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Qualification of the EMR for Swaging Collars on the 787

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ABSTRACT

The Boeing 787 Dreamliner will be the most fuel-efficient airliner in the world when it enters service in 2008. To help achieve this, Boeing will utilize state-of-the-art carbon fiber for primary structures. As a result, new manufacturing techniques and processes are required for assembling the large composite structures. For example, the one-piece composite fuselage barrel limits access to both sides by a single machine. Electroimpact proposed a system utilizing the low recoil Low Voltage Electromagnetic Riveter (LVER) to drill and install bolts. Before Boeing partners could take advantage of a LVER system they required a tentative approval from Boeing for this process. A qualification test program was initiated between Boeing Materials Process and Engineering (MP&E) and Electroimpact to certify the LVER to swage collars on titanium pins in composite material. This paper details those results

INTRODUCTION

Over the years LVER technology has been an accepted method for swaging collars on titanium pins and forming aluminum rivets. LVER heads are impulse devices, which derive their power from the discharge of a bank of capacitors through a pancake coil (1). LVER units are currently in production installing bolts and swaging collars in six major aircraft programs around the world. The electronic nature of LVER technology allows precise control and feedback of the forming parameters. With the LVER you have the ability to apply differential force between the head of the bolt and what is applied on the collar. Recent developments in LVER technology have increased the reliability and quality of the LVER bolt installation system. Developments include innovative tooling for collar feeding and swaging. A compliant swaging die has been developed which will self-align to the bolt, eliminating alignment problems between opposing heads.

Not only do composite structures provide advantage in weight and strength, they also reduce the amount of manufacturing required. The one-piece composite fuselage barrel sections eliminate thousands of fasteners as compared to metallic structures. On a metallic fuselage, fasteners are required to attach both longitudinal stringers and to splice panels together to make a complete barrel. For one-piece composite barrels they are eliminated, but circumferential frames still need to be installed. A one-piece barrel adds new challenges due to limited access. Independent outside and inside machines working together are envisioned for attaching the frames and other fittings on the completed barrel. The lightweight and low recoil of LVER systems make them ideally suited for this application.

Boeing partners require approval by Boeing for manufacturing processes utilized in installing fasteners. With this in mind a test program was design to support pre-qualification of the LVER process for the 787 fuselage. Testing has been performed to evaluate the quality of the LVER swaged collars on threaded pins. Preload and ultimate tensile strengths of the LVER installed collars measure well within acceptable ranges as defined by the Boeing specifications. No composite delaminations were found in micro-sectioned coupons ran at voltages necessary to produce the required preload and ultimate loads.

MAIN SECTION

LVER COLLAR QUALIFICATION

LVER systems currently in production install interference fit titanium pins in aluminum materials with aluminum collars. The 787 fuselage calls for clearance fit pins in composite stacks with titanium collars. Along with the weight and manufacturing time saved from the use of composites, Boeing also looked at reducing the number of different fasteners required. Most airplane programs utilize both threaded pins that require nuts and stump lockbolts that require collars. Boeing chose to eliminate the stump type lockbolt and focus on swaging collars onto threaded pins. Swaging collars on threaded pin is not a new process. It has been successfully implemented on other major airplane programs.

Due to time constraints and the limited supply of materials the qualification was divided into three phases. The goal of phase one was to provide data to allow Boeing to tentatively approve the LVER process for swaging titanium collars on threaded pins in composite structures. This would allow partners to pursue acquiring equipment incorporating LVER technology. Phase one would focus on meeting preload/ultimate tensile requirements while confirming no delaminations in the composite laminate.

The second phase would focus on correlating the swage height with amount of preload and ultimate tensile loads achieved. The goal of phase two is to develop swage height limits for the LVER process that produce acceptable loads.

Phase three will evaluate joint strength and confirm Boeing design values.

PHASE 1

Limited numbers of 1/4 and 3/8 inch diameter titanium collars were available for phase one. Initial focus was to determine if any delaminations occur in the graphite material when using the LVER process. Several 3/8" diameter threaded pins were installed in a 0.227/0.227 (.454") composite stack with LVER swaged titanium collars (See figures 1 and 2). Coupons were run on Electroimpact's test bench, which incorporates the latest LVER technology. When swaging with LVER, the force applied to the head side and collar side of the bolt can be set independently of each other. The force applied to each side of the bolt is a function of the voltage level each capacitor bank is charged to. A wide range of voltages along with differential voltage between the headside and collar side were run.

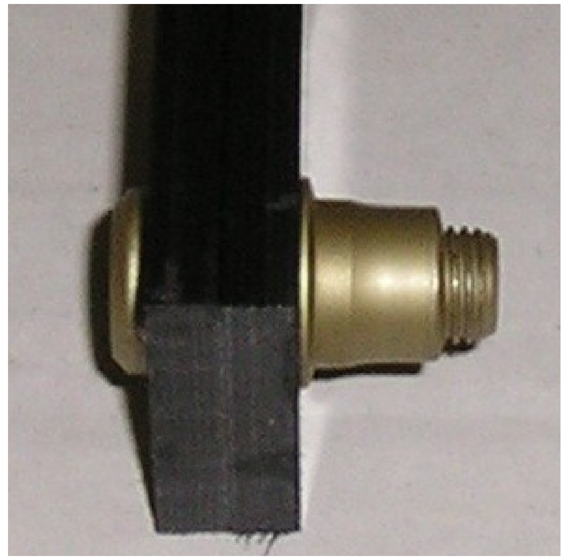


Figure 1 – 3/8 Pin with CT collar in graphite stack.

Figure 2. Tail view of 3/8 pin with CT collar

A selection of bolts with collars were mounted in epoxy resin molds. These molds were sliced down the center with a high precision wafer saw then polished. The polished samples were examined under a precision microscope to check for delaminations (See figure 3 and 4). From a number of iterations testing showed that headside voltage of less than 200 volts resulted in no delaminations. No delaminations were observed on the tail side at any of the voltages.

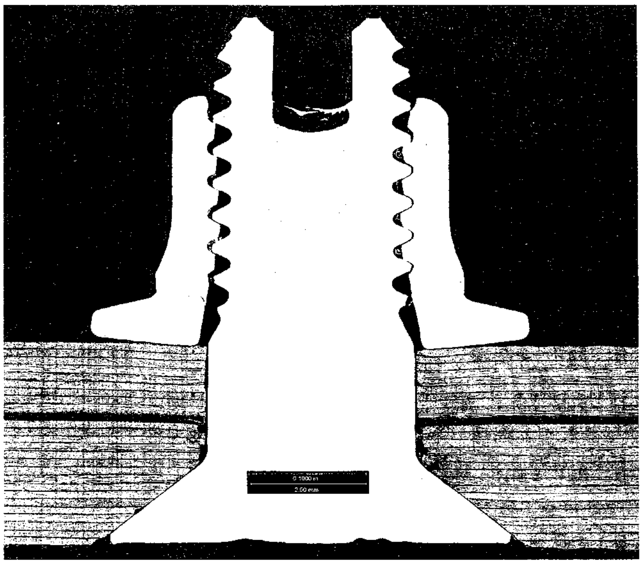


Figure 3. Microsection photo

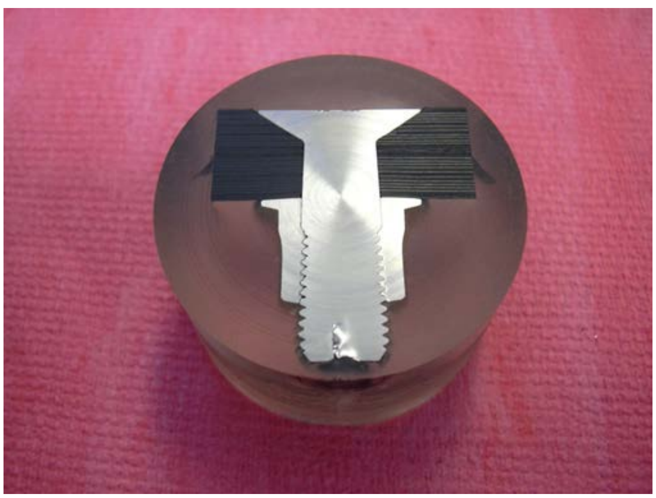


Figure 5 – Sectioned mold

Preload/ultimate tensile spider coupons were fabricated using voltages where there was no risk of delamination (See figure 5). After running a few preload/ultimate tensile coupons it was determined that the highest preloads were achieved with 0 voltage on the headside. For 3/8 bolts a voltage of 340V to 370V on the collar and 0 Volts on the head produced preload and ultimate tensile results that met Boeing desired values. Both countersink and protruding head fasteners were tested.

Figure 5 - Spider Coupon

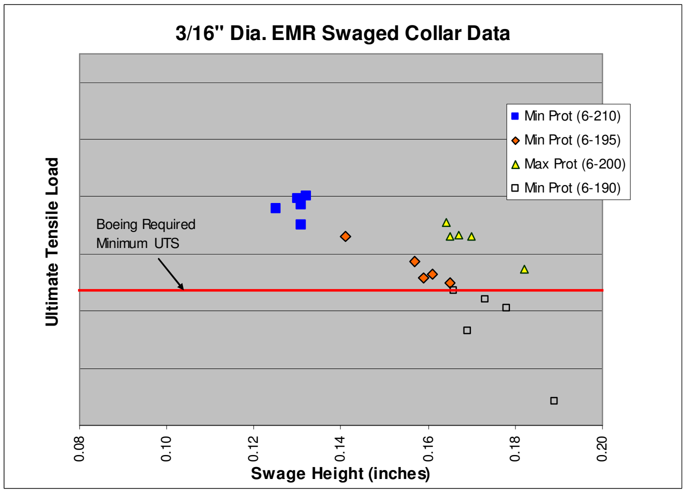
Tests were repeated with 1/4 diameter bolts. No voltage on the headside again produced the highest preload and tensile results. For1/4 bolts a voltage of 245V to 260V on the collar resulted in preloads and tensile loads above the minimum required.

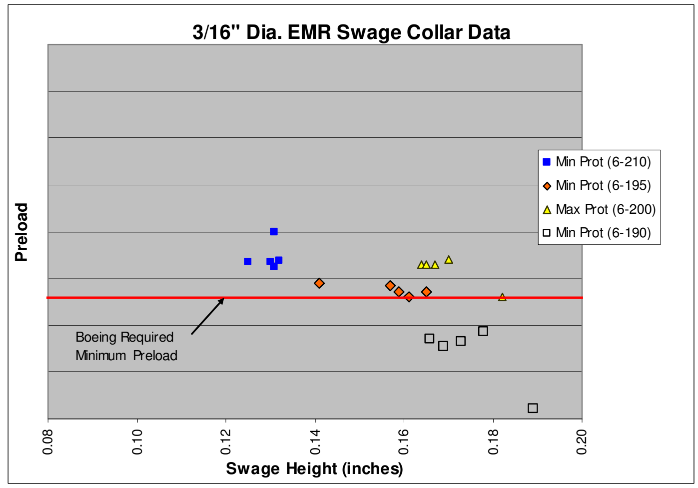
At the end of phase one Boeing issued a statement to the partners reporting that LVER swaging of titanium collars on threaded titanium pins is a viable process for the assembly of graphite structures.

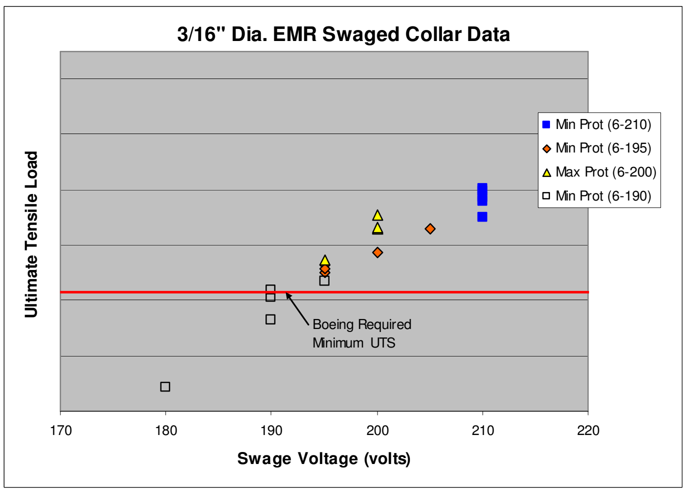
PHASE 2

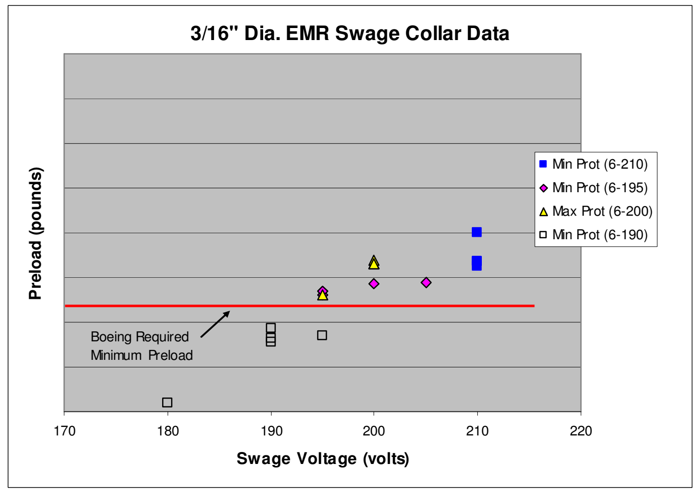
This phase was focused on correlating the swage height with preload and ultimate tensile load achieved. Again, the Electroimpact LVER bench was utilized for forming the collars. The goal was to develop the swage height limits for the Boeing specification. A Go No-Go gage could then be fabricated for production to easily check for proper swage.

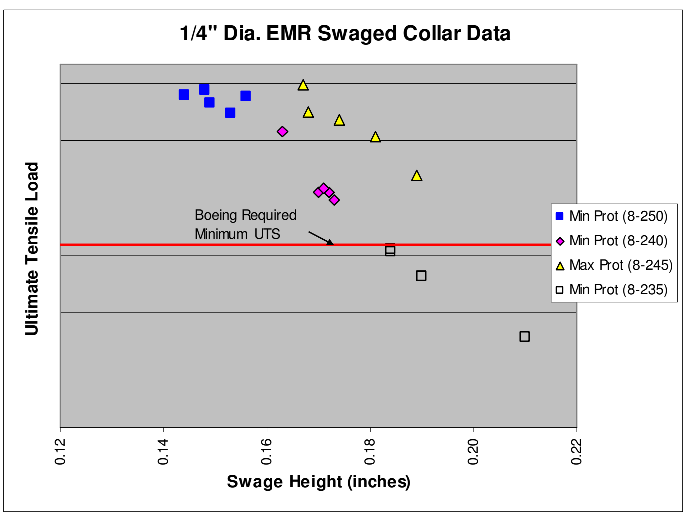
Coupons from 3/16 through 7/16 diameter were completed with various voltage settings. The main purpose was to develop a correlation between swage height and preload and tensile strength and determine the workable range of voltages. Sample data from the 3/16” and ¼” fasteners are presented in attached charts. Results show the process is quite robust and that wide ranges of voltages produce acceptable preload/ultimate tensile loads. Boeing is now in the process of defining the swage height limits for the LVER process.

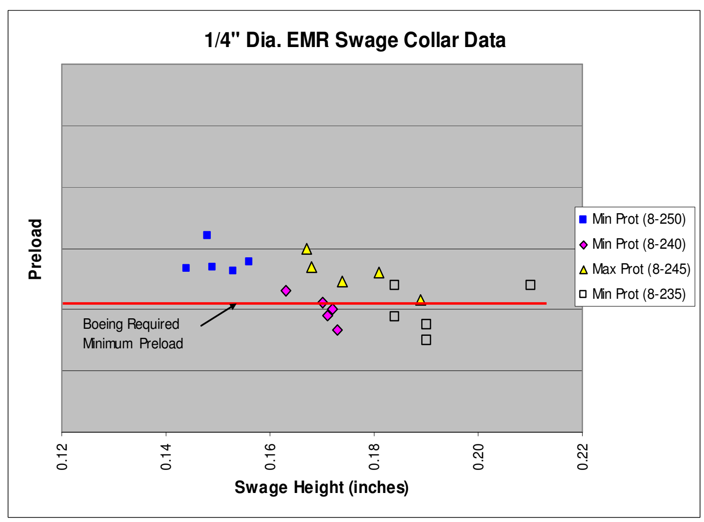












Sample Preload and Tensile data

CONCLUSION

LVER technology is a viable process for installing titanium collars on threaded pins in composite structures. Preload and ultimate tensile are easily achieved without damage to the laminate structure.

ACKNOWLEDGMENTS

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2. Smith, Sam and Potticary, Gary, “Lockbolt Qualification Testing for Wing Panel Assemblies”, SAE Aerofast 2000

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APPENDIX