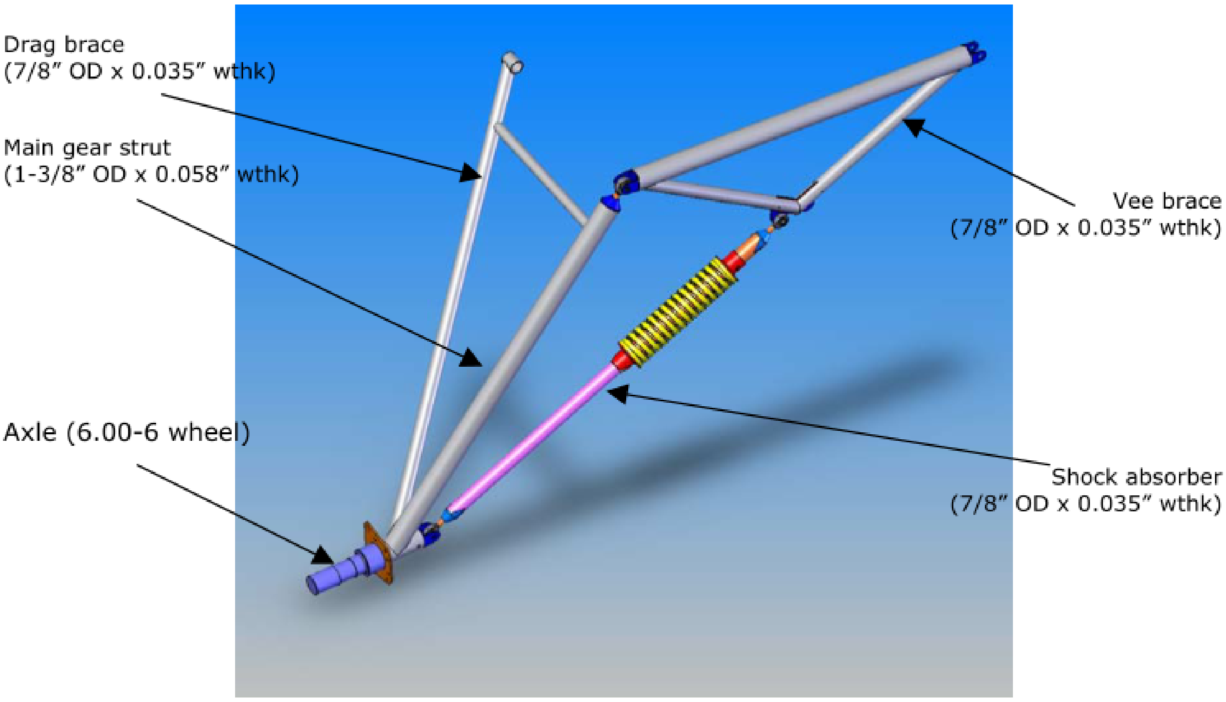
	SPORT CAMPER	Report N°: 32-01-01
	Technical Report	Rev: -1
	Model: LoCamp	Date: Dec.. 2012



MAIN LANDING GEAR STATIC ANALYSIS

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Rev.	Description	Prepared by	Date
NC	Original	See cover	08/12/05
1	Fully revised, loads and analyses	C. Pedetti	20/01/12

1. REFERENCES

REF. 1: JAR-VLA
REF. 2: L. Pazmany, "Landing Gear Design for Light Aircraft", Volume 1, 1986.
REF. 3: Bruhn, "Analysis and Design of Flight Vehicle Structures", Tri-StateOffset Company.
REF. 4: Niu, "Airframe Structural Design", Conmilit Press.
REF. 5: Report No. 57-003 R1 Flight envelope
REF. 6: MMPDS-03 Metallic Material Properties Development and Standardization
REF. 7: Bruhn "Analysis and Design of Flight Vehicle Structures"
REF. 8: SAWE Weight Engineers Handbook
REF. 9: M. Chun-Yung Niu - " Airframe Stress Analysis and Sizing"

2. LIST of ABBREVIATIONS

Dimensions

Length	l, L	mm
Height	h	mm
Diameter	D, d	mm
Thickness	t	mm
Radius	r	mm
Pitch	p	mm
Width	W, w	mm
Eccentricity, edge distance	e	mm
Area, cross section	A	mm^2
Constant	K, k	-
Celsius degrees	°C	
F degrees	°F	
Angle	degrees	

Subscripts

Maximum	max
Minimum	min
VM	Von Mises
Total	tot
Tension, Torsion	t
Compression	c
Shear	s, sh
Bearing	b, br
Ultimate	u
Ultimate Level	U.L.
Yield	y
Limit Level	L.L.
Critical	cr
Allowable	all
Resultant	res
Average	avg

Materials properties

Ultimate tensile strength	σtu-Ftu	MPa
Tensile Yield strength	σty-Fty	MPa
Compressive Yield strength	σcy-Fcy	MPa
Ultimate Shear strength	τsu-Fsu	MPa
Ultimate bearing strength	σbru-Fbru	MPa
Bearing Yield strength	σbry-Fbry	MPa
Young modulus –tension	E	MPa
Young modulus –compression	Ec	MPa
Shear modulus	G	MPa
Poisson ratio	nu,ν, μ	-
Elongation	δ, delta %	
Strain allowable (composite)	ε_t, ε_c, γ_sh	με

Sections properties

Area	A	mm^2
Moment of inertia	I	mm^4
Polar moment of inertia	Ip	mm^4
Torsion constant	J	mm^4
Radius of gyration	ρ	mm
Static moment	Q	mm^3

Abbreviations

dia., d, D	diameter
MS	Margin of Safety
RF	Reserve Factor
FQF	Fatigue Quality Factor
Pr, Pr	Preload
TT	Tightening Torque
FEM	Finite Element Model
2D	Two dimensional
3D	Three dimensional
config.	Configuration
Proto	Prototype
I/F	Interface
O/B	OutBoard
TBD	To Be Defined
TBC	To Be Confirmed
TBW	To Be Written
K,k	Kilo (1.0*e+3)
Ff	fitting factor
A/C	Aircraft
ID,id	identification
N	Newton
m	Meter
mm	Millimeter
Pa	Pascal (N/m^2)
MPa	Mega Pascal (N/mm^2)
CSK	Countersunk
bck	buckling
R.T.	Room Temperature
Lbs	Pounds
Psi	Pound per square inch (Ksi =10^3psi)
Cm	Centimetres
GFC	Fiber Composite
P.T.	Pull Through
S.F.	factor of safety
Rt	tensile/axial ratio
Rs	shear ratio
Rb	bending ratio
ext	external
LC	Load Case
HI	High

VM	Von Mises
fwd	forward
λ	Eigenvalue
FI	Failure Index
SPC	Single Point Constraint
CoG	Centre of Gravity
i.a.w.	in accordance with

Loads

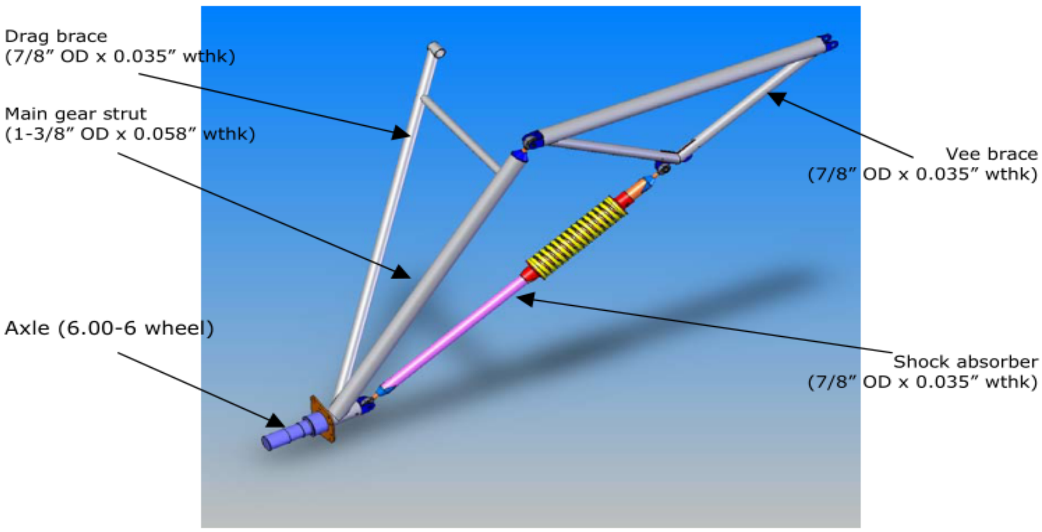
Force	P, F	N, kN
Moment	M	Nmm, Nm
Bending Moment	BM	Nmm, Nm
Axial load	P, F	N, kN
Shear Load	Q, S	N, kN
Torque	T	Nm
Pressure	p, dp	N/mm^2, N/m^2

Stress and strain

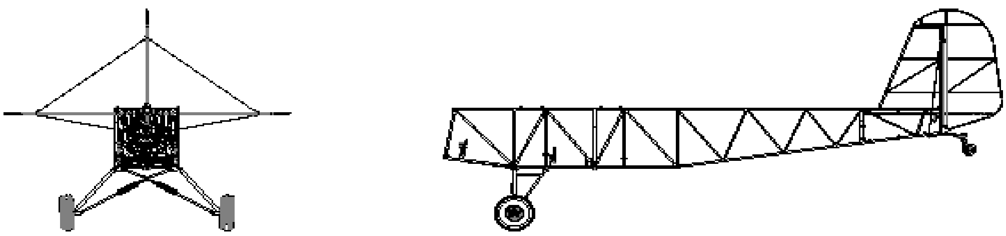
Direct stress	σ	MPa
Shear stress	τ	MPa
Principal stress	σ pr	MPa
Von Mises stress	σ VM	MPa
Strain	ε	
Shear strain	γ	

3. GENERAL

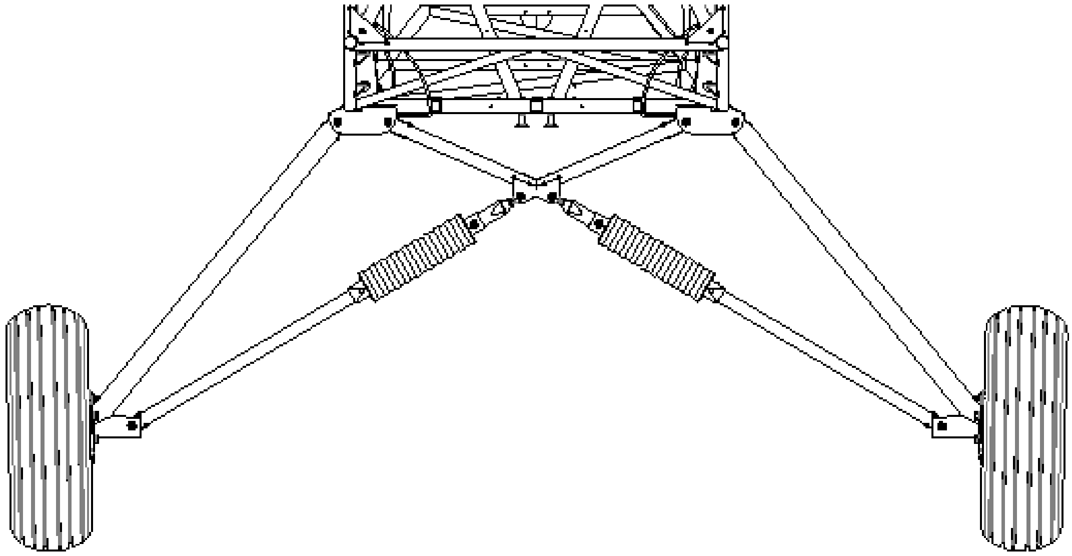
This report deals with the static analysis of the main landing gear unit of the LoCamp light sport aircraft.
The main gear unit of the LoCamp sport aircraft is based on a conventional welded main leg struts (main compression struts + drag braces) with integrated axle housings and two independent shock absorbers (based on a compression loaded rubber discs), one for each strut. The main gear assy is attached to the fuselage welded structure in 4 specific points (load pick-ups) by means of heavy duty hardware.
Whenever was possible, rod end bearings have been used in order to avoid load transfer from load carrying dedicated elements to un-dedicated ones (see Figure below).



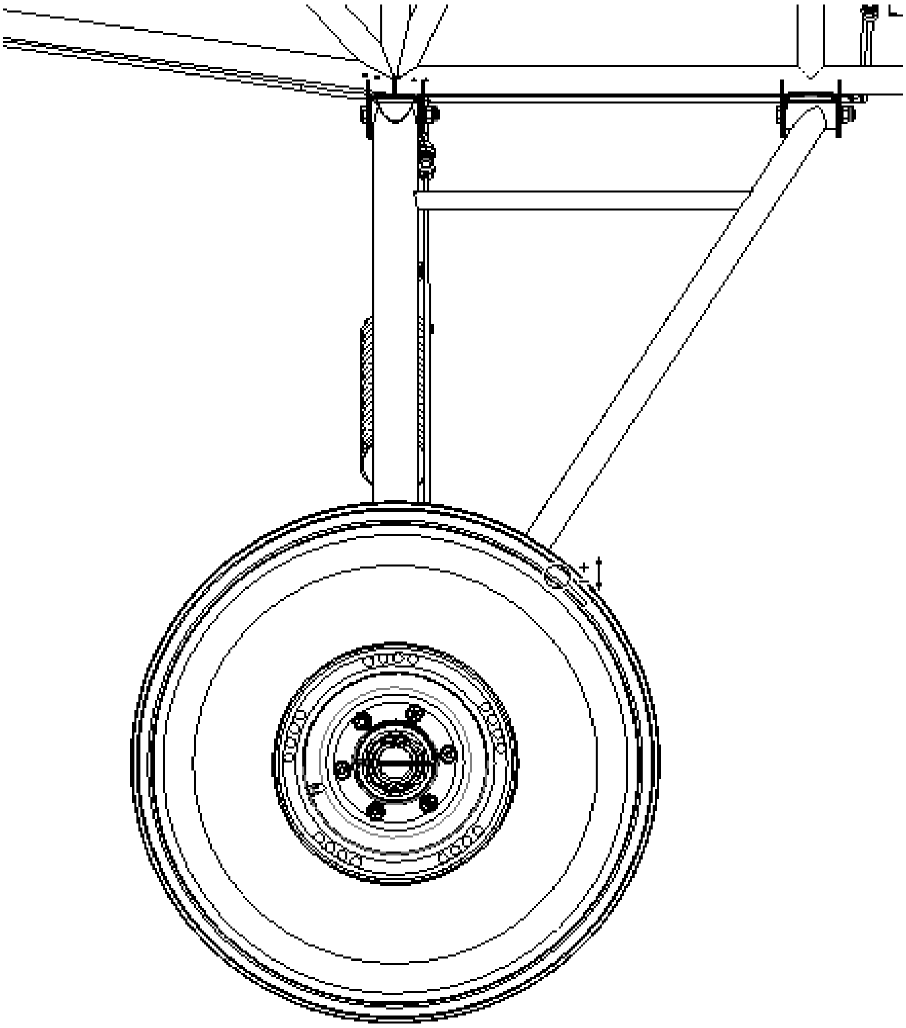
MLG – General view



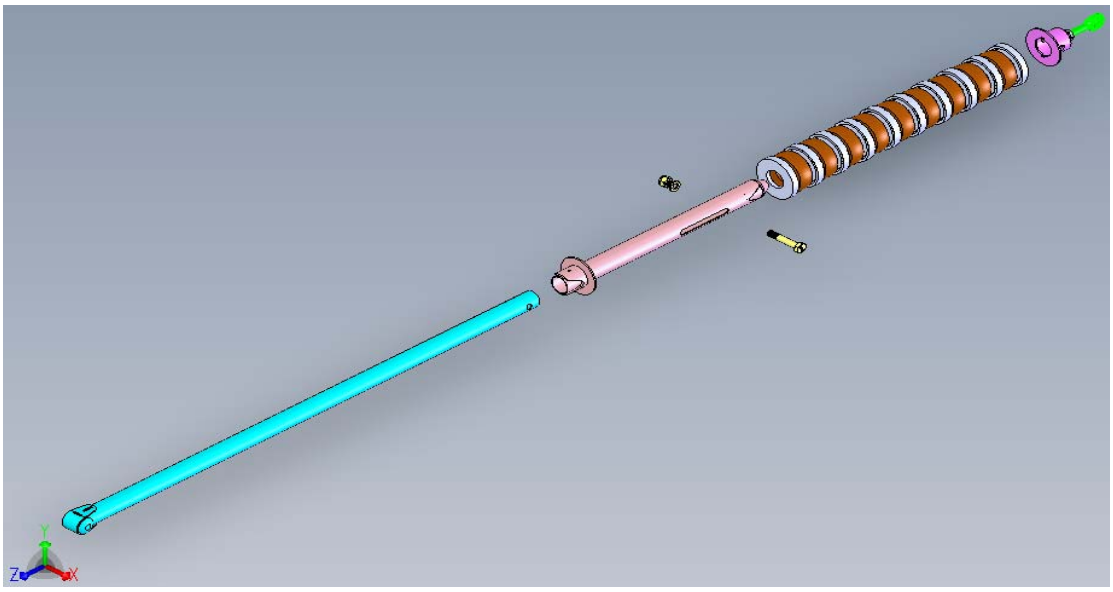
MLG – View on aircraft



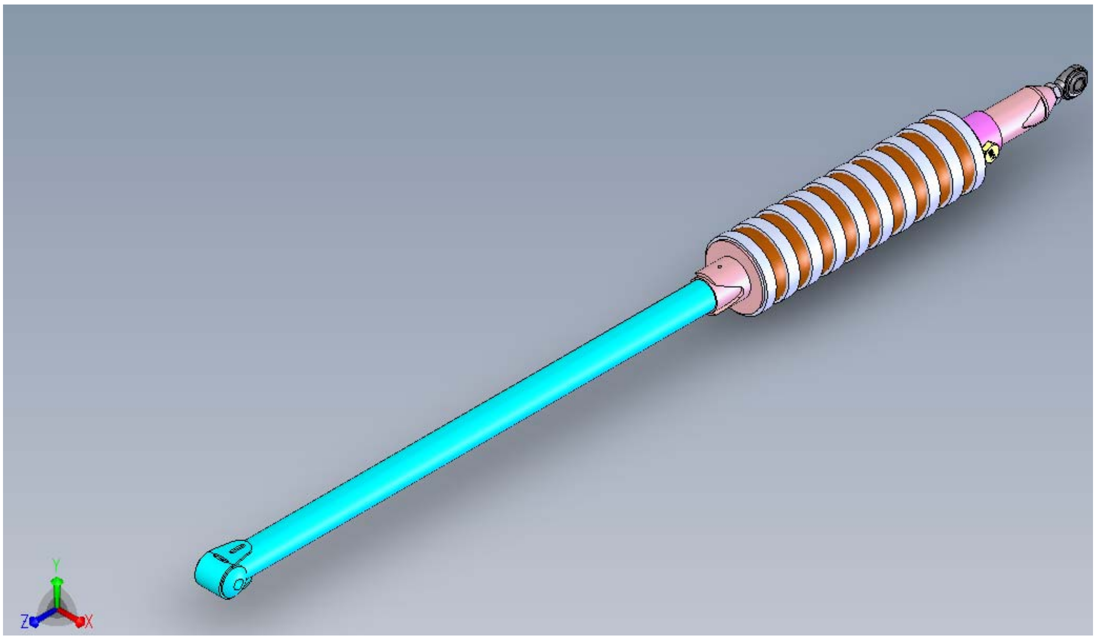
MLG – Front view



MLG – Side view



Shock absorber exploded view



3.1 Commonly Used Formulas

Sign conventions generally accepted in their use are quantities associated with tension action (loads, stresses, strains, etc.) are usually considered as positive, and quantities associated with compressive action are considered as negative. When compressive action is of primary interest, it is sometimes convenient to identify associated properties with a positive sign.

3.1.2 Simple Unit Stresses

$f_t = P / A$ (tension)
$f_c = P / A$ (compression)
$f_b = My / I = M / Z$ (bending)
$f_s = S / A$ (average direct shear stress)
$f_x = SQ / Ib$ (longitudinal or transverse shear stress)
$f_x = Ty / I_p$ (shear stress in round tubes due to torsion)
$f_s = (T/2At)$ (shear stress due to torsion in thin-walled structures of closed section. Note that A is the area enclosed by the median line of the section.)
$f_A = Bf_H$; $f_T = Bf_L$ (axial and tangential stresses, where B = biaxial ratio)
$f_A = f_c + f_b$ (compression and bending)

f_{smax} $\left[f_s \left(f_n \right) \right]$ (compression, bending, and torsion)

/

$f_{n\,max} = f_n/2 + f_{s\,max}$

3.1.3 Deflections (axial)

$e = \delta / L$ (unit deformation or strain)

$E = f/e$ (This equation applied when E is obtained from the same tests in which f and e are measured.)

$\delta = eL = (f / E)L$

$= PL / (AE)$ (This equation applies when the deflection is to be calculated using a known value of E.)

4. MATERIALS

For all tubing, the prescribed material is 25CrMo4 steel as per DIN17204 in its normalized condition. Typical mechanical properties are shown below:

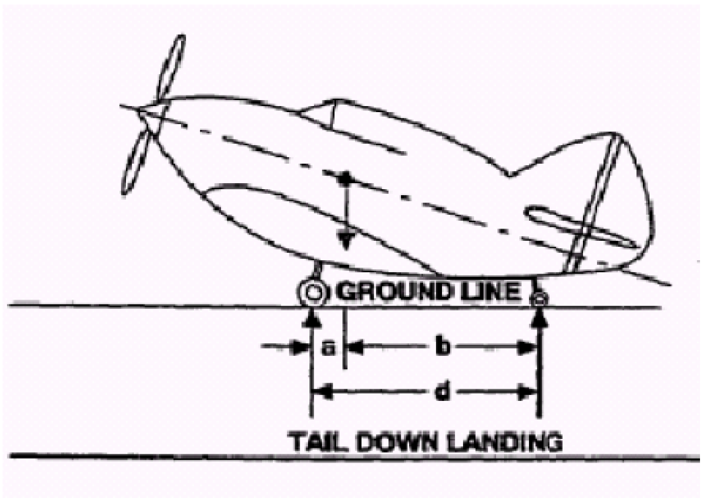
MECHANICAL PROPERTIES — TABLE 4

GRADE	N Rs (MPa) min	N Rm (MPa) min	N Rm (MPa) max	N A % min	SR Rs (MPa) min	SR Rm (MPa) min	SR A % min	C Rm (MPa) min	C A % min	LC Rm (MPa) min	LC A % min	A HB max	A Rm (MPa) min	A A % min
E235	240	360	460	28	370	440	16	480	6	420	12		340	26
E255	255	441	539	23	375	520	12	580	6	520	8		400	24
E355	355	510	630	22	520	600	12	650	5	580	8		490	23
E410	410	550	700	22	590	690	12	750	4	700	8		520	22
C10	215	360	480	25								131		
16MnCrS5												207		
16NiCrMo2												230		
C35	310	540	680	21				590	5	540	7	183	440	22
C45	350/340*	610/590*	760/740*	18				720	4	670	6	220	510	20
C60	390/380*	720/700*	900/880*	14								260		
25CrMo4	390	620	800	18				720	4	670	6	215		
30CrMo4	415	640	820	17								220		
42CrMo4								720	4	670	6	245		

F_{ty} = 390 Mpa; F_{tu} = 620 Mpa; E = 200000 MPa

5. LOADS

The main change with respect the original issue of this report is the use of appendix C of CS-VLA (ref. 1) to obtain the loads on the MLG. In addition, conservatively, the applied loads on the wheel have been obtained considering the aircraft c.g. load factor not the load factor at the wheel reduced by the dynamic effect of shock absorber and tyre.

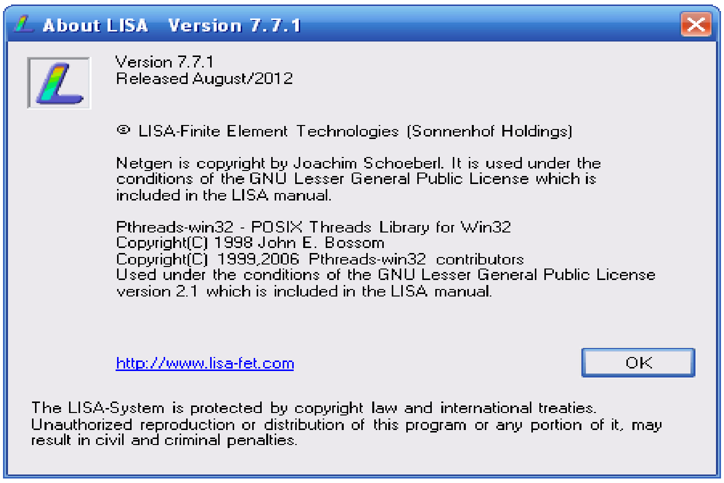


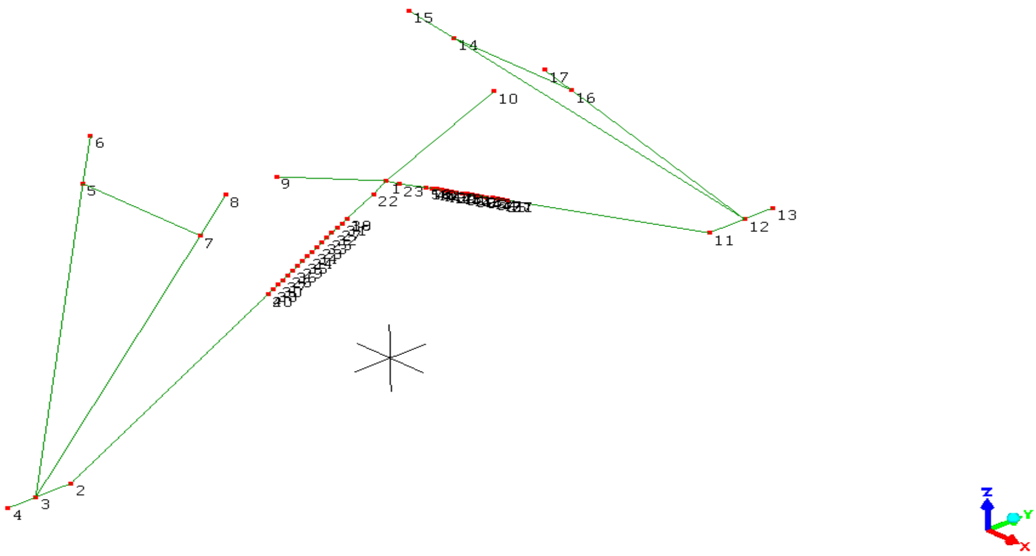
Condition		Tail wheel type				
		Level landing	Tail-down landing	Level landing	Tail-down landing	Remarks
Ref. Para CS23		23.479(a)(1)	23.483(a)(1)			
Vertical component at c.g.		nW	nW	2000		
Fore and aft component at c.g.		KnW	0	500		
Lateral component in either direction at c.g.		0	0	0		
Shock absorber deflection (rubber or spring shock absorber)		100%	100%			
Tyre deflection		Static	Static			
Main wheel loads (both wheels)	Vr	(n-L)W	(n-L)Wb/d	1599,8	1543,6	
	Dr	KnW	0	500		
Tail (nose) wheel loads	Vr	0	(n-l)Wa/d	0	56,2	
	Dr	0	0			
K=		0,25	0,25			
L=		0,667	0,667			
n=		3,33	3,33			
W=		600	600			
Wing lift at landing impact		400	400			
Main wheel loads each wheel, N	Vr			**7847,0**	7023,4	Load per single MLG
	Dr			**2452,5**	275,6	Load per single MLG
E = 0.0981*(56+7.62336*S)/ (0.137505*(254-2.54*S)				20,8		Elastic modulus of each rubber disc of shock absorber
S =				90		Rubber hardness
d =			4755			
a =			167			
b =			4588			

Loads per CS-VLA

6. Finite Element Model (FEM)

The FEM is done using the LISA Finite Elements Modeler and Solutor code. In the following pages the FEM description is provided to allow the check and the possibility of analysis repeatability with the same code or with another.





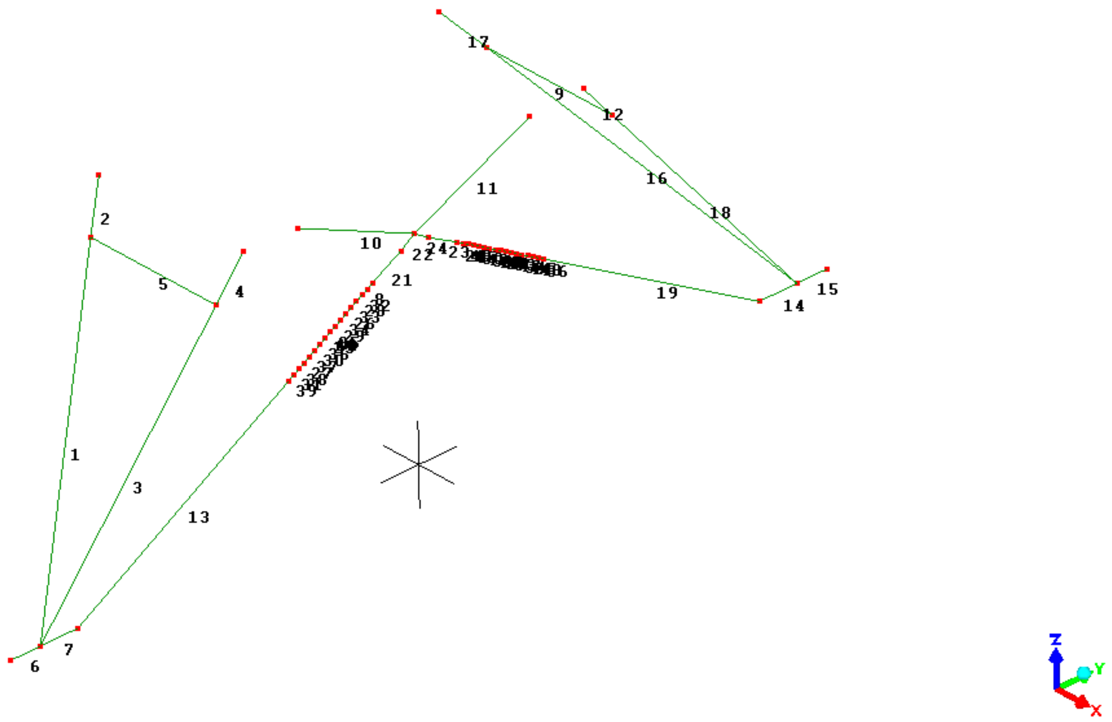
FEM Node ID's

FEM

	FEM		
Node	**X**	**Y**	**Z**
	mm	mm	mm
1	0	0	410,6
2	0	-692,5	0
3	0	-769	0
4	0	-829	0
5	-277,75	-402,63	452,35
6	-320	-345,5	521,5
7	0	-402,63	452,35
8	0	-345,5	523
9	0	-236	519
10	0	236	519
11	0	692,56	0
12	0	769	0
13	0	829	0
14	-277,75	402,63	452,35
15	-320	345,5	521,5
16	0	402,63	452,35
17	0	345,5	523
18	0	-86,57	359,275
19	0	86,57	359,275
20	0	-259,71	256,625
21	0	259,71	256,625
22	0	-28	391,6
23	0	28	391,6
24	0	-173,14	307,95
25	0	-129,855	333,6125
26	0	-216,425	282,2875
27	0	-108,2125	346,4438
28	0	-151,4975	320,7813
29	0	-194,7825	295,1187
30	0	-238,0675	269,4562
31	0	-97,39125	352,8594
32	0	-119,0338	340,0281
33	0	-140,6763	327,1969
34	0	-162,3188	314,3656
35	0	-183,9612	301,5344
36	0	-205,6037	288,7031
37	0	-227,2462	275,8719
38	0	-248,8887	263,0406

	FEM		
Node	**X**	**Y**	**Z**
39	0	-86,57	359,275
40	0	-259,71	256,625
41	0	173,14	307,95
42	0	129,855	333,6125
43	0	216,425	282,2875
44	0	108,2125	346,4438
45	0	151,4975	320,7813
46	0	194,7825	295,1187
47	0	238,0675	269,4562
48	0	97,39125	352,8594
49	0	119,0338	340,0281
50	0	140,6763	327,1969
51	0	162,3188	314,3656
52	0	183,9612	301,5344
53	0	205,6037	288,7031
54	0	227,2462	275,8719
55	0	248,8887	263,0406
56	0	86,57	359,275
57	0	259,71	256,625

FEM GRID's Coordinates

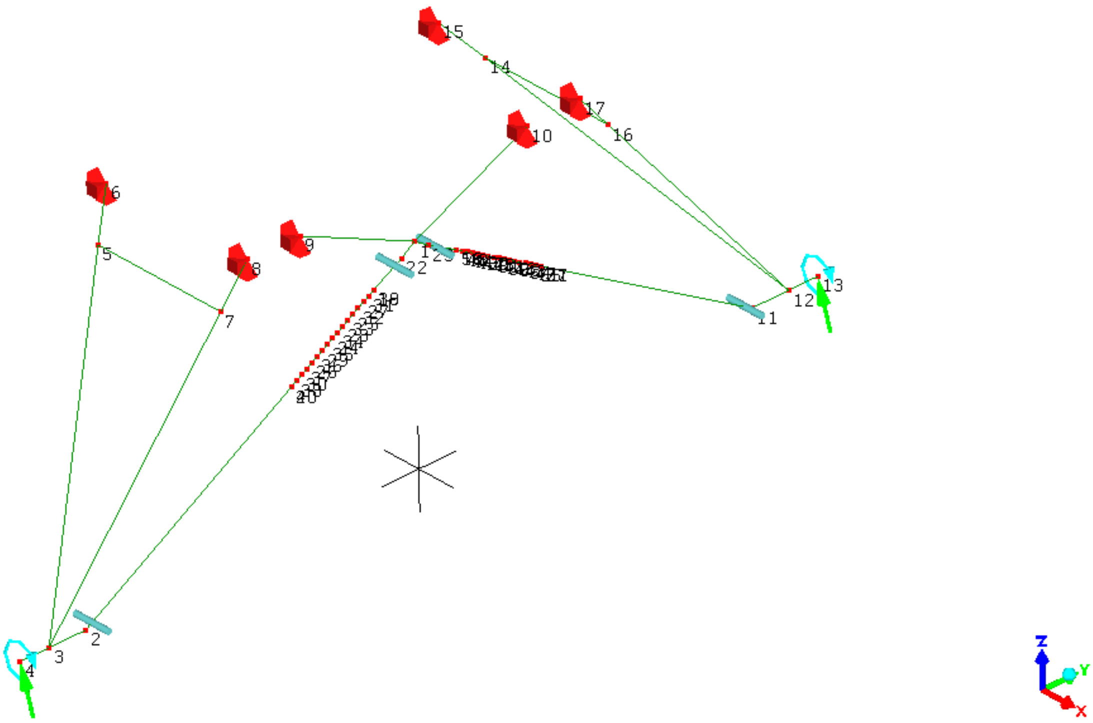


FEM Elements ID's

Element	Shape	Material	Nodes
1	line2	1	3,5
2	line2	1	5,6
3	line2	3	3,7
4	line2	3	7,8
5	line2	2	5,7
6	line2	4	4,3
7	line2	4	3,2
8	line2	6	31,39
9	line2	2	16,14
10	line2	1	1,9
11	line2	1	1,10
12	line2	3	16,17
13	line2	1	2,40
14	line2	4	11,12
15	line2	4	12,13
16	line2	1	12,14
17	line2	1	14,15
18	line2	3	12,16
19	line2	1	11,57
20	line2	6	48,56
21	line2	1	18,22

Element	Shape	Material	Nodes
22	line2	1	22,1
23	line2	1	19,23
24	line2	1	23,1
25	line2	6	35,24
26	line2	6	33,25
27	line2	6	37,26
28	line2	6	32,27
29	line2	6	34,28
30	line2	6	36,29
31	line2	6	38,30
32	line2	5	27,31
33	line2	5	25,32
34	line2	5	28,33
35	line2	5	24,34
36	line2	5	29,35
37	line2	5	26,36
38	line2	5	30,37
39	line2	5	20,38
40	line2	1	40,39
41	line2	1	20,18
42	line2	6	52,41
43	line2	6	50,42
44	line2	6	54,43
45	line2	6	49,44
46	line2	6	51,45
47	line2	6	53,46
48	line2	6	55,47
49	line2	5	44,48
50	line2	5	42,49
51	line2	5	45,50
52	line2	5	41,51
53	line2	5	46,52
54	line2	5	43,53
55	line2	5	47,54
56	line2	5	21,55
57	line2	1	21,19
58	line2	5	21,56
59	line2	1	57,56
60	line2	5	20,39

FEM Element Type, Material and connections



FEM Constraints and Loads for LC1

Node	Property	Value	Load Case
13	forcex	-2453	1
4	forcex	-2453	1
13	forcez	7847	1
4	forcez	7847	1
13	momy	490600	1
4	momy	490600	1

FEM Node Loads (n, Nmm)

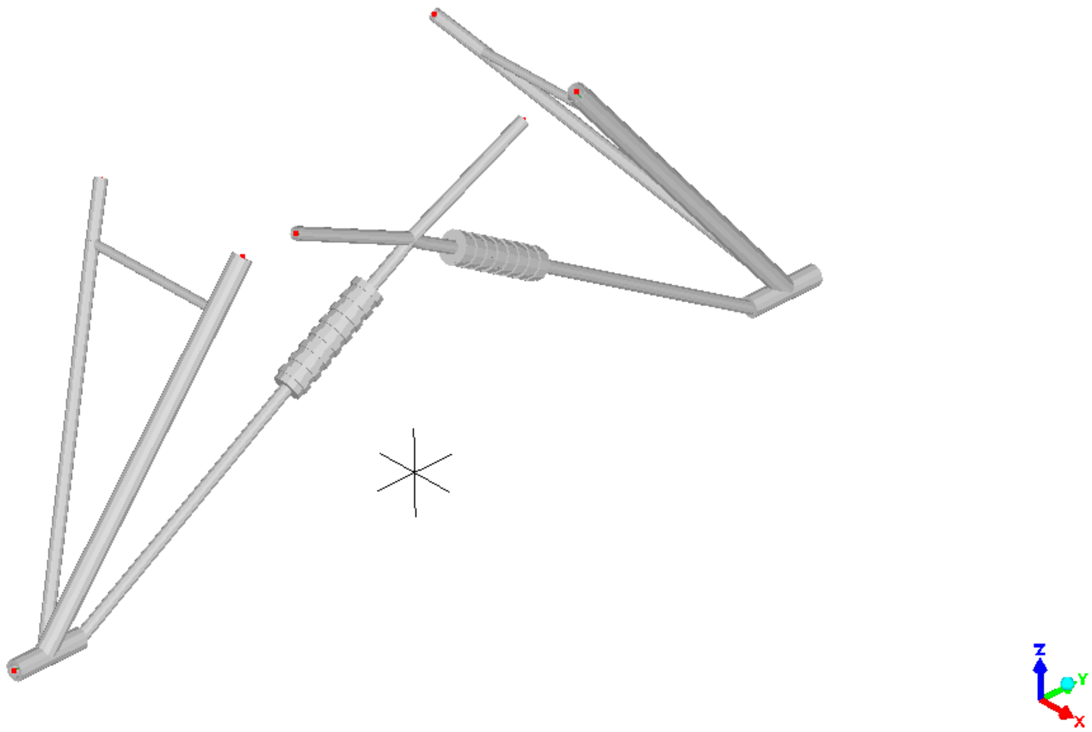
Node	Property	Value
6	displx	0
8	displx	0
17	displx	0
15	displx	0
9	displx	0
10	displx	0
6	disply	0

FEM Node Constraints

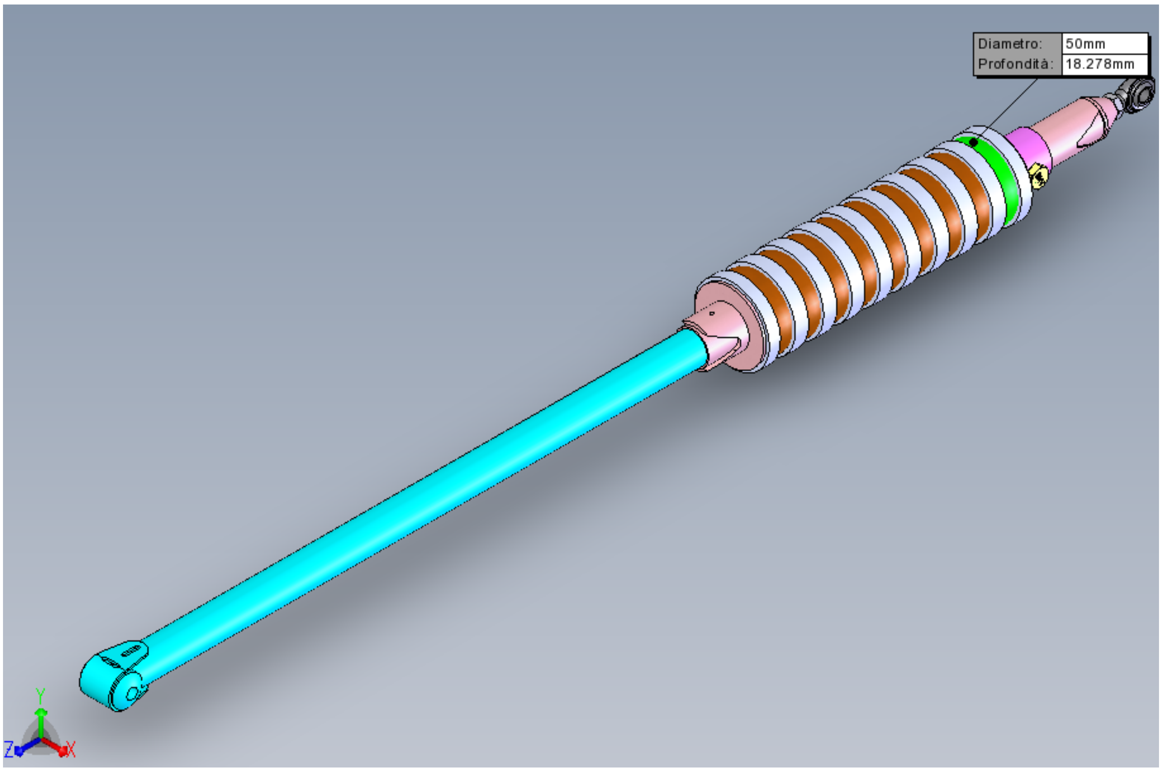
Node	Property	Value
8	disply	0
17	disply	0
15	disply	0
9	disply	0
10	disply	0
6	displz	0
8	displz	0

Node	Property	Value
17	displz	0
15	displz	0
9	displz	0
10	displz	0

FEM Node Constraints



FEM Elements Properties View



Shock absorber design

The shock absorber is made by No. 9 rubber discs 50 mm DIA x 11 mm thickness separated by No. 10 metallic washer 56.5 mm DIA x 10 mm thickness in 7075-T6. The rubber discs E modulus is obtained using the Gent's relation that has the form:

$E = (0.0981(56+7.62336S)/(0.137505(254-2.54S))$

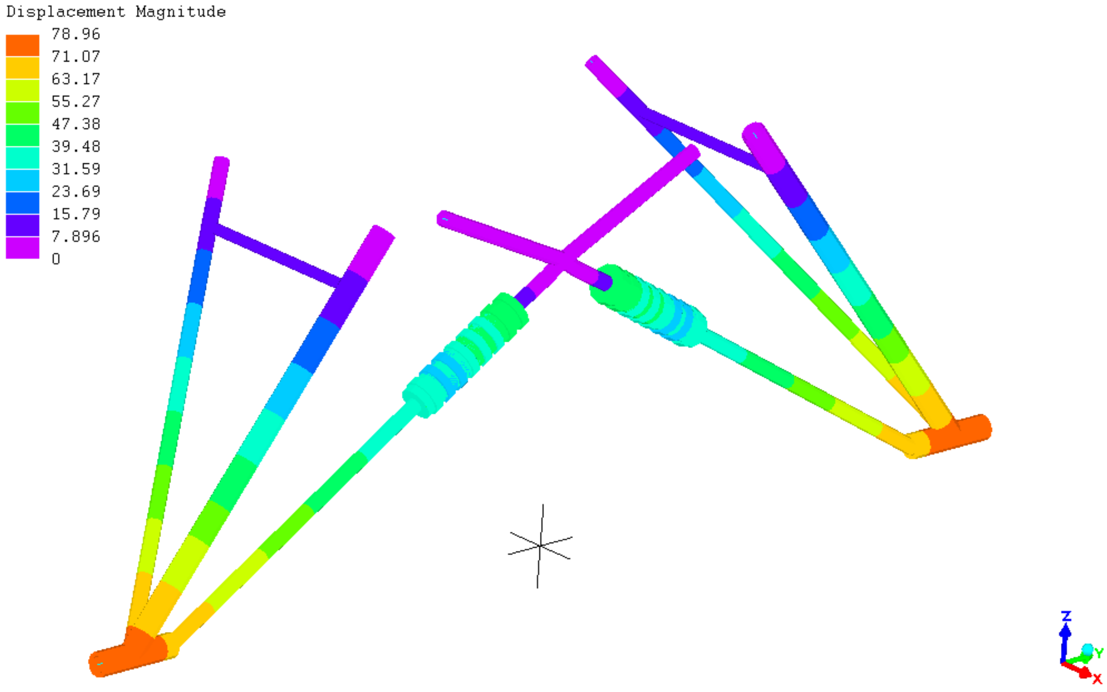
where E is the Young's modulus in MPa and S is the ASTM D2240 type A hardness.

The rubber discs have 90 shore type A hardness.

The single rubber disc E = 20.84 MPa

The spring is obtained using coaxial line elements: one line of elements represents the sequence of metallic and rubber discs, while the other two coaxial line elements represent the shock absorber skeleton (see exploded view on page 9).

7. STRESS ANALYSIS

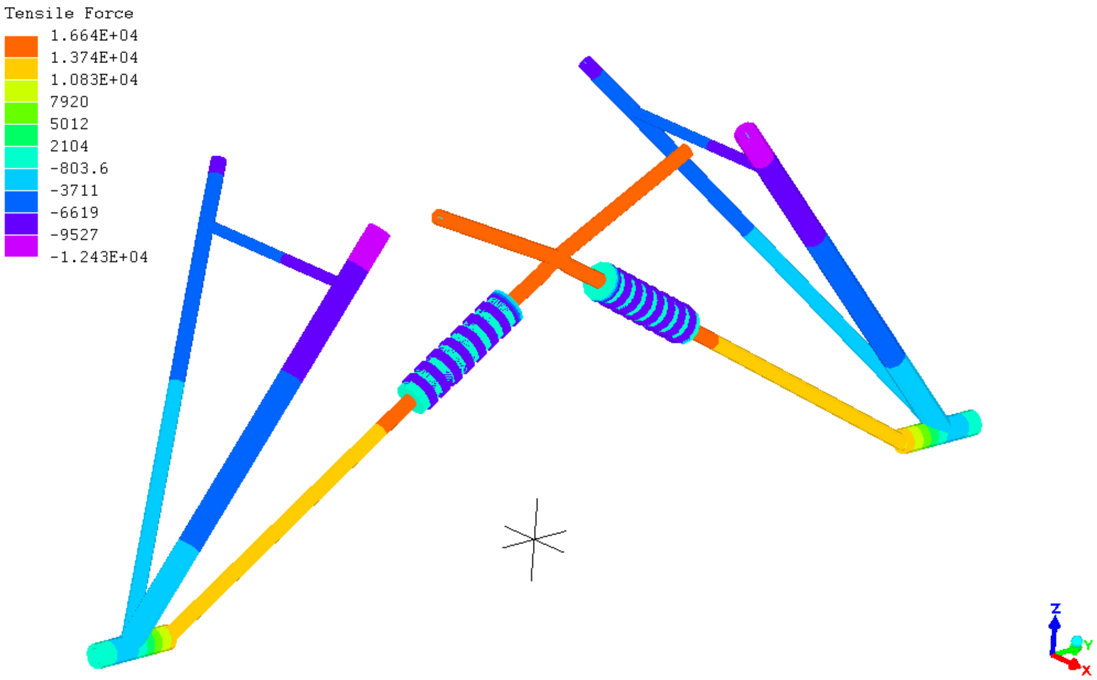


LC1 – Node displacements (mm) Magnitude

In the table on next page the displacements (mm) for all the FEM node are provided. All the data are referred to the LC 1 (level landing) and are referred to Limit Loads.

Max magnitude displacement = 78.96 mm (node 4 & 13).

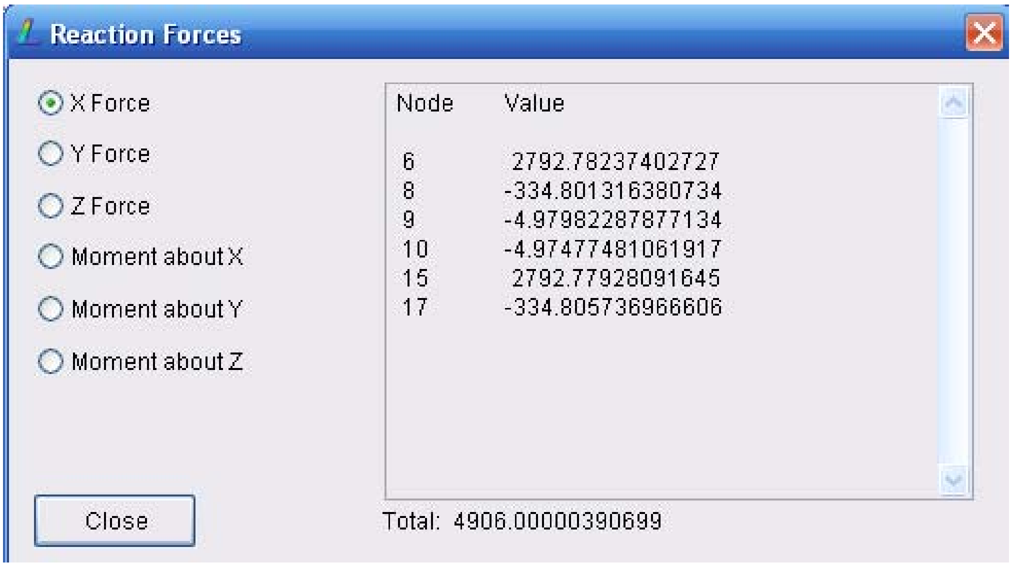
Load case 1					
	Node				
Field value		Displacement Magnitude	Displacement in X	Displacement in Y	Displacement in Z
	1	4,191673	-4,111081	8.246519E-06	-0,8180104
	2	69,71154	-4,062368	-57,78833	38,77764
	3	74,5778	-0,7669708	-57,79602	47,12621
	4	78,96379	1,805003	-57,79602	53,77399
	5	12,67162	0,5550971	-9,550181	8,309982
	6	0	0	0	0
	7	10,02187	0,5670654	-7,758396	6,31852
	8	0	0	0	0
	9	0	0	0	0
	10	0	0	0	0
	11	69,7085	-4,060006	57,78361	38,77945
	12	74,57171	-0,7669305	57,79129	47,12239
	13	78,95815	1,805251	57,79129	53,7708
	14	12,6702	0,5551088	9,549082	8,309081
	15	0	0	0	0
	16	10,02018	0,5670772	7,757073	6,317451
	17	0	0	0	0
	18	10,72102	-6,054521	3,824652	-7,978415
	19	10,67618	-6,054544	-3,798298	-7,930717
	20	33,91666	-9,834716	15,68647	-28,41748
	21	33,7102	-9,83481	-15,57779	-28,23095
	22	4,906474	-4,836333	-0,03940189	-0,8257164
	23	4,906467	-4,836339	0,03946966	-0,8256426
	24	31,90137	-8,524641	0,6916233	-30,73352
	25	36,96761	-8,307864	-4,526236	-35,73649
	26	30,72716	-9,048247	7,48847	-28,39384
	27	40,72261	-8,328278	-6,487471	-39,33044
	28	33,99966	-8,375151	-2,125794	-32,88335
	29	30,77907	-8,750838	3,903788	-29,24952
	30	31,78536	-9,411371	11,42344	-28,12899
	31	44,02566	-8,373204	-8,809177	-42,31485
	32	39,85919	-8,30688	-7,075881	-38,33644
	33	36,4223	-8,331003	-4,892265	-35,11758
	34	33,77205	-8,440078	-2,280556	-32,62078
	35	32,00255	-8,628609	0,7370134	-30,80856
	36	31,22351	-8,891099	4,138216	-29,6434
	37	31,52096	-9,222053	7,90082	-29,08782
	38	32,91795	-9,615974	12,0026	-29,10433
	39	45,22154	-8,441887	-7,98727	-43,70269
	40	31,07489	-7,27568	-21,67792	-21,04237
	41	31,75385	-8,524854	-0,6033279	-30,58218
	42	36,83258	-8,308154	4,614642	-35,58537
	43	30,5544	-9,048378	-7,393996	-28,23167
	44	40,58842	-8,328587	6,57775	-39,17636
	45	33,8602	-8,375406	2,213468	-32,73326
	46	30,62022	-8,751008	-3,813298	-29,09427
	47	31,59672	-9,411475	-11,32298	-27,95651
	48	43,89417	-8,373515	8,900793	-42,15873
	49	39,72874	-8,307181	7,165136	-38,18409
	50	36,28943	-8,331277	4,980189	-34,96727
	51	33,63296	-8,440313	2,368398	-32,47041
	52	31,85349	-8,6288	-0,6477904	-30,65565
	53	31,06117	-8,891249	-4,04593	-29,48512
	54	31,34274	-9,222168	-7,803576	-28,92098
	55	32,72176	-9,616071	-11,89828	-28,92535
	56	45,08495	-8,442194	8,080344	-43,54411
	57	31,04365	-7,276055	21,74661	-20,92492



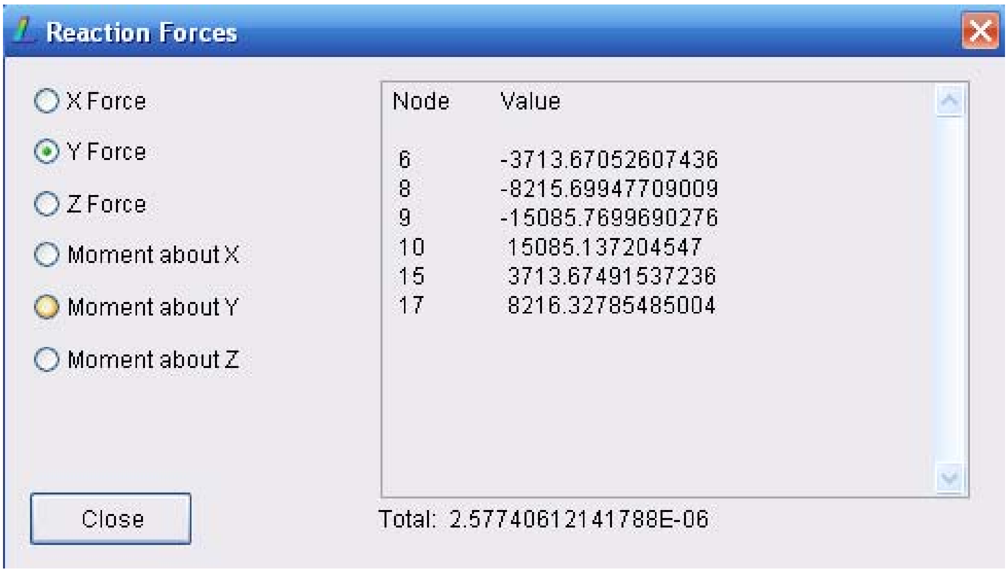
LC1 – Node Axial force, N (L.L.)

In the next page table the axial forces, shear forces and moments for all the FEM elements are provided. All the data in the table are for LC 1 (level landing) and are Limit Loads.

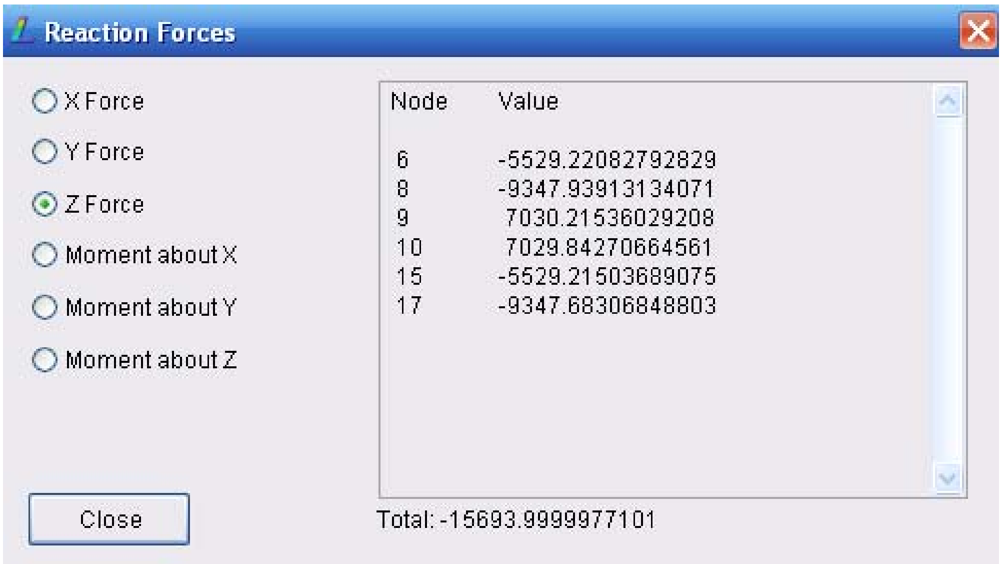
Load case 1							
	Node						
Field value		Tensile Force	Shear Force V	Shear Force W	Torsion	BM about V	BM about W
		N	N	N	Nmm	Nmm	Nmm
	1	15230,86	-0,1243638	4,977299	0,04236382	-885,8864	-9,677296
	2	12888,04	16,18334	-3512,589	-2561,831	392,1039	-310,3207
	3	-1958,467	626,4545	408,7185	-166167,5	-130183,9	19870,56
	4	0	2453	7847	-490600	1.117587E-07	3.72529E-09
	5	-4802,502	-55,66407	255,0646	-8256,358	19928,98	-20516,2
	6	-7186,146	522,4357	499,64	-2.910383E-10	0	-1.396984E-09
	7	-8070,004	-350,246	406,1516	-36428,08	-9487,649	-16701,15
	8	-12434,67	-510,5898	334,8013	4.656613E-10	-6.984919E-10	3.72529E-09
	9	16643,2	91,77098	4,979823	0	-8.731149E-11	7.275958E-12
	10	16642,46	-91,69646	4,974775	1.455192E-11	-8.731149E-11	0
	11	12888,57	-16,04003	3517,436	2560,874	389,9012	-312,1774
	12	-1958,357	-626,2933	0,2284391	166172,1	-130076,4	53488,58
	13	0	-2453	-7847	490600	-8.940697E-08	0
	14	-4802,5	-373,4528	255,0705	8258,901	22616,12	20513,69
	15	-7186,143	-522,4283	499,6396	-5.820766E-11	2.328306E-10	4.656613E-10
	16	-8070,134	-78,48951	406,1698	36430,53	23864,67	16665,35
	17	-12434,86	511,2395	334,8057	2.328306E-10	4.656613E-10	7.450581E-09
	18	13843,99	-177,1159	4,981055	-2496,662	-2763,306	26139,58
	19	13844,41	176,5745	4,973542	2496,938	-2762,525	-26103,79
	20	-8.700832E-11	-3.56124E-11	2.153744E-11	-1.537046E-10	7.003109E-11	-1.952382E-10
	21	-3.274181E-11	-3.599136E-11	5.741777E-12	-1.735619E-11	1.403275E-10	-1.806863E-10
	22	13829,98	245,1668	4,981055	-2592,691	-3015,842	2.911094E-11
	23	13830,38	-245,7203	4,973542	2592,92	-3014,552	2.619416E-10
	24	-9230,466	-33,67774	-4,246305	1692,764	1491,134	-15046,77
	25	-9230,466	-33,67774	-4,246306	1692,764	1704,81	-16741,46
	26	-9230,466	-33,67774	-4,246305	1692,764	1277,458	-13352,09
	27	-9230,466	-33,67774	-4,246306	1692,764	1811,649	-17588,8
	28	-9230,466	-33,67774	-4,246306	1692,764	1597,972	-15894,12
	29	-9230,466	-33,67774	-4,246305	1692,764	1384,296	-14199,43
	30	-9230,466	-33,67774	-4,246305	1692,764	1170,62	-12504,75
	31	-9230,466	-33,67774	-4,246306	1692,764	1865,068	-18012,47
	32	-9230,466	-33,67774	-4,246306	1692,764	1758,229	-17165,13
	33	-9230,466	-33,67773	-4,246306	1692,764	1651,391	-16317,79
	34	-9230,466	-33,67774	-4,246306	1692,764	1544,553	-15470,44
	35	-9230,466	-33,67774	-4,246305	1692,764	1437,715	-14623,1
	36	-9230,466	-33,67774	-4,246305	1692,764	1330,877	-13775,76
	37	-9230,466	-33,67774	-4,246305	1692,764	1224,039	-12928,42
	38	-9230,466	-33,67774	-4,246305	1692,764	1117,201	-12081,08
	39	-1.967749E-07	-4.712136E-08	1.062522E-07	-6.439192E-08	-1.083863E-07	-4.513936E-06
	40	13846,72	36,9267	4,981058	-2539,354	-1722,107	18791,65
	41	-9230,739	34,0058	-4,241279	-1692,94	1491,104	14986,84
	42	-9230,739	34,0058	-4,241279	-1692,94	1704,527	16698,03
	43	-9230,739	34,0058	-4,241278	-1692,94	1277,681	13275,65
	44	-9230,739	34,0058	-4,241279	-1692,94	1811,239	17553,63
	45	-9230,739	34,0058	-4,241279	-1692,94	1597,816	15842,44
	46	-9230,739	34,0058	-4,241279	-1692,94	1384,392	14131,25
	47	-9230,739	34,0058	-4,241278	-1692,94	1170,969	12420,06
	48	-9230,739	34,0058	-4,241279	-1692,94	1864,595	17981,42
	49	-9230,739	34,0058	-4,241279	-1692,94	1757,883	17125,83
	50	-9230,739	34,0058	-4,241279	-1692,94	1651,172	16270,23
	51	-9230,739	34,0058	-4,241279	-1692,94	1544,46	15414,64
	52	-9230,739	34,0058	-4,241279	-1692,94	1437,748	14559,04
	53	-9230,739	34,0058	-4,241279	-1692,94	1331,036	13703,45
	54	-9230,739	34,0058	-4,241278	-1692,94	1224,325	12847,85
	55	-9230,739	34,0058	-4,241277	-1692,94	1117,613	11992,26
	56	-2.24265E-07	3.77143E-07	6.945752E-08	-4.980766E-07	6.876862E-07	3.303445E-06
	57	13847,13	-37,0536	4,973544	2539,566	-1722,911	-18645,57



LC1 Constraint Forces in X direction



LC1 Constraint Forces in Y direction



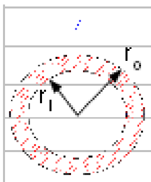
LC1 Constraint Forces in Z direction

7.1 Method of analysis and assumptions

The main components of the landing gear are verified in linear static analysis. Loads provided in the previous tables are always given as limit loads, proper safety factors are then introduced/specified during the analysis.

7.2 Main gear strut analysis

Tube 34.93 DIA x 1.47 mm thk; length = 700 mm
Material: 25 Cr Mo4

	r_o =	17,46	mm	
	r_i =	15,99	mm	
	A =	154	mm²	
	I =	21647	mm⁴	$= 0.25\pi(r_o^4 - r_i^4)$
	J =	43295	mm⁴	$= 0.5\pi(r_o^4 - r_i^4)$
	ρ =	11,8	mm	$= \sqrt{([r_o^2 + r_i^2])} / 2$

The critical column load is:
$P_{cr} = c\pi^2 E J / L^2$
where:
c = 2.05 (fixity coefficient REF. 7 for pinned-fixed column)
$P_{cr} = 2.05*\pi^2*200000*21647/700^2 = 178766$ N

With reference table on page 26 the max compression load is Pc = -12435 N (node 8)

M.S. = (P_{cr}/(Pc*1.5))-1 = (178766/(12435*1.5))-1 = High (U.L.) Level Lading L.C.

The max stress on main gear strut is:
$f_c = 12435/154 = 81$ MPa (L.L.)
$f_s = 4/3*(611/154) = 5.3$ MPa (L.L.)
$f_{von\ Mises} = (81^2 + 3*5.3^2)^{0.5} = 81.5$ MPa

M.S. = ($F_{ty}/f_{von\ Mises}$)-1 = (390/81.5)-1 = High (L.L.)

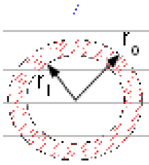
Being the shear stress negligible the M.S. at U.L. is:

M.S. = (F_{tu}/f_c)-1 = (620/81*1.5)-1 = High (U.L. Level landing L.C.)

The max stress on gear strut is in correspondence of the horizontal triangle upper closure where from LISA output we get f = 305.7 Mpa (L.L.)
M.S. = (390/305.7) – 1 = <u>0.27</u> (L.L. Level landing)
M.S. = (620/(305.7*1.5)) – 1 = <u>0.35</u> (U.L. Level landing)

7.3 Drag brace analysis

Tube 22,22 mm DIA x 0.9 mm thk; length = 774 mm



r_o =	11,11	mm		
r_i =	10,21	mm		
A =	60	mm²		
I =	3431	mm⁴	$= 0.25\pi(r_o^4 - r_i^4)$	
J =	6862	mm⁴	$= 0.5\pi(r_o^4 - r_i^4)$	
ρ =	7,5	mm	$= \sqrt{[r_o^2 + r_i^2]} / 2$	

Material: 25 Cr Mo4

The critical column load is:
$P_{cr} = c\pi^2 E J / L^2$
where:
c = 2.05 (fixity coefficient REF. 7 for pinned-fixed column)
$P_{cr} = 2.05*\pi^2*200000*3431/774^2 = 23175$ N

With reference table on page 26 the max compression load is Pc = -7186 N (node 6)

M.S. = (P_{cr}/(Pc*1.5))-1 = (23175/(7186*1.5))-1 = <u>1.15</u> (U.L.) Level Lading L.C.

The max stress on main gear strut is:
$f_c = 7186/60 = 120$ MPa (L.L.)
$f_s = 4/3*((522^2+499^2)^{0.5}/60) = 16$ MPa (L.L.)
$f_{von\ Mises} = (120^2 + 3*16^2)^{0.5} = 123$ MPa

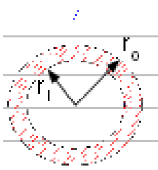
M.S. = ($F_{ty}/f_{von\ Mises}$)-1 = (390/123)-1 = High (L.L.)

Being the shear stress negligible the M.S. at U.L. is:

M.S. = (F_{tu}/f_c)-1 = (620/123*1.5)-1 = High (U.L. Level landing L.C.)

7.4 Shock absorber analysis

Tube 22,22 DIA x 0.9 mm thk.
Material: 25 Cr Mo4



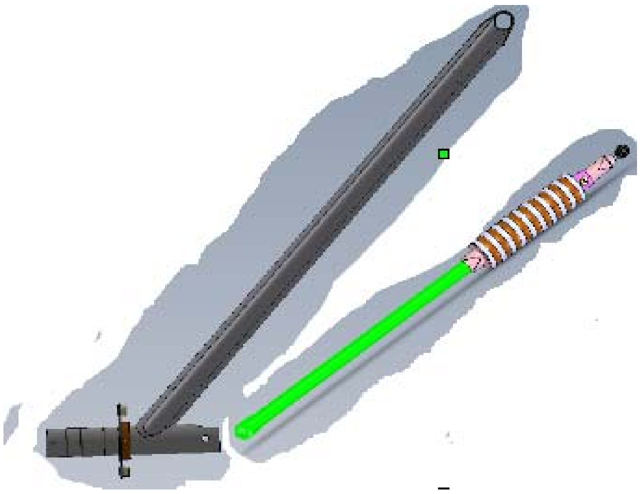
r_o =	11,11	mm	
r_i =	10,21	mm	
A =	60	mm²	
I =	3431	mm⁴	$= 0.25\pi(r_o^4 - r_i^4)$
J =	6862	mm⁴	$= 0.5\pi(r_o^4 - r_i^4)$
ρ =	7,5	mm	$= \sqrt{[r_o^2 + r_i^2]}\ /\ 2$

The max tensile force on tube is Pt = 13830 N (L.L.) see table on page 26.

f_t = 13830/(60-8*0.9*2) = 303.3 MPa (L.L.) on net area

M.S. = (F_{ty}/f_t) – 1 = (390/303.3) – 1 = <u>0.28</u> (load case levele lending L.L.)

M.S. = (F_{tu}/f_t*1.5) – 1 = (620/(303.3*1.5)) – 1 = <u>0.36</u> (load case levele lending U.L.)



Shock absorber lower fitting detail

The compression spring upper retainer is fixed to the sliding tube by means of a AN-5 aviation grade bolt and the wall of the tube is locally reinforced to better withstand high bearing loads. At the ultimate load of P=13830*1.5*1.15 = 23857 N, with Ref. [8] the single shear allowable is: 5750 lbs (25586N). The bolt works in double shear then:

M.S. = (25586*2/13830*1.5*1.15) – 1 = 1.14 (U.L.)

The bearing stress is (thickness of the tube is locally increased by means an internal 2mm thk. welded plug):

f_{br}=0.5*13830/(7.95*2.889) = 301 MPa

M.S. = High by inspection (U.L.)

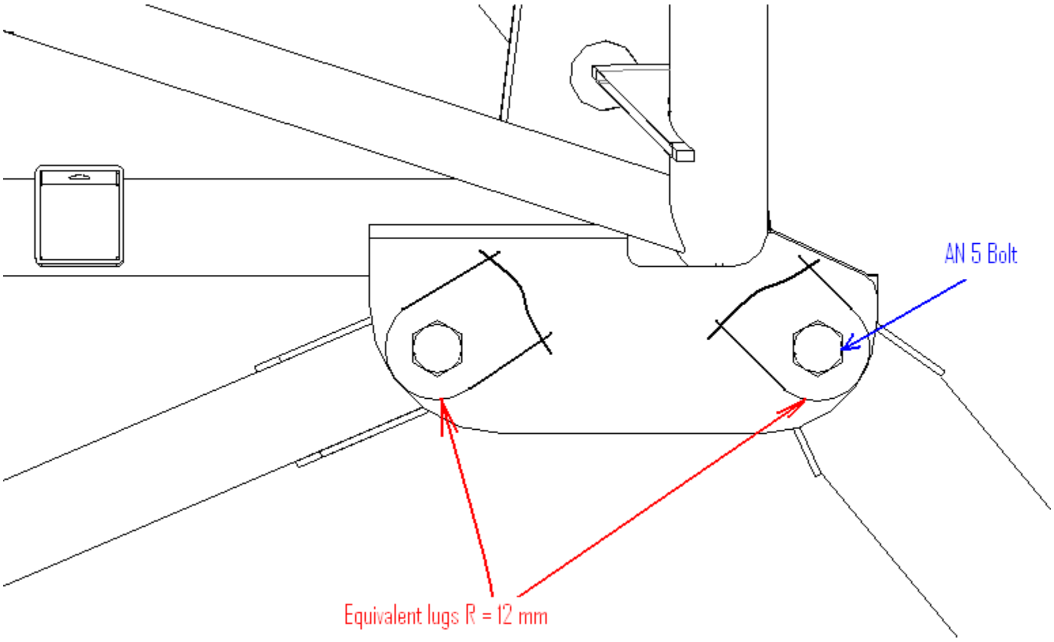
The spring lower retainer (welded limit stop) does not need to be further verified because the type of the welding is similar to the one already seen for the shock absorber's lower end/fitting, except the limit stop has a greater outer diameter (and therefore greater resisting cross-section).

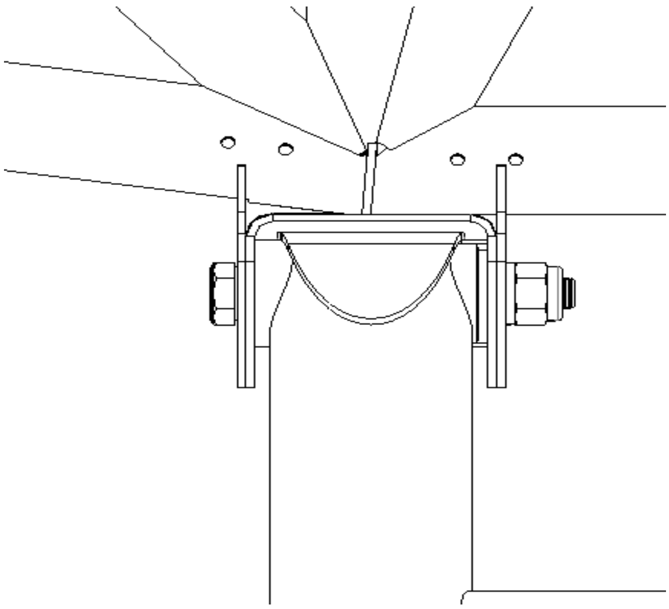
The other tube's end fittings does not need further analyses because they show greater cross section and/or heavier spherical rod ends. Furthermore, all welded joints work under compression loads and, in general, the welded tube's ends are flanged, thus ensuring a good support at the ends.

The connection between shock absorber and wheel axle is done via a bolt AN5. The bolt works in double shear and its single shear allowable per REF. 8 is 5750 lbs equal to 25586 N.

M.S. = (25586*2/13830*1.5*1.15) – 1 = 1.14 (U.L.)

7.5 MLG fittings to fuselage analysis





Main gear strut fitting to fuselage

With reference pages 26 and 27 the reaction forces at node 8 are the followings:

Rx = -335 N (negligible)

Ry = -8216 N

Rz = -9348 N

The lug load is obtained as $(8216^2 + 9348^2)^{0.5}$ = 12445.4 N (L.L.)

LUG DATA & ALLOWABLE (ref. 7)

W, (mm) = 24 DWG No.: MLG-Fuselage Fitting

D, (mm) = 7.93 Material: 25 Cr Mo4

t, (mm) = 3 Ftu, (MPa) = 620

e, (mm) = 12 Ftu; min, (MPa) = 620

c, (mm) = 0 Fty, (MPa) = 390

TENSION ALLOWABLE BEARING ALLOWABLE

At , (mm^2) = 48.21 Abr,(mm^2) = 23.79

Ktu = .9276037 Pbru, (N) = 20178

Ptu, (N) = 27726.26

TRANSVERSE LOAD ALLOWABLE

A1, (mm^2) = 27.58979 Aav, (mm^2) = 26.32139

A2, (mm^2) = 24.105 BETA DEG. = 0

A3, (mm^2) = 24.105 Ktru = 1.409471

A4, (mm^2) = 27.58979 Ptru, (N) = 20789.42

M.S = -------(U.L.)-------> 1.16

M.S. =------ WITH F.F. ----------> 0.88

Bushing Yield Bearing Allowable Pbry, N = 0

LUG Yield Allowable Py, N = 13635.07

M.S. = (13635/12445.4)-1 = 0.09 (L.L.) Level landing L.C.

The AN5 bolt shear M.S. is:

Bolt shear allowable = 5705 lbs (ref. 8) = 25586 N

M.S. = ((25586*2)/(12445.4*1.5*1.15)) – 1 = <u>1.38</u> (U.L.) Level landing L.C.

Looking the gear strut fitting to the fuselage, the AN5 bolt shall withstand bending stress in addition to the shear. The bolt bending is calculated using the method reported in ref. 9.

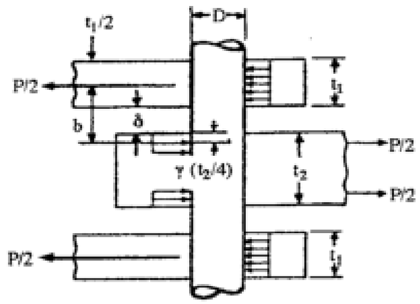


Fig. 9.8.8 Pin Moment Arm for Determination of Bending Moment

Since a weak or smaller pin can cause an inner lug (t_2) to fail at a smaller load, larger pins (ample MS) are always recommended. The moment arm is given by:

$$b = \frac{t_1}{2} + \delta + \gamma\left(\frac{t_2}{4}\right) \qquad \text{Eq. 9.8.8}$$

Compute the following two values:

$$\frac{(P_u)_{min}}{A_{br} F_{tux}}$$

$$r = \frac{a - \frac{D}{2}}{t_2}$$

where:
- t_1 – Outer lug thickness
- t_2 – Inner lug thickness
- $(P_u)_{min}$ – The smaller of P_{bru} (Eq. 9.8.1) and P_{tu} (Eq. 9.8.2) for the inner lug
- P_{tux} – Lug material across grain "F" (see sketch in Fig. 9.8.5)
- D – Pin diameter or D_b (if bushing used)
- δ – Gap (lug chamfer or use flange bushings) as shown in Fig. 9.8.9
- γ – Reduction factor (only applies to the inner lug) as given in Fig. 9.8.10

t_1 = 3 mm

t_2 = 35 mm

A_{br} = 23.79 mm^2

δ = 2 mm

$P_{U\ min}$ = 20178 N

F_{tux} = 620 MPa

a = 12.61 mm

r = (a-D/2)/t_2 = 12.62-4/35 = 0.24

20178/(23.79*620) = 1.36

γ = 0.85 (ref. 9 fig. 9.8.10)

b = (3/2)+2+0.85*(35/4) = 10.9 mm

M = 18668*10.9/2 = 102091 Nmm (bolt bending moment U.L.)

f_b = 102091*(7.93/2)/402 = 1016 MPa

The bolt material allowable is 125 Ksi then the plastic stress allowable per Cozzone method is:

$F_{bu} = F_{tu} + f_0*(k-1)$ where k = 1.7

F_{bu} = 125 + 125*(1.7-1) = 212.5 Ksi = 1465 MPa

M.S. = (1465/1016*1.15)-1 = <u>0.25</u> (U.L.) plastic bending Level landing L.C.

7.6 Shock absorber fitting to fuselage analisys

With reference pages 26 and 27 the reaction load on node 10 are:

Rx = -4.97 N (negligible)

Ry = 15086 N

Rz = 7030 N

The lug load is obtained as resultant of $(15086^2 + 7030^2)^{0.5}$ = 16644 N L.L.

Lug ultimate load = 16644*1.5 = 24966 N

LUG DATA & ALLOWABLE (ref. 7)

W, (mm) = 24 DWG No.: Shock absorber ftg

D, (mm) = 7.93 Material: 25 Cr Mo4

t, (mm) = 6 Ftu, (MPa) = 620

e, (mm) = 12 Ftu; min, (MPa) = 620

c, (mm) = 0 Fty, (MPa) = 390

TENSION ALLOWABLE BEARING ALLOWABLE

At , (mm^2) = 96.42 Abr,(mm^2) = 47.58

Ktu = .9276037 Pbru, (N) = 40355

Ptu, (N) = 55452.52

TRANSVERSE LOAD ALLOWABLE

A1, (mm^2) = 55.17958 Aav, (mm^2) = 52.64278

A2, (mm^2) = 48.21 BETA DEG. = 0

A3, (mm^2) = 48.21 Ktru = 1.409471

A4, (mm^2) = 55.17958 Ptru, (N) = 41578.84

M.S = --------(U.L.)-------> 0.61

M.S. =------ WITH F.F. ----------> 0.41

LUG Yield Allowable Py, N = 27269.6

M.S. = (27270/16644)-1 = 0.64 L.L.

The AN5 bolt shear M.S. is:

Bolt shear allowable = 5705 lbs (ref. 8) = 25586 N

M.S. = ((25586*2)/(16644*1.5*1.15)) – 1 = 0.78 (U.L.) Level landing L.C.

Looking the shock absorer fitting to the fuselage, the AN5 bolt shall withstand bending stress in addition to the shear. The bolt bending is calculated using the method reported in ref. 9.

t_1 = 3 mm

t_2 = 35 mm

A_{br} = 47.58 mm^2

δ = 2 mm

$P_{U\ min}$ = 40355 N

F_{tux} = 620 MPa

a = 12.61 mm

r = (a-D/2)/t_2 = 12.62-4/35 = 0.24

40355/(47.58*620) = 1.36

γ = 0.85 (ref. 9 fig. 9.8.10)

b = (4.5/2)+0.85*(35/4) = 9.7 mm

M = 24966*9.7/2 = 121085 Nmm (bolt bending moment U.L.)

f_b = 121085*(7.93/2)/402 = 1205 MPa

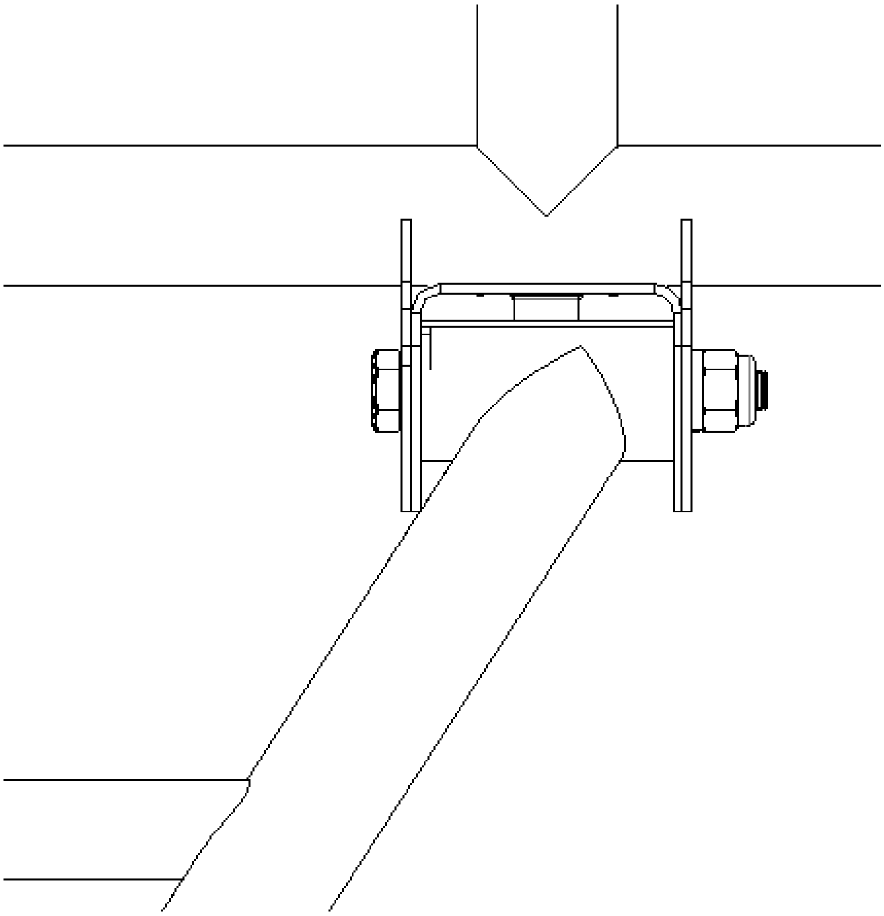
The bolt material allowable is 125 Ksi then the plastic stress allowable per Cozzone method is:

$F_{bu} = F_{tu} + f_0$*(k-1) where k = 1.7

F_{bu} = 125 + 125*(1.7-1) = 212.5 Ksi = 1465 MPa

M.S. = (1465/1205*1.15)-1 = 0.06 (U.L.) plastic bending Level landing L.C.

7.7 Drag brace fitting to fuselage



With reference pages 26 and 27 the reaction forces on node 6 are:

Rx = 2793 N

Ry = -3714 N

Rz = -5529 N

Being the fuselage fitting of the drag brace geometrically equal to that of strut brace we can state that the lug is covered by the analysis done for the strut brace (lug dimension and material are the same, but the applied loads for drag brace are lower). The conection bolt shall be an AN5. The reaction in “X” direction, that is not negligible, is compatible with the AN5 tensile allowable (6500 lbs = 28924 N). The fitting react the Rx in shear + bending as follow:

Ashear = 58*3*2 = 290 mm^2 (flanges cross-section)

f_s = 2793*1.5/290 = 14.5 MPa (negligible)

I = 58*3^3/12 = 130.5 mm^4

BM = 2793*1.5*17 = 71222 Nmm (L.L.)

The bending moment is reacted by the two flanges of the fitting, then the bending stress on each flange is:

f_b = (71222*1.5/2)*1.5/130.5 = 614 Mpa (U.L.)

M.S. = (F_{tu}/f_b) – 1 = (620/614) – 1 = <u>0.00</u> (U.L.) Level landing

7.7 Axle analysis

From LISA output the max stress on axle tube is 123.7 Mpa (L.L.) for level landing load case. The M.S. Is:

M.S. = (620/(123.7*1.5))-1 = High (U.L.)

8 CONCLUSIONS

The analyses performed on MLG structure and its fitting to the fuselage truss show positive Margins of Safety in the main structural items for the worts load case. This analysis is provided as evidence of the CS-VLA compliance.