UNIVERSIDAD POLITÉCNICA
DE LA ZONA METROPOLITANA DE GUADALAJARA

SEGUNDO AVANCE

Ingeniería Mecatrónica 9°B

Integrantes:

Curiel Sánchez Héctor David

Fernández Gaeta Uriel

García Camacho Jesús Alberto

Gomez Medina Jesús Carlos

Salcedo González Alondra

Mtro. Morán Garabito Carlos Enrique

25 de junio del 2019

Dinámica y control de robots

Introducción

El robot cartesiano o también el robot de coordenadas cartesianas es un tipo de robot industrial de tres ejes. Son más simples, pues su programación y configuración trabaja con menos parámetros, y económicos ya que están más limitados en sus funciones que otros robots industriales, pero dependiendo del trabajo a realizar son una buena opción como por ejemplo para realizar dibujos o recoger diversos materiales.

Objetivo general

Realizar diferentes tareas con el robot como: mover objetos de un punto a otro; usarlo como router 3D, láser o herramientas de corte; usarlo como grua cazamuñecos.

Objetivos específicos

- Diseñar las piezas móviles por medio del uso de software de CAD (SolidWorks y ANSYS).
- Estudiar los esfuerzos físicos por medio de simulaciones en ANSYS.
- Construir el mecanismo tomando en cuenta los cálculos de los esfuerzos obtenido de las simulaciones.
- Programar los movimientos del robot por medio de la tarjeta Freescale.
- Hacer pruebas antes de la entrega final para corregir cualquier inconveniente.

Justificación

Representar una oportunidad para realizar un proyecto el cual nos beneficiará, adquiriendo nuevos conocimientos y de igual manera nos permitirá posteriormente utilizarlo para desarrollar nuevos proyectos a futuro.

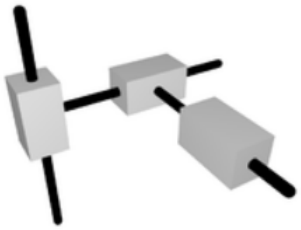
Marco Teórico

Un robot de coordenadas cartesianas (también llamado robot cartesiano) es un robot industrial cuyos tres ejes principales de control son lineales (se mueven en línea recta en lugar de rotar) y forman ángulos rectos unos respecto de los otros. Además de otras características, esta configuración mecánica simplifica las ecuaciones en el control de los brazos robóticos.

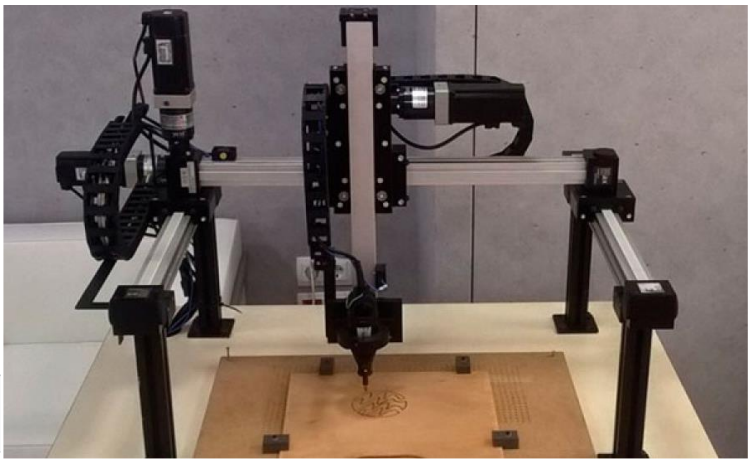
Los robots de coordenadas cartesianas con el eje horizontal limitado y apoyado en sus extremos se denominan robots pórtico y normalmente son bastante grandes.

Una aplicación muy extendida para este tipo de robots es la máquina de control numérico (CN). Las aplicaciones más sencillas son las usadas en las máquinas de fresado o dibujo, donde un taladro o pluma se traslada a lo largo de un plano x-y mientras la herramienta sube y baja sobre la superficie para crear un preciso diseño. Para terminar una breve descripción de las diferentes partes que conforman un robot cartesiano:

- Guía de movimiento: Por rodillos, si el movimiento debe ser rápido o por bolas, si la carga es pesada.
- La trasmisión del robot cartesiano se realiza mediante: Correa dentada para mayores distancias y rapidez y el husillo, más lentas que las anteriores.
- Motores para el accionamiento del movimiento de los ejes del robot cartesiano: Servomotores y el motor paso a paso.
- La presión es uniforme en todo el espacio de trabajo.
- Apto para seguir una trayectoria previamente especificada.
- No resulta adecuada para puntos situados en espacios cerrados.



Esquema cinemático de un robot cartesiano



Materiales y presupuesto

Cantidad	*Material*	*Precio*
3	Motores NEMA 17.	1050
4	Sensores de final de carrera.	80
3	Husillo de 500mm x 8mm.	300
4	Varilla de acero inoxidable de 500mm x 8mm.	400
10	Escuadra de zinc.	150
4	Tubo cuadrado de acero.	0
50	Tornillo y tuerca M5.	100
10	Tornillo M3.	50
2	Camisa de acero inoxidable.	100
4	Chumacera de zinc.	100
2	Base para motor NEMA 17.	100
2	Acoplamiento para husillo y varilla.	50
1	Base de movimiento de eje.	50
1	Pinza.	150
1	Eje de movimiento para pinza.	1200
4	Driver para motor A4988.	200
Varios	Cables de conexión.	100
1	Base de madera	200
	Freescale kl46z	700
	Total:	$5080

Cronograma

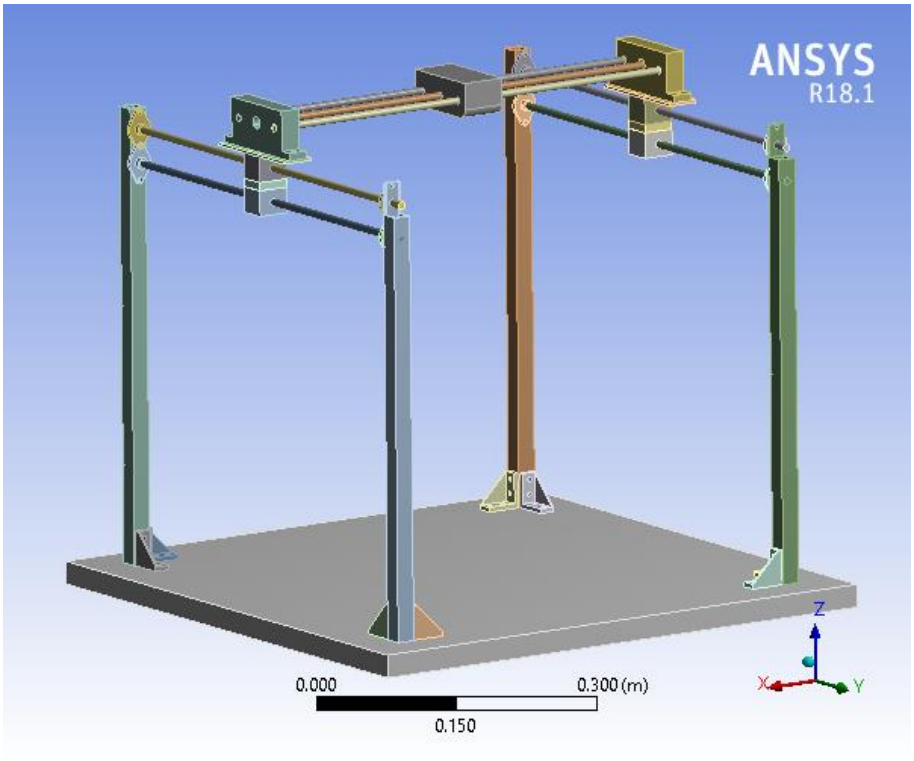
Tarea	Febrero				Marzo				Abril	
	1° Semana	2° Semana	3° Semana	4° Semana	1° Semana	2° Semana	3° Semana	4° Semana	1° Semana	2° Semana
Búsqueda del material	+++ +++ +++									
Investigación		++++ ++++	++++ ++++							
Cotizar material				++++ ++++						
Conseguir material					++++ ++++	++++ ++++				
Armar el circuito							++++ ++++	++++ ++++	+++ +++ ++	+++++ +++

9° Cuatrimestre	Mayo		Junio		Julio				Agosto
	2° Semana	3° y 4° Semana	1° y 2° Semana	3° Semana	4° Semana	1°Semana	2°semana	3°Semana	4° Semana	1° Semana
Detalles a resolver	+++ +++ ++	++++ ++++	++++ ++++	++++ ++++						
Prueba y error corregidos					++++ ++++	++++ ++++	++++ ++++	++++ ++++	+++ +++ ++	
Finaliza proyecto										+++++ +++

Cálculos y simulación

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

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\jesus\Documents\Ansys\Analisis_CNC_files\dp0\Geom\DM\Geom.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_estructura2\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						Structural Steel
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	2.e-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	2.e-002 m
Length Z	2.5e-002 m	0.5 m	3.8e-002 m						0.5 m
Properties									
Volume	9.2946e-003 m³	6.893e-005 m³	6.7313e-006 m³						6.8923e-005 m³
Mass	8.8299 kg	0.5411 kg	1.8646e-002 kg						0.54104 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	0.26966 m	-0.20834 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	-0.26068 m	0.24038 m
Centroid Z	0.61 m	0.85993 m	0.63451 m								0.85992 m
Moment of Inertia Ip1	0.27408 kg·m²	1.0164e-002 kg·m²	4.0618e-006 kg·m²								1.0164e-002 kg·m²
Moment of Inertia Ip2	0.27408 kg·m²	1.0164e-002 kg·m²	1.6329e-006 kg·m²								1.0164e-002 kg·m²
Moment of Inertia Ip3	0.54725 kg·m²	5.9048e-005 kg·m²	4.6632e-006 kg·m²								5.9047e-005 kg·m²
Statistics											
Nodes	30069	4807	709								4897
Elements	5718	2319	298								2363
Mesh Metric	None										
CAD Attributes											
PartTolerance:	0.00000001										
Color: 143.149.175											

TABLE 4
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*	*CNC_husillo\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						Stainless Steel
Nonlinear Effects	Yes								
Thermal Strain Effects	Yes								
Bounding Box									
Length X	2.e-002 m		2.7e-002 m						8.e-003 m
Length Y	2.e-002 m		9.e-003 m						0.5 m
Length Z	0.5 m		4.5001e-002 m						8.e-003 m
Properties									
Volume	7.2632e-005 m³	7.2626e-005 m³	3.0961e-006 m³						2.5132e-005 m³
Mass	0.57016 kg	0.57012 kg	8.5763e-003 kg						0.19477 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
Centroid Y	-0.2595 m		-0.24702 m		0.22807 m		-0.24702 m	0.22807 m	5.2894e-004 m
Centroid Z	0.87244 m	0.87242 m	1.1 m				1.063 m		1.1 m
Moment of	1.1828e-002 kg·m²	1.1825e-002 kg·m²	8.1629e-007 kg·m²						4.0381e-

Inertia Ip1				003 kg·m²
Moment of Inertia Ip2	1.1828e-002 kg·m²	1.1826e-002 kg·m²	3.6663e-007 kg·m²	4.0381e-003 kg·m²
Moment of Inertia Ip3	6.222e-005 kg·m²	6.2217e-005 kg·m²	1.1271e-006 kg·m²	1.5425e-006 kg·m²
Statistics				
Nodes	5148	5135	598	9322
Elements	2488	2477	250	1760
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*	*CNC_camisa\Solid1*	*CNC_camisa\Solid1*	*CNC_camisa\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		Aluminum Alloy	
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		3.5e-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		3.e-002 m	
Length Z	8.e-003 m		9.8527e-003 m	8.e-003 m			5.2e-002 m		2.8e-002 m	
Properties										
Volume	2.5132e-005 m³						1.0705e-004 m³		2.6576e-005 m³	
Mass	0.19477 kg						0.10169 kg		7.3615e-002 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	0.29167 m	-0.20833 m
Centroid Y	5.2894e-004 m	2.5497e-002 m	-4.1503e-002 m	5.2894e-004 m		-8.0034e-003 m			-7.4875e-003 m	
Centroid Z	1.1 m	1.148 m		1.063 m	1.148 m		1.1418 m		1.0999 m	1.0629 m
Moment of Inertia Ip1	4.0381e-003 kg·m²						2.9057e-005 kg·m²		1.0328e-005 kg·m²	
Moment of Inertia Ip2	4.0381e-003 kg·m²						9.2566e-005 kg·m²		1.3214e-005 kg·m²	
Moment of Inertia Ip3	1.5425e-006 kg·m²						1.1344e-004 kg·m²		1.3262e-005 kg·m²	
Statistics										
Nodes	9322						1522		2812	
Elements	1760						775		1728	
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

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 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 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	Geometry Selection										

Method							
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	Program Controlled						

Region	
Geometric Modification	
Contact Geometry Correction	None
Target Geometry Correction	None

TABLE 12
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\Solid 1	CNC_estructura2\Solid 1			CNC_estructura3\Solid 1			CNC_estructura4\Solid 1			CNC_chumacera\Solid 1
Target Bodies	CNC_estructura4\Solid 1	CNC_chumacera\Solid 1	CNC_husillo\Solid 1		CNC_chumacera\Solid 1	CNC_husillo\Solid 1		CNC_chumacera\Solid 1	CNC_husillo\Solid 1		CNC_chumacera\Solid 1
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*	*Contact Region 44*

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*	*Contact Region 66*
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_placa\Solid1	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	Program Controlled									

Stiffness	
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

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\Documents\Ansys\Analisis_CNC_files\dp0\SYS\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 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

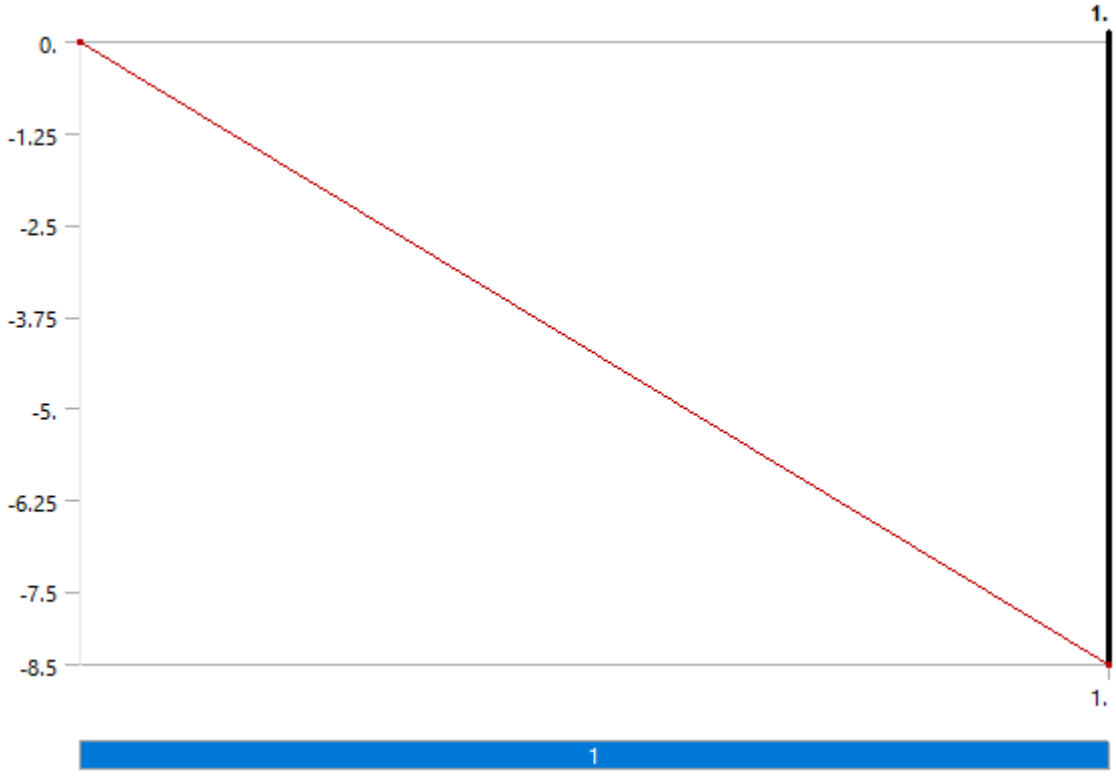


FIGURE 2
Model (B4) > Static Structural (B5) > Force 2

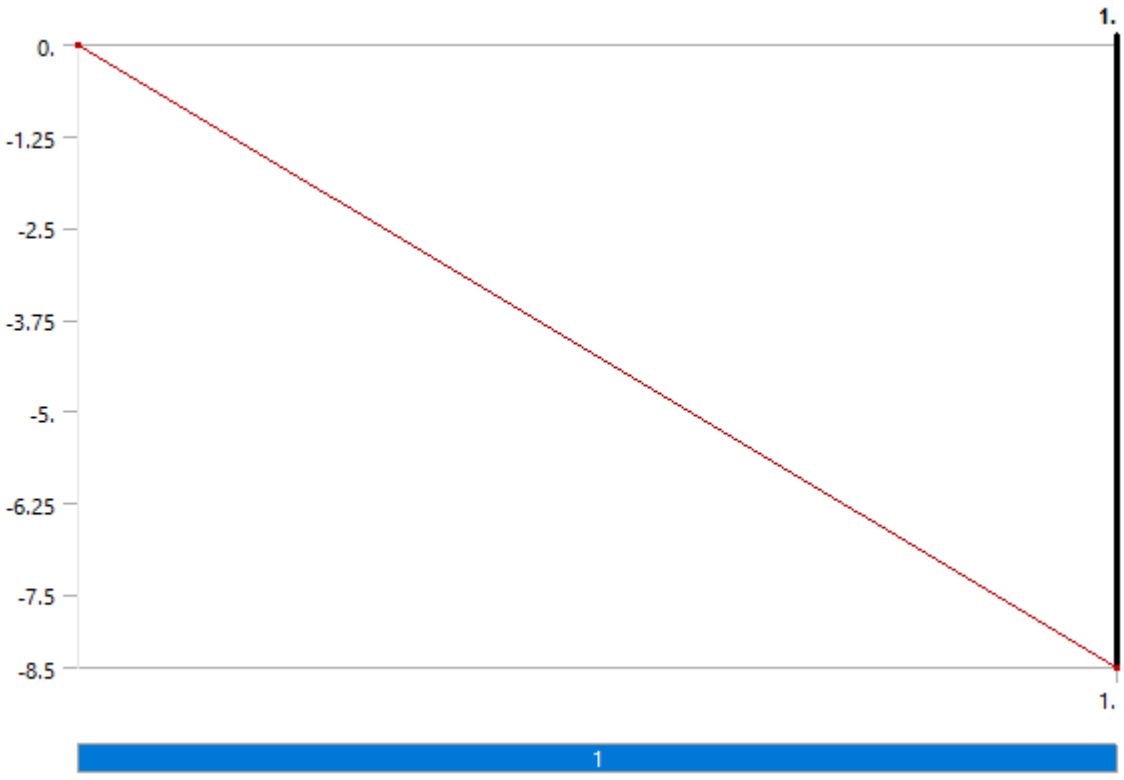
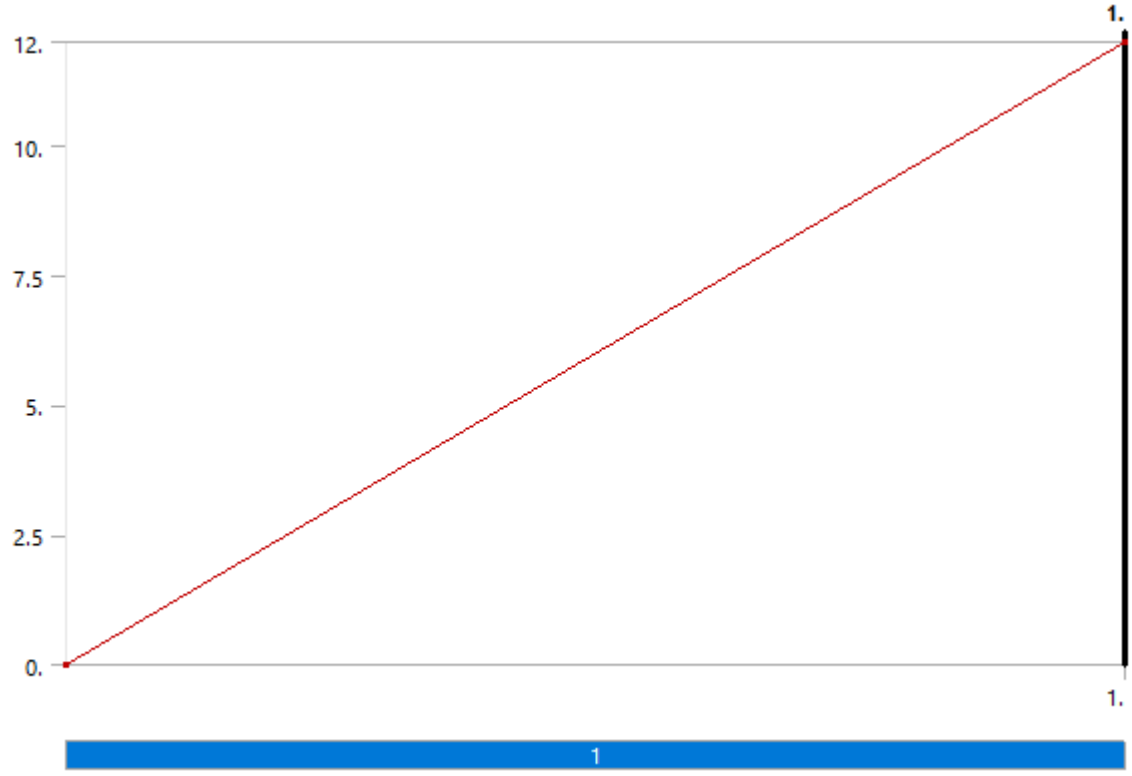


FIGURE 3
Model (B4) > Static Structural (B5) > Force 3



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

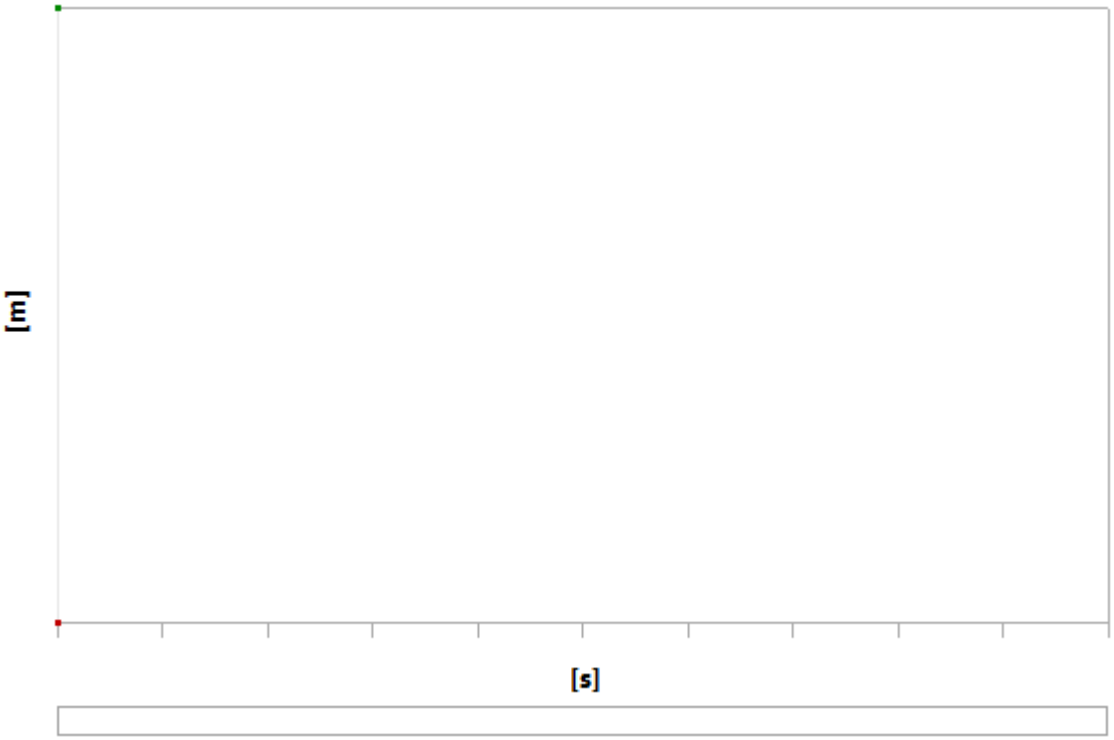


TABLE 24
Model (B4) > Static Structural (B5) > Solution (B6) > Total Deformation

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

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

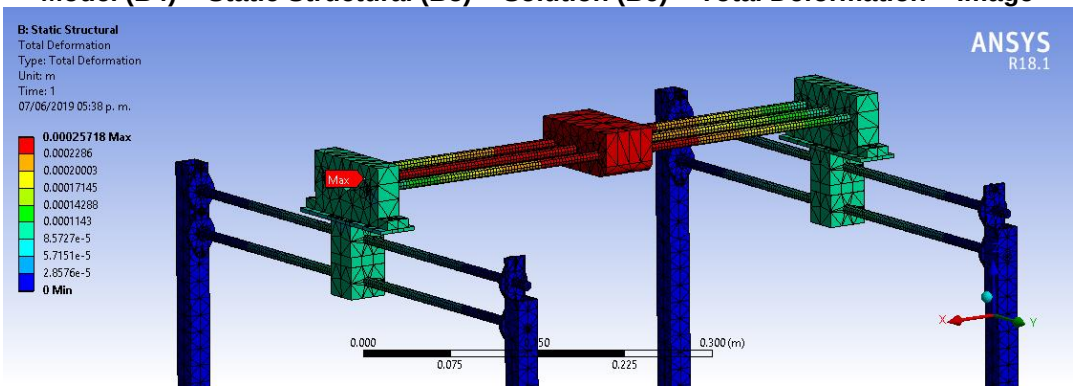


FIGURE 6
Model (B4) > Static Structural (B5) > Solution (B6) > Equivalent Elastic Strain

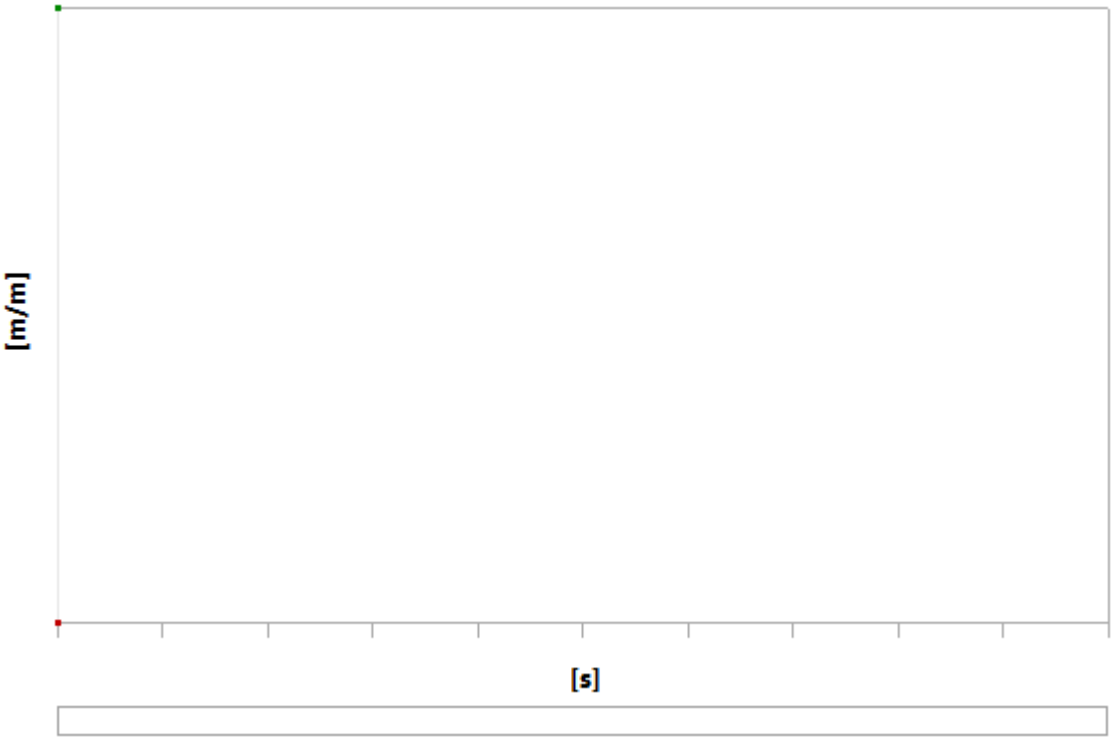


TABLE 25
Model (B4) > Static Structural (B5) > Solution (B6) > Equivalent Elastic Strain

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

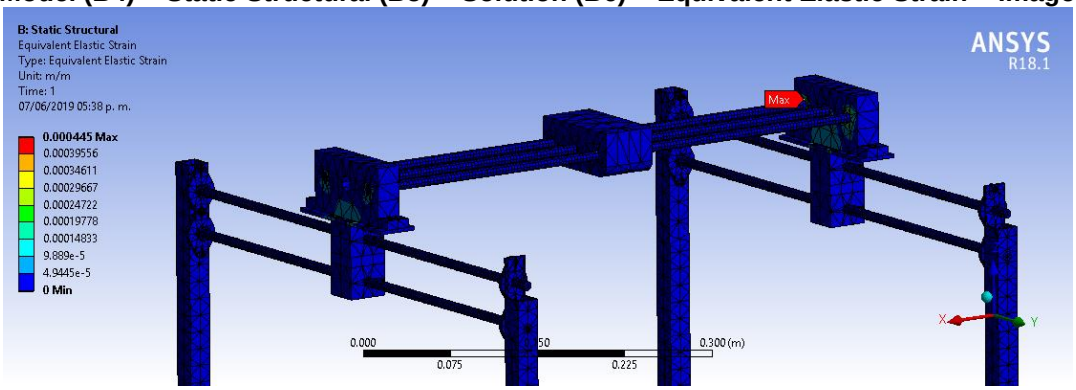


FIGURE 8
Model (B4) > Static Structural (B5) > Solution (B6) > Equivalent Stress

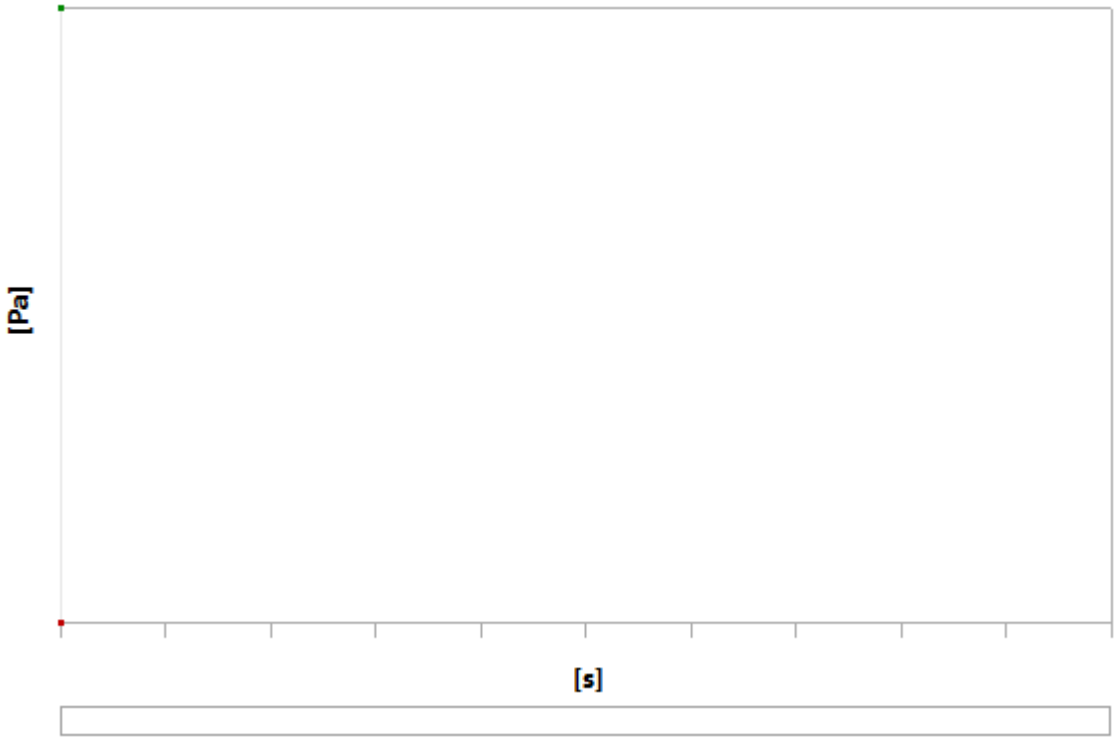
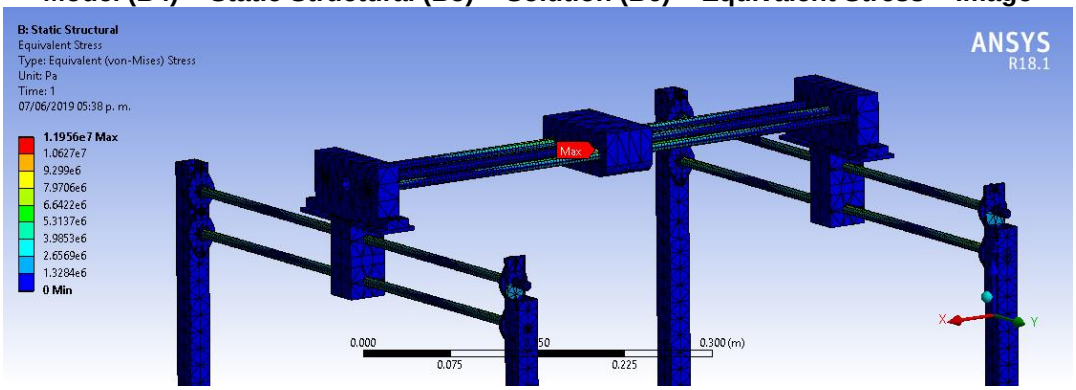


TABLE 26
Model (B4) > Static Structural (B5) > Solution (B6) > Equivalent Stress

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

Bibliografía

- López Segovia, J. L., Alamilla Santiago, M., & Domínguez Vázquez, J. F. (2007). Robot Cartesiano: seguimiento de trayectorias irregulares arbitrarias mediante computadora. Recuperado de https://www.uaeh.edu.mx/docencia/Tesis/icbi/licenciatura/documentos/Robot%20cartesiano%20seguimiento%20de%20trayectorias.pdf
- Robot cartesiano - Robótica, paletizadores y Pick and Place. (2015, 23 octubre). Recuperado 21 mayo, 2019, de http://www.mekkam.com/robotica-industrial/robot-cartesiano/