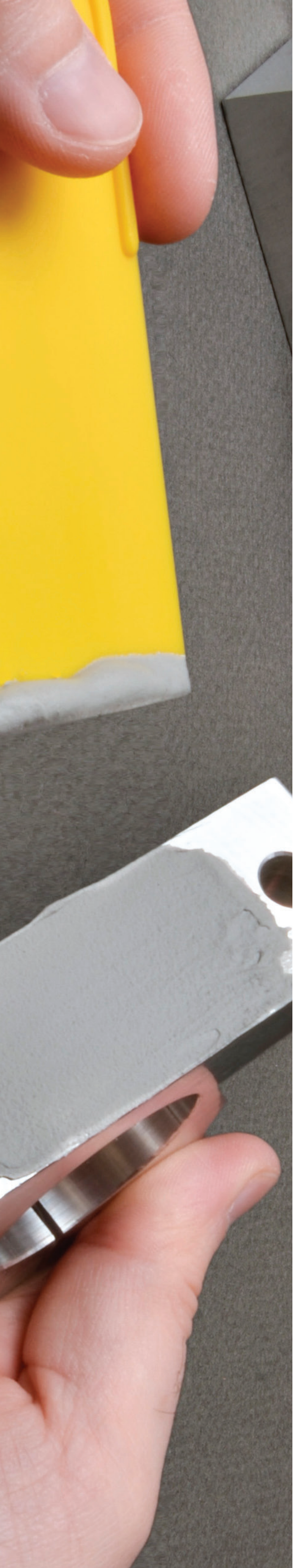

MASTERBOND®

CASE STUDY

Supreme 10HT: Utilized in structural bonding for supersonic aircraft, electronics packaging and capacitor tanks

Master Bond Inc. 154 Hobart Street, Hackensack, NJ 07601 USA
Phone +1.201.343.8983 | Fax +1.201.343.2132 | main@masterbond.com

Supreme 10HT:
Utilized in structural bonding for supersonic aircraft, electronics packaging and capacitor tanks

Because of its outstanding strength and other physical properties, Master Bond Supreme 10HT has been selected for use in several published research studies. Following are summaries of how Supreme 10HT performed in demanding applications.

Control electronics packaging

Application

Electronic control components, which perform logical and signal conditioning functions, are complex devices characterized by large die areas and a large number of small contact pads. Control modules that operate at high temperatures (>175°C) for extended periods of time, such as the Engine Control Units (ECUs) that optimize the performance of automobile engines, present unique design challenges for packaging engineers. Materials used in the fabrication of reliable low temperature control electronics degrade rapidly at high temperatures. Thermal mismatches between traditional organic printed circuit boards and semiconductor dies produce high thermomechanical strains when subjected to extreme temperature swings, leading to premature failure. To ensure the reliability of high temperature control electronics, appropriate packaging materials must be selected.

Key Parameters and Requirements

A study conducted at L'École Polytechnique Fédérale de Lausanne (EPFL) in Lausanne, Switzerland, investigated alternative materials for use in high temperature control electronics packaging.[4] Among the materials tested by the research team were adhesives used for die-to-substrate assembly. The substrate was constructed using low-temperature co-fired ceramic (LTCC) technology, which is stable at temperatures above 200°C, and the underside of the die consisted of bare silicon. Requirements for the die-to-substrate bond included reasonable bond strength and a suitable path for thermal dissipation.

Results

Master Bond Supreme 10HT was one of the adhesives tested in the study. Several test vehicle samples were manufactured for use in high temperature storage and temperature cycling shear tests. Each sample was constructed by dispensing the Supreme 10HT epoxy through a syringe onto the underside of five blank silicon dies, which were then placed onto a test substrate using a component placer. The adhesive bonds were cured for 90 minutes at 120°C (248°F) to complete each sample. One die from each sample was sheared using a shear tester prior to subjecting the samples to heat.

High-temperature tests

Five samples were subjected to 210°C (410°F) temperatures in a process oven. All samples were removed after 24 hours, and one die from each sample was shear tested. The process of heating, removing, and shearing the samples was repeated for intervals of 250 and 1000 hours. Results showed that the strength of the Supreme 10HT samples increased progressively after 24 hours and again after 250 hours. Although the strength of the bond decreased after 1000 hours of heat exposure, it still exceeded the minimum 2.4 Kg force threshold stipulated by MIL-STD-883H method 2019.8.

Temperature cycling tests

An additional five samples were subjected to repeated temperature cycling between 20°C and 180°C. Shear tests were performed on one die from each sample after both 10 and 100 cycles. The Supreme 10HT samples showed no measurable degradation in bond strength after either 10 or 100 cycles, even under a maximum strain of 200µm.

Capacitor Tanks

Application

Capacitor tanks are commonly used in electrical power distribution systems to help maintain consistent line voltage levels. A capacitor tank consists of a metal casing that houses one or more capacitor windings and is filled with a dielectric fluid. The capacitor windings, which include a pair of metal foil electrodes separated by a layer of polypropylene film, are connected via taps to leads that pass through capacitor bushings and terminal caps to exit the capacitor body. The non-metallic capacitor bushings isolate electrical leads from each other and from the metal housing of the capacitor. The bushings also isolate the internal contents of the capacitor from the external environment and prevent the dielectric fluid from seeping out.

Key Parameters and Requirements

To ensure that the bushings provide the appropriate isolation and protection, they must be properly joined and sealed to both the terminal caps (upper end of bushing) and the capacitor tank cover (lower end of bushing). Capacitor bushings are made of an insulating material such as ceramic, glass, glazed material, epoxy, or other polymer. Durable metals, such as stainless steel, are used to fabricate capacitor tank covers, while other metallic materials, such as brass plated with tin, are used to construct terminal caps. The joints between these non-metallic bushings and the metallic components (tank cover and terminal caps) must meet performance, manufacturing, and cost requirements.

Because capacitor tanks are commonly found at the top of utility poles and in electrical substations throughout the world, they are exposed to a myriad of environmental conditions. The sealed joints between the capacitor bushings and the metallic components must be able to withstand a variety of environmental conditions such as high temperatures, substantial temperature fluctuations, prolonged exposure to sunlight, and exposure to wind, rain, snow, and ice. Furthermore, these joints must be capable of maintaining such high performance over a period of approximately 30 years.

Results

Researchers at Cooper Technologies Company in Houston, Texas, ran performance tests on over a dozen commercially available epoxy resin products in an effort to identify compositions that may be used to seal capacitor tanks.[3] First, the lap shear strength was determined for each product, both at a high temperature (75°C–90°C) and at room temperature (25°C). With a lap shear strength of 3782 psi at high temperature and 3006.92 psi at room temperature, Master Bond Supreme 10HT epoxy was cited as one of only four products that exhibited sufficient strength for the application.

The researchers also assessed the compatibility of Supreme 10HT epoxy with dielectric fluid. The team exposed cured seals to the commercially available aromatic dielectric fluid, Edisol VI, via a test apparatus, heating the test apparatus to 75°C for two weeks. They measured several properties of the dielectric fluid, including breakdown voltage, dissipation factor, DC current leakage, surface tension, acidity, and visual appearance, both before and after the heating period. Results indicated that the Supreme 10HT seals did not adversely impact the dielectric. In fact, the dielectric properties measured before the two-week heating process met typical target values and changed very little after the heating process.

The researchers concluded that Master Bond Supreme 10HT is capable of providing a seal between metallic and non-metallic components of a capacitor tank that can withstand the extreme stresses and environmental conditions required.

Mixed adhesive joint for supersonic aircraft

Application

Supersonic aircrafts are subjected to temperatures as low as -55°C when traveling at subsonic speeds at high altitudes and temperatures of approximately 200°C when traveling at or above Mach 2. Adhesive joints on these aircraft must be able to maintain performance levels throughout this broad temperature range. Adhesives designed for low-temperature applications typically lose some of their strength at high temperatures and may even degrade, while adhesives designed for high-temperature applications are generally brittle and may fail at low temperatures. A research team from the University of Porto (Portugal) and the University of Bristol (UK) set out to investigate the possibility of designing a mixed-adhesive joint consisting of both a low-temperature adhesive and a high-temperature adhesive that would support the required load across the entire temperature range.[1]

Key Parameters and Requirements

For a mixed-adhesive joint to succeed in this application, both the low-temperature adhesive and the high-temperature adhesive must exhibit the required strength within its intended application range and must not degrade at temperatures outside this range (refer to Figure 1). If an adhesive fails outside its intended application range, it will no longer be able to sustain any load within its application range.

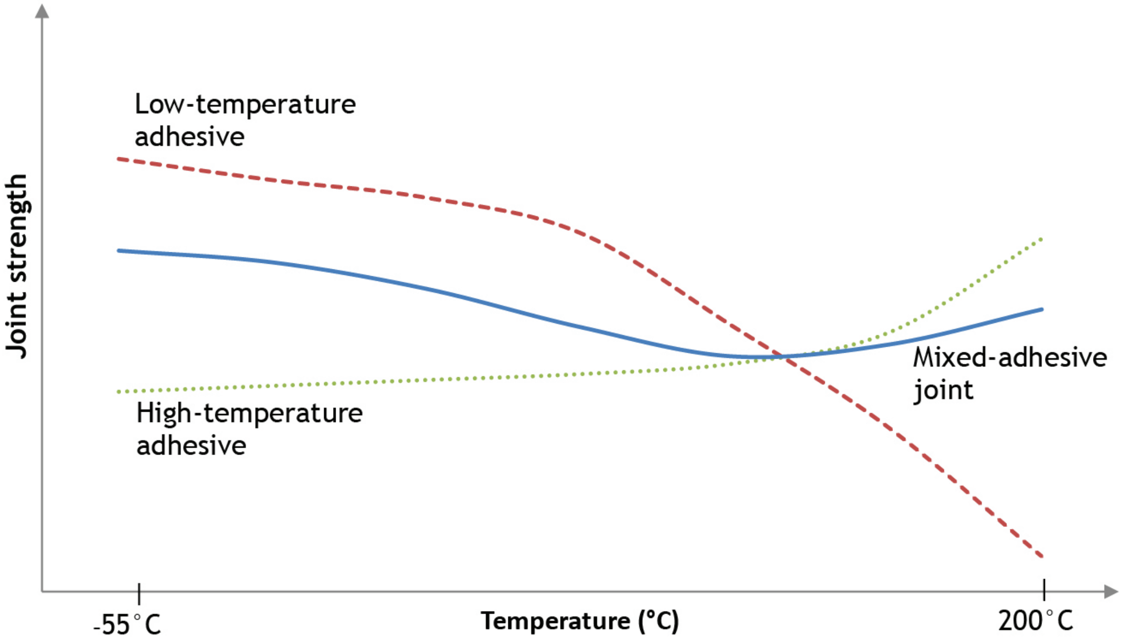

Figure 1: Mixed-adhesive joint concept.

The goal of the research study was to measure the mechanical properties of select adhesives across the entire operating temperature range (-55°C to 200°C) and assess whether a combination of low-temperature and high-temperature adhesives would be able to successfully support the supersonic aircraft application.

Master Bond Supreme 10HT was one of two low-temperature adhesives selected for the study, in addition to a high-temperature bismaleimide adhesive with a glass transition temperature (Tg) of 280°C. The researchers stipulated that the low-temperature adhesive should be ductile, stiff, and strong from -55°C to 100°C or higher in order to support the load throughout this temperature range. Additionally, the low-temperature adhesive should not degrade at temperatures above 100°C, where the high-temperature adhesive carries the load.

Results

The research team conducted tests to measure the mechanical properties in tension and shear of all three adhesives across the operating range of -55°C to 200°C. Stiffness, strength, and ductility tests were performed for four specimens of each adhesive at -55°C, 22°C (room temperature), 100°C, and 200°C. Dynamic tests of stiffness were performed under flexure from -55°C to 200°C to confirm the static stiffness test results. The performance of each adhesive was also tested in single-lap joints using hard steel adherends.

Results showed that Supreme 10HT maintained sufficient stiffness, strength, and ductility to carry a load over the temperature range from -55°C to 100°C and higher (refer to Figures 2-4). Above its Tg (135-140°C), it softened, and was not load bearing.

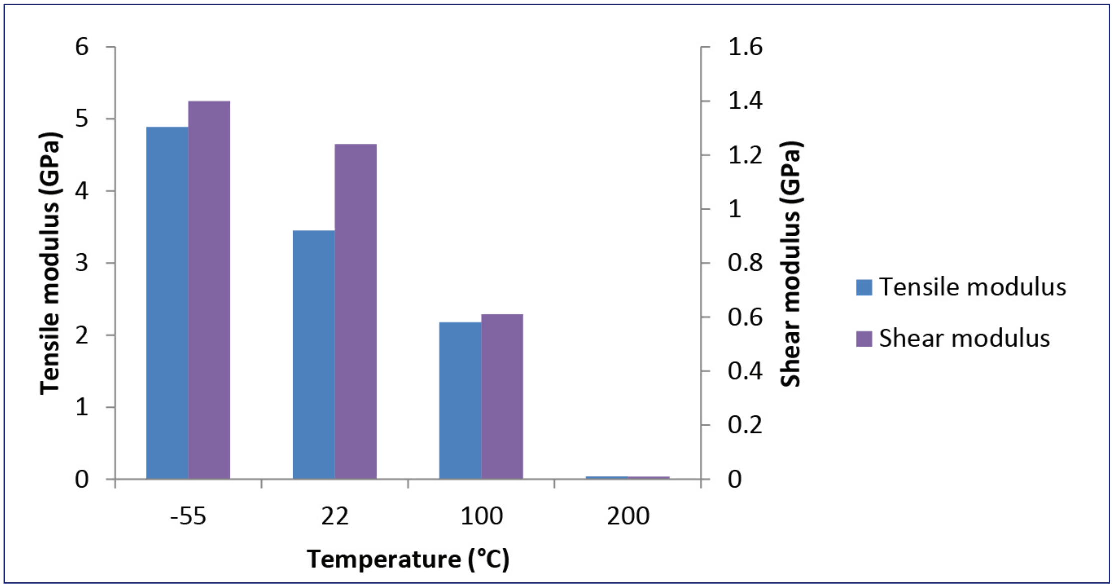

Figure 2: Supreme 10HT tensile and shear moduli.

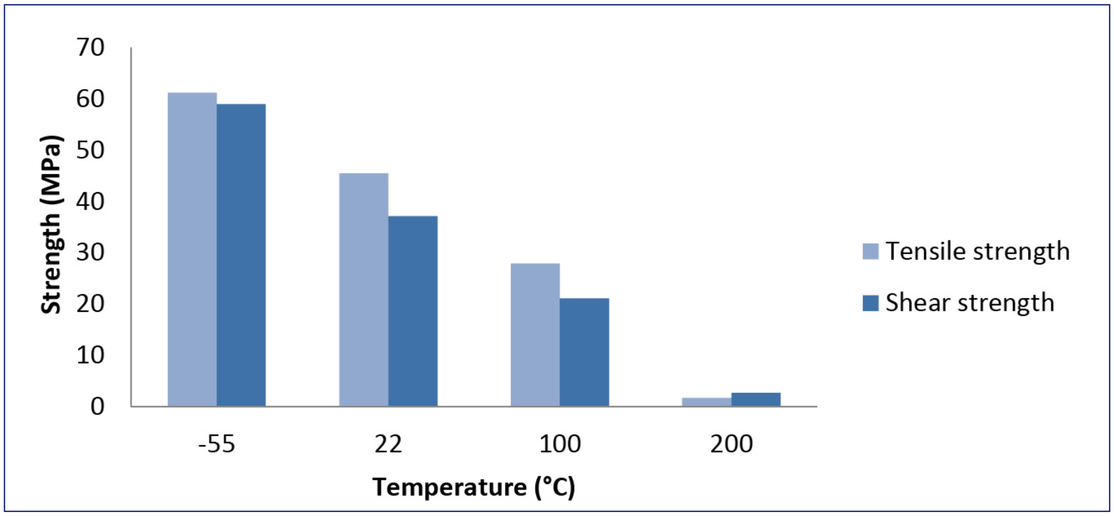

Figure 3: Supreme 10HT tensile and shear strength for steel adherends.

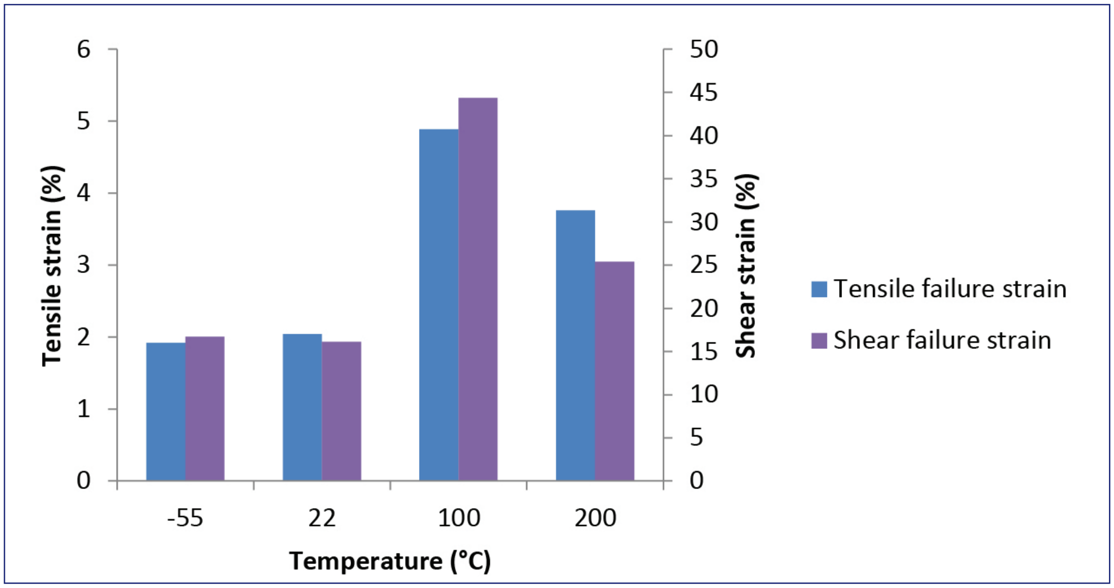

Figure 4: Supreme 10HT ductility.

In single-lap joint tests using hard steel adherends, Supreme 10HT performed well up to 100°C, as Figure 5 illustrates. Results also showed that the high-temperature bismaleimide adhesive was stiff and strong from -55°C to 200°C, brittle for temperatures below 100°C, but more ductile at 200°C. The researchers concluded that Supreme 10HT should be capable of supporting the load through at least 100°C, above which the high-temperature adhesive can bear the load safely, and proposed a future study in which mixed-joint adhesives are designed and tested.

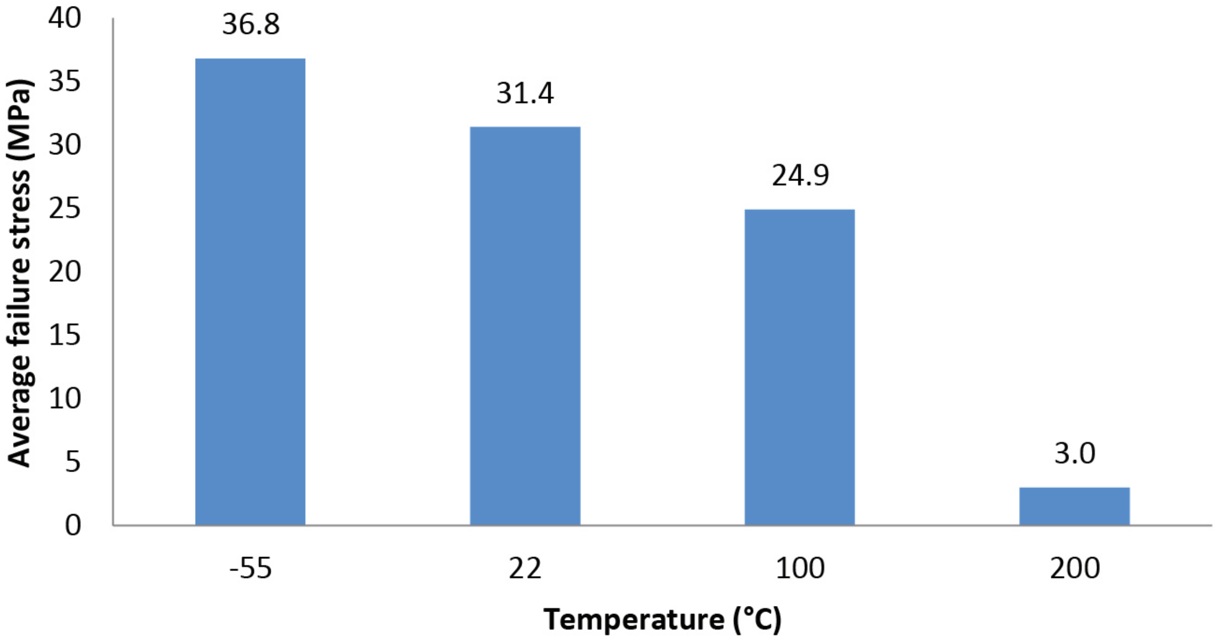

Figure 5: Lap shear strength of Supreme 10HT in a single-lap joint using hard steel adherends.

In a later study, the researchers fabricated double-lap joints consisting of titanium and a composite material.[2] They tested two different mixed-adhesive joint designs, designated MAJ1-1 and MAJ-3, using Supreme 10HT and the same high-temperature bismaleimide adhesive examined in the earlier study (refer to Figure 6). Results shown in Figure 7 indicate that the mixed-adhesive joints improved the overall strength performance of the joint across the temperature range (55°C–200°C).

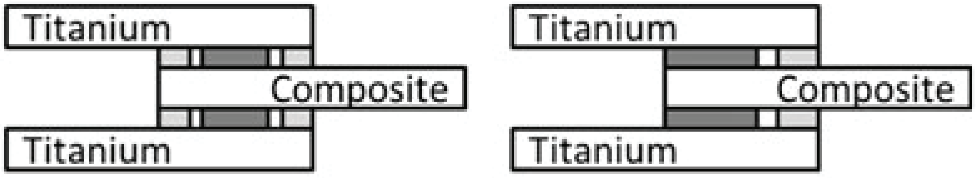

Figure 6: Mixed-adhesive double-lap joint designs using Supreme 10HT (light shading) and a high-temperature adhesive (dark shading).

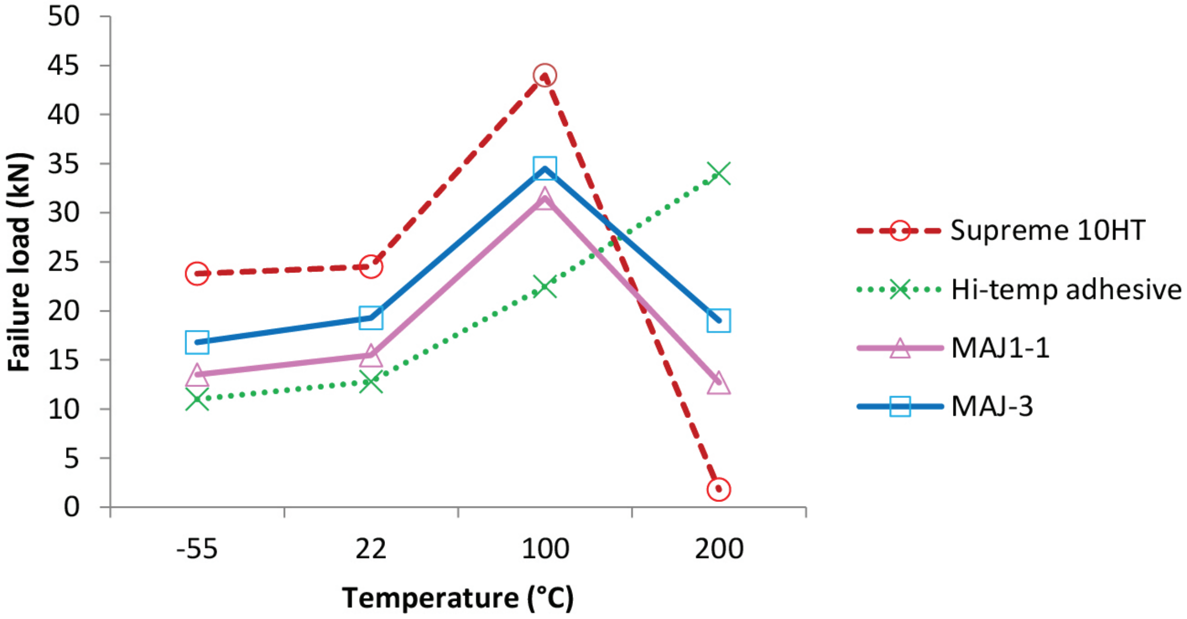

Figure 7: Failure load for titanium/composite double-lap joints.

Conclusion

In several research studies, Master Bond Supreme 10HT has been shown to be exceptionally strong, durable, and tough over a wide range of temperatures and after repeated thermal cycling. Supreme 10HT performed well in a variety of applications with both similar and dissimilar substrates and was compatible with a commercially available dielectric fluid. The combination of outstanding performance and convenient handling makes Supreme 10HT an excellent choice for applications in the aerospace, automotive, electronics, military/defense, and other industries.

References

[1] Da Silva, L. F. M. and Adams, R.D. "Measurement of the mechanical properties of structural adhesives in tension and shear over a wide range of temperatures," *Journal of Adhesion Science and Technology*, 2005, vol. 19, no. 2, pp. 109-141. doi: 10.1163/1568561053148449. Accessed 2 May 2018.

[2] Da Silva, L. F. M. "Methods to improve the strength of adhesive joints," Retrieved from https://sigarra.up.pt/feup/pt/conteudos_service.conteudos_cont?pct_id=47671&pv_cod=54awyHjmGJp7.

[3] Li, C., et al. "Joining dissimilar materials using an epoxy resin composition." US Patent 9,761,374 B2. 12 Sept. 2017.

[4] Slater, C., et al. "Packaging technologies for high temperature control electronics," *Proceedings, International Conference and Exhibition on High Temperature Electronics Network (HiTEN)* , vol. 2013, Jan. 2013, pp. 184-192. doi: 10.4071/HITEN-TP15. Accessed 26 Apr. 2018.