Leave as it is.

Parametric study for optimal design of rivet jointed composite plates considering interference fit

Tae Ho Yoon*, Seung Jo Kim [Tae Ho Yoon]: auseyoon@aeroguy.snu.ac.kr**

***School of Mechanical and Aerospace Engineering, Seoul National University, Korea**
****Flight Vehicle Research Center and School of Mechanical and Aerospace Engineering, Seoul National University, Korea**

Keywords: *Countersunk rivet, Composite plate, Interference fit, Finite element*

1 Introduction

The usage of composite materials in aerospace structures has been increased steadily due to the higher stiffness and strength per weight. However, one of the disadvantages of composite materials used in aircraft structures is the joint of neighboring parts. There are many mechanical fasteners such as pins, bolts, and rivets in a fuselage and wing skins of aircrafts using composite materials. These joints are needed to connect other composite parts with different materials and various geometries in aerospace structures, but the hole of rivet or bolt joints sometimes become the starting point of the serious cracks. Therefore it has been doing a lot of research literatures on the behavior of a bolt or rivet jointed composite plates.

Recently, the study on bolted joints with a metal or composite plate was concentrated by the BOJCAS project [1]. Whereas a parameter study of rivet jointed aluminum alloy considering fatigue was examined through three dimensional simple meshes modeling by C-P Fung [2]. And, simulation of the cold expansion of a rivet jointed metallic material was dealt [3]. These rivet researches were all done just by using a homogenized model. But there were not yet many researches in the joint with composite materials because it may be easy to failure when a rivet was been fixing. As one of these researches, the rivet joint considering the geometric parameter of an interference fit was experimented by using EMR equipment for a fatigue life enhancement [4]. In these days, there is actively doing many researches related rivet jointed composite materials about airplane for fatigue enhancement.

In this paper, the refined analysis of the countersunk rivet jointed composite plates was performed by considering the effects of parameters such as the angle degree of a countersunk rivet head, an clearance, a riveting force, and a washer dimension, etc. The countersunk rivet jointed composite plates are modeled by using the three dimensional finite elements considering three dimensional geometrical features of the countersunk rivet. These models were analyzed by using LS-DYNA3D with parallel processing. Refined mesh was used to describe the stress concentration effects during riveting. Using this refined model, the detailed stress distributions at the critical area around the rivet hole due to the structural behaviors from a tension loading are also presented. As a result, the parameter studies include a friction coefficient, a laminated sequence, a clearance, the degree of a rivet head, and a washer dimension. So it can be shown that the models considering parameters for optimal design are important for predicting effective structural behaviors of a rivet jointed composite plates.

2 Modeling of rivet jointed composite plates

2.1 Rivet joint configuration

The geometry dimension of a rivet jointed composite plates is shown in Fig. 1. We measured rivet shaft directional location around hole most serious area of stress concentration or starting point of crack propagation due to interference effect. Composite plates, manufactured from composite material of the carbon-epoxy pre-preg material system AS4/8552 with nominal fiber volume fraction 63.5%, were basically used and the countersunk rivet and washer are considered as being made of Titanum [3]. The hole diameter was 4.4 mm, inner diameter of washer size is 4.1mm, outer diameter is 8.2mm, respectively. The elastic properties of the material constituents, the uni-

directional lamina and the quasi-isotropic laminate stacking sequence $[\pm 45/0/90]_{4s}$ using 0.13 mm thick are given in Table 1. The thickness (t) was approximately 3.12 mm with 32 plies.

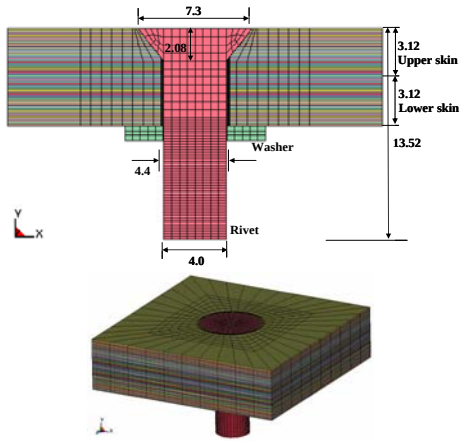

Fig. 1. Countersunk rivet jointed composite plates

Table. 1. Elastic properties of materials and their constituents [1]

Material	E_{11} (GPa)	E_{22} (GPa)	E_{33} (GPa)	G_{12} (GPa)	G_{13} (GPa)	G_{23} (GPa)	ν_{12}	ν_{13}	ν_{32}
Fiber	238	-	-	22	-	-	0.2	-	-
Matrix	3.3	-	-	1.2	-	-	0.35	-	-
Lamina	140	10	10	5.2	5.2	3.9	0.3	0.3	0.5
Titanium	110	-	-	-	-	-	0.29	-	-

2.6 Relative interference fit

The relative interference is measured by the following formula (1) [4]:

$$Relative\ interference = \frac{D - D_0}{D_0}(\%) \qquad (1)$$

Where D is the diameter of deformed shaft, D_0 is the initial diameter of aperture.

3 Parametric studies

Interference effect from parameters of a riveting force, rivet geometry, and a washer dimension on countersink rivet jointed composite plates was considered. As see in the Fig. 2, the influence of coefficient was considered by using the LS-DYNA3D to this analysis. Also, effects of a clearance were examined and compared to previous experimental data [4].

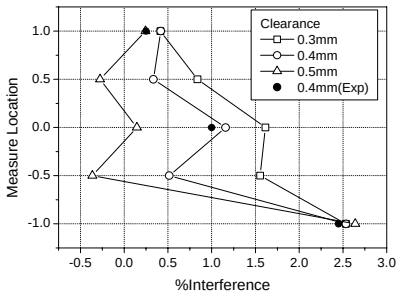

Fig. 2. Interference with clearance effect

4 Conclusions

Through the three dimensional finite element modeling of one countersunk rivet jointed composite plates using the refined model, local stress concentration effects, which are important to expect a local crack, on the hole of a rivet jointed composite plates was examined. Also, the parameter studies for optimal design of rivet jointed composite plates were considered, which is about a riveting force, a clearance, and a washer dimension. We founded there are many conditions of various parameter to consider proper in rivet jointed composite plates for fatigue life expansion and service life prolongation. After, we will consider other parameters such as a laminate sequence, the material property of a rivet and a washer, and a friction coefficient considering an interference effect for an efficient riveted lap joint. As a result, these parametric results can be useful for a rivet jointed composite plates design as a basic reference.

References

[1] Johan Ekh, Hoakim Schon: Load transfer in multirow, single shear, composite-to-aluminum lap joints, *Composite Science and Technology* 66 (2005), pp.875-885.

[2] C-P Fung and J Smart : Riveted single lap joints. Part 1: a numerical parametric study, *Proc. Instn Mech. Engrs*, Vol 211 Part G (1997), pp.13-27.

[3] P.F.P. de Matos, P.M.G.P. Moreira, P.P. Camanho, P.M.S.T. de Castro: Numerical simulation of cold working of rivet holes, *Finite Elements in Analysis and Design* 41 (2005), pp.989-1007.

[4] Zengqiang Cao, M. Cardew-Hall: Interference-fit riveting technique in fiber composite laminates, *Aerospace Science and Technology*, 10 (2006), pp. 327-330.