Overview of **Elastomeric Bladders** *for* ***Composite Fabrication***

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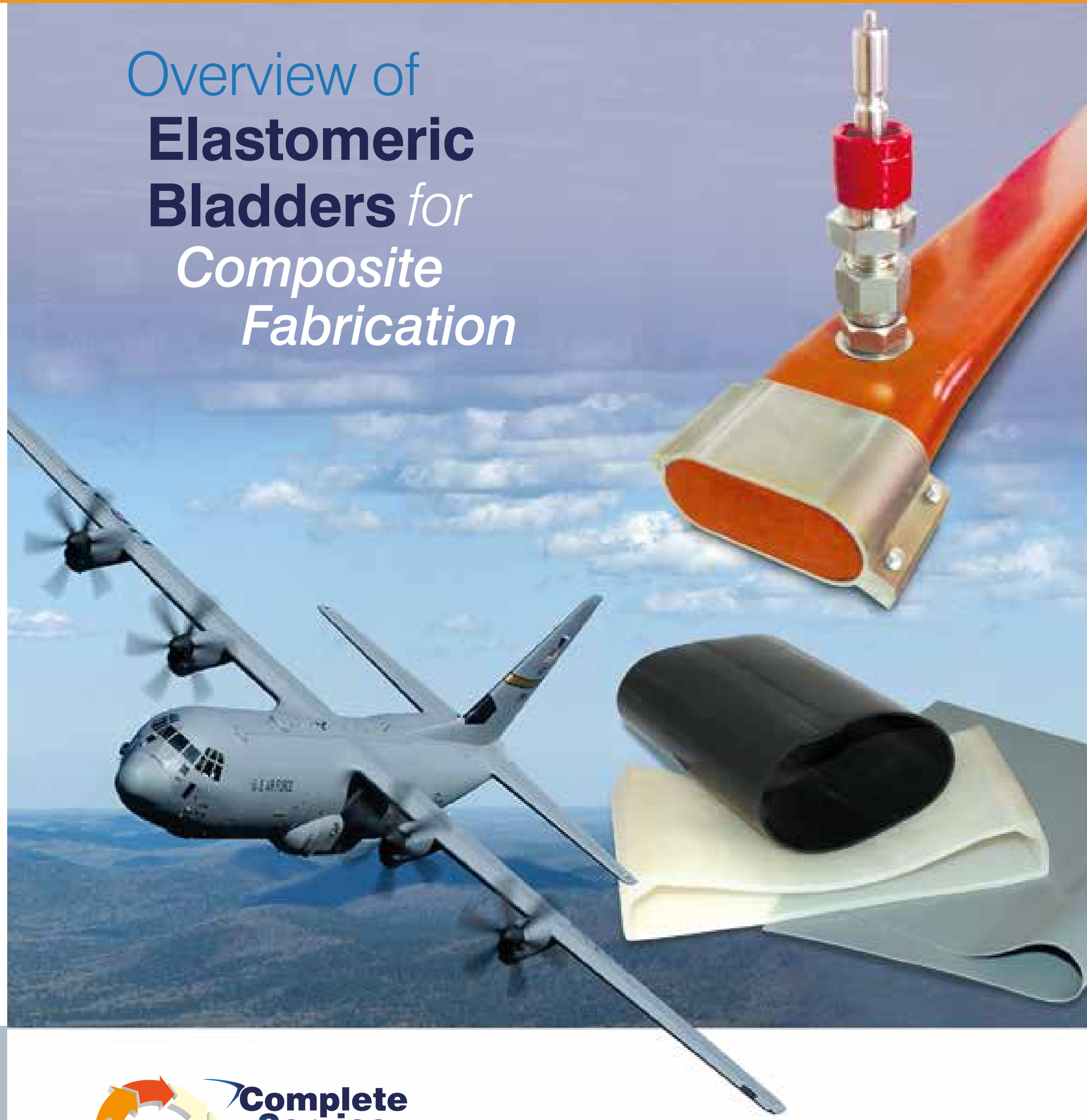

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What are Elastomeric Bladders?

Elastomeric bladders are used as trapped tooling to form composite structures with internal cavities. The bladders can be removed after the composite is cured.

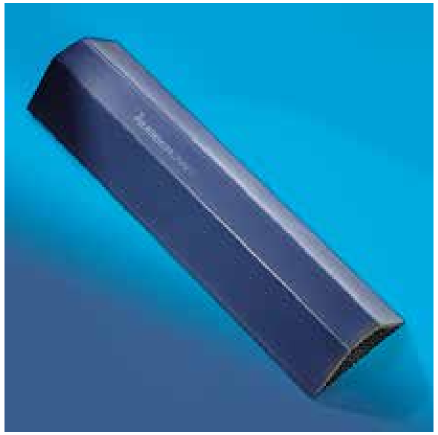
Examples include hollow beams and hat stiffeners on composite skins. Bladders are also used to form hollow structures with a fully tooled outer mold line, which are sometimes referred to as “closed mold” application. Examples of structures made using this tooling approach include ailerons, winglets, and various secondary structures.

A wide variety of materials, surface treatments, reinforcements, and internal supports are available to support various fabrication processes.

For example in an autoclave, the inside of the bladder can be connect or be open to the autoclave pressure while the outside of the bladder is in contact with the composite near vacuum.

Bladders are pressurized with a working fluid (typically nitrogen), and compress the composite laminate prior to and during the cure. Often the bladders are simply vented to the autoclave or, in the case of out-of-autoclave applications, to the oven environment.

In other cases the inside of the bladder can be connected to a pressurized gas. A bladder around a solid mandrel only expands due to the thermal expansion of the elastomer.



After molding, the bladders are removed and can typically be reused a number of times before they need to be replaced. Because they are flexible, it is possible to remove rubber bladders from cavities that are highly curved or that have varying cross sections.

The bladders can be tailored to the specific application using a variety of different elastomers, reinforcements, surface treatments, and internal stiffeners. For example, they can be made to resist deflection caused by the pressure applied by automated fiber placement (AFP) machines.

Elastomeric bladders can also offer varying degrees of mechanical support. For example, in an outer mold line (OML) tool the bladders can be stiff enough in selected directions to achieve the required location tolerances. Reinforcements are also used to stiffen the bladders to withstand lay-up pressure in automated fiber placement applications.

Closed mold and hat-stiffened panel application examples are discussed in more detail.

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Bladders in “Closed Molded” Applications

Elastomeric bladders are used to fabricate composite parts in “closed mold” applications, where the outer part surface is in contact with a mold tool on both the top and bottom surface of the part. There are a variety of reasons to use this tooling approach.

In practice, most parts made this way are hollow, and there is not a simple way to fabricate them in the conventional vacuum bag/autoclave manufacturing approach. The rubber bladder serves a similar function as the vacuum bag does in a conventional fabrication approach - it allows the composite laminate to be consolidated and compressed during the cure process. The bladder can be pressurized either by venting it to the oven or autoclave, or by introducing a pressurized fluid. Nitrogen, air, steam, oil or other liquids and gasses can be used to apply pressure.

The mold may be held closed by autoclave pressure, atmospheric pressure (for low pressure infusions), mechanical fasteners, or by a hydraulic press. The heat may be applied by oven, autoclave, circulating heated fluids, heated platens of a press or direct heating of the mold.

Single Cavity Approach

Examples of single-cavity hollow composite parts for aerospace applications include rotor blades for helicopters, spars and box-beams. Some simple shapes can be fabricated around an internal metallic mandrel, but this is not possible, or impractical for complex hollow structures. More complex hollow structures may use a multi-cavity approach.

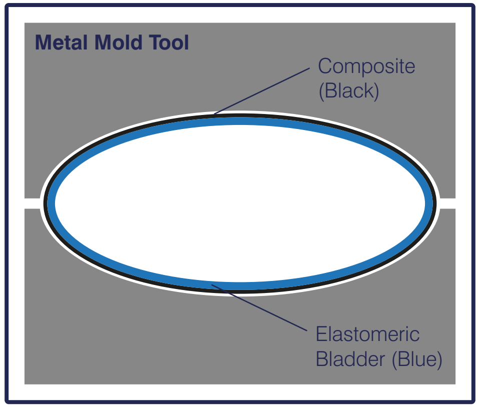

Figure 1. *A simple, single cavity composite part can be bladder-molded with a single elastomeric bladder.*

Multi-Cavity Approach

Special techniques must be used to ensure correct positioning of the internal ribs when fabricating this type of structure. Examples of multi-cavity hollow parts include ailerons, winglets, and doors. Bladders have been used in prepreg carbon fiber applications, resin transfer molding (RTM), and vacuum assisted resin transfer molding (VARTM).

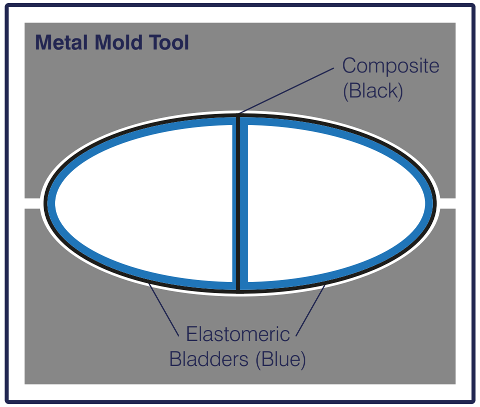

Figure 2. *Multi-cavity bladder molding can be used to fabricate highly integrated complex composite structures.*

Using Elastomeric Bladders to Fabricate Skin-stringer structures

Elastomeric bladders are also used to create hat stiffeners (also known as omega stiffeners, hat stringers, omega stringers etc) on stiffened composite panels. Applications include Boeing 787, A350XWB fuselages, business jet horizontal stabilizers and vertical fins, nacelle structurers, other platforms.

There are several potential approaches to fabricating the integrated skin-stringer panel. Co-curing is defined as curing multiple elements simultaneously, while there are also being bonded together at the same time.

What is Co-Bonding?

Co-bonding, means bonding two elements, where one of the elements is pre-cured and the other is cured simultaneously with the bond operations. Secondary bonding is defined as the bonding of two previously cured elements.

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Figure 3. *Aircraft fuselage, (source: harpers magazine) https://harpers.org/blog/2013/07/boeings-plastic-planes/*

Fuselage Structures

The photo shows a composite skin-stringer fuselage structure with several of the fuselage frames fastened to the skin. In most cases, the stringer preform and the skin are co-cured. In a few cases the pre-cured stringers are co-bonded with the skin, meaning that the pre-cured stringer is bonded to the skin while the skin is being cured. In current production applications, the pre-cured fuselage frames (circumferential stiffeners) are secondarily bonded and fastened to the pre-cured skin.

Inner Mold Line (IML) Tooling Approach

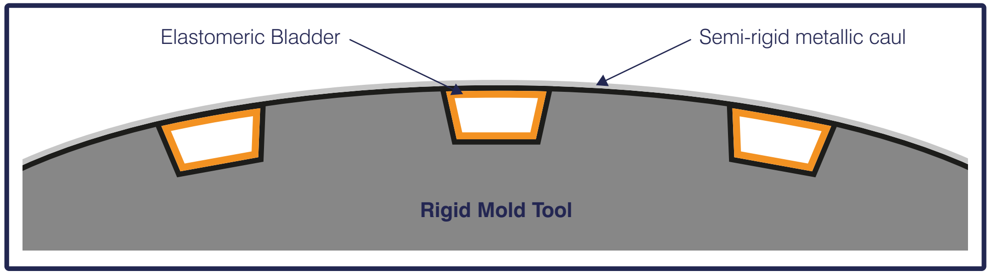

Figure 4. *Inner Mold Line (IML) tooling approach.*

The inner mold line tooling approach usually starts with the layup and consolidation of the stringer preforms on a separate stringer layup tool. The stringer preforms are transferred into the mold tool, then the bladders are placed in the stringer cavities. The skin is then applied using automated tow placement machines. Alternatively, for small parts the skin could be applied manually and debulked before being transferred to the mold tool. A semi-rigid caul is positioned over the skin. A vacuum bag is then applied over the semi-rigid caul. The bladders are vented to the autoclave and a semi-rigid caul over the top controls the outer mold line of the structure. The main drawback of this tooling approach is that it is very expensive to tool. It may require a multi-piece mold tool that can be disassembled. A key advantage is that the skin laminate can be co-cured with the stringers while maintaining very good tolerances and laminate quality.

Outer Mold Line (OML) Tooling Approach

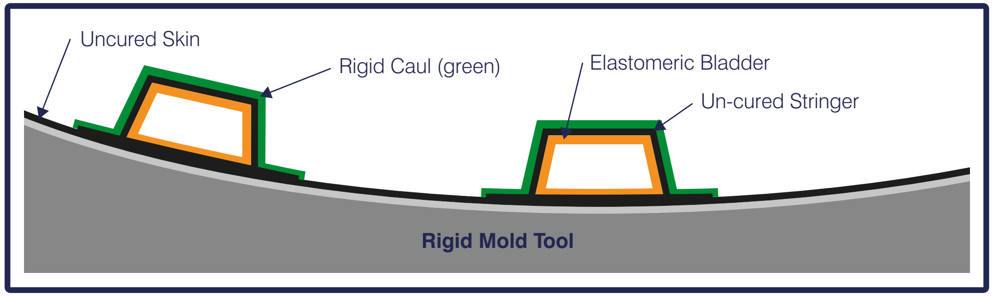

Figure 5. *Outer Mold Line (OML) tooling approach with co-cured stringers*

A second method of co-curing the stringers with the skin uses an outer mold line (OML) tool and rigid caul plates. This is a less expensive tooling approach than using IML tooling, in most cases. Laminate quality and positional tolerance in the stringers may be less reliable than the IML tool approach. While not easy, you could make a one piece barrel section with an OML approach.

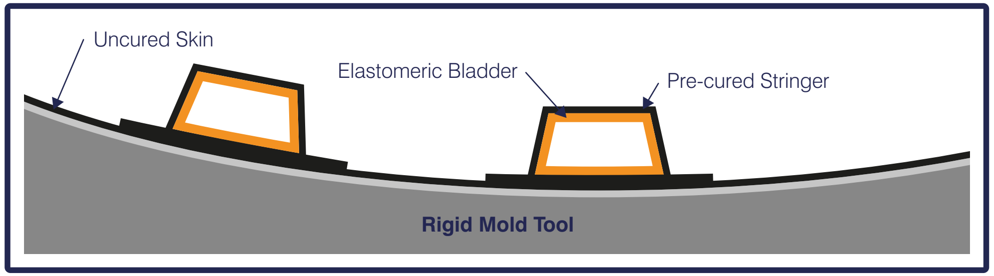

Figure 6. *Outer Mold Line (OML) tooling approach with pre-cured stringers.*

Elastomeric bladders can also be used to co-bond pre-cured stringers with an uncured skin on an OML mold tool. A vacuum bag goes over the assembly prior to autoclave curing, and the bladders can be vented to the autoclave. This method tends to present the most difficulties with laminate quality in the skin, compared to the other methods discussed, due to pressure variation on the uncured skin at the corner locations of the pre-cured stringer.

A variation on this approach is to pre-cure both the skin and stringers, then use bladders to support the stringer and prevent distortion during a secondary bonding operation using a vacuum bag.