Introduction to Landing Gear

Company Overview

-Messier-Dowty is a French based company and part of SNECMA Group which is an international aerospace group producing engines, landing gear, etc…

-Messier-Dowty employs 3000 people worldwide, and has sites in the France, England, Singapore, China, USA, and Canada.

-In Canada there is a site in Ajax, which design and manufacture landing gears and their systems, and a site in Montreal which manufactures the large components of the A340.

-Messier-Dowty's landing gears are on over 19000 aircraft making 30000 landing a day.

Company Overview

Airbus

-A300/310, A318/319/A320/A321, A330/A340, A340-500/600, A380.

Military

-Nimrod 2000, F/A-18 C/D, E/F, V22, AV8B, T-45, Rafale B, C, M, Mirage 2000, etc...

Business/Regional

-BA-609, Global 5000, Global Express, Challenger 600/601/604, Canadair RJ, Dehavilland DHC-8, Falcon 7X, Piaggio, Raytheon H-4000.

Ajax Site

-The Ajax site design and manufactures landing gears and their systems.

-We specialize in the business and regional aircraft for bombardier.

-Our program include all the Bombardier jets, DHC-8, Falcon-7X, F/A-18 E/F, AV8B, V-22, A340 CLG, and the newly acquired Russian Regional Jet.

-Of the over 500 employees, nearly 200 are in the engineering department. The rest make up manufacturing, as well as finance and contracts.

-Some of the highlight of the manufacturing facilities are the High Velocity Oxygen Fuel Coating (HVOF) as an alternative to chrome, as well as a state of the art assembly facility.

Engineering Department

Design – Produce CATIA models and drawings for every components and systems on the landing gear. Ensure functionality and assembly of the components.

Dynamics – Determine the external loads applied to the landing gears using FAR/JAR requirements and landing simulation software. Also determine the geometries of the metering orifice and pin in the shock struts.

Stress – Ensure the structural integrity of the landing gears. From the external loads determined by dynamics, determine internal loads to size and selected materials on all components that see load.

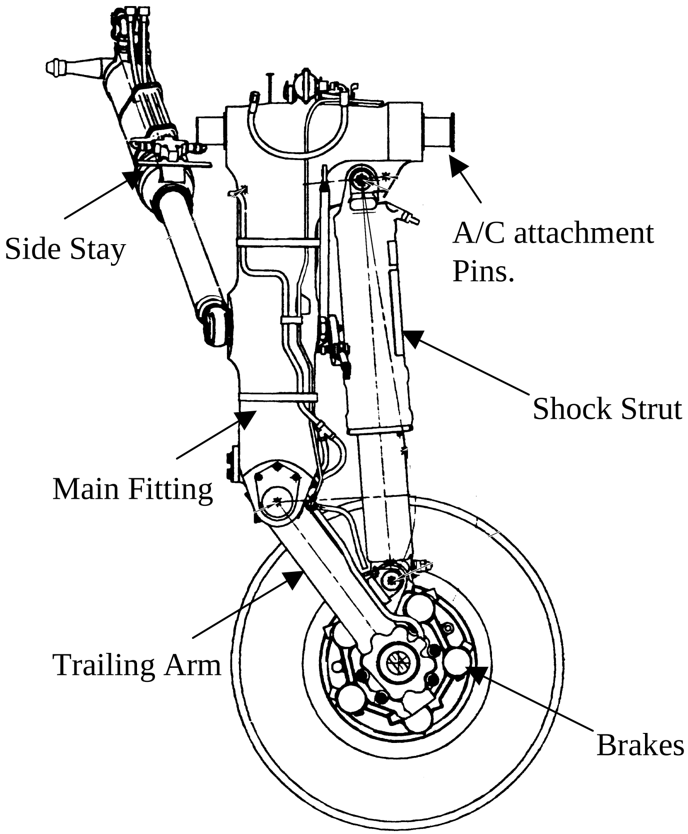
Test – Confirm that landing gear can handle landing gear loads in strength and fatigue. Perform testing required to certify gears. Also confirm airspring curve of the shock strut as well as confirm landing simulations through drop test.

Systems – In charge of all aspects related to the electrical and hydraulic systems of the landing gear systems. This reaches from the pilots steering wheel to the head lights mounted on the nose gear.

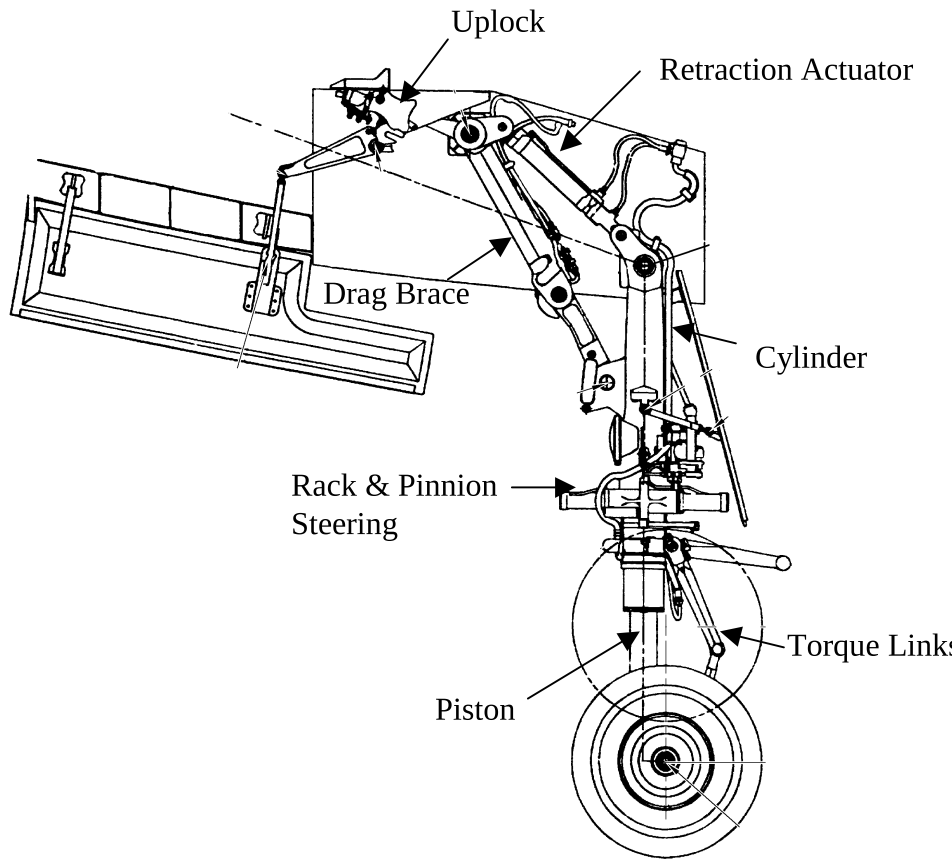
Support – Support both manufacturing and in-service landing gears. Address any non-conformance in manufacturing of the parts as well as any incidences or non-conformances on in-service landing gears.

Research and Development – Look into all new technologies related to landing gears from new manufacturing processes to new design ideas.

Landing Gear Overview

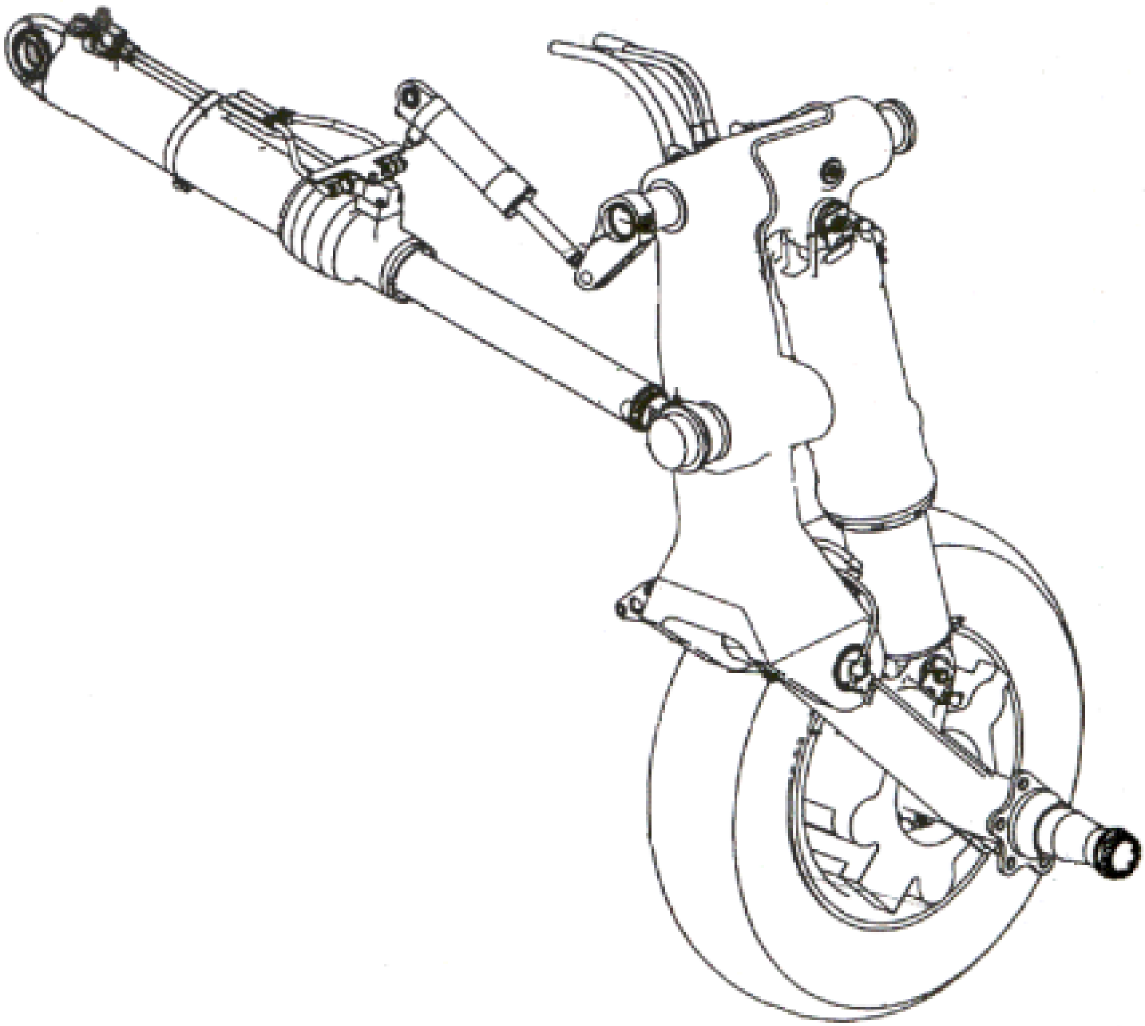


Main Landing Gear



Nose Landing Gear

Landing Gear Overview



Program Life Overview

-RFI (Request for Information)

-RFP (Request for Proposal)

-Contract Awarded

Russian Regional Jet

-Preliminary Design Review (PDR)

-Critical Design Review (CDR)

Falcon 7X

-First Test Articles Manufactured

-Certification Testing

-Final Report Writing

H-4000

-Certification

BD-100

-Production

-Service **RJ, Global, F/A-18, Challenger, DHC-8, etc…**

Design Process Overview

Geometry Definition
-Early in the life of the program, the geometry of the landing gear attachment point and by size are defined.

Initial Design
-The initial design is drawn based on customer requirements and geometry definitions and experience.

Loads
-Using FAR/JAR requirements, landing gear stiffness, a/c weights, etc…, the loads determined through landing simulations.

Sizing & Materials
-The original design is analyzed with the loads to determine the dimensions and materials required to handle the loads.

Design
-The original design is then changed to meet the stress requirements.

Iteration
-The new design then creates a second iteration due to changes in the gears stiffness and weight distribution. Multiple iterations may be required to get the design right.

Detailed Design
-The final detailed drawing are created and the detailed analysis of the structure for strength and fatigue begins.

Analysis Overview

-There are two department that perform the analysis.
-Dynamics
-Stress

-Dynamics must design the metering pin and orifice in order to obtain the gas spring curve, and then use then use the gas spring curve with other inputs to run the landing simulations and determine the ground loads. The ground loads are the vertical, drag, and side loads applied to the axle and ground.

-Stress takes all the load cases and uses a finite element program to determine the internal loads of the gear. The internal loads can then be used to analyze the entire landing gear. The stress analysis consists of two parts:

-Strength Analysis: This is to ensure that the components do not yield under the limit loading and do not break under the limit loading with an applied factor of safety of 1.5.

-Fatigue Analysis: To ensure that the components do not exceed a damage of 1 after a 15000 cycles with an applied scatter factor of 3.

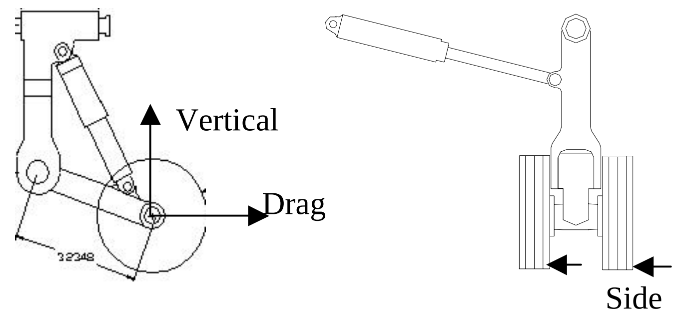
Dynamics - Loads

-The load on a landing gear can be separated into two categories; **Ground Load**, and **Landing Loads**.

-The **Ground loads** are typically derived based on FAR/JAR requirements.

-Side Load always acts at the ground.

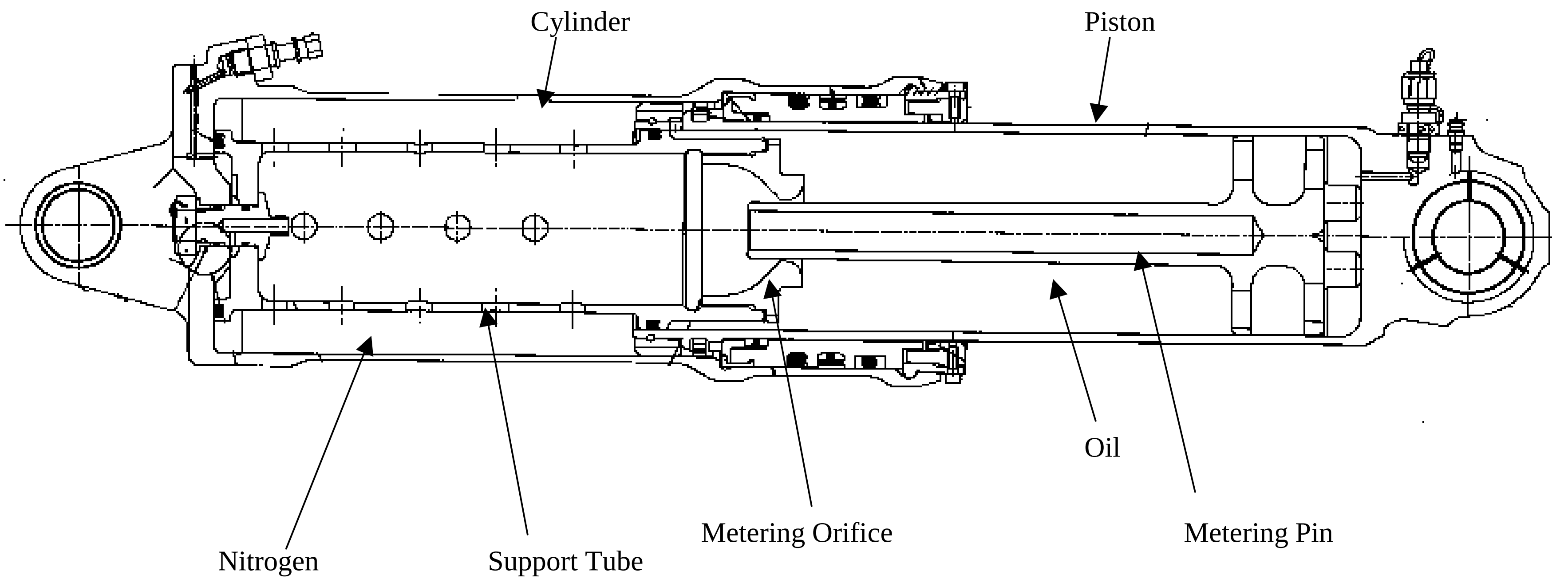
-Drag Loads act at the axle, except on the main landing gear in braking cases where the drag load acts at the ground.



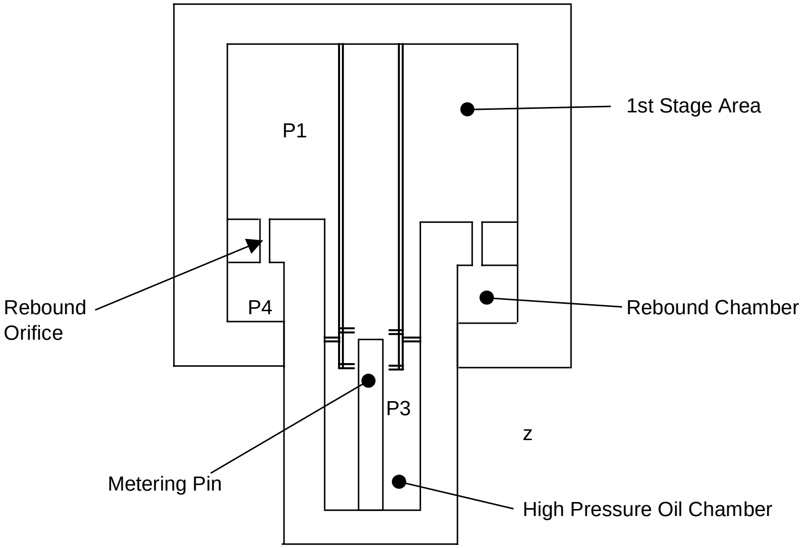
-The **Landing loads** are calculated using a landing simulation program. The requirements for the cases are from the FAR/JAR, but the inputs for the landing simulation program are specific to the landing gear and the aircraft.

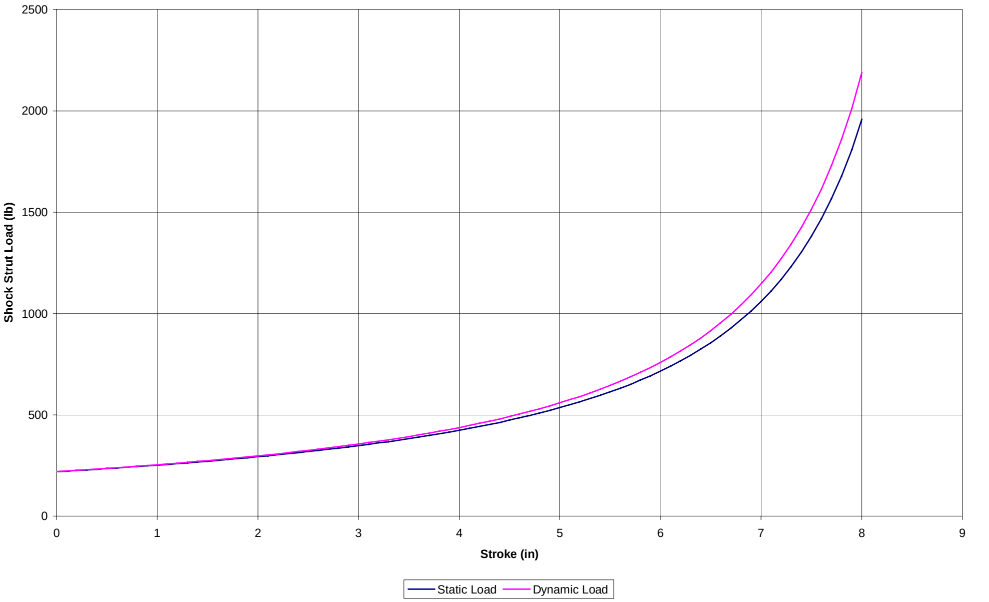
Note: Each load case occurs at a certain shock absorber stroke. This mean that a higher drag or side load at a lower stroke may not be as critical as a lower drag or side load more fully extended stroke.

Dynamics – Shock Strut



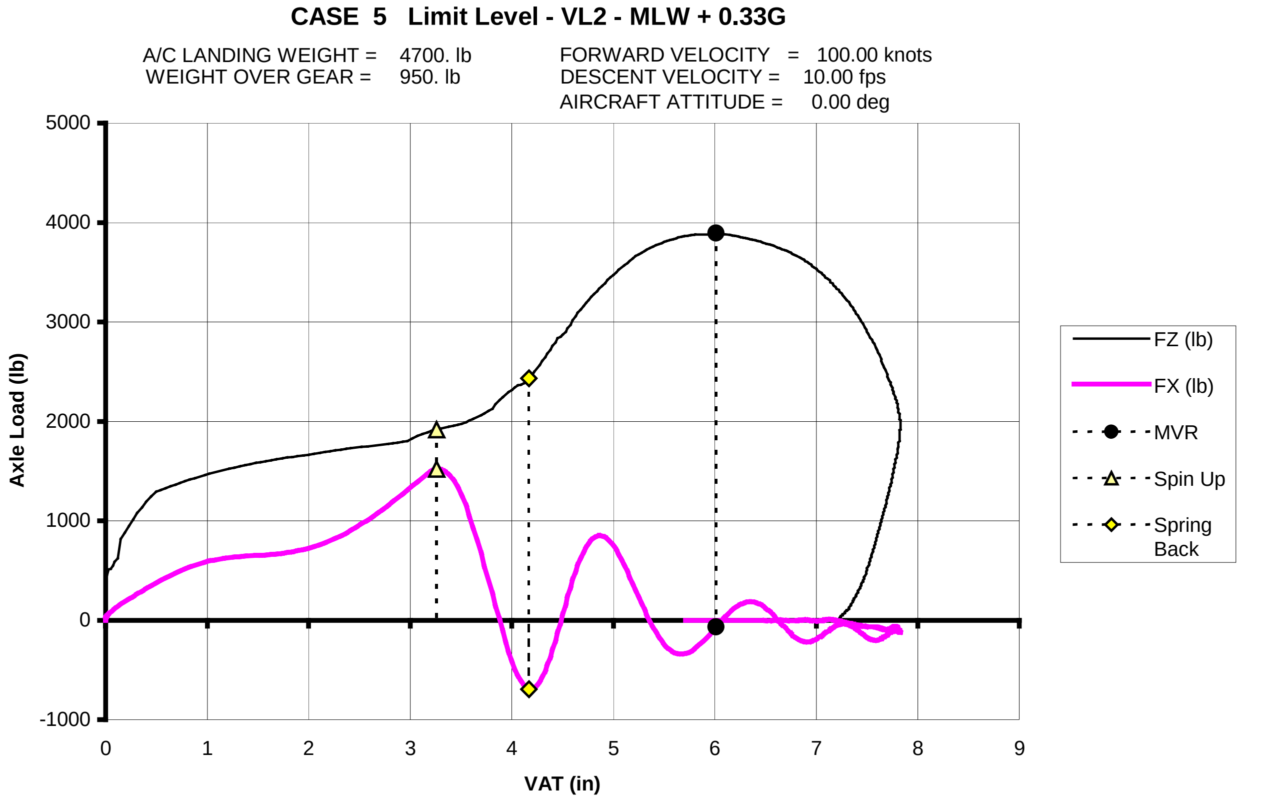
Dynamics – Shock Strut





Dynamics – Landing Loads

-For each Landing Case Output, there are three design conditions to examine; **Spin Up**, **Spring Back**, and **Maximum Vertical Reaction (MVR).** Of all the landing cases, the critical case for each of these conditions is selected as the design case.



Dynamics – Landing Load Program Inputs

-Landing Gear Stiffness (determined by Stress using Unit loads in their Beam Model)

-Tire Data (Tire Deflections, Friction Coefficients)

-Weights (MLW, WOG, Piston Weight)

-Shock Strut Data (airspring curve, maximum stroke, oil data)

-Metering Pin Data (Geometry along the length)

Note: Any change in these inputs will change the landing load predictions. The loads affect the design of the gear and all the stress analysis that follows. Something as simple as a change in the tire will require a new iteration in all the stress reports and possibly some design changes.

Dynamics – Landing Load Verification

-The landing loads are verified through a drop test. The drop test will simulate all the parameters used in the landing predictions program and will verify the ability of the shock strut.

-Any discrepancies will be seen when comparing outputs from the test to the landing simulation, and adjustments will be made, if needed to match the simulated results to the test results.

-To simulate the forward velocity, the tires are spun up before the gear is dropped.

Example Loads Summary

LOADING	1	MVR(L)		50-50
LOADING	2	MVR(L)		57.45-42.55
LOADING	3	MVR(L)		42.55-57.45
LOADING	4	MVR(L)		FLAT TIRE - STRBD
LOADING	5	MVR(L)		FLAT TIRE - PORT
LOADING	6	MVR(TD8)		50-50
LOADING	7	MVR(TD8)		57.53-42.47
LOADING	8	MVR(TD8)		42.47-57.53
LOADING	9	MVR(TD8)		FLAT TIRE - STRBD
LOADING	10	MVR(TD8)		FLAT TIRE - PORT
LOADING	11	SPIN UP(TD8)		50-50
LOADING	12	SPIN UP(TD8)		58.50-41.50
LOADING	13	SPIN UP(TD8)		41.50-58.50
LOADING	14	SPIN UP(TD8)		FLAT TIRE - STRBD
LOADING	15	SPIN UP(TD8)		FLAT TIRE - PORT
LOADING	16	SP-BACK(TD8)		50-50
LOADING	17	SP-BACK(TD8)		60.17-39.83
LOADING	18	SP-BACK(TD8)		39.83-60.17
LOADING	19	SP-BACK(TD8)		FLAT TIRE - STRBD
LOADING	20	SP-BACK(TD8)		FLAT TIRE - PORT
LOADING	21	SIDE LOAD(PORT)	CONF.3	50-50
LOADING	22	SIDE LOAD(PORT)	CONF.3	42.49-57.51
LOADING	23	SIDE LOAD(PORT)	CONF.3	FLAT TIRE - STRBD
LOADING	24	SIDE LOAD(PORT)	CONF.3	FLAT TIRE - PORT
LOADING	25	SIDE LOAD(PORT)	CONF.6	50-50
LOADING	26	SIDE LOAD(PORT)	CONF.6	20.77-79.23
LOADING	27	SIDE LOAD(PORT)	CONF.6	FLAT TIRE - STRBD
LOADING	28	SIDE LOAD(PORT)	CONF.6	FLAT TIRE - PORT
LOADING	29	SIDE LOAD(STBD)	CONF.3	50-50
LOADING	30	SIDE LOAD(STBD)	CONF.3	75.01-24.99
LOADING	31	SIDE LOAD(STBD)	CONF.3	FLAT TIRE - STRBD
LOADING	32	SIDE LOAD(STBD)	CONF.3	FLAT TIRE - PORT
LOADING	33	SIDE LOAD(STBD)	CONF.6	50-50
LOADING	34	SIDE LOAD(STBD)	CONF.6	53.10-46.90
LOADING	35	SIDE LOAD(STBD)	CONF.6	FLAT TIRE - STRBD
LOADING	36	SIDE LOAD(STBD)	CONF.6	FLAT TIRE - PORT
LOADING	37	DRIFT LAND(PORT)	CONF.3	50-50
LOADING	38	DRIFT LAND(PORT)	CONF.3	51.89-48.11
LOADING	39	DRIFT LAND(PORT)	CONF.6	50-50
LOADING	40	DRIFT LAND(PORT)	CONF.6	35.32-64.68
LOADING	41	DRIFT LAND(STBD)	CONF.3	50-50
LOADING	42	DRIFT LAND(STBD)	CONF.3	64.68-35.32
LOADING	43	DRIFT LAND(STBD)	CONF.6	50-50
LOADING	44	DRIFT LAND(STBD)	CONF.6	48.11-51.89
LOADING	45	2G T0 RUN 2P		50-50
LOADING	46	2G T0 RUN 2P		56.43-43.57
LOADING	47	2G T0 RUN 2P		43.57-56.43
LOADING	48	2G T0 RUN 2P		FLAT TIRE - STRBD
LOADING	49	2G T0 RUN 2P		FLAT TIRE - PORT
LOADING	50	JAR T0 RUN (L) +	CONF.3	50-50
LOADING	51	JAR T0 RUN (L) +	CONF.3	52.19-47.81
LOADING	52	JAR T0 RUN (L) +	CONF.3	FLAT TIRE - STRBD
LOADING	53	JAR T0 RUN (L) +	CONF.3	FLAT TIRE - PORT
LOADING	54	JAR T0 RUN (L) +	CONF.6	50-50
LOADING	55	JAR T0 RUN (L) +	CONF.6	37.83-62.17
LOADING	56	JAR T0 RUN (L) +	CONF.6	FLAT TIRE - STRBD
LOADING	57	JAR T0 RUN (L) +	CONF.6	FLAT TIRE - PORT
LOADING	58	JAR T0 RUN (L) -	CONF.3	50-50
LOADING	59	JAR T0 RUN (L) -	CONF.3	62.17-37.83
LOADING	60	JAR T0 RUN (L) -	CONF.3	FLAT TIRE - STRBD
LOADING	61	JAR T0 RUN (L) -	CONF.3	FLAT TIRE - PORT
LOADING	62	JAR T0 RUN (L) -	CONF.6	50-50
LOADING	63	JAR T0 RUN (L) -	CONF.6	47.81-52.19
LOADING	64	JAR T0 RUN (L) -	CONF.6	FLAT TIRE - STRBD
LOADING	65	JAR T0 RUN (L) -	CONF.6	FLAT TIRE - PORT
LOADING	65	JAR T0 RUN (L) -	CONF.6	FLAT TIRE - PORT
LOADING	66	JAR T0 RUN(TD12) +	CONF.3	50-50
LOADING	67	JAR T0 RUN(TD12) +	CONF.3	52.17-47.83
LOADING	68	JAR T0 RUN(TD12) +	CONF.3	FLAT TIRE - STRBD
LOADING	69	JAR T0 RUN(TD12) +	CONF.3	FLAT TIRE - PORT
LOADING	70	JAR T0 RUN(TD12) +	CONF.6	50-50
LOADING	71	JAR T0 RUN(TD12) +	CONF.6	37.96-62.04
LOADING	72	JAR T0 RUN(TD12) +	CONF.6	FLAT TIRE - STRBD
LOADING	73	JAR T0 RUN(TD12) +	CONF.6	FLAT TIRE - PORT
LOADING	74	JAR TO RUN(TD12) -	CONF.3	50-50
LOADING	75	JAR TO RUN(TD12) -	CONF.3	62.04-37.96
LOADING	76	JAR TO RUN(TD12) -	CONF.3	FLAT TIRE - STRBD
LOADING	77	JAR TO RUN(TD12) -	CONF.3	FLAT TIRE - PORT
LOADING	78	JAR TO RUN(TD12) -	CONF.6	50-50
LOADING	79	JAR TO RUN(TD12) -	CONF.6	47.83-52.17
LOADING	80	JAR TO RUN(TD12) -	CONF.6	FLAT TIRE - STRBD
LOADING	81	JAR TO RUN(TD12) -	CONF.6	FLAT TIRE - PORT
LOADING	82	2P BRK.ROLL		50-50
LOADING	83	2P BRK.ROLL		58.92-41.08
LOADING	84	2P BRK.ROLL		41.08-58.92
LOADING	85	2P BRK.ROLL		FLAT TIRE - STRBD
LOADING	86	2P BRK.ROLL		FLAT TIRE - PORT
LOADING	87	REV.BRK W/THR.		50-50
LOADING	88	REV.BRK W/THR.		59.64-40.36
LOADING	89	REV.BRK W/THR.		40.36-59.64
LOADING	90	REV.BRK W/THR.		FLAT TIRE - STRBD
LOADING	91	REV.BRK W/THR.		FLAT TIRE - PORT
LOADING	92	N.W. YAW B	CONF.3	50-50
LOADING	93	N.W. YAW B	CONF.3	62.45-37.55
LOADING	94	N.W. YAW B	CONF.3	FLAT TIRE - STRBD
LOADING	95	N.W. YAW B	CONF.3	FLAT TIRE – PORT
LOADING	96	N.W. YAW B	CONF.6	50-50
LOADING	97	N.W. YAW B	CONF.6	41.09-58.91
LOADING	98	N.W. YAW B	CONF.6	FLAT TIRE - STRBD
LOADING	99	N.W. YAW B	CONF.6	FLAT TIRE - PORT
LOADING	100	TURNING RIGHT	CONF.3	50-50
LOADING	101	TURNING RIGHT	CONF.3	44.90-55.10
LOADING	102	TURNING RIGHT	CONF.3	FLAT TIRE - STRBD
LOADING	103	TURNING RIGHT	CONF.3	FLAT TIRE - PORT
LOADING	104	TURNING RIGHT	CONF.6	50-50
LOADING	105	TURNING RIGHT	CONF.6	31.21-68.79
LOADING	106	TURNING RIGHT	CONF.6	FLAT TIRE - STRBD
LOADING	107	TURNING RIGHT	CONF.6	FLAT TIRE - PORT
LOADING	108	PIVOTING 1		50-50
LOADING	109	PIVOTING 1		60.05-39.95
LOADING	110	PIVOTING 1		39.95-60.05
LOADING	111	PIVOTING 2		50-50
LOADING	112	PIVOTING 2		60.05-39.95
LOADING	113	PIVOTING 2		39.95-60.05
LOADING	114	DEBOG FWD, RX @ AXLE		50-50
LOADING	115	DEBOG FWD STBD, RX @ AXLE		50-50
LOADING	116	DEBOG FWD PORT, RX @ AXLE		50-50
LOADING	117	DEBOG FWD, RX @ A/C		50-50
LOADING	118	DEBOG FWD STBD, RX @ A/C		50-50
LOADING	119	DEBOG FWD PORT, RX @ A/C		50-50
LOADING	120	DEBOG AFT, RX @ AXLE		50-50
LOADING	121	DEBOG AFT STBD, RX @ AXLE		50-50
LOADING	122	DEBOG AFT PORT, RX @ AXLE		50-50
LOADING	123	DEBOG AFT, RX @ A/C		50-50
LOADING	124	DEBOG AFT STBD, RX @ A/C		50-50
LOADING	125	DEBOG AFT PORT, RX @ A/C		50-50

Landing Gear Stress Analysis

-With the Ground Loads determined (I.e. Vertical, Drag, and Side), the stress engineer can then analyze the impact of these loads on the geometry provided by the design engineer.

As discussed earlier, the stress analysis can be broke up into two groups; Strength Analysis, and Fatigue Analysis.

The **Strength Analysis** on Landing Gears can be broken down into two different approaches:

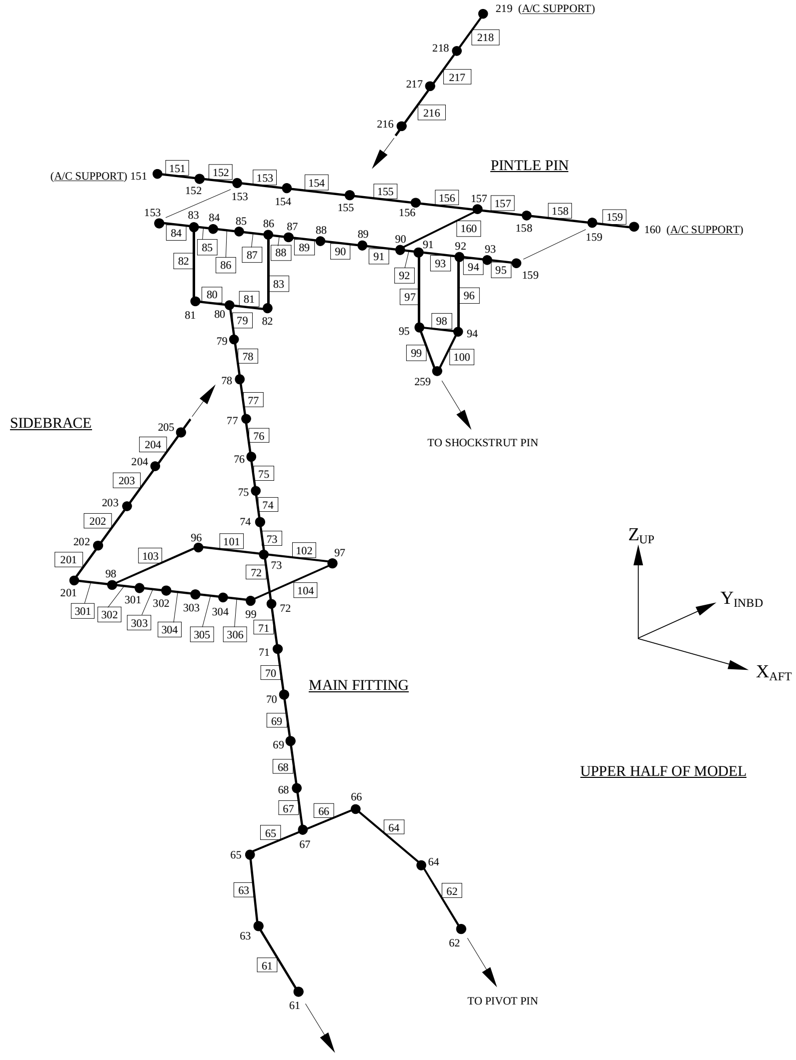
1) Classical Method
   -Consists of the analysis critical sections throughout all the major
2) Finite Element Analysis Method

The **Fatigue Analysis** uses classical approaches, but the Finite Elements results can sometime be used as inputs for the fatigue analysis.

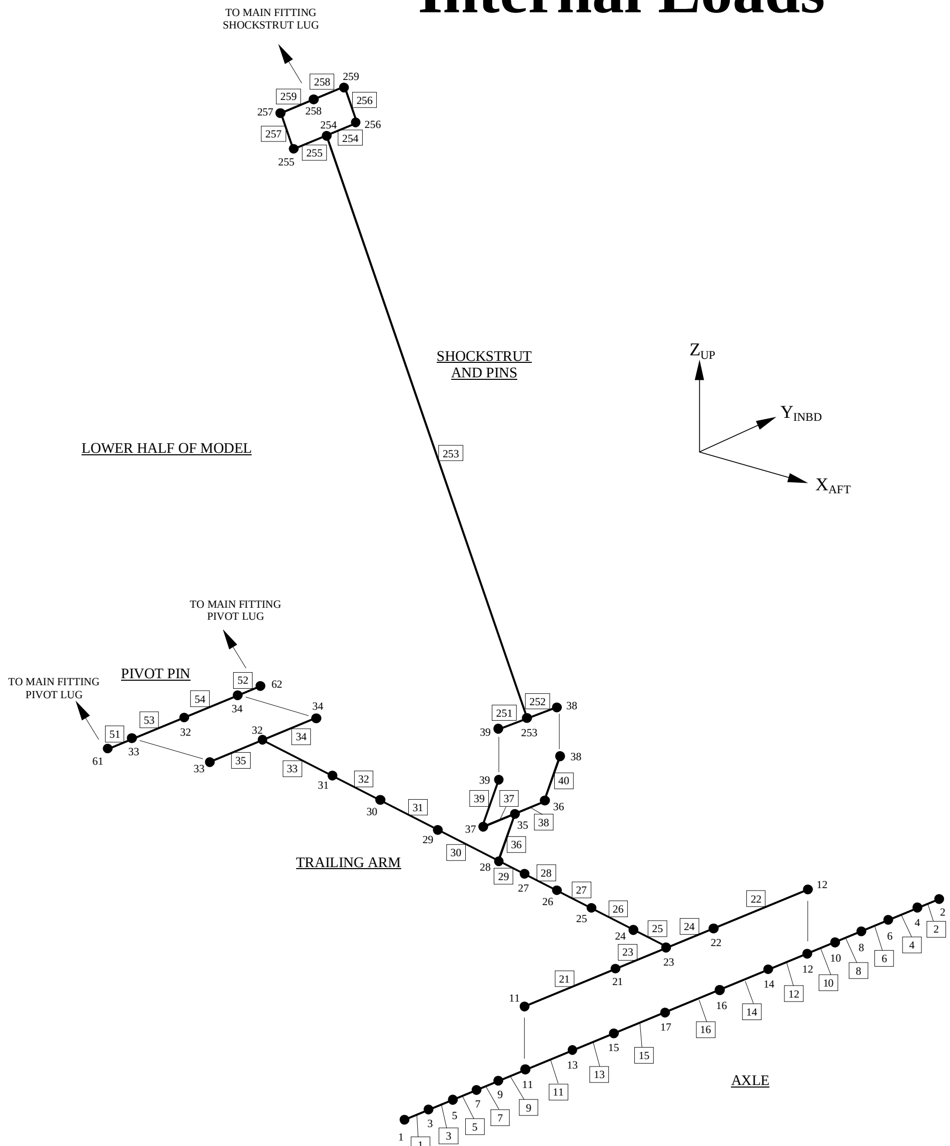
Before any analysis can be done, the first step is to determine the internal loads.

Internal Loads

-The internal loads are determined by using a Finite Element Beam Model.



Internal Loads



Internal Loads

-The Beam model accounts for deflections.

-You can select your nodes to be at sections of interest that you want to analyze.

-The output gives you Fx, Fy, Fz, Mx, My, Mz at every node.

-The internal loads also give you an indication of the most efficient cross section to use on a member. (I.e. if a member see bending primarily about 1 axis, you may select an I-beam section)

The internal loads can be used in the strength analysis in both the Finite Element approach and the classical method of sections approach.

-When analyzing a component using Finite Element software, you may need the internal loads to know the applied loads on that component.

-When analyzing a section in the classical approach, the forces and moments at the node on the section of interest are used to directly analyze the section.

Analysis of a Section

Limit

```
MATERIAL :  7075-T7351 ALUM PLATE 2.5-3.0 AMS-QQ-A-250/12

     FCU =  60000.   psi             FCY =  47000.   psi
    FBUX =  86500.   psi            FBYX =  58500.   psi
    FBUY =  86500.   psi            FBYY =  58500.   psi
     FSU =  39000.   psi             FSY =  30550.   psi
     FTP =  46000.   psi               E = 10.3 E06  psi
```

Material Allowables

Stress Concentration

```
APPLIED LOADS - LIMIT ANALYSIS (KT = 1.000) KT of 2.6 on Mz only

     MBX =  -13615.   lb-in          MBY =        0.   lb-in
     PSX =       0.   lb             PSY =        0.   lb
     PCU =    6989.   lb
```

Applied Loads

```
PROPERTIES OF RECTANGULAR SECTION:

     B =   1.4250          H =   1.4400
  AREA =   2.0520        D/T =   0.0000

  XBAR =   0.7125       YBAR =   0.7200
   QXX =   0.3694        QYY =   0.3655
   IXX =   0.3546        IYY =   0.3472
   ZXX =   0.4925        ZYY =   0.4874
 THETX =   1.3333      THETY =   1.3333
 KTORS =   0.5922       KTOR =   1.6351
  TORZ =   0.6116
   TX  =   1.4400         TY  =   1.4250
```

Sectional Properties

```
STRESSES - LIMIT ANALYSIS (KT = 1.000)

 FC  = PCU/AREA =   3406. psi                    RCX = 0.072

 FBX = MBX/ZXX  =  27646. psi                    RBX = 0.473
 FBY = MBY/ZYY  =      0. psi                    RBY = 0.000

 FSX = RY . PSX . QYY/(TX . IYY) =       0. psi  RSX = 0.000
 FSY = RX . PSY . QXX/(TY . IXX) =       0. psi  RSY = 0.000

         USING THE VON MISES YIELD CRITERION

                                                 M.S. = 0.835
```

Axial Stress

Bending Stress

Shear Stress

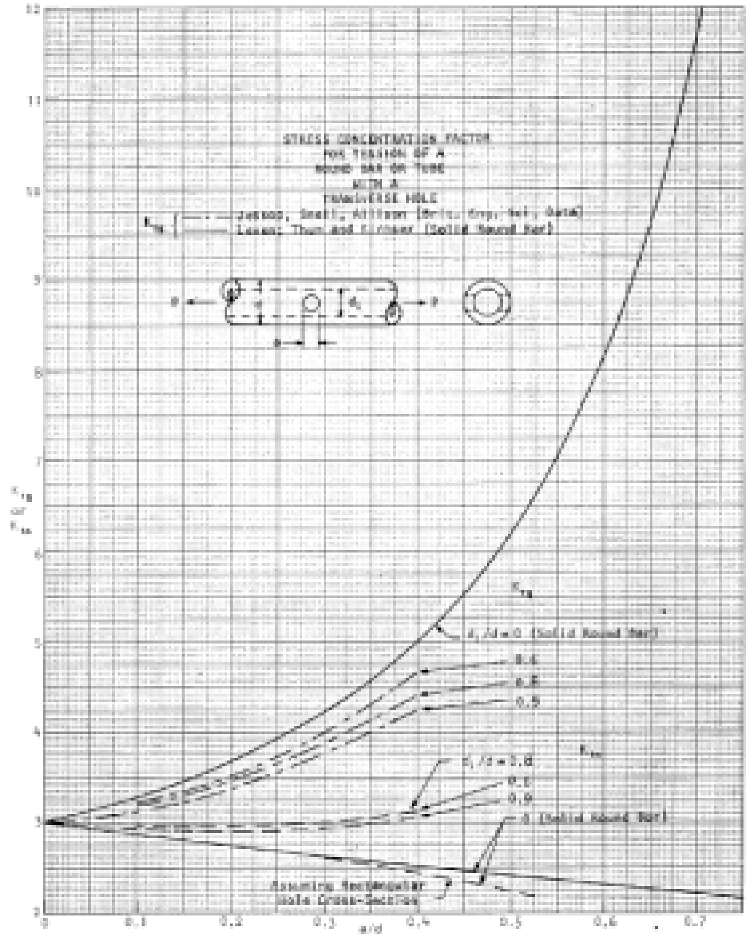
M.S.

Ultimate

```
MATERIAL :  7075-T7351 ALUM PLATE 2.5-3.0 AMS-QQ-A-250/12

     FCU =  60000.   psi             FCY =  47000.   psi
    FBUX =  86500.   psi            FBYX =  58500.   psi
    FBUY =  86500.   psi            FBYY =  58500.   psi
     FSU =  39000.   psi             FSY =  30550.   psi
     FTP =  46000.   psi               E = 10.3 E06  psi

APPLIED LOADS - ULTIMATE ANALYSIS

     MBX =   -7855.   lb-in          MBY =        0.   lb-in
     PSX =       0.   lb             PSY =        0.   lb
     PCU =   10483.   lb

PROPERTIES OF RECTANGULAR SECTION:

     B =   1.2020 *        H =   1.4400
  AREA =   1.7309        D/T =   0.0000

  XBAR =   0.6010       YBAR =   0.7200
   QXX =   0.3116        QYY =   0.2601
   IXX =   0.2991        IYY =   0.2084
   ZXX =   0.4154        ZYY =   0.3468
 THETX =   1.3333      THETY =   1.3333
 KTORS =   0.4130       KTOR =   2.1641
  TORZ =   0.4621
   TX  =   1.4400         TY  =   1.2020

STRESSES - ULTIMATE ANALYSIS

 FC  = PCU/AREA =   6056. psi                        RCX = 0.101

 FBX = MBX/ZXX  =  18909. psi                        RBX = 0.219
 FBY = MBY/ZYY  =      0. psi                        RBY = 0.000

 FSX = RY . PSX . QYY/(TX . IYY) =       0. psi      RSX = 0.000
 FSY = RX . PSY . QXX/(TY . IXX) =       0. psi      RSY = 0.000

 USING INTERACTION CURVES FOR ABOVE APPLIED LOADS COMBINED

                                                     M.S. = 2.129
```

Analysis of a Section – Stress Concentration

A stress concentration factor is applied to the limit stress in stress concentration such as a radius, hole, Edge, etc…



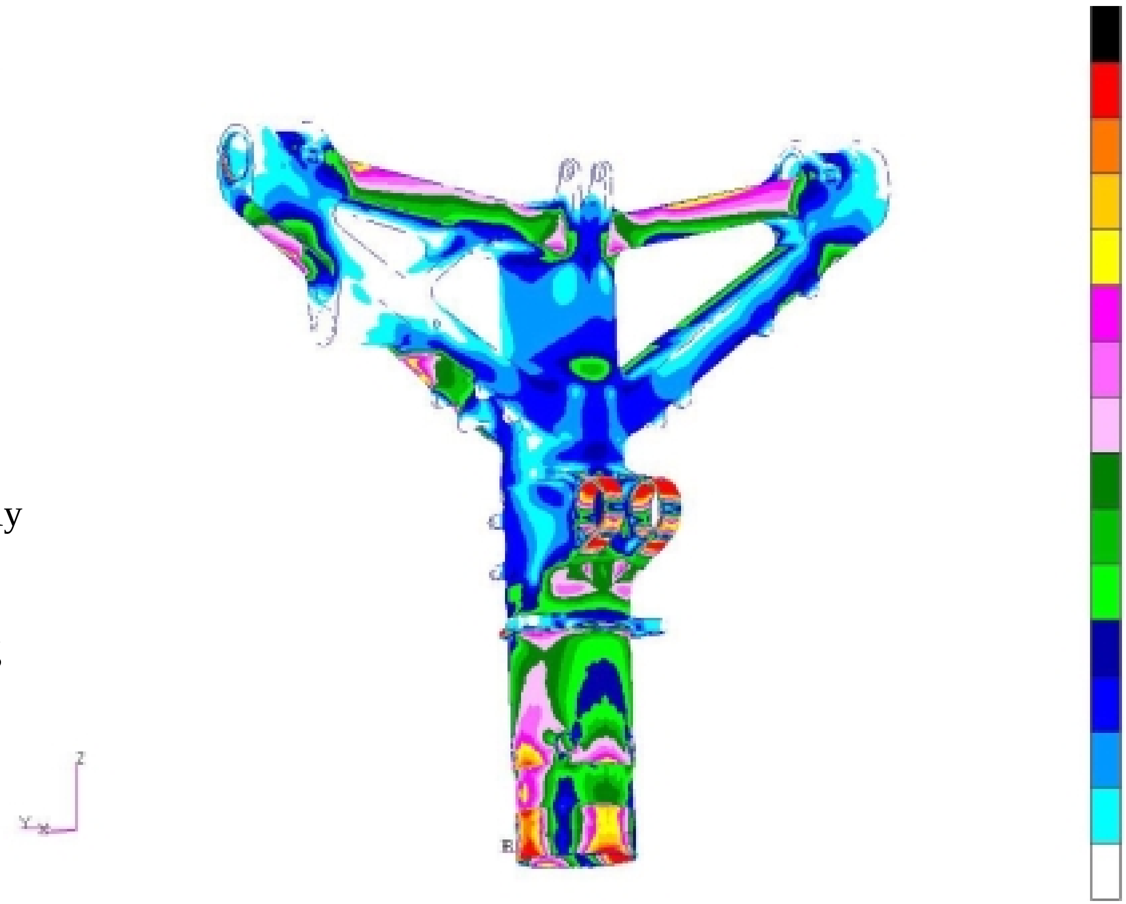
Finite Element Stress Analysis

-Our FEA is done in MSC Patran with Abaqus as the solve.

-Patran allows us to import Catia geometry and modify and mesh, or to create geometries from scratch.

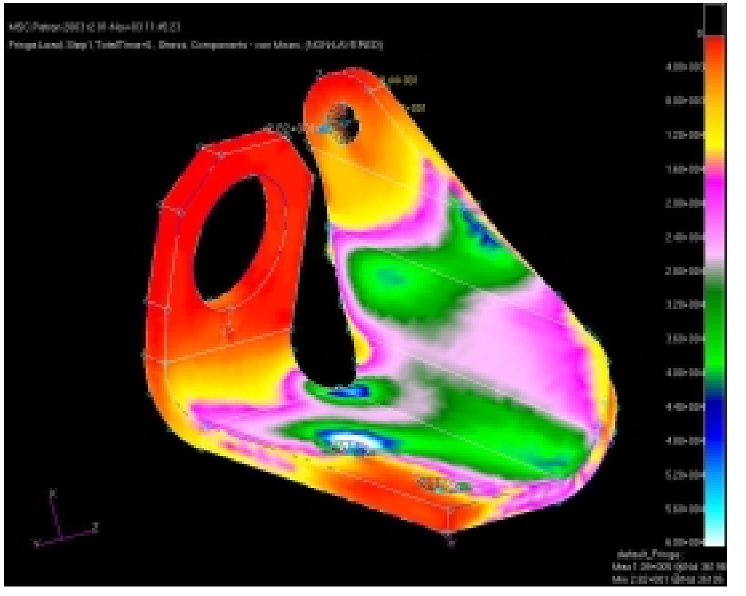
-Although modifying the geometry, and meshing can be very time consuming, the most difficult part of FEA is properly defining the boundary conditions.

-Pin Loads are typically simulated using pressures in a sinusoidal distribution.



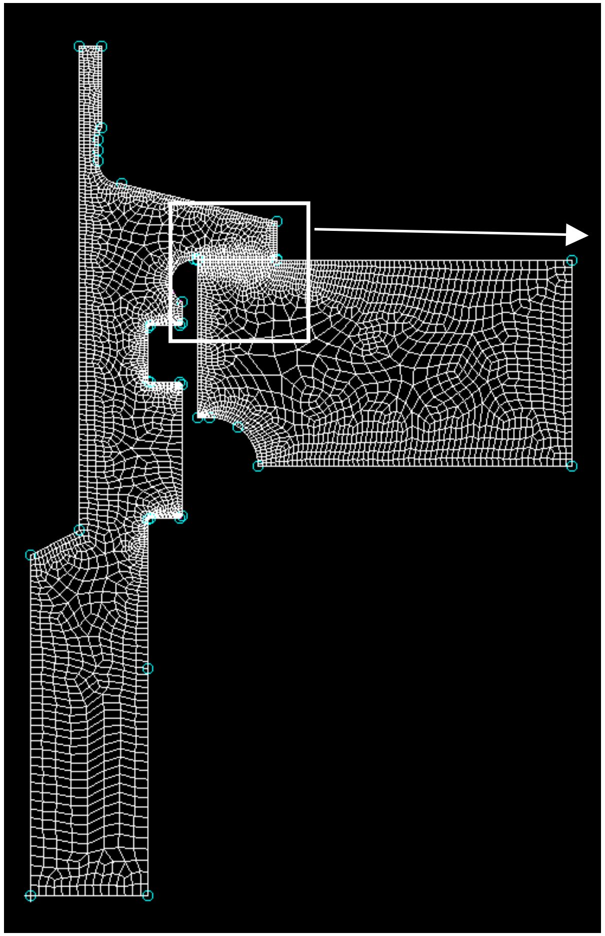
Finite Element Stress Analysis

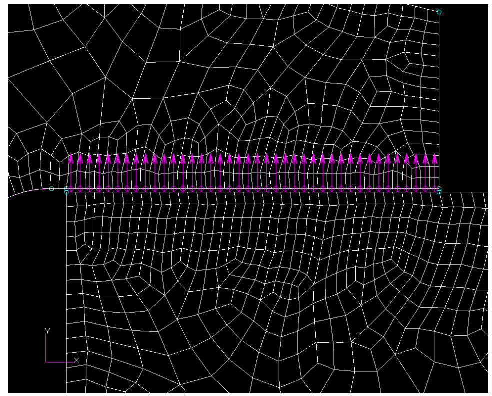
-Another good use of FEA is on the smaller components with the more complicated geometries that are difficult to idealize.

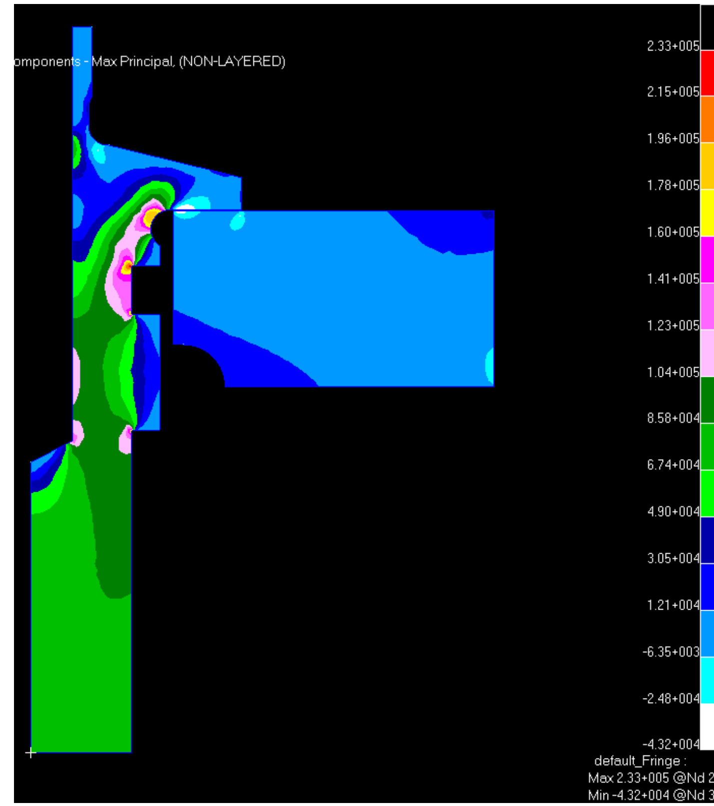


Finite Element Analysis – Contact

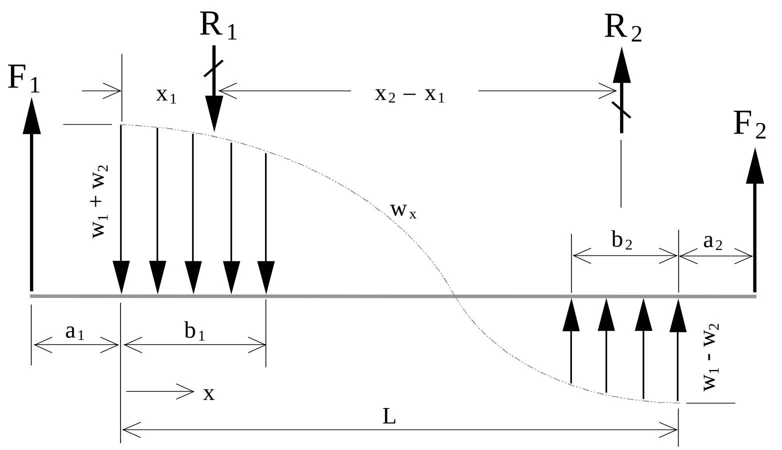
-The best way to simulate the interaction between two components is using contact analysis.

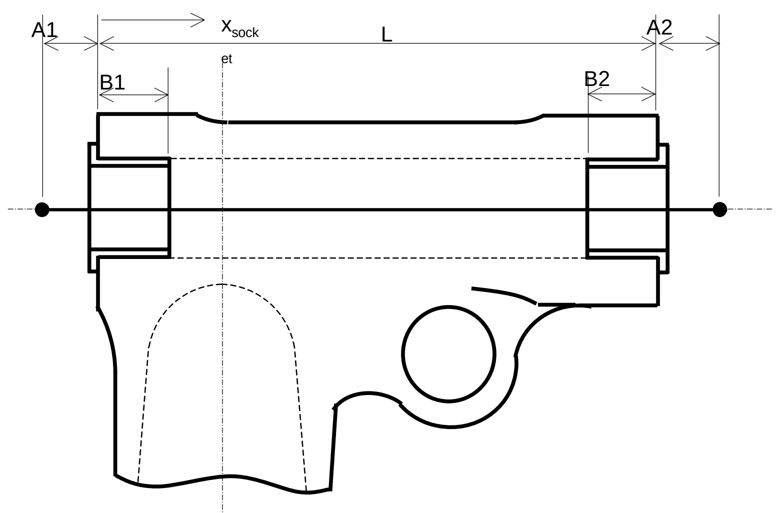






Socket Analysis





PIN AND SOCKET ANALYSIS
=======================

L = 10.000 in
A1 = 2.500 in
A2 = 1.750 in
B1 = 1.250 in
B2 = 1.000 in

F1= 1000. lb
F2= 0. lb
M = 0. lb-in

SOCKET REACTIONS :

W1 = 731. lb/in
W2 = 368. lb/in

R1 = 1351. lb
R2 = 351. lb

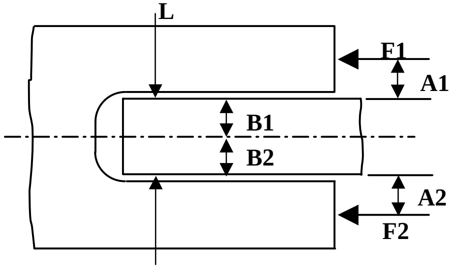
X1 = 0.620 in
X2 = 9.509 in

X (in)	SHEAR (lb)	B.M (lb-in)
0.000	1000.	2500.
1.250	-351.	2898.
9.000	-351.	178.
10.000	0.	0.

PEAK MOMENT = 2957. lb-in AT X = 0.918 in

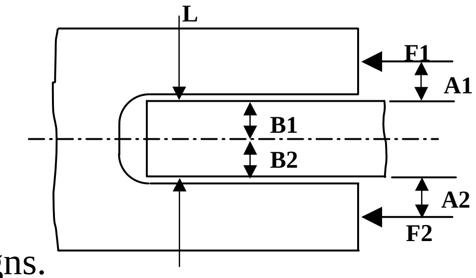
Design Notes:

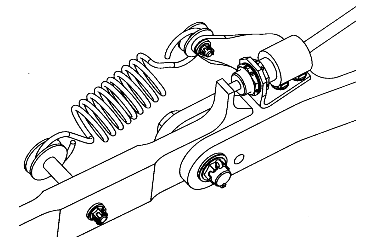
- -Large A1 or A2 increases pin bending.
- -Smaller B1 or B2 increases the distributed load through socket.
- -A shorter overall socket length reduces pin bending, but increases the socket reactions.



Clevis Analysis

-Understanding how to size a clevis is simple yet very important as aircraft have thousands of clevises throughout. Any place there is an actuator you can expect a clevis at each end. Any pin is likely connected through a clevis.





1. Determine the maximum load through the clevis.

2. Estimate the pin outer diameter based on previous designs.

3. Use the bearing allowable of the lugs to determine the thickness of the lugs.

4. With the geometry of the socket determined, perform a socket analysis.

5. Using a D/T = 7, check the margin of safety on the pin.

6. A. If the Margin of Safety on the pin is large, lower the pin OD and re-size the lugs.
   B. If the Margin of Safety on the pin is negative, increase the pin OD and re-size the lugs.

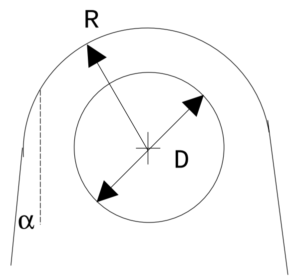
7. Leave yourself a little margin of safety because when the design selects the bushes, the flange thickness can effect your A1 and A2 in you socket analysis.

$Fbrg = P/A = P / (D*T)$

Fbrg is your allowable bearing stress
For the material. (See MIL Handbook)

Lug Analysis

-Lug Analysis is used to ensure the pin does not shear through the lug is either transverse or axial loading.




```
TRANSVERSELY AND AXIALLY LOADED LUG
===================================

  PAX  (ULT) =       0.    lb       R    =   0.4050   in
  PTR  (ULT) =    1623.    lb       D    =   0.3270   in
  PAXY (YLD) =       0.    lb       T    =   0.3700   in
  PTRY (YLD) =    1082.    lb            =   0.0000   Deg

  A1   =  0.1071    in2             A3   =   0.0894   in2
  A2   =  0.0894    in2             A4   =   0.1071   in2

  AAV  =  6/(3/A1 + 1/A2 + 1/A3 + 1/A4) =   0.1004   in2
  ABR  =  (D)(T)                         =   0.1210   in2

  FTU  =   60000.   psi             KBRU =   1.0002
  FTUX =   55000.   psi             KTRU =   0.5204
  FTYX =   45000.   psi             KTRY =   0.9302

  YIELD FACTOR, C =1.1000

  PBRU = ( KBRU )( ABR )( FTU )          =   7261.0   lb
  PTRU = ( KTRU )( ABR )( FTUX )         =   3463.2   lb
  PYAX = ( C )( FTYX )( PBRU )/( FTUX ) =   6534.9   lb
  PYTR = ( KTRY )( ABR )( FTYX )         =   5064.5   lb

  RAXU = ( PAX )/( PBRU )    = 0.000
  RTRU = ( PTR )/( PTRU )    = 0.469
  RAXY = ( PAXY )/( PYAX )   = 0.000
  RTRY = ( PTRY )/( PYTR )   = 0.214

                     1.0
  M.S. = ---------------------------  -  1.0  =   3.070
 (YLD)           1.6       1.6 0.625
        1.15(RAXY    + RTRY    )

                     1.0
  M.S. = ---------------------------  -  1.0  =   0.855
 (ULT)           1.6       1.6 0.625
        1.15(RAXU    + RTRU    )
```

Shear Out Bearing Strength → PBRU

Transverse Ultimate Strength → PTRU

Shear Out Yield → PYAX

Transverse Yield Strength → PYTR

-You can find these exact formulas and tables in Bruhn starting on **p. D1.5**

Torque Requirements

TORQUE REQUIREMENTS

THREAD PARAMETERS -

THREAD ENGAGED LENGTH	L	=	0.141 in
MALE THD. MIN. PITCH DIA.	PD	=	0.463 in
INSERT MIN. PITCH DIA.	IPD	=	0.468 in
MALE THD. MIN. MINOR DIA.	MMD	=	0.432 in
MALE THD. INSIDE DIAMETER	ID	=	0.000 in
NO. OF THREADS PER INCH	TPI	=	20. tpi
MIN. THD. CO-EF. OF FRIC.	MUW	=	0.080
MIN. HEAD CO-EF. OF FRIC.	MUWP	=	0.080
MAX. THD. CO-EF. OF FRIC.	MUB	=	0.200
MAX. HEAD CO-EF. OF FRIC.	MUBP	=	0.200
ONE HALF THE THREAD ANGLE	BETA	=	30.00 Deg
MALE THD. MEAN HEAD RADIUS	MHR	=	0.630 in
MALE THD. ULT. SHEAR STRGTH.	FSU	=	132.0 ksi
MALE THD. ULT. TENSILE STRGTH.	FTU	=	115.0 ksi
FEMALE THD. ULT. SHEAR STRGTH.	FSU	=	79.2 ksi
LOAD ON MALE THD.	LOAD	=	207. lb

Axial load due to pre-torque = $T / (\text{Pitch} / 2\pi + \mu \times PD / (2 \times \cos\alpha) + \mu \times MHR)$

m μ = minimum coefficient of friction = 0.08

α = half thread angle = 30°

ALLOWABLE LOADS -

MALE THREAD-(SHEAR)	P1	=	6772. lb
MALE THREAD CORE-(TENSION)	P2	=	16840. lb
FEMALE THREAD-(SHEAR)	P3	=	4100. lb
CRITICAL ALLOWABLE LOAD	P	=	4100. lb
MAXIMUM SAFE TORQUE	TMAX	=	262. lb-in
MINIMUM REQUIRED TORQUE	TMIN	=	38.8 lb-in

RECOMMENDED TORQUE VALUE IS lb-in

Other Strength Analyses

-Column Buckling – Drag Brace, Metering Pin, Door Links, etc.. Must consider end moments, eccentricities, initial displacements. (Ref. Craig)

-Crippling Analysis – Stack Tube, Support Tube.

-Hertz Contact Stress (Ref. Roark's Formulas for Stress & Strain)

-Thread Shear Analysis

-Thread Undercut Analysis

-Cylinder Head Junction (hoops stresses, plate bending at head hole)

-Pressure Vessels

Fatigue Analysis

Most components that fail will fail in fatigue. For this reason it is very important that the fatigue loads be well understood.

-The **Fatigue Spectrum** consists of the loads that the landing gear will see through the course of its life, and the frequency and order in which they will occur. The fatigue spectrum is done in flight block. Flight blocks mean that the landing gear fatigue loads occur in the order they would during typical flights.

Taxi Load, Take off load, Landing Load, Braking Load, Taxi Load, Turning Load, Jacking Load

-The Fatigue Spectrum may include 15000 taxi load application, but only 1 application of the critical landing load applied in the strength analysis.

-You can see that having a good idea of how the pilots fly the planes on a daily basis will have a large impact on how your component does in fatigue. We are continually trying the improve the validity of our fatigue spectrums.

Fatigue Damage

-Fatigue Damage is the fraction of the require life that a part has achieved.

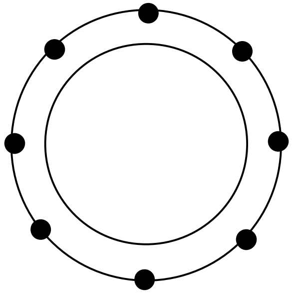
-For Landing Gear Structural components, the components are said to have a safe life of 15000 cycles with a scatter factor of 5.

-A scatter factor of 5 mean that we must design and test the part to handle 15000*5 = 75000 cycles.

-A fatigue damage of 0.5 means the part has seen half its life where 1 is a full life.

-Your Fatigue Spectrum consists of hundreds of load applied in varying magnitudes, directions, and frequencies, as determined by the fatigue spectrum.

-When you analyze a specific section, each load applied from the spectrum contributes damage to part of the section depending on the direction and magnitude that the load is applied across the section.



-After applying the entire fatigue spectrum loads to the section, the damage on the entire section must be less than 1.

-Since testing a landing gear using the design spectrum would take years (10000's of load applications), fatigue testing is carried out on an equal damage basis. This is to say that higher loads are applied to the test article for fewer cycles to replicate the design damage.