

Understanding FRP Booms and their Use in Aerial Devices

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Introduction

The need to deliver electricity to the customer in an efficient and reliable manner has become an imperative for utilities the world over. Increasing use of computers and other sensitive equipment has driven this need to a place of higher importance. Power shutdowns for line maintenance can cause large losses to both utilities and their customers.

One method of addressing this problem is to use aerial devices with insulating fiberglass reinforced plastic (FRP) booms. These machines have provided a safe and effective tool for maintaining both transmission and distribution lines in the United States for over 40 years.

Because widespread use of FRP is a relatively new phenomenon when compared to metals, its performance characteristics are not as widely understood. To address this problem, it is helpful to know something about its history. When this is combined with basic knowledge of design, manufacture, and quality issues, utilities can make a confident and informed choice to use aerial devices with FRP booms.

History

The potential for using fiberglass as a structural material was realized in the 1920's by A. A. Griffith, who reported strengths of drawn glass fibers up to 900,000 psi (6000 Mpa). However, the use of fiberglass did not become common until the late 1940's. Early applications during this time exploited the noncorrosive nature of the composite and clear sheeting, chemical-resistant process equipment, and boat hulls.

In a few years the excellent dielectric properties of FRP materials were being used to advantage for working live power lines. In the early stages, at least one manufacturer applied a coating of fiberglass over an aluminum or steel boom to provide contact protection. These first booms were made by hand lay-up of fiberglass mat and polyester resin.

The next step in the progression was to leave the aluminum or steel out and use the fiberglass as both a structural and insulating element. By 1955, three manufacturers in the United States were making aerial lifts with all fiberglass upper booms.

Over the years, work practices evolved as distribution and transmission voltages increased. Aerial devices have also evolved continuously over time, the design driven by the need to

provide safe access for the lineman. Among the latest design refinements we see in the U.S. are machines that can provide access without the need for the booms to swing out into traffic.

Another important improvement is designs with smooth, uncluttered booms that are less likely to become entangled in trees or guy wires. Many U.S. machines have a fiberglass lower boom insert to provide chassis insulation. This offers protection to the ground crew and passersby. Some telescoping booms even provide insulation when the upper boom is fully retracted. All of these improvements have been shaped by experience.

A majority of the booms sold by Waco Boom Company are for hot stick or gloving applications rather than bare hand work. In this more common case the insulated machine provides redundant protection in case the gloving or hot stick procedures fail. In an analogous way insulated machines provide protection for linemen working on line that are supposed to be turned off and for some reason are not.

It should be noted that insulated booms are intended to provide protection from phase to earth ground contact. Phase to phase and phase to overhead ground contact must, be avoided with proper operator training and a long insulation length on the upper boom.

FRP boom design, production methods and testing have matured greatly in the past few decades. ANSI, which sets standards in the U.S. for FRP booms, has mandated periodic dielectric testing as well as increased structural safety factors. These changes have increased the confidence and safety level of the utilities using FRP booms. The few structural failures that have occurred over the past several decades have been attributed to overloading and/or fatigue of booms that did not have good fatigue resistance.

Designing FRP Booms

There are only a few basic design criteria for a FRP boom. First, the boom must provide reliable strength and stiffness to support the workers and their equipment. It must also provide this strength throughout the working life of the aerial device – generally 10-15 years with effective maintenance. The boom must have inherently high dielectric strength to provide insulation. In addition, it must not lose its dielectric properties due to exposure to sunlight, moisture, hydraulic oil, or other environmental contaminants. Finally, it must be possible to incorporate the boom into an aerial lift structure by bolting and adhesive bonding, and this normally requires some degree of dimensional consistency.

By nature, FRP allows for creativity in design. Since the finished material is a composite of two distinct materials, the final properties can be widely tailored to meet the application. Thus, design with FRP should only be undertaken by individuals who are trained to understand the additional complexities of design with composite materials.

FRP Boom Manufacturing Process

There are a wide variety of processes and materials used to manufacture FRP booms, each with inherent strengths and weaknesses. For the sake of comparison, the most widely used materials and cross-sectional shapes will be considered in this study:

1. Hand lay-up with woven roving, chopped mat and polyester resin. Fiberglass cloth is saturated by hand with resin and applied to a mold. The finished part is rolled or compacted and allowed to cure at room temperature. These parts are typically made in a rectangular shape with large radii.

2. Centrifugally cast with longitudinal fibers, chopped strand mat and polyester resin. Fiberglass broad goods such as mat are rolled into a long hollow tube, like the shape of rolled new carpet. The roll is placed in a hollow metal pipe and resin is sprayed on the fiberglass. The pipe is spun to distribute the resin and allowed to cure at room temperature. These parts are limited to a cylindrical shape.

3. Filament winding with continuous roving and epoxy/anhydride resin. Continuous rovings of fiberglass are impregnated with resin in a mechanical bath and wound around a rotating mandrel at various angles. The finished part is pressed and cured in an oven at approximately 300F for approximately five hours. These parts can be made in rectangular or cylindrical shapes. The rectangular shape, which is most widely used, will be considered.

4. Pultrusion with filled vinyl ester resin, chopped mat, and surfacing veil. Rovings and glass cloth are impregnated with resin in a mechanical bath and pulled through a heated die into a continuous shape. Filler is added to resin to reduce cost and lubricate the die. These parts can be made in round or rectangular cross-sections. The rectangular shape, which is the most widely used type, will be considered.

The Quality Control Used in the Process Determines Final Properties

Using a superior processing method is not enough to ensure a high quality boom, because any process that is not correctly performed will result in an inferior product. As a minimum, the boom manufacturer should have the following quality controls in place:

1. Only certified materials from reliable manufacturers should be used. Low-grade materials are sometimes used in marine and recreational applications where poor quality is not as life threatening. These materials should not be used for high-risk structural applications. Using low quality materials saves cost in the short run, but such negligence brings an unacceptable risk of dielectric or structural failure.

2. No woven materials should be used in the boom construction. These materials reduce the fatigue life of the boom by as much as half. With proper design practice this limitation can be overcome. However, there is no reason to use these materials since replacements are now available, which are known as “stitched” materials.

3. Controls should be placed to ensure that the resin is adequately cured. Inadequately cured resin decreases the physical strength of the material drastically (by 50% or more) and can decrease the dielectric strength as well.

4. The fiberglass to resin ratio must be maintained at a consistent value. This can be done either through the processing method or by checking the part once it is completed. Low fiberglass content is extremely detrimental to the physical strength and results in a low strength to weight ratio.

5. Full-scale load tests to failure should be performed to confirm that the design methods being used are correct. Results from these tests at Waco Boom Company Ltd have shown that properly designed and manufactured FRP booms can be stronger than steel at one fourth the weight. Improperly designed booms – for example, if the boom is designed using the same engineering method as for a steel boom – will lead to a weak, inefficient product.

Conclusion

Employing insulated aerial devices is a proven, cost effective way of maintaining overhead lines. Use of FRP booms in these devices has become progressively safer over the last 45 years.

By choosing booms that are made with high quality materials, sound manufacturing methods, and sufficient quality controls, the purchaser can be assured of initial safety. With proper care and maintenance, the boom will give many years of service after the purchase.

