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Input

Formulation of the problem

Relevance of the work

High competition in the market of passenger airliners requires manufacturers to work on improving existing structures, makes manufacturers look for fundamentally new approaches in the design and production of parts. The economic efficiency of the aircraft depends on its flight performance: capacity, speed, range, fuel consumption. In turn, all these characteristics depend on the choice of aircraft layout, weight efficiently, propulsive efficiency.

This paper will be devoted to the design of floor passenger beam. The calculation of the optimal beam geometry has a significant impact on the weight efficiency of the structure and on the safety of operation. Bed design will be an extra load throughout the entire operation of the aircraft, which will lead to increased fuel consumption and reduced economic efficiency. This should not be allowed in conditions where the customer has a choice and meticulously approaches it.

With using semi-empirical calculation methods was designed the optimal cross section geometry of the beam and chosen optimal spacing for stiffener. This led to maximum weight efficiency and satisfaction of the conditions of the FAR 25.

I SECTION

1.1 Description

Fuselage Structure

A typical fuselage is a semi-monocoque structure acting as a beam that consists of the outer fuselage skin, stringers or longerons, frames, and bulkheads. The fuselage is also a pressure vessel and the hoop tension pressure loads are applied directly to the skin.The fuselage skin carries the cabin pressurization loads as well as the shear from the applied external transverse and torsional loads.

The stringers, or longerons, carry the major axial forces resulting from the fuselage bending moment. Stringers also serve to stabilize the fuselage skin in compression. Skin an stringers work together to carry the fuselage lateral and vertical bending loads. Fuselage skins and stringers are the primary load path in the fuselage.

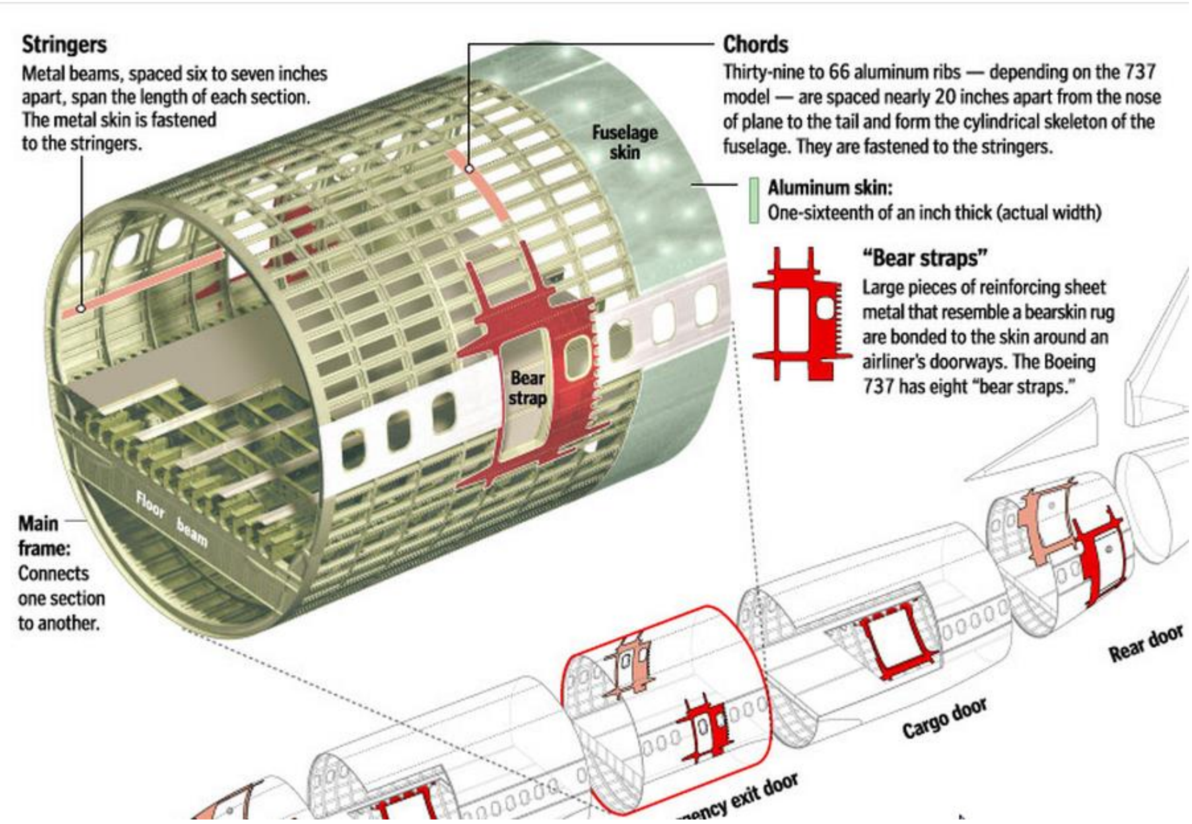


Figure 1 - Fuselage Structure

Frame members are used to maintain the shape of the fuselage and also to reduce the column length of the stringers in compression. Frames also provide locations to introduce loads into the skin and stringers.

Some frames are reinforced and enlarged to permit the introduction of large concentrated loads such as landing gear or wing loads. These frames are often referred to as bulkheads. Two important bulkheads are the forward and aft pressure bulkhead that from the ends of the pressure vessel. These bulkheads typically only carry pressure loads.

The payloads (seats, galleys, lavatories, etc.) and other dead weight loads are applied to the floor beams and/or the frames and transferred through shear ties to the skin.

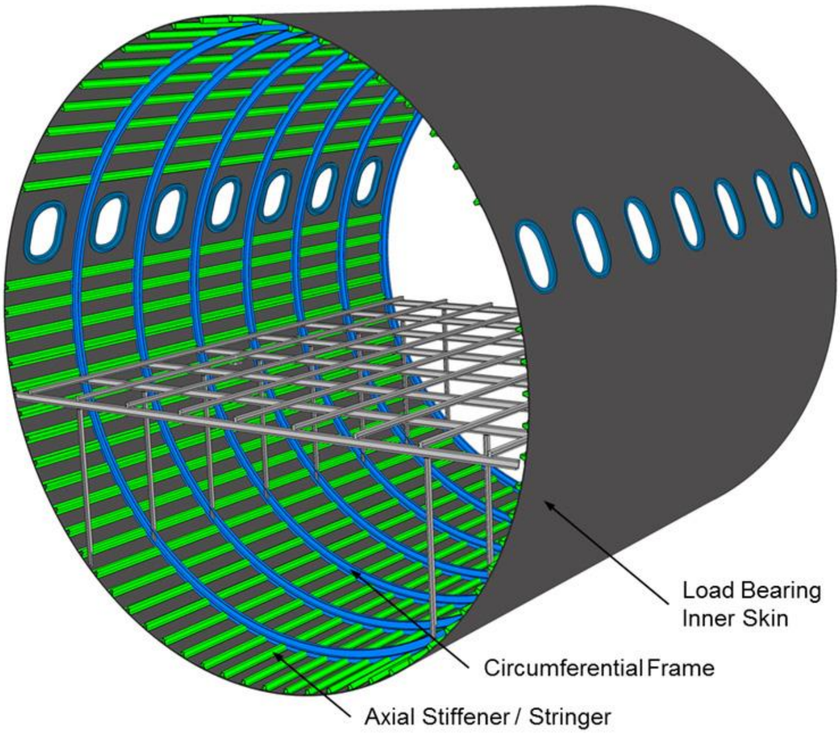


Figure 2 – FEM Fuselage Structure

1.2 Floor Beam

Floor beams are part of a redundant floor structure that support the passenger seats, galleys, etc. The floor beams are supported at the ends by the frames and are further supported by two floor stanchions as shown on page 16. Seat tracks run over the floor beams and attach to the floor beam upper chords or beam webs. The seat tracks are attached to the floor beams to transfer the loads from seats, etc. to the beams and to ensure that the floor beams work together to carry the applied loads. The floor grid (floor beams plus seat tracks) is covered by floor panels that attach to the seat tracks and may attach to the floor beam upper chords.

The purpose of the project is to design a floor beam for a commercial jet transport which will meet all of the federal regulatory requirements for structural integrity. Engineers will design the beam to the specified applied loads and their reactions at the frame, stanchions and seat tracks. Additionally the beam will be designed to the specified geometric maximum envelope, system penetration requirements and structural interface requirements. The beam will be designed to optimize its weight by reducing margins of safety to meet the design requirements.

Figure 3 – Section fluselage

The floor beam described in this design project is symmetric about BL 0 (aircraft centerline) with supporting stanchions being at BL 97.0 on the left and right side.

The maximum depth of the floor beam can be 10.5 inches.

The floor beam shall be designed to accommodate the system penetration with clearances identified in the rear view sketch. The floor beam shall attach to and be supported by a shear tied zee frame as described in Section A-A.

The floor beam shall attach to and be supported by a square tube section stanchion. One of the legs of the stanchion is cut back locally for attachment to beam as shown in Section B-B. The stanchion is typically 1.8 x 1.8 inch outside dimension with 0.080 wall thickness. The material is 7075-T651. The floor beam shall attach to all seat tracks. The attachment must be designed for 6000 Ibs. vertical load (up or down). The seat tracks may be a M4 section or J section.

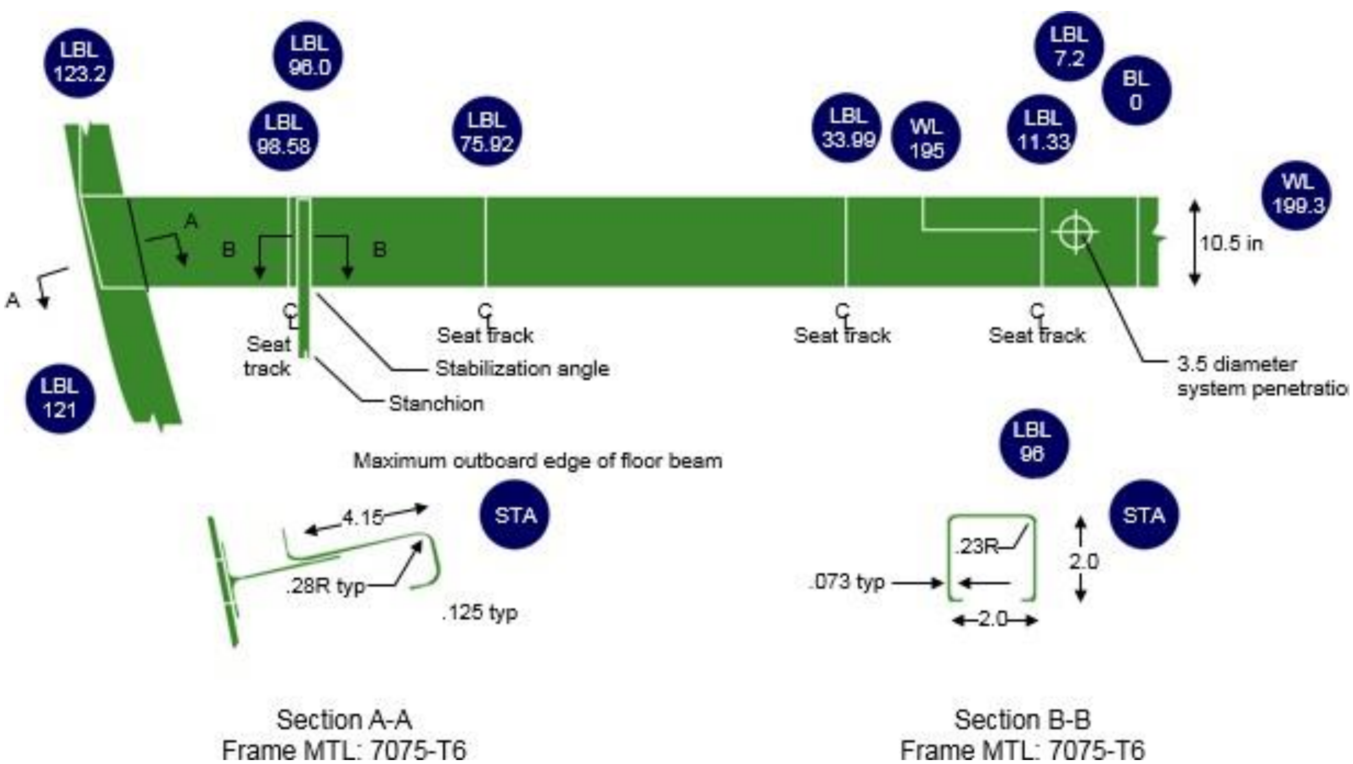
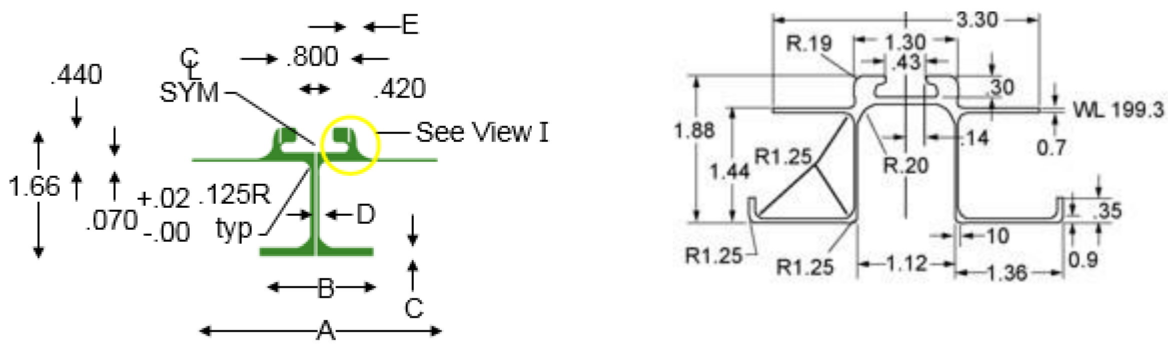


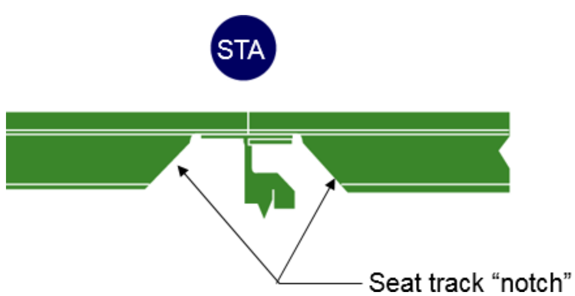
Figure 4 – Floor Beam

1.3 Seat Track

Along the beam there are places for connecting with seat track, through which comes the load from the weight of the passengers. On the shear diagram these points are marked by sharp jumps. On the bending diagram are marked by change slope of chart. Loads vary along the beam, so beam designed with vary geometry of cross-section along the span. On Fig 1.4 is shown arrangement of the beam span: zones, seat track coordinates, stiffener locations and stanchions and frame.



A	B	C	D	E	R
3.12 (138)	1.60	.14	.085	.19	.26



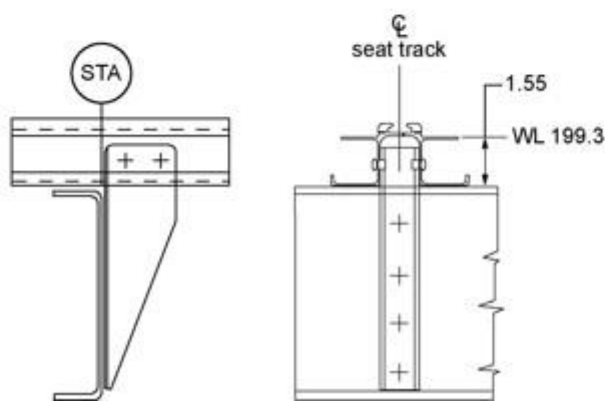


Figure 5 - Option

1.4 Airplane load analysis

Floor structure ultimate loads are defined by limit load multiplied by a factor of safety of 1.5. (Limit loads are the maximum loads expected in service.) The floor beam must be designed to meet a variety of conditions including flight loads, decompression loads and emergency landing loads.

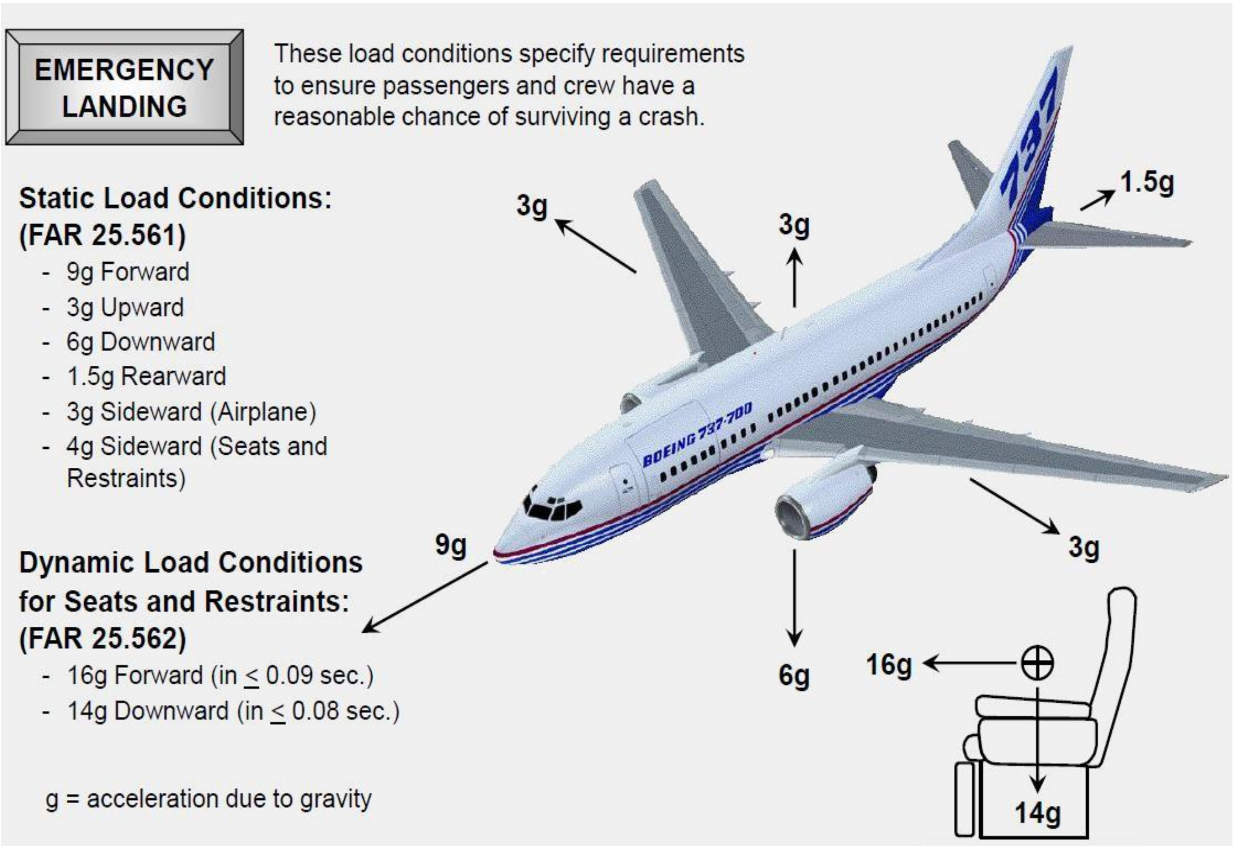


Figure 6 – Load factor

Since the calculation is carried out according to a foreign method, all calculations are performed in the American measurement system:

psi - [$\frac{pound}{inch^2}$] = 6894,757 [Pa]

lbs - [pound] = 4.54 [N]

in – [inch] = 254 [mm]

The beam is designed in accordance with FAR-25 [See Appendix A] for eight load cases. Maximum load values were chosen in the tables for each cross section. Every LC describes magnitude and direction of acceleration and cabin pressure. The beam internal loads were taken from finite element analysis:

Load case (further LC) 1 – 18.8 psi and axial P=6807 lbs. (d) The airplane structure must be designed to be able to withstand the pressure differential loads corresponding to the maximum relief valve setting multiplied by a factor of 1.33 for airplanes to be approved for operation to 45,000 feet [2, Sec. 25.365].

LC 2 – 6.0 g DOWN axial + compression P=1640 lbs. The airplane, although it may be damaged in emergency landing conditions on land or water, must be designed as prescribed in this section to protect each occupant under those conditions. The structure must be designed to give each occupant every reasonable chance of escaping serious injury in a minor crash landing when – the occupant experiences the following ultimate inertia forces acting separately relative to the surrounding structure: Downward 6.0g [2, Sec. 25.561].

LC 3 – 4.5 g DOWN and axial P=3465 lbs. Discrete Gust Design Criteria. The airplane is assumed to be subjected to symmetrical vertical and lateral gusts in level flight [2, Sec. 25.341]

LC 4 – 1.0g DOWN+2.09psi P=1134 lbs. Combined with pressure Δp=2.09psi [2, Sec. 25.341]

LC 5 – 1.0g DOWN+2.09psi axial compression P=-1476 lbs. Combined with pressure Δp=2.09psi [2, Sec. 25.341]

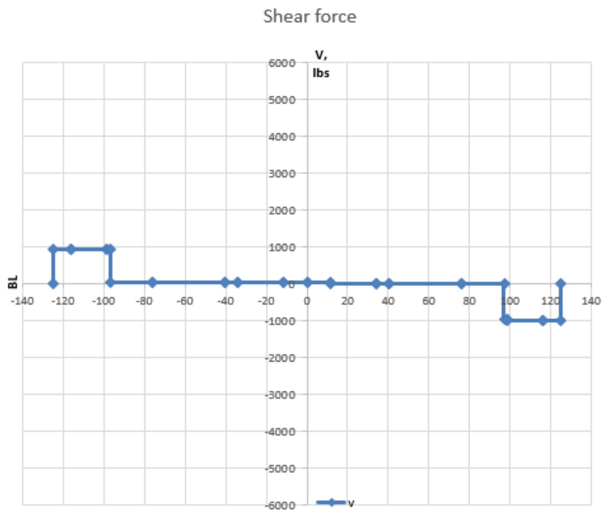
LC 6 – 2,0 g UP+14.1psi P=7008 lbs. Combined with pressure Δp=14.1psi [2, Sec. 25.341]

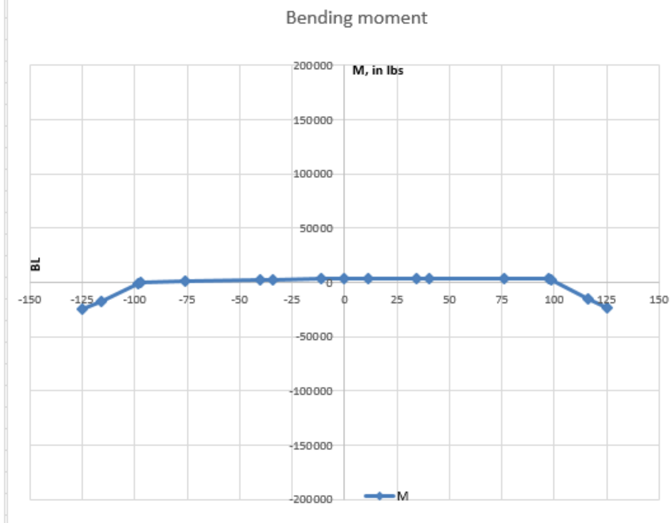
LC 7 – 2.78]psi UP P=5004 lbs. The fail-safe feature of the design may be considered in determining the probability of failure or penetration and probable size of openings, provided that possible improper operation of closure devices and inadvertent door openings are also considered. Furthermore, the resulting differential pressure loads must be combined in a rational and conservative manner with 1–g level flight loads and any loads arising from emergency depressurization conditions. These loads may be considered as ultimate conditions; however, any deformations associated with these conditions must not interfere with continued safe flight and landing. The pressure relief provided by intercompartment venting may also be considered. [2, Sec. 25.365]

LC 8 – 3.0 g Up P=2865 lbs. The airplane, although it may be damaged in emergency landing conditions on land or water, must be designed as prescribed in this section to protect each occupant under those conditions. The structure must be designed to give each occupant every reasonable chance of escaping serious injury in a minor crash landing when – the occupant experiences the following ultimate inertia forces acting separately relative to the surrounding structure: Upward 3.0g [2, Sec. 25.561].

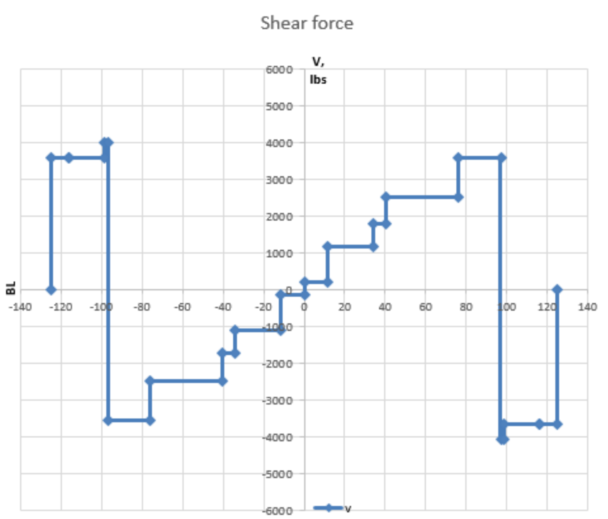
Bending diagrams Fig and shear diagrams Fig 2 for each LC :

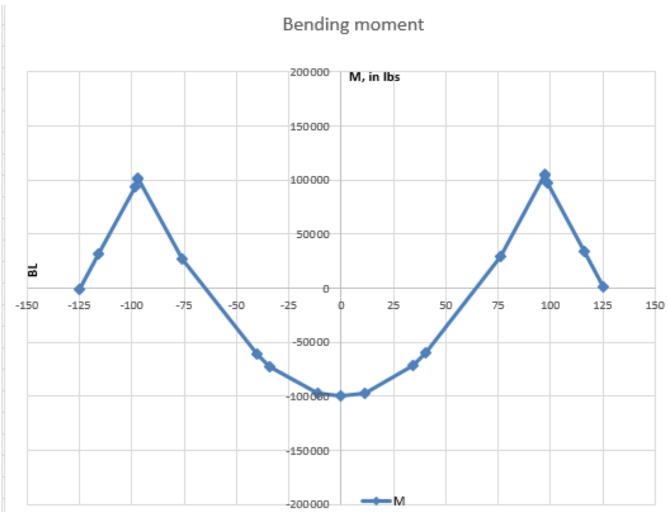
For LC 1:



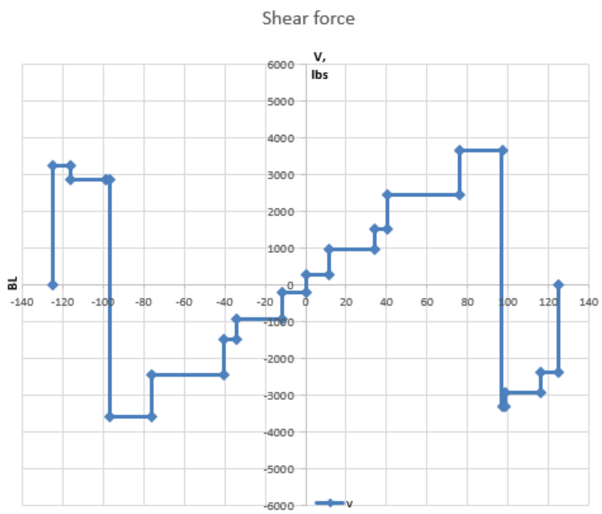


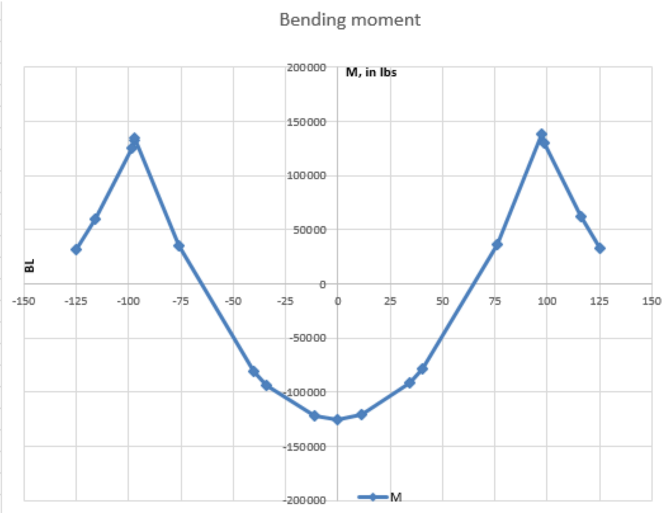
For LC 2:



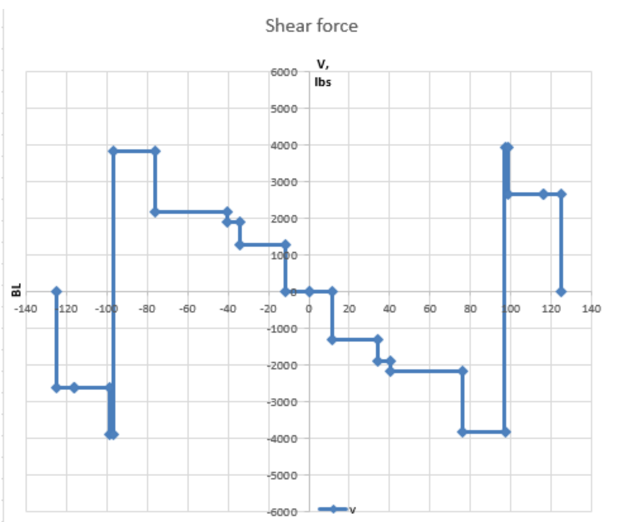


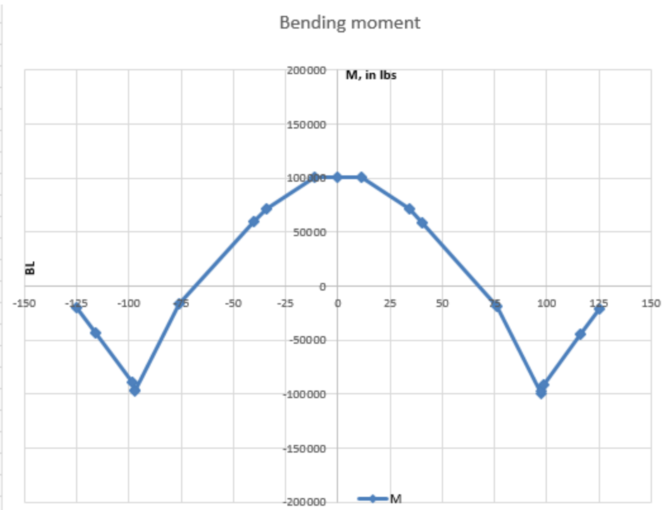
For LC 3:



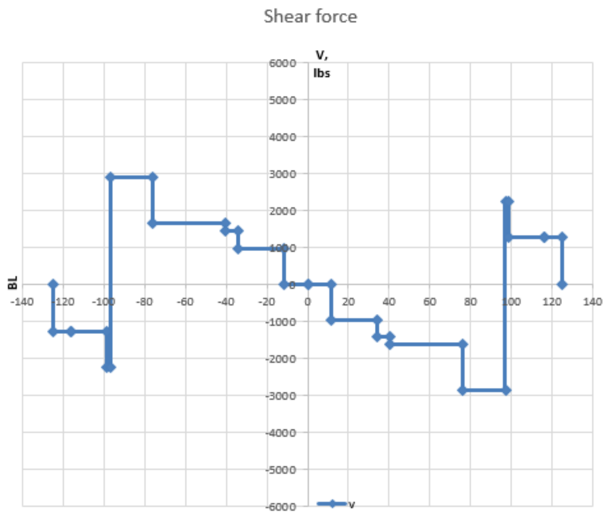


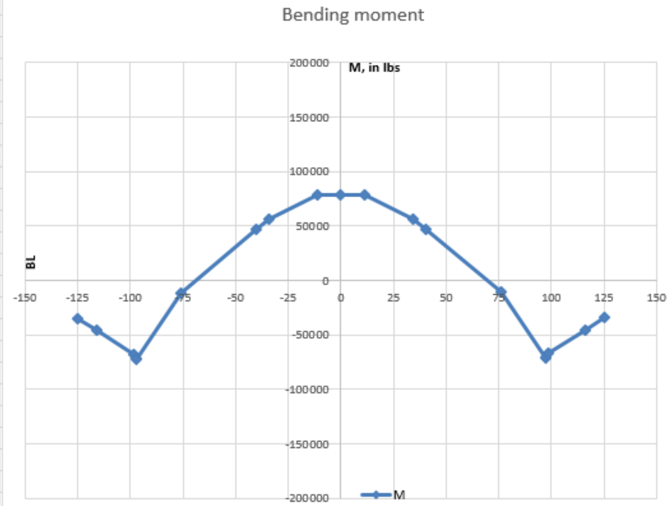
For LC 4:



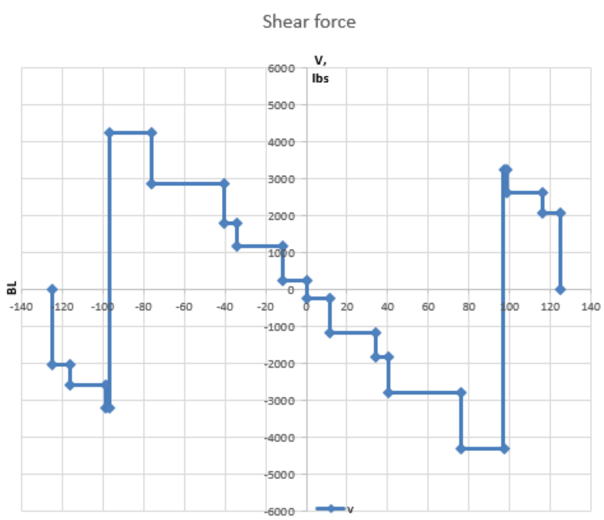


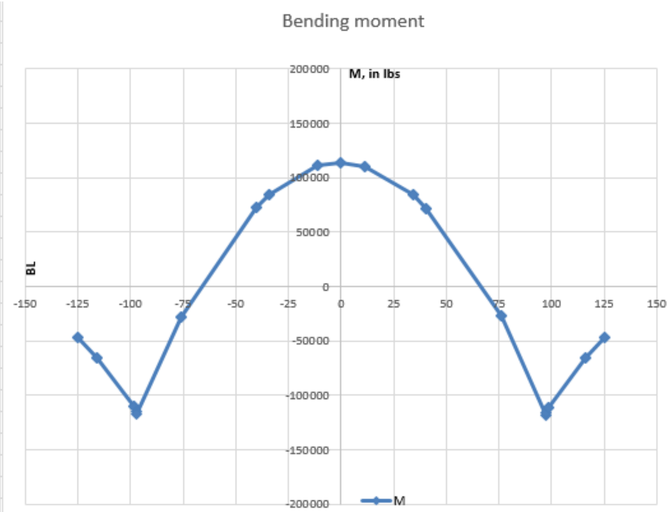
For LC 5:



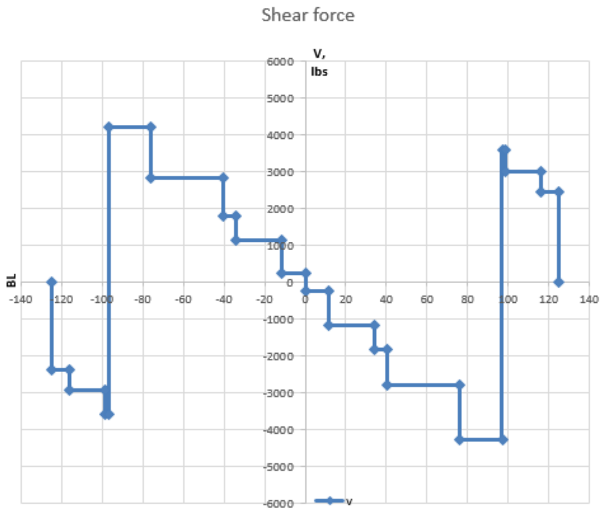


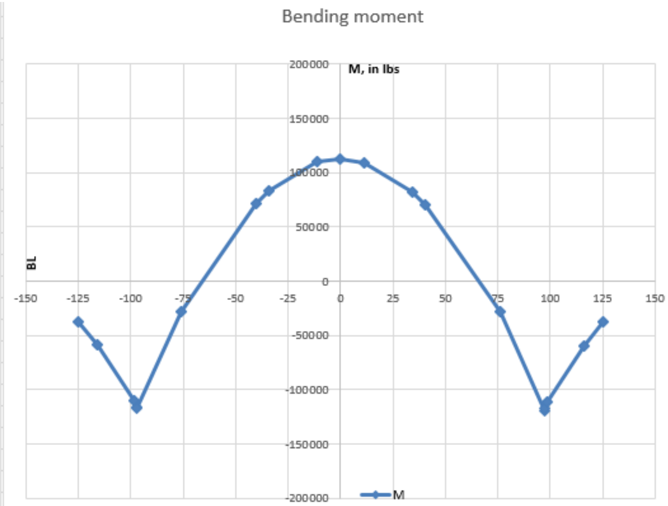
For LC 6:



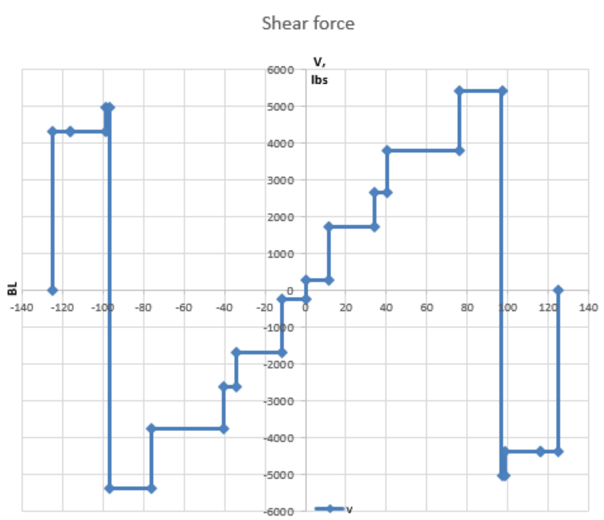


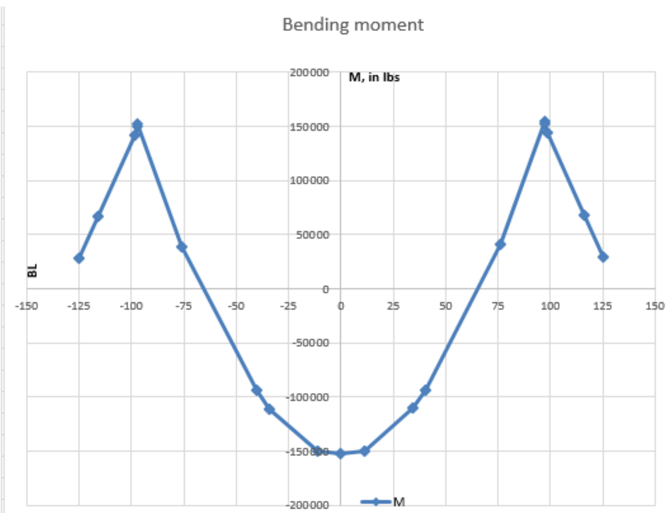
For LC 7:



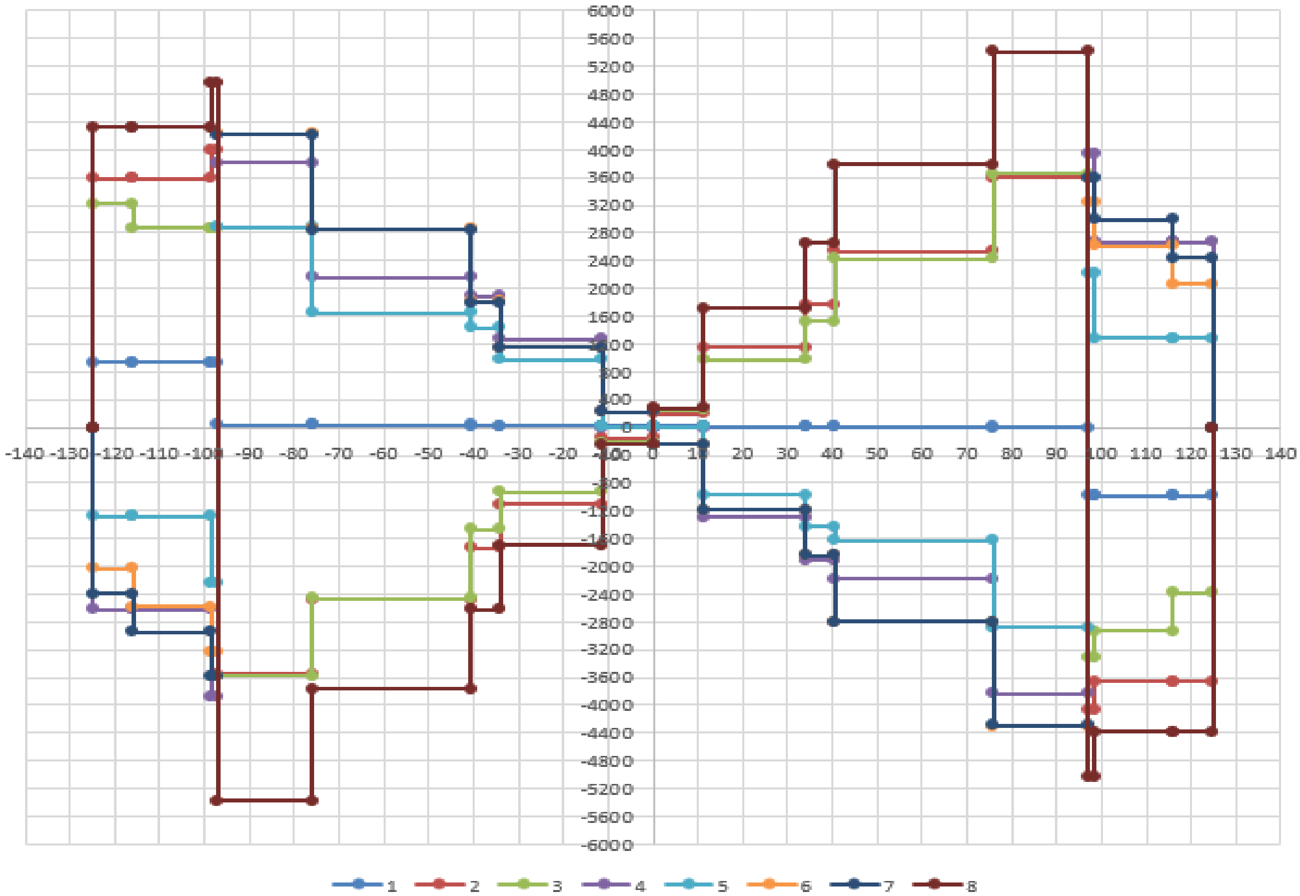


For LC 8:

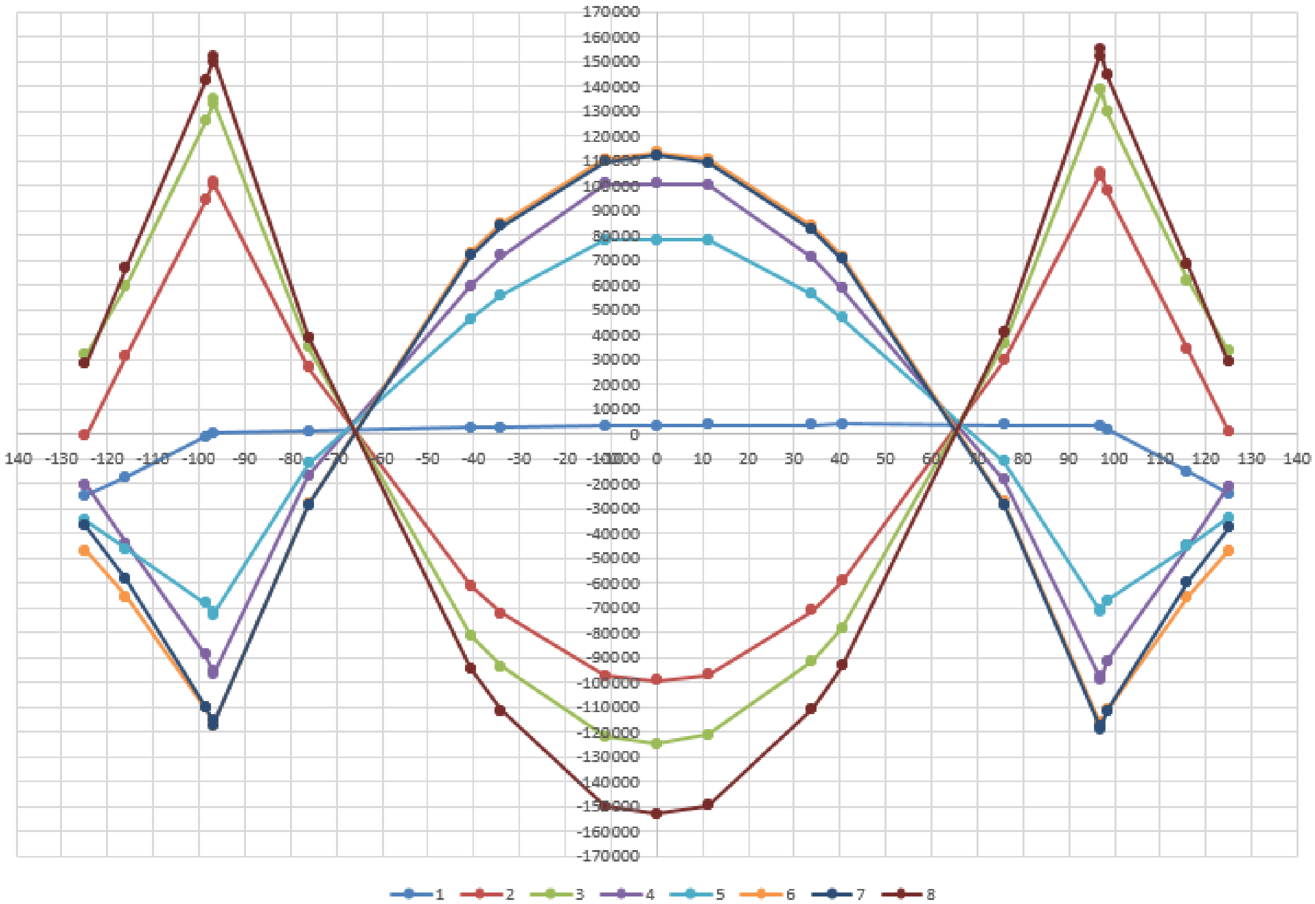




General view for Shear:



General view for bending:



1.5 Design philosophy

The main regulatory instrument, which are subject to certification aircraft manufacture type is FAR-25 / JAR-25

Loaded

The requirements identified through exploitative strength and load calculation. In the absence other directions under a given load understand operational load.

In the absence of other indications loads acting in the air, on land and on water, must be balanced inertia forces of all parts of the aircraft. The distribution of these loads can be rough or should accurately reflect actual conditions.

If deformation under load design significantly alter the distribution of external or internal loads, this redistribution must be considered.

Safety factor

If no other instructions, safety factor is assumed to be 1.5. In it multiply specified operating load, considered as external load on the structure. If the loading conditions defined through computational load, multiplied by a factor of safety is not necessary, unless otherwise indicated.

The strength and deformation

The design should withstand the effect of operating loads without hazardous plastic deformation. With all the loads of performance including, deformation structures should not affect the safety of operation.

The construction is estimated to withstand the load without breaking for 3s. However, when structural strength is confirmed by dynamic tests imitating real load conditions, the requirement is not imposed 3c.

Static tests performed to design load should take into account the movement and deformation of action of these loads. If you are using analytical techniques conformity requirements of strength under design load, must show that:

Impact slight deformation;

Deformations that occur are fully taken into account in the calculations.

Conditions emergency landing

The design of the aircraft must be such that even if damaged aircraft in the below conditions emergency landing on land or water ensured the safety of all passengers and crew members.

The design of the aircraft must be such that the passengers and crew was available real opportunity to avoid serious injury during emergency landing with minor destruction.

For equipment in cargo and passenger cabin of any large masses accepted following:

1) These mass should be located so that when they are apart:

a) does not directly harm the passengers and crew;

b) not penetrated fuel tanks or pipelines or do not result in a fire or explosion due to the destruction of roughly located;

c) Do not block any rescue equipment for use during an emergency landing.

2) If this is not possible (for example, APU, located in the fuselage), each such mass and its mounts are inclusive to withstand given above for passengers and crew. Local units anchorages strength qi masses should also be provided to load a 1.33 times greater if they are significantly worn frequent permutations (for example, frequently changing interior).

Chairs and some weight (and their support structure) under load, the above should not deform, not to create hindrances rapid evacuation of passengers and crew.

1.6 General design considerations

The design of the aircraft not should have the following features and parts, which, as experience has shown, creating emergency conditions or are unreliable. The suitability of parts and components that cast doubt shall be determined by appropriate tests.

Materials

The suitability and durability of materials used for the manufacture of parts, failure of which could adversely affect safety, must:

a) determined by experience or by trials.

b) meet approved specifications (TU industries, military technical specifications or technical standards) that ensures strength and other properties taken in numerical data;

c) evaluated for the effect of environmental conditions expected in service, such as temperature and humidity.

Strength characteristics of materials and their calculated values

Characteristics of strength of materials should be based on a sufficient number of tests so that the calculated value can be set on the basis of statistics.

Calculated values of the characteristics of the material should be selected so as to reduce the possibility of damage due to volatility design properties. With the exception of the requirements listed in paragraphs (e) and (1) of this paragraph, compliance must be shown by selecting design values that provide the material strength with the following probability:

1) 99% - 95% by the confidence interval when applied loads are transmitted through a single element unit whose destruction leads to loss of structural integrity of the unit.

2) 90% - 95% by the confidence interval for statistically undetectable construction in which the destruction of any particular element leads to that applied load safely distributed to other load-bearing elements.

Must be taken into account the impact of environmental conditions such as temperature and humidity, the calculated values used in critical cell sites or construction materials if conditions range aircraft this effect is material.

To be able to perform assessments calculated in accordance with paragraph should be identified 25,571 range and statistically reasonable level estimates of fatigue and fracture of materials design.

Can be used other calculated values of the characteristics of the material, if approved by the competent authority.

Special additional safety factors

The safety factor should be multiplied by coefficients corresponding maximum security to every detail of construction, the strength of which:

a) unreliable;

b) may deteriorate in service to the planned replacement;

c) can vary significantly due to imperfections in manufacturing processes or methods of control.

Analysis aviation materials.

Another long been a major material used to manufacture aircraft bearing structure was wood. It is known that tree - a natural composite material that has a perfect set of specific characteristics. However, wood is easily exposed to the environment without any additional processing that greatly reduces its performance and durability.

So metallurgists have long sought a material that would set specific characteristics relatively high weight and was thus easy to manufacture and use.

Moving along the historical timeline, the most commonly used materials in aircraft after the trees were metallic materials. Their use is allowed to change the approach to the use of internal volume of the aircraft and secured reduce catastrophic damage cases in separate parts of the design in the air.

Basic metal materials used in aircraft:

- aircraft steel - 30HMA, 30HGSA, 12X18H10T and their foreign counterparts;

- titanium alloys - VK10, T5K10, TT10K78-B and their foreign counterparts;

- aluminum alloys - D16T, VK95 / 96, D20, AMC, AMG and their foreign counterparts;

- Magnesium alloys - MA14, Ml10 more.

However, these materials are also exposed to the environment - corrosion, aging, significantly reducing their characteristics. To increase the service life of these materials is necessary to use additional methods of processing, technology of materials and designs with them. All this increases the price of the final product.

In recent decades actively introduced in the aviation industry composites.

Composite materials (composites km) - artificial materials composed of two or more heterogeneous and insoluble in each other component, interconnected physical and chemical bonds.

One component is a composite reinforcement, or filler, providing the required mechanical properties of the material and the other components - a matrix that provides collaboration reinforcing elements. As used matrix polymer, metal, ceramic and carbon materials, depending on the type of composite materials which acquire common name.

Additional components that serve as reinforcing material, glass, boric, carbon, organic, Whiskers (carbides, borides, nitrides, etc.) And metal wires that have high strength and hardness. In forming compositions used effectively individual properties of the constituent elements of the compositions.

The properties of composites depend on the composition component ratio and the strength of the connection between them. Combining the volumetric component parts can be depending on the purpose to obtain materials with the required values of strength, heat resistance, modulus of elasticity or receive the necessary compositions with special properties, such as magnetic, etc.

Composite materials have high specific strength, stiffness, high wear resistance, fatigue strength. With them you can make normal sizes design. Composite materials are very promising structural materials for aerospace industry.

But some composites have drawbacks: high cost, anisotropy properties, increased knowledge-based production, the need for special expensive equipment and raw materials, and therefore a developed industrial and scientific base.

Composite materials are classified according to the geometry of the filler in its location and nature of the matrix component layout fillers in nature component, composite material structure.

However, composites today are still not analyzed and tested, so their number is far inferior to the main aluminum alloy used for the design of structures - 2024 and 7075.

Also, to date, has documented facts using additive technology in the aircraft industry - manufacturing parts using 3D-printing. This detail may produce both metallic materials and plastic. This technology allows us to produce parts more complex forms when a mechanical by make them difficult or impossible.

Here are the basic mechanical properties of materials used in the aircraft industry.

Specification	AMS 4045 and AMS-QQ-A-250/12[a]																				
Form	Sheet							Plate													
Temper	T6 and T62[b]							T651													
Thickness, in.	0.008-0.011	0.012-0.039		0.040-0.125		0.126-0.249		0.250-0.499		0.500-1.000		1.001-2.000		2.001-2.500		2.501-3.000		3.001-3.500		3.501-4.000	
Basis	S	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
Mechanical Properties:																					
F_{tu}, ksi:																					
L	...	76	78	78	80	78	80	77	79	77	79	76	78	75	77	71	73	70	72	66	68
LT	74	76	78	78	80	78	80	78	80	78	80	77	79	76	78	72	74	71	73	67	69
ST	...	...	...	...	...	...	...	...	...	...	...	...	...	70[c]	71[c]	66[c]	68[c]	65[c]	67[c]	61[c]	63[c]
F_{ty}, ksi:																					
L	...	69	72	70	72	71	73	69	71	70	72	69	71	66	68	63	65	60	62	56	58
LT	63	67	70	68	70	69	71	67	69	68	70	67	69	64	66	61	63	58	60	54	56
ST	...	...	...	...	...	...	...	...	...	...	...	...	...	59[c]	61[c]	56[c]	58[c]	54[c]	55[c]	50[c]	52[c]
F_{cy}, ksi:																					
L	...	68	71	69	71	70	72	67	69	68	70	66	68	62	64	58	60	55	57	51	52
LT	...	71	74	72	74	73	75	71	73	72	74	71	73	68	70	65	67	61	64	57	59
ST	...	...	...	...	...	...	...	...	...	...	...	...	...	67	70	64	66	61	63	57	59
F_{su}, ksi	...	46	47	47	48	47	48	43	44	44	45	44	45	44	45	42	43	42	43	39	41
F_{bru}[d], ksi:																					
(e/D = 1.5)	...	118	121	121	124	121	124	117	120	117	120	116	119	114	117	108	111	107	110	101	104
(e/D = 2.0)	...	152	156	156	160	156	160	145	148	145	148	143	147	141	145	134	137	132	135	124	128
F_{bry}[d], ksi:																					
(e/D = 1.5)	...	100	105	102	105	103	106	97	100	100	103	100	103	98	101	94	97	89	93	84	87
(e/D = 2.0)	...	117	122	119	122	121	124	114	118	117	120	117	120	113	117	109	112	104	108	98	103
e, percent (S-Basis):																					
LT	5	7	...	8	...	8	...	9	...	7	...	6	...	5	...	5	...	5	...	3	...
E, 10^3 ksi	10.3							10.3													
E_c, 10^3 ksi	10.5							10.6													
G, 10^3 ksi	3.9							3.9													
μ	0.33							0.33													
Physical Properties:																					
ω, lb/in.^{3}	0.101																				
C, K, and α	See Figure 3.7.7.0																				

a Mechanical properties were established under MIL-QQ-A-250/12.

b Design allowables were based upon data obtained from testing T6 temper sheet and from testing samples of sheet, supplied in the O or F temper, which were heat treated to demonstrate response to heat treatment by suppliers. Properties obtained by the user may be lower than those listed if the material has been formed or otherwise cold-worked, particularly in the annealed temper, prior to solution heat treatment.

c Caution: This specific alloy, temper, and product form exhibits poor stress-corrosion cracking resistance in this grain direction. It corresponds to an SCC resistance rating of D, as indicated in Table 3.1.2.3.1(a).

d Bearing values are "dry pin" values per Section 1.4.7.1. See Table 3.1.2.1.1.

Fig 7 - The main mechanical characteristics of the material 7075

Specification	AMS 4037 and AMS-QQ-A-250/4[a]																	AMS-QQ-A-250/4[a]		
Form	Sheet					Plate												Sheet		Plate
Temper	T3					T351												T361		
Thickness, in.	0.008-0.009	0.010-0.128		0.129-0.249		0.250-0.499		0.500-1.000		1.001-1.500		1.501-2.000		2.001-3.000		3.001-4.000		0.020-0.062	0.063-0.249	0.250-0.500
Basis	S	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	S	S	S
Mechanical Properties:																				
F_{tu}, ksi:																				
L	64	64	65	65	66	64	66	63	65	62	64	62	64	60	62	57	59	68	69	67
LT	63	63	64	64	65	64	66	63	65	62	64	62	64	60	62	57	59	67	68	66
ST	...	...	...	...	...	...	...	...	...	...	...	...	...	52[b]	54[b]	49[b]	51[b]	...	...	...
F_{ty}, ksi:																				
L	47	47	48	47	48	48	50	48	50	47	50	47	49	46	48	43	46	56	56	54
LT	42	42	43	42	43	42	44	42	44	42	44	42	44	42	44	41	43	50	51	49
ST	...	...	...	...	...	...	...	...	...	...	...	...	...	38[b]	40[b]	38[b]	39[b]	...	...	...
F_{cy}, ksi:																				
L	39	39	40	39	40	39	41	39	41	39	40	38	40	37	39	35	37	47	48	46
LT	45	45	46	45	46	45	47	45	47	44	46	44	46	43	45	41	43	53	54	52
ST	...	...	...	...	...	...	...	...	...	...	...	...	...	46	48	44	47	...	...	...
F_{su}, ksi	39	39	40	40	41	38	39	37	38	37	38	37	38	35	37	34	35	42	42	41
F_{bru}[c], ksi:																				
(e/D = 1.5)	104	104	106	106	107	97	100	95	98	94	97	94	97	91	94	86	89	111	112	109
(e/D = 2.0)	129	129	131	131	133	119	122	117	120	115	119	115	119	111	115	106	109	137	139	135
F_{bry}[c], ksi:																				
(e/D = 1.5)	73	73	75	73	75	72	76	72	76	72	76	72	76	72	76	70	74	82	84	81
(e/D = 2.0)	88	88	90	88	90	86	90	86	90	86	90	86	90	86	90	84	88	97	99	96
e, percent (S-Basis):																				
LT	10	[d]	...	[d]	...	12	...	8	...	7	...	6	...	4	...	4	...	8	9	9[e]
E, 10^3 ksi	10.5					10.7												10.5		10.7
E_c, 10^3 ksi	10.7					10.9												10.7		10.9
G, 10^3 ksi	4.0					4.0												4.0		4.0
μ	0.33					0.33												0.33		0.33
Physical Properties:																				
ω, lb/in.	0.100																			
C, K, and α	See Figure 3.2.4.0																			

a Mechanical properties were established under MIL-QQ-A-250/4..

b Caution: This specific alloy, temper, and product form exhibits poor stress corrosion cracking resistance in this grain direction. It corresponds to an SCC resistance rating of D, as indicated in Table 3.1.2.3.1(a).

c Bearing values are "dry pin" values per Section 1.4.7.1. See Table 3.1.2.1.1.

d See Table 3.2.4.0(c).

e 10% for 0.500 inch.

Fig 8 – The main mechanical characteristics of the material 2024

FORM	Extrusions		
CONDITION	Annealed		
THICKNESS, IN	≤ 2.000		2.001 – 3.000
BASIS	A	B	S
①			
F_{tu}, ksi			
L	130	137	130
LT ②	130	137	130
F_{ty}, ksi			
L	116	120	120
LT ②	116	120	120
F_{cy}, ksi			
L	120	129	120
LT	125	130	129*
F_{su}, ksi	84	88	83*
F_{sy}, ksi ③	77	80	78*
F_{bru}, ksi			
e/D=1.5	193	203	193*
e/D=1.7	211	222	211*
e/D=2.0	238	250	238*
F_{bry}, ksi			
e/D=1.5	157	162	162*
e/D=1.7	167	173	173*
e/D=2.0	183	189	189*
Elong., % ④			
L	10		
LT ②	8		
μ, Elastic	0.31		
E, 10^6 psi	16.9		
E_c, 10^6 psi	17.2		
G, 10^6 psi	6.5		

Fig 9 - The main mechanical characteristics of the material in Ti-6Al-4V

II SECTION.

2.1 Settlement part

It is assumed that the focused beam is loaded by forces coming from TN seat tracks - longitudinal power elements of the floor of the aircraft, which are mounted passenger seat.

The most critical load cases:

- LC6 - 2.0g Up + 14.1psi, P = 7008 lbs;
- LC8 - 3.0g Up, P = 2865 lbs;

where 14.1psi - internal pressure airflow from the passenger cabin,

Check the strength of the beam to bend.

To determine the stresses acting on any design which used the following formula.

Normal stress from the effects of axial force:

$$f = \frac{P}{A}$$

where $f - normal\ stresses\ in\ section$

$P - axial\ force\ that\ acts\ on\ the\ section$;

$A - cross - sectional\ area.$

Normal stress from the effects of bending moment:

$$f_b = \frac{-(M_y I_x + M_x I_{xy})x + (M_x I_y + M_y I_{xy})y}{I_x I_y - (I_{xy})^2}$$

where $f_b - normal\ stresses\ in\ section$;

$M_y - bending\ moment\ about\ the\ y\ axis$;

$M_x - bending\ moment\ about\ x\ axis$;

$I_x - the\ axial\ moment\ of\ inertia\ of\ the\ section\ relative\ to\ the\ x\ axis$;

$I_y - the\ axial\ moment\ of\ inertia\ of\ the\ section\ relative\ to\ the\ y - axis$;

$I_{xy} - centrifugal\ moment\ of\ inertia\ of\ the\ section$;

$x - the\ x\ coordinate\ of\ the\ point\ at\ which\ the\ stresses\ are\ calculated$;

Related transverse stresses from the action (shear) force:

$$f_s = \frac{VQ}{Ib}$$

Where: $f_s - shear\ cross - section\ stress$

$V - the\ value\ of\ the\ transverse\ force\ that\ the\ cross\ section\ actions$;

$Q - the\ first\ moment\ (moment\ of\ resistance)\ of\ the\ cut - off\ section$;

$I - axial\ moment\ of\ inertia\ of\ the\ entire\ section$;

$b - the\ width\ of\ the\ cross -$
$section\ element\ to\ the\ exact\ points\ where\ the\ stresses\ are\ calculated.$

The strength of the design of the projected determined according to the characteristics of the material, shape and size of the cross-sectional load conditions.

The strength of the design is characterized by safety factor (Margin of safety), which is given by:

$$MS = \frac{F}{f} - 1$$

Where: F - allowable stresses is selected according to the material used;

f - current section in tension.

Thus, depending on the type of stress allowable calculated as:

$F_{tu} - maximum\ tensile\ stresses;$

$F_{cy} - the\ compressive\ yield\ stress;$

$F_{su} - maximum\ compression\ stresses;$

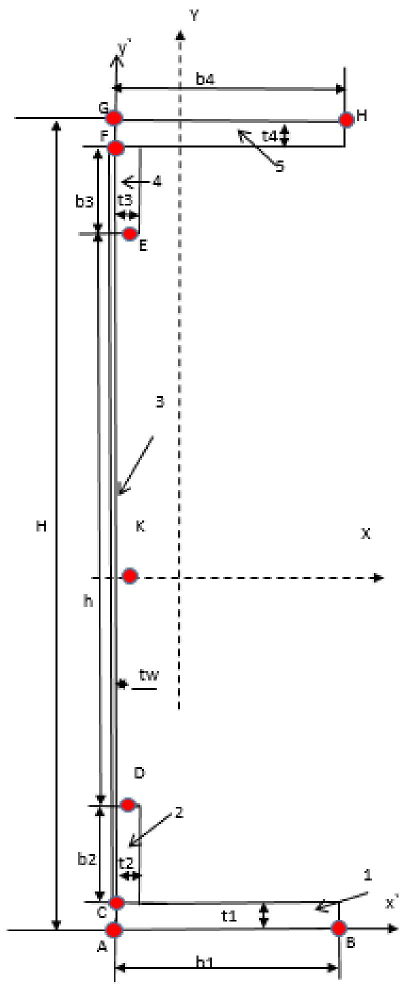
For each section of the beam size and the optimum settings at which efficiency is achieved design - lack sufficient strength and a large excess idle material.

Here are the results of calculations in the software package MS Excel.

1.Sections properties

H	h	tw	b1	t1	b2	t2	b3	t3	b4	t4
10.5	8.46	0.105	1.3	0.2	0.85	0.2	0.8	0.14	1.35	0.19

Part section number	Fi(in^2)	Xi(in)	Yi(in)	Sy`(in^3)	Sx`(in^3)	Iix-x	Fi*(Yi-Yc.g.)^2	Iiy-y	Fi*(Xi-Xc.g.)^2	Xi-Xc.g.)*(Yi-Yc
1	0.2600	0.6500	0.1000	0.1690	0.0260	0.0009	6.4978	0.0366	0.0426	-0.5261
2	0.1700	0.1000	0.6250	0.0170	0.1063	0.0102	3.4031	0.0006	0.0036	0.1104
3	0.8883	0.0525	5.2800	0.0466	4.6902	5.2981	0.0290	0.0008	0.0330	-0.0310
4	0.1120	0.0700	9.9100	0.0078	1.1099	0.0060	2.5921	0.0002	0.0034	-0.0944
5	0.2565	0.6750	10.4050	0.1731	2.6689	0.0008	7.2210	0.0390	0.0474	0.5849
Σ	1.6868			0.4136	8.6013	25.0590		0.2071		0.0439



Centr of gravity section:	Yc.g.(in)=	5.0992
	Xc.g.(in)=	0.2452
Moment of inertia section:	Iy(in^4)=	0.2071
	Ix(in^4)=	25.0590
The product of inertia:	Ixy(in^4)=	0.0439
	tg α=	-0.00177

First moment of inertia of segment above point:

Point	Sx	Sy
A	0	0
B	0	0
C	1.2997837	0.105246
D	2.0603922	0.0767
K	2.92117	0.1586
E	1.8997591	0.0858
F	1.3609459	0.110242
H	0	0
G	0	0

Points	Y	X	t
A	-5.099	-0.245	1.3
B	-5.099	1.055	1.3
C	-4.899	-0.245	1.3
D	-4.049	-0.140	0.105
K	0.215	-0.140	0.105
E	4.411	-0.140	0.105
F	5.211	-0.245	1.35
H	5.401	1.105	1.35
G	5.401	-0.245	1.35

Fig 10 - Section Properties Calculation

2. Determination normal, shear stress (lbs/in^2) and MS

	Point	Bending stress	Axis stress	Total stress (Bending stress + Axis stress)	Shear stress	MS Total stress	MS Shear stress
Lower flange	A	-20048	-972	-21020	0.000	4.235	-
	B	-21141		-22114	0.000	4.075	-
	C	-19253		-20226	-95.683	4.362	469.305
	D	-15965		-16938	######	5.015	292.918
	K	972		0	######	########	207.068
Upper flange	E	17638		16666	######	3.680	318.311
	F	20904		19932	-7.792	2.913	#######
	H	20523		19551	0.000	2.990	-
	G	21658		20686	0.000	2.771	-

2.014752

-1.985463 q=

Maximum total stress: ft_max= -22114 Maximum shear stress: fsh_max= -216

Minimal MS for total stress: MS= 2.77 Minimal MS for shear stress: MS= 207.07

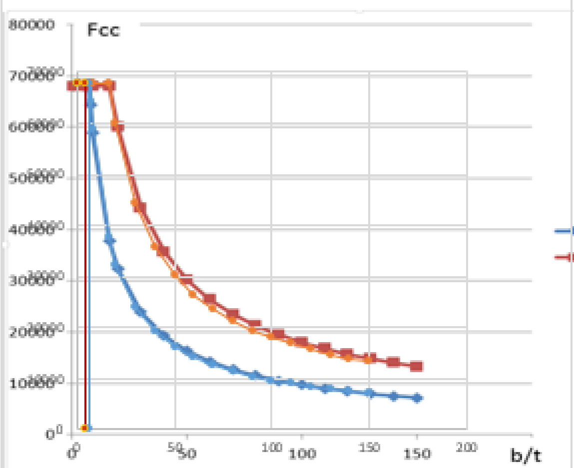
Tension Stress ratio: Rb= |ft_max| / Ftu Rb= 0.284 Shear Stress ratio: Rs= |fsh_max| / Fsu Rs= 0.00481

MS Tension MS= 2.77062

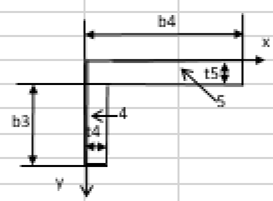
3.Determination allowable crippling stress

Compression flange is: Lower flange

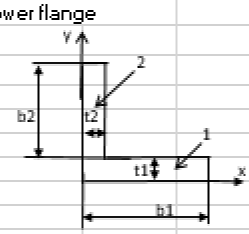
aximum compressive stress (fc_max) p -22114



Upper flange



Lower flange



7075-T651 One edge free
b/t
1
5
6
7.16
8
9
16.26
20
30
40
50
60
70
80
90
100
110
120
130
140
150

$$MS\_cc = \frac{Fcc}{fc\_max} - 1$$

Segment	Free	bn	tn	bn/tn	bn*tn	Fccn	bi*ti*Fccn	Fcc
1	1	1.3	0.2	6.50	0.26	68000	17680	68000
2	1	0.85	0.2	4.25	0.17	68000	11560	

$$Fcc = \frac{\sum bn*tn*Fcc}{\sum bn*tn}$$

Minimal MS for crippling stress: MS= 2.08

Fig 11 - Stress calculations

2.2 Check the stability of beam compression element

To work effectively any design analysis not only for strength. Because when changing load conditions and geometric parameters of construction starts on another.

Besides analyzing the strength, design also analyze for resistance. During stable construction, it is understood that the property of storage form a straight longitudinal axis in diets of compressive axial force. Resistance is characterized by an axial force which design can withstand without strain the longitudinal axis. This force is called the critical buckling force. In shrinking critical reach, construction still resists curvature. However, the most insignificant force exceeding this value leads to transverse deformation, distortion longitudinal axis that leads to the effect of "longitudinal bending" appears eccentricity application of force, which leads to bending moment. Thus even longer increasing strength, deflection rod grow eccentricity increase, and so on closed cycle. In the structure breaks down under the influence of the great general moment from significant cross-strain.

This loss of stability inherent in long thin rods.

The phenomenon of buckling structure depends on the flexibility of conditions fixing ends (edges), cross-sectional shape and characteristics of the material, design load conditions.

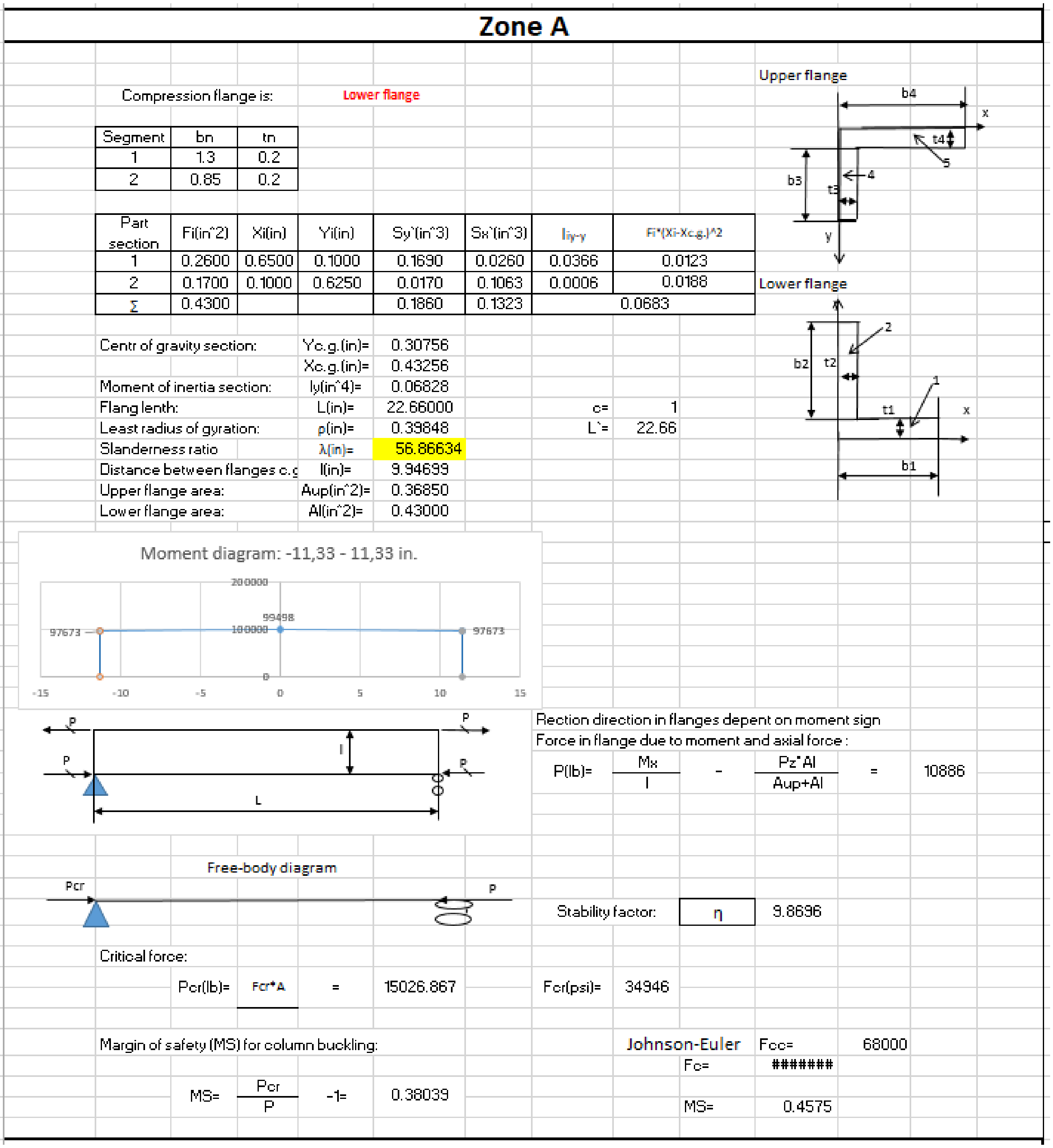
Flexibility (λ) - the value of inverse stiffness in compression rod. Tightening rod describes the ability to resist distortion of the longitudinal axis.

$$\lambda = \frac{L}{\rho}$$

Where: L - length of the element being analyzed;

ρ - minimum radius of inertia.

Terms fixing characterize stiffness support, which is attached to the structure. Also, the stability depends on the load. The coefficient (s), taking into account the above conditions are given in the table and the graph



Zone A

Compression flange is: Lower flange

Segment	bn	tn
1	1.3	0.2
2	0.85	0.2

Part section	Fi(in^2)	Xi(in)	Yi(in)	Sy`(in^3)	Sx`(in^3)	Iiy-y	Fi*(Xi-Xc.g.)^2
1	0.2600	0.6500	0.1000	0.1690	0.0260	0.0366	0.0123
2	0.1700	0.1000	0.6250	0.0170	0.1063	0.0006	0.0188
Σ	0.4300			0.1860	0.1323		0.0683

Centr of gravity section:	Yc.g.(in)=	0.30756
	Xc.g.(in)=	0.43256
Moment of inertia section:	Iy(in^4)=	0.06828
Flang lenth:	L(in)=	22.66000
Least radius of gyration:	ρ(in)=	0.39848
Slanderness ratio	λ(in)=	56.86634
Distance between flanges c.g	l(in)=	9.94699
Upper flange area:	Aup(in^2)=	0.36850
Lower flange area:	Al(in^2)=	0.43000

c= 1

L`= 22.66

Rection direction in flanges depent on moment sign

Force in flange due to moment and axial force :

$$P(lb) = \frac{Mx}{l} - \frac{Pz^*Al}{Aup+Al} = 10886$$

Stability factor: η 9.8696

Critical force:

Pcr(lb)= Fcr*A = 15026.867

Fcr(psi)= 34946

Margin of safety (MS) for column buckling:

$$MS = \frac{Pcr}{P} - 1 = 0.38039$$

Johnson-Euler Fcc= 68000

Fc= #######

MS= 0.4575

Fig 12 - Column buckling

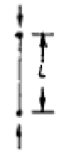
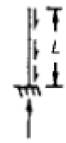
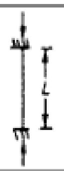
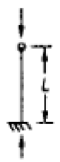
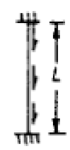
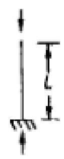
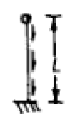
Column shape and end fixity		End fixity coefficient	Column shape and end fixity		End fixity coefficient
	Uniform column, axially loaded, pinned ends	$c = 1$ $\frac{1}{\sqrt{c}} = 1$		Uniform column, distributed axis load, one end fixed, one end free	$c = 0.794$ $\frac{1}{\sqrt{c}} = 1.12$
	Uniform column, axially loaded, fixed ends	$c = 4$ $\frac{1}{\sqrt{c}} = 0.5$		Uniform column, distributed axis load, pinned ends	$c = 1.87$ $\frac{1}{\sqrt{c}} = 0.732$
	Uniform column, axially loaded, one end fixed, one pinned end	$c = 2.05$ $\frac{1}{\sqrt{c}} = 0.7$		Uniform column, distributed axis load, fixed ends	$c = 7.5$ (Approx.) $\frac{1}{\sqrt{c}} = 0.365$
	Uniform column, axially loaded, one end fixed, one end free	$c = 0.25$ $\frac{1}{\sqrt{c}} = 2$		Uniform column, distributed axis load, one end fixed, one end pinned	$c = 6.08$ $\frac{1}{\sqrt{c}} = 0.406$

Fig 13 - Dependence of the "C" on the conditions for establishing and load

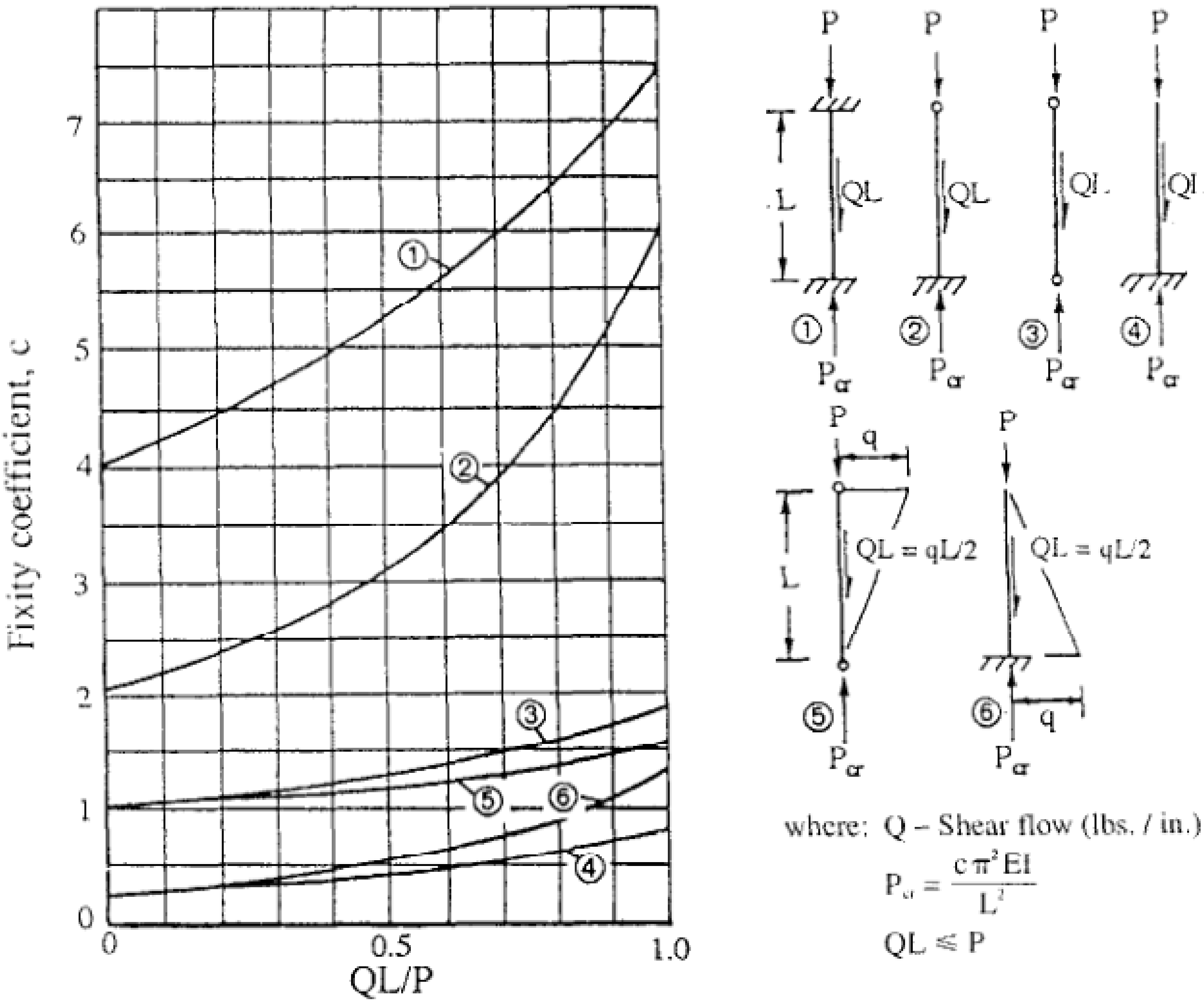


Fig 14 - Dependence of the "C" fixing the conditions for distributed load

Stability design calculated on several conditions that were formed and described formulas:

1. Euler's formula

$$P_E = \frac{\pi^2 EI}{L^2}$$

where;$P_E -\ Euler\ force\ of\ loss\ of\ stability$

$E - modulus\ of\ material\ elasticity\ for\ compression;$

$I - minimum\ axial\ moment\ of\ inertia\ of\ the\ section;$

$L' - effective\ bar\ length,\ L' = \frac{L}{c}.$

In the transition to stresses, we get:

$$F_{cr} = \frac{\pi^2 E}{\left(\frac{L'}{\rho}\right)^2}$$

With a decrease in value $\left(\frac{L'}{\rho}\right)^2$, the nature of the destruction of the structure changes. She begins to lose stability out of reach, squeezing a critical value, but much earlier.

Experiments show that characterized buckling can be visualized following schedule and divided into 3 sections.

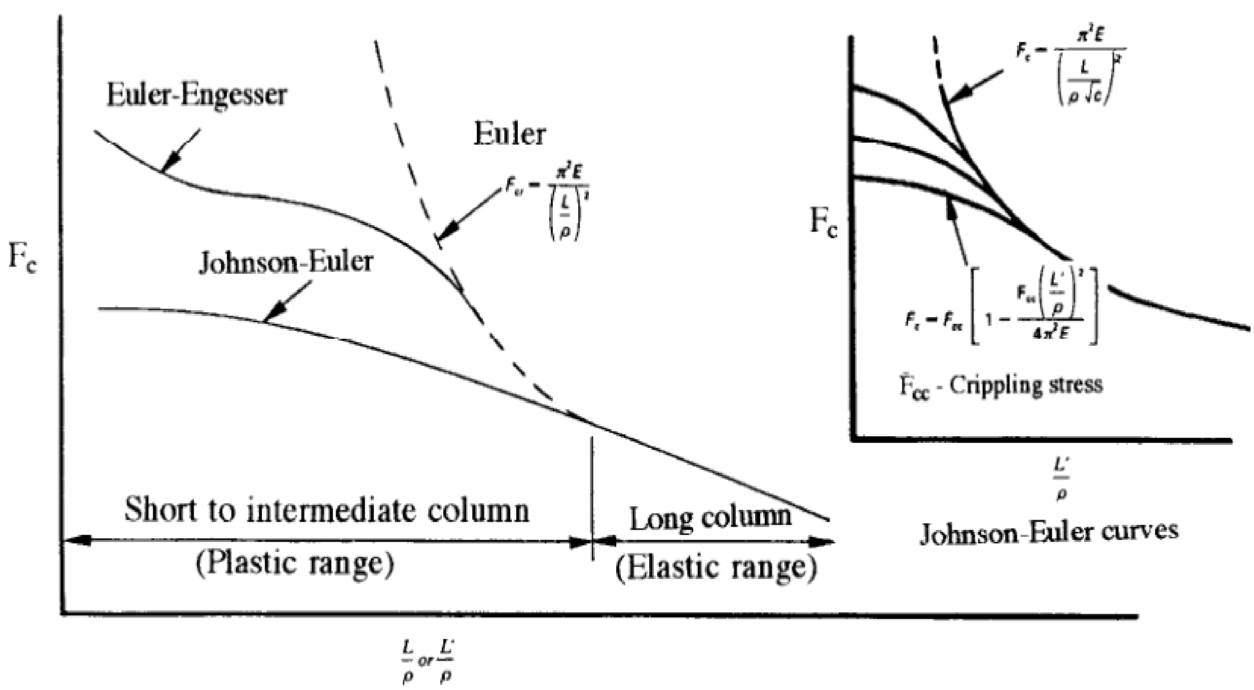


Figure 15 - Calculation Methods

Loss of stability according to the Euler formula is determined for thin and long rods.$\frac{L'}{\rho} \geq 80$

Loss stability in Euler formula defined for thin and long rods.$\frac{L'}{\rho} \geq 80$

Buckling under the formula of Euler-Engesser is defined for relatively medium length and thickness of the rods. For such road buckling section is characterized by plastic deformation, resulting in destruction occurs and when. Formula Euler-Engesser like Euler's formula, but it is already included tangent modulus of elasticity (tangential).$P < P_{cr}\ (F < F_{cr}) E_t$

$$F_{cr} = \frac{\pi^2 E_t}{\left(\frac{L'}{\rho}\right)^2}$$

The third section describes the most short roads molded or bent cross section. These rods are analyzed by the formula Johnson-Euler.

$$F_c = F_{cc} - \frac{F_{cc}^2 \left(\frac{L}{\rho\sqrt{c}}\right)^2}{4\pi^2 E}$$

where;$F_c -\ compression\ stress$

$F_{cc} - creppling\ stress$;

c $- braking\ factor$;

$\rho - minimum\ radius\ of\ inertia$;

$E - modulus\ of\ compression.$

In this formula, apparently, appears the term "stress crippling. " This phenomenon - crippling - also applies to cases of loss stability. Crippling - loss of the bearing capacity of the construction due to plastic deformation sectional shape. These plastic deformation resulting from local buckling individual elements section, which is why happens redistribution of stresses on the section. Thus, when the entire structure is still under force or stress is much smaller than the critical value, the overload spot-sectional plastic strain reaches a threshold. After that, the material begins to plastically deformed as causes loss bearing capacity. By crippling particularly prone to bent sections formed of manufacturing in which explicit angles and facets loose items. Tension crippling for each case determined mainly experimentally, however, based on the tests for typical sections, was built typical graphics. These graphs can use to determine the critical strain crippling for any section.

2.3 Calculation attachment of the flange to web

Strength on Fastener: $P = \frac{V\ (6D)}{h_c} = 608.4\ lbs$

Where V – maximum shear load, h_c – beam depth, 6D – standard fastener pitch, D - fastener diameter.

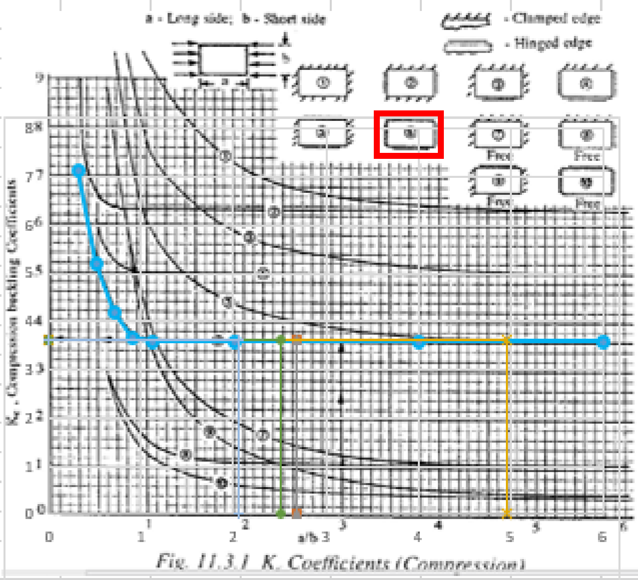
From engineering experience selected fasteners made of 7075-T731 (E) material. The distance between the fasteners - 6D

Fastener Diameter		$\frac{3}{32}$	$\frac{1}{8}$	$\frac{5}{32}$	$\frac{3}{16}$	$\frac{1}{4}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{9}{16}$
Fastener Material	F_{su} (Ksi)	Ultimate Single Shear Load (lbs./fastener)									
1100F (A)	9										
5056 (B)	28	203	363	556	802	1450	2295	3275			
2117-T3 (AD)	30	217	388	596	862	1555	2460	3510			
2017-T31 (D)	34	247	442	675	977	1765	2785	3980			
2017-T3 (D)	38	275	494	755	1090	1970	3115	4445			
2024-T31 (DD)	41	296	531	814	1175	2125	3360	4800			
7075-T73 (E)	41										
7075-T731 (E)	43	311	558	854	1230	2230	3525	5030			
A-286 CRES	90	—	—	1726	2485	4415	6906	9938			
Ti-6A1-4V & Alloy Steel	95	—	—	1822	2623	4660	7290	10490	14280	18650	23610
Alloy Steel	108	—	—	2071	2982	5300	8280	11930	16240	21210	26840
	125	—	—	2397	3452	6140	9590	13810	18790	24540	31060
	132	—	—	2531	3645	6480	10120	14580	19840	25920	32800

Figure 16– Rivet shear strength allowable

The design at issue in the work, analyzed the conditions match the Euler-Engesser, Johnson Euler, and analyzed on crippling also tested various combinations of buckling. Below results of calculation, sections package MS Excel.

Zone A



thicknes_t(in)= 0.105

a(in)= 22.66

h=b(in)= 8.46

$$\frac{a}{h} = 2.6785$$

Kc= 3.6

Initial buckling stress:

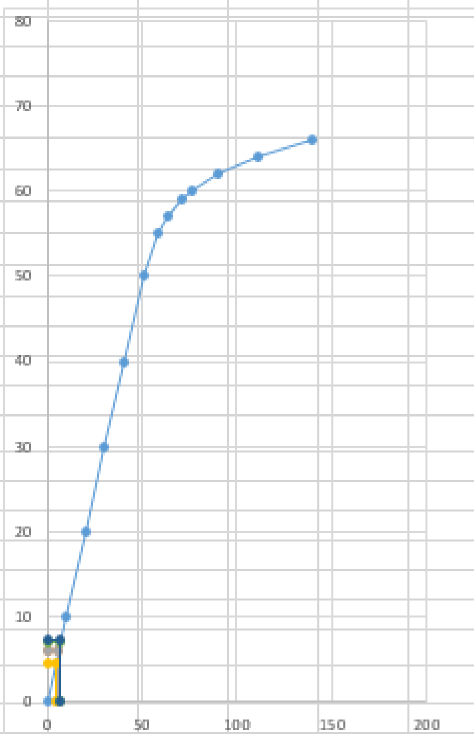
Fccr = Kc ηc Ec (tw/h)^2

$$\frac{Fccr}{\eta c} = Kc\ Ec\ (tw/h)^{\wedge}2 = 5.8782 \ (ksi)$$

40

ηc - Plasticity reduction factor in compression loac

$$eta\_cx = \left(\frac{Et}{E}\right)^{0.5} = \left(\frac{1}{1+\left(\frac{0.002*E*n}{Fcy}\right)*\left(\frac{Fccr}{Fcy}\right)^{n-1}}\right)^{0.5}$$



Fccr/ηc	Fccr
0	0
10	10
20	20
30	30
40.008	40
50.581	50
58.466	55
63.658	57
71.29	59
76.427	60
90.342	62
110.65	64
139.4	66
178.93	68

Fccr (ksi) 5.8782

$$\text{Margin of safety} = \frac{Fccr}{f_{compr}} -1 = 5.046$$

Compresion stress due to axial load in some LC

$$Rc = \frac{f_{compr}}{Fc.cr} = 0.165$$

Figure 17 - Initial buckling stress for web an in-plane compression load

Zone A

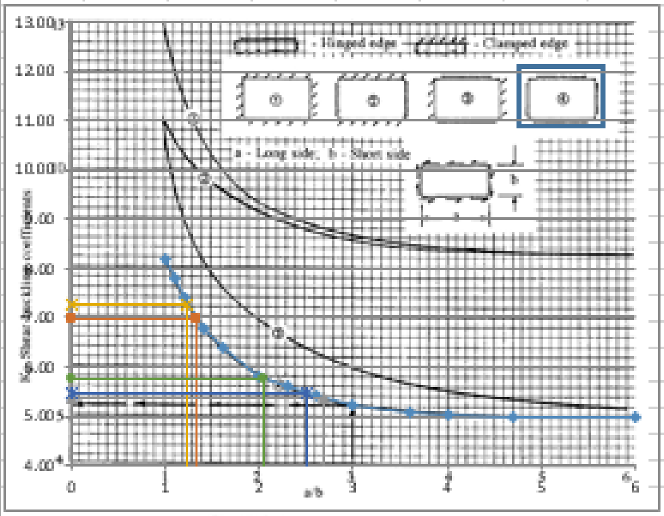


Fig. 11.3.5 K. Coefficients (Shear)

a/b	Ks.cr
1	8.20
1.1	7.8
1.2	7.4
1.4	6.8
1.6	6.4
2	5.8
2.3	5.6
2.6	5.4
3	5.2
3.6	5.08
4	5.05
4.7	5
6	5

thicknes_t(in)= 0.105
a(in)= 11.33
h=b(in)= 8.46

$\frac{a}{h}$ = 1.339243

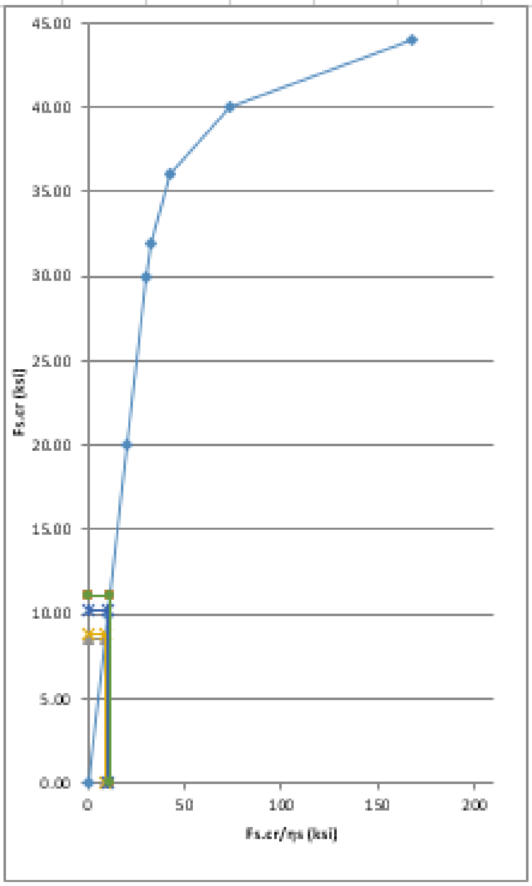
Ks= 6.9823

Initial buckling stress:

Fs.cr = Ks.cr ηs E (tw/h)^2

or $F_{s.cr} = K_s \eta_s E\left(\frac{t}{b}\right)^2$

$\frac{Fs.cr}{\eta s}$ = Ks.cr E (tw/h)^2= 11.078 (ksi)



Fs.cr/ηs	Fs.cr
0	0.00
10	10.00
20.00009	20.00
30.20313	30.00
32.6873	32.00
42.00989	36.00
73.86647	40.00
166.9699	44.00
387.4836	48.00

Fs.cr(ksi 11.078

Margin of safety= $\frac{Fs.cr}{f_{s.stress}}$ -1= 50.22293

Rs = $\frac{f_{s.stress}}{Fs.cr}$ = 0.01952

Figure 18 - Initial buckling stress for web an in-plane shear load

Zone A

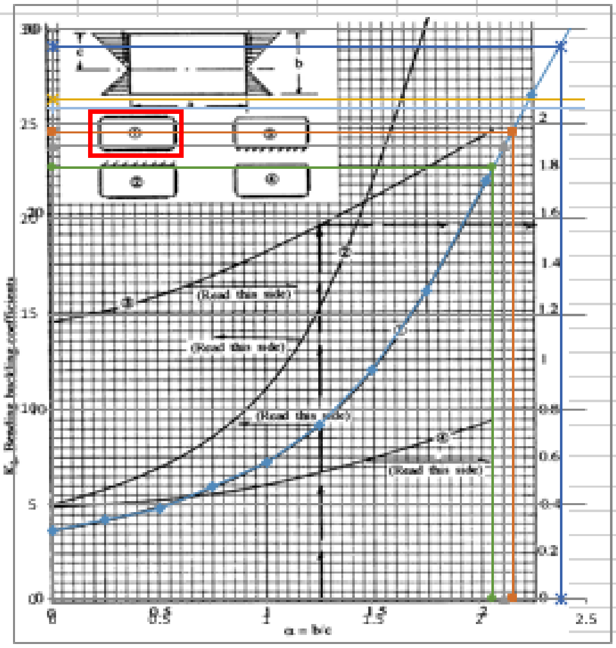


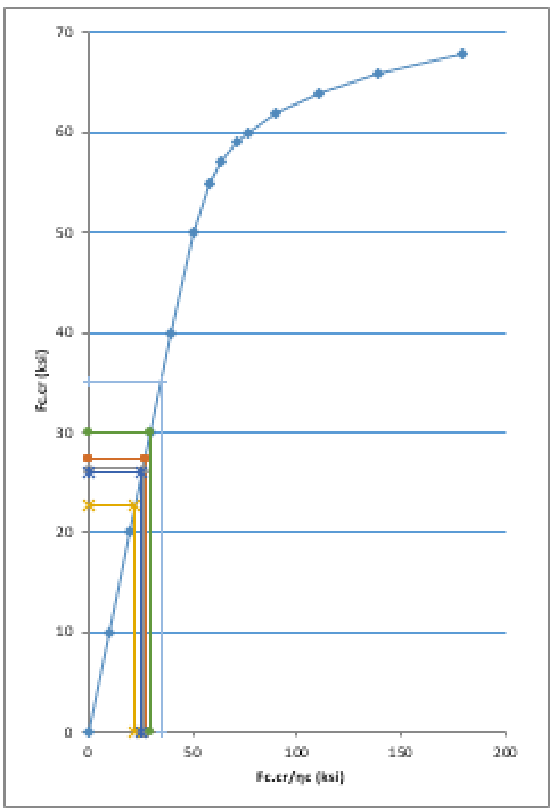
Fig. 11.3.6 K_b Coefficients (Bending) – $\frac{a}{b} > 1.0$

thicknes_t(in)=	0.105	
a(in)=	22.66	
h=b(in)=	10.11	
c(in)=	4.6841	
$\frac{b}{c}$	=	2.15837
Kb=	24.626	

$$F_{b,cr} = K_b \eta_c E \left(\frac{t}{b}\right)^2$$

Fb.cr = Kb.cr ηc E (tw/h)^2

$\frac{\text{Fb.cr}}{\eta c}$ = Kb.cr E (tw/h)^2= 27.359 (ksi)

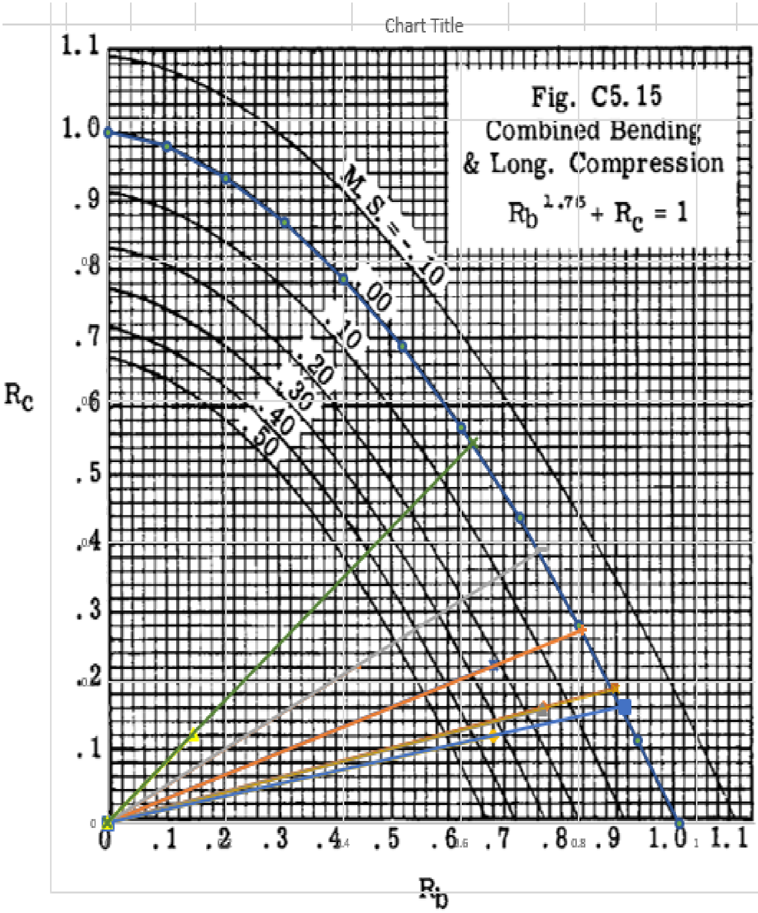


Fc.cr= Fb.cr= 27.359 (ksi)

MS = $\frac{\text{Fb.cr}}{\text{fD}}$ -1= 0.3527

Rb = $\frac{\text{fD}}{\text{Fb.cr}}$ = ######

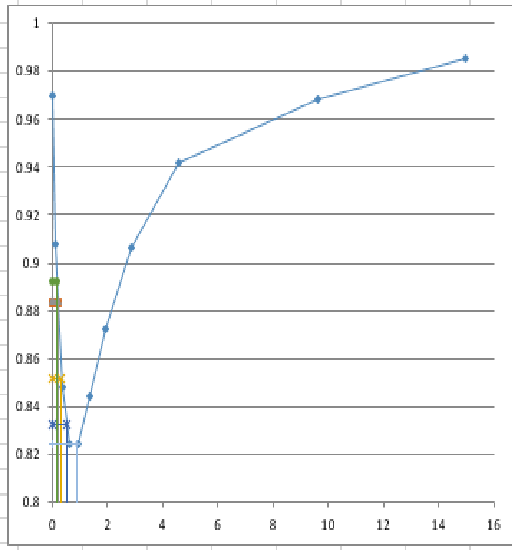
Figure 19 - Initial buckling stress for web an in-plane bending load



Rc
0
0.12
0.282
0.435
0.565
0.68
0.775
0.855
0.92
0.963
0.985

Rb	Rc
0	0.985
0.1	0.963
0.2	0.92
0.3	0.855
0.4	0.775
0.5	0.68
0.6	0.565
0.7	0.435
0.8	0.282
0.9	0.12
0.97	0

tgα	ρ
15	0.985
9.63	0.968178
4.6	0.941488
2.85	0.906104
1.9375	0.872138
1.36	0.844038
0.941667	0.824151
0.621429	0.824151
0.3525	0.848248
0.133333	0.907965
0	0.97



Zone	Rb	Rc	tgα=Rc/Rb	Rb^{allow}	Rc^{allow}	$M.S._{b+c}$
A	0.7393	0.165399433	0.223736168	0.86202	0.19287	0.166057

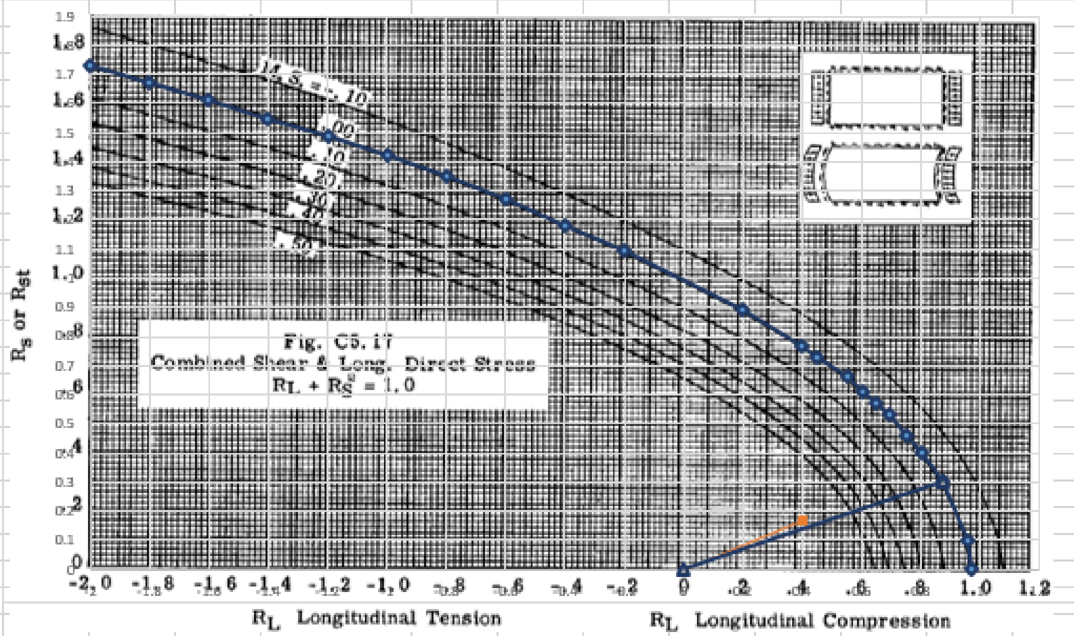
tgα1	tgα2	ρ1	ρ2	k	b	ρ
0.1333	0.3525	0.907964757	0.848247605	-0.27247	0.94429	0.883332

tgα	ρ
0	0.8833
0.2237	0.8833
0.2237	0

Ractual	
Rb	Rc
0	0
0.7393	0.165399433

Rallow	
Rb^{allow}	Rc^{allow}
0	0
0.86202	0.19287

Figure 20 – MS for bending + compression load



Zone	Rs	R_L	tgα=RL/Rc	R_L^{allow}	Rs^{allow}	M.S.$_{L+c}$
A	0.4	0.1654	0.413498584	0.87	0.3	1.1261

R_L^{tens}	R_L^{comp}
no_tens	0.1654

tgα1	tgα2	ρ1	ρ2	k	b	ρ
0.3448	0.1047	0.9203	0.960221329	-0.166	0.9776	0.9203

tgα	ρ
0	0.9203
0.3448	0.9203
0.3448	0

Ractual	
Rs	Rc
0	0
0.4	0.1654

Rallow	
Rs^{allow}	Rc^{allow}
0	0
0.87	0.3

Zone	Rs	R_L	M.S.$_{L+c}$
A	0.4	0	

R_L^{tens}	R_L^{comp}
#DIV/0!	0

Figure 21 – MS for shear + compression load

2.4 Section Summary

Section 2 was performed calculations strength and resistance elements section of the beam. It was performed the following tasks:

- Analyzes the load and critical cases selected for analysis;
- An analog current loads and stresses calculated in section of the beam;
- The analysis of beams for stability on several criteria;
- The optimum size of the beam cross-sections and the optimum step transverse and longitudinal ribs.

III SECTION

3.1 Analysis attaching beams to the frames

Basic requirements for hardware:

1. Factor landing. In accordance with FAR 25.625 maximum landing factor that must be taken when analyzing mount - 1.15:

- factor of 1.15 should be adopted for the analysis of all types including securing landing and jam fasteners;

- at every landing, every detail should be considered a place where the cross section parameters unchanged according to the original;

Cases where the landing factor can not be used:

- for bindings that are made by the adopted methodology and based on experimental data received;

- the use of other factors for designing, which is higher than 1.15.

2. The total strength of attachment. This is the main requirement. The total strength of attachment be equal to or be higher than the strength of each of the structures are connected. Each side attachment should not be designed separately for maximum strength, leading to excess weight and resources for the implementation of this fixture. Clamps should be placed on supporting elements such as Stringer, frames, spars etc. to increase their strength.

3. Eccentricity. The moment resulting from the eccentricity of the connection causes an increase in load due to the emergence additional tensile force at the ends of the fastener. The stresses in the sheet are not greater than the stresses of deformation, and the maximum stresses of the tensile are in the elastic zone.

The main critical case when analyzing the connections are offset (cut) fasteners and crumpling sheet material.

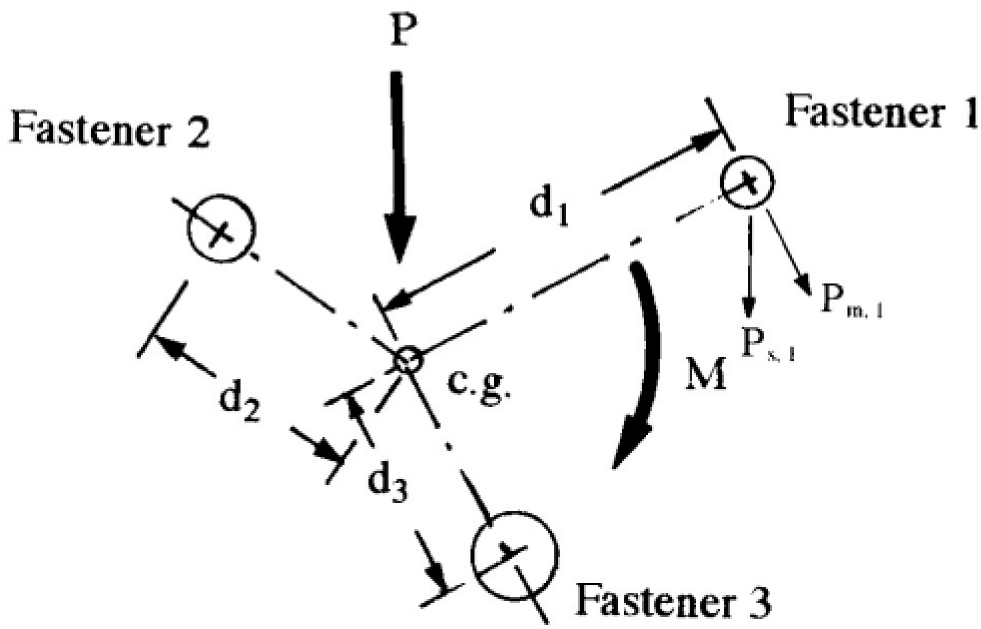


Figure 22 - Fastener Cluster

Shear load on given fasteners 1, due to a concentrated load, P:

$$P_{s.1} = P\left(\frac{A_1}{\sum A}\right)$$

Shear load on given fasteners 1, due to a moment, M:

$$P_{m.1} = M\left(\frac{A_1 \cdot d_1}{\sum A \cdot d^2}\right)$$

Where A – Fastener area, d – Distance from centroid of the fastener cluster to given fastener.

3.2 Static strengths analysis

In our case, three rows were installed of fasteners with verticalpitch equals 0.978 in. and horizontal pitch equals 1.08 in. Diameter rivets were installed 0.25 in and with diam 0.156 in. As far from the center were placed fasteners with d 0.156 in, it is explained higher load on this region. Calculation of centroid is tabulated in Table below.

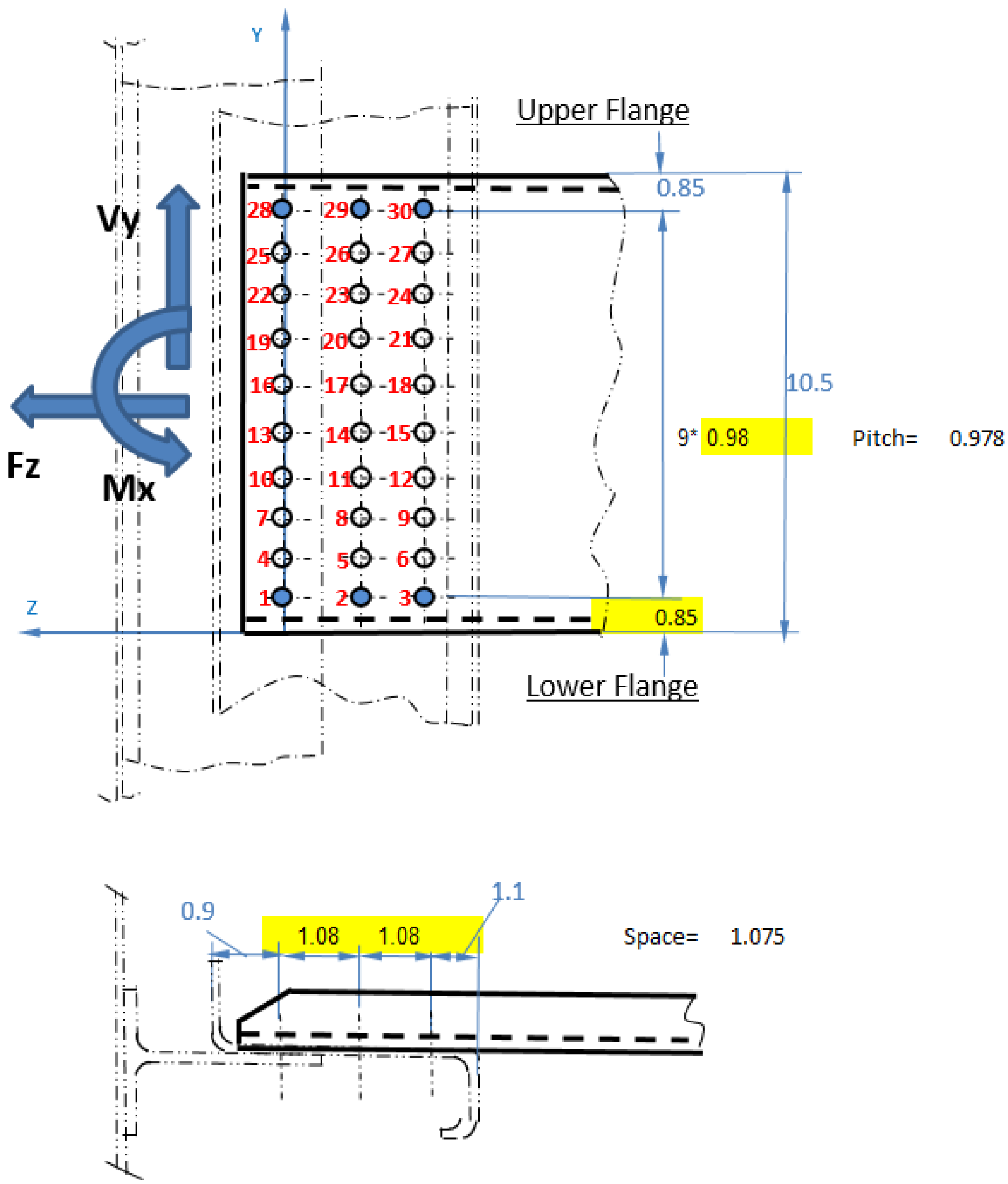


Figure 23 - Fastener location

Fastener Material: 7075-T731 (E)

Ultimate shear load: for d = 0.25 - Psh = 2230 (pounds), for d = 0.156 - Psh = =1230 (pounds)

Table 1 – Calculation of centroid

Fastener ID	Y	Z	D	t_{web}	Ai	Ai*Yi	Ai*Zi	Ai*(Yi-Ycg	Ai*(Zi-Zcg)
1	0,55	0	0,25	0,116	0,0491	0,0270	0,0000	1,0890	0,0567
2	0,55	-1,075	0,25	0,116	0,0491	0,0270	-0,0528	1,0890	0,0000
3	0,55	-2,15	0,25	0,116	0,0491	0,0270	-0,1055	1,0890	0,0567
4	1,83	0	0,156	0,116	0,0191	0,0350	0,0000	0,2249	0,0221
5	1,83	-1,075	0,156	0,116	0,0191	0,0350	-0,0205	0,2249	0,0000
6	1,83	-2,15	0,156	0,116	0,0191	0,0350	-0,0411	0,2249	0,0221
7	2,81	0	0,156	0,116	0,0191	0,0537	0,0000	0,1147	0,0221
8	2,81	-1,075	0,156	0,116	0,0191	0,0537	-0,0205	0,1147	0,0000
9	2,81	-2,15	0,156	0,116	0,0191	0,0537	-0,0411	0,1147	0,0221
10	3,79	0	0,156	0,116	0,0191	0,0724	0,0000	0,0413	0,0221
11	3,79	-1,075	0,156	0,116	0,0191	0,0724	-0,0205	0,0413	0,0000
12	3,79	-2,15	0,156	0,116	0,0191	0,0724	-0,0411	0,0413	0,0221
13	4,77	0	0,156	0,116	0,0191	0,0912	0,0000	0,0046	0,0221
14	4,77	-1,075	0,156	0,116	0,0191	0,0912	-0,0205	0,0046	0,0000
15	4,77	-2,15	0,156	0,116	0,0191	0,0912	-0,0411	0,0046	0,0221
16	5,75	0	0,156	0,116	0,0191	0,1099	0,0000	0,0046	0,0221
17	5,75	-1,075	0,156	0,116	0,0191	0,1099	-0,0205	0,0046	0,0000
18	5,75	-2,15	0,156	0,116	0,0191	0,1099	-0,0411	0,0046	0,0221
19	6,73	0	0,156	0,116	0,0191	0,1286	0,0000	0,0413	0,0221
20	6,73	-1,075	0,156	0,116	0,0191	0,1286	-0,0205	0,0413	0,0000
21	6,73	-2,15	0,156	0,116	0,0191	0,1286	-0,0411	0,0413	0,0221
22	7,71	0	0,156	0,116	0,0191	0,1474	0,0000	0,1147	0,0221
23	7,71	-1,075	0,156	0,116	0,0191	0,1474	-0,0205	0,1147	0,0000
24	7,71	-2,15	0,156	0,116	0,0191	0,1474	-0,0411	0,1147	0,0221
25	8,69	0	0,156	0,116	0,0191	0,1661	0,0000	0,2249	0,0221
26	8,69	-1,075	0,156	0,116	0,0191	0,1661	-0,0205	0,2249	0,0000
27	8,69	-2,15	0,156	0,116	0,0191	0,1661	-0,0411	0,2249	0,0221
28	9,97	0	0,25	0,116	0,0491	0,4894	0,0000	1,0890	0,0567
29	9,97	-1,075	0,25	0,116	0,0491	0,4894	-0,0528	1,0890	0,0000
30	9,97	-2,15	0,25	0,116	0,0491	0,4894	-0,1055	1,0890	0,0567
Σ					0,7532	3,9621	-0,8097	8,8467	0,5803

Center of gravity fastener group coordinates:

$$Y_{c.g.} = \frac{\sum A_i \cdot Y_i}{\sum A_i} = \frac{3.9621}{0.7532} = 5.26\ in$$

$$Z_{c.g.} = \frac{\sum A_i \cdot Z_i}{\sum A_i} = \frac{-0.8097}{0.7532} = -1.075\ in$$

Fastener load components:

$$R_{yv} = -V_y \cdot \frac{A_i}{\sum A_i}\ lbs$$

$$R_{z-axial} = -F_{axial} \cdot \frac{A_i}{\sum A_i}\ lbs$$

$$R_{yMx} = \frac{-M_x \cdot A_i \cdot (Z_i - Z_{cg})}{\left[\sum A_i \cdot (Y_i - Y_{cg})^2 + \sum A_i \cdot (Z_i - Z_{cg})^2\right]}$$

$$R_{zMx} = \frac{-M_x \cdot A_i \cdot (Y_i - Y)}{\left[\sum A_i \cdot (Y_i - Y_{cg})^2 + \sum A_i \cdot (Z_i - Z_{cg})^2\right]}$$

$$R_{\Sigma} = \left(\left(R_{yv} + R_{yMx}\right)^2 + \left(R_{z-axial} + R_{zMx}\right)^2\right)$$

Table 2 – Fastener load components

Fastener ID	R_{yz} (lbs)	R_{yMx} (lbs)	$R_{z\text{-}axial}$ (lbs)	R_{zMx} (lbs)	R_{Σ} (lbs)	P_{shu} (lbs)	P_{bru} (lbs)	MS_{sh}	MS_{br}
1,0	89,0	-123,6	-198,6	-541,4	740,8	2230,0	4263,0	2,0	4,8
2,0	89,0	0,0	-198,6	-541,4	745,3	2230,0	4263,0	2,0	4,7
3,0	89,0	123,6	-198,6	-541,4	769,9	2230,0	4263,0	1,9	4,5
4,0	34,7	-48,1	-77,3	-153,5	231,2	1230,0	2660,1	4,3	10,5
5,0	34,7	0,0	-77,3	-153,5	233,4	1230,0	2660,1	4,3	10,4
6,0	34,7	48,1	-77,3	-153,5	245,2	1230,0	2660,1	4,0	9,8
7,0	34,7	-48,1	-77,3	-109,7	187,5	1230,0	2660,1	5,6	13,2
8,0	34,7	0,0	-77,3	-109,7	190,2	1230,0	2660,1	5,5	13,0
9,0	34,7	48,1	-77,3	-109,7	204,5	1230,0	2660,1	5,0	12,0
10,0	34,7	-48,1	-77,3	-65,8	143,8	1230,0	2660,1	7,6	17,5
11,0	34,7	0,0	-77,3	-65,8	147,3	1230,0	2660,1	7,4	17,1
12,0	34,7	48,1	-77,3	-65,8	165,3	1230,0	2660,1	6,4	15,1
13,0	34,7	-48,1	-77,3	-21,9	100,2	1230,0	2660,1	11,3	25,6
14,0	34,7	0,0	-77,3	-21,9	105,1	1230,0	2660,1	10,7	24,3
15,0	34,7	48,1	-77,3	-21,9	129,3	1230,0	2660,1	8,5	19,6
16,0	34,7	-48,1	-77,3	21,9	57,0	1230,0	2660,1	20,6	45,7
17,0	34,7	0,0	-77,3	21,9	65,4	1230,0	2660,1	17,8	39,7
18,0	34,7	48,1	-77,3	21,9	99,6	1230,0	2660,1	11,3	25,7
19,0	34,7	-48,1	-77,3	65,8	17,7	1230,0	2660,1	68,4	149,0
20,0	34,7	0,0	-77,3	65,8	36,5	1230,0	2660,1	32,7	71,8
21,0	34,7	48,1	-77,3	65,8	83,6	1230,0	2660,1	13,7	30,8
22,0	34,7	-48,1	-77,3	109,7	35,0	1230,0	2660,1	34,1	75,0
23,0	34,7	0,0	-77,3	109,7	47,4	1230,0	2660,1	25,0	55,1
24,0	34,7	48,1	-77,3	109,7	88,9	1230,0	2660,1	12,8	28,9
25,0	34,7	-48,1	-77,3	153,5	77,3	1230,0	2660,1	14,9	33,4
26,0	34,7	0,0	-77,3	153,5	83,7	1230,0	2660,1	13,7	30,8
27,0	34,7	48,1	-77,3	153,5	112,5	1230,0	2660,1	9,9	22,6
28,0	89,0	-123,6	-198,6	541,4	344,5	2230,0	4263,0	5,5	11,4
29,0	89,0	0,0	-198,6	541,4	354,1	2230,0	4263,0	5,3	11,0
30,0	89,0	123,6	-198,6	541,4	403,3	2230,0	4263,0	4,5	9,6

3.3 Joint fatigue analysis

For durability analysis used service loads, see Table 7.1. Loads are explained by the fuselage pressurized cycles. Analysis is being done for fasteners 1,2,3,28,29,30. In this region are acting maximum axial loads due to moment.

Table 2 – Applied loads

Vy (lbs)	Axial (lbs)	M (lbs*in)
-1366	3048	22074

Table 2 – Normal and shear stress for cross section (psi)

	Point	Bending stress	Axis stress	Total stress (Bending stress + Axis stress)	Shear stress
Lower flange	A	-4410	1579	-2831	0
	B	-3262		-1683	0
	C	-4223		-2644	61,02874
	D	-3449		-1870	1035,747
Web	K	-1579		0	1480,328
Upper flange	E	3769		5348	846,7564
	F	4353		5932	55,27676
	H	5572		7151	0
	G	4506		6085	0

Upper beam flange is fastened to the frame with 3 rivets from 7075-T731 (E) alloy.

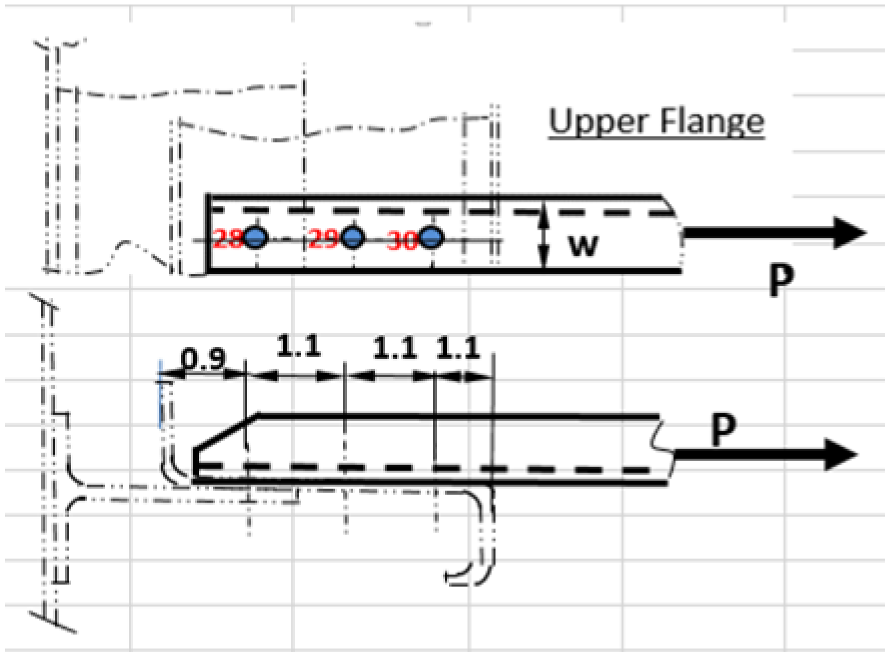


Figure 24 – Upper Flange scheme

Where W – 1.3 in., P – load transferred by flange.

$$P = f_G \cdot A_{lower} = 4506 \cdot 0.468 = 2108.8\ lbs$$

Where A_{lower} – gross section area.

Fatigue quality index (K) must be determined before the beginning of fatigue analysis to esdtimate joint fatigue life. Severity factor (SF) is the local peak stress due by load transfer and bypass load.

$$K_{tgross} = SF = \left(\frac{\alpha \cdot \beta}{f_g}\right)\left[\left(\frac{K_{tb} \cdot \Delta P}{D \cdot t}\right) \cdot \theta + \left(\frac{K_{tg} \cdot P}{W \cdot t}\right)\right]$$

Where α – Fastener hole condition factor, for Cold worked hole 0.7. β – Hole filling factor, for rivets 0.75. D – Fastener diameter. Ktb – Bearing stress concentration factor, Fig. 7.4. Ktg – Stress concentration factor, Fig 7.5. θ – Bearing distribution factor, Fig. 7.6.

Fastener №30 load:

$$\Delta P = R1 = 0.33 \cdot P = 0.33 * 2108 = 695.64\ lbs$$

Bypass load on splice:

$$Pbypass = P - \Delta P = 2108.8 - 695.64 = 1413.16\ lbs$$

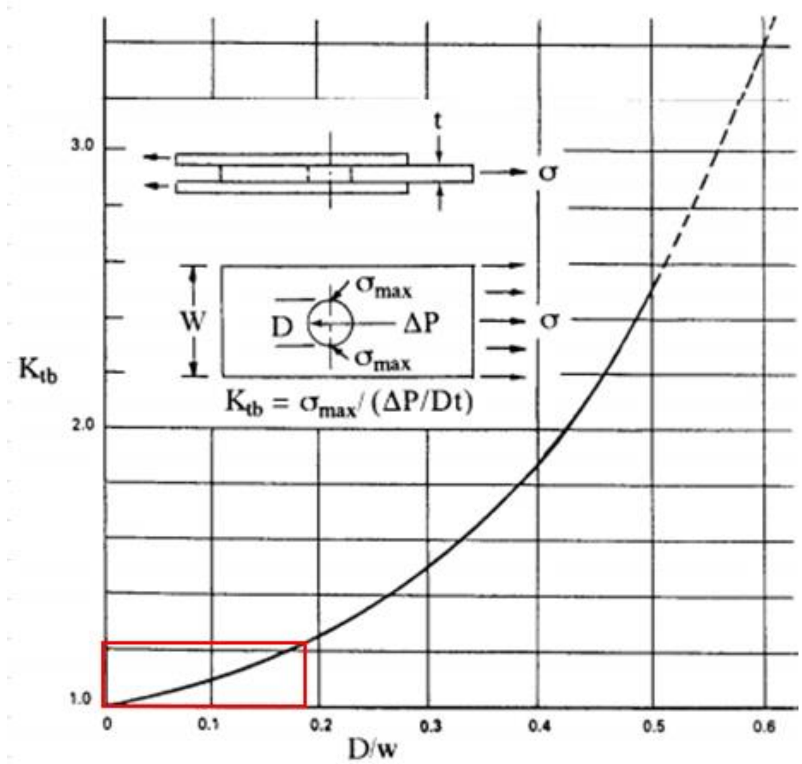


Figure 25– Bearing stress concentration factor Ktb

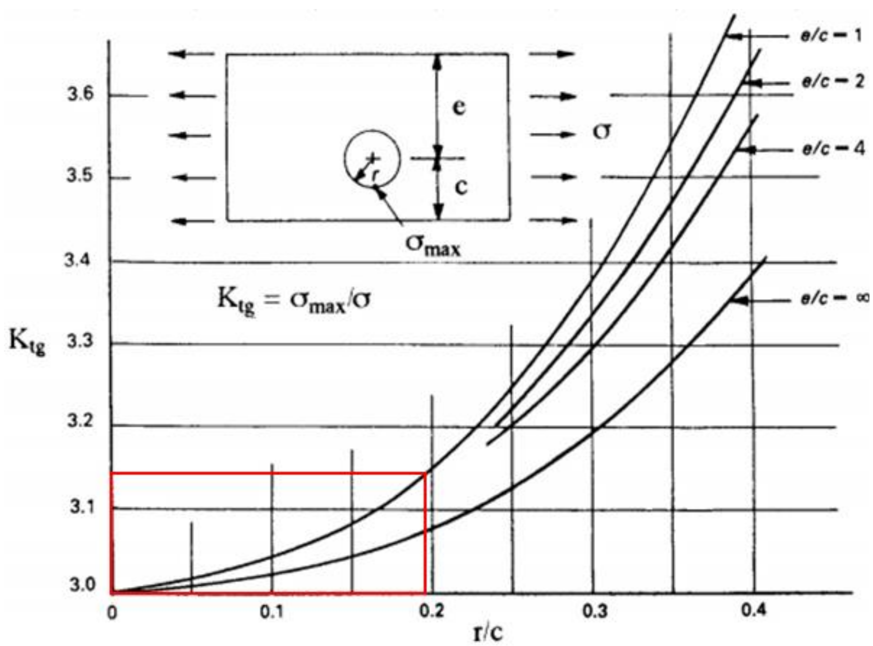


Figure 26 – Bearing stress concentration factor Ktb

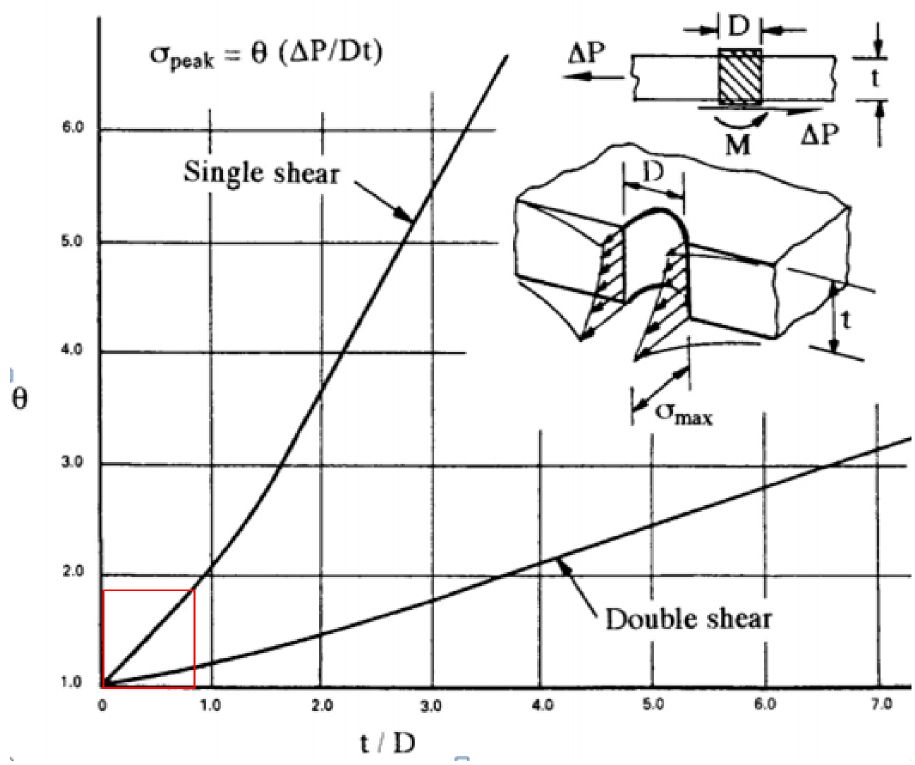


Figure 27 – Bearing distribution factor θ

$$K_{tgross} = \left(\frac{0.7 \cdot 0.75}{4506}\right)\left[\left(\frac{1.21 \cdot 695.64}{0.25 \cdot 0.18}\right) \cdot 1.85 + \left(\frac{3.14 \cdot 2108.8}{1.3 \cdot 0.18}\right)\right] = 7.328$$

$$K_{tactual} = K_{tgross} \cdot \frac{A_{net}}{A_{gross}} = K_{tgross} \cdot \frac{t \cdot (W-D)}{t \cdot W} = 7.328 \cdot \frac{0.18 \cdot (1.3-0.25)}{0.18 \cdot 1.3} = 5.918$$

$$f_{net} = f_{max} \cdot \frac{A_{net}}{A_{gross}} = 4506 * 0.807 = 3639\,psi$$

The stress

$$Smax = f_{net} = 3639\,psi$$

$$Sm = \frac{S_{max} - S_{min}}{2} = \frac{3639-0}{2} = 1819.5\,psi$$

For determining the number of cycles was used S/N curves on Fig.7.7 for $K_{tactual}$=5 [4]. Since the Smax and Sm are very small for this graph, so was chosen maximum value for chart Mean Stress=0. Therefore, Number of cycles $N_f = 1.8 \cdot 10^7$

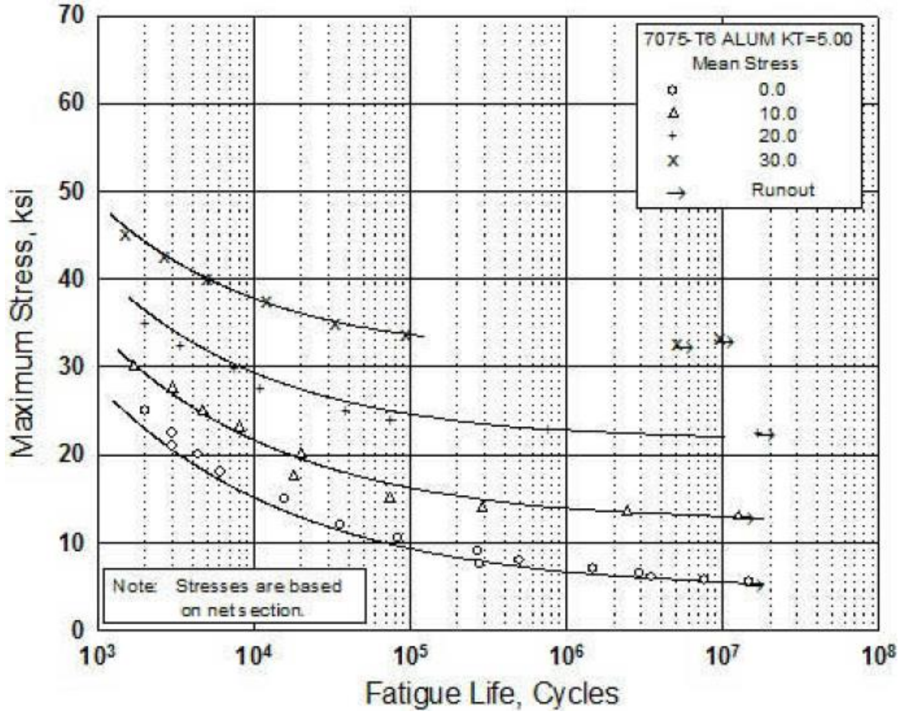


Figure 28 – S/N curves for Ktactual, 7075-T6 aluminum alloy

3.4 Conclusions section

Based on the current load and selected in section 2 of the geometric parameters of the beam was designed to connect beams and frames chosen the required number and placement of fasteners. Static and fatigue analysis was performed.

Conclusion

The thesis was conducted optimization and design of beams and floors made nastuph purposes:

1. The selected material for the beam.

2. Calculations beams for strength and stability.

3. the optimum dimensions of cross sections and longitudinal and transverse step edges.

4. Analysis of the connection beam frames, the optimum number of fasteners and their location.

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