Structure responses in the riveted and the friction stir welded stringer panel under the tensile loading

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Abstract In this paper, applications of friction stir welding in the integral fuselage structure are studied. In order to compare with the traditional riveted stringer panel, the integral panels are joined by two ways: one is by single-row rivets and the other one is by friction stir welding. Two kind finite element models are built by Abaqus 6.10. Stress distributions are analyzed and compared. For welded panel, a FORTRAN program of the SIGINI subroutine is made to input the residual stress profile to the finite element model of friction stir welded panel. Compared with the rivet joint, friction stir welded joint can reduce the weight of fuselage. In the same applied stress, the sample joint with rivets has the higher stress areas around the rivet hole, the sample joint with friction stir welding avoids the stress concentration in junctions.

Keywords Friction stir weld; riveted stringer panel; welded panel; stress distribution.

1. Introduction

Friction stir welding (FSW) is a solid state welding process that has received the world wide attention, particularly for joining aluminum alloys. Because FSW has a lower heat input than the traditional fusion welding, the plastic shrinkage of joint induced by heat in FSW is also lower, which will help to reduce the welding residual stress and distortion of structure. Consequently, FSW has been widely used in modern aero structures.

A significant amount of work has been conducted in the past few years to understand the properties of friction stir welding joints. Aidy studied the crack coalescence in 2024-T351 Al alloy friction stir welded joints and discussed the fatigue endurance of FSW joint [1]. Zhang established the two-dimensional numerical models of friction stir welding and gave the numerical simulation of FSW process [2]. Dinaharan studied the effect of friction stir welding on microstructure, mechanical and wear properties of AA6061/ZrB_2 [3]. Xu studied the residual stress in thick aluminum friction stir welded butt joints [4].

2. Numerical Simulation

2.1 Parameters settings

Finite element analysis is run by Abaqus 6.10. The riveted stringer panel and the welded panel are of the same size (shown in Fig.1). The length of the panel is 1113mm, the width in the middle is 200mm and in both ends is 288mm, and the thickness is 2mm. There are three rows of rivet hole along the direction of the riveted stringer panel width, one of which is located in the middle and the other two rows are located on both sides, 150 mm from the middle rivet holes. Three stringers (shown in Fig.2) will be fixed on the panel by 30 rivets. The width of the surface of the stringer which contacts with the panel is 28mm, the height of the stringer is 28mm, and the thickness is always 2mm in every part of the stringer. The material of panel and stringers is aluminum-lithium alloy, the Young’s modulus is 77000 and the Poisson’s ratio is 0.33. The material of rivet is 45 steel; two parameters are 210000 and 0.269. Welded panel is joined by welding instead riveting to joint panel and stringers, and the size of the welded panel are the same with the riveted stringer panel except using 10 mm width weld zone to replace the three rows of rivet hole. The material parameters in the weld zone are 55000 and 0.33. After assembly, contact surface between different parts of the panel has been set up. In the riveted stringer panel, each group of mutually contacting surface are defined as an contact pair, then four contact pairs in the riveted stringer panel were built. In the welded panel, the constraint tie were set up to characterize the welded areas in panel and stringers, other contact areas were defined as contact pairs in same parameters with riveted stringer panel.

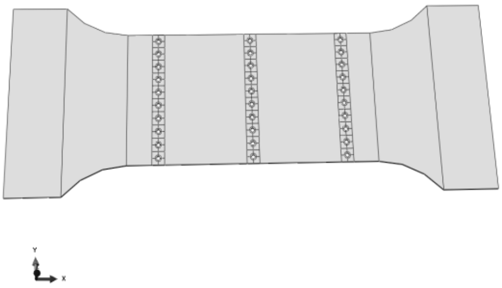

Fig.1 Riveted stringer panel

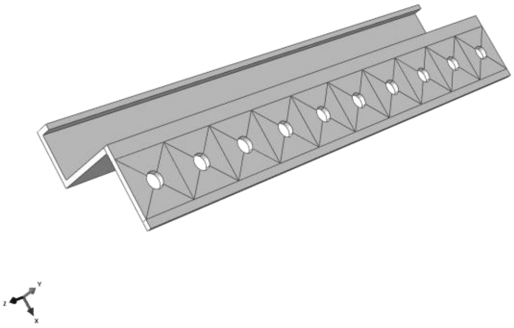

Fig.2 Stringer

2.2 Mesh

Reasonable mesh of complex structure need appropriate partition (Fig.1 illustrates the partition of each part of this panel). In order to get a more accurate calculation result, the rivet must be meshed carefully. The areas around the rivet holes are critical areas where stress concentrate will emerge in tensile load, so these areas also need meticulous grid. Based on this principle, the panel were meshed carefully (shown in Fig.3). Mesh of the welded panel is easier because there is no rivet in welded model.

2.3 Loads

The same load is applied to the two models. 200MPa tensile pressure is loaded along the x direction, in addition, a FORTRAN program of the SIGINI subroutine is made to input the residual stress profile to the finite element model of friction stir welded panel before tensile pressure is loaded.

2.4 Results

Fig.4 shows the numerical simulation result of riveted stringer panel, the high stress areas appears around the rivet holes (especially the middle row) and the curved areas on both sides, the stress in stringers is lower compare with the panel. The maximum stress around the rivet holes reaches more than 600MPa (exceed the ultimate strength of the material) and the stress in the curved areas reaches from 400MPa to 500MPa (shown in Table.1), stress in other areas is much lower than these areas. So the rivets connection areas on the panel may be the first to be destroyed in proper tensile load.

Fig.5 shows the numerical simulation result of welded panel, the high stress areas appears in the top of the welded areas and the curved areas on both sides, stringers are also the low stress areas. The maximum stress in the curved areas is nearly 400MPa, a little higher than 350MPa in the top of the welded areas, however, the tensile strength of the welded area is much lower than the base material (about 70% of the base material), and so the welded areas will be weak zone.

After comparison of the results of two different models show in Table 1, under the same tensile load， stress profile in welded panel is uniform and much lower than it in riveted stringer panel, so we can predict that the welded panel could withstand the larger tensile load than riveted stringer panel.

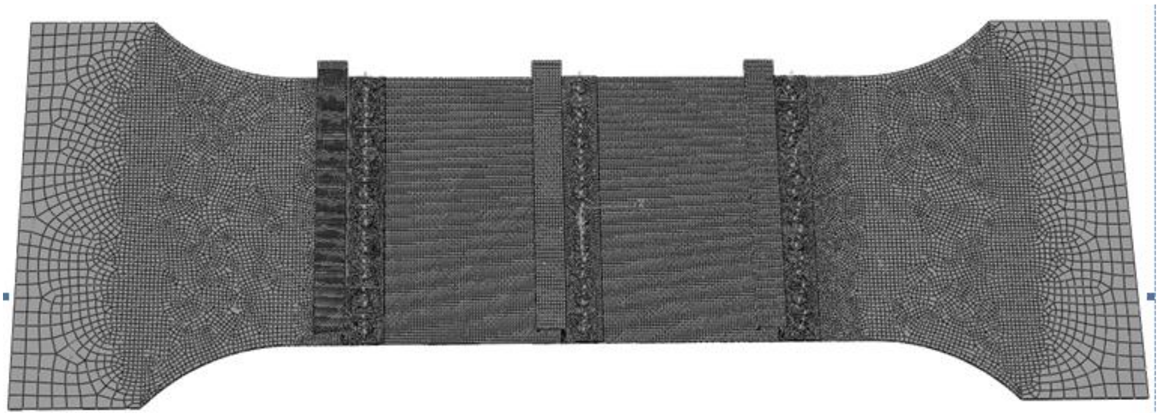

Fig.3 Mesh of riveted stringer panel

Table.1 Comparison of stress

Stress in Riveted panel (MPa)			Stress in Welded Panel (MPa)		
Panel	Around Holes	Stringers	Panel	Welded Areas	Stringers
<300	>600	<100	<300	200~400	<200

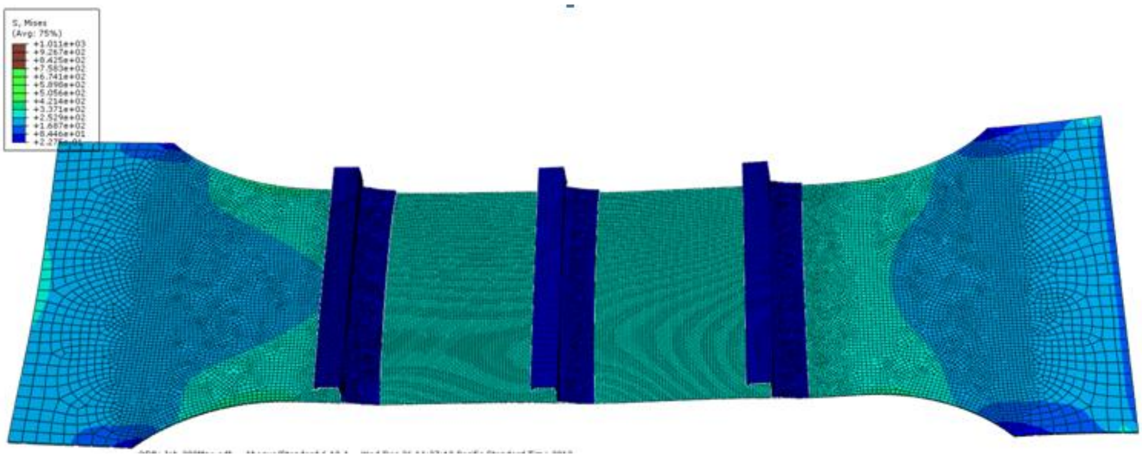

Fig.4 Riveted stringer panel

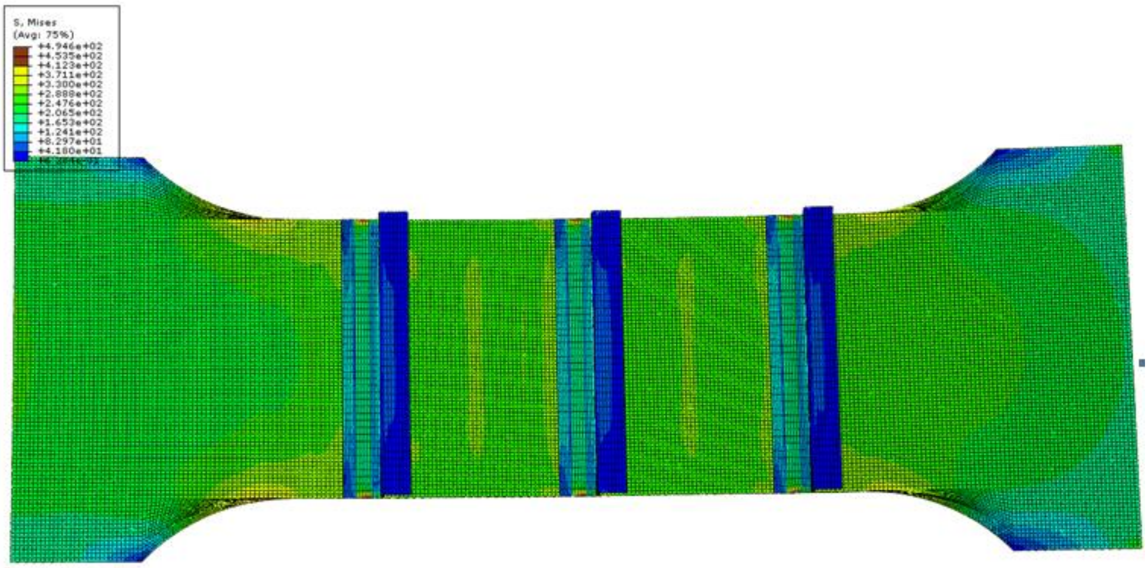

Fig.5 Welded panel

3. Comparison with the Test Results.

Tests were performed to compare this two kinds of structures in tensile load. Six panels consist of three riveted stringer panels and three welded panels were tested by MTS, and the results are shown in Table.2. Two of riveted stringer panels were destroyed in rivet holes on one side and the other one is destroyed in the middle row of rivet holes, the welded panels are all destroyed in welded areas. These results can be used as validation of the numerical simulation.

Table.2 Testing and simulation results

			Simulation Result
	Number	Failure Position	High Stress Area
Riveted panel	1	Left holes	Around holes
	2	Left holes	
	3	Middle holes	
Welded panel	1	Left weld	Welded areas
	2	Middle weld	
	3	Middle weld	

4. Summary

In this study, the main conclusions are

(1) A more uniform stress distribution in welded panel than riveted stringer panel under the same applied stress, the sample joint with friction stir welding avoids the stress concentration in junctions.

(2) The tensile strength of welded structure is higher than riveted stringer structure in certain situation.

References

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