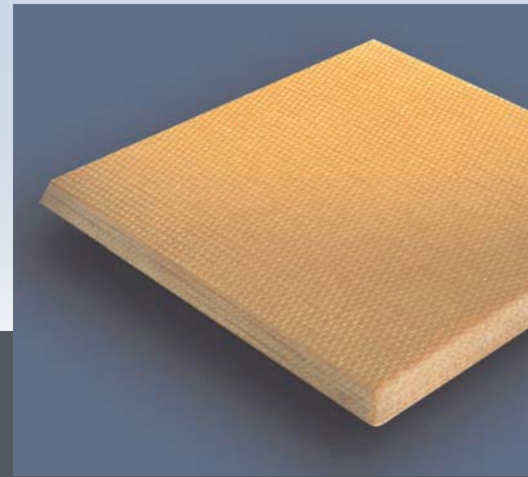
NORPLEX MICARTA

High Performance
Thermoset Composites



This high performance thermoset composite material is manufactured from a woven glass fabric and a high-temperature phenolic resin system. The resulting composite material provides excellent flame resistance and high physical strength.

Thermosets Take the Heat and Pressure in Missile Propulsion Systems

Recent performance trials of tactical missiles by the U.S. military revealed a major design deficiency that was solved by the use of a fabricated thermoset composite component. Exposed to tremendous heat and pressure inside a fired missile, the specified thermoplastic component responsible for holding the solid propellant stable would sometimes break free from the solid propellant surrounding it and shoot out of the rocket motor. With the component no longer in place, the rocket exhaust could not direct the rocket and keep the missile on course. What is more, the displaced component was also a danger to aircraft and personnel in the area.

The U.S. military replaced the thermoplastic part with one made of a high performance thermoset composite material. A combination of phenolic resin and fiberglass, the new component has the strength and heat resistance to hold its position in a flaming stream of rocket exhaust. In addition, the material does not corrode, even when encased for years in solid rocket propellant. Possible alternatives were considered, including moldable phenolic-fiberglass, metal, and ceramics. Moldable composites are relatively inexpensive, but lack the strength of phenolic-fiberglass thermoset systems that are machined into the desired shape. Metals and ceramics are not easily machined, are heavier than thermoset composites, and are more expensive.

Why the Plug was Pulled

The design deficiency was discovered in a missile used to destroy enemy tanks, bunkers, and buildings. Fired by a variety of aircraft, the missile can travel 12 miles on its propellant load, which burns up in about six seconds. To fuel the missile, liquid propellant is poured into the rocket assembly.

Inside the missile, a chemical reaction solidifies the propellant, which used to be held in place by the old thermoplastic part, a plug made of molded polyurethane foam. This plug was supposed to help keep the missile on course by controlling the shape of the flame coming out of the rocket nozzle as the propellant burned.

For years, the polyurethane plug was installed in thousands of missiles. But recently, the U.S. military found that it was not doing what the missile's designers had planned. The plug was supposed to remain in place and intact long enough to perform its two functions, then burn up in the rocket flame. Instead, the plug was coming loose as the solid propellant around it burned away. Soon after this process began, the tremendous pressure inside the rocket dislodged the plug from the propellant and sent it flying out the back of the rocket nozzle.

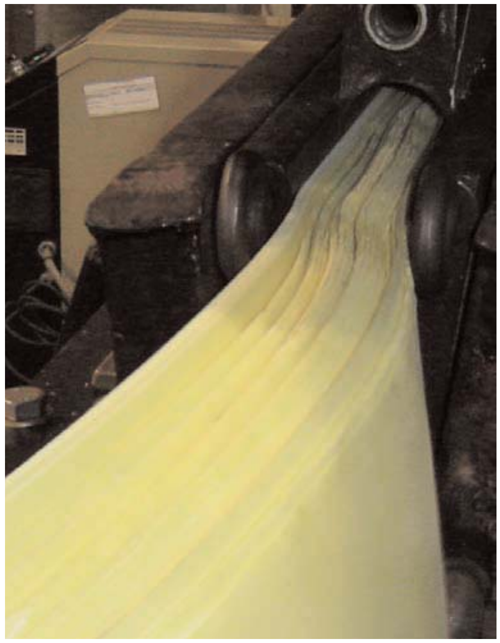
The plug's unplanned departure destabilized the rocket flame, which affected the course of the missile. Perhaps more alarming, the displaced plug became a missile of sorts itself, heading back toward the aircraft it came from at thousands of miles per hour.

When these potentially disastrous problems were discovered, the plug was pulled from the missiles. To replace it, engineers designed a new component called a rod grain stabilizer. This component consists of a rod with three legs glued to it. The rod is several inches long and about an inch in diameter. The three legs, each measuring about half an inch in diameter, are attached at 45° angles to the rod and are equally spaced around its circumference. As propellant is consumed during the firing process, the stabilizer's symmetrical design helps to ensure uniform fuel burning and reduces the change to the rocket's center of gravity. Approximately half of the stabilizer burns up with the propellant, but enough of it remains for the part to hold its position and do its job throughout the process.

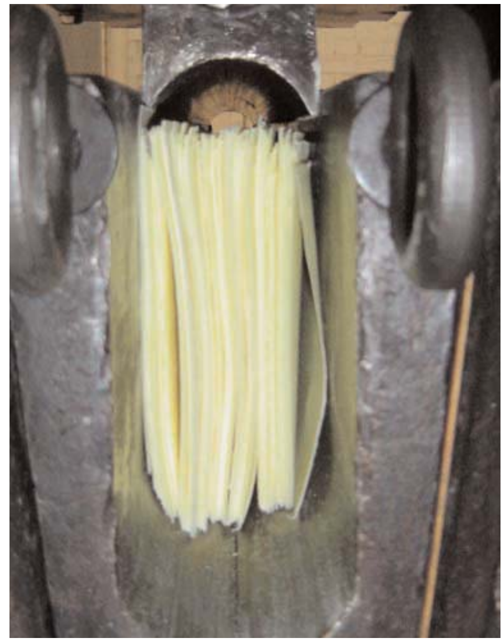
Thermoset Advantages

The stabilizer's rod and legs are made of a thermoset composite consisting of high-temperature phenolic resin and a fiberglass substrate. Unlike thermoplastics (such as polyurethane), which melt when exposed to high temperatures, this thermoset features extremely high flame resistance. When exposed to a flame, the material's outer surface chars, but this charred outer surface acts as insulation that protects the inner material. So when a missile is streaking through the sky, the thermoset stabilizer inside survives to perform its critical functions even when temperatures reach up to 5,000°C for short periods of time.

Besides flame resistance, the thermoset composite provides high physical strength that allows the stabilizer to withstand the crushing forces produced by the rocket fuel as it ignites and propels the missile toward its target. By comparison, thermoplastic is not nearly as strong; substantially more



The process of creating themoset composite rods, such as those that are used in the manufacture of the missle stabilizer, can be described in four basic steps. The first step is to load the prepreg material into the mold.



The second step is to close the mold around the material.

The above picture shows the thermoset composite material beginning to compress, which is the third step in the process.

In the fourth step, the material begins to melt and flow into the final compression molded shape. The final product is a rod that will be ground and finished as required, then machined to the component's specifications.

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of it would have to be used to make a stabilizer as durable as one made of thermoset material. As a result, a thermoplastic stabilizer with sufficient strength would be much heavier than an equivalent thermoset component - a major disadvantage in military aircraft applications, where weight saved during the design process helps to make aircraft more maneuverable and allows them to carry more weapons or troops into combat.

The final design requirement was corrosion resistance. Once placed inside a missile, the stabilizer might remain embedded in corrosive propellant for up to ten years if the missile is not used during that time. That does not present a problem for parts made of thermoset composites, which will not corrode even when encased for years in rocket fuel. The same can be said of some thermoplastics such as Teflon®, which offer high resistance to chemicals. But these thermoplastics are too soft to meet the other physical requirements of this demanding application.

Metal and Ceramic Options

Common metals such as carbon steel, nickel, and copper certainly have enough strength for this application. But these metals would corrode in the propellant cake well before the end of a missile's long lifespan.

Some metal alloys offer chemical exposure properties that would be adequate for the job. But these exotic alloys are heavier and more expensive than phenolic fiberglass composites. In addition, these hard alloys must be cut with an even harder metal, which makes them very difficult to machine. By contrast, phenolic fiberglass composite is relatively easy to machine with a conventional hardened metal tool. The reason: machining the composite involves cutting through individual plies of material. In terms of difficulty, the process is roughly equivalent to machining aluminum - and even easier in some cases.

Like certain metal alloys, ceramics offer the strength and corrosion resistance required by the stabilizer. But ceramics also share the disadvantages of the metal alloys. For instance, ceramic options are two to three times heavier than phenolic fiberglass composites.

Phenolic Fiberglass Alternatives

What about other phenolic fiberglass alternatives? For example, phenolic resin can be combined with a structural glass material called S-2, which offers higher strength than other types of fiberglass. But it is also five times more expensive than the fiberglass used to make the stabilizer. The glass chosen for the job provides all the necessary properties - and at a price that helps manufacturers keep the cost of the component as low as possible.

If cost were the only consideration, the stabilizer might be made of phenolic fiberglass combinations that can be molded into the desired shape in a single step. This is a much simpler process than the one actually used to make the stabilizer, in which the central rod and its three legs are individually machined and then assembled to produce the finished part. However, moldable versions of the material are relatively brittle because the short glass fibers do not hold together as firmly as the longer woven glass fibers in machined phenolic fiberglass composites. Inside a missile, these brittle materials could shatter under the tremendous stress produced by igniting propellant. Shattering could produce dangerous high-speed projectiles like the old polyurethane plugs.

Conclusion

Phenolic fiberglass thermoset composites excel in extreme aircraft environments, offering superior strength and heat resistance that is lacking in thermoplastics. Compared to metal and ceramic alternatives, thermoset composites are relatively inexpensive and easy to machine. Thermosets are also lighter than metal and ceramic options, thereby contributing to increased aircraft maneuverability and carrying capacity.

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