Practica 3.
Análisis estructural. (ANSYS)
Ingeniería en Mecatrónica.

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¿Qué es un análisis estructural?

Análisis estructural se refiere al uso de las ecuaciones de la resistencia de materiales para encontrar los esfuerzos internos, deformaciones y tensiones que actúan sobre una estructura resistente, como edificaciones o esqueletos resistentes de maquinaria. Igualmente el análisis dinámico estudiaría el comportamiento dinámico de dichas estructuras y la aparición de posibles vibraciones perniciosas para la estructura.

Determinación de esfuerzos.

El tipo de método empleado difiere según la complejidad y estructuras muy sencillas entre los que se encuentran la teoría de vigas de Euler-Bernoulli es el método más simple, es aplicable sólo a barras esbeltas sometidas a flexión y esfuerzos axiales. Naturalmente no todas las estructuras se dejan analizar por este método. Cuando existen elementos estructurales bidimensionales en general deben emplearse métodos basados en resolver ecuaciones diferenciales.

- Métodos programables:
    - Así para determinar esfuerzos sobre **marcos** o **pórticos** se usa frecuentemente el método matricial de la rigidez basado en el modelo de barras largas, que modeliza los elementos resistentes como elementos unidimensionales sometidos predominantemente a flexión
    - Cuando se trata de analizar elementos más pequeños o con forma irregular donde pueden producirse concentraciones de tensiones se usan métodos numéricos más complejos como el Método de los elementos finitos.

Determinación de resistencia y rigidez.

A partir de los esfuerzos se pueden calcular directamente los desplazamientos y las tensiones. En el caso del método de los elementos finitos se suele determinar directamente el desplazamiento sin necesidad de calcular los esfuerzos internos. Una estructura correctamente diseñada además de ser funcional y económica debe cumplir obligatoriamente dos criterios razonables de seguridad:

1. El criterio de resistencia, consistente en comprobar en que en ninguno de sus puntos el material sobrepasa unas tensiones admisibles máximas.
2. El criterio de rigidez, consistente en comprobar que bajo las fuerzas y solicitaciones actuantes los desplazamientos y deformaciones de la estructura no sobrepasan un cierto límite. Dicho límite está relacionado con criterios de funcionalidad, pero también de estabilidad o de aplicabilidad de la teoría de la elasticidad lineal.

Modelos materiales.

Dentro del análisis estructural es importante modelizar el comportamiento de los materiales empleados mediante una ecuación constitutiva adecuada. Los tipos modelos de materiales más frecuentes son:

- Modelo elástico lineal e isótropo, el más usado, ya que el teorema de Rivlin-Ericksen permite establecer que para deformaciones suficientemente pequeñas todo sólido elástico es asintóticamente lineal e isótropo.
- Modelo elástico lineal ortotrópico, constituye una modificación de modelo isótropo para materiales cuya resistencia y comportamiento depende de la dirección, laminados, elementos de madera, etc., requieren modelos ortótropos para ser adecuadamente modelizados.
- Modelos de plasticidad y viscoplasticidad. Los metales a partir de ciertos valores de tensión experimentan deformaciones plásticas irreversibles, así como otras no linealidades. El cálculo plástico a costa de complicar las leyes materiales da una predicción más exacta de las cargas de colapso o fallo de las estructuras, así como un ahorro en material al poder tener en cuenta el rango de trabajo de los materiales en el que estos están experimentando transformaciones irreversibles, pero sin alcanzar las cargas de fallo o colapso.
- Modelos de daño.

Objetivo.

Obtener el análisis estático estructural por medio de ANSYS, el cual nos va a determinar cuál será la fuerza de torque necesaria en cada eje de nuestro brazo robótico cilíndrico. Posteriormente se realizarán los cambios necesarios en la estructura física para así poder instalar los componentes electrónicos (actuadores).

Materiales.

- SolidWorks.
- Ansys.
- Diseño estructural. (CAD)

Procedimiento.

- CAD terminado de la estructura del brazo robótico cilíndrico.
- Exportar CAD como archivo IGS.
- Importar CAD en ANSYS para obtener los parámetros deseados.
- Obtener análisis estático estructural.

Resultados Obtenidos.

Project

First Saved	Friday, May 31, 2019
Last Saved	Friday, May 31, 2019
Product Version	18.1 Release
Save Project Before Solution	No
Save Project After Solution	No

Contents

Report Not Finalized

Not all objects described below are in a finalized state. As a result, data may be incomplete, obsolete or in error. View first state problem. To finalize this report, edit objects as needed and solve the analyses.

Units

TABLE 1

Unit System	Metric (m, kg, N, s, V, A) Degrees rad/s Celsius
Angle	Degrees
Rotational Velocity	rad/s
Temperature	Celsius

Model (B4)

Geometry

TABLE 2
Model (B4) > Geometry

Object Name	*Geometry*
State	Fully Defined
Definition	
Source	C:\Users\Alexis Viorato\Documents\ensamblaje 1 robot cilindrico.IGS
Type	Iges

Length Unit	Meters
Element Control	Program Controlled
Display Style	Body Color
Bounding Box	
Length X	0.53317 m
Length Y	0.51434 m
Length Z	0.37002 m
Properties	
Volume	1.8869e-003 m³
Mass	14.813 kg
Scale Factor Value	1.
Statistics	
Bodies	18
Active Bodies	18
Nodes	20155
Elements	5049
Mesh Metric	None
Basic Geometry Options	
Solid Bodies	Yes
Surface Bodies	Yes
Line Bodies	No
Parameters	Independent
Parameter Key	ANS;DS
Attributes	No
Named Selections	No
Material Properties	No
Advanced Geometry Options	
Use Associativity	Yes
Coordinate Systems	No
Reader Mode Saves Updated File	No
Use Instances	Yes
Smart CAD Update	Yes
Compare Parts On Update	No
Attach File Via Temp File	Yes
Temporary Directory	C:\Users\Alexis Viorato\AppData\Local\Temp
Analysis Type	3-D
Mixed Import Resolution	None
Decompose Disjoint Geometry	Yes
Enclosure and Symmetry Processing	Yes

TABLE 3
Model (B4) > Geometry > Parts

Object Name	*Part 1*	*Part 2*	*Part 3*	*Part 4*	*Part 5*	*Part 6*	*Part 7*	*Part 8*	*Part 9*	*Part 10*	*Part 11*
State	Meshed										
Graphics Properties											
Visible	Yes										
Transparency	1										
Definition											
Suppressed	No										
Stiffness Behavior	Flexible										
Coordinate System	Default Coordinate System										
Reference Temperature	By Environment										
Behavior	None										
Material											
Assignment	Structural Steel										
Nonlinear Effects	Yes										
Thermal Strain Effects	Yes										
Bounding Box											
Length X	1.e-002 m		7.62e-002 m	1.e-002 m	0.4254 m	8.5123e-002 m	0.30785 m				0.17724 m
Length Y	1.e-002 m		7.2938e-002 m	1.e-002 m	0.51434 m	0.11625 m	0.27609 m				0.17971 m
Length Z	1.e-002 m		1.27e-002 m	0.35 m	1.e-002 m		1.3611e-002 m				7.0023e-002 m
Properties											
Volume	7.8532e-007 m³		3.5295e-005 m³	2.7486e-005 m³	1.1226e-003 m³	3.9927e-005 m³	3.1413e-005 m³				1.8939e-004 m³
Mass	6.1648e-003 kg		0.27706 kg	0.21577 kg	8.8128 kg	0.31343 kg	0.24659 kg				1.4867 kg

Centroid X	0.15108 m	0.13986 m	0.16904 m		0.16907 m	0.14996 m	0.33299 m	0.29974 m	0.31637 m	0.29974 m	0.2045 m
Centroid Y	-9.2869e-002 m	-0.11521 m	-5.7126e-002 m		-5.7061e-002 m	-9.5097e-002 m	-3.9339e-002 m	-1.9887e-003 m	-2.0664e-002 m	-1.9887e-003 m	-9.6817e-002 m
Centroid Z	-0.11019 m		-9.1542e-002 m	4.9808e-002 m	-0.12019 m	-0.11019 m	0.23481 m		0.20981 m	0.18481 m	0.20951 m
Moment of Inertia Ip1	8.9133e-008 kg·m²		1.5191e-004 kg·m²	2.183e-003 kg·m²	4.6069e-002 kg·m²	4.5073e-005 kg·m²	3.2581e-003 kg·m²				2.4494e-003 kg·m²
Moment of Inertia Ip2	8.9153e-008 kg·m²		7.9649e-005 kg·m²	2.183e-003 kg·m²	0.14906 kg·m²	3.0019e-004 kg·m²	3.2581e-003 kg·m²				1.7041e-003 kg·m²
Moment of Inertia Ip3	7.6146e-008 kg·m²		7.966e-005 kg·m²	2.6458e-006 kg·m²	0.19499 kg·m²	3.4004e-004 kg·m²	3.0237e-006 kg·m²				3.2561e-003 kg·m²
Statistics											
Nodes	860		1383	854	1638	492	854				4349
Elements	155		164	154	212	54	154				2022
Mesh Metric	None										

TABLE 4
Model (B4) > Geometry > Parts

Object Name	*Part 12*	*Part 13*	*Part 14*	*Part 15*	*Part 16*	*Part 17*	*Part 18*
State	Meshed						
Graphics Properties							
Visible	Yes						
Transparency	1						
Definition							
Suppressed	No						
Stiffness Behavior	Flexible						
Coordinate System	Default Coordinate System						
Reference Temperature	By Environment						
Behavior	None						
Material							

Assignment	Structural Steel						
Nonlinear Effects	Yes						
Thermal Strain Effects	Yes						
Bounding Box							
Length X	1.e-002 m			5.4947e-002 m		9.9884e-002 m	0.14118 m
Length Y	1.e-002 m			5.9995e-002 m		9.9768e-002 m	0.14118 m
Length Z	0.3 m			7.e-002 m		1.e-002 m	2.5e-002 m
Properties							
Volume	2.356e-005 m³			4.6849e-005 m³			1.3375e-004 m³
Mass	0.18494 kg			0.36776 kg			1.05 kg
Centroid X	0.17109 m	0.13374 m	0.16699 m	0.46231 m	0.17098 m	0.16963 m	0.16935 m
Centroid Y	-2.183e-002 m	-5.5071e-002 m	-9.2421e-002 m	0.10867 m	-0.15061 m	-5.716e-002 m	-5.7144e-002 m
Centroid Z	7.4808e-002 m			0.20939 m		0.21981 m	-7.3884e-002 m
Moment of Inertia Ip1	1.375e-003 kg·m²			1.4992e-004 kg·m²			5.5149e-004 kg·m²
Moment of Inertia Ip2	1.375e-003 kg·m²			1.5988e-004 kg·m²			5.6884e-004 kg·m²
Moment of Inertia Ip3	2.2678e-006 kg·m²			3.0366e-004 kg·m²			1.0024e-003 kg·m²
Statistics							
Nodes	796			800			1515
Elements	143			92			812
Mesh Metric	None						

Coordinate Systems

TABLE 5
Model (B4) > Coordinate Systems > Coordinate System

Object Name	*Global Coordinate System*
State	Fully Defined
Definition	
Type	Cartesian
Coordinate System ID	0.
Origin	
Origin X	0. m
Origin Y	0. m

Origin Z	0. m
Directional Vectors	
X Axis Data	[1. 0. 0.]
Y Axis Data	[0. 1. 0.]
Z Axis Data	[0. 0. 1.]

Connections

TABLE 6
Model (B4) > Connections

Object Name	*Connections*
State	Fully Defined
Auto Detection	
Generate Automatic Connection On Refresh	Yes
Transparency	
Enabled	Yes

TABLE 7
Model (B4) > Connections > Contacts

Object Name	*Contacts*
State	Fully Defined
Definition	
Connection Type	Contact
Scope	
Scoping Method	Geometry Selection
Geometry	All Bodies
Auto Detection	
Tolerance Type	Slider
Tolerance Slider	0.
Tolerance Value	2.0702e-003 m
Use Range	No
Face/Face	Yes
Face Overlap Tolerance	Off
Cylindrical Faces	Include
Face/Edge	No
Edge/Edge	No
Priority	Include All
Group By	Bodies
Search Across	Bodies
Statistics	
Connections	35
Active Connections	35

TABLE 8
Model (B4) > Connections > Contacts > Contact Regions

Object Name	*Contact Region*	*Contact Region 2*	*Contact Region 3*	*Contact Region 4*	*Contact Region 5*	*Contact Region 6*	*Contact Region 7*	*Contact Region 8*	*Contact Region 9*	*Contact Region 10*	*Contact Region 11*
State	Fully Defined										
Scope											
Scoping Method	Geometry Selection										
Contact	1 Face	2 Faces	1 Face	2 Faces		1 Face	2 Faces				
Target	1 Face	2 Faces	1 Face	2 Faces		1 Face	2 Faces				
Contact Bodies	Part 1		Part 2		Part 3		Part 4				
Target Bodies	Part 5	Part 6	Part 5	Part 6	Part 4	Part 18	Part 5	Part 6	Part 11	Part 17	Part 18
Definition											
Type	Bonded										
Scope Mode	Automatic										
Behavior	Program Controlled										
Trim Contact	Program Controlled										
Trim Tolerance	2.0702e-003 m										
Suppressed	No										
Advanced											
Formulation	Program Controlled										
Detection Method	Program Controlled										
Penetration Tolerance	Program Controlled										
Elastic Slip Tolerance	Program Controlled										
Normal Stiffness	Program Controlled										
Update Stiffness	Program Controlled										
Pinball Region	Program Controlled										

Geometric Modification	
Contact Geometry Correction	None
Target Geometry Correction	None

TABLE 9
Model (B4) > Connections > Contacts > Contact Regions

Object Name	*Contact Region 12*	*Contact Region 13*	*Contact Region 14*	*Contact Region 15*	*Contact Region 16*	*Contact Region 17*	*Contact Region 18*	*Contact Region 19*	*Contact Region 20*	*Contact Region 21*	*Contact Region 22*
State	Fully Defined										
Scope											
Scoping Method	Geometry Selection										
Contact	1 Face	2 Faces									
Target	1 Face	6 Faces	2 Faces		6 Faces	2 Faces		6 Faces	2 Faces		6 Faces
Contact Bodies	Part 5	Part 7			Part 8			Part 9			Part 10
Target Bodies	Part 6	Part 11	Part 15	Part 16	Part 11	Part 15	Part 16	Part 11	Part 15	Part 16	Part 11
Definition											
Type	Bonded										
Scope Mode	Automatic										
Behavior	Program Controlled										
Trim Contact	Program Controlled										
Trim Tolerance	2.0702e-003 m										
Suppressed	No										
Advanced											
Formulation	Program Controlled										
Detection Method	Program Controlled										
Penetration Tolerance	Program Controlled										

Elastic Slip Tolerance	Program Controlled
Normal Stiffness	Program Controlled
Update Stiffness	Program Controlled
Pinball Region	Program Controlled
Geometric Modification	
Contact Geometry Correction	None
Target Geometry Correction	None

TABLE 10
Model (B4) > Connections > Contacts > Contact Regions

Object Name	*Contact Region 23*	*Contact Region 24*	*Contact Region 25*	*Contact Region 26*	*Contact Region 27*	*Contact Region 28*	*Contact Region 29*	*Contact Region 30*	*Contact Region 31*	*Contact Region 32*	*Contact Region 33*
State	Fully Defined										
Scope											
Scoping Method	Geometry Selection										
Contact	2 Faces					1 Face	2 Faces		3 Faces	2 Faces	3 Faces
Target	2 Faces					1 Face	2 Faces		3 Faces	2 Faces	3 Faces
Contact Bodies	Part 10		Part 11					Part 12		Part 13	
Target Bodies	Part 15	Part 16	Part 12	Part 13	Part 14	Part 16	Part 17		Part 18	Part 17	Part 18
Definition											
Type	Bonded										
Scope Mode	Automatic										
Behavior	Program Controlled										
Trim Contact	Program Controlled										
Trim Tolerance	2.0702e-003 m										
Suppressed	No										

Advanced	
Formulation	Program Controlled
Detection Method	Program Controlled
Penetration Tolerance	Program Controlled
Elastic Slip Tolerance	Program Controlled
Normal Stiffness	Program Controlled
Update Stiffness	Program Controlled
Pinball Region	Program Controlled
Geometric Modification	
Contact Geometry Correction	None
Target Geometry Correction	None

TABLE 11
Model (B4) > Connections > Contacts > Contact Regions

Object Name	*Contact Region 34*	*Contact Region 35*
State	Fully Defined	
Scope		
Scoping Method	Geometry Selection	
Contact	2 Faces	3 Faces
Target	2 Faces	3 Faces
Contact Bodies	Part 14	
Target Bodies	Part 17	Part 18
Definition		
Type	Bonded	
Scope Mode	Automatic	
Behavior	Program Controlled	
Trim Contact	Program Controlled	
Trim Tolerance	2.0702e-003 m	
Suppressed	No	
Advanced		
Formulation	Program Controlled	
Detection Method	Program Controlled	

Penetration Tolerance	Program Controlled
Elastic Slip Tolerance	Program Controlled
Normal Stiffness	Program Controlled
Update Stiffness	Program Controlled
Pinball Region	Program Controlled
Geometric Modification	
Contact Geometry Correction	None
Target Geometry Correction	None

Mesh

TABLE 12
Model (B4) > Mesh

Object Name	*Mesh*
State	Solved
Display	
Display Style	Body Color
Defaults	
Physics Preference	Mechanical
Relevance	0
Element Order	Program Controlled
Sizing	
Size Function	Adaptive
Relevance Center	Coarse
Element Size	Default
Initial Size Seed	Assembly
Transition	Fast
Span Angle Center	Coarse
Automatic Mesh Based Defeaturing	On
Defeature Size	Default
Minimum Edge Length	7.8197e-004 m
Quality	
Check Mesh Quality	Yes, Errors
Error Limits	Standard Mechanical
Target Quality	Default (0.050000)
Smoothing	Medium
Mesh Metric	None
Inflation	
Use Automatic Inflation	None
Inflation Option	Smooth Transition
Transition Ratio	0.272
Maximum Layers	5
Growth Rate	1.2

Inflation Algorithm	Pre
View Advanced Options	No
Advanced	
Number of CPUs for Parallel Part Meshing	Program Controlled
Straight Sided Elements	No
Number of Retries	Default (4)
Rigid Body Behavior	Dimensionally Reduced
Mesh Morphing	Disabled
Triangle Surface Mesher	Program Controlled
Topology Checking	No
Pinch Tolerance	Please Define
Generate Pinch on Refresh	No
Statistics	
Nodes	20155
Elements	5049

Static Structural (B5)

TABLE 13
Model (B4) > Analysis

Object Name	*Static Structural (B5)*
State	Solved
Definition	
Physics Type	Structural
Analysis Type	Static Structural
Solver Target	Mechanical APDL
Options	
Environment Temperature	22. °C
Generate Input Only	No

TABLE 14
Model (B4) > Static Structural (B5) > Analysis Settings

Object Name	*Analysis Settings*
State	Fully Defined
Step Controls	
Number Of Steps	1.
Current Step Number	1.
Step End Time	1. s
Auto Time Stepping	Program Controlled
Solver Controls	
Solver Type	Program Controlled
Weak Springs	Off
Solver Pivot Checking	Program Controlled

Large Deflection	Off
Inertia Relief	Off
Rotordynamics Controls	
Coriolis Effect	Off
Restart Controls	
Generate Restart Points	Program Controlled
Retain Files After Full Solve	No
Combined Restart Files	Program Controlled
Nonlinear Controls	
Newton-Raphson Option	Program Controlled
Force Convergence	Program Controlled
Moment Convergence	Program Controlled
Displacement Convergence	Program Controlled
Rotation Convergence	Program Controlled
Line Search	Program Controlled
Stabilization	Off
Output Controls	
Stress	Yes
Strain	Yes
Nodal Forces	No
Contact Miscellaneous	No
General Miscellaneous	No
Store Results At	All Time Points
Analysis Data Management	
Solver Files Directory	C:\Users\Alexis Viorato\Desktop\Análisis_files\dp0\SYS-1\MECH\
Future Analysis	None
Scratch Solver Files Directory	
Save MAPDL db	No
Delete Unneeded Files	Yes
Nonlinear Solution	No
Solver Units	Active System
Solver Unit System	mks

TABLE 15
Model (B4) > Static Structural (B5) > Loads

Object Name	*Pressure*	*Pressure 2*	*Fixed Support*
State	Fully Defined		
Scope			
Scoping Method	Geometry Selection		
Geometry	1 Face		
Definition			
Type	Pressure		Fixed Support
Define By	Normal To		

Applied By	Surface Effect		
Magnitude	100. Pa (ramped)	-200. Pa (ramped)	
Suppressed	No		

FIGURE 1
Model (B4) > Static Structural (B5) > Pressure

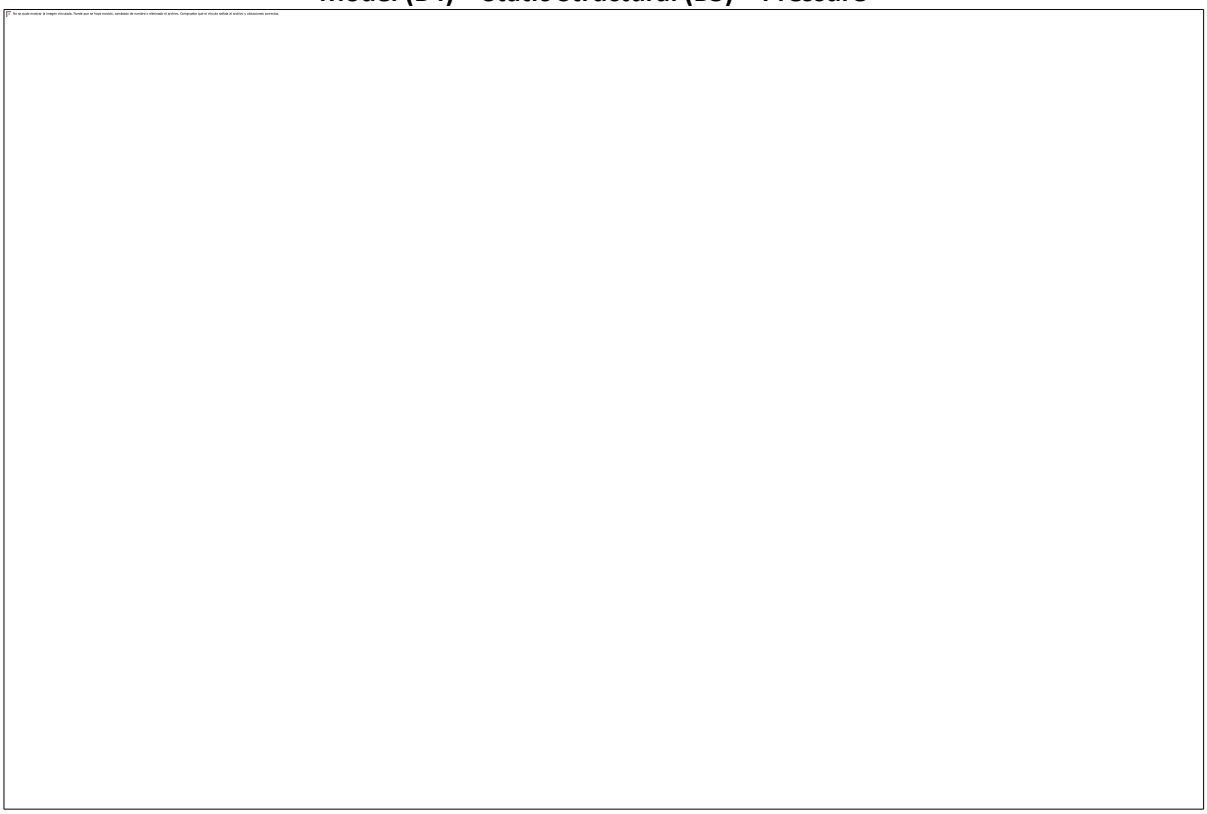
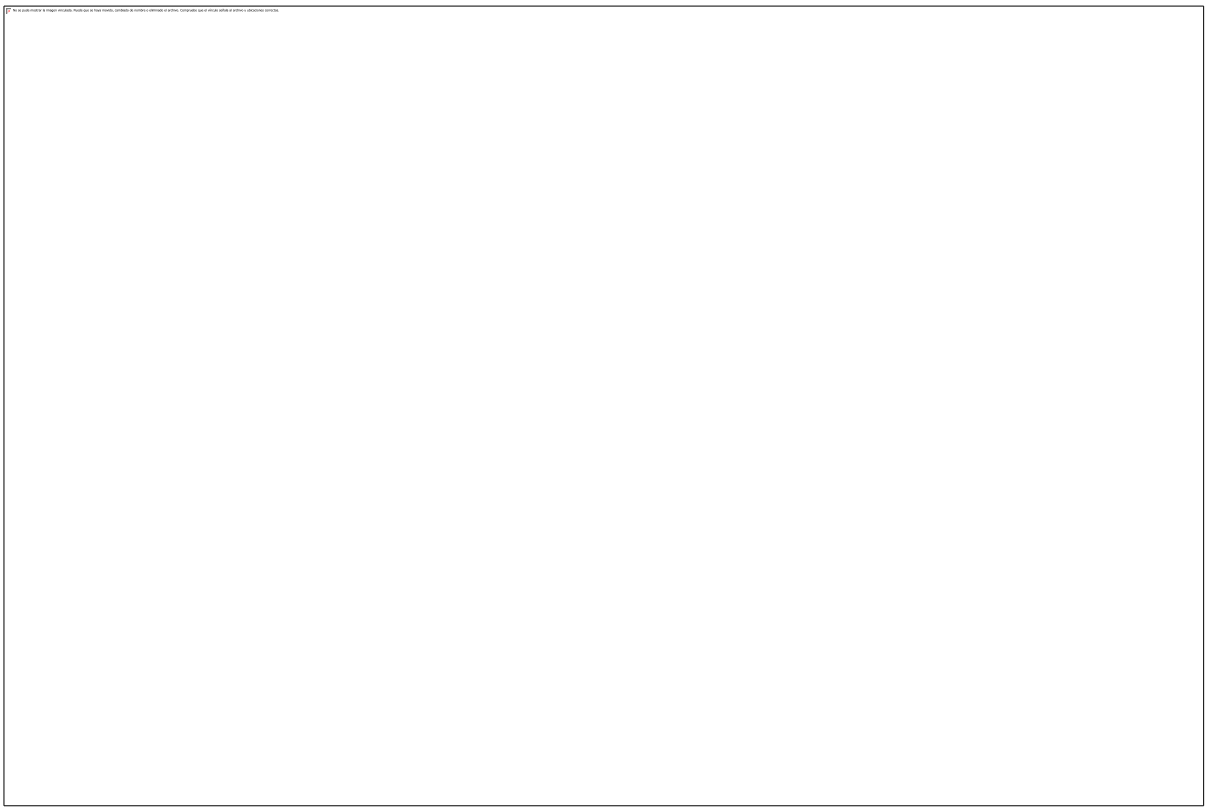


FIGURE 2
Model (B4) > Static Structural (B5) > Pressure 2



Solution (B6)

TABLE 16
Model (B4) > Static Structural (B5) > Solution

Object Name	*Solution (B6)*
State	Solved
Adaptive Mesh Refinement	
Max Refinement Loops	1.
Refinement Depth	2.
Information	
Status	Done
MAPDL Elapsed Time	32. s
MAPDL Memory Used	162. MB
MAPDL Result File Size	7.625 MB
Post Processing	
Beam Section Results	No

TABLE 17
Model (B4) > Static Structural (B5) > Solution (B6) > Solution Information

Object Name	*Solution Information*
State	Solved
Solution Information	

Solution Output	Solver Output
Newton-Raphson Residuals	0
Identify Element Violations	0
Update Interval	2.5 s
Display Points	All
FE Connection Visibility	
Activate Visibility	Yes
Display	All FE Connectors
Draw Connections Attached To	All Nodes
Line Color	Connection Type
Visible on Results	No
Line Thickness	Single
Display Type	Lines

TABLE 18
Model (B4) > Static Structural (B5) > Solution (B6) > Results

Object Name	*Equivalent Stress*	*Total Deformation*
State	Solved	
Scope		
Scoping Method	Geometry Selection	
Geometry	All Bodies	
Definition		
Type	Equivalent (von-Mises) Stress	Total Deformation
By	Time	
Display Time	Last	
Calculate Time History	Yes	
Identifier		
Suppressed	No	
Integration Point Results		
Display Option	Averaged	
Average Across Bodies	No	
Results		
Minimum	1.6537e-003 Pa	0. m
Maximum	2.2116e+006 Pa	3.3113e-005 m
Minimum Occurs On	Part 5	
Maximum Occurs On	Part 4	Part 15
Information		
Time	1. s	
Load Step	1	
Substep	1	
Iteration Number	1	

FIGURE 3
Model (B4) > Static Structural (B5) > Solution (B6) > Equivalent Stress

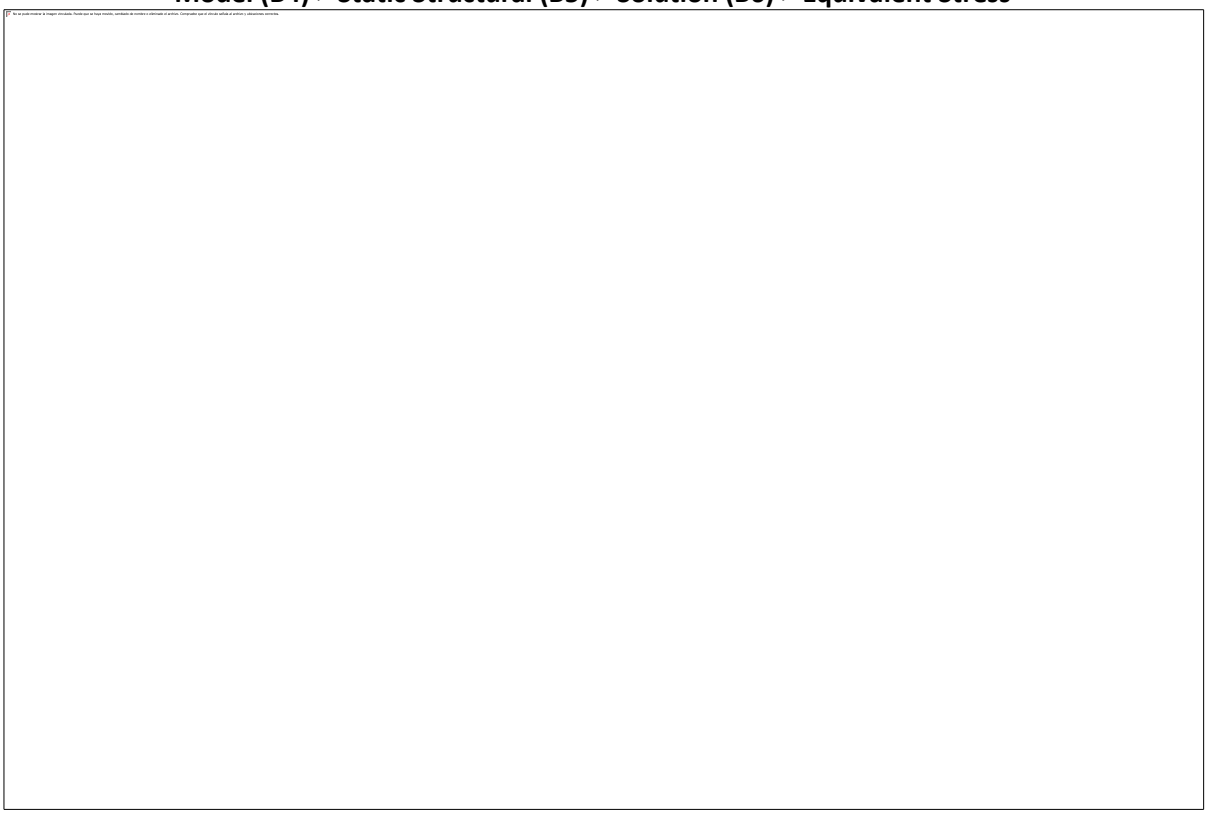


TABLE 19
Model (B4) > Static Structural (B5) > Solution (B6) > Equivalent Stress

Time [s]	Minimum [Pa]	Maximum [Pa]
1.	1.6537e-003	2.2116e+006

FIGURE 4
Model (B4) > Static Structural (B5) > Solution (B6) > Equivalent Stress > Figure

FIGURE 5
Model (B4) > Static Structural (B5) > Solution (B6) > Total Deformation

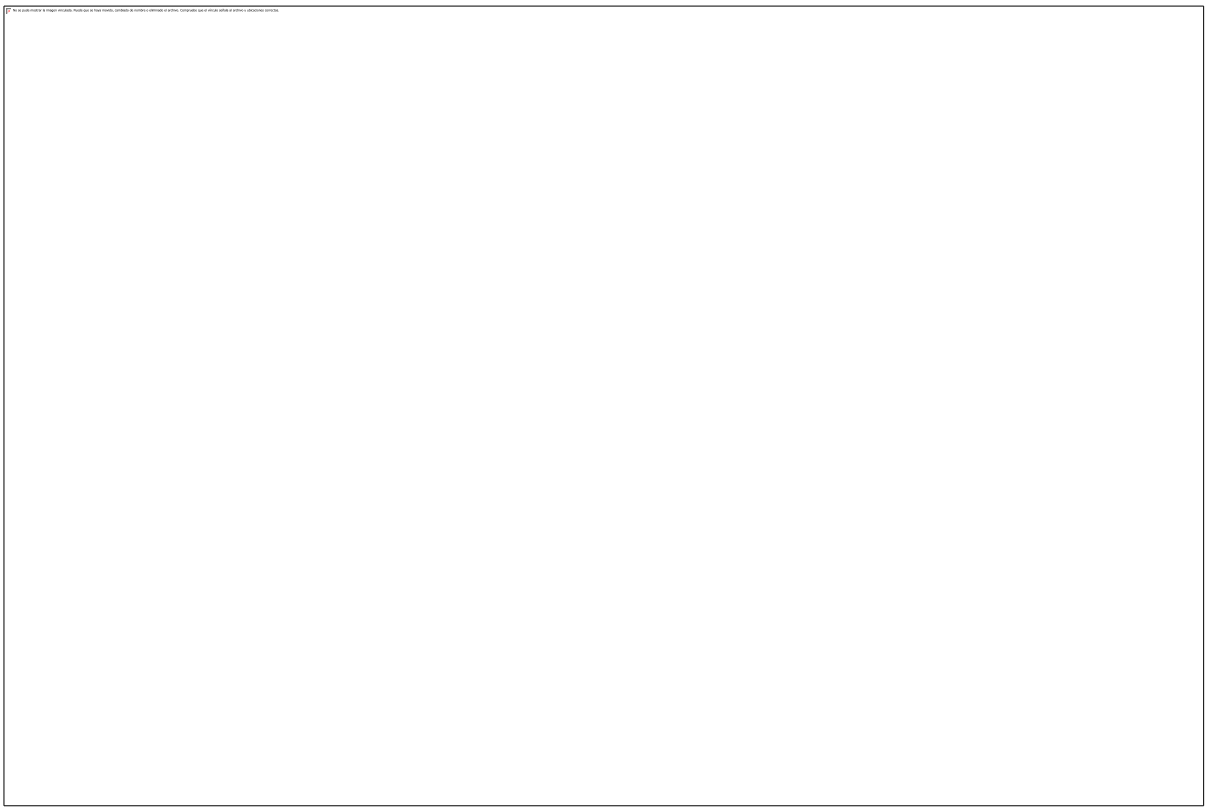


TABLE 20
Model (B4) > Static Structural (B5) > Solution (B6) > Total Deformation

Time [s]	Minimum [m]	Maximum [m]
1.	0.	3.3113e-005

FIGURE 6
Model (B4) > Static Structural (B5) > Solution (B6) > Total Deformation > Figure

Material Data

Structural Steel

TABLE 21
Structural Steel > Constants

Density	7850 kg m^-3
Isotropic Secant Coefficient of Thermal Expansion	1.2e-005 C^-1
Specific Heat	434 J kg^-1 C^-1
Isotropic Thermal Conductivity	60.5 W m^-1 C^-1
Isotropic Resistivity	1.7e-007 ohm m

TABLE 22
Structural Steel > Appearance

Red	Green	Blue
132	139	179

TABLE 23
Structural Steel > Compressive Ultimate Strength

Compressive Ultimate Strength Pa
0

TABLE 24
Structural Steel > Compressive Yield Strength

Compressive Yield Strength Pa
2.5e+008

TABLE 25
Structural Steel > Tensile Yield Strength

Tensile Yield Strength Pa
2.5e+008

TABLE 26
Structural Steel > Tensile Ultimate Strength

Tensile Ultimate Strength Pa
4.6e+008

TABLE 27
Structural Steel > Isotropic Secant Coefficient of Thermal Expansion

Zero-Thermal-Strain Reference Temperature C
22

TABLE 28
Structural Steel > Alternating Stress Mean Stress

Alternating Stress Pa	Cycles	Mean Stress Pa
3.999e+009	10	0
2.827e+009	20	0
1.896e+009	50	0
1.413e+009	100	0
1.069e+009	200	0
4.41e+008	2000	0
2.62e+008	10000	0
2.14e+008	20000	0
1.38e+008	1.e+005	0
1.14e+008	2.e+005	0
8.62e+007	1.e+006	0

TABLE 29
Structural Steel > Strain-Life Parameters

Strength Coefficient Pa	Strength Exponent	Ductility Coefficient	Ductility Exponent	Cyclic Strength Coefficient Pa	Cyclic Strain Hardening Exponent
9.2e+008	-0.106	0.213	-0.47	1.e+009	0.2

TABLE 30
Structural Steel > Isotropic Elasticity

Temperature C	Young's Modulus Pa	Poisson's Ratio	Bulk Modulus Pa	Shear Modulus Pa
	2.e+011	0.3	1.6667e+011	7.6923e+010

TABLE 31
Structural Steel > Isotropic Relative Permeability

Relative Permeability
10000

Conclusión.