries is supported by ANSYS elite channel partner Cybernet Systems Co. Ltd.



▲ Change over time in distribution of seal surface pressure for gasket (b) with tilt angle +θ of 40 degrees