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The structural analysis and strength evaluation of the rivet nut joint for composite repair

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ABSTRACT

Fiber reinforced polymer (FRP) composite laminates have become popular for aero-structures and mechanical parts as they are lighter, stronger and tougher than metals. Damage to composite structures reduces their service life. To improve their service life, the damages needs to be repaired so that their structural integrity can be restored. A rivet nut joint is a prominent technique that is used for composite repair when access to only one side of the component is available.

In this paper, we test and analyze the strengths of various specimens that are repaired using the rivet nut method. Single lap joint specimens with four different w/d (width to diameter) ratios and three e/d (edge to diameter) ratios were manufactured and tested. Tensile tests were performed on the rivet nut joints and their failure modes were evaluated. Additionally, the failure loads of the rivet nut joints were compared to those from using mechanically bolted joints. Finite element analyses of the rivet nut joints were performed and the stresses around the holes were calculated. Finally, the experimental failure modes and loads were compared with those determined from the finite element analyses.

1. Introduction

Fiber reinforced polymer (FRP) composite laminates have become popular for aero-structures and mechanical parts as they are lighter, stronger and tougher than metals. Damage to composite structures reduce their service life. To improve their service life, any damage needs to be repaired so that their structural integrity can be restored. Generally, bolted and bonded patch repair methods are used for repairing damaged composite panels. Several experiments and analyses on repairing composite panels have been previously performed.

Kradinov et al. [1] repaired and tested composite panels using a bolted patch and compared the experiment to analytic results. Her and Shie [2] analyzed a bolted repair of a composite laminate structure based on assumptions for rigid bolts and a compatible deformation between the laminate and patch. Breitzman et al. [3] performed a three-dimensional nonlinear analysis on repair failure predictions and suggested optimal stacking sequences to minimize the von Mises stresses in the adhesive. Xiaoquan et al. [4] carried out experimental and finite element studies to understand the damage propagation and ultimate strength of scarf patch repaired CFRP laminates under a uni-axial tensile load. Kashfuddoja and Ramji [5] studied the optimum patch shape and size for a bonded repair in damaged carbon fiber reinforced polymer panels. Koh et al. [6] used surface-mounted piezoceramic array elements to detect of disbond growth in a cyclically loaded and bonded composite repair patch. Takeda et al. [7] studied debonding monitoring of composite repair patches using embedded small-diameter FBG sensors. A bonded repair is very sensitive to the environmental conditions, [8] and a bolted repair causes stress concentrations and requires accessibility from both sides to complete the repair. A rivet nut joint is a prominent technique that is used for composite repairs and only requires access to one side of a panel.

In this paper, we tested and analyzed the strengths of various specimens repaired using the rivet nut method. Single lap joint specimens with four different w/d (width to diameter) ratios and three e/d (edge to diameter) ratios were manufactured and tested. Tensile tests were performed on the rivet nut joints and their failure modes were evaluated. Additionally, the failure loads for the rivet nut joints were compared with those from mechanically bolted joints. Finite element analyses were performed on the rivet nut joints, and the stresses around the holes were calculated. Finally, the experimental failure modes and loads were compared to those determined from the finite element analyses.

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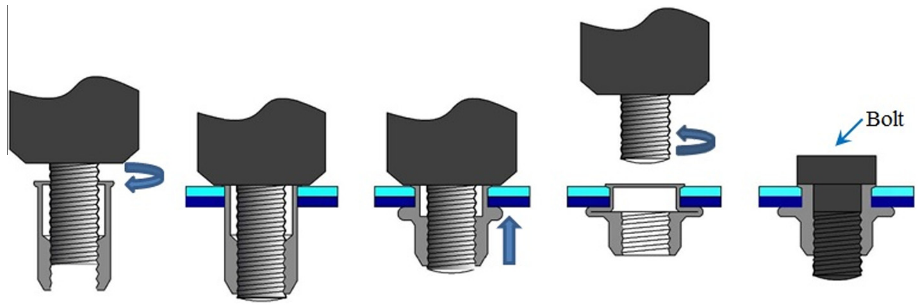

Fig. 1. Schmatic diagram of the rivet nut clamping process.

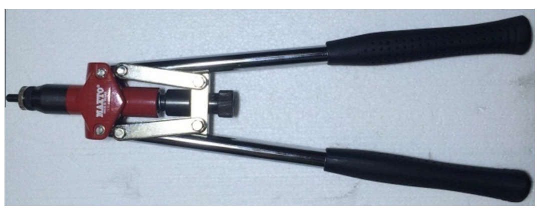

Fig. 2. Rivet nut clamping tool.

Table 1
Dimensions of the rivet nut and bolt joints.

Model	*W* (mm)	*l* (mm)	*t* (mm)	*d* (mm)	*w*/*d*	*e*/*d*
W2–E1.5	20	120	2	10	2	1.5
W3–E1.5	30	120	2	10	3	1.5
W4–E1.5	40	120	2	10	4	1.5
W5–E1.5	50	120	2	10	5	1.5
W3–E2.0	30	120	2	10	3	2.0
W3–E2.5	30	120	2	10	3	2.5
W3–E3.0	30	120	2	10	3	3.0

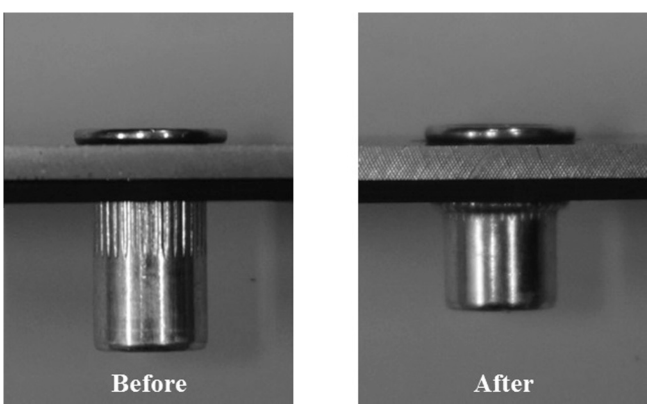

Fig. 3. Photograph of the rivet nut shape before and after the clamping process.

2. Tensile test specimen

Rivet nut joints with four different *w*/*d* ratios and three different *e*/*d* ratios were manufactured and tested in this work. Fig. 1 shows a schematic diagram of the rivet nut clamping process. As shown in Fig. 1, the rivet nut clamping tool is joined with the rivet nut by rotating the knob of the clamping tool. After rotating the knob, the knob of the clamping tool is pulled by the rivet nut clamping tool, as shown in Fig. 2, forming the washerlike shape in the rivet nut. The bolt is inserted to the rivet nut for sealing up the hole of the joint. Fig. 3 shows a photograph of the rivet nut shape before and after the clamping process. Rivet nut and bolt joints with the same geometry were made, and their strengths were compared. Schematic diagrams of the rivet nut and bolt joints are shown in Fig. 4, and the dimensions of the rivet nut and bolt joints are summarized in Table 1. The USN 125 carbon/epoxy uni-directional prepreg from SK Chemical Co. was used for the composite adherends, and their stacking sequence was $[45/-45/0/90/0/45/-45/0]_S$. Table 2 shows the basic material properties for the carbon/epoxy composites. SM45C steel with a thickness of 3 mm was used for the steel adherend and the heat treated commercial wrench bolt. The yield and ultimate strengths for these components were 1100 MPa and 1200 MPa, respectively. Additionally, commercial non-heat treated rivet nuts from JFASTENER Co. (yield strength = 205 MPa) were used. The tensile stress–strain curve for the rivet nut is shown in Fig. 5.

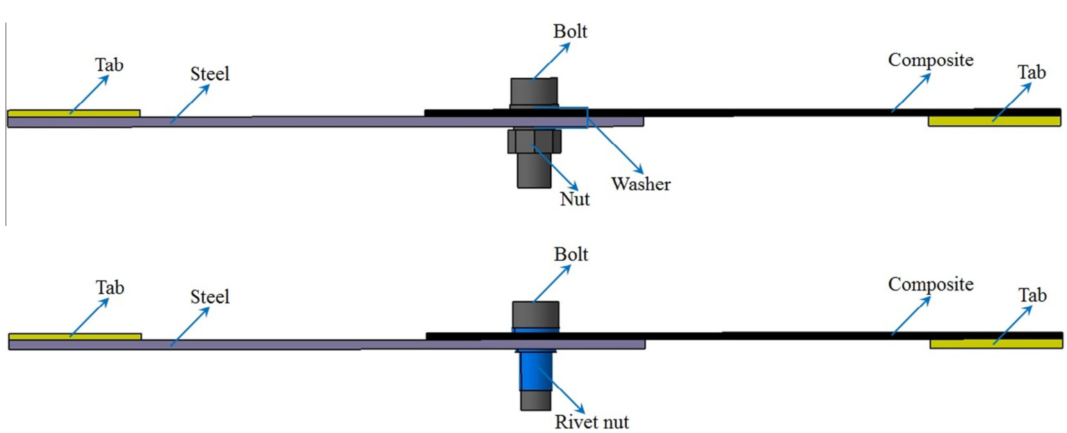

Fig. 4. Schematic diagrams of the rivet nut and bolt joints.