

The Interference-Fit Bolted Joining of Hybrid Metal/Composite

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ABSTRACT

Joints represent potential weak points in the structure, the design of the overall structure tends to follow from the design of the joint. To date, metal/ composite joints are general in current aircraft structure. Some of the reasons for lower joint efficiency in composites are: brittleness which means little stress relief around the highest loaded holes, anisotropy which leads to higher stress concentration factors, low transverse strength, susceptibility to delamination, and sensitivity to environmental conditions. All of these factors together with the complexity of composite failure modes, make the analysis and design of composite joints far more complex than that of metallic joints. Fatigue failure is the root causes which make aircraft unserviceable. 75-80% of fatigue failures occur in the joints of structure, therefore researching joints is very important for improving aircraft life.

Much effort has been put into solving the technical challenge for composite bolted joints. In this study the interference-fit bolted joining of composite/metal hybrid has been studied. Composite and metal plates were purchased and clipped. Fasteners for interference-fit were manufactured, and the methods of drilling were researched. Composite/metal hybrid joints with different interference were manufactured by electromagnetic riveting technology. Then fatigue test of these joints were carried out. The test results presented in this paper indicated that suitable interference can improve the fatigue life of composite/metal hybrid joints. Interference of 0.5%~1.5% is more suitable for composite joints and 1.5%~2.5% can all improve metal/composite joints fatigue life more than doubled.

KEYWORDS: composite/metal hybrid, interference-fit, bolted joining, sleeve, drilling, electromagnetic riveting, fatigue life

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INTRODUCTION^[1,2,3,4,5,6,7,8,9,10]

Metal/composite joints are seeing an expanded use in the design of aircraft components for variety of applications where the light weight, higher strength and corrosion resistance are primary concerns. In the manufacturing of joints, the key is how to machining fastener holes and realize the needed interference. At same time composite holes are not damaged.

Machining fastener holes in composite material can be quite problematic. While machining ductile materials such as steel or aluminum results in shearing of the material and the formation of consistent chips, machining of composites involves a more complex mechanism with fracture of the fibers under compression or bending combined with shearing of the matrix material. Drilling fastener holes in composite does not compare to the uniformity of aluminum or steel, which can be expected to remain consistent from a drill's entry point to its exit. The most common defects observed in drilled composite holes are fiber fractures, fiber pull-outs,

chipping, drill entry and exit delaminations, voids and pitting. Therefore, machining fastener holes of metal/ composite joints is a challenge.

Bolted joining is usually used in the structure which will be disassembled in the future and transmit high load. In the structure which will not be disassembled in the future and transmit high load, interference fit bolted joining is also be used. Electromagnetic riveting can complete deforming in short time and the shank of bolt expand evenly, which can realize uniform interference along the hole wall, reduce installing damage and improve the fatigue life of joining. Electromagnetic riveting have demonstrated clear advantages in reducing interference fit fastener installation cycle times and increasing component reliability. Usually electromagnetic riveting is used for fastening the structure using large-diameter fasteners and thicker laminates.

Enhanced machining techniques can improve hole's clearance and surface quality. Electromagnetic riveting techniques assure uniform interference value between fastener and hole, reduce installing damage. This paper



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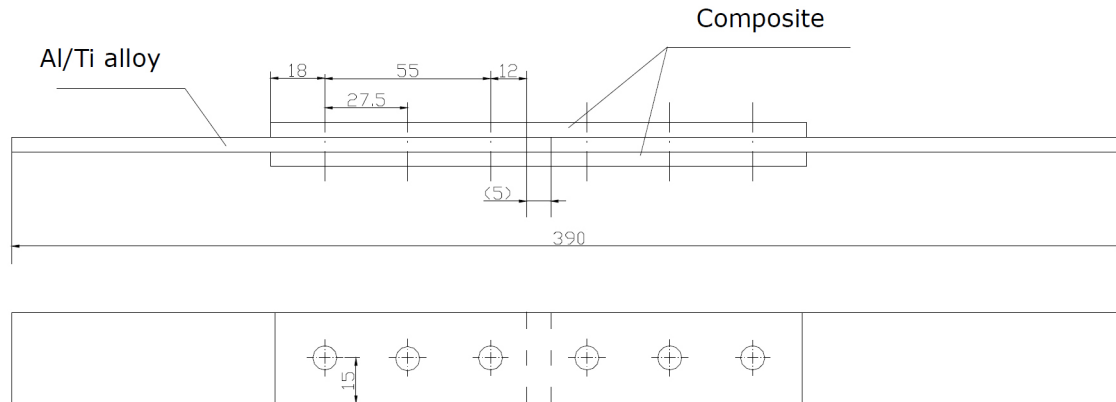


Figure1. Test plates and joints structure

presents joints fatigue test results obtained with bolted interference fit and assembled by electromagnetic riveting.

1. EXPERIMENTAL PROCEDURE

1.1. Material

175×30(length×width) mm composite (T700-12K/QY9511) plates with stacking sequence of $[(-45^\circ/45^\circ/90^\circ/0^\circ)]$ and 190×30(length×width) mm metal plates (TA15/M and 7B04/T74) as shown in [Figure 1](#) were prepared. The thickness of composite, Ti and Al plate, is 4.8, 3.5 and 6.0 mm respectively.

1.2. Fastener

6Al-4V Titanium alloy interference-fit bolt and GH2132 sleeve with flush shear head and diameter of 6mm were manufactured and shown in [figure 2](#), whose surface coating were all solid film lube and cetyl alcohol lube. TC16 Titanium alloy thick self-locking nuts with hexagon head and MJ6×1 thread were purchased. The purchased stainless steel 1Cr18Ni9Ti washers with part number HB1 521 6×12×1 were used.



a) bolt

b) sleeve

Figure2. Interference-fit bolt and sleeve

1.3. Drilling

The accuracy of hole decides the fatigue life of joints. Only when dimension of holes are approximate to theoretical value, bolted joints are not influenced by additional bending

stress and extrusion stress and joints strength cannot be reduced. Roughness of holes is influenced by fish tail, mean value of surface ripple, microhardness of surface, and value of residual stress, etc. Drills leave cutting trace on the inner surface of holes, which reduce joints' strength.

In this paper, joints holes were drilled using carbide twist drills and countersink drills, adaptive drilling and peak_drilling equipment. A backup plate was used at exit side of the plate. The methods of drilling and multiple reaming were applied for machining holes of joints. The metal plate and composite plate were clamped tightly and drilled simultaneously. All the drilling was conducted at a spindle speed of more 5000rpm for composite plate, 1000~3000 rpm for aluminum plate and less 800 rpm for titanium. Chips and debris created during drilling were continually removed using vacuum system. Drills were inspected visually for any noticeable wear or chipping prior to drilling each joints. All the above ensure the quality of holes. After drilling, the fastener holes were cleaned to remove any residual debris. Finally each hole was inspected and measured. Hole dimensions were matched to minimum interference requirements designed. [Table 1](#) lists the hole inspection data obtained from these drilling.

1.4. Assembly

[Figure 3](#) shows the installation sequence of interference bolts. First, machined holes are inspected including holes' dimension and bur of hole margin. Secondly, sleeve is put into qualified hole. Thirdly, thread end of interference bolt is put into sleeve. Fourthly, the head of gun of electromagnetic riveting equipment is put tightly on the head of bolt and riveted. In this test, voltage of riveting gun was adjusted to 2.9KV and bolt was installed by riveting 2~3 times. Fifthly, hi- nut is crewed into bolt. Sixthly, installation is finished until hi- nut break off.