



EV_2_3_Diseño de robot con CAD- Ansys

Dinámica y control de robots.

Integrantes:

Curiel Sánchez Héctor David

Fernández Gaeta Uriel

García Camacho Jesús Alberto

Gómez Medina Jesús Carlos

Salcedo González Alondra

Ingeniería Mecatrónica 9°B

Maestro: Carlos Enrique Morán Garabito.

07 de junio del 2019



Objetivo

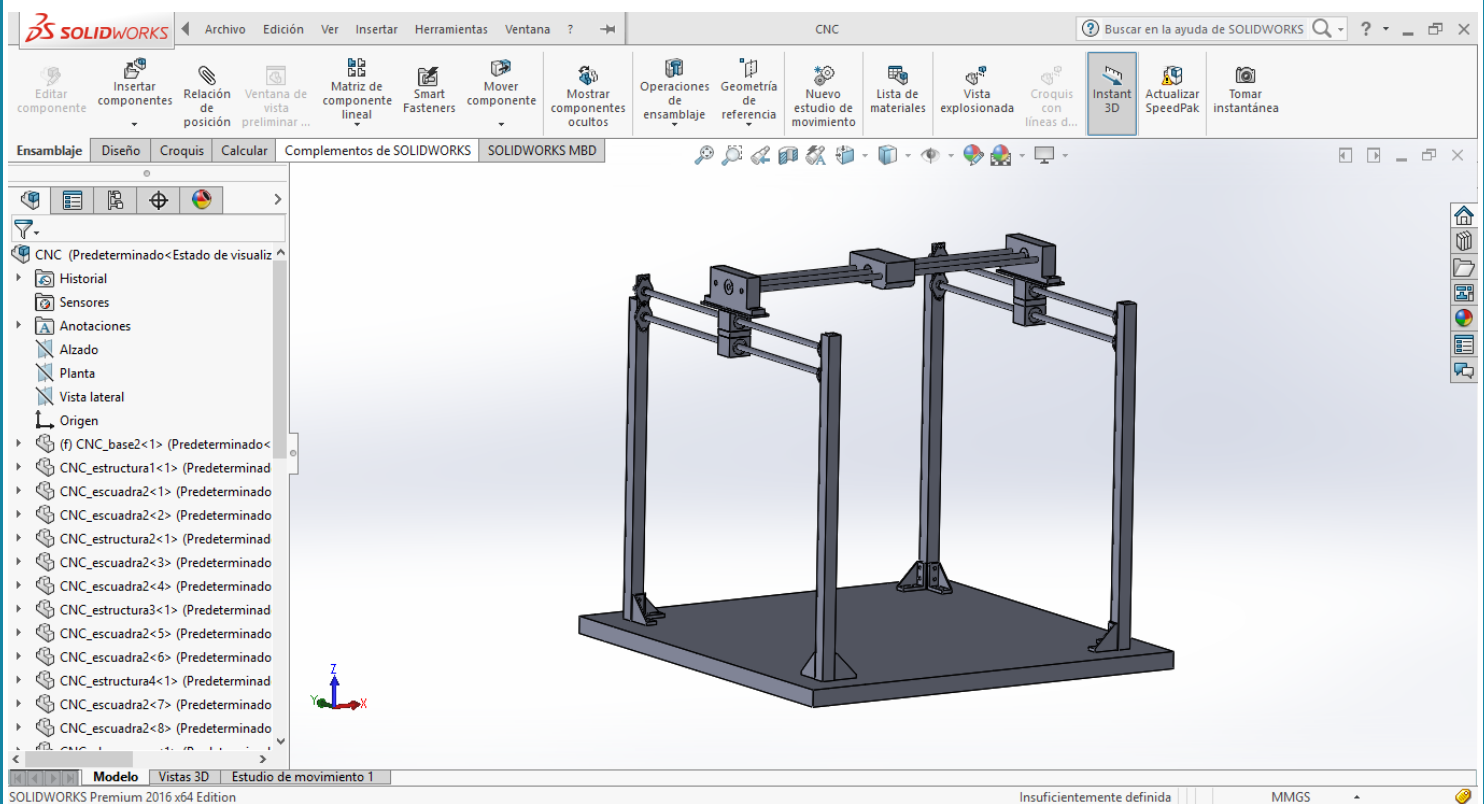
Diseñar en software CAD el robot manipulador seleccionado y en software CAE realizar los análisis estructurales y de esfuerzos presentes en dicho robot.

Materiales

- PC.
- Software CAD (en este caso Solidworks) y software CAE (en este caso Ansys).

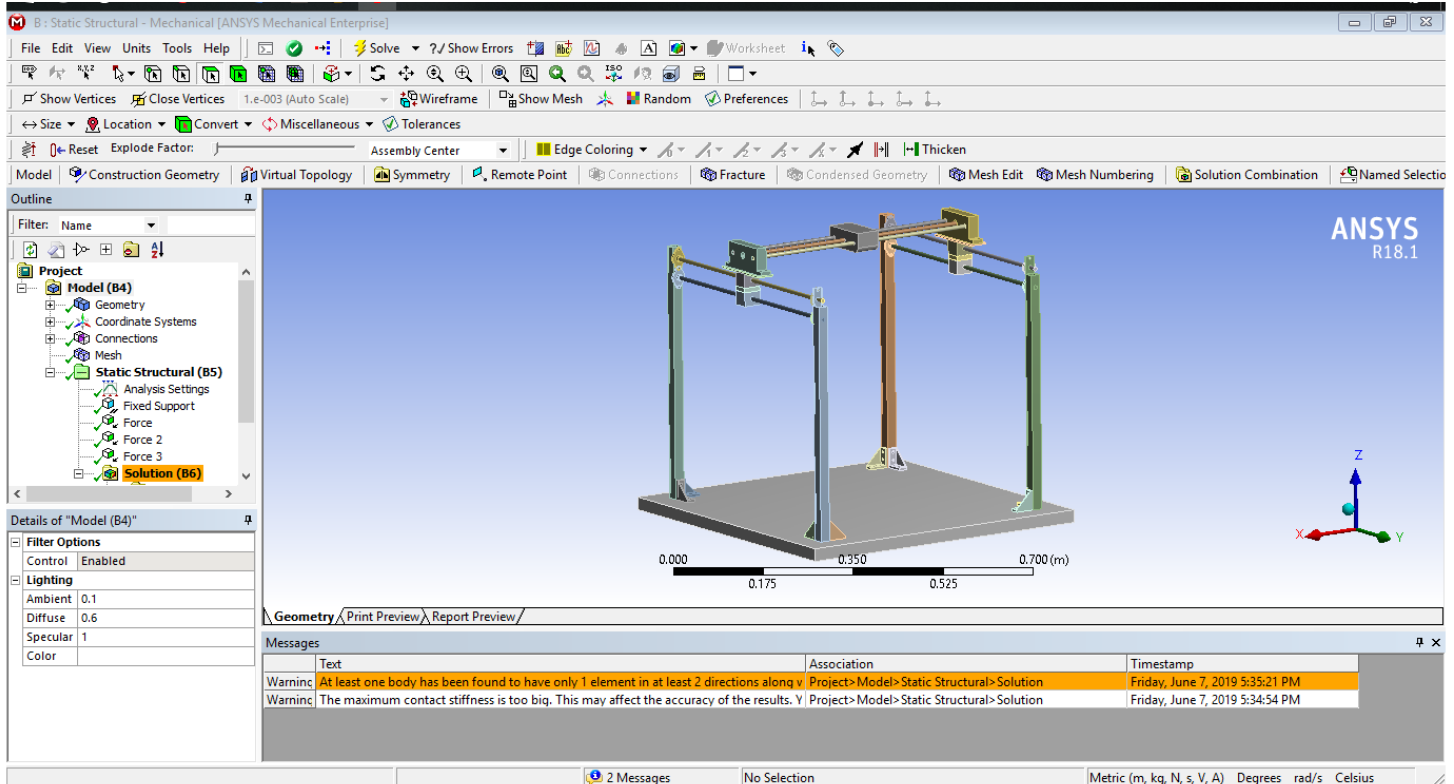
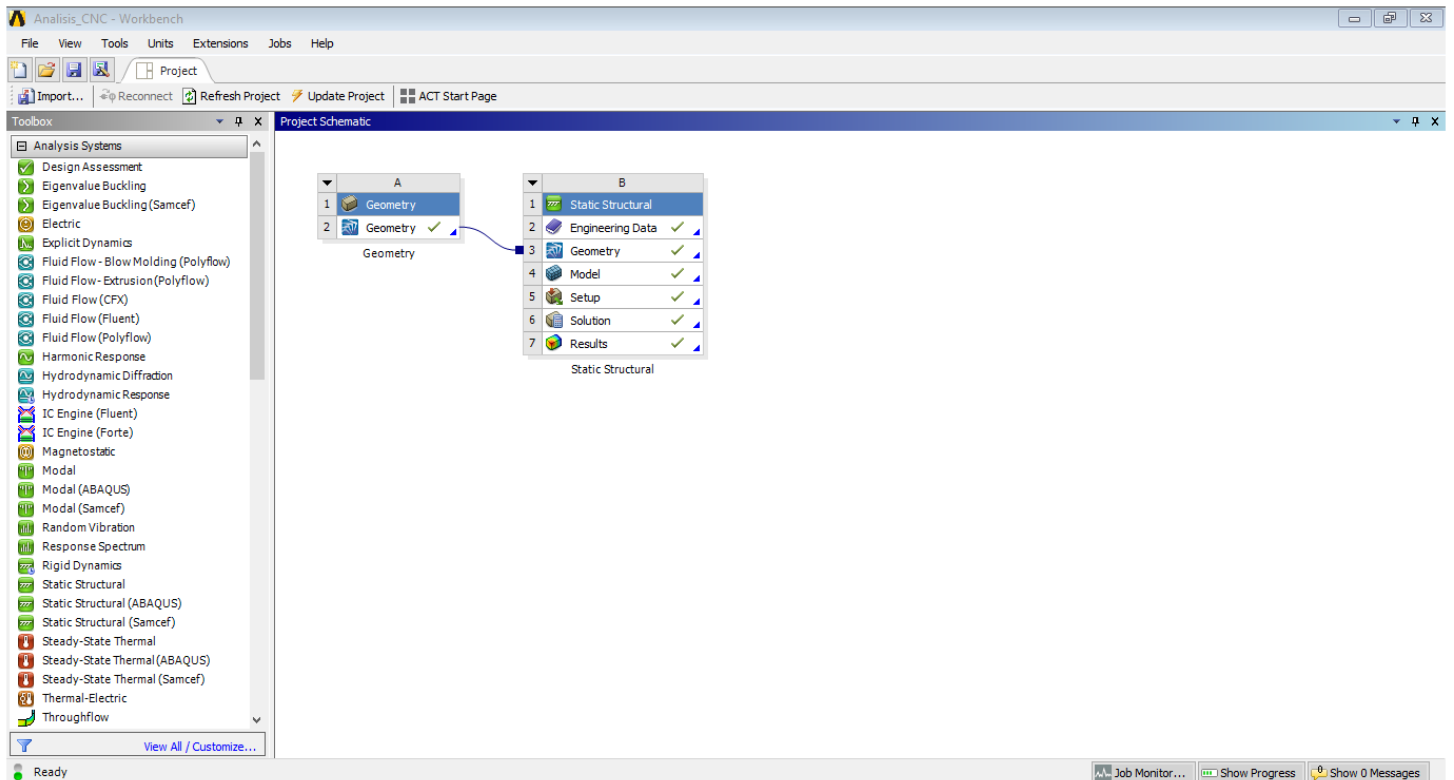
Procedimiento

1.- Con base en los conocimientos adquiridos sobre dibujo en ingeniería, se diseña el prototipo de robot seleccionado, siguiendo los estándares del SI y demás:





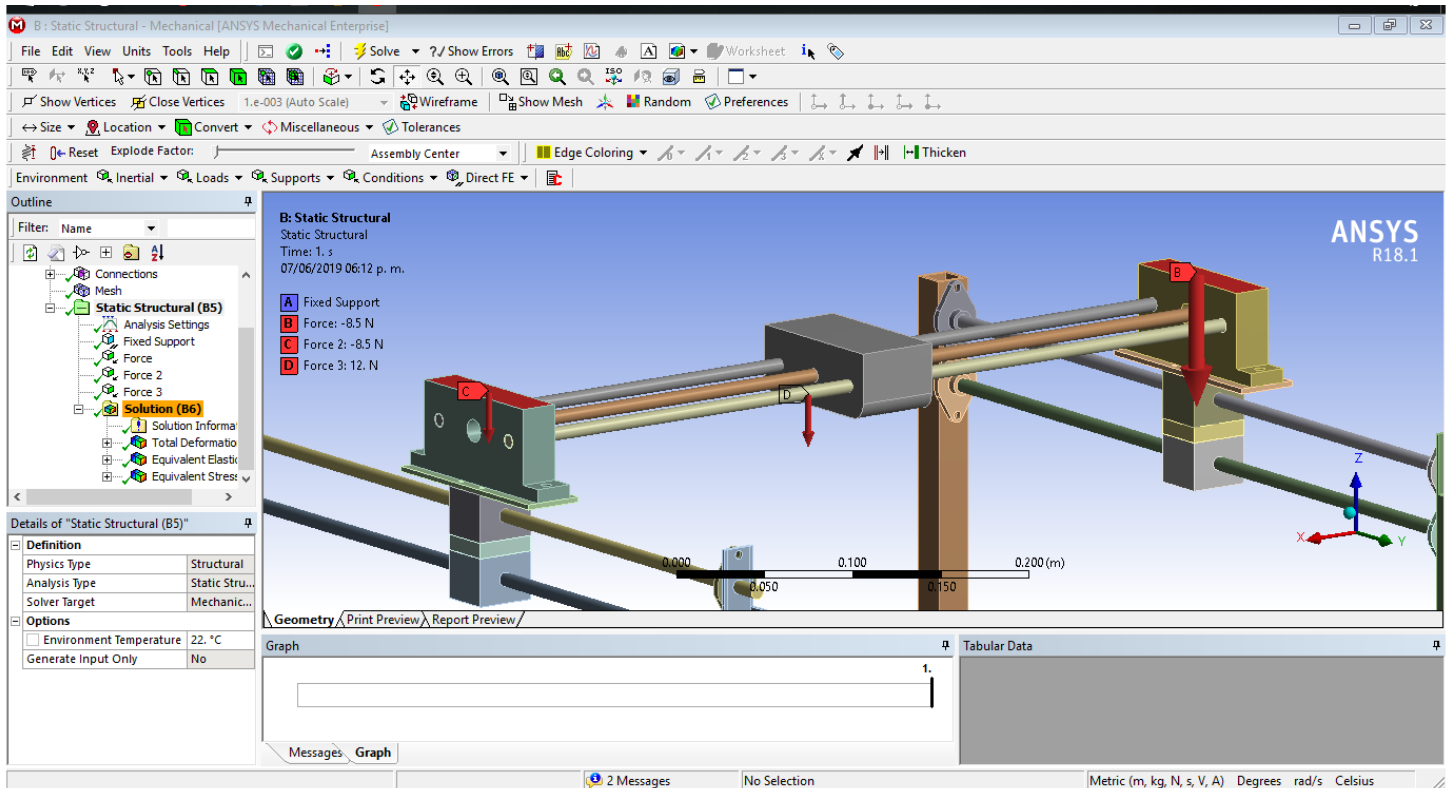
2.- Una vez obtenido el ensamble completo del robot, se procede a analizar su estructura en Ansys:





Resultados

Se inició el análisis del robot colocando diferentes fuerzas en base a los puntos de mayor y soporte de peso, tal es el caso de los tres puntos siguientes:

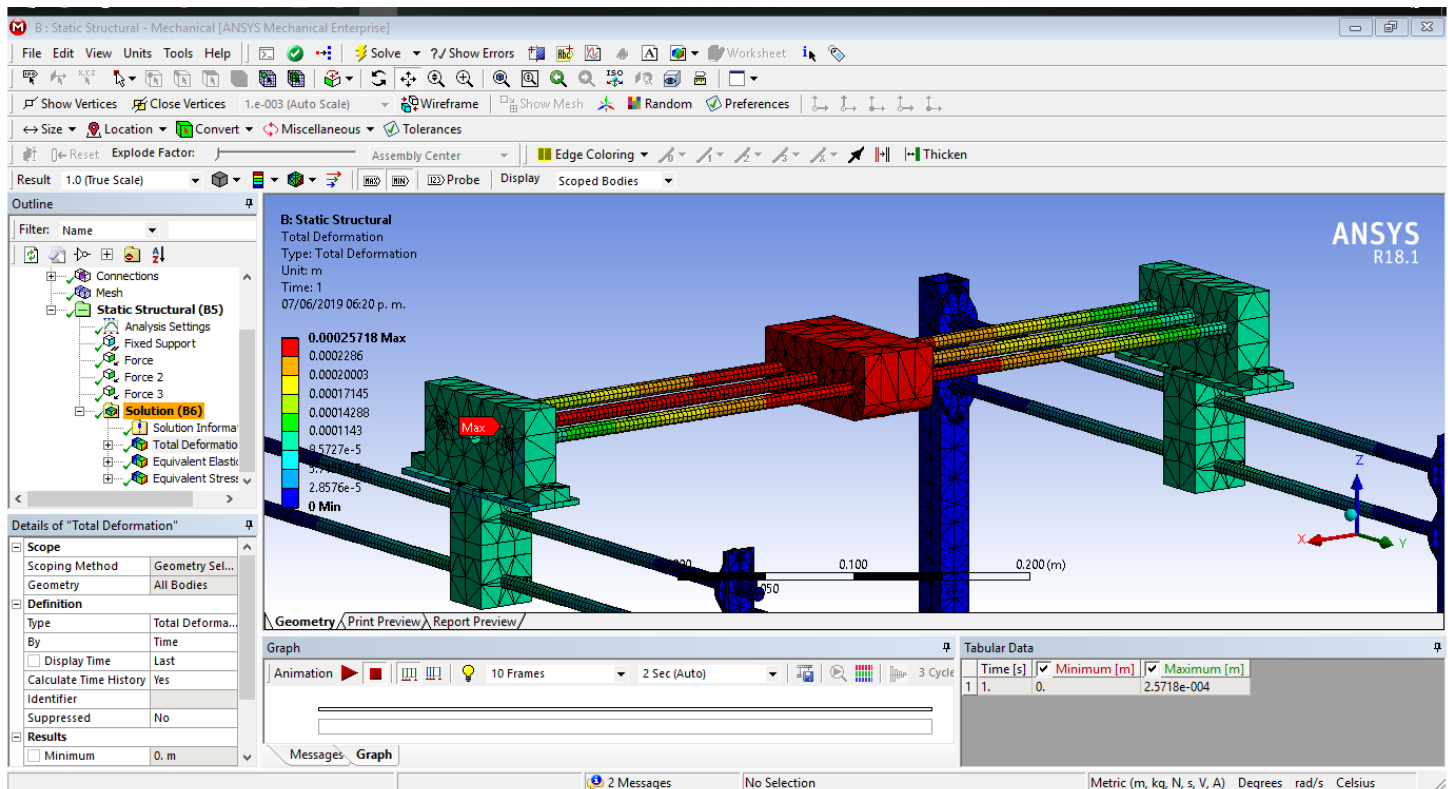


Las dimensiones del robot son las reales en cada una de las piezas utilizadas.

En los puntos B y C la fuerza aplicada hacia abajo es de 8.5 N, pues el peso que estos puntos en la estructura van a soportar será de 850 g cada uno. El peso total para toda la extensión de la estructura es 1.7 kg.

En el punto D es donde se concentra el mayor peso, pues en esa zona es donde se colocará una pinza de máximo 200 g que levantará un peso máximo de 1 kg. El resultado a grandes rasgos es una fuerza de 12 N.

Los siguientes análisis se basan en las fuerzas aplicadas, en su totalidad lo que necesitamos saber es la deformación total a causa de las fuerzas B, C y D:



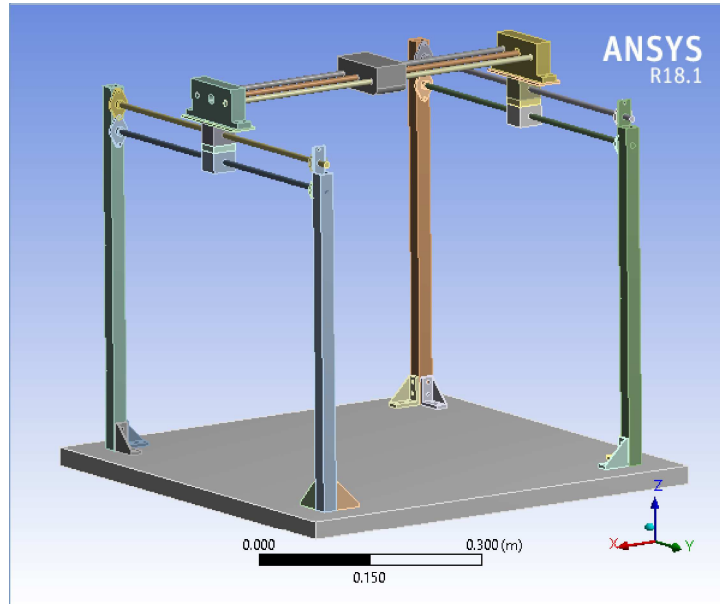
Como se observa en la imagen, la zona roja representa la máxima deformación en m que sufre el robot. Sus valores son tan mínimos que puede despreciarse si respetamos el peso máximo admitido que es de 1.2 kg.

Se realizaron otras dos simulaciones, utilizando pesos de 5.2 kg y 10.2 kg. La deformación sigue siendo mínima pues su máximo en 10.2 kg es de 0.00257 m. Pero no ignoremos que esto es solo una simulación. Si le colocáramos un peso de 10.2 kg al punto D del robot, la deformación sería diferente en valores. También debemos tener en cuenta que tres de las barras cilíndricas presentes son husillos, y se encargan de la movilidad del robot, por lo que al aumentar el peso en el punto D, el torque necesario para el movimiento aumentaría.



Project

First Saved	Friday, June 7, 2019
Last Saved	Friday, June 7, 2019
Product Version	18.1 Release
Save Project Before Solution	No
Save Project After Solution	No



Contents

- [Units](#)
- [Model \(B4\)](#)
 - [Geometry](#)
 - [Parts](#)
 - [Coordinate Systems](#)
 - [Connections](#)
 - [Contacts](#)
 - [Contact Regions](#)
 - [Mesh](#)
 - [Static Structural \(B5\)](#)
 - [Analysis Settings](#)
 - [Loads](#)
 - [Solution \(B6\)](#)
 - [Solution Information](#)
 - [Results](#)
- [Material Data](#)
 - [Polyethylene](#)
 - [Structural Steel](#)
 - [Aluminum Alloy](#)
 - [Stainless Steel](#)

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	<i>Geometry</i>
State	Fully Defined
Definition	
Source	C:\Users\jesus\Documents\Ansys\CNC.scdoc
Type	SpaceClaim
Length Unit	Meters
Element Control	Program Controlled
Display Style	Body Color
Bounding Box	
Length X	0.61 m
Length Y	0.61 m
Length Z	0.5715 m
Properties	
Volume	1.0353e-002 m³
Mass	14.422 kg
Scale Factor Value	1.
Statistics	
Bodies	41
Active Bodies	41
Nodes	144010
Elements	41653
Mesh Metric	None
Basic Geometry Options	
Solid Bodies	Yes
Surface Bodies	Yes
Line Bodies	Yes
Parameters	Independent
Parameter Key	
Attributes	Yes
Attribute Key	
Named Selections	Yes
Named Selection Key	
Material Properties	Yes
Advanced Geometry Options	
Use Associativity	Yes
Coordinate Systems	Yes
Coordinate System Key	
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\jesus\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	CNC_base2 \\Solid1	CNC_estructura1 \\Solid1	CNC_escuadra2 \\Solid1	CNC_escuadra2 \\Solid1	CNC_escuadra2 \\Solid1	CNC_escuadra2 \\Solid1	CNC_escuadra2 \\Solid1	CNC_escuadra2 \\Solid1	CNC_escuadra2 \\Solid1	CNC_escuadra2 \\Solid1	CNC_escuadra2 \\Solid1
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	Polyethylene	Structural Steel	Aluminum Alloy								
Nonlinear Effects	Yes										
Thermal Strain Effects	Yes										
Bounding Box											
Length X	0.61 m	2.e-002 m	1.7e-002 m	3.8e-002 m			1.7e-002 m		3.8e-002 m	1.7e-002 m	3.8e-002 m
Length Y	0.61 m	2.e-002 m	3.8e-002 m	1.7e-002 m			3.8e-002 m		1.7e-002 m	3.8e-002 m	1.7e-002 m
Length Z	2.5e-002 m	0.5 m	3.8e-002 m								
Properties											
Volume	9.2946e-003 m³	6.893e-005 m³	6.7313e-006 m³								
Mass	8.8299 kg	0.5411 kg	1.8646e-002 kg								
Centroid X	4.1673e-002 m	0.29168 m	0.29289 m	0.26966 m	-0.18632 m	-0.20954 m		-0.18632 m	0.29289 m	0.29289 m	0.29289 m
Centroid Y	-9.4711e-003 m	0.24038 m	0.21852 m	0.24174 m		0.21852 m	-0.23746 m	-0.26068 m	-0.23746 m	-0.23746 m	-0.23746 m
Centroid Z	0.61 m	0.85993 m	0.63451 m								
Moment of Inertia Ip1	0.27408 kg·m²	1.0164e-002 kg·m²	4.0618e-006 kg·m²								
Moment of Inertia Ip2	0.27408 kg·m²	1.0164e-002 kg·m²	1.6329e-006 kg·m²								
Moment of Inertia Ip3	0.54725 kg·m²	5.9048e-005 kg·m²	4.6632e-006 kg·m²								
Statistics											
Nodes	30069	4807	709								
Elements	5718	2319	298								
Mesh Metric	None										
CAD Attributes											
PartTolerance:	0.00000001										
Color:143.149.175											

TABLE 4
Model (B4) > Geometry > Parts

Model (B4) > Geometry > Parts										
Object Name	CNC_estructura3 Solid1	CNC_estructura4 Solid1	CNC_chumacera Solid1	CNC_chumacera Solid1	CNC_chumacera Solid1	CNC_chumacera Solid1	CNC_chumacera Solid1	CNC_chumacera Solid1	CNC_chumacera Solid1	CNC_chumacera Solid1
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	Aluminum Alloy								
Nonlinear Effects	Yes									
Thermal Strain Effects	Yes									
Bounding Box										
Length X	2.e-002 m					2.7e-002 m				
Length Y	2.e-002 m					9.e-003 m				
Length Z	0.5 m					4.5001e-002 m				
Properties										
Volume	7.2632e-005 m³	7.2626e-005 m³					3.0961e-006 m³			
Mass	0.57016 kg	0.57012 kg					8.5763e-003 kg			
Centroid X	-0.20834 m	0.29168 m	0.29167 m	-0.20833 m	0.29167 m	-0.20833 m	0.29167 m	-0.20833 m	0.29167 m	0.29167 m
Centroid Y	-0.2595 m		-0.24702 m			0.22807 m			-0.24702 m	
Centroid Z	0.87244 m	0.87242 m	1.1 m							
Moment of Inertia Ip1	1.1828e-002 kg·m²	1.1825e-002 kg·m²	8.1629e-007 kg·m²							
Moment of Inertia Ip2	1.1828e-002 kg·m²	1.1826e-002 kg·m²	3.6663e-007 kg·m²							

Moment of Inertia Ip3	6.222e-005 kg·m²	6.2217e-005 kg·m²	1.1271e-006 kg·m²
Statistics			
Nodes	5148	5135	598
Elements	2488	2477	250
Mesh Metric	None		
CAD Attributes			
PartTolerance:	0.00000001		
Color:143.149.175			

TABLE 5
Model (B4) > Geometry > Parts

Object Name	CNC_husillo\Solid1	CNC_husillo\Solid1	CNC_husillo\Solid1	CNC_husillo\Solid1	CNC_husillo\Solid1	CNC_husillo\Solid1	CNC_soporte\Solid1	CNC_soporte\Solid1
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	Stainless Steel						Polyethylene	
Nonlinear Effects	Yes							
Thermal Strain Effects	Yes							
Bounding Box								
Length X	8.e-003 m	0.5 m		8.e-003 m		0.5 m	2.2e-002 m	
Length Y	0.5 m	8.e-003 m	9.8527e-003 m	0.5 m		8.e-003 m	0.123 m	
Length Z	8.e-003 m		9.8527e-003 m	8.e-003 m			5.2e-002 m	
Properties								
Volume	2.5132e-005 m³						1.0705e-004 m³	
Mass	0.19477 kg						0.10169 kg	
Centroid X	-0.20833 m	5.2673e-002 m		0.29167 m	-0.20833 m	3.0673e-002 m	0.29178 m	-0.20822 m
Centroid Y	5.2894e-004 m	2.5497e-002 m	-4.1503e-002 m	5.2894e-004 m		-8.0034e-003 m		
Centroid Z	1.1 m	1.148 m		1.063 m		1.148 m	1.1418 m	
Moment of Inertia Ip1	4.0381e-003 kg·m²						2.9057e-005 kg·m²	
Moment of Inertia Ip2	4.0381e-003 kg·m²						9.2566e-005 kg·m²	
Moment of Inertia Ip3	1.5425e-006 kg·m²						1.1344e-004 kg·m²	
Statistics								
Nodes	9322						1522	
Elements	1760						775	
Mesh Metric	None							
CAD Attributes								
PartTolerance:	0.00000001							
Color:143.149.175								

TABLE 6
Model (B4) > Geometry > Parts

Object Name	CNC_camisa\Solid1	CNC_placa\Solid1	CNC_placa\Solid1	CNC_relleno\Solid1	CNC_relleno\Solid1	CNC_balero\Solid1	CNC_balero\Solid1	CNC_basepinza\Solid1
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	Aluminum Alloy	Polyethylene			Aluminum Alloy			Structural Steel
Nonlinear Effects	Yes							
Thermal Strain Effects	Yes							
Bounding Box								
Length X	3.5e-002 m				5.e-003 m		4.8e-002 m	
Length Y	3.e-002 m	0.123 m		3.e-002 m		2.1e-002 m		9.5e-002 m
Length Z	2.8e-002 m	3.e-003 m		8.92e-003 m		2.1e-002 m		3.9e-002 m
Properties								
Volume	2.6576e-005 m³	1.2712e-005 m³		9.366e-006 m³		1.4804e-006 m³		1.5364e-004 m³
Mass	7.3615e-002 kg	1.2077e-002 kg		2.5944e-002 kg		4.1007e-003 kg		1.2061 kg
Centroid X	0.29167 m		-0.20833 m	0.29167 m	-0.20833 m	-0.21683 m	0.28317 m	4.122e-002 m
Centroid Y	-7.4875e-003 m	-8.0034e-003 m						
Centroid Z	1.0629 m	1.1155 m		1.0815 m		1.148 m		1.1505 m
Moment of Inertia Ip1	1.0328e-005 kg·m²	1.2488e-006 kg·m²		2.8205e-006 kg·m²		1.3773e-007 kg·m²		3.93e-004 kg·m²
Moment of Inertia Ip2	1.3214e-005 kg·m²	1.5139e-005 kg·m²		4.5942e-006 kg·m²		1.3773e-007 kg·m²		1.2161e-003 kg·m²
Moment of Inertia Ip3	1.3262e-005 kg·m²	1.6369e-005 kg·m²		2.1178e-006 kg·m²		2.5839e-007 kg·m²		1.1353e-003 kg·m²

Statistics					
Nodes	2812	948	70	157	1602
Elements	1728	114	6	16	850
Mesh Metric	None				
CAD Attributes					
PartTolerance:	0.00000001				
Color:143.149.175					

Coordinate Systems

TABLE 7
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 8
Model (B4) > Connections

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

TABLE 9
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	2.587e-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	68
Active Connections	68

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

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										
Target	1 Face										
Contact Bodies	CNC_base2\Solid1										
Target Bodies	CNC_estructura1 \Solid1	CNC_escuadra2\Solid1								CNC_estructura2 \Solid1	CNC_estructura3 \Solid1
Definition											
Type	Bonded										
Scope Mode	Automatic										
Behavior	Program Controlled										
Trim Contact	Program Controlled										
Trim Tolerance	2.587e-003 m										
Suppressed	No										
Advanced											
Formulation	Program Controlled										
Detection Method	Program Controlled										
Penetration Tolerance	Program Controlled										
Elastic Slip	Program Controlled										

Tolerance	
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 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										
Target	1 Face										
Contact Bodies	CNC_base2\Solid1	CNC_estructura1\Solid1				CNC_escuadra2\Solid1					
Target Bodies	CNC_estructura4 \Solid1	CNC_escuadra2\Solid1	CNC_chumacera\Solid1		CNC_husillo\Solid1	CNC_estructura2\Solid1	CNC_estructura3\Solid1		CNC_estructura4 \Solid1		
Definition											
Type	Bonded										
Scope Mode	Automatic										
Behavior	Program Controlled										
Trim Contact	Program Controlled										
Trim Tolerance	2.587e-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 12
Model (B4) > Connections > Contacts > Contact Regions

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	1 Face										
Target	1 Face										
Contact Bodies	CNC_escuadra2\Solid1	CNC_estructura2\Solid1			CNC_estructura3\Solid1			CNC_estructura4\Solid1			CNC_chumacera\Solid1
Target Bodies	CNC_estructura4\Solid1	CNC_chumacera\Solid1	CNC_husillo\Solid1	CNC_chumacera\Solid1	CNC_husillo\Solid1	CNC_chumacera\Solid1	CNC_husillo\Solid1	CNC_chumacera\Solid1	CNC_husillo\Solid1	CNC_chumacera\Solid1	CNC_husillo\Solid1
Definition											
Type	Bonded										
Scope Mode	Automatic										
Behavior	Program Controlled										
Trim Contact	Program Controlled										
Trim Tolerance	2.587e-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 13
Model (B4) > Connections > Contacts > Contact Regions

Object Name	Contact Region 34	Contact Region 35	Contact Region 36	Contact Region 37	Contact Region 38	Contact Region 39	Contact Region 40	Contact Region 41	Contact Region 42	Contact Region 43
State	Fully Defined									
Scope										
Scoping Method	Geometry Selection									
Contact	1 Face									
Target	1 Face	2 Faces	1 Face			2 Faces	1 Face			
Contact Bodies	CNC_chumacera\Solid1									
Target Bodies	CNC_husillo\Solid1	CNC_chumacera\Solid1	CNC_husillo\Solid1	CNC_chumacera\Solid1	CNC_husillo\Solid1	CNC_chumacera\Solid1	CNC_husillo\Solid1			
Definition										
Type	Bonded									
Scope Mode	Automatic									
Behavior	Program Controlled									
Trim Contact	Program Controlled									
Trim Tolerance	2.587e-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 14
Model (B4) > Connections > Contacts > Contact Regions

Object Name	Contact Region 45	Contact Region 46	Contact Region 47	Contact Region 48	Contact Region 49	Contact Region 50	Contact Region 51	Contact Region 52	Contact Region 53	Contact Region 54	Contact Region 55
State	Fully Defined										
Scope											
Scoping Method	Geometry Selection										
Contact	1 Face										
Target	1 Face										
Contact Bodies	CNC_husillo\Solid1										
Target Bodies	CNC_camisa\Solid1	CNC_soporte\Solid1	CNC_basepinza\Solid1	CNC_soporte\Solid1	CNC_basepinza\Solid1	CNC_camisa\Solid1	CNC_soporte\Solid1				
Definition											
Type	Bonded										
Scope Mode	Automatic										
Behavior	Program Controlled										
Trim Contact	Program Controlled										
Trim Tolerance	2.587e-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 15
Model (B4) > Connections > Contacts > Contact Regions

Object Name	Contact Region 56	Contact Region 57	Contact Region 58	Contact Region 59	Contact Region 60	Contact Region 61	Contact Region 62	Contact Region 63	Contact Region 64	Contact Region 65

State	Fully Defined									
Scope										
Scoping Method	Geometry Selection									
Contact	1 Face			2 Faces		1 Face		2 Faces		1 Face
Target	1 Face			2 Faces		1 Face		2 Faces		1 Face
Contact Bodies	CNC_husillo\Solid1			CNC_soporte\Solid1					CNC_camisa\Solid1	
Target Bodies	CNC_balero\Solid1	CNC_basepinza\Solid1	CNC_placa\Solid1	CNC_balero\Solid1	CNC_placa\Solid1	CNC_balero\Solid1	CNC_placa\Solid1	CNC_relleno\Solid1	CNC_pla	
Definition										
Type	Bonded									
Scope Mode	Automatic									
Behavior	Program Controlled									
Trim Contact	Program Controlled									
Trim Tolerance	2.587e-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 16
Model (B4) > Connections > Contacts > Contact Regions

Model (B4) > Connections > Contacts > Contact Regions	
Object Name	Contact Region 67 Contact Region 68
State	Fully Defined
Scope	
Scoping Method	Geometry Selection
Contact	1 Face
Target	1 Face
Contact Bodies	CNC_camisa\Solid1
Target Bodies	CNC_relleno\Solid1
Definition	
Type	Bonded
Scope Mode	Automatic
Behavior	Program Controlled
Trim Contact	Program Controlled
Trim Tolerance	2.587e-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 17
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	Fine
Element Size	Default
Initial Size Seed	Assembly
Transition	Fast
Span Angle Center	Coarse

Automatic Mesh Based Defeaturing	On
Defeature Size	Default
Minimum Edge Length	2.e-003 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	144010
Elements	41653

Static Structural (B5)

TABLE 18
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 19
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\jesus\AppData\Local\Temp\WB_LSKJCGM_jesus_11052_2\unsaved_project_files\dp0\SYSMECH\
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 20				
Model (B4) > Static Structural (B5) > Loads				
Object Name	Fixed Support	Force	Force 2	Force 3
State	Fully Defined			
Scope				
Scoping Method	Geometry Selection			
Geometry	1 Face			
Definition				
Type	Fixed Support	Force		
Suppressed	No			
Define By	Vector			
Magnitude	-8.5 N (ramped) 12. N (ramped)			
Direction	Defined			

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

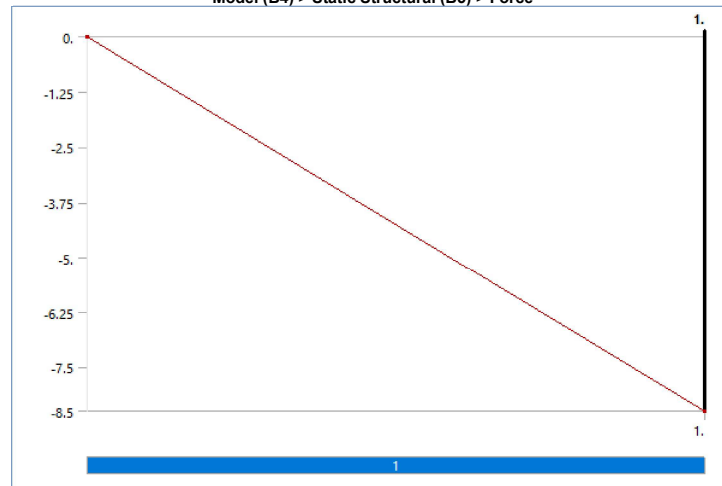


FIGURE 2
Model (B4) > Static Structural (B5) > Force 2

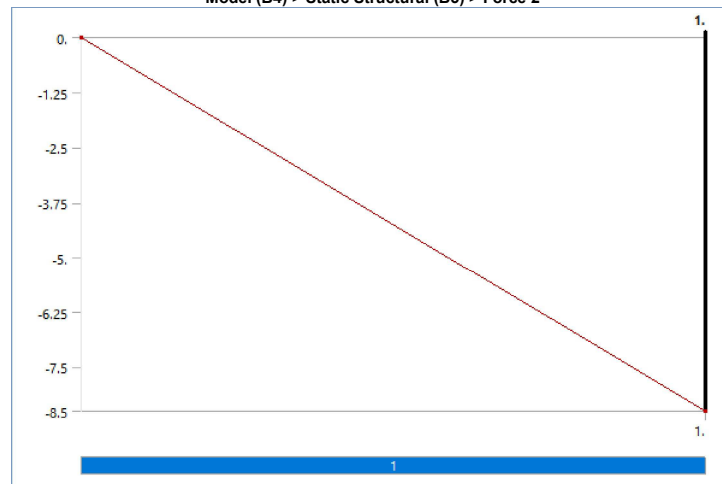
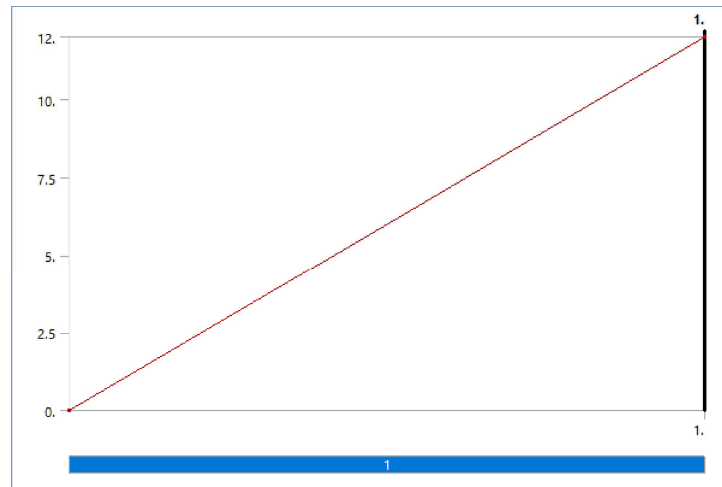


FIGURE 3
Model (B4) > Static Structural (B5) > Force 3



Solution (B6)

TABLE 21
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	31. s
MAPDL Memory Used	2.4785 GB
MAPDL Result File Size	46.563 MB
Post Processing	
Beam Section Results	No

TABLE 22
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 23
Model (B4) > Static Structural (B5) > Solution (B6) > Results

Object Name	Total Deformation	Equivalent Elastic Strain	Equivalent Stress
State	Solved		
Scope			
Scoping Method	Geometry Selection		
Geometry	All Bodies		
Definition			
Type	Total Deformation	Equivalent Elastic Strain	Equivalent (von-Mises) Stress
By	Time		
Display Time	Last		
Calculate Time History	Yes		
Identifier			
Suppressed	No		
Results			
Minimum	0. m	0. m/m	0. Pa
Maximum	2.5718e-004 m	4.45e-004 m/m	1.1956e+007 Pa
Minimum Occurs On	CNC_base2\Solid1		
Maximum Occurs On	CNC_husillo\Solid1	CNC_soporte\Solid1	CNC_husillo\Solid1
Information			
Time	1. s		
Load Step	1		
Substep	1		
Iteration Number	1		
Integration Point Results			
Display Option	Averaged		
Average Across Bodies	No		

FIGURE 4
Model (B4) > Static Structural (B5) > Solution (B6) > Total Deformation

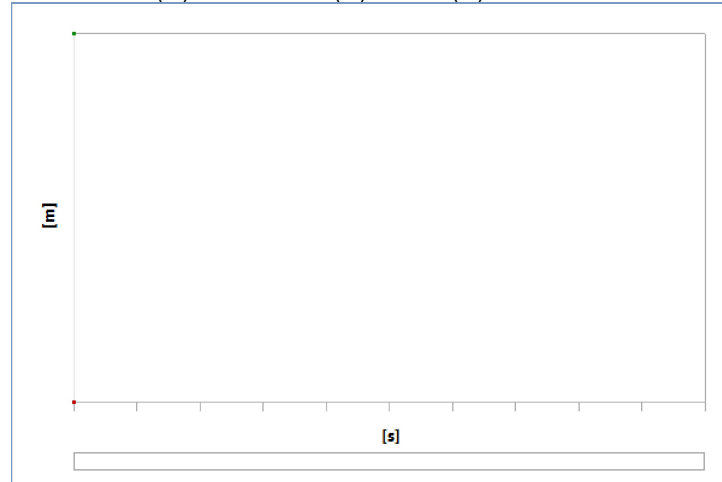


TABLE 24
Model (B4) > Static Structural (B5) > Solution (B6) > Total Deformation

Time [s]	Minimum [m]	Maximum [m]
1.	0.	2.5718e-004

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

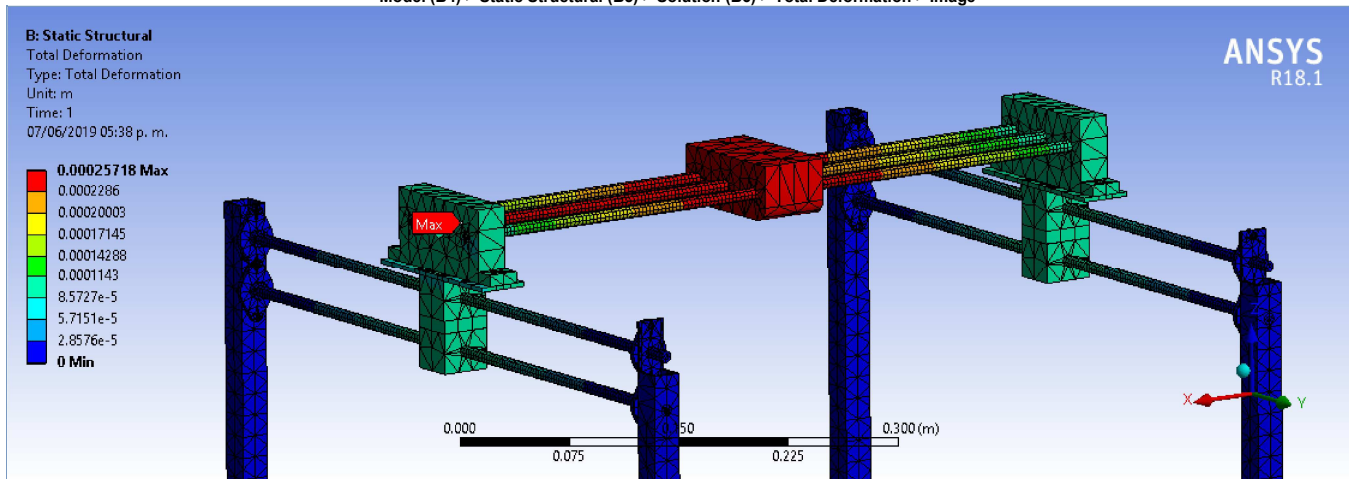


FIGURE 6
Model (B4) > Static Structural (B5) > Solution (B6) > Equivalent Elastic Strain

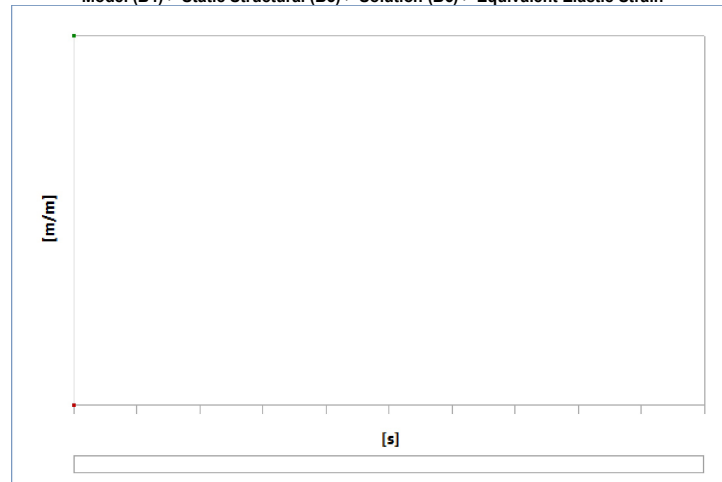


TABLE 25
Model (B4) > Static Structural (B5) > Solution (B6) > Equivalent Elastic Strain

Time [s]	Minimum [m/m]	Maximum [m/m]
1.	0.	4.45e-004

FIGURE 7
Model (B4) > Static Structural (B5) > Solution (B6) > Equivalent Elastic Strain > Image

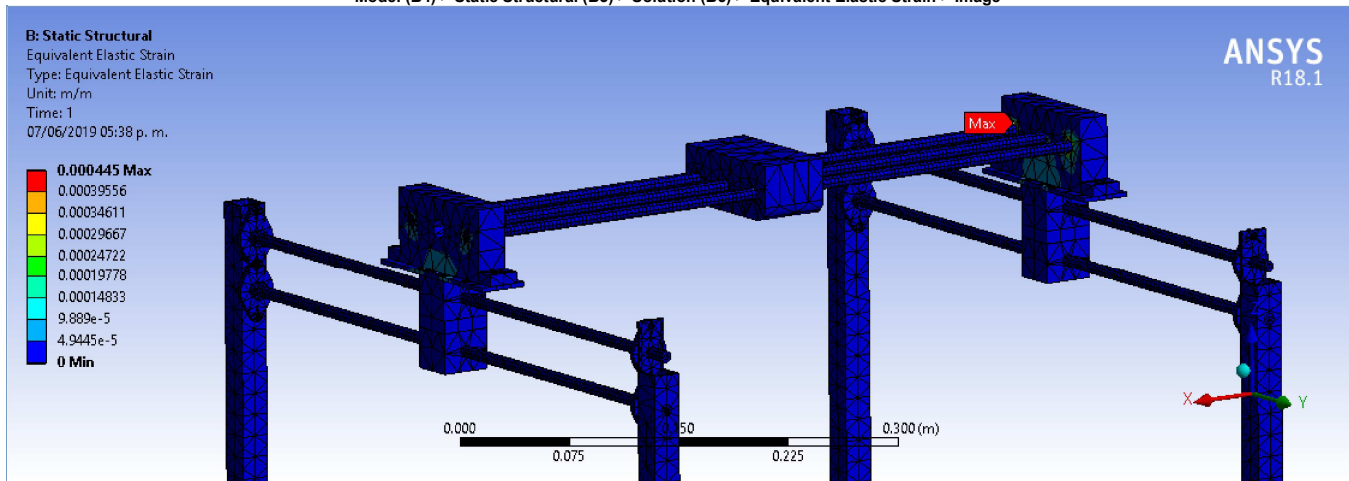


FIGURE 8
Model (B4) > Static Structural (B5) > Solution (B6) > Equivalent Stress

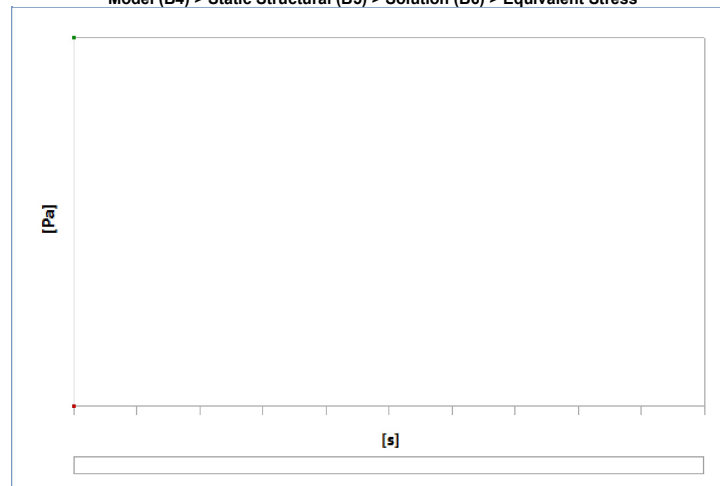
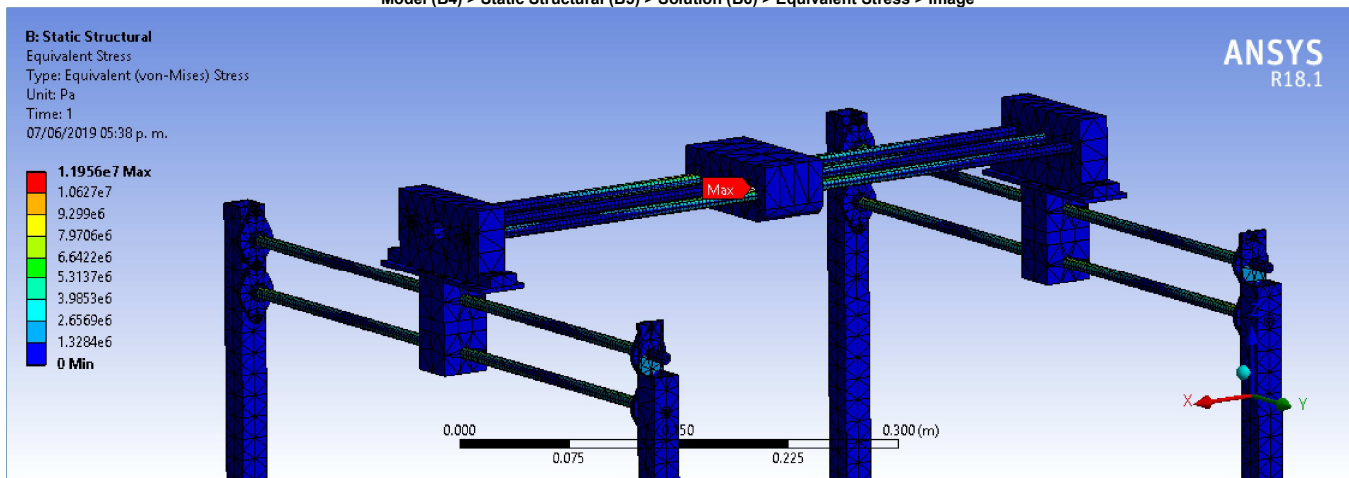


TABLE 26
Model (B4) > Static Structural (B5) > Solution (B6) > Equivalent Stress

Time [s]	Minimum [Pa]	Maximum [Pa]
1.	0.	1.1956e+007

FIGURE 9
Model (B4) > Static Structural (B5) > Solution (B6) > Equivalent Stress > Image



Material Data

Polyethylene

TABLE 27
Polyethylene > Constants

Density	950 kg m ⁻³
Isotropic Secant Coefficient of Thermal Expansion	2.3e-004 C ⁻¹
Specific Heat	2300 J kg ⁻¹ C ⁻¹
Isotropic Thermal Conductivity	0.28 W m ⁻¹ C ⁻¹

TABLE 28
Polyethylene > Appearance

Red	Green	Blue
130	154	176

TABLE 29
Polyethylene > Compressive Ultimate Strength

Compressive Ultimate Strength Pa
0

TABLE 30
Polyethylene > Compressive Yield Strength

Compressive Yield Strength Pa
0

TABLE 31
Polyethylene > Tensile Yield Strength

Tensile Yield Strength Pa
2.5e+007

TABLE 32
Polyethylene > Tensile Ultimate Strength

Tensile Ultimate Strength Pa
3.3e+007

TABLE 33
Polyethylene > Isotropic Secant Coefficient of Thermal Expansion

Zero-Thermal-Strain Reference Temperature C
22

TABLE 34 Polyethylene > Isotropic Elasticity				
Temperature C	Young's Modulus Pa	Poisson's Ratio	Bulk Modulus Pa	Shear Modulus Pa
	1.1e+009	0.42	2.2917e+009	3.8732e+008

Structural Steel

TABLE 35
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 36
Structural Steel > Appearance

Red	Green	Blue
132	139	179

TABLE 37
Structural Steel > Compressive Ultimate Strength

Compressive Ultimate Strength Pa
0

TABLE 38
Structural Steel > Compressive Yield Strength

Compressive Yield Strength Pa
2.5e+008

TABLE 39
Structural Steel > Tensile Yield Strength

Tensile Yield Strength Pa
2.5e+008

TABLE 40
Structural Steel > Tensile Ultimate Strength

Tensile Ultimate Strength Pa
4.6e+008

TABLE 41
Structural Steel > Isotropic Secant Coefficient of Thermal Expansion

Zero-Thermal-Strain Reference Temperature C
22

TABLE 42
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 43
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 44
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 45
Structural Steel > Isotropic Relative Permeability

Relative Permeability
10000

Aluminum Alloy

TABLE 46
Aluminum Alloy > Constants

Density	2770 kg m^-3
Isotropic Secant Coefficient of Thermal Expansion	2.3e-005 C^-1
Specific Heat	875 J kg^-1 C^-1

TABLE 47
Aluminum Alloy > Appearance

Red	Green	Blue
138	104	46

TABLE 48
Aluminum Alloy > Compressive Ultimate Strength

Compressive Ultimate Strength Pa
0

TABLE 49
Aluminum Alloy > Compressive Yield Strength

Compressive Yield Strength Pa
2.8e+008

TABLE 50
Aluminum Alloy > Tensile Yield Strength

Tensile Yield Strength Pa
2.8e+008

TABLE 51
Aluminum Alloy > Tensile Ultimate Strength

Tensile Ultimate Strength Pa
3.1e+008

TABLE 52
Aluminum Alloy > Isotropic Secant Coefficient of Thermal Expansion

Zero-Thermal-Strain Reference Temperature C
22

TABLE 53
Aluminum Alloy > Isotropic Thermal Conductivity

Thermal Conductivity W m^-1 C^-1	Temperature C
114	-100
144	0
165	100
175	200

TABLE 54
Aluminum Alloy > Alternating Stress R-Ratio

Alternating Stress Pa	Cycles	R-Ratio
2.758e+008	1700	-1
2.413e+008	5000	-1
2.068e+008	34000	-1
1.724e+008	1.4e+005	-1
1.379e+008	8.e+005	-1
1.172e+008	2.4e+006	-1
8.963e+007	5.5e+007	-1
8.274e+007	1.e+008	-1
1.706e+008	50000	-0.5
1.396e+008	3.5e+005	-0.5
1.086e+008	3.7e+006	-0.5
8.791e+007	1.4e+007	-0.5
7.757e+007	5.e+007	-0.5
7.239e+007	1.e+008	-0.5
1.448e+008	50000	0
1.207e+008	1.9e+005	0
1.034e+008	1.3e+006	0
9.308e+007	4.4e+006	0

8.618e+007	1.2e+007	0
7.239e+007	1.e+008	0
7.412e+007	3.e+005	0.5
7.067e+007	1.5e+006	0.5
6.636e+007	1.2e+007	0.5
6.205e+007	1.e+008	0.5

TABLE 55
Aluminum Alloy > Isotropic Resistivity

Resistivity ohm m	Temperature C
2.43e-008	0
2.67e-008	20
3.63e-008	100

TABLE 56
Aluminum Alloy > Isotropic Elasticity

Temperature C	Young's Modulus Pa	Poisson's Ratio	Bulk Modulus Pa	Shear Modulus Pa
	7.1e+010	0.33	6.9608e+010	2.6692e+010

TABLE 57
Aluminum Alloy > Isotropic Relative Permeability

Relative Permeability
1

Stainless Steel

TABLE 58
Stainless Steel > Constants

Density	7750 kg m ⁻³
Isotropic Secant Coefficient of Thermal Expansion	1.7e-005 C ⁻¹
Specific Heat	480 J kg ⁻¹ C ⁻¹
Isotropic Thermal Conductivity	15.1 W m ⁻¹ C ⁻¹
Isotropic Resistivity	7.7e-007 ohm m

TABLE 59
Stainless Steel > Appearance

Red	Green	Blue
176	154	176

TABLE 60
Stainless Steel > Compressive Ultimate Strength

Compressive Ultimate Strength Pa
0

TABLE 61
Stainless Steel > Compressive Yield Strength

Compressive Yield Strength Pa
2.07e+008

TABLE 62
Stainless Steel > Tensile Yield Strength

Tensile Yield Strength Pa
2.07e+008

TABLE 63
Stainless Steel > Tensile Ultimate Strength

Tensile Ultimate Strength Pa
5.86e+008

TABLE 64
Stainless Steel > Isotropic Secant Coefficient of Thermal Expansion

Zero-Thermal-Strain Reference Temperature C
22

TABLE 65
Stainless Steel > Isotropic Elasticity

Temperature C	Young's Modulus Pa	Poisson's Ratio	Bulk Modulus Pa	Shear Modulus Pa
	1.93e+011	0.31	1.693e+011	7.3664e+010

TABLE 66
Stainless Steel > Isotropic Relative Permeability

Relative Permeability
1