XYTRON™ G4080HR:

MEETING THE CHALLENGES OF THERMAL MANAGEMENT IN ELECTRIC VEHICLES

Xytron™

Introduction

As electrification of vehicles continues to gain momentum, there is an increased need for engineering plastic materials for thermal management systems (TMS). TMS are designed to keep the ambient temperature around a component within a specified range, optimizing its operating conditions to extend its service life and reduce energy consumption. Hybrid cars and fully electric vehicles bring new challenges to TMS, yet the right materials can help automobile makers to stay ahead of the competition in terms of design cycles, versatility of components, and total costs.

The main challenges for TMS materials used in increasingly electric vehicles are exposure temperature and exposure time. In a fully electric vehicle, the operating temperature of the TMS is lower than it would be in an internal combustion–powered vehicle, yet the runtime is twice as long. Since fully electric vehicles cannot have the battery temperature fall below freezing, vehicles operating at high latitudes will need the TMS to warm the batteries in the winter when the vehicle stops. This exposes the TMS to double the maximum exposure time to water-resistant glycol coolant. For fuel-driven vehicles, the TMS needs to be able to withstand 1,000 to 3,000 hours of coolant exposure. For fully electric vehicles, the material needs to withstand exposure for 6,000 to 10,000 hours. After such lengthy thermal aging periods, the performance of many materials will drop dramatically.

Hybrid vehicles combine a gas engine, newly fitted drive motor, and electronic control system. The compact layout and higher local temperature due to poor heat dissipation mean that the TMS needs to work at higher temperatures, and under higher pressures. OEMs are paying close attention to thermal aging resistance at temperatures of 135°C to 150°C. Most materials are severely challenged to perform after heat aging at these temperatures.

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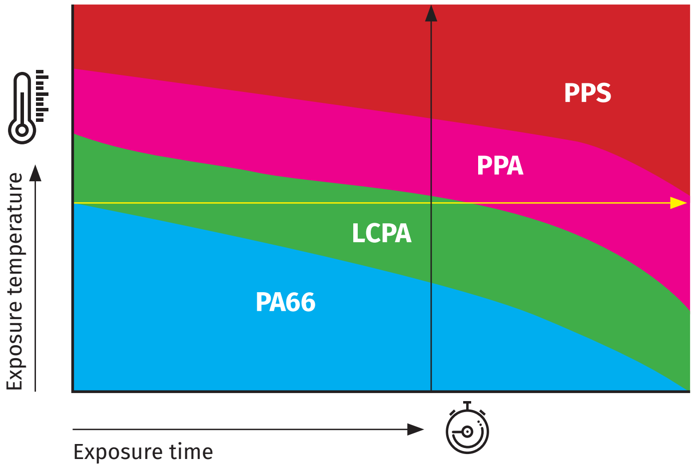
Material performance at elevated temperatures for long exposures

The main engineering plastics used in TMS are polyamide 66 (PA66), long chain polyamides (LCPA), polyphthalamide (PPA) and polyphenylene sulphide (PPS). The chart below shows the performance of these materials at various temperatures and exposure times. The purple line demonstrates that, as the exposure temperature increases, some materials are no longer suitable for the application. Once the temperature exceeds 130°C, PPS and PPA are differentiated by their thermal stability. The yellow line shows that as the exposure time increases, materials that may be able to take the heat during low exposure times are unable to withstand longer exposure times. PPS shows the lowest mechanical degradation at high temperatures for long exposure periods, followed by PPA, LCPA, and PA66.

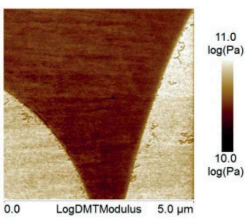
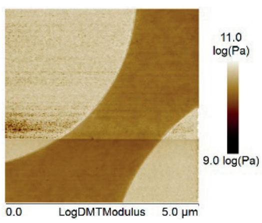
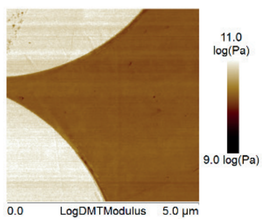
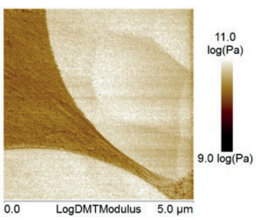
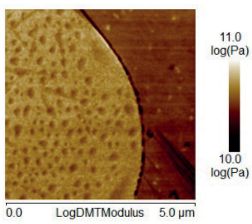
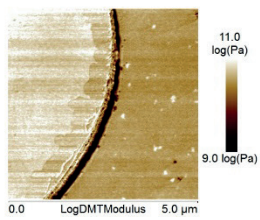


Understanding the differences in aging resistance performance

The heat aging performance of different materials is primarily dependent on the hydrolysis resistance of the resins that make up the material. TMS are exposed to coolant, which is a mixture of water and glycol. At high temperatures, water can cause severe damage to many materials due to hydrolysis. This means that the stronger a material's resistance to hydrolysis, the better it will perform in TMS applications. Since PPA, LCPA, and PA66 belong to the polyamide family, they all demonstrate insufficient resistance to hydrolysis in the polyamide amino bond. PPA has the highest hydrolysis resistance in this family, which can be further improved with modification. PPS, on the other hand, has an intrinsically different molecular structure from polyamides. Its simple but stable molecular structure is based on thioether bonds and benzene rings, enabling it to withstand concentrated sulphuric acid and, consequently, makes it highly resistant to hydrolysis. Since long-term performance under complex working conditions is crucial for electric vehicles, PPS and PPA are the recommended materials in the design of key TMS components.

Physical aging of PPS

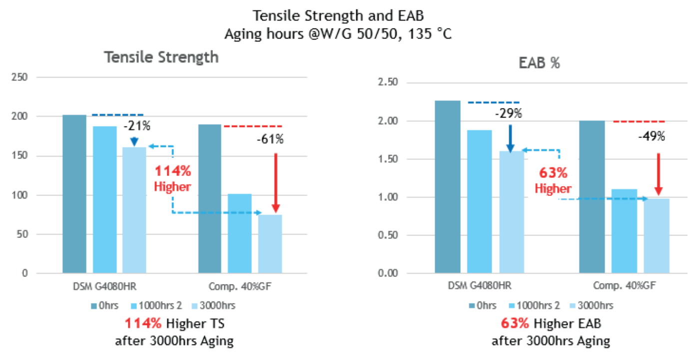
The engineering plastics used in TMS are made from a combination of resins and glass fibers. The bonding interface between the glass fiber and resin is prone to cracking when exposed to water, directly affecting the anti-aging performance of different PPS materials. DSM's Xytron material uses a unique technology to create a very strong bond between the glass fibers and PPS resin, significantly slowing the aging of the material. The chart below shows changes in the bonding interface between glass fibers and PPS resin – viewed under an atomic force microscope before and after thermal aging with water-glycol fluid at 135°C.

	0 hours	**1000 hours**	**3000 hours**
DSM 40%GF PPS G4080HR			
Competition 40%GF PPS			

The materials selected for this test were all PPS reinforced with 40% glass fiber, yet the differences in the bonding interfaces after aging are obvious. We used atomic force microscopy to visualize the differences at the micro-level. The white areas in each image represent glass fibers, the yellow areas are the PPS resin, and the black areas are the width of the bonding interface. Prior to aging, the bonding interfaces of the two materials show virtually no black areas, indicating that the interface is both smooth and seamless. Heat aging over long exposure causes the black area to increase in width at the bonding interface of the competitive material (second line), demonstrating that a deep crack has formed on the bonding interface. The bonding interface of Xytron G4080HR shows only a thin line after 3,000 hours of aging at 135°C, demonstrating a very strong bond between the resin and glass fibers. With increased aging time or challenging driving conditions, the microscopic cracks will extend until the part eventually cracks or breaks, causing the leaks with which car owners are all too familiar.

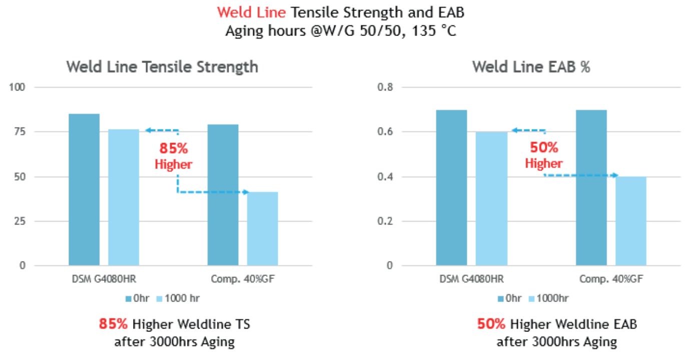
DSM launched Xytron G4080HR for commercial use in the automotive industry. The material's strong bonding interface technology provides excellent long-term hydrolysis resistance, helping DSM's customers meet the challenges brought about by the changing needs in TMS applications.

This innovation doesn't only affect the material's aging. The charts below show the tensile strength and elongation at break (EAB) of Xytron G4080HR and a competitive material. After 3,000 hours of aging in water-glycol fluid at 135°C, the Xytron material's tensile strength decreased by 21% vs. the 61% decrease seen in the competitive material. This results in Xytron having a tensile strength 114% higher than the competition. The Xytron material's EAB decreased by 29% vs. 49% from the competitive material. This results in an EAB that is 63% higher than the competition after aging.



Xytron G4080HR's bonding interface technology also improves tensile strength and EAB at weld lines. Widely regarded as the weakest links in the structure of a part, weld lines inevitably appear on TMS parts during injection molding. The weld lines' tensile strength also determines the strength of the entire part, and therefore the part thickness required to meet the application's requirements.

The charts below show the aging resistance of different materials with specially prepared weld lines. After 1,000 hours of aging at 135°C, the measured weld line tensile strength is maintained at 75MPa, 85% higher than the competition. The weld line EAB remains at 0.6%, 50% higher than the competitive material. This data demonstrates that the mechanical properties of Xytron G4080HR at the weld line can also withstand rigorous testing.



The industry is also looking at improving the long-term reliability of cooling systems for the new generation of electric vehicles, potentially by upgrading the coolant. The aging resistance of materials exposed to different coolants is a third, and important, factor in selecting a material for TMS. PPS materials – particularly Xytron G4080HR – can minimize a company's need to alter designs because of coolant changes, since they are resistant to strong corrosives like sulphuric acid.

Conclusion

DSM's Xytron G4080HR facilitates more flexibility in designing lighter TMS components with thinner walls that enable them to cut costs. The material enables designers to more easily predict the long-term performance of the final component due to is superior aging resistance and weld line strength retention. As with all of our material sales, Xytron G4080HR is backed by a wealth of experimental data gathered via extensive testing in various mediums at different temperatures and for different periods of time. This includes authoritative data from third-party certification bodies in Germany, which is instrumental in helping customers effectively predict the long-term performance and service life of components.

As OEMs and TMS component suppliers face a complex competitive environment and increasingly demanding technical requirements, testing new part designs for aging performance in various working conditions is both labor intensive and time consuming. Adopting a more stable and reliable material solution can reduce the risks associated with new designs to accelerate product development. Xytron G4080HR offers better long-term performance in the most demanding conditions. This provides the freedom to optimize the design while reducing the overall cost and weight of the component – ultimately enabling OEMs to place reliable TMS components into a wide range of vehicle models.