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DESIGN OF END CONNECTORS FOR A TURNBUCKLE IN ORDER TO SELECT MATERIALS UNDER DIFFERENT TENSILE LOADS

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Abstract — *A Turn-Buckle is a device for adjusting tension as well as length of ropes, cables, tie rods and other tensioning system. It consists of two threaded ends, one with a left hand thread and other one is right hand thread. The end connections are required to fulfill the working in various applications. This project comprises of studies of adequate design calculation for stresses acting on threaded rod and at end connections. We have taken different size of rod dimension along with step loads of ends like eye end, hook end and jaw end. Different ends are subjected to tensile loading utilized in different applications and hence stresses are generated. Now for safe design of whole assembly stresses are analyzed and compared with standard selected materials. Here, the attempt is done to select better material in context with stress generation and material costing. For proper selection of material number of loads are taken with minimum incremental steps in selected range. A Matlab programming is done to solve such kind of design having number of iterations. According to design formulation, solid modeling is done for turnbuckle, end connections and assembled them. For convince in calculation, we have taken uniform m material for whole the assembly. After solid modeling, assemblies are analyses in order to find stresses induced. The Ansys results are for supporting the analytical values. .*

Keywords- *Coupler Nut, End connectors, tensile stress, Shear stress, Deformation, Solid Modeling*

I. INTRODUCTION

Turnbuckle is a coupling with internal screw threads used to connect two rods, lengths of ship's rigging, lashing etc. lengthwise or to regulate their length or tension. The principles of the operation for a turnbuckle is to have the screw operating clockwise and counter clockwise to close the steel products or barrels. Turnbuckle can also be custom designed for particular needs of industry. They are more commonly made of steel but can be forged in iron as well. The purpose of the strong metal forged steel or iron turnbuckles is to pull tons of weight safely and surely. The turnbuckles are adjusted until the barrel is closed and the constraint tightly compressed. Turnbuckles are designed by releasing tension in a cable without adding unbearable stress onto ends of the cables particular attachment. They have high load carrying capacity and compact size. The main advantage of turnbuckle is the adjusting of tension and length just by rotating the coupler without much effort. Turnbuckle is one of the most essential and life saving product manufactured globally today.
If we want to increase the range of load carrying capacity of turnbuckle, then material cost would be increase and ultimately, the cost of turnbuckle would increase. Yielding of the loop or one of the ringbolts will release the tensile forces in the system and could make operation unsafe. Fatigue fracture of the loop or one of the ringbolts could at any of the points of stress concentration in the turnbuckle assembly. Fracture of loop or one of the ringbolts could take place as a result of excessive loading of the system or as a result of impact loading if material lose their toughness in service.

II. DESIGN FORMULATION FOR TURN BUCKLE

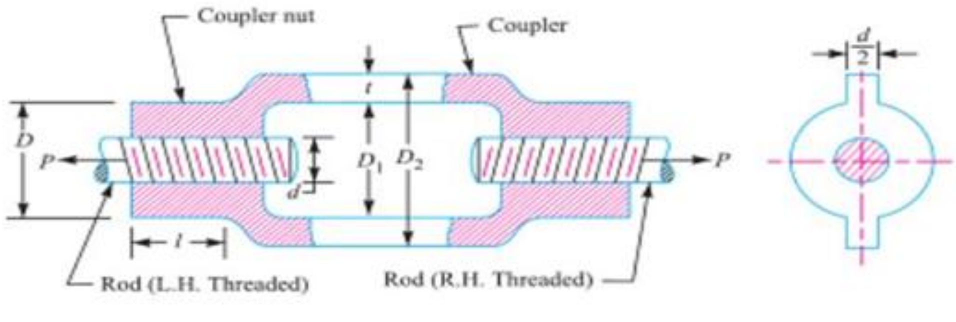

Fig. 1 Turn Buckle or Coupler Nut

2.1 Diameter of tie rod (d_c):

To design a threaded section, design load is taken as 1.25 the normal load.

Direct tensile load $P_d = 1.25P$

By considering the tearing of the thread of the rods at their roots.

Tensile stress $\sigma_t = \frac{4P_d}{\pi d_c^2}$

The nominal diameter can be selected from ISO matric screw threads table, $d_o = \frac{d_c}{0.84}$

2.2 Length of coupler nut (l):

Consider the direct shearing of the thread at the root of coupler nut and screw

a) The direct shear stress induced in screw thread

$$\tau_s = \frac{P}{\pi d_c l}$$

b) The direct shear stress induced in nut

$$\tau_n = \frac{P}{\pi d_o l}$$

c) Check of crushing of thread

$$P_d = \frac{\pi}{4}(d_o^2 - d_c^2) \times n \times \sigma_c \times l$$

2.3 Outside diameter of coupler nut (D)

The outside diameter of the coupler nut may be obtained by considering permissible tensile stress for the material of coupler nut. We know that,

$$\sigma_t = \frac{4P}{[\pi \times (D^2 - d_o^2)]}$$

The actual practice, the diameter of the coupler nut D is taken from $1.25d_o$ to $1.5d_o$., D is taken as , $D = 1.25d_o$

2.4 Outside diameter of coupler (D_2)

The outside diameter of the coupler is obtained by considering permissible tensile stress. In actual practice, the outside diameter of the coupler D_2 is taken as $1.5d_o$ to $1.7d_o$. So $D_2 = 1.5d_o$

2.5 Length of coupler (L_n)

$L_n = 6d_o$

2.6 Thickness of coupler (t)

$t = 0.75d_o$

2.7 Thickness of coupler nut (t_1)

$t_1 = 0.5d_o$

III. DESIGN FORMULATION FOR END CONNECTORS

3.1 Design of Jaw end

3.1.1 Rod in tension

Considering the rod is subjected to a direct tensile stress.

$$\sigma_t = \frac{4P}{\pi d^2}$$

3.1.2 Pin in shear

Due to direct tensile strength, the single eye is subjected to double shear. So, shear stress is,

$$\tau = \frac{2P}{\pi d^2}$$

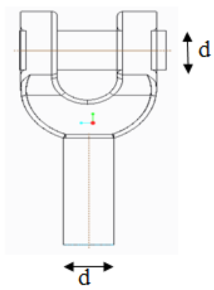

Fig. 2 Jaw End

3.1.3 Pin in Bending

Assume there is no clearance or slack but in actual, pin is loose in forks to permit angular moment of one with respect to other, so it is subjected to bending moment in addition to shear, considering uniformly distributed load along the portion of pin. So, bending moment is,

$$\sigma_b = \frac{4P(1.2d)}{\pi d^3}$$

3.2 Design of Eye End

[1] Tensile stress, $\sigma_t = \frac{4P}{\pi(0.8d^2)}$

[2] Shear stress, $\tau = 1.75\sigma_t$

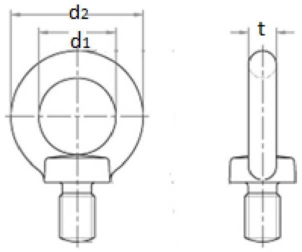

Fig. 3 Eye End

3.3 Design of Hook End

[1] Tensile stress = $\frac{Load\ (P)}{Area\ (A)}$

For Trapezoidal section $\quad A = \frac{1}{2}(b_1 + b_2)\ h$

For circular section $\quad A = \frac{\pi}{4}\ d^4$

[2] Shear stress, $\tau = 1.75\sigma_t$

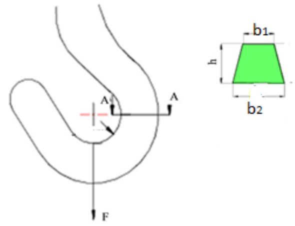

Fig. 4 Hook End

IV. PROGRAMMING FOR PARAMETRIC DESIGN

4.1 Programme for turn buckle

```
function [ft,fsscrew,fsnut,Ln,D,D2,t,t1]=dia_rod(P,dc)
 for P =15000:15000:90000;
 % (1) Diameter of tie rod dc
 % Pd is design load ,P is actual load
 Pd = 1.25*P;
 % tensile stress ,ft
 ft = 4*Pd/(pi*(dc*dc));
 do = dc/0.84;
 % do is nominal dia.
 % (2)Length of coupler nut ,Ln
 Ln = 6*do;
 % (a)shear stress induced in screw thread
 fsscrew = P/(pi*dc*Ln);
 % (b)shear stress induced in nut
 fsnut = P/(pi*do*Ln);
 % (3) Outer dia. of coupler nut (D)
 % ft = 4*P/(pi*((D*D)-(do*do));
 D = sqrt((4*P/(ft*pi))+(do*do));
 % (4) out. dia of coupler nu (D2)
 D2 = 1.5*do;
 % (5) Thickness of coupler nut (t)
 t = 0.75*do;
 % (6) thickness of coupler nut (t1)
 t1 = 0.5*do;
 data =[ft  fsscrew  fsnut  Ln  D  D2  t  t1 ];
 disp(data)
 end
end
```

4.2 Programme for hook end

```
function [ ft1,ft2,fs] = hook design(P,d)
 for  P = 15000:15000:90000
 b1 = 0.489*d;
 b2 = 1.73*d;
 h = 1.54*d;
 % Area for trapezoidal section ,
 A1 = (b1+b2)*(h/2);
 % Area for circular section ,
 A2 = (pi*d*d)/4;
```



```
 % (1) Tensile stress
 %  ft = load(P)/Area(A)
 % ft1 is tensile stress for trapezoidal c/s
 % ft2 is tensile stress for circular c/s
 ft1 = P/A1;
 ft2 = P/A2;
 % (2 shear stress .
 fs = 1.75*ft1;
 data = [ft1  ft2  fs];
 disp(data)
 end
end
```

4.3 Programme for eye end

```
function [ ft,fs ] = eyedesign(P,d)
for P = 15000:15000:90000
% (1) Tensile stress
ft = (4*P)/(pi*(0.8*d)^2);
% (2) shear stress
fs = 1.75*ft;
data = [ft  fs];
disp(data)
end
end
```

4.4 Programme for jaw end

```
function [ ft,fs,fb ] = jawdesign(P,d)
for P = 15000:15000:90000;
% (1) Rod in tension ,
% tensile stress
ft = 4*P/(pi*d*d);
% (2) Pin in shear ,
% shear stress
fs = 2*P/(pi*d*d);
% (3) Pin in bending ,
% bending stress
fb = (4*P*1.2*d)/(pi*d*d*d);
data = [ft  fs  fb];
disp(data)
end
end
```

V. RESULT AND DISCUSSION

5.1 Parametric Calculation of Turnbuckle

In this work, We have done analytical design manually by taking rod diameter of coupler nut with variation in load from 5 kN to 90 kN in step increment of 15 kN. For each selected diameter of rod, parameters of turnbuckle and end connections are calculated. Here, rod diameter is taken like 10 mm, 30 mm and 60 mm, according to type of duty load (low, medium and heavy). In design calculation, stresses which are responsible for failure are calculated. Such values are compared with standard working values of materials. We have taken standard materials which are used widely for manufacturing of turnbuckle. For simplicity in comparison, factor of safety is taken 4 for whole calculation. Working value of materials is found from standard ultimate values of material. In context with material, we have taken following material.

Table No 1. Materials and Tesile and Shear stress values

No.	Material	σ_t (N/mm^2)	τ_s (N/mm^2)
1.	Silicon Bronze	186.25	325.93
2.	Medium Carbon Steel	130	227.5
3.	Stainless Steel	126.25	220.85
4.	Low Carbon Steel	102.5	179.37
5.	Brass	100	175

First, analytical design is done manually to calculate stresses induced in rod and other parameters of component. A Matlab programming is used to check all iterative steps in calculation. Along with the turnbuckle, the end connections are also checked by applying the define loads and induced stresses are found. Stresses induced in threaded rods as well as in the end are compared with standard working value of define materials. Which material is suitable for particular load as well as base on cost, the better material is selected.

Table No 2. Calculated parameter in design

TURNBUCKLE PARAMETERS									
Dia.(mm)	Load (kN)	σ_t (N/mm²)	$\tau_{s(screw)}$ (N/mm²)	$\tau_{s(nut)}$ (N/mm²)	L_n (mm)	D (mm)	D_2 (mm)	t(mm)	t_1(mm)
10	5	79.57	2.28	1.87	71.428	14.9	17.85	8.92	5.95
	15	238.73	6.68	5.61	71.428	14.9	17.85	8.92	5.95
	30	477.46	13.37	11.23	71.428	14.9	17.85	8.92	5.95
	45	716.19	20.05	16.84	71.428	14.9	17.85	8.92	5.95
	60	954.92	26.73	22.46	71.428	14.9	17.85	8.92	5.95
	75	1193.7	33.04	28.1	71.428	14.9	17.85	8.92	5.95
	90	1432.4	40.8	33.7	71.428	14.9	17.85	8.92	5.95
30	5	8.84	0.247	0.208	214.28	44.67	53.57	26.78	17.85
	15	26.52	0.742	0.623	214.28	44.67	53.57	26.78	17.85
	30	53.05	1.485	1.24	214.28	44.67	53.57	26.78	17.85
	45	79.57	2.21	1.87	214.28	44.67	53.57	26.78	17.85
	60	106.10	2.97	2.49	214.28	44.67	53.57	26.78	17.85
	75	132.62	3.71	3.11	214.28	44.67	53.57	26.78	17.85
	90	159.15	4.45	3.74	214.28	44.67	53.57	26.78	17.85
60	5	2.21	0.061	0.052	428.57	89.34	107.14	53.57	30.71
	15	6.63	0.185	0.156	428.57	89.34	107.14	53.57	30.71
	30	13.26	0.371	0.311	428.57	89.34	107.14	53.57	30.71
	45	19.84	0.557	0.467	428.57	89.34	107.14	53.57	30.71
	60	26.52	0.742	0.623	428.57	89.34	107.14	53.57	30.71
	75	33.15	0.928	0.780	428.57	89.34	107.14	53.57	30.71
	90	39.78	1.114	0.635	428.57	89.34	107.14	53.57	30.71

5.2Parameteric Calculation of End Connections

The different ends have induced stresses like Jaw, eye and hook ends are subjected to tensile loading and hence a pin of Jaw end fails in shear and bending, While eye and hook end fails in shear. So in order to find induced stresses, load is varied from 5KN to 90KN with incremental step of 15KN. Also same loading application is used by taking define rod diameters like 10mm, 30mm and 60mm. The said is calculated by programming and summarized as given below.

Table No 3. Calculated parameters of Eye

EYE END DESIGN PARAMETERS			
Dia. (mm))	Load (kN)	σ_t(N/mm²)	τ_s(N/mm²)
10	5	99.47	174.07
	15	298.41	522.22
	30	596.8	1044.5
	45	895.2	1566.7
	60	1193.7	2028.9
	75	1492.1	2611.1
	90	1790.5	3133.4
30	5	11.05	19.34
	15	33.15	58.02
	30	66.31	116.05
	45	99.47	174.07
	60	132.62	232.10
	75	165.78	290.12
	90	198.94	348.15
60	5	2.76	4.83
	15	8.28	14.5
	30	16.57	29.01
	45	24.86	43.51
	60	33.15	58.02
	75	41.46	72.53
	90	49.73	87.03

Table No 4. Calculated parameters of Hook and Jaw

		HOOK DESIGN PARAMETERS			JAW DESIIGN PRAMETER		
Dia. (mm)	Load (kN)	(Trapezoidal) σ_t(N/mm²)	(Circular) σ_t(N/mm²)	τ_s (N/mm²)	σ_t (N/mm²)	τ_s (N/mm²)	σ_b (N/mm²)
10	5	29.26	63.66	51.21	63.66	31.83	76.39
	15	87.78	190.98	153.63	190.98	95.49	229.18
	30	175.57	381.57	307.26	381.97	190.98	458.36
	45	263.36	572.95	460.89	572.95	286.47	687.54
	60	351.75	763.94	614.52	463.94	381.97	916.73
	75	438.94	954.92	768.15	954.9	477.5	1145.9
	90	526.75	1145.9	921.8	1145.9	573.6	1375.1
30	5	3.25	7.07	5.69	7.07	3.53	8.48
	15	9.75	21.22	17.07	21.22	10.61	25.46
	30	19.50	42.44	34.14	42.44	21.22	5.92
	45	29.26	63.66	51.21	63.66	31.83	76.39
	60	39.07	84.88	68.28	84.88	42.44	101.85
	75	48.77	106.103	85.35	106.1	53.05	127.32
	90	58.52	127.3	102.42	127.32	63.66	162.78
60	5	0.812	1.76	1.42	1.76	0.88	2.12
	15	2.43	5.30	4.26	5.3	2.65	6.36
	30	4.87	10.61	8.52	10.61	5.30	12.73
	45	7.31	15.51	12.8	15.91	7.95	19.09
	60	9.75	21.22	17.07	21.22	10.61	25.46
	75	12.19	26.52	21.33	26.52	13.26	31.83
	90	14.63	31.83	25.6	31.83	19.91	38.19

5.3 Stress analysis in Ansys:

Here ,We have done stress analysis for different types of ends of turnbuckles like eye , hook and jaw end .In that we have applied tensile force at ends and checked value of Tensile stress, shear stress and deformation by applying varying load such as 15 kN,60 kN,90 kN for different material such as silicon bronze , medium carbon steel and low carbon steel of 30 mm diameter of coupler nut. We observed that, In the application of tensile stress, Eye end is preferable and silicone bronze is better from group of materials available for manufacturing of turnbuckle and ends.

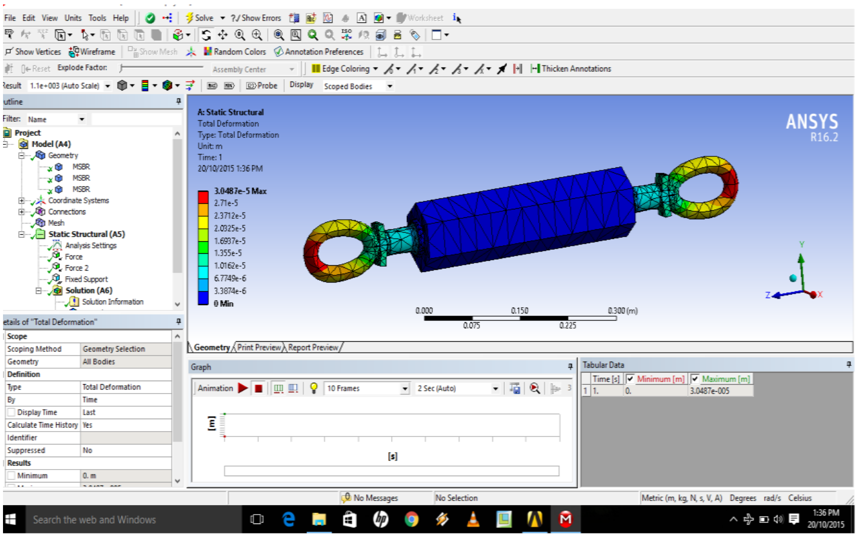

Fig. 5 Eye End (MCS), 15 KN

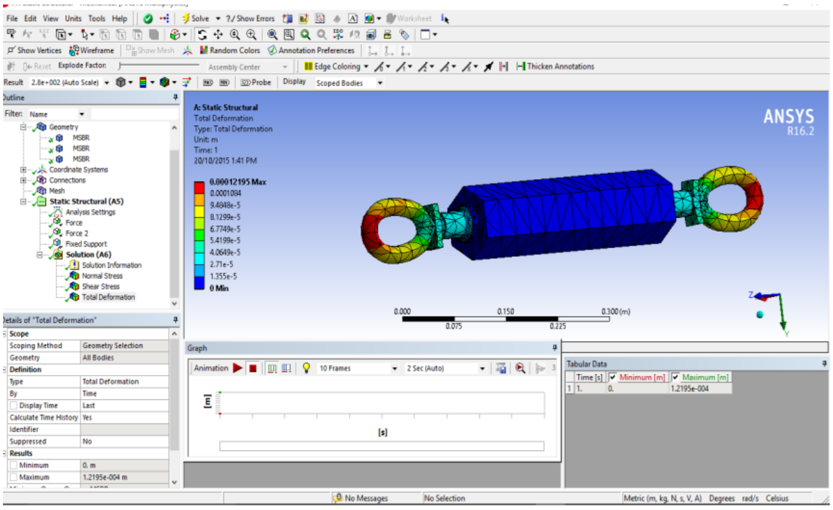

Fig. 6 Eye End (MCS), 60 KN

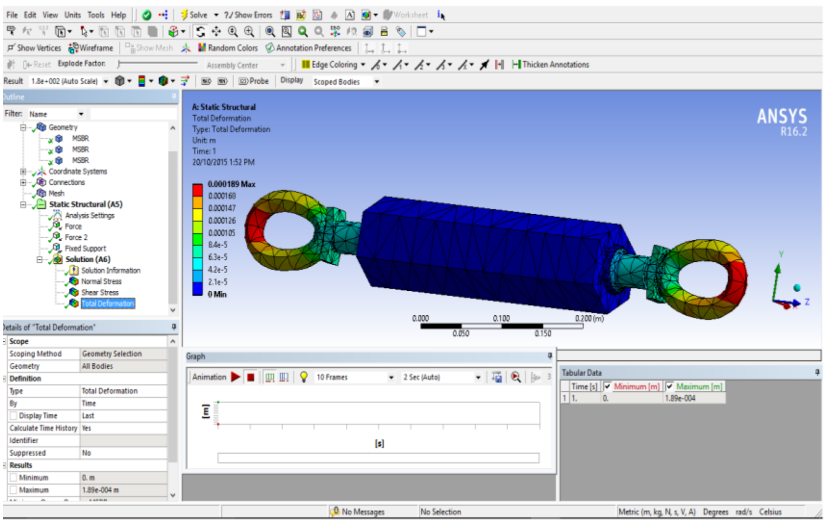

Fig. 7 Eye End (Silicon Bronze), 90KN

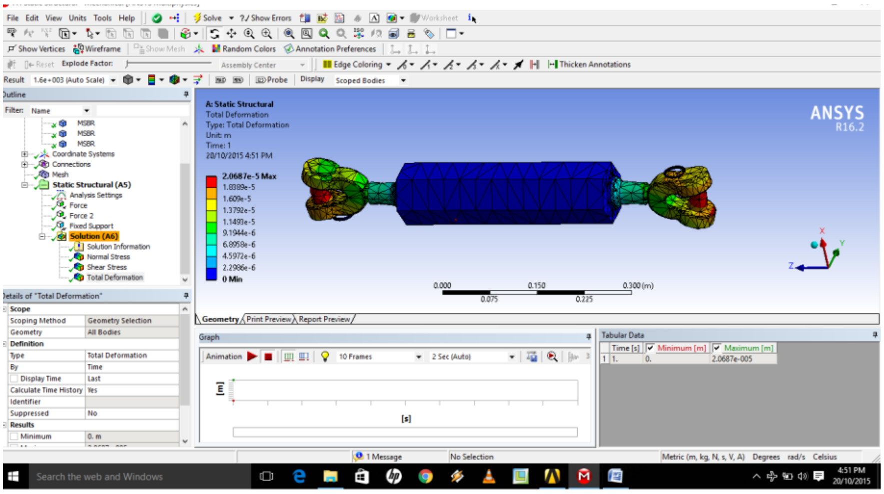

Fig.8 Jaw End(MCS), 15KN

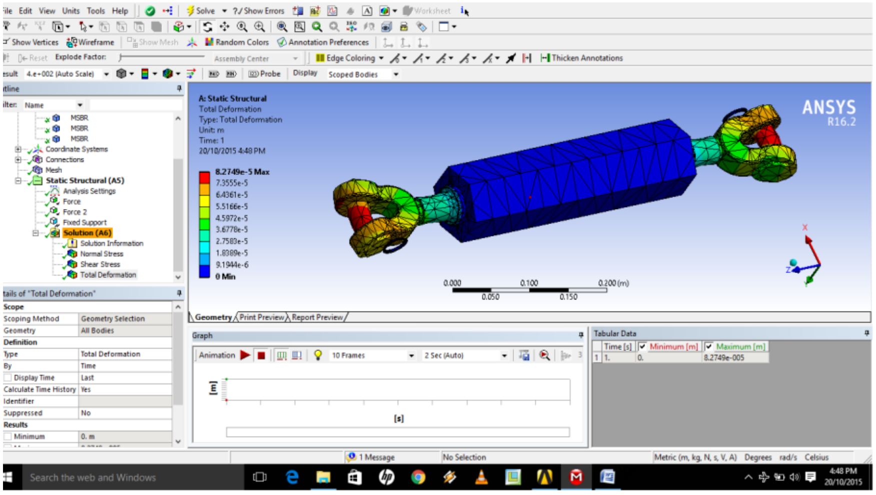

Fig.9 Jaw End (MCD) 60KN

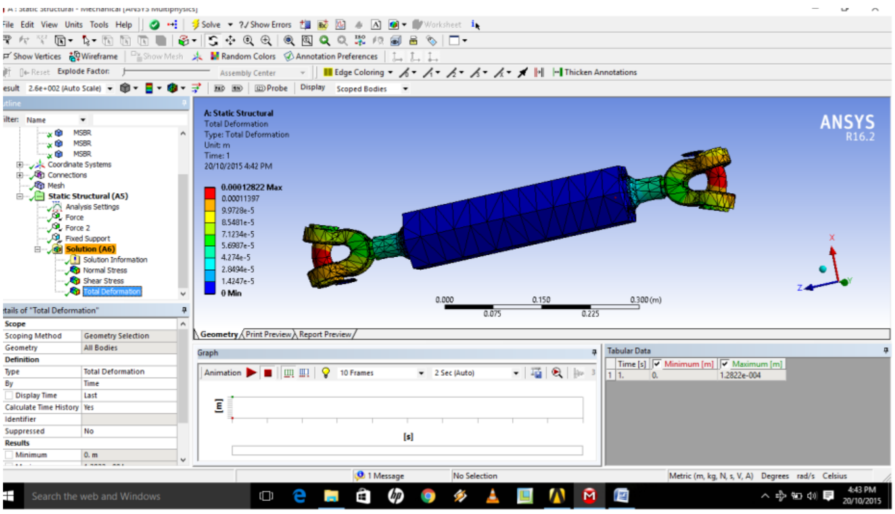

Fig.10 Jaw End (Silicon Bronze), 90KN

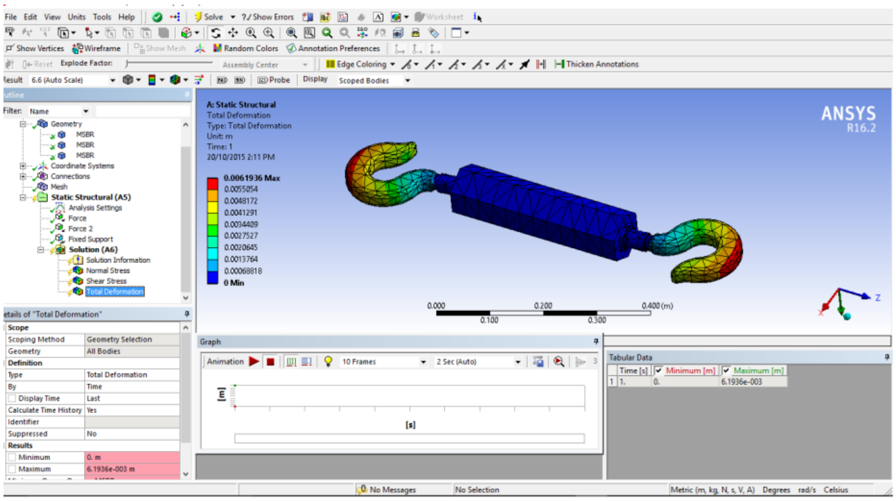

Fig.11 Hook End (MCS), 15KN

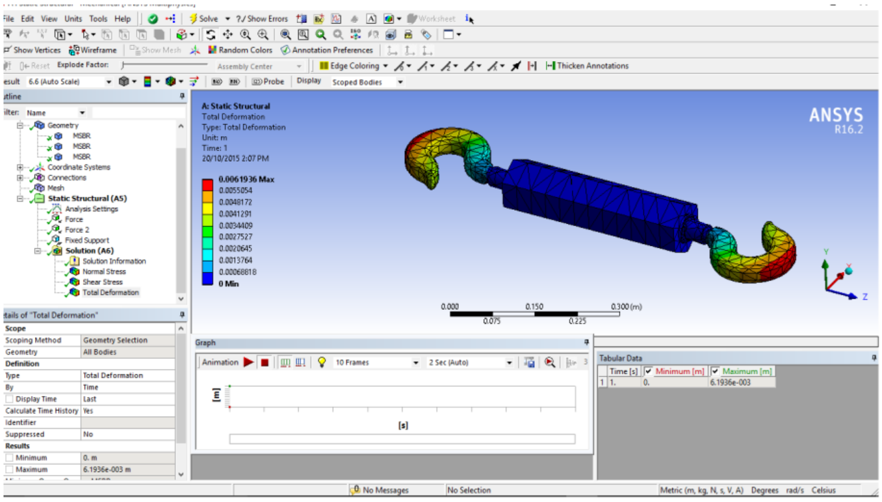

Fig. 12 Hook End (MCS), 60KN

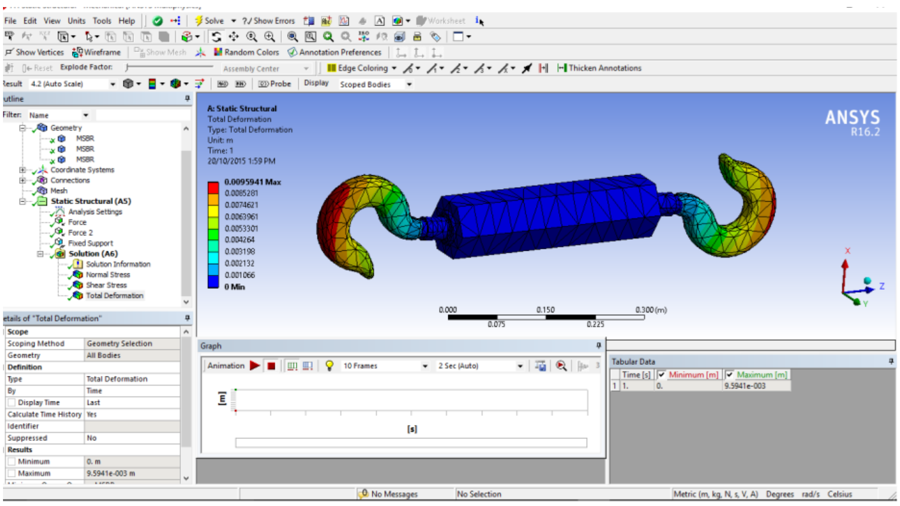

Fig.13 Hook End (Silicon Bronze), 90KN

CONCLUSION

Here, from analytical and graphical analysis for turnbuckle, it shows that for 10 mm rod diameter, Silicon Bronze is applicable at 5 kN load. Other materials like Medium Carbon Steel and Stainless Steel are alternatives. For 30 mm diameter, Silicone Bronze, Medium Carbon Steel and Stainless Steel are applicable under 5 kN, 15 kN, 30 kN, 45 kN load. For 60 mm diameter, all materials are applicable from 5 kN to 90 kN load.

If we consider stress analysis in End connections, in Eye failure due to shear is significant than tensile. In Hook, failure due to shear is higher than tensile while in Jaw, failure due to bending is noticeable. In Eye,from Silicon Bronze, Medium Carbon Steel and Stainless Steel are applicable for 10 mm and 30 mm rod diameter. While for 60 mm diameter, all materials are applicable. For Hook, Silicon Bronze, Medium Carbon Steel and Stainless Steel are applicable for 10 mm diameter up to 15 kN load while for 30 mm and 60 mm diameter, all materials are applicable for all selected loads. For Jaw, for 10 mm diameter, all materials are applicable for only 5 kN load, for 30 mm, they are preferable from 5 kN to 60 kN load and 60 mm diameter, all materials are applicable for 5 kN to 90kN load.

Ultimately, it is concluded that, for lesser diameter, Silicon Bronze gives better performance while for larger diameter, Medium Carbon Steel and Stainless Steel are better option. As far as the cost is concerned, Silicon Bronze is costlier than other materials and Medium Carbon Steel and Stainless Steel are less costlier and easily available for manufacturing of Turnbuckle. Hence, the later materials are most utilized in the application.

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