

Grommet Hole Reinforcement and Lightning Strike Protection in Composite Structural Assembly

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ABSTRACT

Aircraft design and assembly challenges include provision of hole protection from lightning strike in fastened joints, especially in the vicinity of fuel tanks or electrical services. Installation of interference fit fasteners helps minimize the effect of lightning strike and also enhances the durability and load transfer ability of the joint. However, these are known to cause laminate damage during installation which can degrade the fastener system performance. Use of a pre-installed expanded grommet into the hole prior to installing interference fit fasteners has been shown to greatly enhance the effectiveness of the joint as well as the conductivity of electrical current into the structure to minimize arcing or plasma discharge at the fastener in the event of lightning strike.

The Fatigue Technology (FTI) GromEx® system provides such hole protection for fastener installations into composites, allowing for the installation of interference fit fasteners without detrimental impact to the laminate. In a test program performed to evaluate the performance of the GromEx system under lightning strike testing, in accordance with the methods specified in SAE ARP 5416, it was found that interference fit fasteners, combined with the expanded grommets, eliminated gaps between the fastener and surrounding structure that could cause sparking during a lightning strike. These joints provide very low resistance between the fastening system and the structure and improved joint durability by more than four times. A description of the GromEx installation process, the structural benefits afforded by the GromEx system as well as the results of lightning strike simulated direct strike tests on

complete tanks or tank Sections for a Zone 1A environment, are discussed in this paper.

INTRODUCTION

One of the biggest challenges confronting composite aircraft design and assembly is accommodating the effect of projected in-service lightning strike damage that could occur if the charge is not adequately and rapidly dissipated into the structure. This is particularly critical in and around fuel tanks and other sensitive locations where high intensity lightning strike discharge could cause sparking and potential for explosion or shorting of electrical services. Typical fasteners are conductive and usually provide less resistance than the surrounding composite skin panels, resulting in more current passing through the fasteners. This can result in arcing or plasma discharge surrounding the fastener or at the securing collar or nut interfaces within the internal structure. It will usually result in extensive damage to the surrounding composite skins.

Interference fit fasteners are generally used to help minimize the effect of lightning strike and also to enhance the durability and load transfer ability of the joint. The problem is that these are known to cause laminate damage during installation which can actually degrade the capability of the joint. The inherent difficulties associated with installation of interference fit fasteners is somewhat mitigated by sleeve type fasteners, however they do not provide flexibility in assembly nor facilitate subsequent removal of the fastener should it be necessary.

The FTI GromEx system is designed to provide an enhanced independent grommet that is cold expanded into the

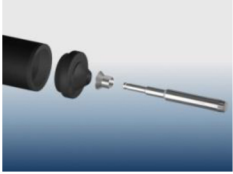
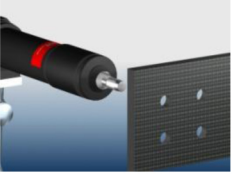
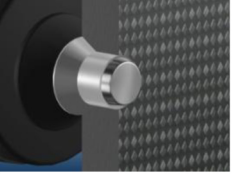
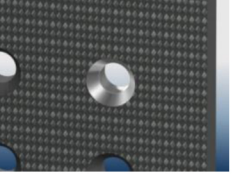
				
Step 1: Assemble parts for processing. Slide grommet onto mandrel.	Step 2: Slide grommet and mandrel into puller.	Step 3: Place grommet and mandrel into open hole (clearance fit).	Step 4: Activate puller to expand the grommet into the hole.	Finished Installation

Figure 1. GromEx expanded grommet installation process

composite to protect the hole and to act as a “sleeve” for the insertion of interference fit fasteners. The amount of radial expansion of the grommet is tailored to ensure adequate retention without causing localized damage to the composite. It is this high level of relative interference and the intimate contact in the composite that provides the conductivity path that minimizes the damage due to lightning strike when used with a variety of interference fit fasteners.

In addition to the greatly improved conductivity of the joint a range of other structural benefits are realized by using the GromEx system including:

- increased fatigue life and durability of the joint
- improved static performance of the joint
- allowing higher interference fit of the fastener through a stacked joint
- the ability to remove and replace the fastener without causing secondary removal/insertion damage in the composite matrix
- versatility of assembly by allowing a range of different fastener types in the one joint or assembly,
- improved sealing of a fuel tank joint assembly
- the ability to “sleeve” a composite metal hybrid joint

FTI has performed extensive mechanical testing of its range of expanded bushing type products in CFRP to determine the guidelines for their use and to generate a general database for performance of these products in composite materials [1]. This paper discusses the fatigue and durability test results along with the mechanical static and dynamic testing of the GromEx system compared to bare fastened joints. These tests include the results of post installation sectioning to assess the effect on laminate integrity in a variety of different composite

matrix materials. The results of the arc entry lightning strike tests demonstrate how lightning will be conducted through the structure in a simulated built-up joint or sub-structure resulting in considerably less damage than typical fastened joints with the ability to discharge a higher current without sparking.

GROMMET HOLE REINFORCEMENT

GROMEX PROCESS OVERVIEW

GromEx is a thinner walled grommet derivative of FTI's expanded bushing technology; used extensively in metal structures. Its adaptation for use in composite material is the subject of this paper. The GromEx system is based on cold expanding an initially clearance fit grommet into a hole. A specially sized grommet, with a proprietary lubricant on the inside surface, is radially expanded into the hole using a tapered expansion mandrel. The process of expanding the grommet into the composite hole, at an expansion level below the threshold that could cause damage to the surrounding composite, will yield it into the hole creating an interference fit. An example of a typical GromEx installation is shown in [Figure 1](#). Overall, the expanded grommet installation method provides a rapid, consistent and non-damaging grommet installation.

QUALIFICATION AND PERFORMANCE EVALUATION

To ensure that GromEx grommets would have optimum performance characteristics, a number of specific tests were selected to meet the design criteria as defined after discussion with various OEM's in the aerospace industry. Based on the established design criteria, an extensive GromEx development test program was performed to establish

guidelines for use of the GromEx system in a range of composite materials. However, the matrix and composition of composite materials varies widely in the industry and therefore specific design allowable data should be confirmed or derived based on the composites used.

Although the basic design premise of GromEx was to provide open hole protection for removable access panels, the intimate contact afforded by the expansion of the grommet into the hole also proved beneficial in dissipating the charge in panels subjected to lightning strike. The charge was rapidly and efficiently dissipated through the grommet into the surrounding composite material with minimal or no damage or arcing under the test conditions [2]. Furthermore, the expanded grommet fulfilled an important design requirement for structural attachment in composite airplanes by facilitating use of interference fit fasteners to enhance the load transfer and durability of joints. This high interference fit of the grommet also allows repetitive fastener installation and removal by protecting the bore of the hole.

LAMINATE INTEGRITY

To confirm that use of the expanded grommet system would not cause detrimental damage to the composite structure as a result of the installation, GromEx grommets were installed into composite laminate and then sectioned. An example of a section micrograph is shown in [Figure 2](#). Separate sections were also taken to investigate the effects of multiple installations and removals of interference fit fasteners into the installed grommets. Minimum starting hole diameters were used in all cases, as these represent the maximum expansion since this will have the highest probability of causing damage to the structure. No damage was detected, even at the critical juncture of the countersink.

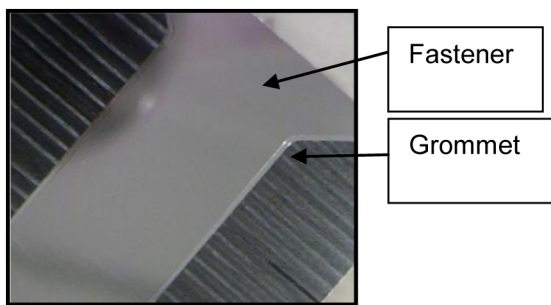


Figure 2. Photograph of sectioned part with fastener and grommet

GROMEX RETENTION

To quantify the retention of the grommet in the parent structure, GromEx grommets were installed and then pushed out of the parent material to examine the removal force required and the interference level of the grommet in the hole. A specially designed pin was placed into the grommet

with a close-tolerance clearance fit, and the grommet was pushed out of the parent material using a hydraulic test frame to determine the exact amount of force required to remove the GromEx from the parent material.

FASTENER REMOVAL AND REPLACEMENT

One of the major advantages of using the GromEx system for installation of fasteners into composites is the ability to remove or replace fasteners without requiring additional machining or over-sizing of the hole in the parent material. Durability testing shows that the installation and removal forces of the grommet remain very consistent after multiple fastener installation and removals as shown in [Figure 3](#). Although the removal forces required for the GromEx grommet were less than those required for fastener removal, the grommet is still retained in the hole during fastener removal because of the greater coefficient of friction between the grommet and the composite. The inner diameter of the GromEx grommet remains very consistent after multiple installations, ensuring consistent interference fit for the fastener. Also, the grommet does not move in the hole as a result of these operations. This provides a stable environment for repeat installations.

JOINT STATIC TESTS

Static joint tests were conducted using ASTM D5961 [3] as a guideline with MS24694 tension head fasteners installed in single-shear and double-fastener test specimens. [Figure 4](#) shows the single shear specimen configuration. The fasteners were tested in bare hole configurations and where GromEx grommets were installed into the test plates through both panels for hole protection. All fasteners were installed flush to the composite and torqued to 218 in-lb $\pm$ 10 percent. The static test results showed similar ultimate forces to failure for the different test configurations even though holes for the GromEx installation were larger to accommodate the sleeve thickness.

JOINT FATIGUE TESTS

Joint fatigue tests were carried out in similar specimens with the same faster configuration and with grommets installed through both panels as used in the static test. Guidelines defined in ASTM D3479 [4] were used. Fatigue load levels were derived from the static failure loads. Tension head fasteners were installed clearance fit (0.0010 inch nominal) into both a bare hole and GromEx grommet hole and also installed interference fit (0.0017 inch nominal) into a GromEx grommet. A buckling support fixture was used to minimize bending in the specimens. Failure was defined as an inability to maintain stroke limits set at 2 percent, or 0.005 inch displacement.