Parametric studies on the channel type tension fitting in aircraft

SHWETHA JAIN
Dept. of Civil Engineering, The Oxford College of Engineering
Bangalore, Karnataka State, India
shwethajainjinesh@gmail.com
http://www.theoxford.edu/

AMARNATH K
Prof. and Head, Dept. of Civil Engineering, the Oxford College of Engineering
Bangalore, Karnataka, India
sri.valuers@gmail.com
http://www.theoxford.edu/

SUBRAMANYA SASTRY SS
AGM (Tech), Engineering Vertical, Infotech Enterprises Limited
Hyderabad, Karnataka, India
Subramanya.Sastry@Infotech-Enterprises.com
http://Infotech-Enterprises.com

Abstract:

Tension Fittings are commonly classified into four types. They are Bathtub fitting, Channel fitting, Angle fitting, 'PI' fitting and Double angle fitting. Tension fittings are conservatively sized as their weight is usually small relative to their importance. In this paper two analysis methods of Channel fitting are compared. Simplified method of approach to the design of channel fitting is studied in detail with respect to various parameters affecting the design. Margin of safety is calculated using two methods and compared. The two methods are compared and contrasted for their results prediction. Aluminum alloy 7050-T7452 is selected for the study.

Keywords: Tension fittings, Channel fittings and Angle Fittings

I. INTRODUCTION

A tension fittings are one in which the bolt is loaded primarily in tension and they are used in the various applications like removable wing root joints of fighter wings, wing root joints at the four corners of the wing box, circumferential production joints on assemblies of fuselage sections, axial load transfer of the fuselage stringer by using tension bolt to go through major bulkhead web rather than by cutting a large hole in the web and back-up fittings for support pylons, flap track etc., which have to go through wing box [1].

Since the state of stress in a tension fitting is very complex, conventional structural analysis is extremely difficult to obtain with reasonable results. The methods used in this paper have rational basis and give loads agreeing well with available test data [2]. A fitting factor of 1.15 [1 2] is applied in the analysis while calculating the margin of safety. The analysis will show a minimum margin of safety of greater than 0.2 [1 2]. This condition is demonstrated for both yield and ultimate conditions. Eccentricity of the load is inevitable because of the shape of the fitting and various ruling dimensions. But the resulting stresses are kept to a minimum to give the required margin of safety. A minimum edge distance of 2.5D and pitch of 6D is considered in the present study. In this paper, diameter of the rivets is kept to a minimum and only fitting wall thickness is considered as the variable parameter.

II. ANALYTICAL MODELING

The various parameters of the channel fitting under study are described below.

Type of the fitting: Channel Fitting
Diameter of bolt: 0.562 in (14.27 mm)
Diameter of rivet: 0.15625 in (3.97 mm)
Size of the fitting: 2 inch by 2 inch by 4.5 in (50.8 mm * 50.8 mm * 101.6 mm)
Ultimate load: 30 Kips (133.476 KN)

A list of parameters used in this study is provided below.

P_{ult} – Ultimate load on the fitting
MS – Margin of Safety
t_a - Fitting wall thickness
t_b - Fitting web thickness
t_c - Fitting end thickness
A_g – Gross area of web
A_n – Net area of web
λ – Fitting Factor (1.15)
Pad end – Load application end connected to the load bearing and dissipating member of aircraft
Wall end – End of the outstanding leg of the channel fitting connected to the backup structure
Web end – Web end of the channel fitting connected to the backup structure

A typical representation of the channel fitting under study is shown in Fig. 1.

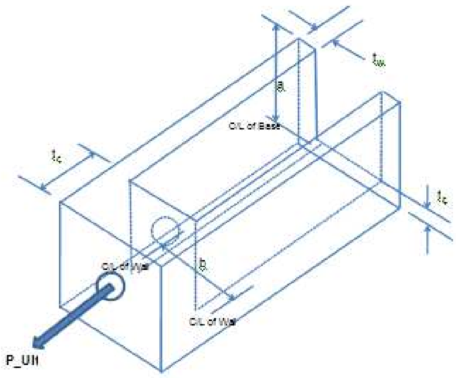

Fig.1: Pictorial view of channel fitting under study

III. LOADS AND BOUNDARY CONDITIONS

The channel fitting under study is assumed to be connected firmly to the backup structure using Titanium rivets (Ti-6Al-4V).

The loading on the beam is assumed in the form of a bolt load (numerical value is given under Section 2). This bolt load is a typical characteristic load of a class of channel fittings in fighter planes.

IV. MATERIALS

The materials used in channel fitting under study are as follows.

1. Fitting: Aluminium alloy 7050-T7452 (Hand Forging, AMS 4108)
2. Bolt: Alloy steel (F_{su} = 95 Ksi)
3. Washer: Steel

V. ANALYSIS

Design of Fitting wall

1. As a first step, the channel fitting is made of a ductile material (Aluminium, 7050-T7452).
2. Check the channel fitting for limitation on dimensions.
3. Determine the tension on the fitting wall using the relation $f_{ta} = (P/A_n)$, where P is the ultimate load and A_n is the net tension area.
4. Calculate the moment of inertia, centre of gravity of the channel section.
5. Determine the eccentricities of the load from the centre of gravity of the channel section.
6. Calculate the moment of the load due to the effect of eccentricity on the wall end and web end of the channel fitting.
7. Calculate the bending tensile stress (f_{nx}, f_{ny}) in the wall using the moment and moment of inertia of the fitting.
8. Calculate the total maximum tension stress as $f_{tu} = f_{ta} + f_{nx} + f_{ny}$.
9. Calculate margin of safety for ultimate load, MS = (Ftu/λ*ftu)-1 > 0.20, where λ is the fitting factor (1.15)
10. Check all fasteners between fitting and attached member for failure against shear, tension and shear tension interaction modes of failure.

Design of Fitting end

1. Bending: Compute the ultimate bending stress in the fitting end, $f_{bu} = (k_c*P/t_c^2)$. This bending stress is function of the aspect ratio of the fitting (a/b).
2. Calculate the margin safety and make sure that it's value is greater than 0.2 after using a fitting factor of 1.15.
3. Calculate the ultimate shear stress through the bolt hole, $f_{su} = (P/0.6\pi D_{w,o}t_c)$.
4. Calculate the margin of safety using the formula, $MS = (F_{su}/\lambda f_{su})-1 > 0.2$.

Exact Method

The exact method [2] differs from the approximate method as given below.

1. Use of tension efficiency factor to account for the uniform and staggered rivet pattern in determining the wall tension stress ratio.
2. Calculation of wall tension and bending stress ratio and interaction between the tension and bending.
3. Effect of stress concentration factor on allowable bending stress.

The margin of safety is computed using the exact method and compared with the results of approximate method.

VI. RESULTS AND DISCUSSIONS

The results are presented in the form of graphs and tables. Table 1 and 2 show the margin of safety obtained for the Aluminium alloy 7050-T7452 under study. Table 3 shows the comparison of results between the approximate and exact methods. Figures 2 shows the variation of Margin of safety near the web end of channel fitting with the change in thickness of fitting wall. Figures 3 shows the variation of Margin of safety near the wall end of channel fitting with the thickness of fitting wall. Figures 4 shows the variation of

Margin of safety near the pad end of channel fitting with the thickness of fitting wall. Figures 5 shows the variation of Margin of safety for shear through bolt hole of channel fitting.

Table 1: Table of stress in the channel fitting

Fitting wall thickness, ta, in	Bending stress near web of fitting (ksi)	Bending stress near wall end of fitting (ksi)	Total stress near web of fitting (ksi)	Total stress near wall end of fitting (ksi)
0.15	17.94	35.89	58.02	75.97
0.16	16.69	32.11	55.37	70.79
0.17	15.55	28.88	52.92	66.24
0.22	11.14	17.91	43.09	49.87

Table 2: Table of margin of safety at various location of the channel fitting

Comparison of approximate and exact solutions				
Sl. No.	Description	Approx. Method	Exact Method	Percentage difference
1	Gross area (sq.in)	1.15	1.15	0.00
2	Location of C.G. from wall end (inch)	0.76	0.79	3.17
3	Tension Efficiency Factor	N/A	0.82	N/A
4	Bending-Tension interaction	N/A	0.3577	N/A
5	Stress in wall (ksi)	26.20	26.20	0.00
6	Stress in end pad (ksi)	48.38	63.86	24.24

Table 3: Table of comparison of various results between approximate and exact methods

Comparison of approximate and exact solutions				
Sl. No.	Description	Approx. Method	Exact Method	Percentage difference
1	Gross area (sq.in)	1.15	1.15	0.00
2	Location of C.G. from wall end (inch)	0.76	0.79	3.17
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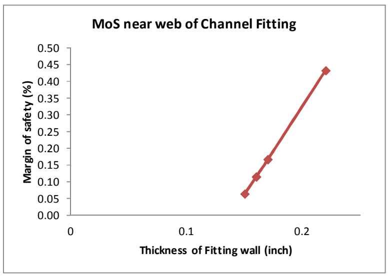

Fig. 2: Margin of safety near the web of channel fitting

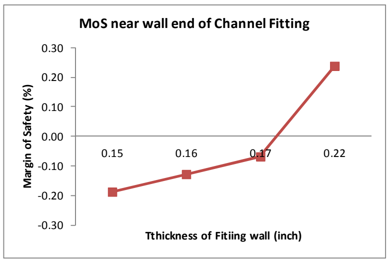

Fig. 3: Margin of safety near the wall end of channel fitting

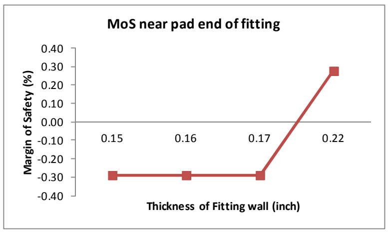

Fig. 4: Margin of safety near the pad end of channel fitting

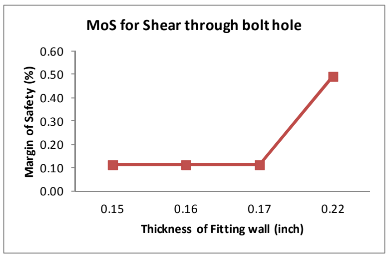

Fig. 5: Margin of safety for shear through bolt hole of channel fitting

The detailed study of results is presented below.

1. The study is presented for a channel fitting of cross section 2 inch * 2 inch (50.8 mm).
2. From Table 1, it is observed that as thickness of the wall of the fitting increases by 46.67%, bending stress near the web end of the fitting decreases by 37.9%.
3. From Table 1, it is observed that as thickness of the wall of the fitting increases by 46.67%, bending stress near the wall end of the fitting decreases by 50.1%.
4. From Table 1, it is observed that as thickness of the wall of the fitting increases by 46.67%, total stress near the web end of the fitting decreases by 25.73%.
5. From Table 1, it is observed that as thickness of the wall of the fitting increases by 46.67%, total stress near the wall end of the fitting decreases by 34.35%.
6. From Table 2, it is observed that that as thickness of the wall of the fitting increases by 46.67%, margin of safety near web end of fitting increases by 43% while it increases by only 24% from a negative margin.

7. From Table 2, it is observed that that as thickness of the wall of the fitting increases by 46.67%, there is no improvement in the margin of safety in the rivets because it is independent of the wall thickness or web thickness. It is single shear value of the rivet and is governed by the diameter of the rivet rather than on the thickness of web or wall in bearing.
8. From Table 2, it is observed that that as thickness of the wall of the fitting increases by 46.67%, margin of safety for bending at the fitting end increases from -29% to 28%.
9. From Table 2, it is observed that that as thickness of the wall of the fitting increases by 46.67%, margin of safety for shear through bolt hole increases by 3.45 times the original value.
10. Table 3 shows a comparison of the results obtained from the approximate and exact methods. The difference in the various computed quantities is indicated in percentage for comparison purposes.

VII. CONCLUSIONS

1. Approximate method doesn't take into consideration the reduction in efficiency of the channel fitting due to the presence of rivet holes.
2. Approximate method doesn't take into consideration the effect of bending-tension interaction in the channel fitting.
3. Approximate method under predicts the stress in the end pad by 24.24% as compared to the exact method.

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