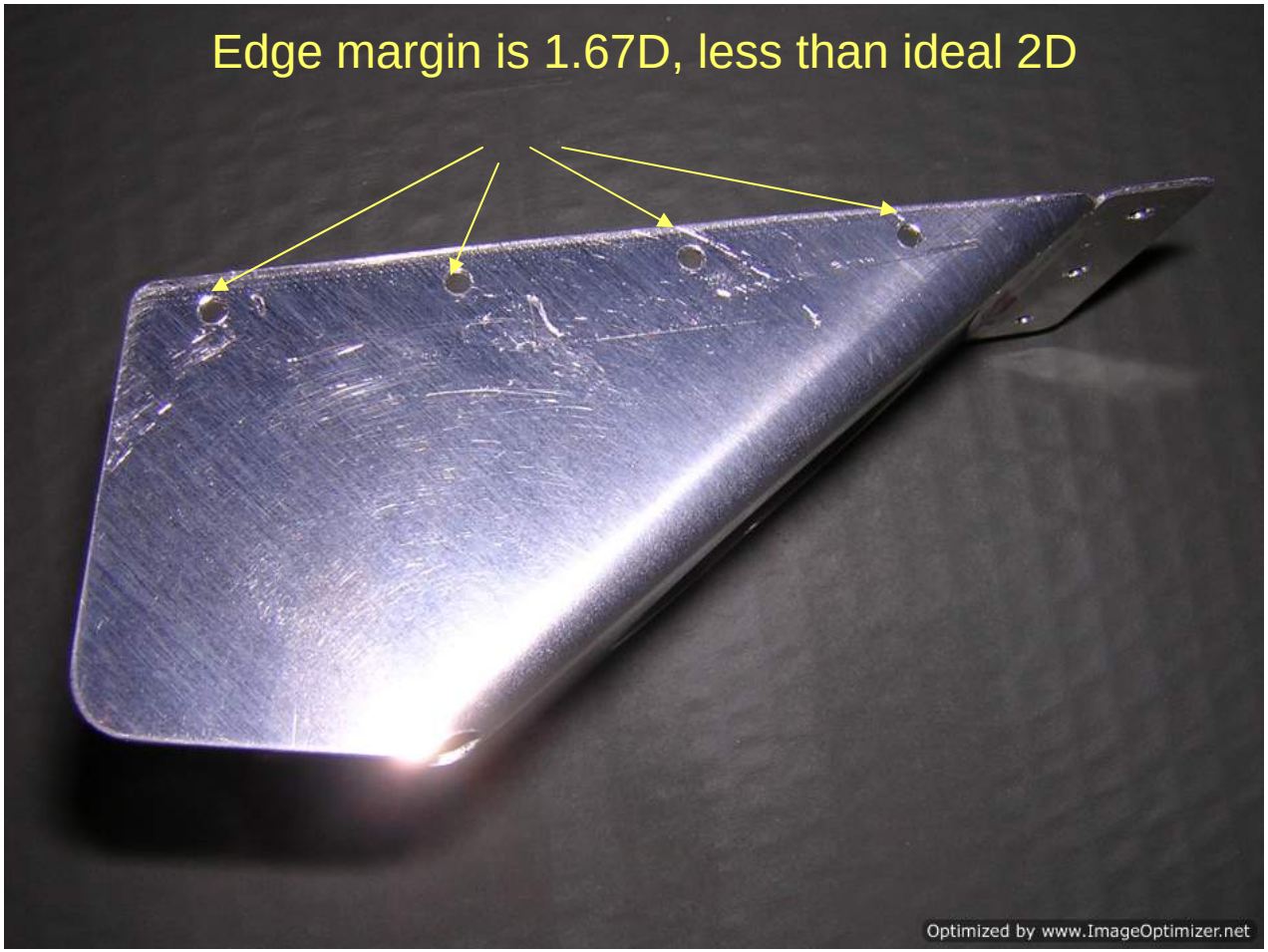
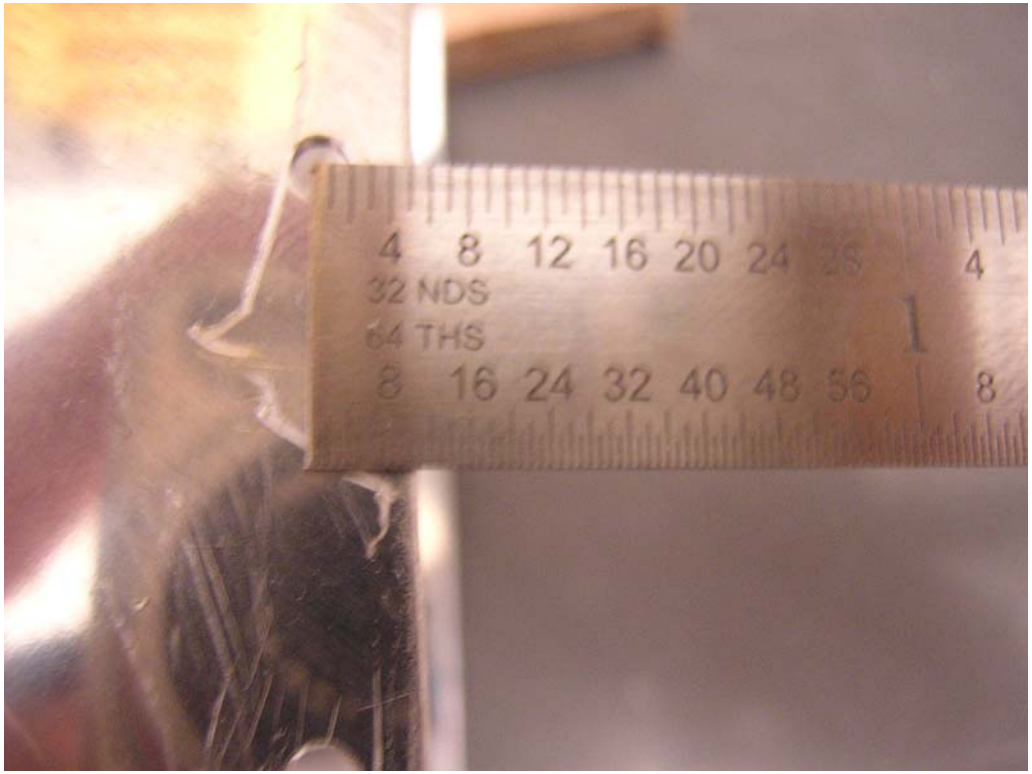
Issue: Edge margin on rudder horn brace R-710, Build date: 05-09-2011





Hole size: 3/32
Ideal EM: 2D=6/32
Actual EM = (5/32)/(3/32)=1.7

Horn brace material:
2024-T3 clad sheet, t=0.032”

Analysis:

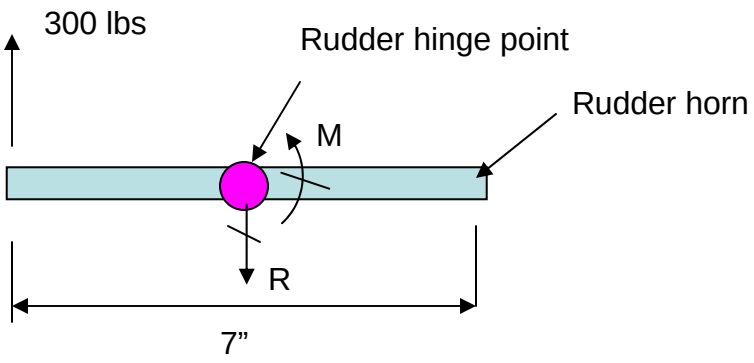
Load:
The purpose of the brace is to help transfer the moment on the rudder surface. The aerodynamic load is normally small for the rudder. The maximum load on the rudder will be limited by the force can be produced by pilot (FAR 23.395)

The pilot limit load for rudder with dual control system can be calculated below, with a 1.25 factor included

Max pilot force = 300 lbs (FAR 25.397 c)

Because the rudder control is a simple pull-pull cable system, the pilot force is the same as the force applied on the rudder horn

Free body diagram for Rudder Horn:



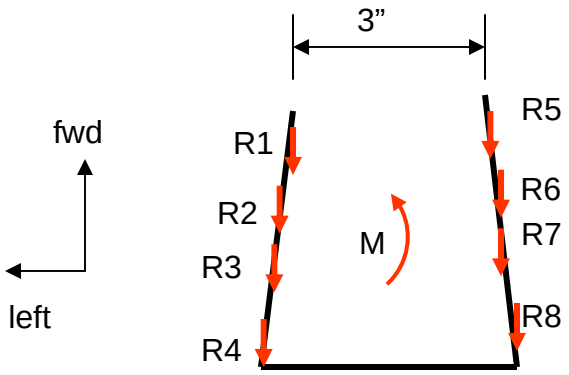
Max moment to be balance:

M= 300*3.5= 1050 in-lbs

Conservatively assuming this moment is carried to rudder structure 100% by the brace

Analysis (Continued):

Static strength check:



Shear load at rivets:
R1=R2= … = R8 = 1050/3/4 = 88 lbs

The joint allowable for rivet with 2D edge margin:
Rivet diameter = 0.0938”
Rivet Material = 2117-T3
Rivet Type: flush head
Joint material and thickness: 2024-T3, 0.032”, machine countersunk

Joint single shear allowable (Rm Temp) = 178 lbs
Rivet shear strength = 207 lbs

So the joint strength is limited by the shear out, a reduction factor for short edge margin should be included in the calculation

Reduction factor for E/D=1.7 (from E/D =2) is about 1.7/2=0.85

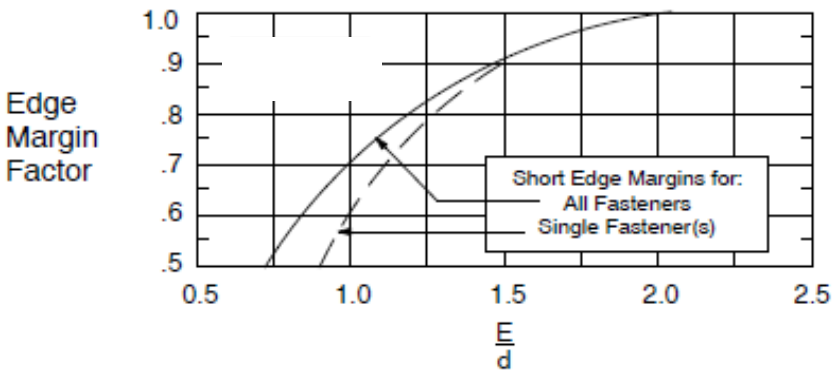
Joint allowable for E/D =1.7 is then

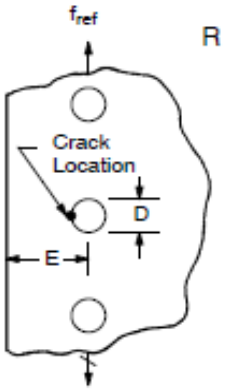
178*0.85 = 151 lbs

MS = 151/88 -1 = 0.71 (OK for static load)

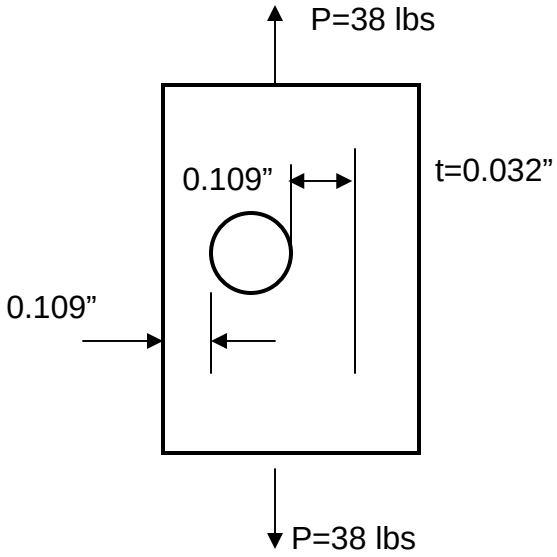
Analysis (Continued):

Check for fatigue strength:





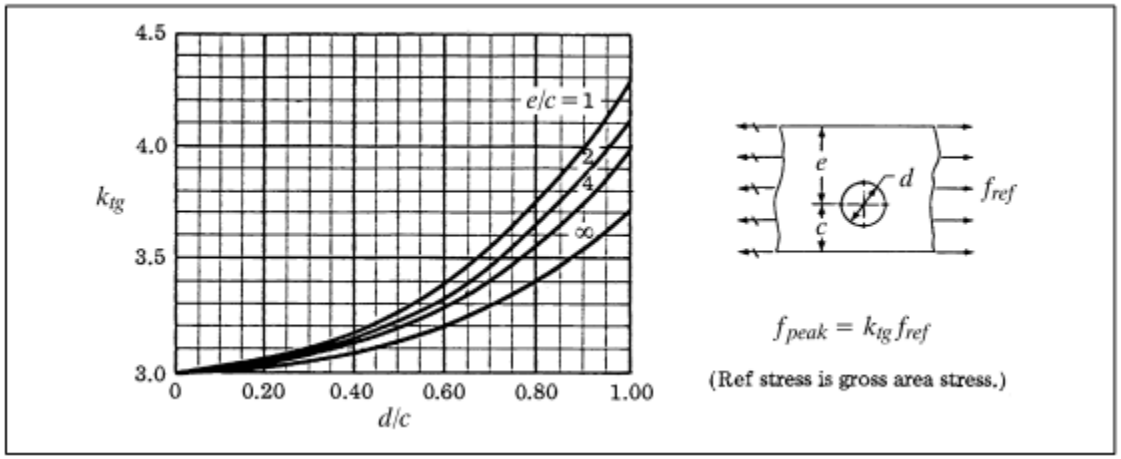
For E/D =1.7on a non fluid tight rivet joint, the reduction factor for fatigue strength is about 0.95



For fatigue load, the minimum limit pilot load of 130 lbs is used
With 130 lbs control force, the rivet shear force is 88*130/300 = 38 lbs

Nominal stress assuming effective material width on the side of hole away from edge= 38/(0.109*2*0.032) = 5.5 ksi

Stress concentration Factor:



For E/D = 1.7, d/c=0.6, and assuming e/c=1
Ktg = 3.4

With nominal stress of 5.5ksi, the peak fatigue stress is then

5.5*3.4=18.7 ksi

For 2024-T3 clad sheet, the fatigue allowable cut off value is 20 ksi, with a reduction factor of 0.9, the new fatigue allowable is then 20*0.95 = 19 ksi

MS=19/18.7 -1 =0.01 (OK)

So, the fatigue with E/D=1.7 is acceptable, assuming pilot using 130 lbs load on rudder all the time. Also, this stress concentration factor in this analysis based on an unplugged hole, and relative fatigue life of a plugged hole is about 4 times the unplugged hole

Also talked with Ken of Vans Aircraft about this issue on 5/10/2011, he said there are a lot of RV built with similar less than ideal margin in this part, but never heard of any fatigue related problems. So I just build on.

FAR 25.397(c):

(c) *Limit pilot forces and torques.* The limit pilot forces and torques are as follows:

Control	**Maximum forces or torques**	**Minimum forces or torques**
Aileron:		
Stick	100 lbs	40 lbs.
Wheel[1]	80 D in.-lbs[2]	40 D in.-lbs.
Elevator:		
Stick	250 lbs	100 lbs.
Wheel (symmetrical)	300 lbs	100 lbs.
Wheel (unsymmetrical)[3]		100 lbs.
Rudder	300 lbs	130 lbs.

From public paper: 777 Empennage Certification Approach
http://www.swcomposites.com/Papers/777EmpCert.pdf

Table 1: Regulations Concerning Composite Structure Certification

Topic	Reg	Subject
Material and process specifications	25.603 25.605	• Control of materials • Fabrication methods
Material properties	25.613 25.615 25.619	• Material strength properties and design values • Design properties • Special factors
Proof strength	25.305 25.307	• Strength and deformation • Proof of structure
Damage tolerance	25.571	• Fatigue evaluation • Residual strength • Discrete source damage
Other	25.581 25.609	• Lightning protection • Protection of structure