Fermilab

Particle Physics Division
Mechanical Department Engineering Note

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Title: Cavity Handling Universal Head --- Stress Analysis

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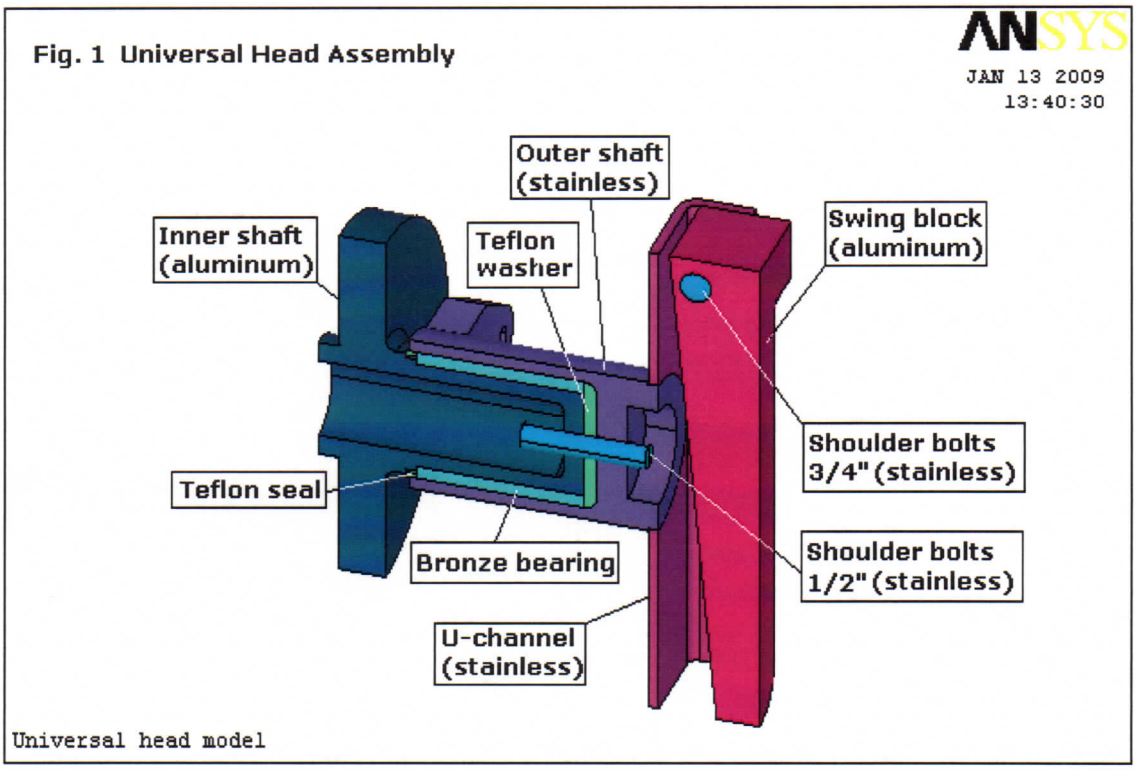
Key Words: 1.3 GHz 9-cell Cavity, cavity handling fixture, cart, universal head, frame grip.

Summary: The 1.3 GHz 9-cell cavity handling fixture consists of a commercial cart, a universal head, a grip assembly, and a frame. This engineering note documents the stress analysis of the universal head (other components are treated separately in other engineering notes), to show that the design of the universal head is structurally sound. The load analyzed is 500 lb, 12 inch from the universal head face.

The universal head assembly is shown in Fig.1 (The half model does not show all components). The swing block is attached to a commercial cart. The u-channel and the outer shaft are welded together. The 3/4 in shoulder bolt allows the outer shaft assembly to rotate with respect to the swing block. The bronze bearing and 1/2 in shoulder bolt allow the inner shaft rotate with respect to outer shaft. The frame grip assembly will be connected to the face of the universal head. The total weight of the universal head is about 30 lbs, and its center of gravity is about 6 inch from the back surface of the swing block.

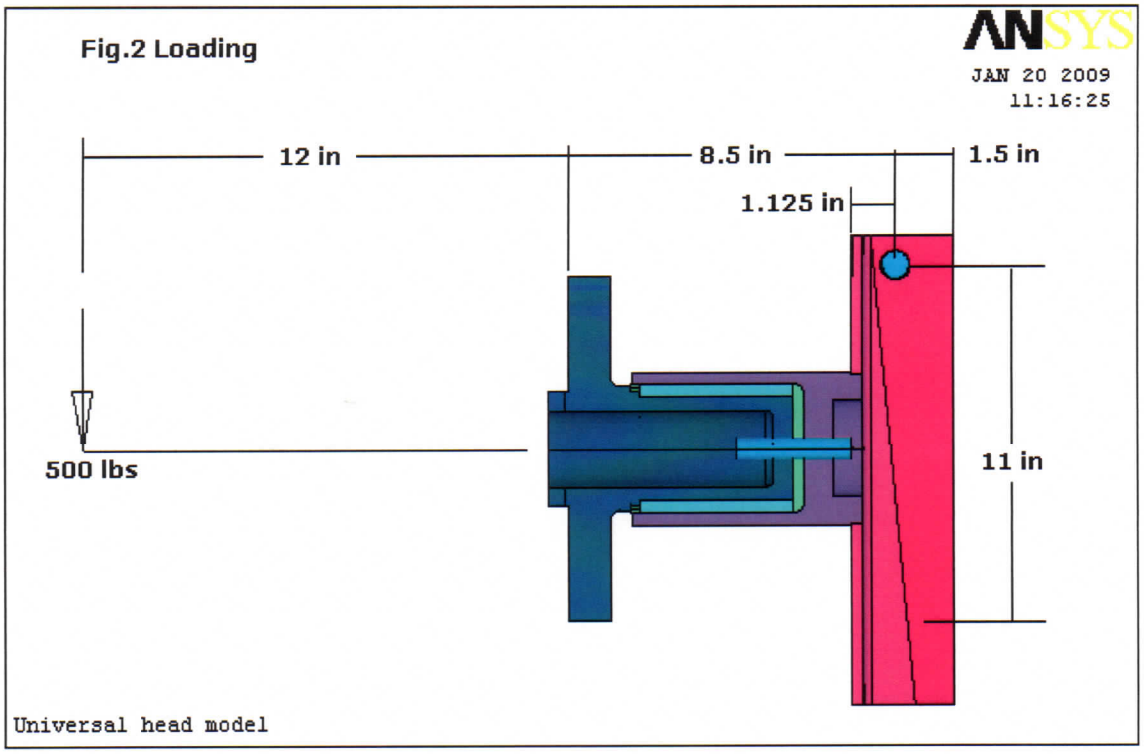


For this analysis we assume that the load carried by the universal head is 500 lbs (actual load will be about half this number), and the center of the load is 12 inches away from the face of the universal head. The loading situation is shown in Fig.2.

Now we analyze the stress in each component.

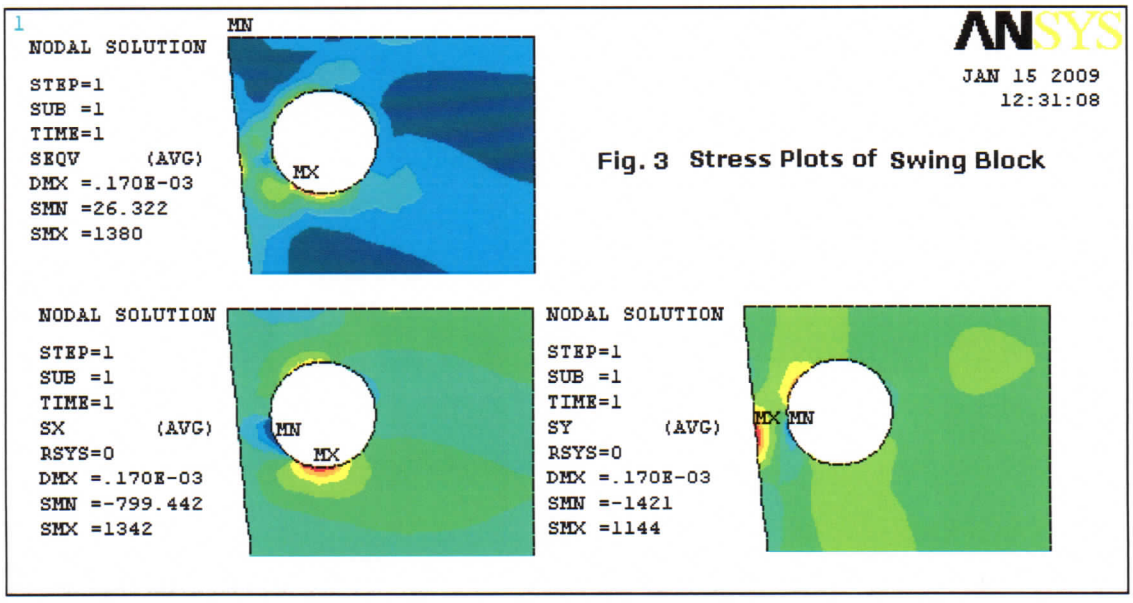
3/4 in shoulder bolt

The shear force comes in two ways: one is the 500 lb load; another is due to the moment that is about 1000 lb force, pulling the shoulder bolt away from the swing block. The combined shear force is 1118 lb. Shear force acts in two positions, so at each position, the shear force is $F = 559$ lb. Cross sectional area of the bolt is $A = \pi r^2 = 0.442$ in^2. The shear stress is $\tau = 1265$ psi. The stainless steel 316L has yield stress of 42000 psi and ultimate strength of 81000 psi. So the shoulder bolt is OK.



Swing block

The stress concentration in the swing block should be around the shoulder bolt hole. We made a 2-D model of the swing block. The loads applied are Fx = -1000 / 4.5 = -222 lb/in, Fy = -500 / 4.5 = -111 lb/in. The stress plots are shown in Fig.3. The maximum equivalent stress is 1380 psi. The swing block is made of aluminum 7075-T6. It has yield stress of 70000 psi at room temperature.



U-channel

The stress in U-channel is also concentrated around the bolt hole. The loads applied are Fx = 1000 / 0.5 = 2000 lb/in, Fy = 500 / 0.5 = 1000 lb/in. The stresses are plotted in Fig.4. The maximum equivalent stress is 11988 psi. Compare this with yield stress of 42000 psi for stainless steel 316L, the safety factor is 3.5.

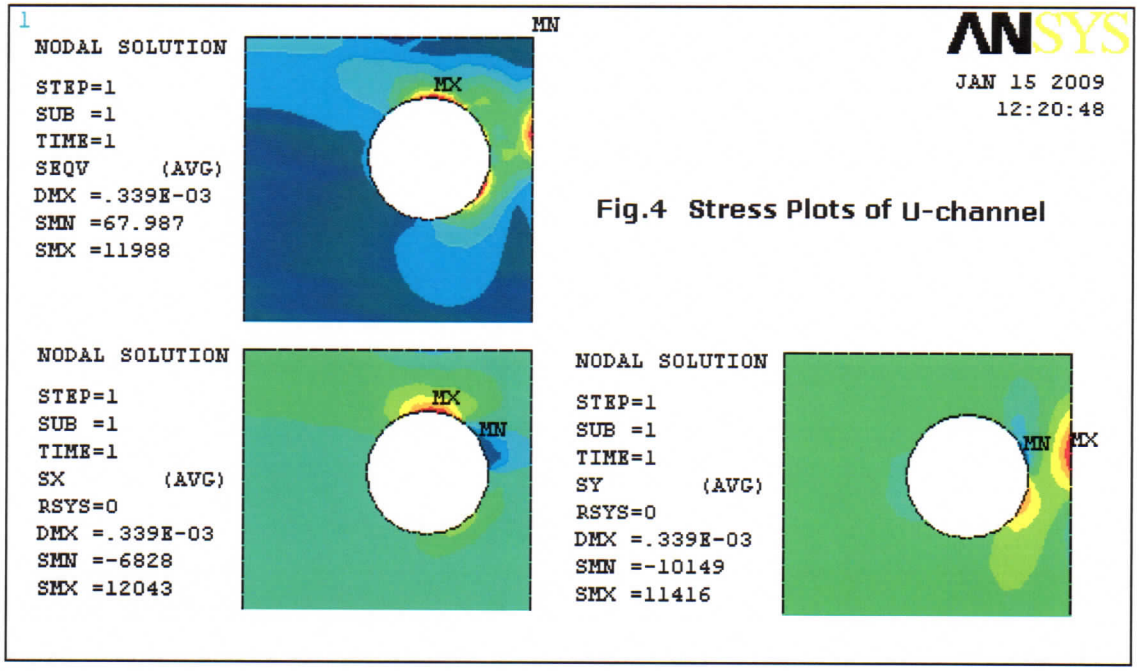
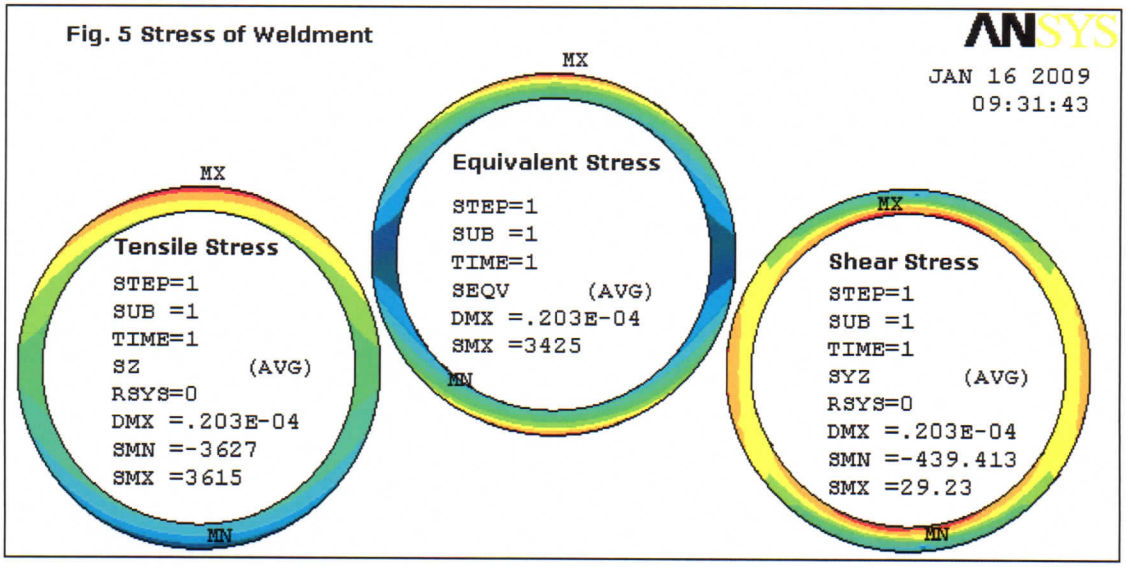


Fig.4 Stress Plots of U-channel

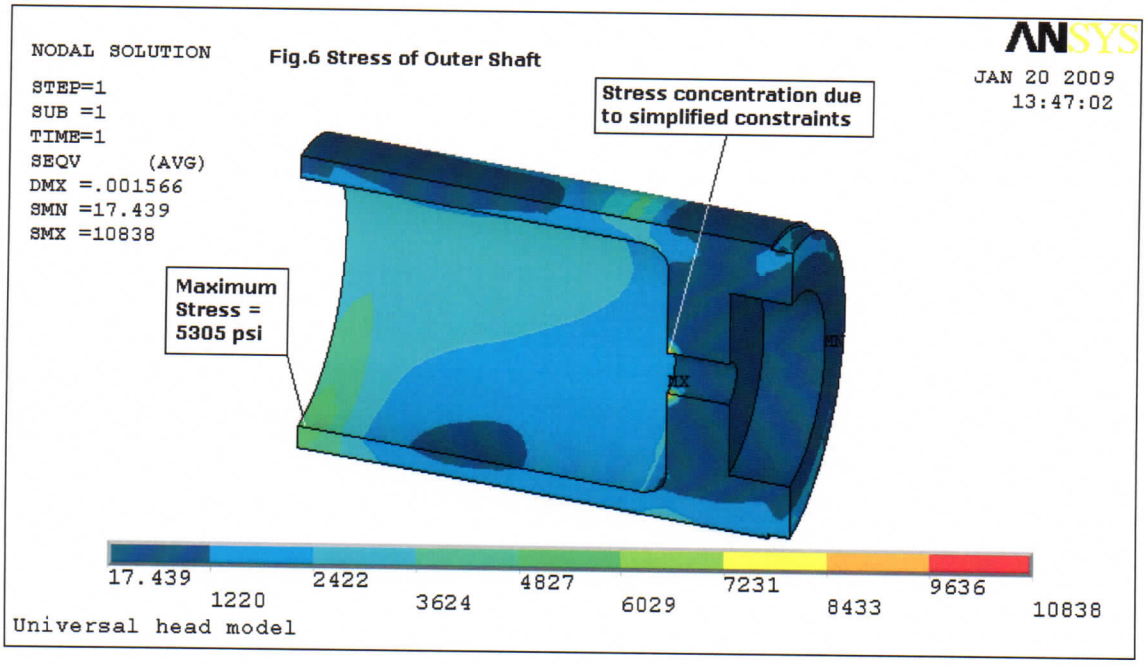
Weldment

The thickness of weld is 0.31 in. We made a model of a tube, with ID = 3.9 in, thickness = 0.31 in. Applied force and moment load. The stresses are plotted in Fig.5. The stress numbers are small.



Inner and Outer Shafts

The loading situations in the outer and inner shafts are not as simple as the components analyzed above. The 1/2 inch shoulder bolt constrains the axial movement of the inner shaft relative to the outer shaft. A 3D model is built to analyze the stress in inner and outer shafts. Modeled are inner shaft, bearing and outer shaft, with contact surfaces between them. The relative axial movement is constrained at the bolt hole through coupled degree of freedom. Stresses (equivalent stress) are plotted in Figs. 6~8 for each modeled component. Note that, some stress concentrations are due to simplified loading and constraining. They will not exist in real situation. All of them are in the safe stress region.



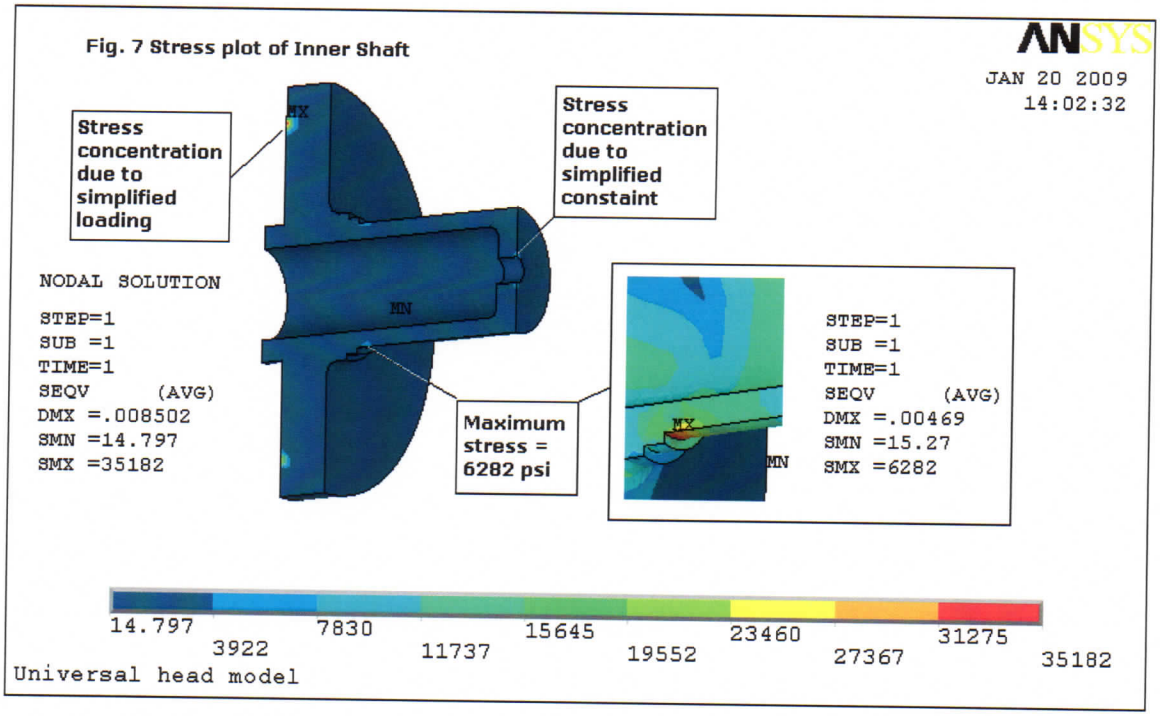


Fig. 7 Stress plot of Inner Shaft
ANSYS
JAN 20 2009
14:02:32
Stress concentration due to simplified loading
Stress concentration due to simplified constaint
Maximum stress = 6282 psi
NODAL SOLUTION
STEP=1
SUB =1
TIME=1
SEQV (AVG)
DMX =.008502
SMN =14.797
SMX =35182
STEP=1
SUB =1
TIME=1
SEQV (AVG)
DMX =.00469
SMN =15.27
SMX =6282
MX
MN
14.797
3922
7830
11737
15645
19552
23460
27367
31275
35182
Universal head model

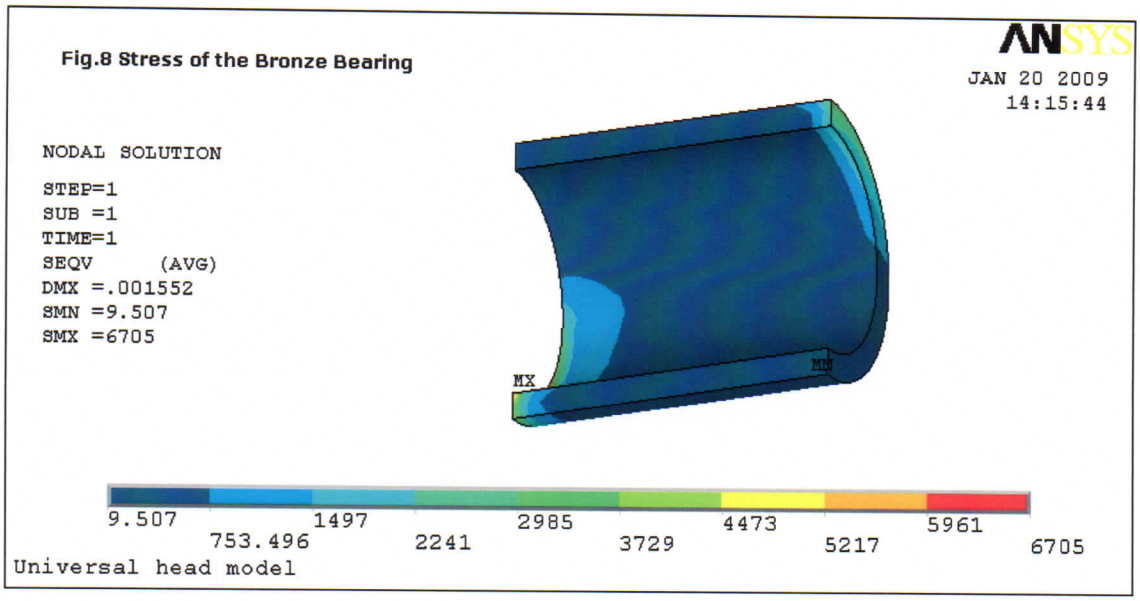


Fig.8 Stress of the Bronze Bearing
ANSYS
JAN 20 2009
14:15:44
NODAL SOLUTION
STEP=1
SUB =1
TIME=1
SEQV (AVG)
DMX =.001552
SMN =9.507
SMX =6705
MX
MN
9.507
753.496
1497
2241
2985
3729
4473
5217
5961
6705
Universal head model

Conclusion

The results are summarized in the table below. All stresses (for 500 lb, 12 inch from universal head face) are under yield. The safety factors are calculated. The smallest safety factor is for bronze bearing. But this is not a structurally critical component. The next smallest number is for u-channel. It has a safety factor of 3.5.

Component	Material (or assumed)	Yield Stress (ksi)	Shear Stress / Eqv Stress (ksi)	Safety Factor
shoulder bolt	(S.S. 316L)	42	1.265	33
Swing Block	Aluminum 7075-T6	70	1.380	50
U-channel	S.S. 316L	42	11.988	3.5
Weldment	(S.S. 316L)	42	3.425	12
Outer Shaft	S.S. 316L	42	5.305	7.9
Bronze Bearing	(Bronze)	12	6.705	1.8
Inner Shaft	Aluminum 6061-T6	40	6.282	6.3

References

1. Properties of Aluminum Alloys, J.Gilbert Kaufman, ASM 1999

Material properties at room temperature

Material	Tensile Strength	Yield Strength
6061-T6	45 ksi	40 ksi
7075-T6	80 ksi	70 ksi

2. http://www.lenntech.com/Stainless-steel-316L.htm

Tensile Strength, Ultimate	558 Mpa	81 ksi
Tensile Strength, Yield	290 Mpa 0.2% YS	42 ksi

3. http://www.efunda.com/materials/common_matl

Material	Yield Stress(MPa)	Ultimate Stress(MPa)
Bronze; Regular	82 - 690	200 - 830
Bronze; Manganese	170 - 450	450 - 620

Amendment

Consider the situation in which the load is off axis by 4 inches. There will be an additional twist moment of 2000 in-lb. From previous analysis results, we see that the most concerned component is the u-channel. Let us list what loads it has: 1) from 500 lb load, we have F_y = 250 lb on each side; 2) from bending moment, we have F_x = 500 lb; 3) from twist moment, we have F_y = 400 lb on one side, and F_y = -400 lb on the other side. We take the larger load, consider F_x = 500 lb, and F_y = 650 lb. The stresses are plotted in Fig. 9. The safety factor will be reduced to 2.4.

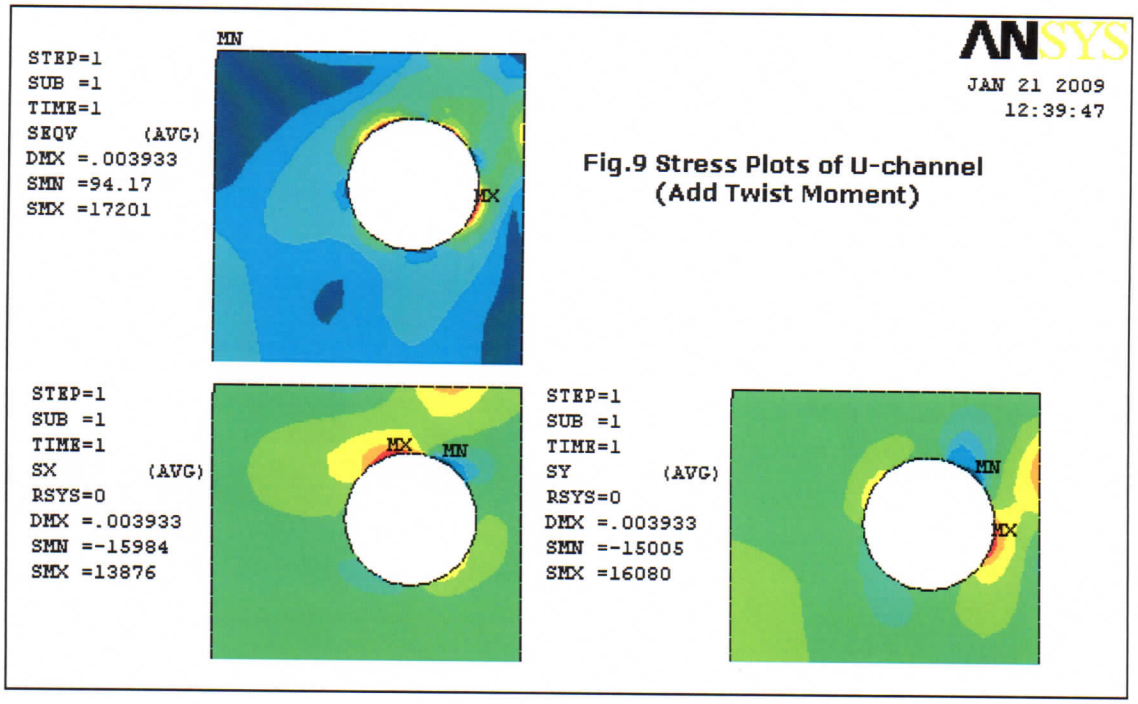


Fig.9 Stress Plots of U-channel (Add Twist Moment)

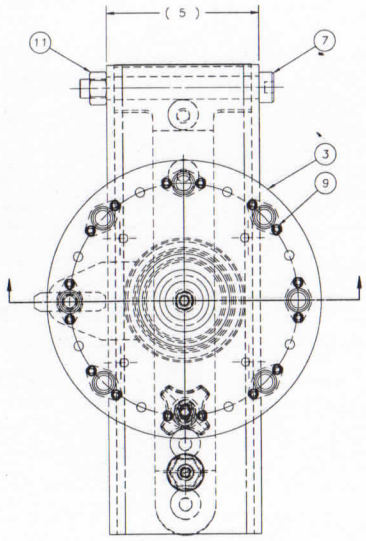
Shear stress on collar weldment

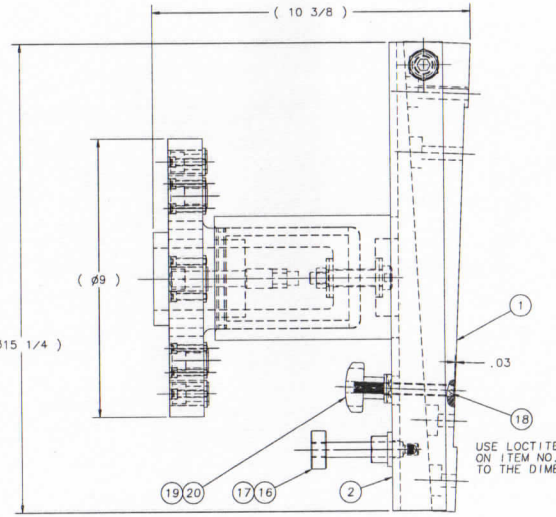
The weldment thickness id 0.31 in, the length is 2.09 in, area = 0.65 in^2. Twisting force is 2000 in-lb/2in = 1000 lb. So the shear stress is τ= 1540 psi. The safety factor = 42/1.54 = 27.

Shear Stress on 1/2 in quick-release pin

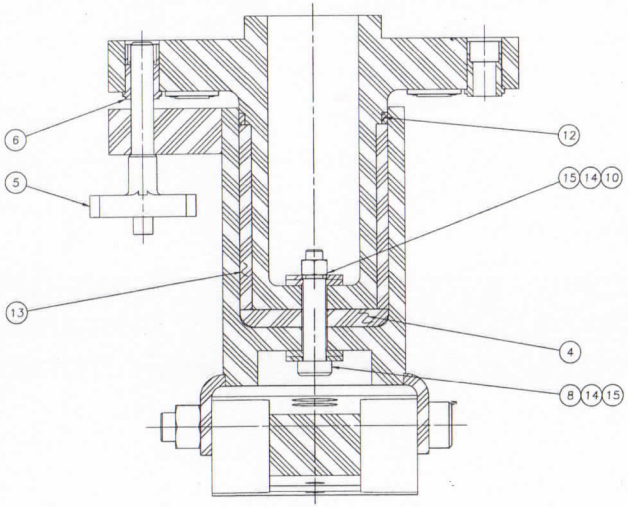
Area = $\pi r^2 = \pi(0.25)^2$ = 0.196 in2. Force = 2000 in-lb/3.75 in = 533 lb. τ = 2719 psi. Safety factor = 42/2.719 = 15.

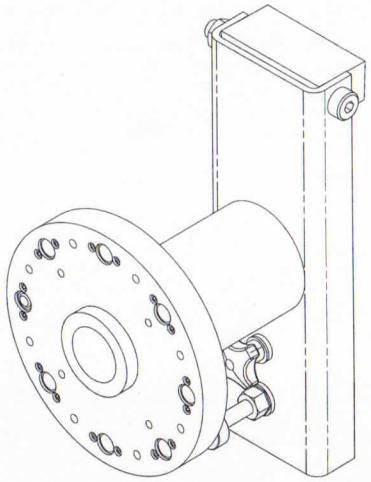
REV	DESCRIPTION	DRAWN	DATE
		APPROVED	DATE
A	E.C.O. NO. 8911, ADDED ITEMS 18, 19, 20	F. MCCONOLOGUE	13-OCT-2008
		D. OLIS	13-OCT-2008





USE LOCTITE 262 THREADLOCKER ON ITEM NO. 18 TO LOCK ITEM TO THE DIMENSION SHOWN





APPROXIMATE WEIGHT: 35 LBS.

ITEM	PART NO.	DESCRIPTION OR SIZE	QTY.
20	McMASTER-CARR 4384K3	KNOB, 303 SST	1
19	McMASTER-CARR 91944A450	SPHERICAL WASHER SET, 18-8 SST 3/8	1
18	McMASTER-CARR 95412A636	THREADED ROD, 18-8 SST 3/8-16 X 3.00 LG.	1
17	CARR-LANE CL-4A-FSS-S	TYPE A SWIVEL SCREW FOOT	1
16	CARR-LANE CL-40-BSS-S	KNURLED HEAD SWIVEL SCREW	1
15	MB-457608	GASKET	2
14		1/2" FLAT WASHER, S.S.	2
13	STOCK DRIVE PRODUCTS A784-SP688832	BRONZE BEARING, 4" LG.	1
12	MB-457607	TEFLON SEAL	1
11		5/8-11 UNC LOCK NUT, BRASS	1
10		3/8-16 UNC LOCK NUT, BRASS	1
9		#10-32 UNF SHCS, 5/8" LG, S.S.	16
8		1/2" SHOULDER BOLT, 1 3/4" LONG, S.S.	1
7		3/4" SHOULDER BOLT, 5" LONG, S.S.	1
6	McMASTER-CARR 94715A530	1/2" QUICK RELEASE PIN RECEPTICLE	8
5	McMASTER-CARR 90293A412	1/2" QUICK RELEASE PIN	1
4	MB-457351	TEFLON WASHER	1
3	MC-457327	INNER SHAFT	1
2	MC-457326	OUTER SHAFT WELDMENT	1
1	MB-457322	SWING BLOCK	1

PARTS LIST

UNLESS OTHERWISE SPECIFIED			ORIGINATOR	S.REEVES	23-JUL-2007
.XX	.XXX	ANGLES	DRAWN	D.HURD	23-AUG-2007
± .02	± .005	±0.5°	CHECKED	S.REEVES	11-SEP-2007
			APPROVED	A.ROWE	11-SEP-2007

1. BREAK ALL SHARP EDGES .015 MAX.
2. DO NOT SCALE DRAWING.
3. DIMENSIONS BASED UPON ASME Y14.5M-1994
4. MAX. ALL MACH. SURFACES
5. DRAWING UNITS: U.S. INCH

USED ON: MD-457358

MATERIAL: SEE PARTS LIST

FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY

SCRF - BCP FACILITY
LIFT CART UNIVERSAL HEAD ROTATING ASSEMBLY

SCALE	DRAWING NUMBER	SHEET	REV
3/4	5525.000-MD-457539	1 OF 1	A

CREATED WITH : Ideas12NXSeries | GROUP: TD/DOCIS-DESIGN-COMPUTING