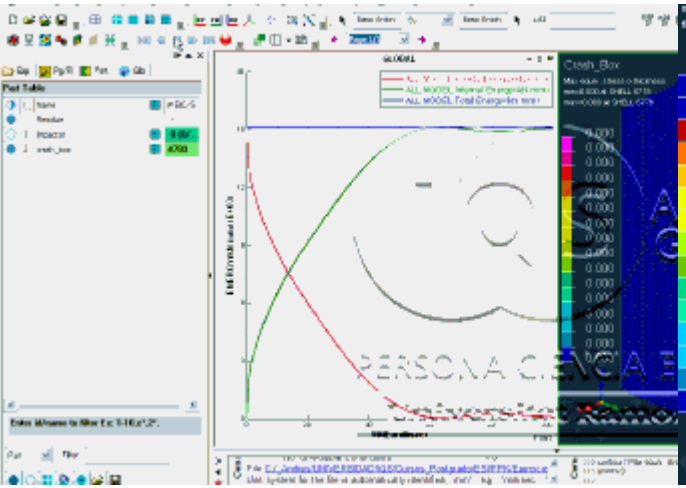
S01t.- Introducción curso ANSYS.

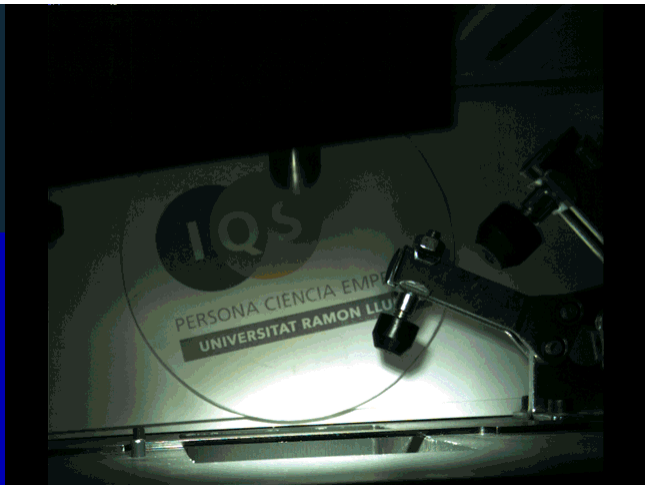
Mejora 2122…

- Presentación profesor

Dr. Andrés-Amador García Granada

- Ingeniero industrial por ETSEIB UPC especialidad Mecánica de Estructuras (1996) y PhD University of Bristol (2000)
- Ha trabajado siempre en temas de simulación en EDAG, SEAT y AUDI entre otras en las que realizaba las simulaciones y ensayos de choques con la creación de la base de materiales para poder llevarlos a cabo.
- Desde el 2007 trabaja como profesor en IQS siendo jefe de departamento de ingeniería industrial desde octubre de 2018.





• Presentación curso

- Necesidades de espacio para frenar un impacto. Diferencia entre impacto elástico y plástico. Discusión sobre la rotura. Comportamiento del material a compresión o flexión. Vibraciones, Pandeo, Influencia de temperatura, Creep.
- Obtención de curvas de material para estimar espacios y hacer simulaciones. Tratamiento de ensayo a tracción y de flexión. Ensayo charpy.
- Modelos de material disponibles en ANSYS Diferencias entre cálculos explícitos e implícitos. Unidades coherentes. Importancia de la malla y del time step. Mallado SHELL. Posibilidades de pre-procesador industrial como ANSA.
- Cálculo de costes con SolidWorks Costing y Topology optimisation.
- Cálculos de impacto, vibraciones, rigidez, creep.
- Resumen de curso introductorio para centrar las necesidades en un curso práctico avanzado si se considerara necesario.

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• Presentación curso

- La formación, con un total de 10h, será 100% online a repartir en 5 sesiones de 2horas cada una.

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- Test inicial

Test comparativo crash

*Obligatorio

Nombre y Apellidos *

Tu respuesta

Email de contacto *

Tu respuesta

¿Cuántos [km/h] equivalen a 5[m/s]?

Tu respuesta

¿Qué energía cinética tiene un paquete de 20[kg] que cae a 5[m/s]?

Tu respuesta

5[m/s]*3600[s/h]/1000[m/km]= 18[km/h] 9de9

$m*v^2/2=20[kg]*5^2/2[m^2/s^2]=250[N.m] =250[J]$ 9de9

$v=\sqrt{(2gh)}= \sqrt{(2*10*1.25)}=5[m/s]$ 8de9

$t=v/a=5/100=0.05[s]$ 8de9

$s=at^2/2=v^2/(2a)=5^2/(2*100)=0.125[m]$ 4de9

Estiramos $0.01/100=0.0001$ y por tanto $\sigma=E\varepsilon=200000[MPa]*0.0001=20[MPa]$ no plastifica
$F=\sigma A=20*10*1=200[N]$ 3de9

Estiramos $1/100=0.01$ y por tanto $\sigma=E\varepsilon=200000[MPa]*0.01=2000[MPa]$ que plastifica y por tanto plastifica $\sigma=200[MPa]$
$F=\sigma A=200*10*1=2000[N]$ 0de9

¿Qué velocidad impacta un paquete que cae desde 1.25[m] de altura sin rozamientos considerando g=10[m/s^2]?

Tu respuesta

¿Cuánto tiempo tarda un paquete en pasar de 5m/s a 0 si se le aplica una aceleración constante de 100[m/s^2]?

Tu respuesta

¿Cuánto espacio necesitamos para parar un paquete y pasar de 5m/s a 0 si se le aplica una aceleración constante de 100[m/s^2]?

Tu respuesta

Si tenemos una pieza de acero que plastifica a 2000MPa de forma perfecta con Lx=100 x Ly=10 x Lz=1[mm] y estiramos en x 0.01mm ¿Qué fuerza aplicamos?

Tu respuesta

Si tenemos una pieza de acero que plastifica a 200MPa de forma perfecta con Lx=100 x Ly=10 x Lz=1[mm] y estiramos en x 1mm ¿Qué fuerza aplicamos?

$E=kx^2/2=1000000*(0.001)^2/2=0.5[J]$ 6de9

En un muelle de k=1000000[N/m] ¿Qué energía almacena al comprimir 1[mm]

Tu respuesta

Encontrar propiedades de molded pulp es difícil, En [1]el módulo de Young es aproximadamente 1200[MPa] mientras [2]da la curva entera plastificando a unos 20[MPa] 0de9.

Dar el módulo de Young de molded pulp

Tu respuesta

0.1/0.0001=1000 pasos de cálculo 2de9

Para calcular 0.1[s] con un time step de 0.1[us] ¿Cuántos pasos de cálculo necesito?

Tu respuesta

Para hacer algo de un espesor de 1[mm] como sólido el tamaño de malla es muy pequeño y el time step pequeño y número de elementos Elevado impide que acabe el cálculo. 1de9

¿Por que usan modelo 2D tipo SHELL en simulaciones de automoción, trenes, aeronautica?

Tu respuesta

[1] https://www.researchgate.net/publication/347339887_The_impact_of_molded_pulp_product_process_on_the_mechanical_properties_of_molded_BCTMP/fulltext/5fe13c44299bf140883332cf/The-impact-of-molded-pulp-product-process-on-the-mechanical-properties-of-molded-BCTMP.pdf

[2] https://www.researchgate.net/publication/339505304_Poisson%27s_ratios_of_molded_pulp_materials_by_digital_image_correlation_method_and_uniaxial_tensile_test

Dar el time step estable para una malla de 1[mm] de acero

Según [3]el incremento se calcula: 0de9

$$\Delta t \leq \min\left(L_e\sqrt{\frac{\rho}{\hat{\lambda}+2\hat{\mu}}}\right) \quad \Delta t = kL\sqrt{\delta / E}$$

k	[-]	1	1	1	0.9
		Steel	Aluminium	PP-LGF	Steel
E	[GPa]	210	70	3	210
d	[kg/mm^3]	7.85E-06	2.80E-06	1.04E-06	7.85E-06
Time_step_for_L10	[µs]	1.93E+00	2.00E+00	5.89E+00	1.74E+00
Time_step_for_L5	[µs]	9.67E-01	1.00E+00	2.94E+00	8.70E-01
L_for_time_1µs	[mm]	5.17E+00	5.00E+00	1.70E+00	5.75E+00
L_for_time_0.5µs	[mm]	2.59E+00	2.50E+00	8.49E-01	2.87E+00

(1)https://www.researchgate.net/publication/347339887_The_impact_of_molded_pulp_product_process_on_the_mechanical_properties_of_molded_BCTMP/fulltext/5fe13c44299bf140883332cf/The-impact-of-molded-pulp-product-process-on-the-mechanical-properties-of-molded-BCTMP.pdf
(2)https://www.researchgate.net/publication/339505304_Poisson%27s_ratios_of_molded_pulp_materials_by_digital_image_correlation_method_and_uniaxial_tensile_test
(3) https://abaqus-docs.mit.edu/2017/English/SIMACAEANLRefMap/simaanl-c-expdynamic.htm

• Ejemplo inicial

Vamos a estirar 1mm una barra de 1x20x300[mm] de acero en 1[ms].
(A=20x1=20[mm2], L=300[mm])

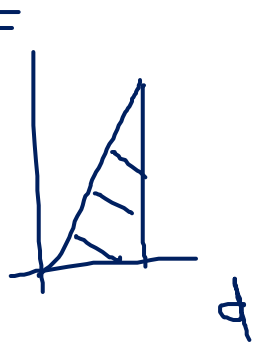
Estática: F= EADL/L

deformación: $\varepsilon=\Delta L/L=1/300=0.003333[-]=0.33\%$

tensión: $\sigma=Ee=200[GPa]*0.003333=0.6667[GPa]=666.7[MPa]$

fuerza: $F=\sigma A=666.7*20*1=13333[N]=13.33[kN]$

energía: $E=F\Delta L/2=13333*0.001/2=6.667[J]=6.667[kN\cdot mm]$



Dinámica: $F= EA\Delta L/L + ma$

aceleración: $a=2*\Delta L/(t^2)/2=1[mm/ms2]=1000[m/s2]$

masa: $m=7.85e\text{-}6[kg/mm^3]*300*20*1[mm^3]=4.71e\text{-}2[kg]$

fuerza inercial: $F_i=ma=47.1[N]$

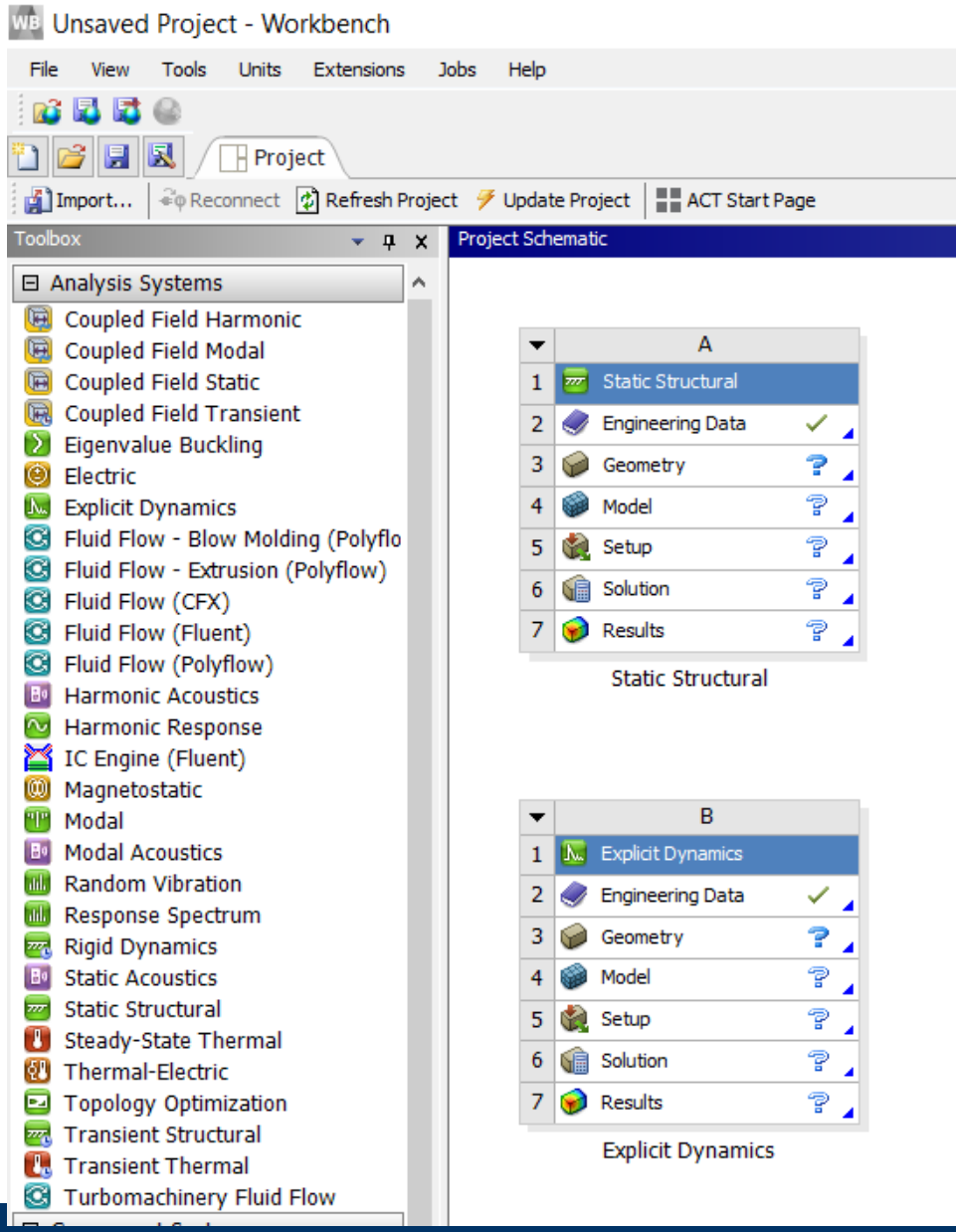
velocidad: $v=a*t=1[m/s]=1[mm/ms]$

energía cin.: $0.5*m*v^2=0.02352[J]=0.002352[kN\cdot mm]$

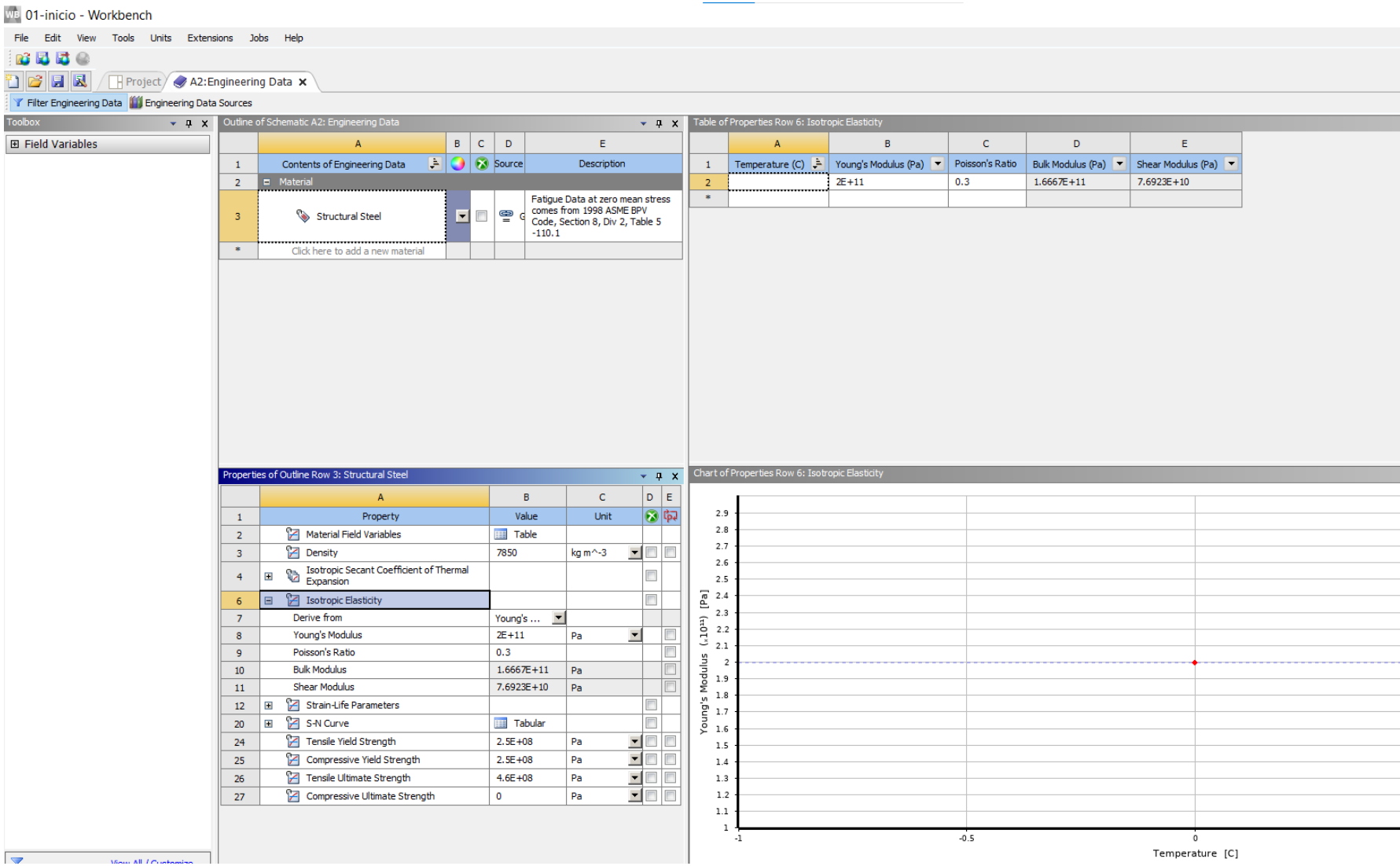
Para estas masas y aceleraciones la fuerza inercial es muy pequeña en comparación a la fuerza de deformación.

• Presentación Asignatura

Se pretende hacer un pequeño curso de uso de ANSYS Workbench comparando estática y dinámica

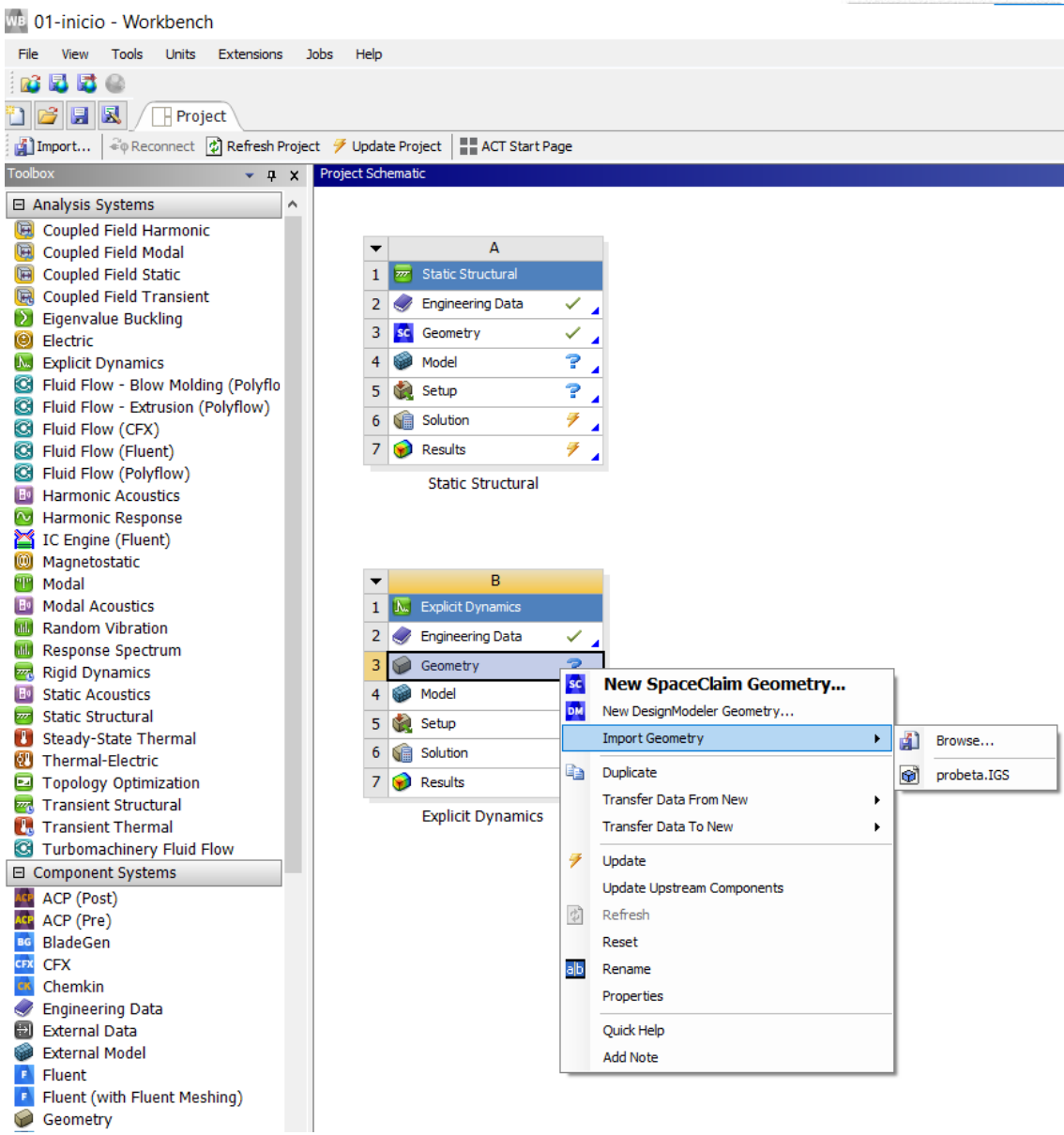


- Propiedades de material en Engineering data



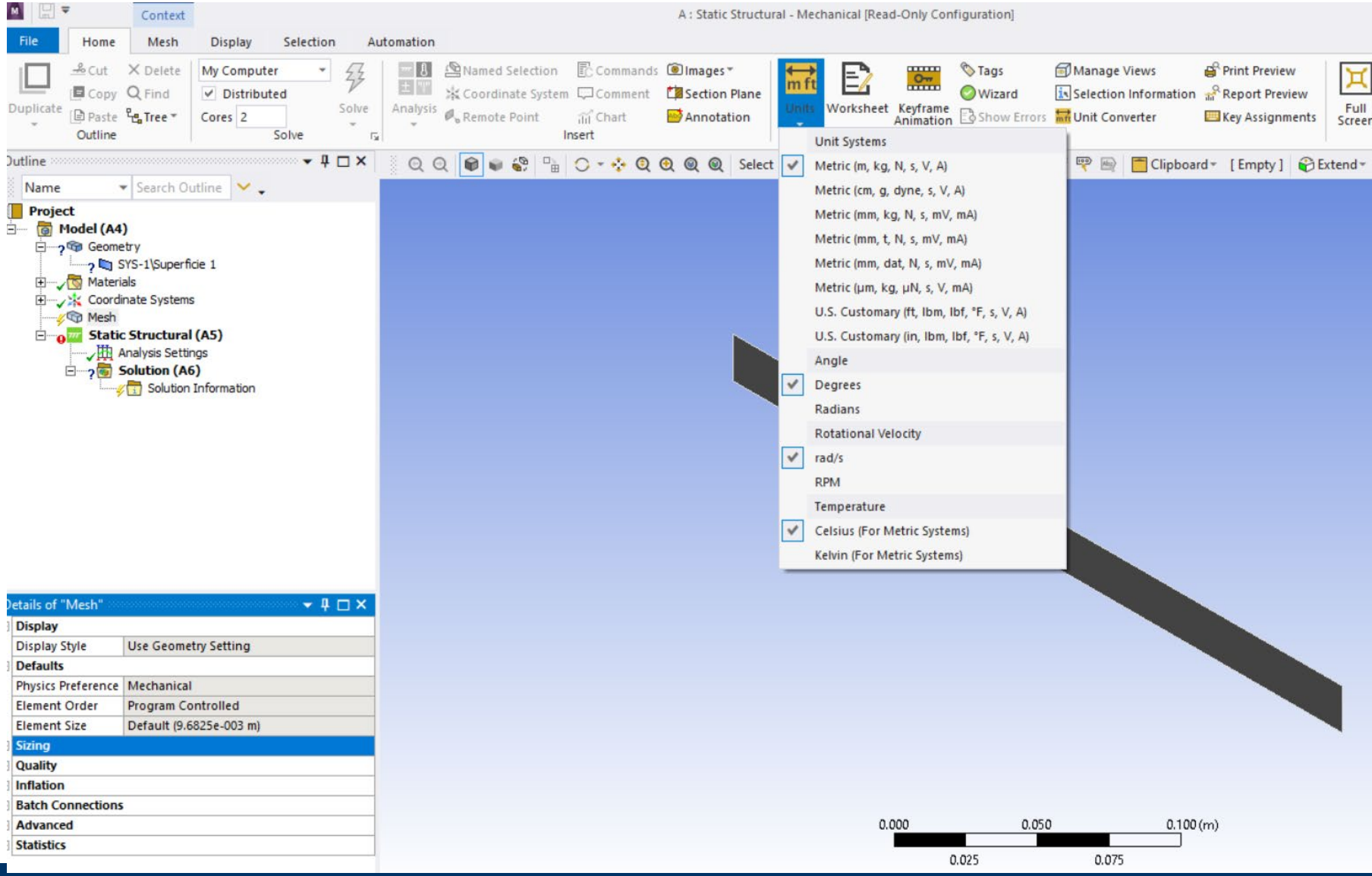
- Geometría

Importar o dibujar en SpaceClaim



- Modelo

Editar



- Unidades

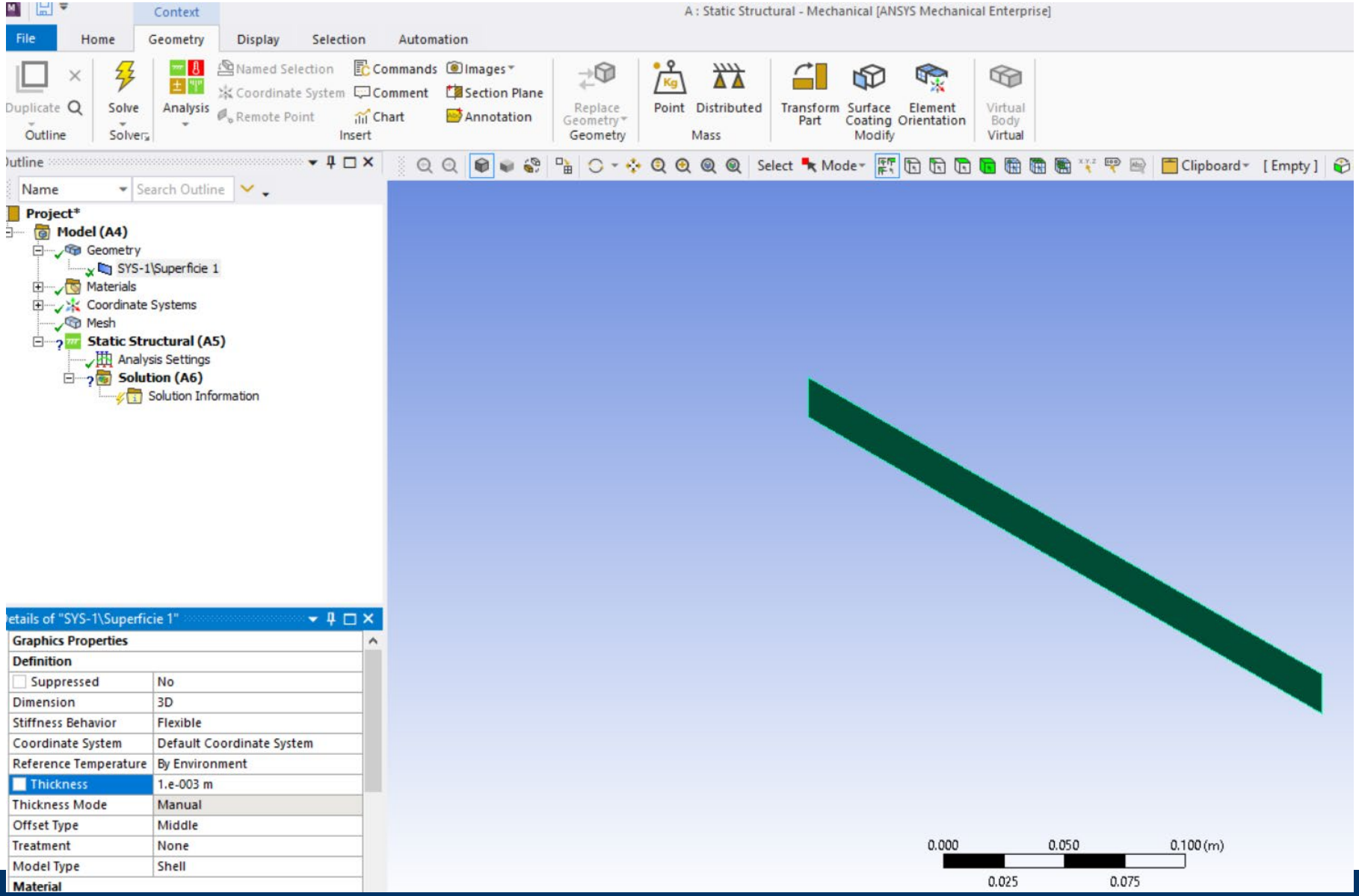
En grupo VW se utilizan las unidades marcadas en este cuadro para Implícito (Abaqus y Nastran) y explícito (PamCrash)

basic units			derived units		
LENGTH	MASS	TIME	FORCE	STRESS	ENERGY
cm	g	s	dyn=g cm/s^2	dyn/cm^2	dyn cm=erg
m	kg	s	N=kg m/s^2	N/m^2=Pa	N m=J
cm	100 kg	s	N=100 kg cm/s^2	N/cm^2=10^{-1}bar	cm
mm	ton	s	N=ton mm/s^2	N/mm^2=MPa	N mm ← implícito
mm	kg	ms	kN=kg mm/ms^2	kN/mm^2=GPa	kN mm ← explícito
mm	dton	s	kgf=9.81 ton mm/s^2	kgf/mm^2	kgf mm
cm	g	μs	10^7 N=g cm/μs^2	10^7 N/cm^2=Mbar	10^7 N cm
ft	slug	s	lbf (or pf) = slug ft/s^2	lbf/ft^2 (or pf/ft^2)	lbf ft (or pf ft),
mm	kg/G	ms	10^3 kgf=metric ton-f	9.81 GPa	9.81 kN mm

Se ha de ir con mucho cuidado al pasar los modelos de un software a otro, incluso con las cartas de materiales.

- Modelo

Editar



- Modelo

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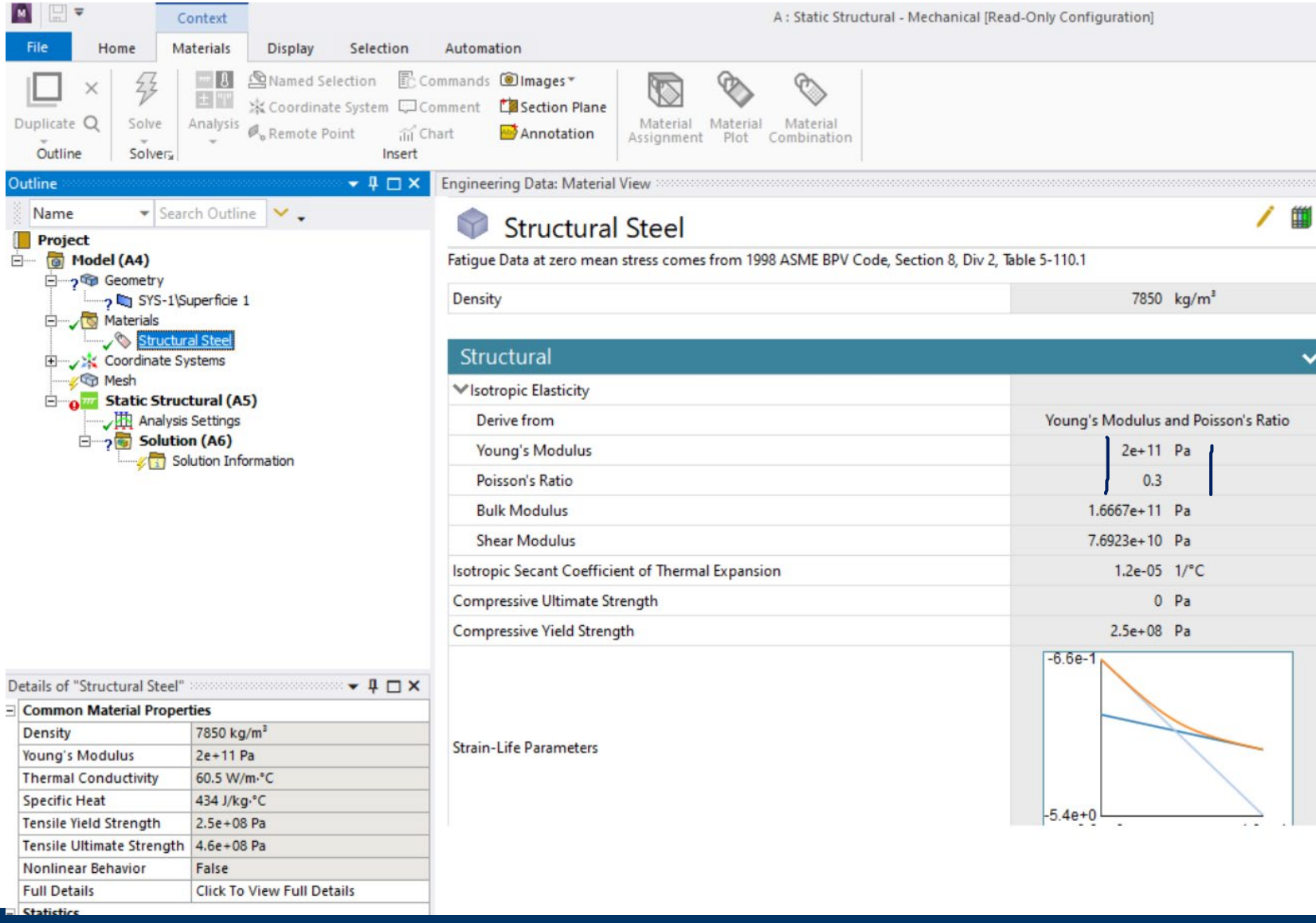
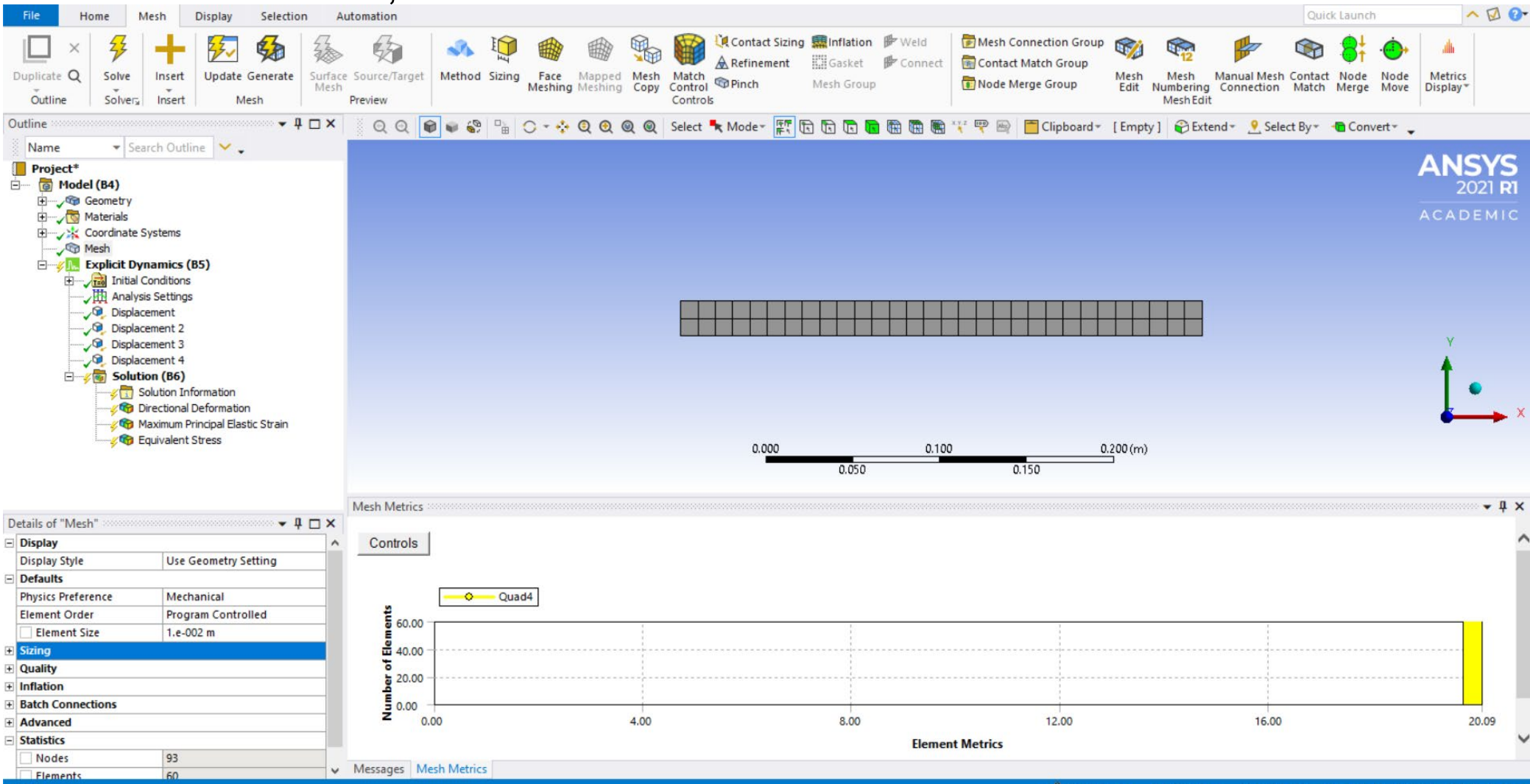


- Modelo

2x30=60elementos, 31x3=93 nodos



- Modelo

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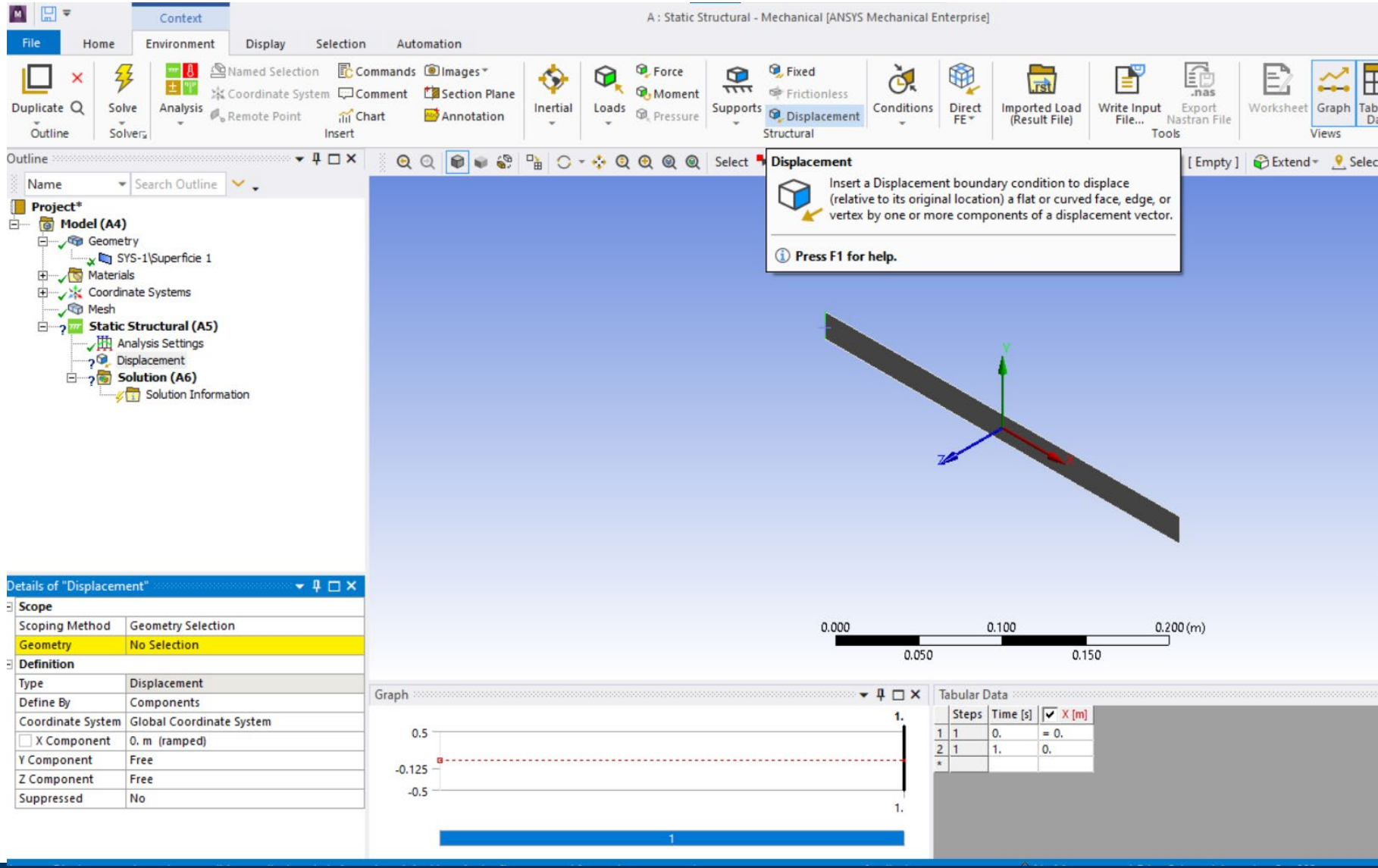

- Modelo

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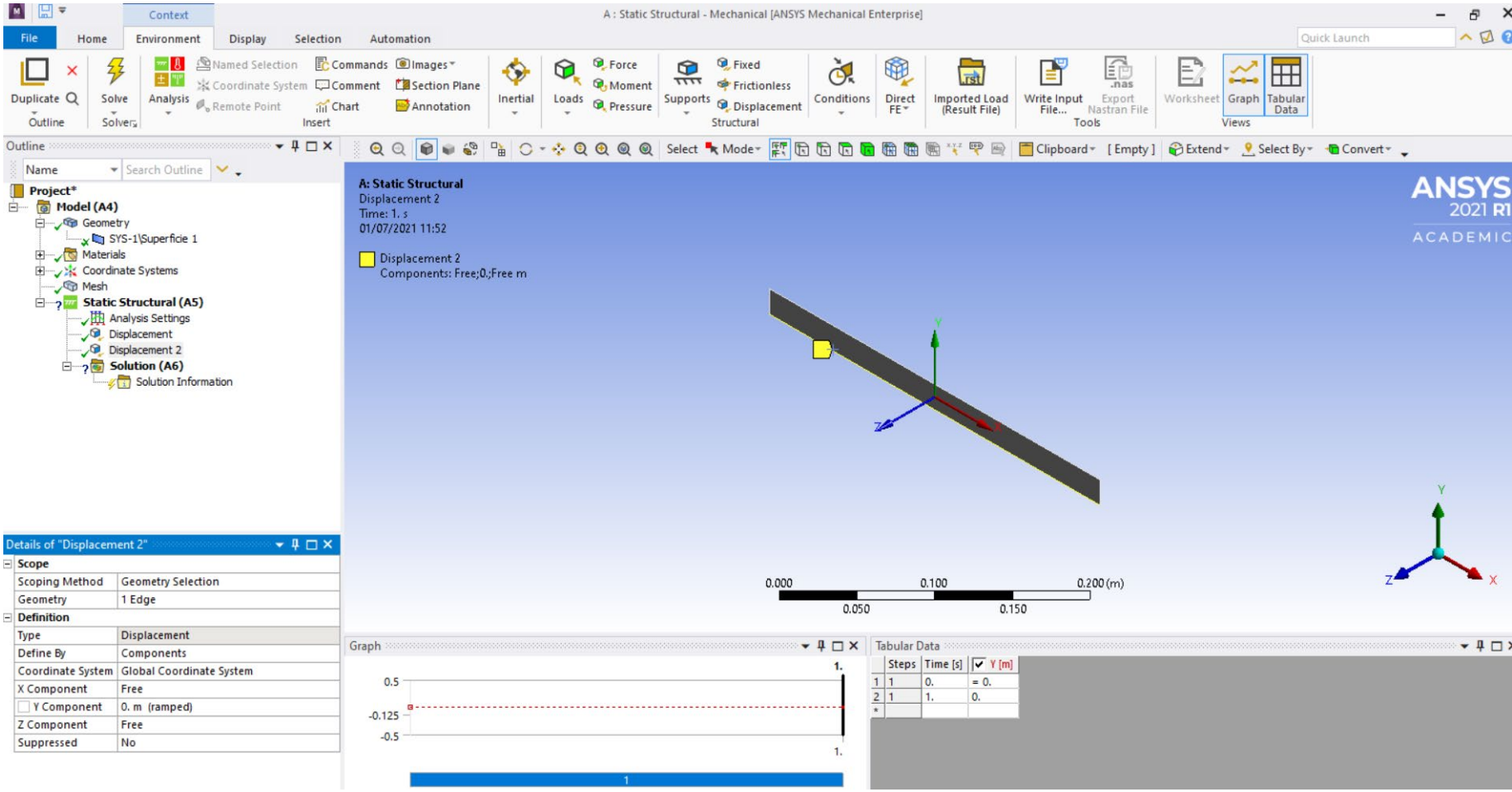

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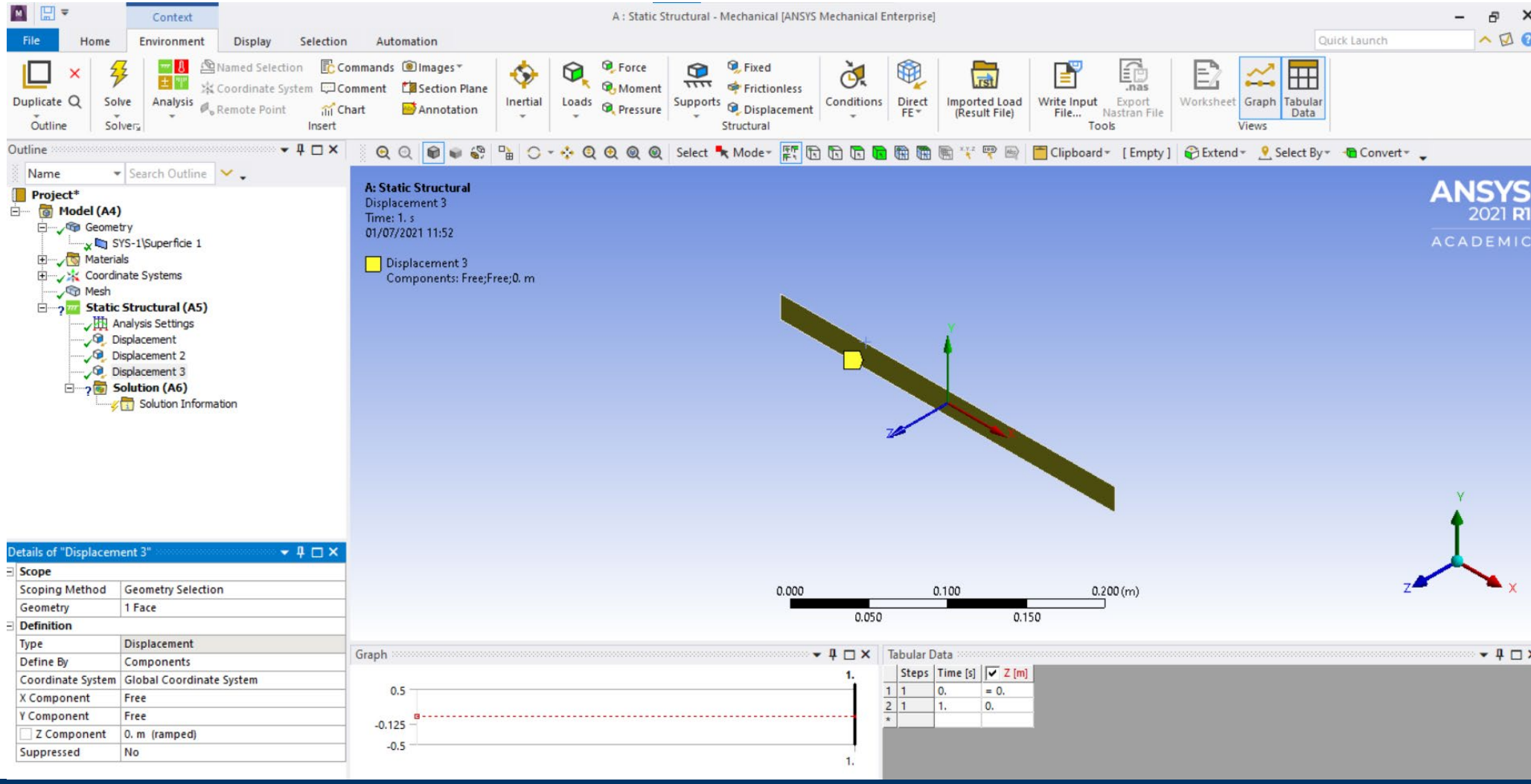

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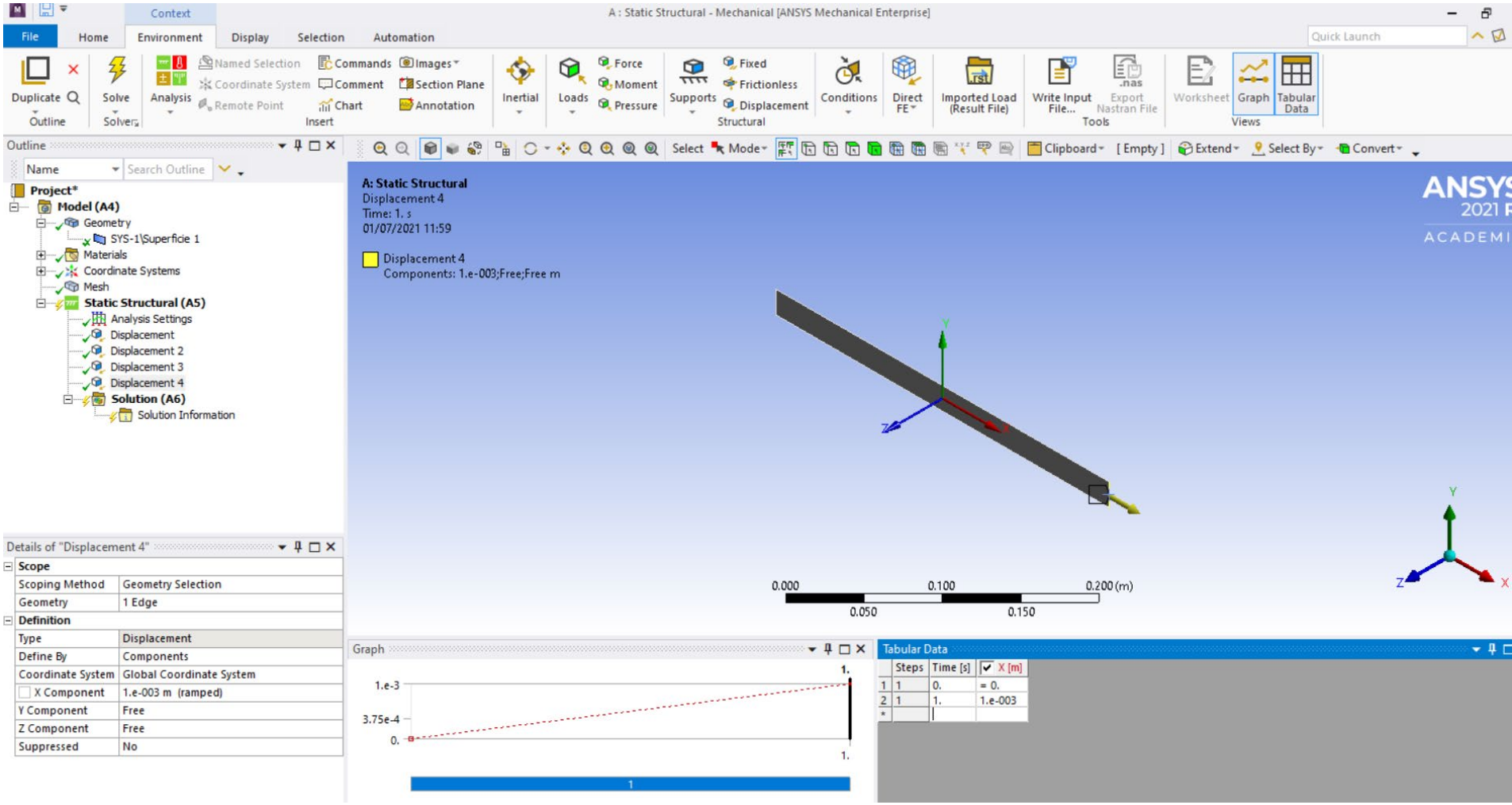

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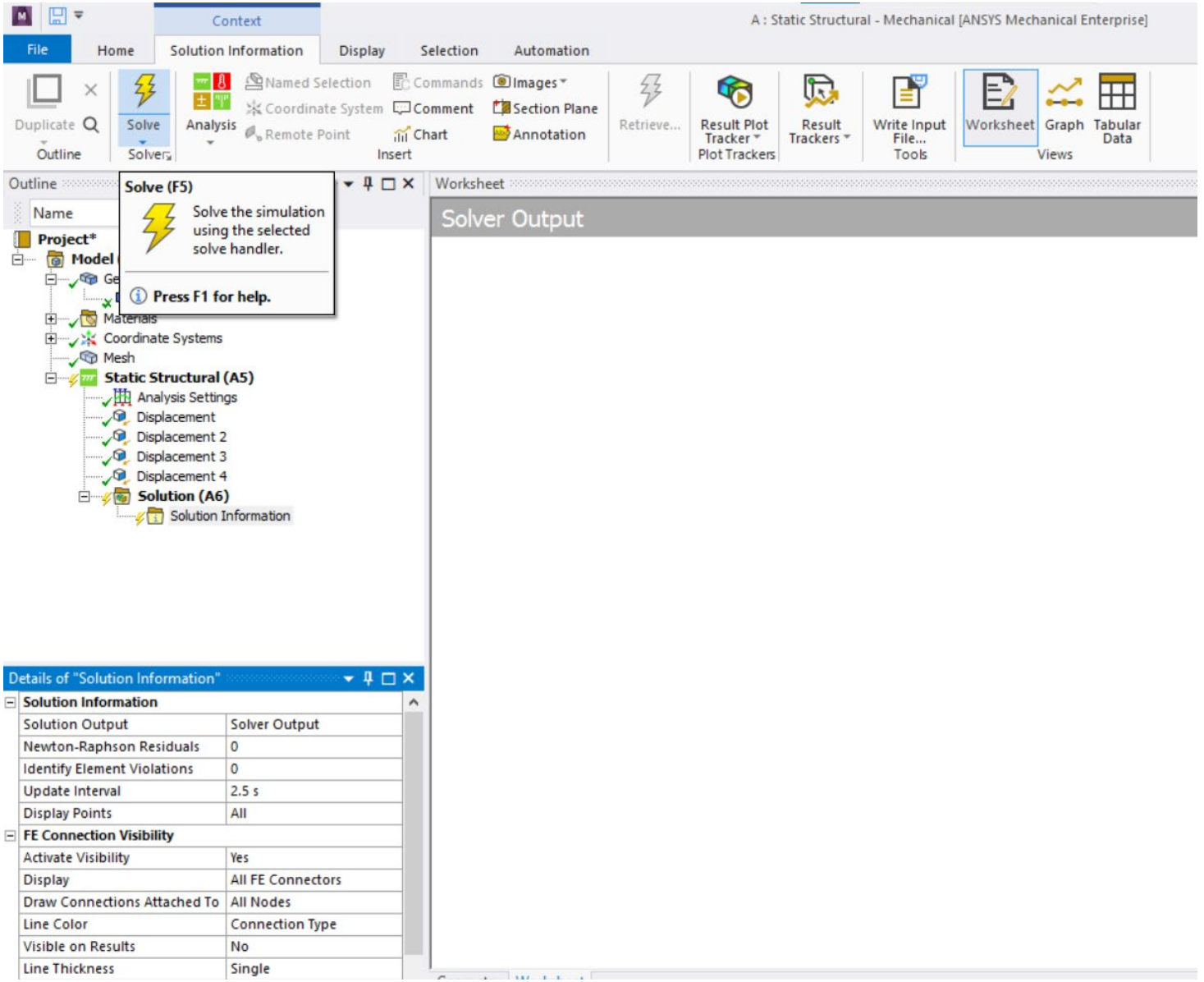

- Modelo

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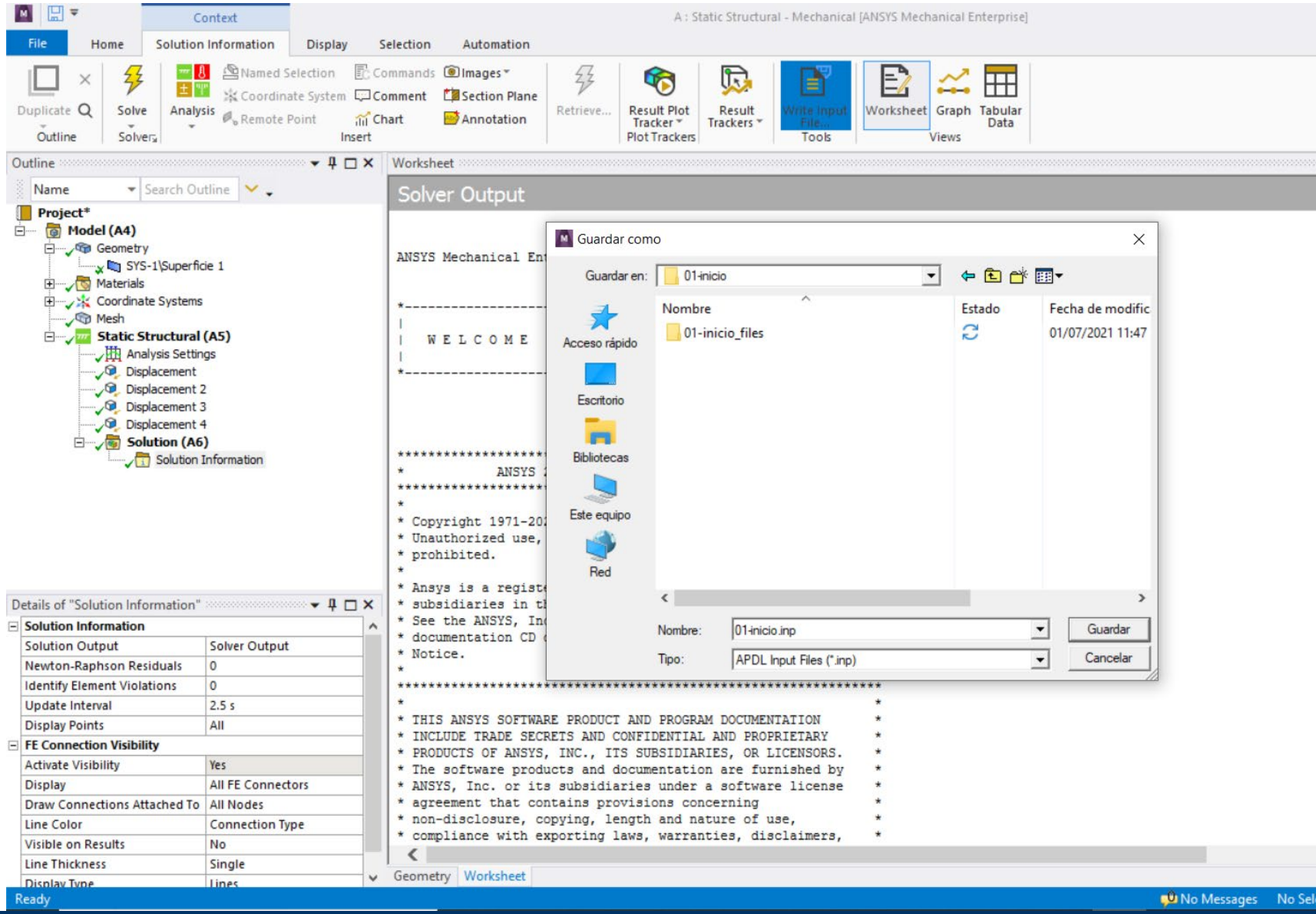


- Editar 01-inicio.inp

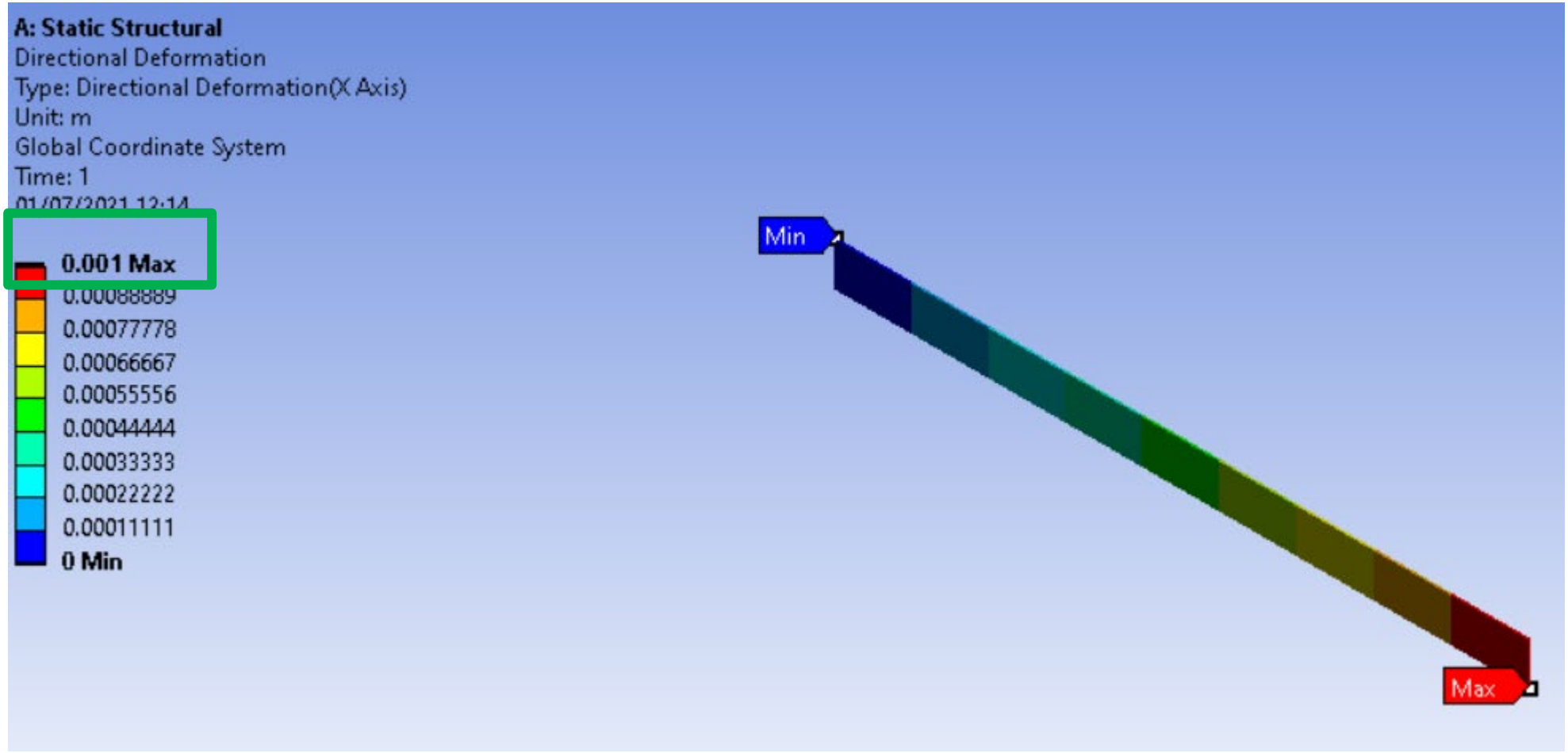
```
/batch
/config,noeldb,1     ! force off writing results to database
*get,_wallstrt,active,,time,wall
! ANSYS input file written by Workbench version 2021 R1
! File used for geometry attach: C:\Users\andres.garcia\OneDrive - IQS\ASIGNATURAS\ANSYS\01-inicio\01-inicio_files\dp0\SYS-1\DM\SYS-1.scdoc
/title,01-inicio--Static Structural (A5)
! ****** Begin Custom Load Command Snippet ******
/COM, ACT Extensions:
/COM,     LSDYNA, 2021.1
/COM,     5f463412-bd3e-484b-87e7-cbc0a665e474, wbex
/COM,
! ****** End   Custom Load Command Snippet ******
*DIM,_wb_ProjectScratch_dir,string,248
_wb_ProjectScratch_dir(1) = 'C:\Users\andres.garcia\OneDrive - IQS\ASIGNATURAS\ANSYS\01-inicio\01-inicio_files\dp0\SYS-1\MECH\'
*DIM,_wb_SolverFiles_dir,string,248
_wb_SolverFiles_dir(1) = 'C:\Users\andres.garcia\OneDrive - IQS\ASIGNATURAS\ANSYS\01-inicio\01-inicio_files\dp0\SYS-1\MECH\'
*DIM,_wb_userfiles_dir,string,248
_wb_userfiles_dir(1) = 'C:\Users\andres.garcia\OneDrive - IQS\ASIGNATURAS\ANSYS\01-inicio\01-inicio_files\user_files\'
/com,--- Data in consistent MKS units. See Solving Units in the help system for more information.
/units,MKS
/nopr
/wb,file,start              !  signify a WB generated input file
/prep7
! Turn off shape checking because checks already performed inside WB mesher.
! See help system for more information.
SHPP,OFF,,NOWARN
/nolist
etcon,set             ! allow ANSYS to choose best KEYOP's for 180x elements, resets any applicable keyopt to MAPDL defaults
/com,*********** Nodes for the whole assembly ***********
nblock,3,,105
(1i9,3e20.9e3)
        1     1.500000000E-01    -1.000000000E-02     0.000000000E+00
        2     1.500000000E-01     1.000000000E-02     0.000000000E+00
        3     1.500000000E-01     0.000000000E+00     0.000000000E+00

       95     1.306438228E-01     9.364204967E-09     0.000000000E+00
       96     1.403216358E-01     5.812327962E-09     0.000000000E+00
-1
/wb,elem,start           !  set before creation of elements
/com,*********** Elements for Body 1 "SYS-1\Superficie 1" ***********
et,1,181
keyo,1,3,2
eblock,19,solid,,62
(19i9)
        1        1        1        1        0        0        0        0        4        0        1       67       63       64       94
        1        1        1        1        0        0        0        0        4        0        2       67       68       62       63
```

- Editar 01-inicio.inp

```
      1       1       1       1       0       0       0       0       4       0      61      66       1       3      96
      1       1       1       1       0       0       0       0       4       0      62       3       2       5      96
-1
!Material Id = {B17834B5-0960-437F-8E88-2E143AC17914}
/wb,elem,end                !  done creating elements
/com,*********** Send User Defined Coordinate System(s) ***********
csys,0
toffst,273.15,  ! Temperature offset from absolute zero
/com,*********** Set Reference Temperature ***********
tref,22.
/wb,mat,start               !  starting to send materials
/com,*********** Send Materials ***********
Temperature = 'TEMP' ! Temperature
MP,DENS,1,7850, ! kg m^-3
MP,ALPX,1,1.2e-05,  ! C^-1
MP,C,1,434, ! J kg^-1 C^-1
MP,KXX,1,60.5,  ! W m^-1 C^-1
MP,RSVX,1,1.7e-07,  ! kg m^3 A^-2 s^-3
MP,EX,1,200000000000,   ! Pa
MP,NUXY,1,0.3,
MP,MURX,1,10000,

/wb,mat,end                 !  done sending materials
/com,*********** Send Sheet Properties ***********
sectype,1,shell
secdata,1.e-003
secoff,mid

!************************ Model Summary ********************
!SYS-1\Superficie 1,    Structural Steel,   matid,  1
!************************ End Model Summary ********************
! get the diagonal of the bounding box. Needed later for other things
```

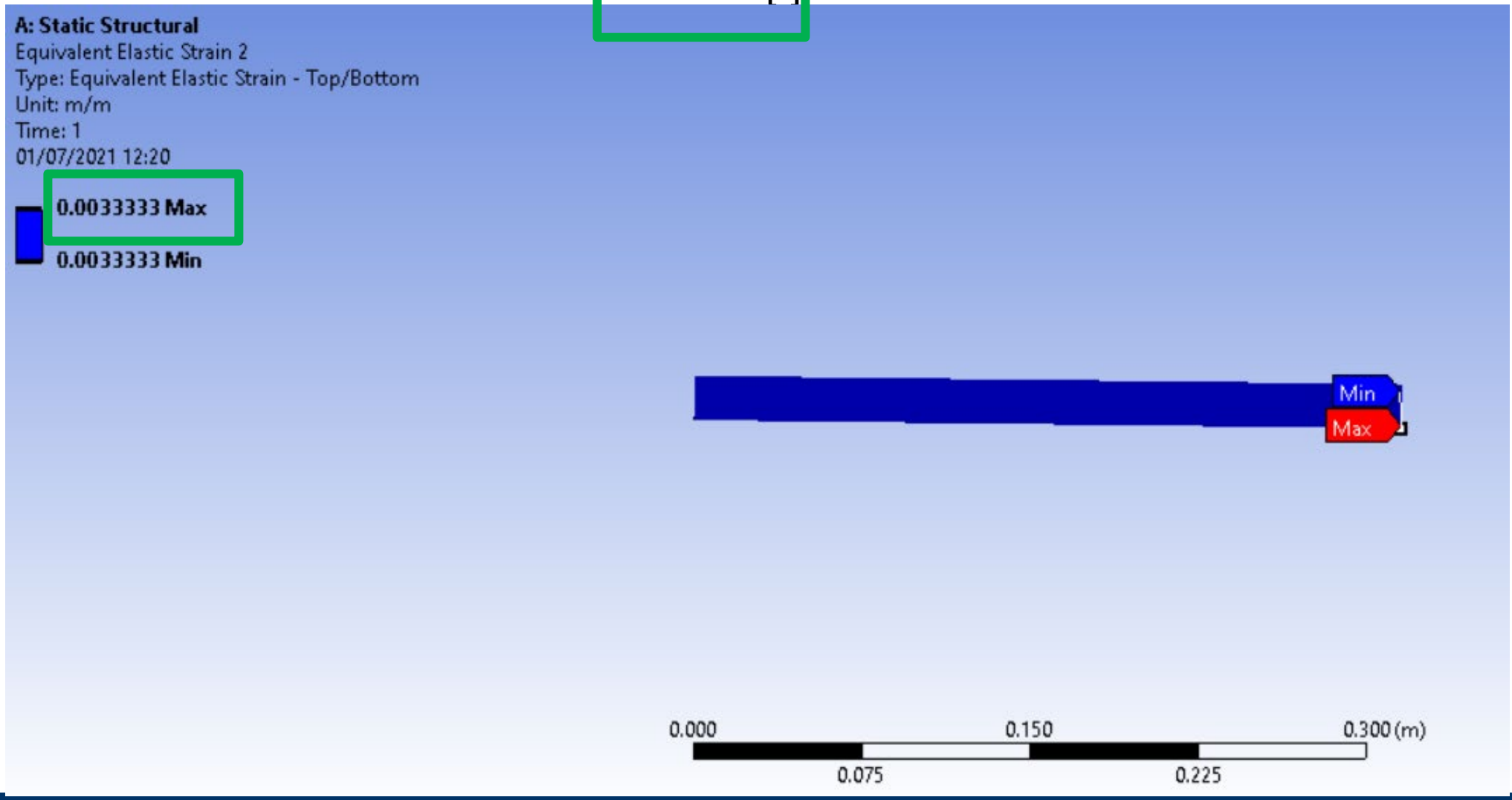
- Results

Comprobamos que hemos estirado 1mm en X como especificado **OK**



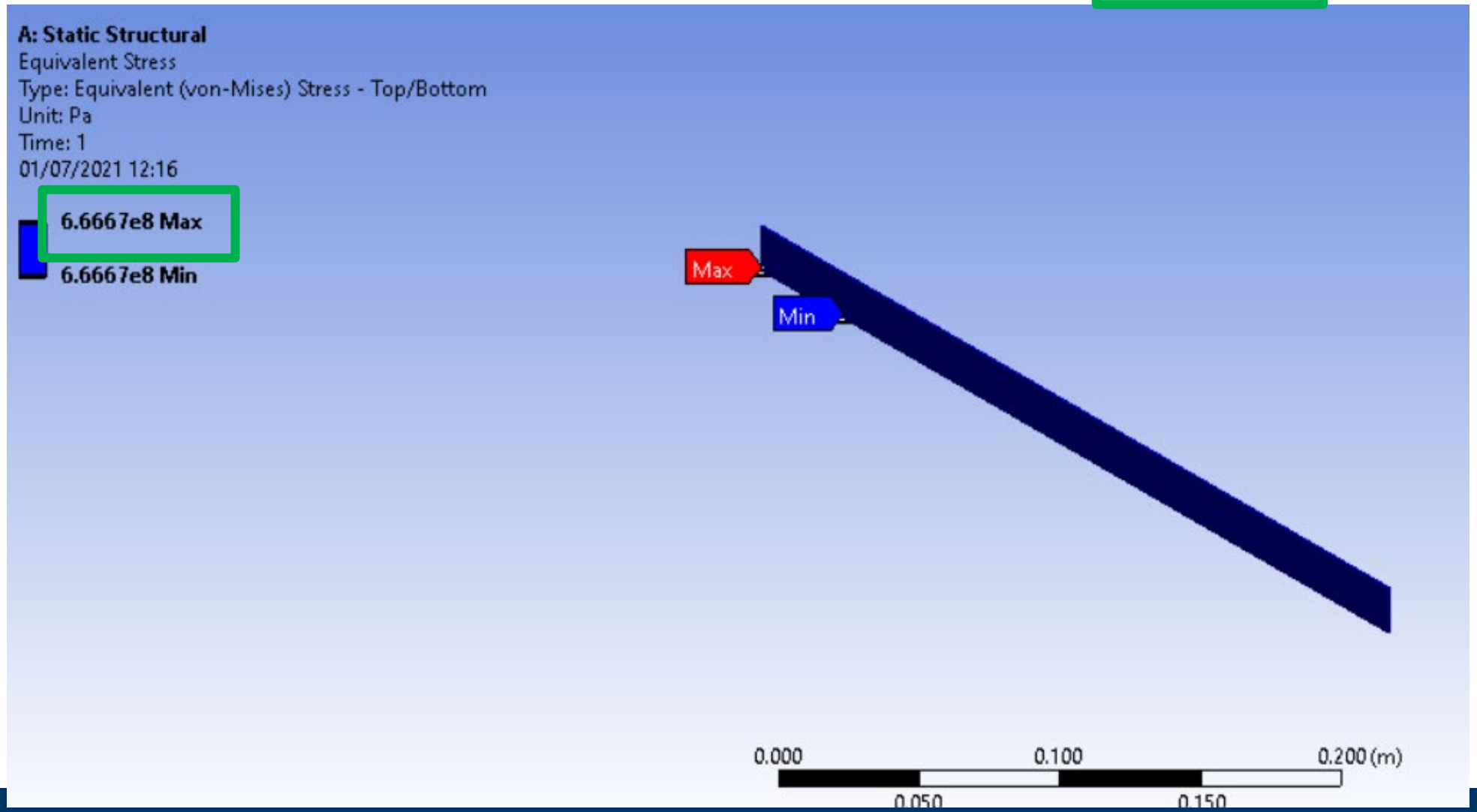
- Results

deformación: $\varepsilon=\Delta L/L=1/300=$ 0.003333[-] $=0.3333\%$ **OK**



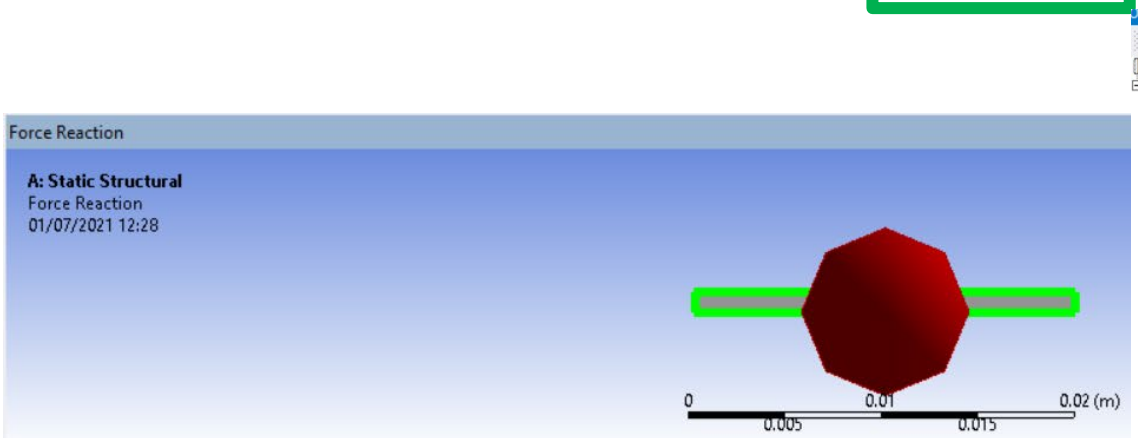
- Results

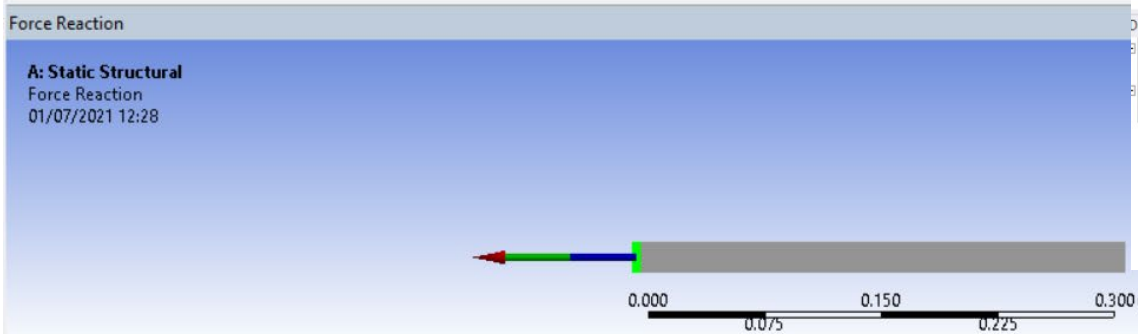
tensión: $\sigma=Ee=200[GPa]*0.0033=0.6667[GPa]=666.7[MPa]=6.667e8[Pa]$ OK

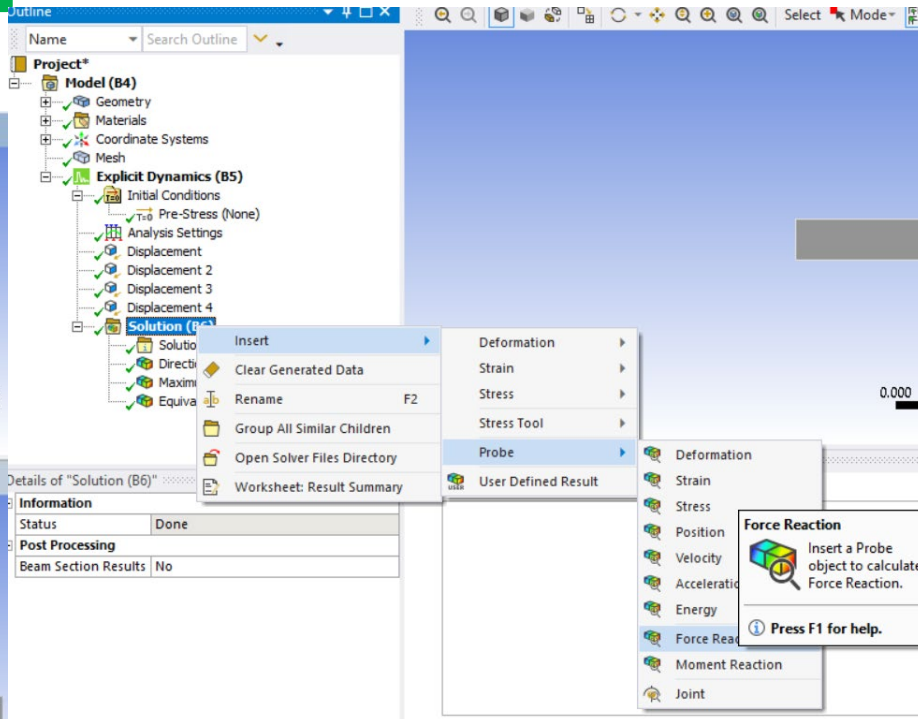


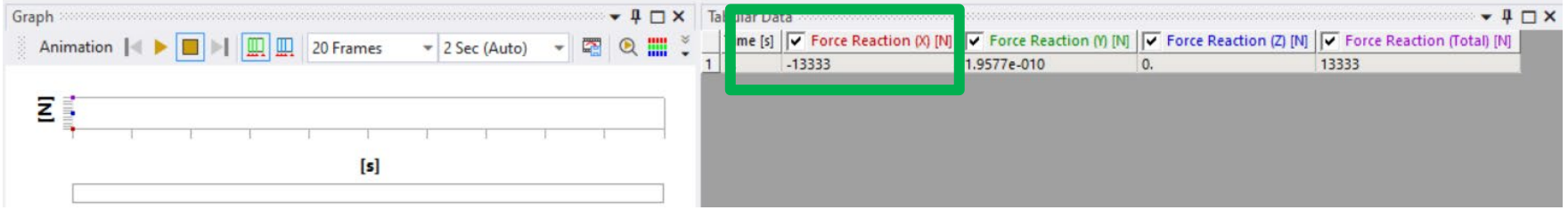
- Results

fuerza: $F=\sigma A=666.7*20*1=$ 13333[N] $=13.33[kN]$ **OK**



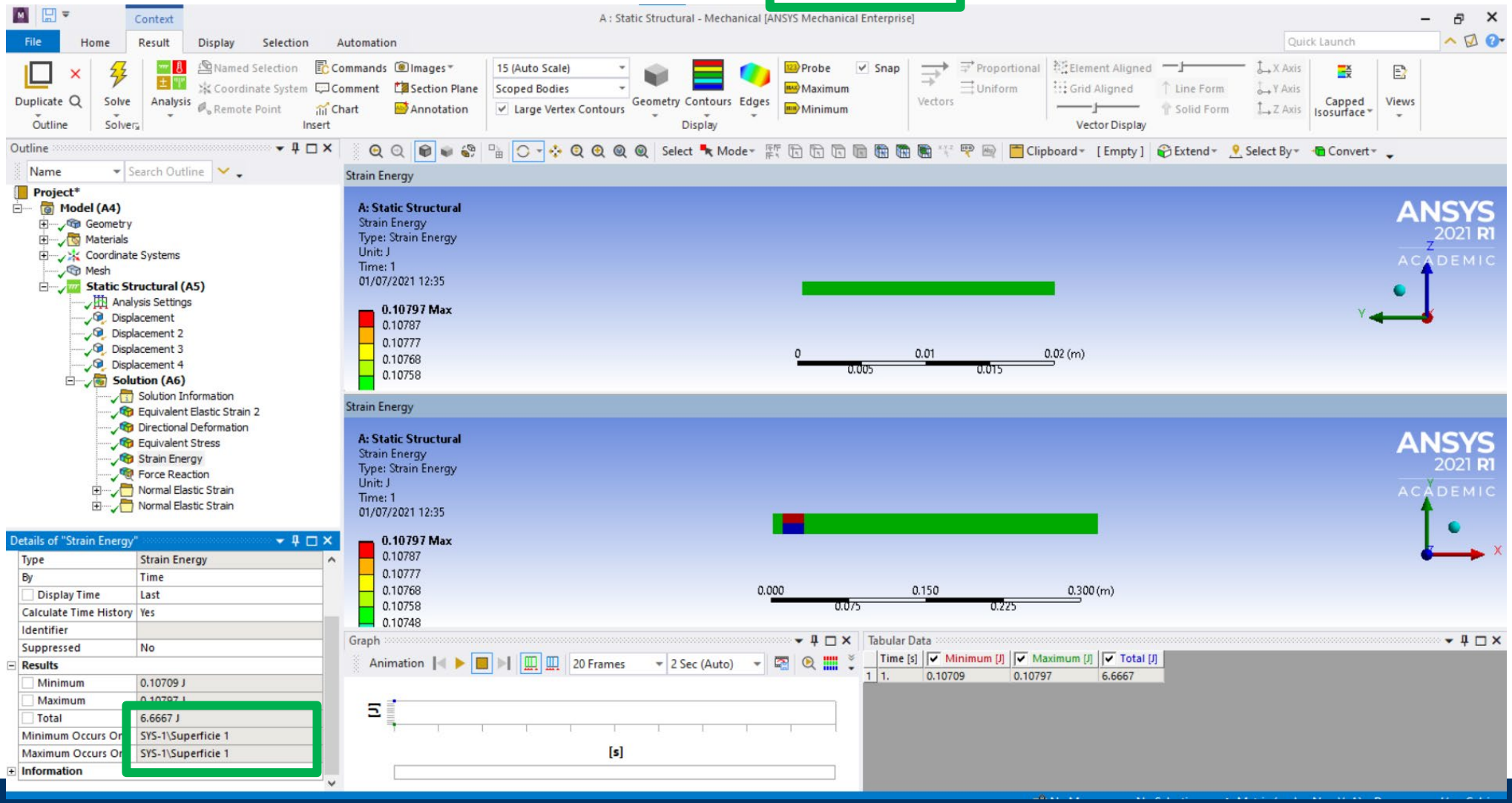






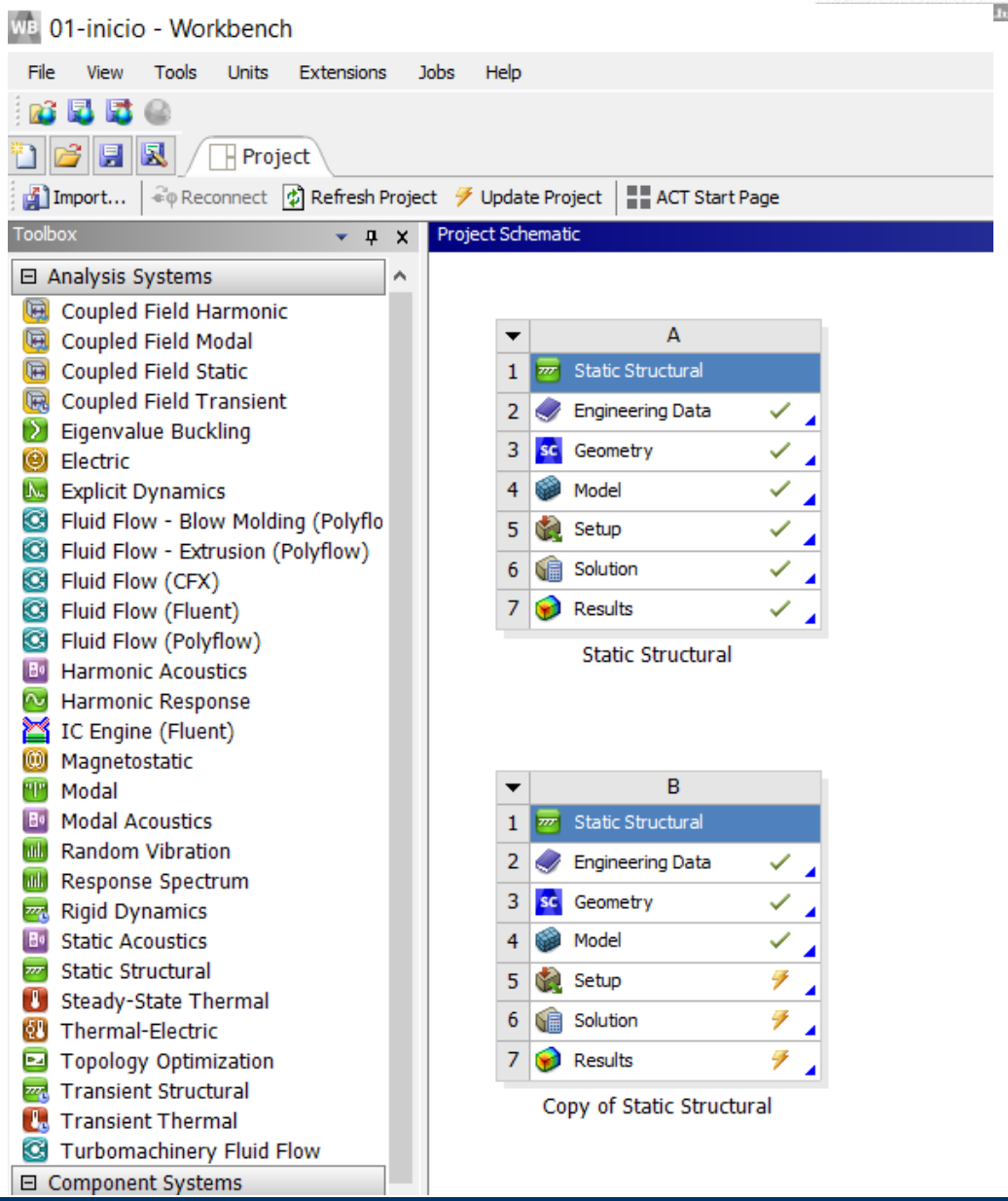
- Results

energía: E=FΔL/2=13333*0.001/2= 6.667[J] =6.667[kN·mm] **OK**



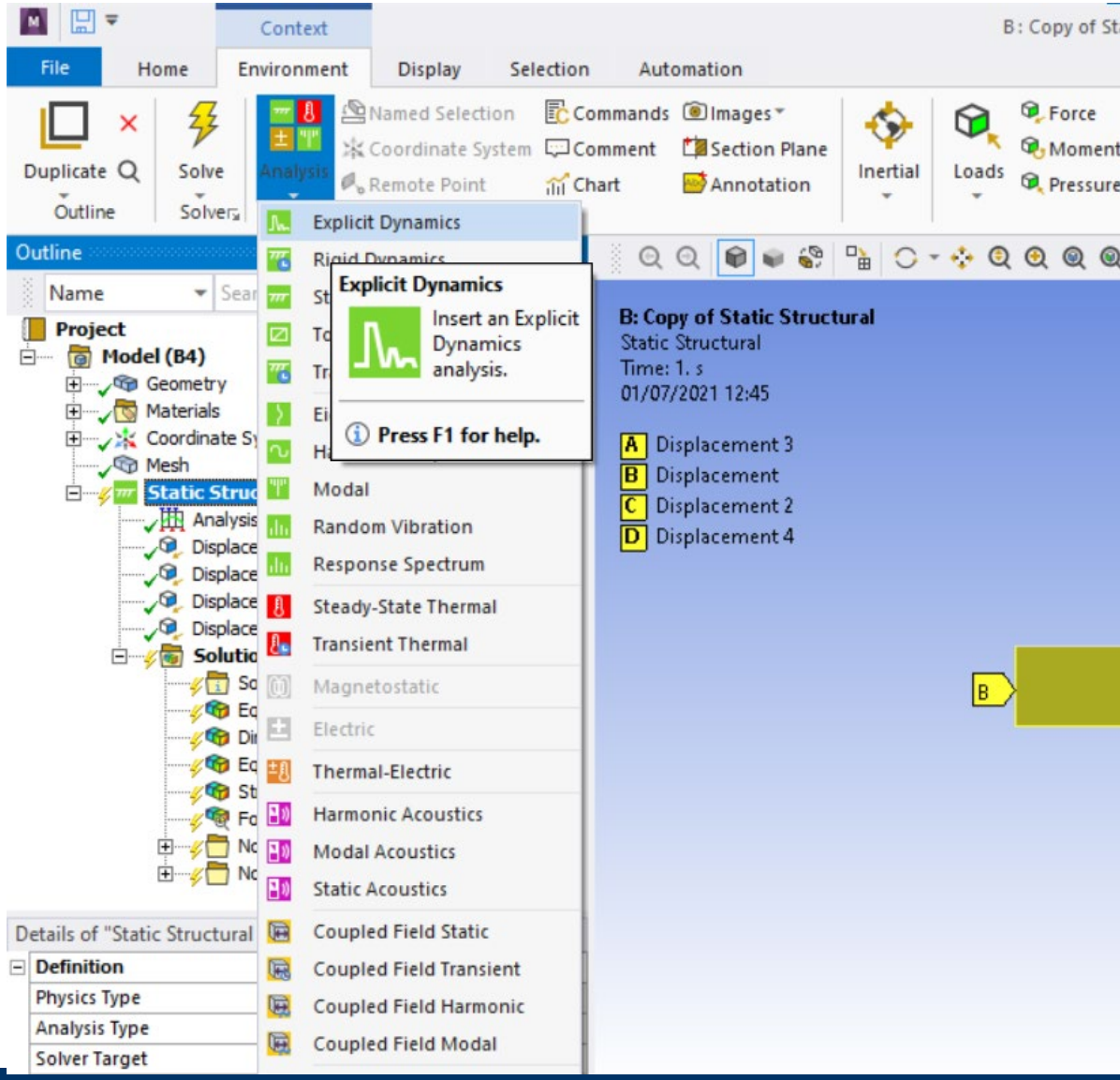
- Dinámica

Repetimos el proceso pero haciendo una copia del estático

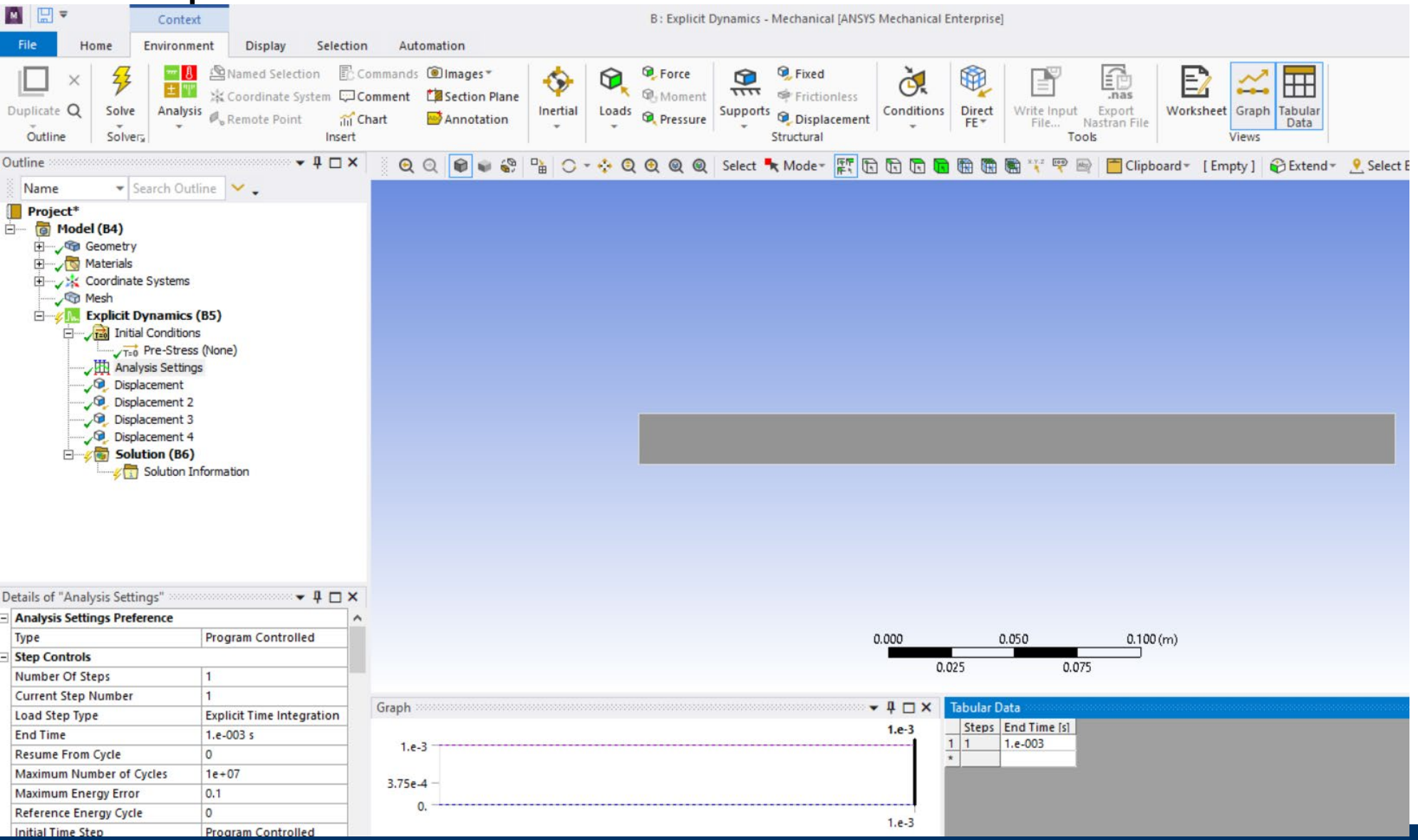


- Setup

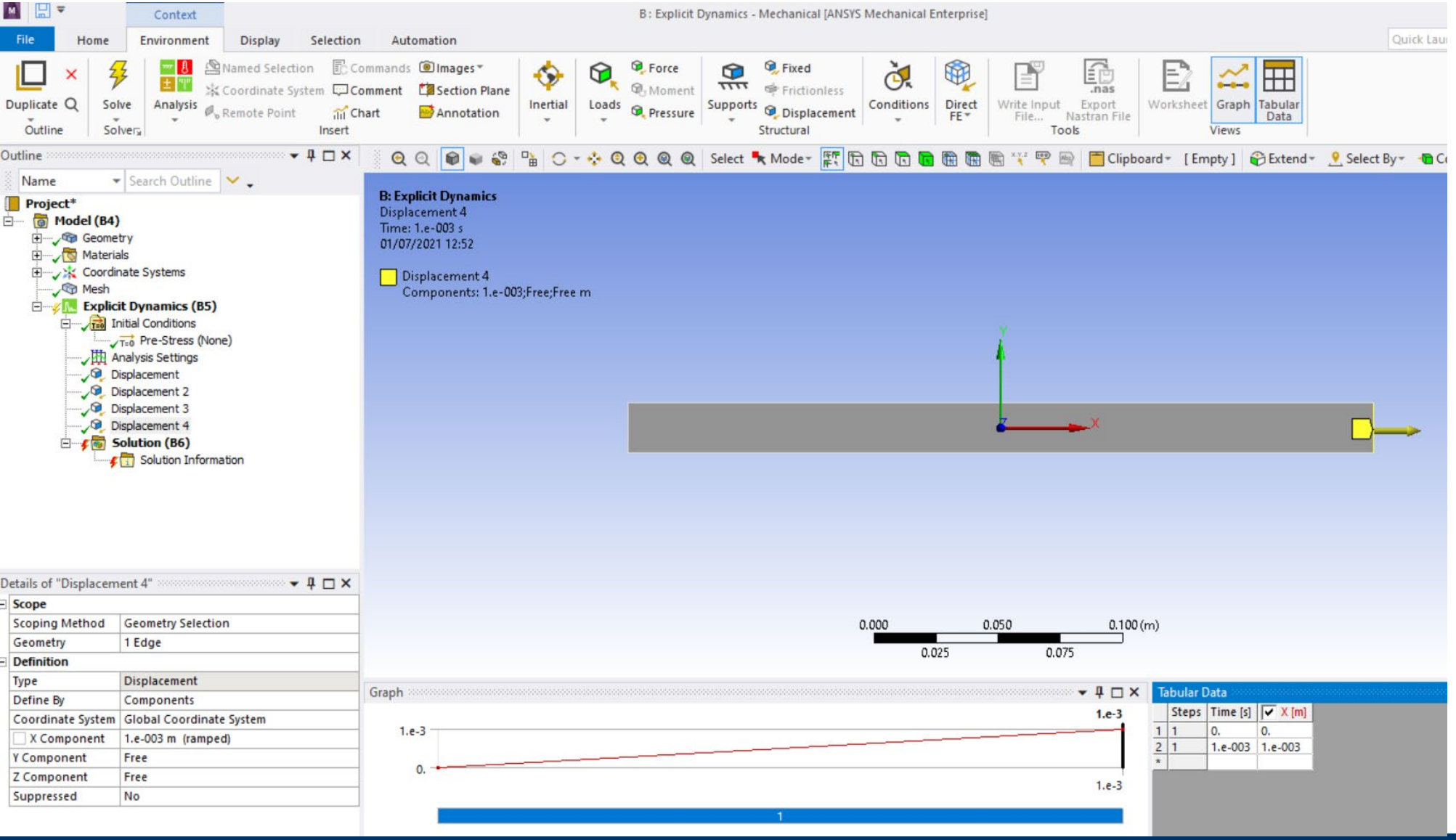
Desde Setup cambiamos a explícito



- Setup

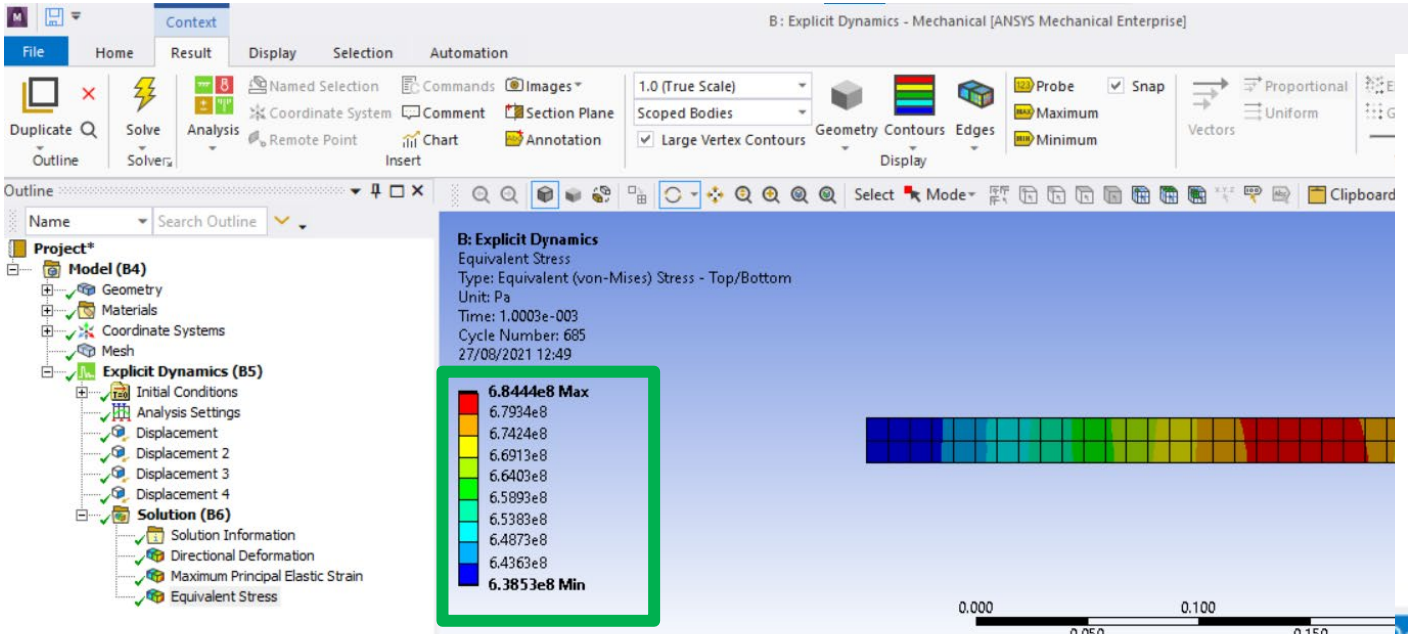

B: Explicit Dynamics - Mechanical [ANSYS Mechanical Enterprise]
Context
File
Home
Environment
Display
Selection
Automation
Duplicate
Outline
Solve
Solver
Analysis
Named Selection
Coordinate System
Remote Point
Commands
Comment
Chart
Images
Section Plane
Annotation
Insert
Inertial
Loads
Force
Moment
Pressure
Supports
Fixed
Frictionless
Displacement
Structural
Conditions
Direct FE
Write Input File...
Export Nastran File
Tools
Worksheet
Graph
Tabular Data
Views
Outline
Name
Search Outline
Project*
Model (B4)
Geometry
Materials
Coordinate Systems
Mesh
Explicit Dynamics (B5)
Initial Conditions
Pre-Stress (None)
Analysis Settings
Displacement
Displacement 2
Displacement 3
Displacement 4
Solution (B6)
Solution Information
Select
Mode
Clipboard
[Empty]
Extend
0.000
0.050
0.100 (m)
0.025
0.075
Details of "Analysis Settings"
Analysis Settings Preference
Type
Program Controlled
Step Controls
Number Of Steps
1
Current Step Number
1
Load Step Type
Explicit Time Integration
End Time
1.e-003 s
Resume From Cycle
0
Maximum Number of Cycles
1e+07
Maximum Energy Error
0.1
Reference Energy Cycle
0
Initial Time Step
Program Controlled
Graph
1.e-3
1.e-3
3.75e-4
0.
1.e-3
Tabular Data
Steps
End Time [s]
1
1
1.e-003

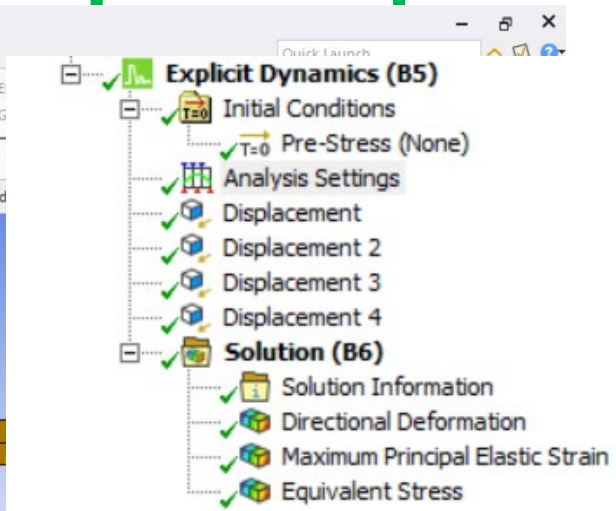
- Setup

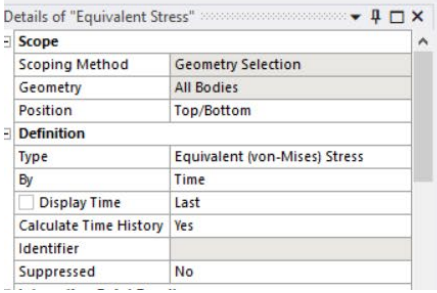

B : Explicit Dynamics - Mechanical [ANSYS Mechanical Enterprise]
Context
File
Home
Environment
Display
Selection
Automation
Duplicate
Outline
Solve
Solvers
Analysis
Named Selection
Coordinate System
Remote Point
Commands
Comment
Chart
Images
Section Plane
Annotation
Insert
Inertial
Loads
Force
Moment
Pressure
Supports
Fixed
Frictionless
Displacement
Structural
Conditions
Direct FE
Write Input File...
Export Nastran File
Tools
Worksheet
Graph
Tabular Data
Views
Outline
Name
Search Outline
Project*
Model (B4)
Geometry
Materials
Coordinate Systems
Mesh
Explicit Dynamics (B5)
Initial Conditions
Pre-Stress (None)
Analysis Settings
Displacement
Displacement 2
Displacement 3
Displacement 4
Solution (B6)
Solution Information
Select
Mode
Clipboard
[Empty]
Extend
Select By
B: Explicit Dynamics
Displacement 4
Time: 1.e-003 s
01/07/2021 12:52
Displacement 4
Components: 1.e-003;Free;Free m
0.000
0.050
0.100 (m)
0.025
0.075
Details of "Displacement 4"
Scope
Scoping Method
Geometry Selection
Geometry
1 Edge
Definition
Type
Displacement
Define By
Components
Coordinate System
Global Coordinate System
X Component
1.e-003 m (ramped)
Y Component
Free
Z Component
Free
Suppressed
No
Graph
1.e-3
0.
1.e-3
1
Tabular Data
Steps
Time [s]
X [m]
1
1
0.
0.
2
1
1.e-003
1.e-003

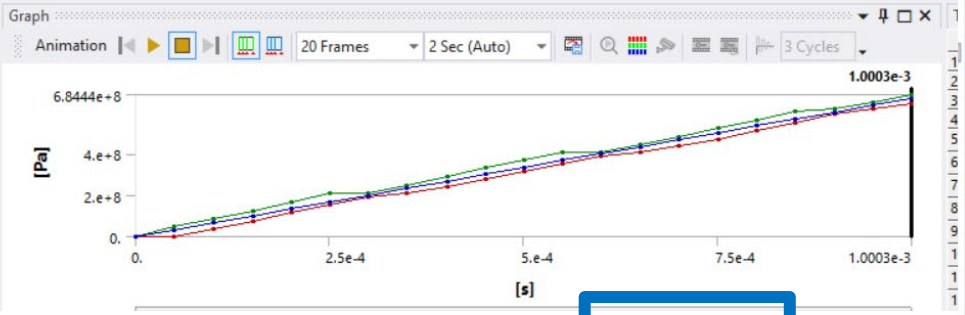
- Results

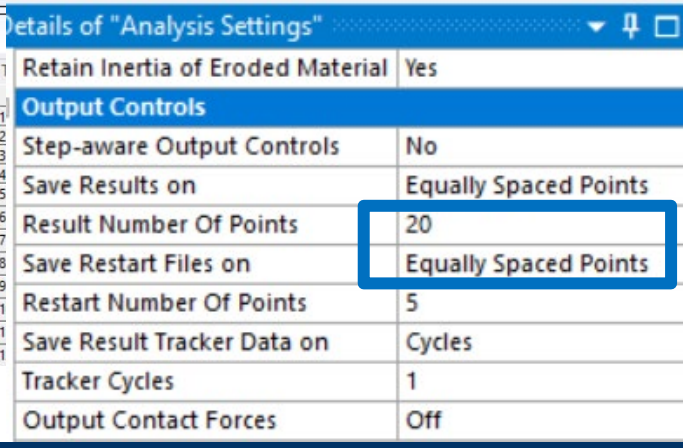
tensión: $\sigma = Ee = 200[GPa]*0.0033 = 0.6667[GPa] = 666.7[MPa] = 6.667e8[Pa]$ OK







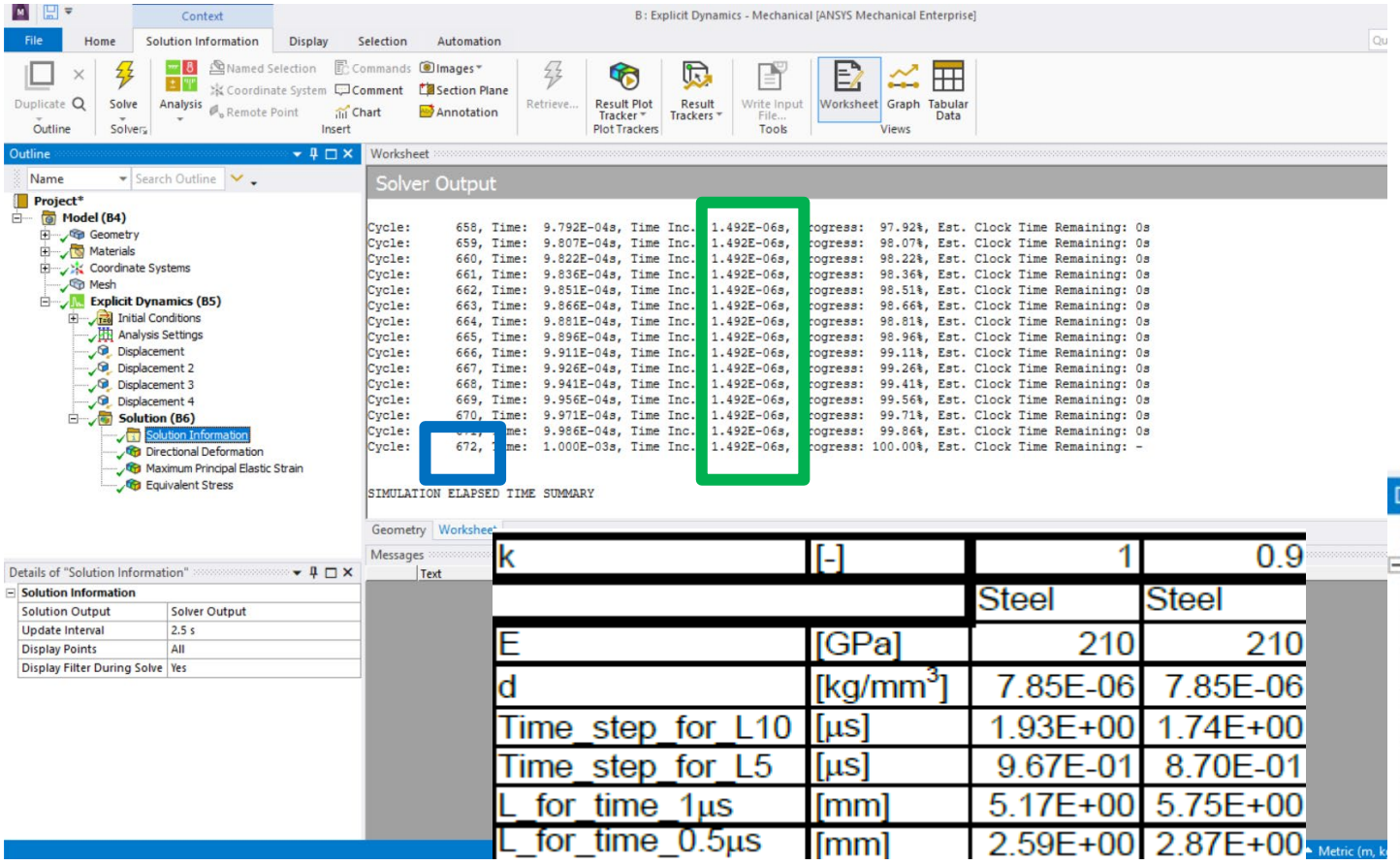




Escribimos cada 50 microsegundos para tener 20 pasos

- Time step

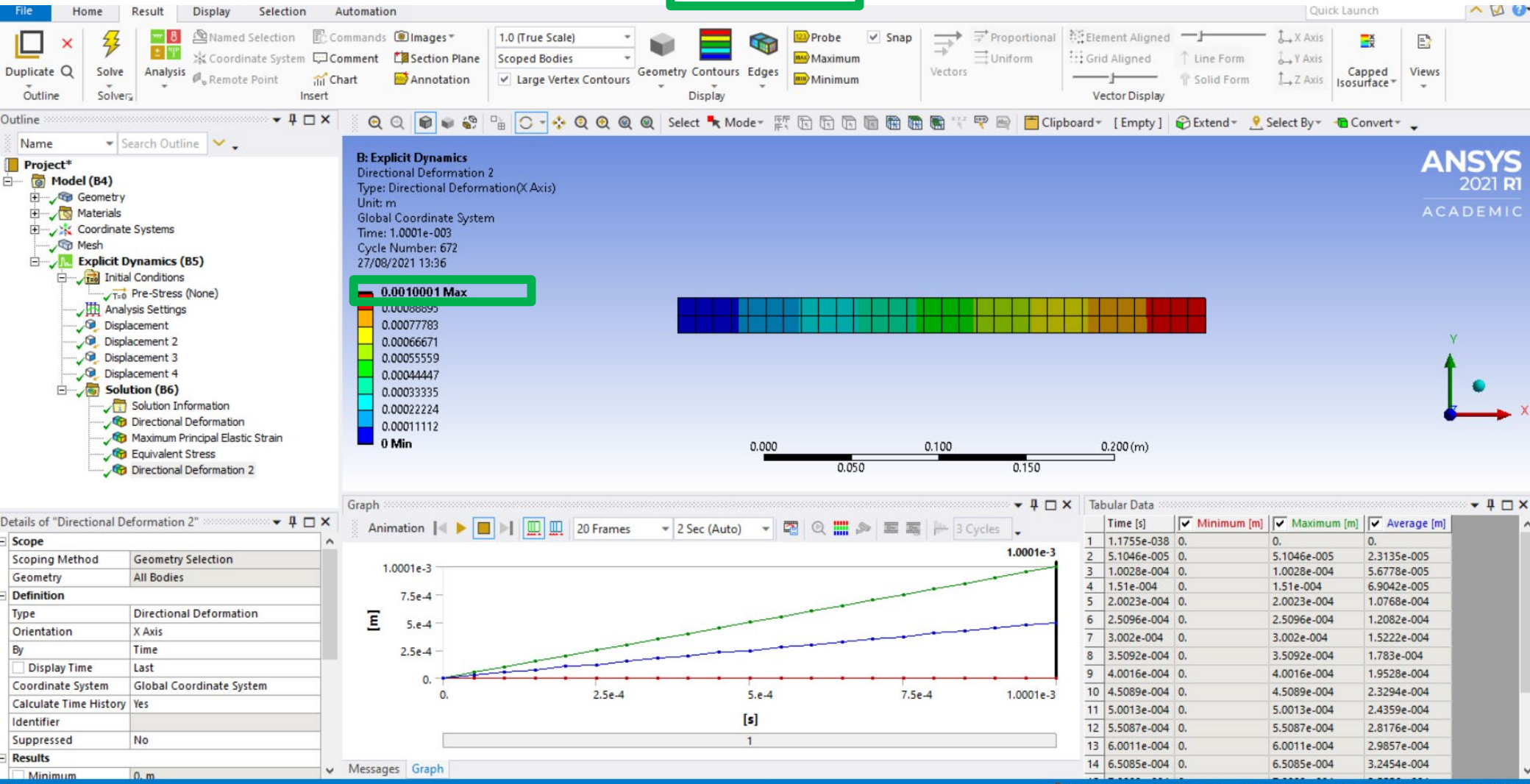
Como tenemos una malla de longitud 10mm de acero el time step debería ser de unos 1.9 microsegundos y algo menos debido al amortiguamiento. Por lo tanto para calcular un milisegundo necesitará 0.001/1.49e-6= 671 pasos mas el inicia 672



k	[-]	1	0.9
		Steel	Steel
E	[GPa]	210	210
d	[kg/mm^3]	7.85E-06	7.85E-06
Time_step_for_L10	[µs]	1.93E+00	1.74E+00
Time_step_for_L5	[µs]	9.67E-01	8.70E-01
L_for_time_1µs	[mm]	5.17E+00	5.75E+00
L_for_time_0.5µs	[mm]	2.59E+00	2.87E+00

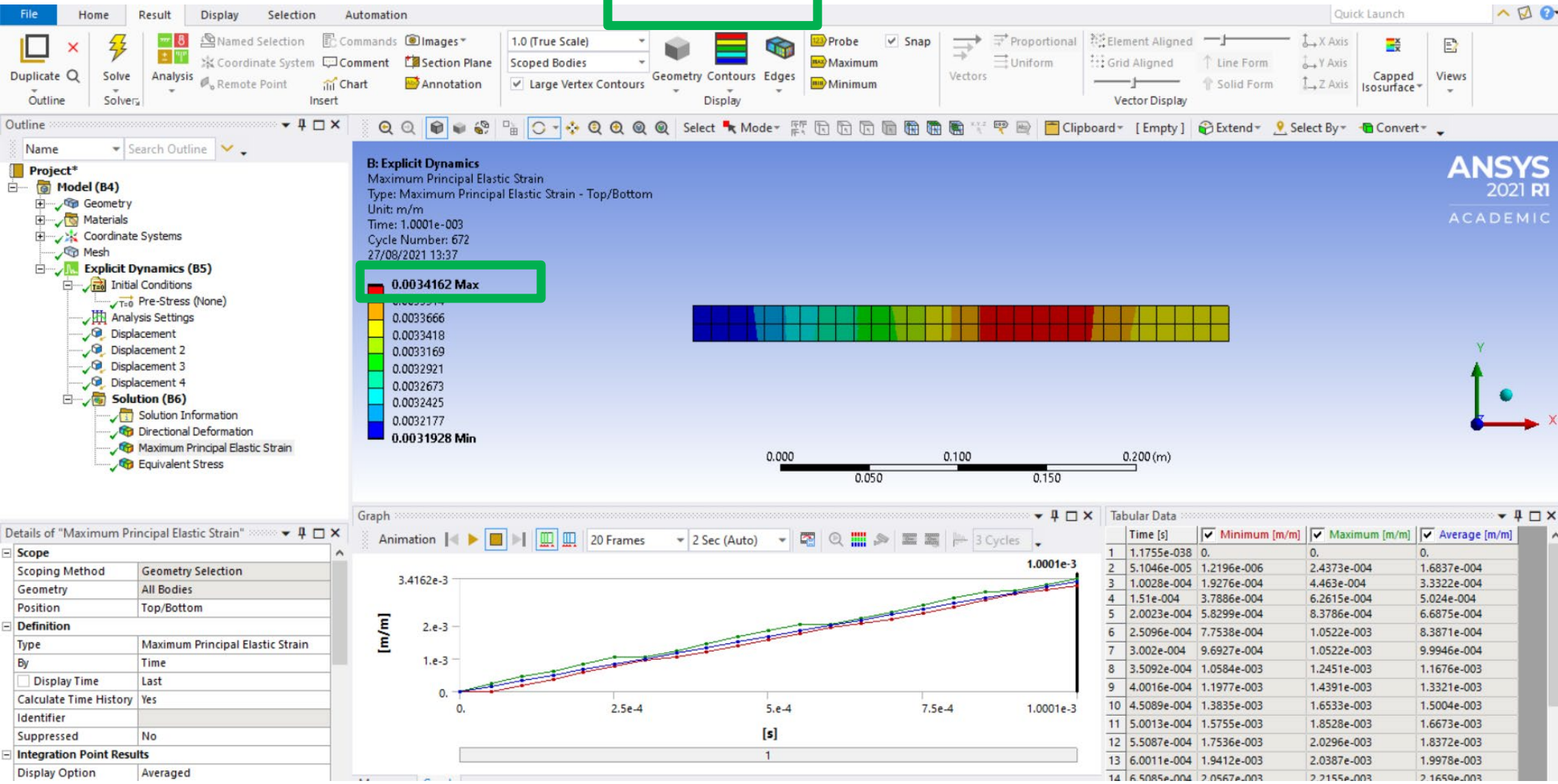
- Results

Comprobamos que hemos estirado 1mm en X como especificado **OK**



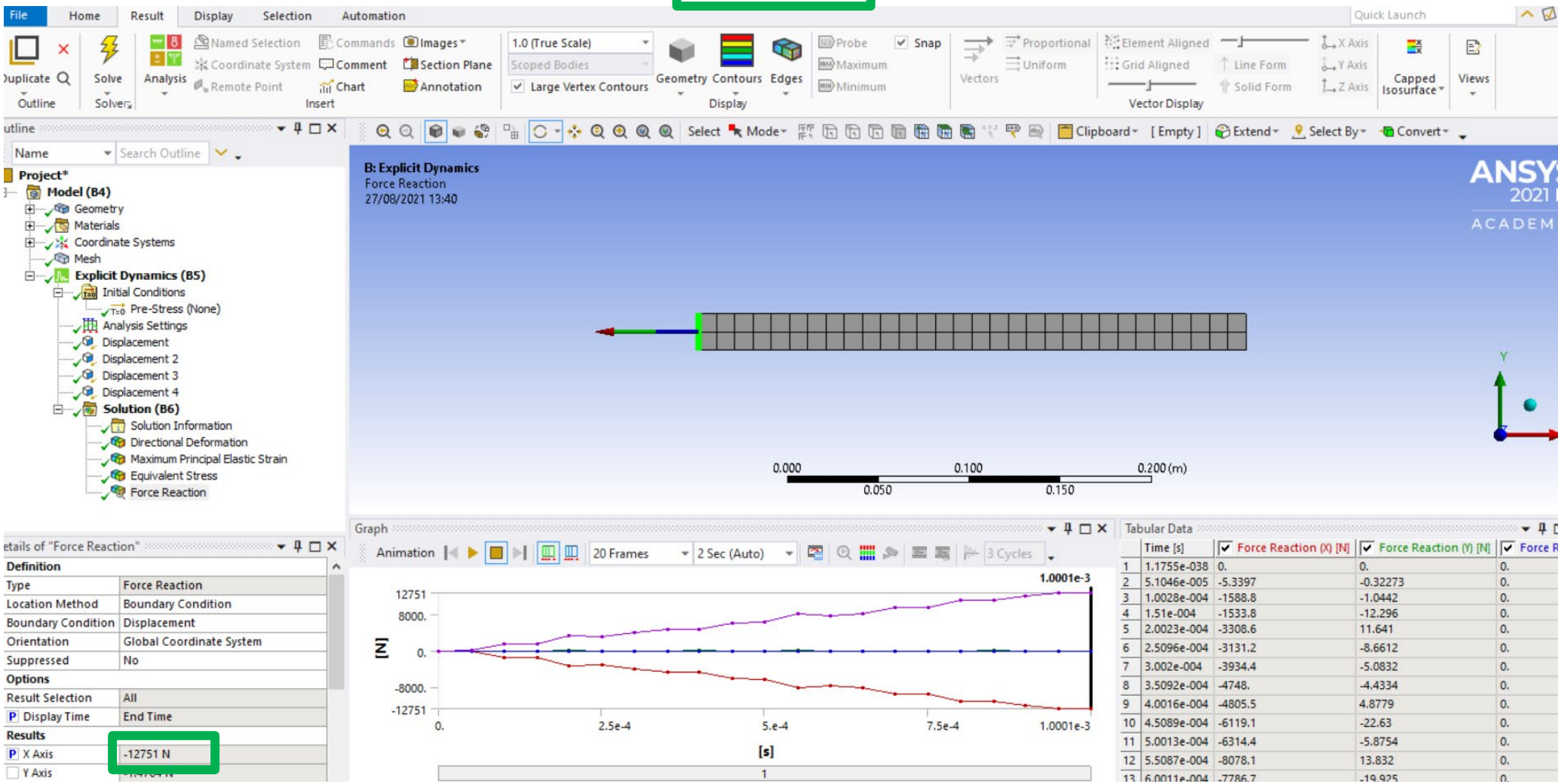
- Results

deformación: $\varepsilon=\Delta L/L=1/300=$ 0.003333[-] $=0.3333\%$ **OK**



- Results

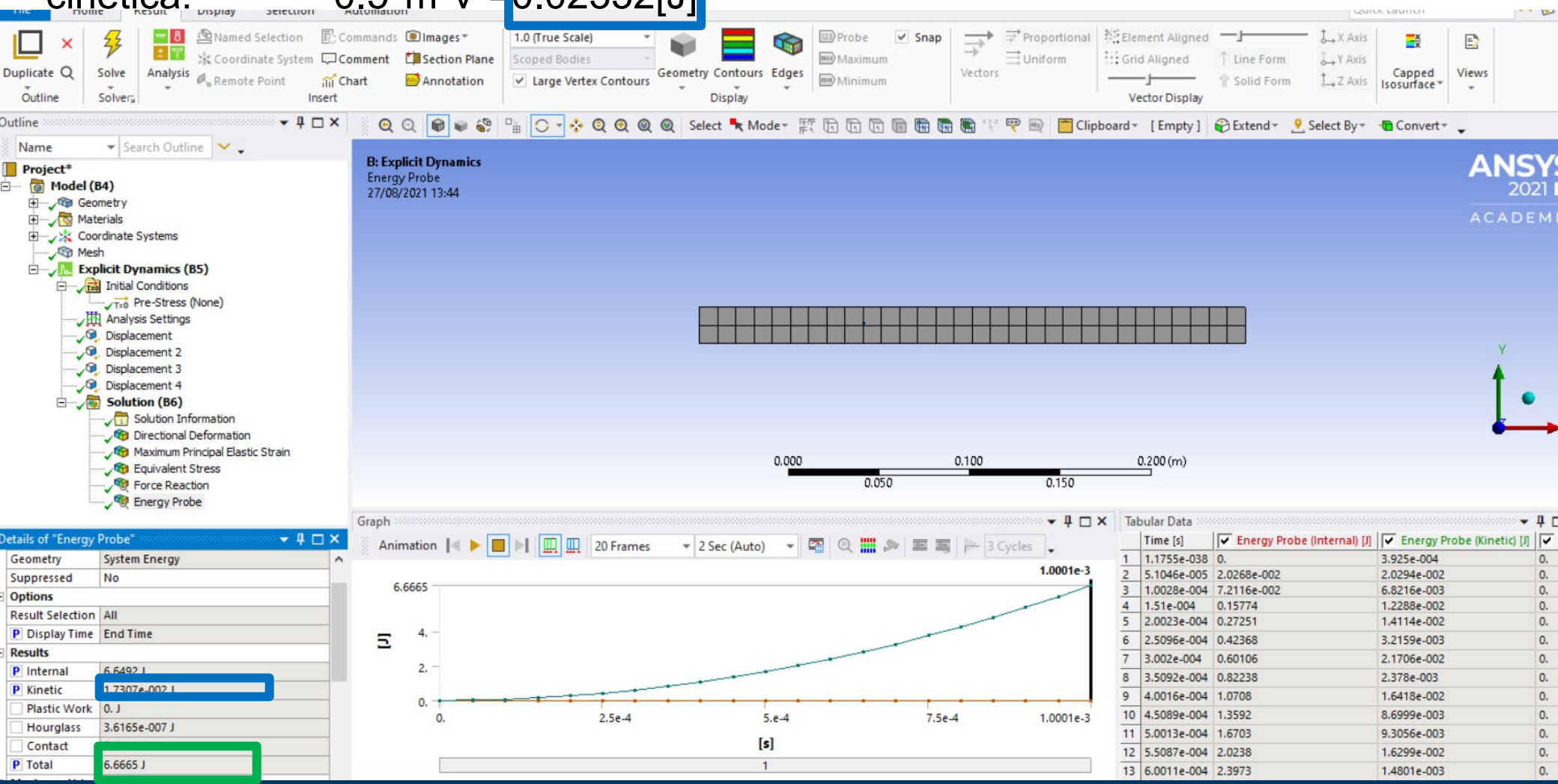
fuerza: $F=\sigma A=666.7*20*1=$ 13333[N] $=13.33$[kN] **OK** simulación 12.75[kN]



- Results

energía: E=FΔL/2=13333*0.001/2= 6.667[J] =6.667[kN·mm] **OK +** energía

cinética: $0.5*m*v^2$= 0.02352[J]



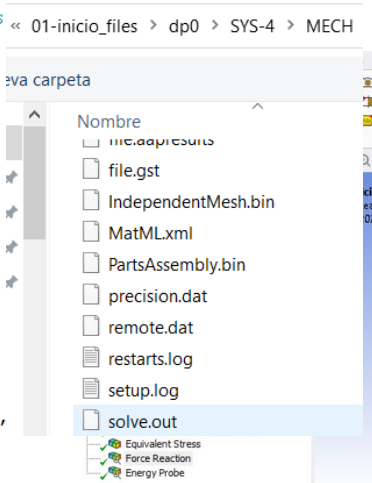
- Ejercicio

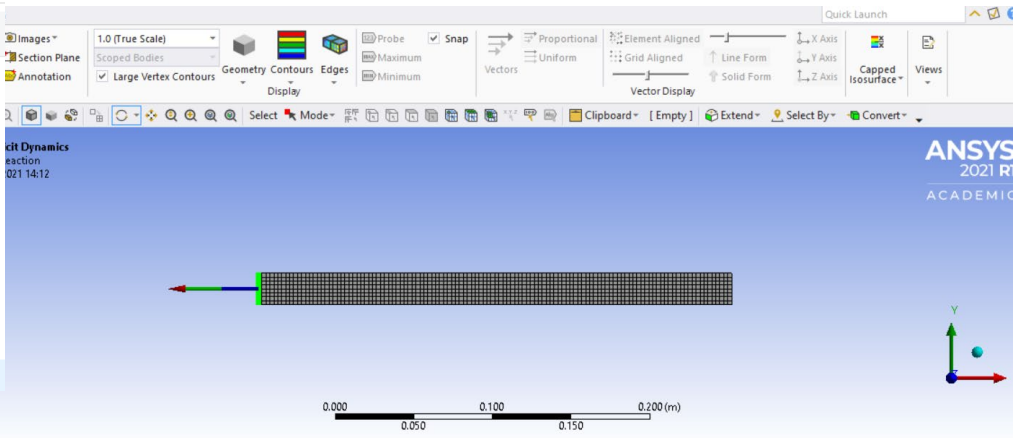
Realizar el mismo cálculo con malla de 2.5mm ¿Cuántos elementos tendremos? ¿Cuánto durará el cálculo? ¿Hay diferencias en los resultados?

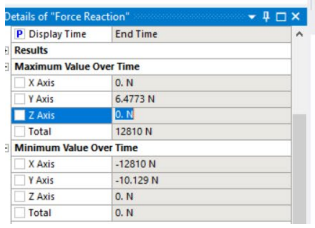
Ahora tenemos los 60elementos x 4x4=960. Además el time step es 4 veces más pequeño y por tanto tendremos un tiempo de cálculo x4x4x4=64 pero en este cálculo tan rápido no se nota. La fuerza pasa de 12.75[kN] a 12.81[kN] similar dentro de un cálculo explícito

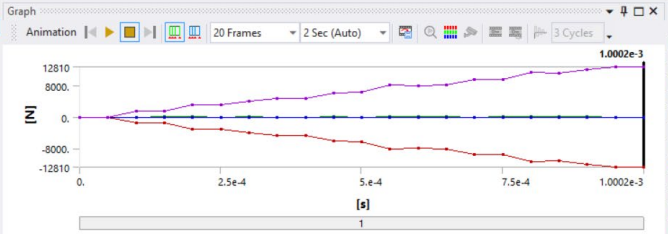
```
Cycle:      672, Time:  1.000E-03s, Time Inc.: 1.492E-06s


 SIMULATION ELAPSED TIME SUMMARY

 EXECUTION FROM CYCLE        0 TO      672
 ELAPSED RUN TIME IN SOLVER =      3.88333E-03 Minutes
 TOTAL ELAPSED RUN TIME     =      1.36167E-02 Minutes
 JOB RAN OVER     2 WORKERS
 JOB RAN USING Intel MPI
 JOB RAN USING DECOMPOSITION AUTO

 Problem terminated .... wrapup time reached
```

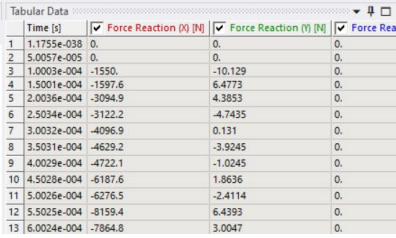
```
Cycle:     2683, Time:  1.000E-03s, Time Inc.: 3.731E-07s,


 SIMULATION ELAPSED TIME SUMMARY

 EXECUTION FROM CYCLE        0 TO     2683
 ELAPSED RUN TIME IN SOLVER =      4.40000E-02 Minutes
 TOTAL ELAPSED RUN TIME     =      6.54667E-02 Minutes
 JOB RAN OVER     2 WORKERS
 JOB RAN USING Intel MPI
 JOB RAN USING DECOMPOSITION AUTO

 Problem terminated .... wrapup time reached
```











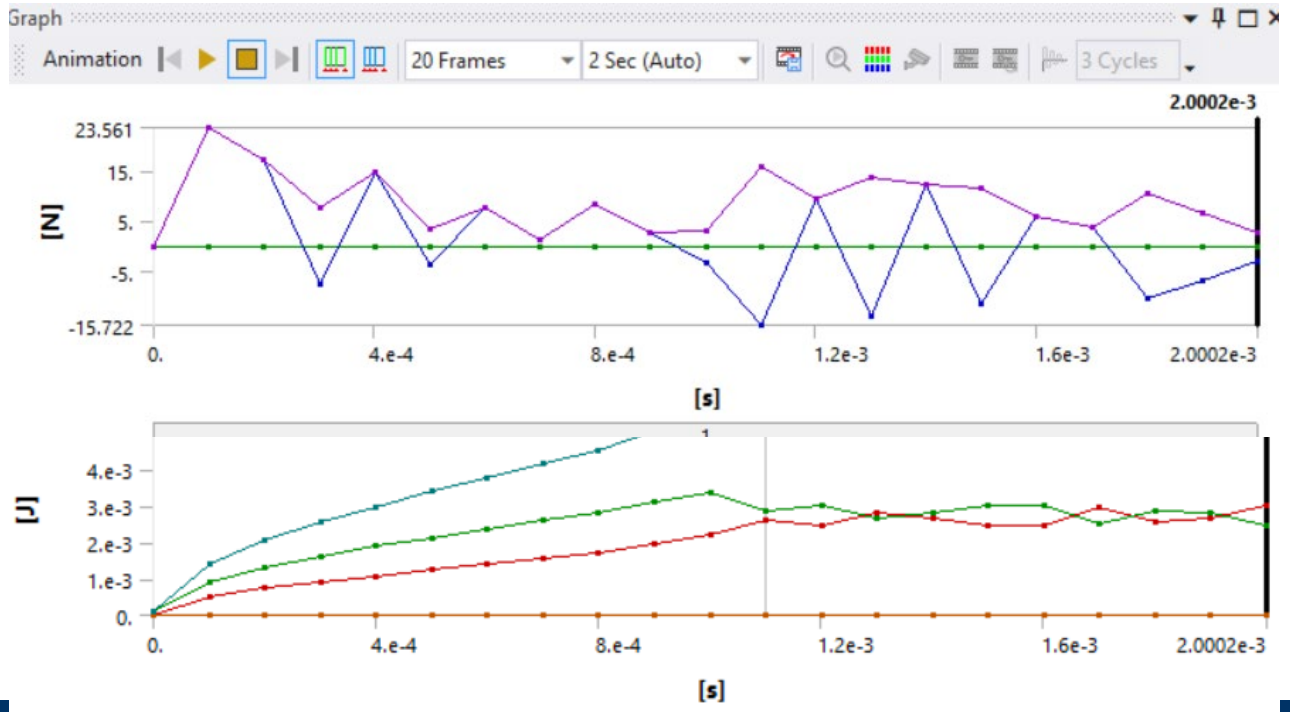
- Ejercicio

Aplicar un desplazamiento de 1[mm] en Z como una viga en voladizo en 1[us] y mantener hasta 2[us]. ¿Qué fuerza necesitamos? ¿Qué tensión tendremos? ¿Qué pasa tras el primer us?

Viga en voladizo

$$z_L = \frac{FL^3}{3EI} = \frac{4FL^3}{Ebh^3} \qquad \sigma_{\max} = M_{\max}\frac{\frac{h}{2}}{I} = FL\frac{6}{bh^2}$$

	A	B	C	D
1	input	E	Pa	2.00E+11
2	input	Lx	m	0.3
3	input	Ly	m	0.02
4	input	Lz	m	0.001
5	output	F-z1mm	N	1.48E-01
6	output	s-z1mm	Pa	1.33E+07
7	output	E-z1mm	J	9.88E+05



- Resumen.

➢ Presentación asignatura.

➢ Necesidad de espacio para poder frenar con poca fuerza y aceleración

➢ Caso de tracción en explícito e implícito

➢ Problema de tamaño de malla y necesidad de usar SHELL.

S02t.- Plasticidad e impacto.

Mejora 2122…

• Repaso última sesión

Importancia de conversión de unidades.

Propiedades de material: densidad, módulo de Young, curva plástica, Poisson, amortiguamiento…

Impactos suelen ocurrir en pocos milisegundos.

Si el material es más duro da más aceleración y si es más blando puede chocar con la pared, El factor de seguridad es tener más espacio.

La energía cinética se transforma en energía de deformación.

Se suele usar el mallado de superficie tipo SHEL para que pueda acabar el cálculo en un tiempo razonable.

Importancia de tamaño de malla y time step. Para acero de longitud 10[mm] el time step está entorno a 2[us] por lo que para simular 20[ms] se necesitan 10000 pasos de cálculo.

En sesión 1 hay un ejemplo para verificar que hacemos bien la simulación.

Andrés García, andres.garcia@iqs.url.edu ,Vía Augusta, 390 – 08017. Barcelona. (+34) 932 672 000-ext.283 F. (+34)932 056 266

• Ejemplo largas deformaciones

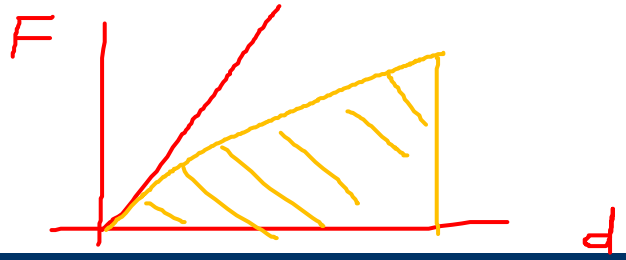
Vamos a estirar 300[mm] una barra de 1x20x300[mm] de acero en 1[ms].
(A=20x1=20[mm2], L=300[mm])

Estática pequeña deformación:

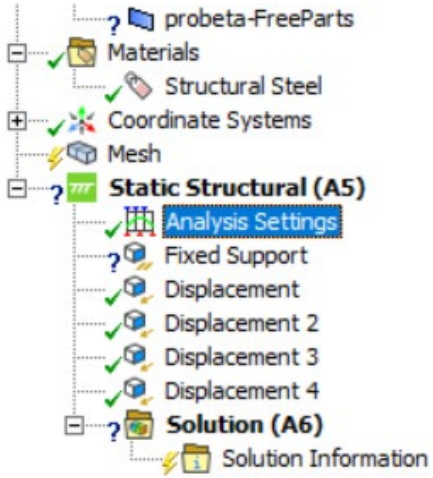
deformación: $\varepsilon=\Delta L/L=300/300=1[-]=100\%$
tensión: $\sigma=E\varepsilon=200[GPa]*1=200[GPa]=200000[MPa]$
fuerza: $F=\sigma A=200000*20*1=4000000[N]=4000[kN]$
energía: $E=F\Delta L/2=4000000*0.3/2=0.6[MJ]$

Estática larga deformación:

deformación: $\varepsilon=\ln(1+\Delta L/L)=300/300=0.6931[-]=69.3\%$
tensión: $\sigma=E\varepsilon=200[GPa]*0.6931=139[GPa]=139000[MPa]$
fuerza: $F=\sigma A*(1-\nu\varepsilon)^2=139000*20*1*(1-0.3*0.6931)^2=1740000[N]=1740[kN]$
energía: $E=F\Delta L/2=1740*0.3/2=0.261[MJ]$ deberíamos integrar…



- Resultados en ANSYS implícito



A: Static Structural
Equivalent Elastic Strain
Type: Equivalent Elastic Strain - Top/Bottom
Unit: m/m
Time: 1.e-003
30/08/2021 16:54

1 OK

A: Static Structural
Equivalent Stress
Type: Equivalent (von-Mises) Stress - Top/Bottom
Unit: Pa
Time: 1.e-003
30/08/2021 16:53

2e+11 Max
2e+11 Min

2e11 OK

ANSYS Workbench - Warning

The deformation is large compared to the model bounding box. Verify boundary conditions or consider turning large deflection on. Refer to Troubleshooting in the Help System for more details.

A: Static Structural
Equivalent Elastic Strain
Type: Equivalent Elastic Strain - Top/Bottom
Unit: m/m
Time: 1.e-003
30/08/2021 17:01

0.69321 Max

0.6931 OK

A: Static Structural
Equivalent Stress
Type: Equivalent (von-Mises) Stress - Top/Bottom
Unit: Pa
Time: 1.e-003
30/08/2021 17:02

1.3864e+11 Max
1.3864e+11 Min

1.39e11 OK

Details of "Analysis Settings"

Step Controls	
Number Of Steps	1.
Current Step Number	1.
Step End Time	1.e-003 s
Auto Time Stepping	Program Controlled
Solver Controls	
Solver Type	Program Controlled
Weak Springs	Off
Solver Pivot Checking	Program Controlled
Large Deflection	Off → ON
Inertia Relief	Off
Quasi-Static Solution	Off

Maximum Value Over Time	
X Axis	-4.e+006 N
Y Axis	8.0814e-010 N
Z Axis	0. N
Total	4.e+006 N

4e6 OK

Results	
Minimum	10000 J
Maximum	10000 J
Total	6.e+005 J

6e5 OK

Maximum Value Over Time	
X Axis	-1.8287e+006 N
Y Axis	519.49 N
Z Axis	0. N
Total	1.8287e+006 N

1.74e6 nOK

Results	
Minimum	6338.6 J
Maximum	6338.6 J
Total	3.8031e+005 J

2.61e5 nOK

https://ansyshelp.ansys.com/account/secured?returnurl=/Views/Secured/corp/v212/en/exd_ag/ds_plasticity.html?q=true%20stress

- # Resultados en ANSYS Explícito cargando en 0.001[s]

Encontramos el error de energy error too large.

stops the calculation in Explicit Dynamics and let user examine the results before running the calculation further.

Usually, you would need to pay attention to the energy balance if there is a spike in the energy history curve under Solution -> Solution Information -> Energy Conservation.

If the energy error gradually increases, usually the results are OK. If the energy error goes up very quickly in very few cycles, you need to examine the results and the model setup very carefully since it usually indicates the problems with the model setup or the solutions. There could also be problems in the result due to eroded elements, element sizes not small enough and other similar symptoms.

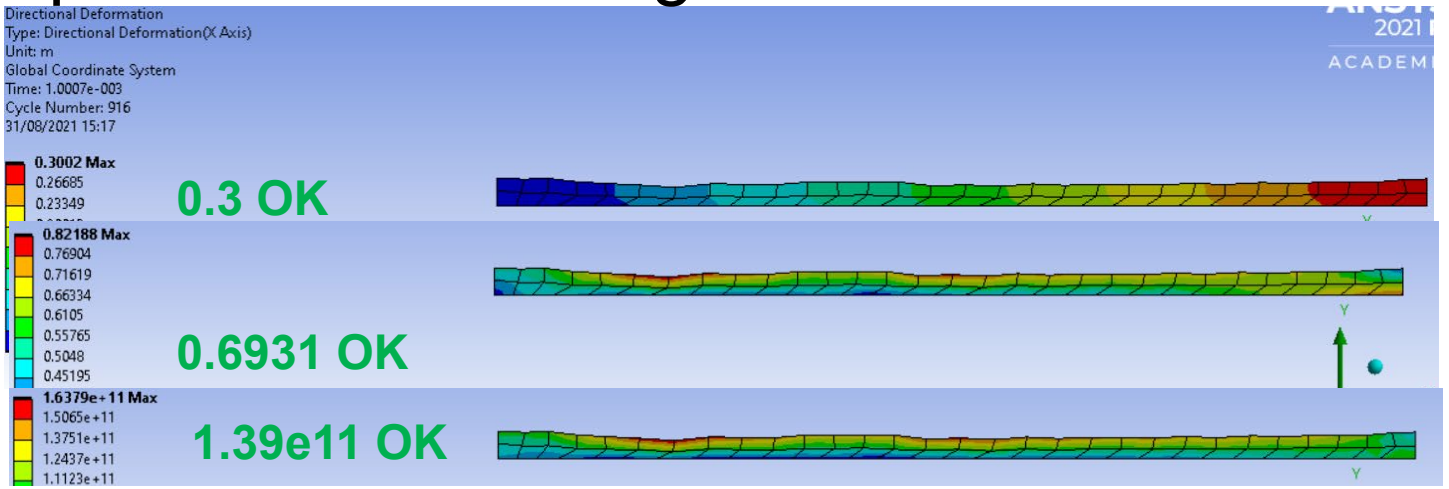
Now, If you think the energy balance looks ok and just want to get the problem to run you can Disable the energy balance check by setting the Reference Energy Cycle to the same number as Maximum Number of Cycles (default 1E+7) in Step Controls. This disables the energy error check in Explicit Dynamics and Autodyn Component systems. The program will still calculate the energy and the energy error but it won't interrupt the solving process when the energy error exceeds the specified value.

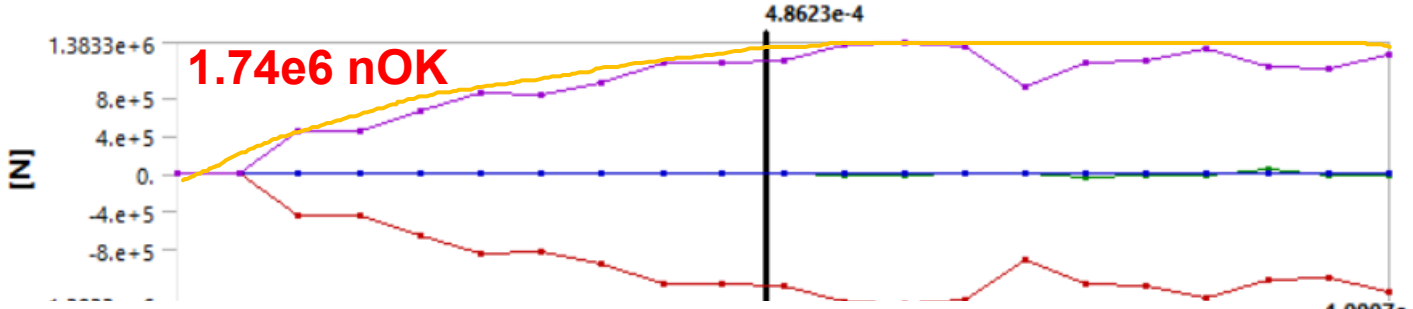
Details of "Analysis Settings"

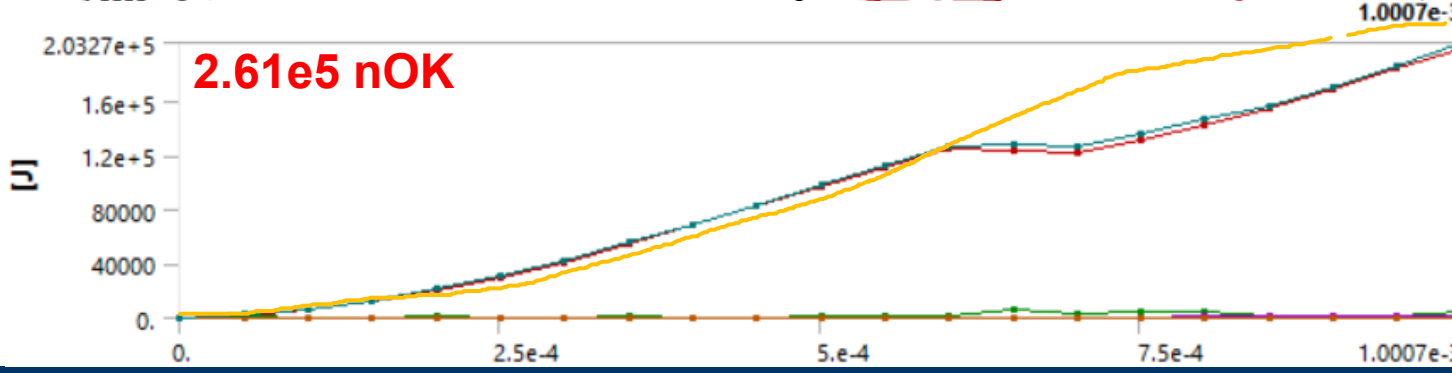
Analysis Settings Preference	
Type	Program Controlled
Step Controls	
Number Of Steps	1
Current Step Number	1
Load Step Type	Explicit Time Integrati
End Time	0.3
Resume From Cycle	0
Maximum Number of Cycles	1e+07
Maximum Energy Error	1.e+007
Reference Energy Cycle	0
Initial Time Step	Program Controlled
Minimum Time Step	Program Controlled

• Solución sin comprobación de energías

En la solución explícita con tanta deformación no se consigue un movimiento uniforme con tensiones muy similares como en el implícito.







• Plasticidad

Vamos a estirar 3[mm] una barra de 1x20x300[mm] de acero en 1[ms]. (A=20x1=20[mm2], L=300[mm]) pero que plastifica a los 200[MPa]

Estática pequeña deformación:

deformación: $\varepsilon=\Delta L/L=3/300=0.01[-]=1\%$

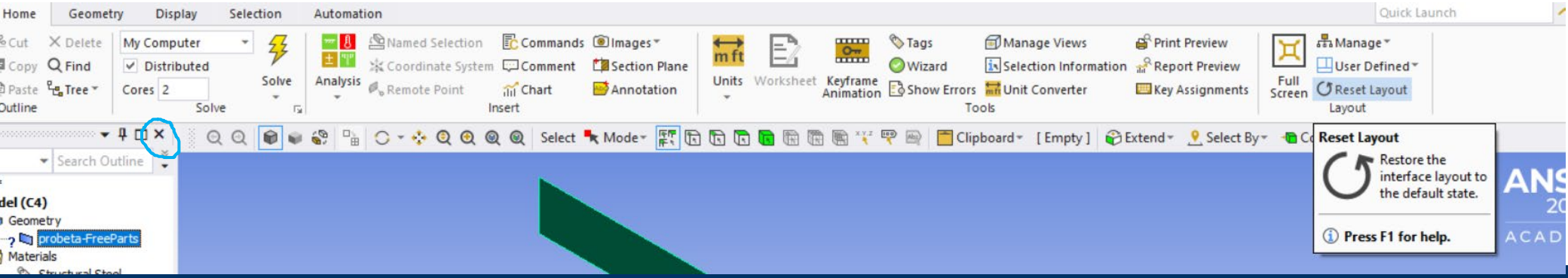
tensión: $\sigma=E\varepsilon=200[GPa]*0.01=2[GPa]=2000[MPa]$ pero como plastifica se quedará en 200[MPa].

fuerza: $F=\sigma A=200*20*1=4000[N]=4[kN]$

energía: $E=F\Delta L=4000*0.003=12[J]$ ahora es una zona plana.

$12-\frac{12}{20}=11'4[J]$

En Ansys si cierras por accidente una ventana hacer Reset Layout



• Cambio material

Toolbox

- Physical Properties
- Linear Elastic
- Hyperelastic Experimental Data
- Hyperelastic
- Chaboche Test Data
- Plasticity
  - Bilinear Isotropic Hardening
  - Multilinear Isotropic Hardening
  - Nonlinear Isotropic Hardening Powe
  - Nonlinear Isotropic Hardening Voce
  - Bilinear Kinematic Hardening
  - Multilinear Kinematic Hardening
  - Chaboche Kinematic Hardening
  - Chaboche Kinematic Hardening w/
  - Anand Viscoplasticity
  - Exponential Visco-Hardening (EVH)
  - Perzyna Viscoplasticity
  - Peirce Viscoplasticity
  - Gurson Model
  - Hill Yield Criterion
- Creep
- Life
- Strength
- Gasket
- Viscoelastic Test Data
- Viscoelastic
- Shape Memory Alloy
- Geomechanical
- Damage
- Cohesive Zone
- Fracture Criteria
- Crack Growth Laws
- Custom Material Models

Outline of Schematic C2: Engineering Data

	A	B	C	D	E
1	Contents of Engineering Data			Source	Description
2	Material				
3	Structural Steel			Ger	Fatigue Data at zero mean stress comes from 1998 ASME BPV Code, Section 8, Div 2, Table 5-110.1
*	Click here to add a new material				

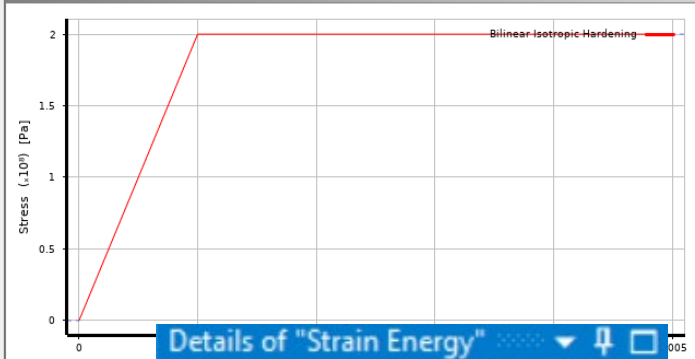
Table of Properties Row 12: Bilinear Isotropic Hardening

	A	B	C
1	Temperature (C)	Yield Strength (Pa)	Tangent Modulus (Pa)
2		2E+08	0
*			

Properties of Outline Row 3: Structural Steel

	A	B	C	D	E
1	Property	Value	Unit		
2	Material Field Variables	Table			
3	Density	7850	kg m^-3		
4	Isotropic Secant Coefficient of Thermal Expansion				
6	Isotropic Elasticity				
12	Bilinear Isotropic Hardening				
13	Yield Strength	2E+08	Pa		
14	Tangent Modulus	0	Pa		
15	Strain-Life Parameters				
23	S-N Curve	Tabular			
27	Tensile Yield Strength	2.5E+08	Pa		
28	Compressive Yield Strength	2.5E+08	Pa		
29	Tensile Ultimate Strength	4.6E+08	Pa		
30	Compressive Ultimate Strength	0	Pa		

Chart of Properties Row 12: Bilinear Isotropic Hardening



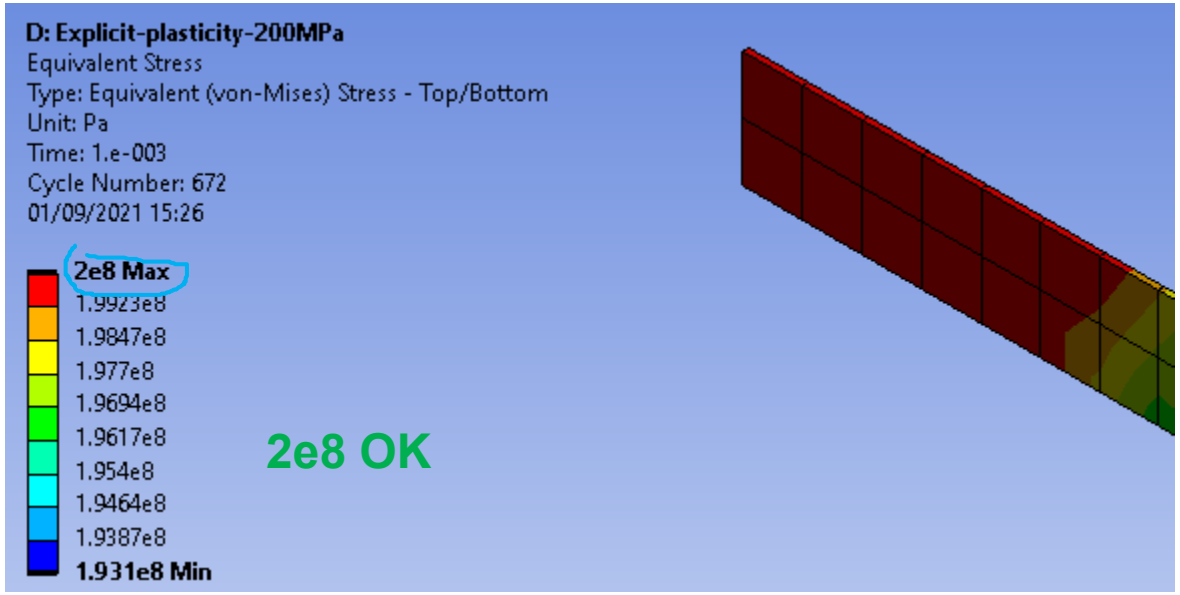
Display Time	End Time
Results	4e3 OK
Maximum Value Over Time	
X Axis	-4000. N
Y Axis	-1.7418e-008 N
Z Axis	-1.0303e-014 N
Total	4001.5 N
Minimum Value Over Time	
X Axis	-4001.5 N

Details of "Strain Energy"

Type	Strain Energy
By	Time
Display Time	Last
Calculate Time History	Yes
Identifier	
Suppressed	No
Results	
Minimum	0.19 J
Maximum	0.19 J
Total	11.4 J

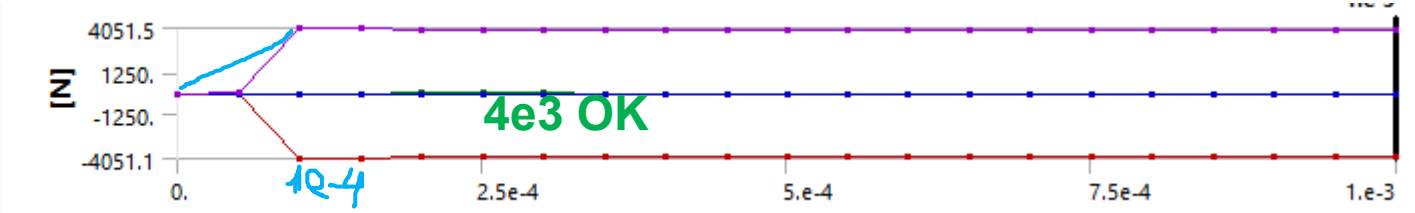
11.4 OK

- Repetimos en explícito



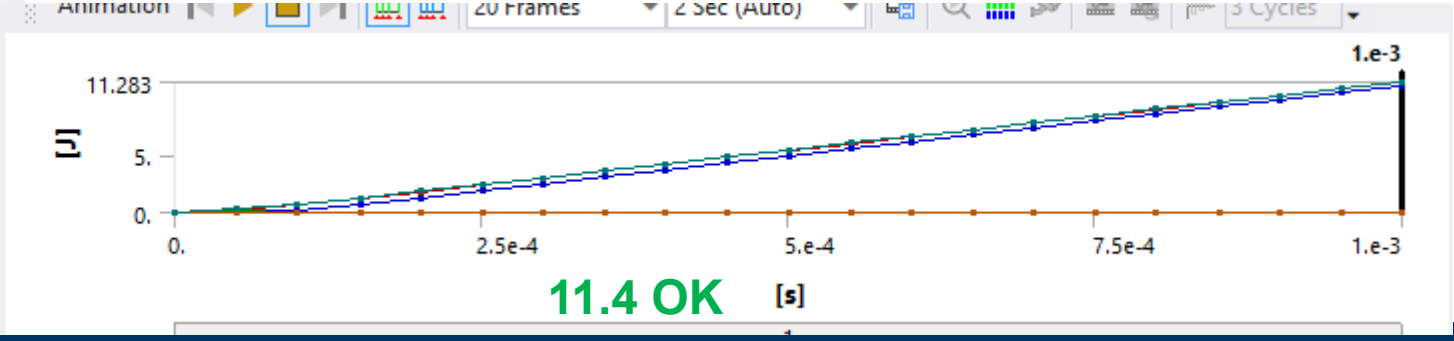
Maximum Value Over Time	
X Axis	0. N
Y Axis	9.5636 N
Z Axis	0. N
Total	4051.5 N

Minimum Value Over Time	



Maximum Value Over Time	
Internal	11.269 J
Kinetic	0.18259 J
Plastic Work	10.943 J
Hourglass	3.6588e-002 J
Contact	0. J
Total	11.283 J

Minimum Value Over Time	
Internal	0. J



- De tracción a impacto masa y velocidad

Para nuestra barra de 1x20x300 su rigidez es k=F/X=EA/L=1.33e7[N/m]. Si lo consideramos como un muelle y le ponemos una masa de 13.3[kg] en la punta tendremos una frecuencia raíz(1.33e7/13.3)=1000[rad/s] o 1.59E+02[hz] y por tanto periodo 6.28E-03[s]. Si le colocamos una velocidad de 1[m/s] tendremos la misma energía de 6.67[J] que en el caso elástico en que estirábamos 1[mm]

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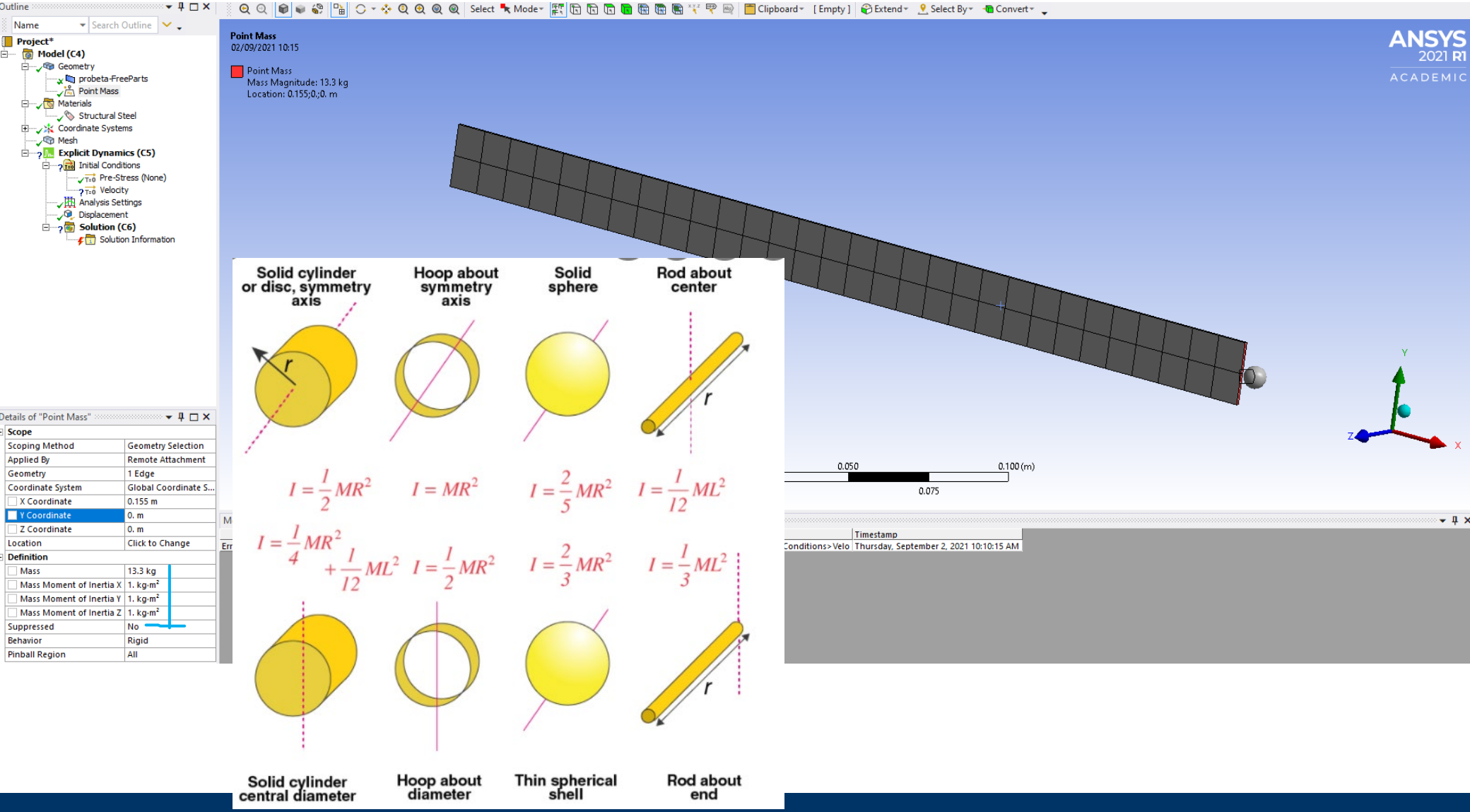
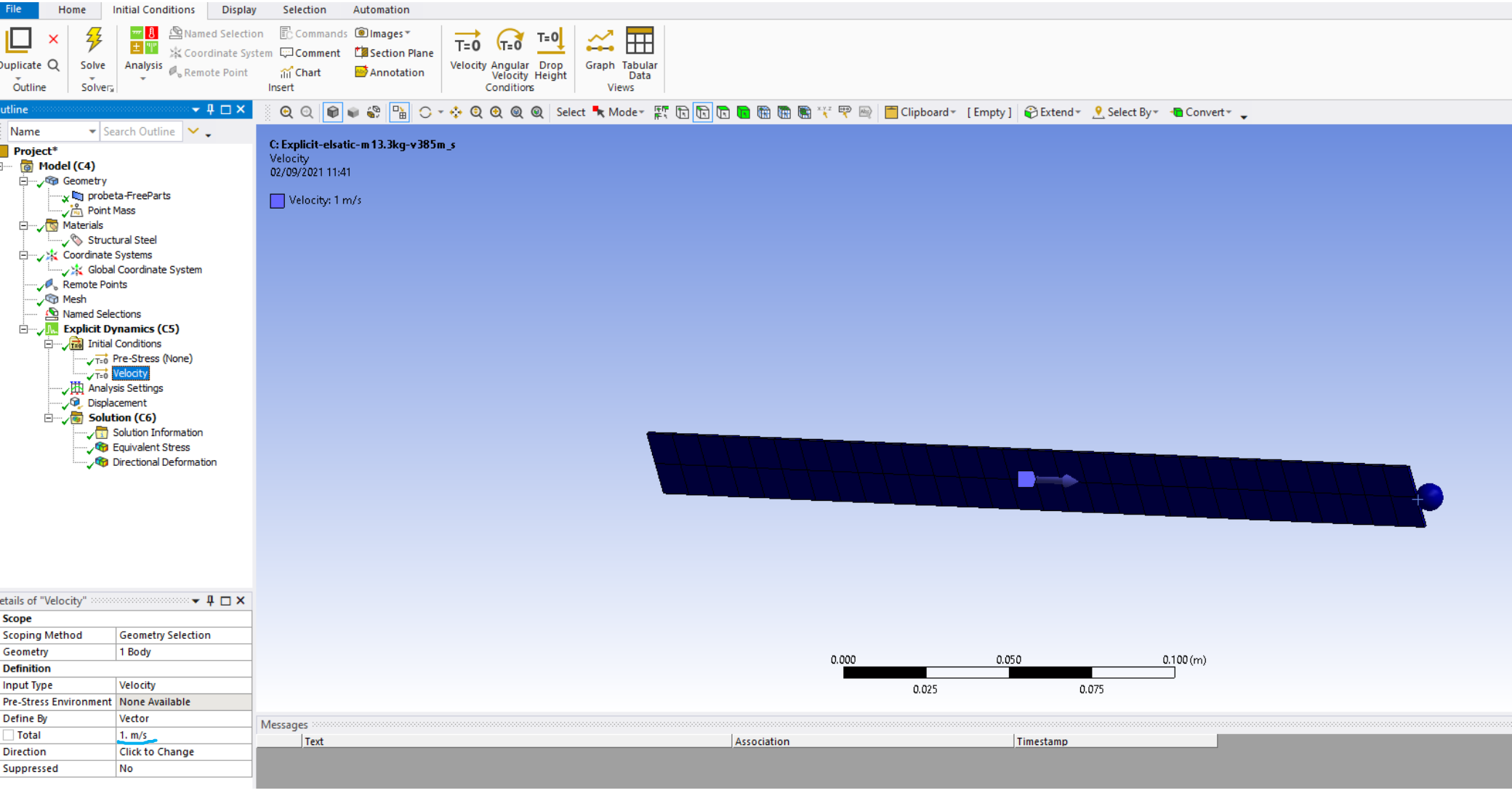
- Masa añadida



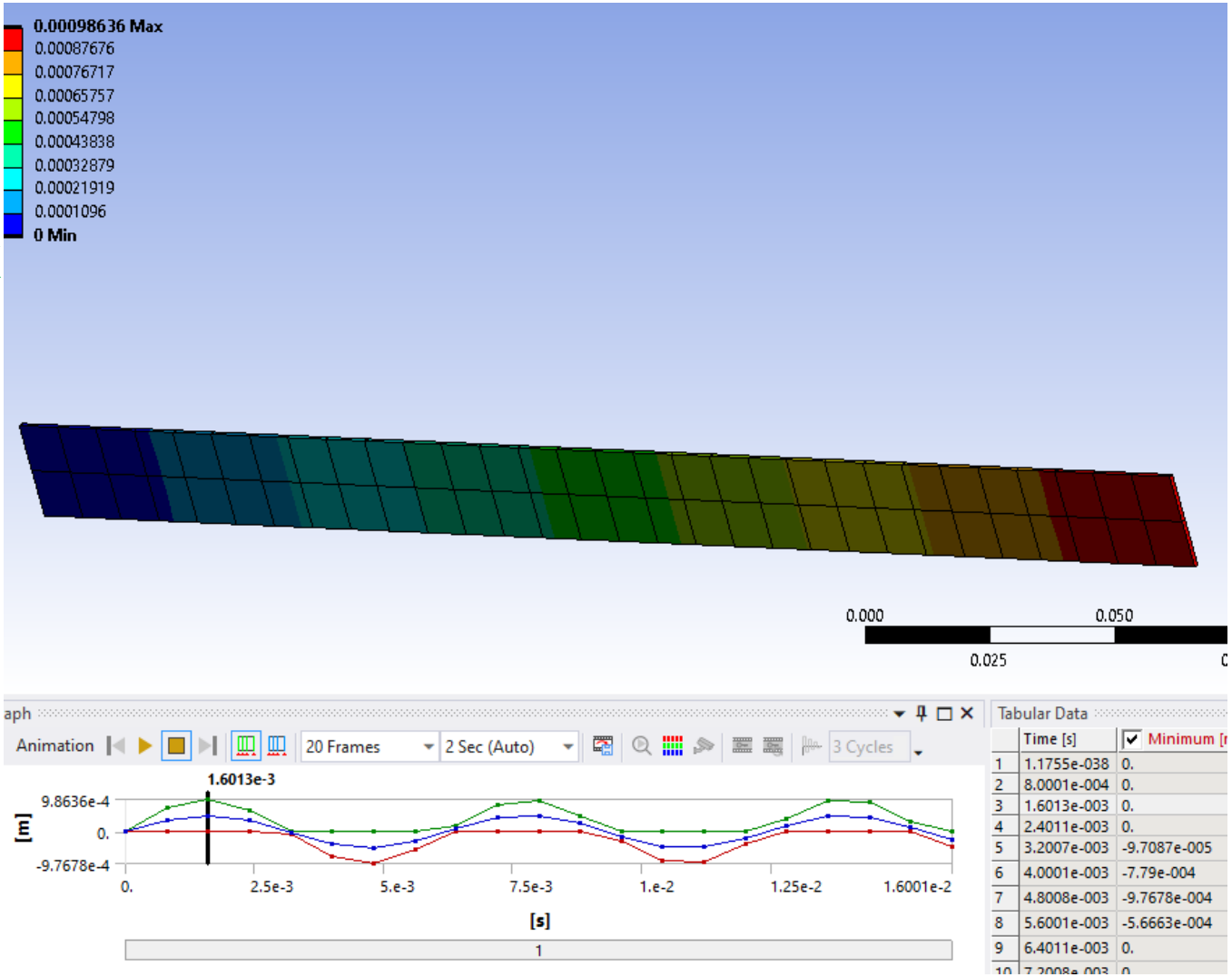
- Velocidad inicial



- Comprobación

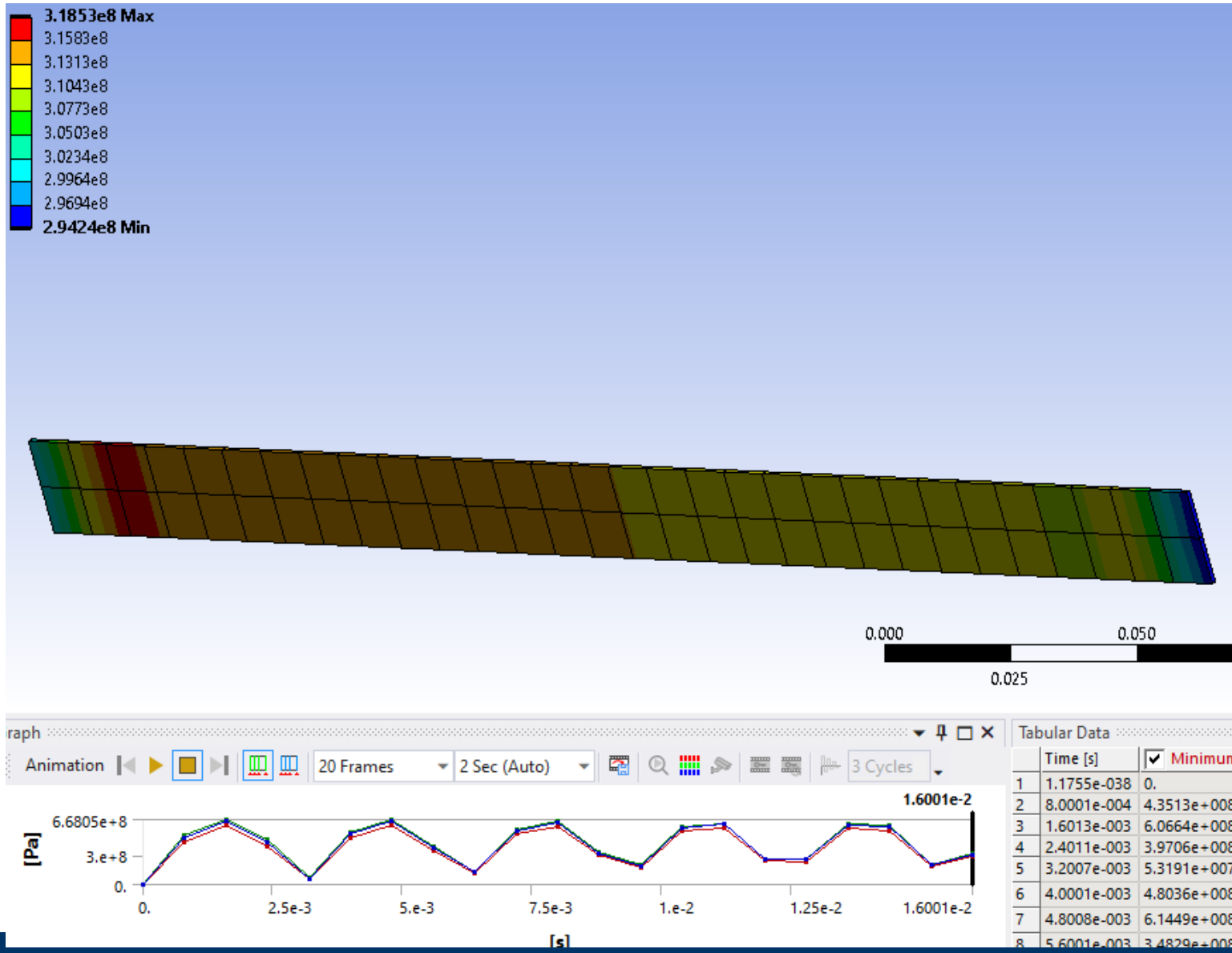
1[mm] OK

6.28[ms] OK



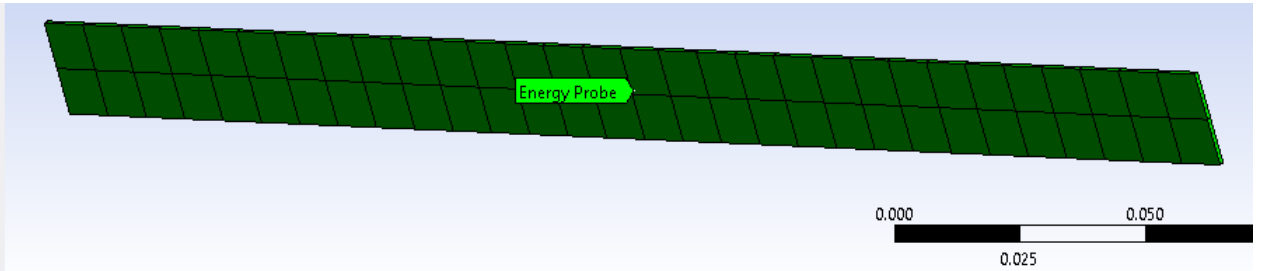
- Comprobación

667[MPa] OK



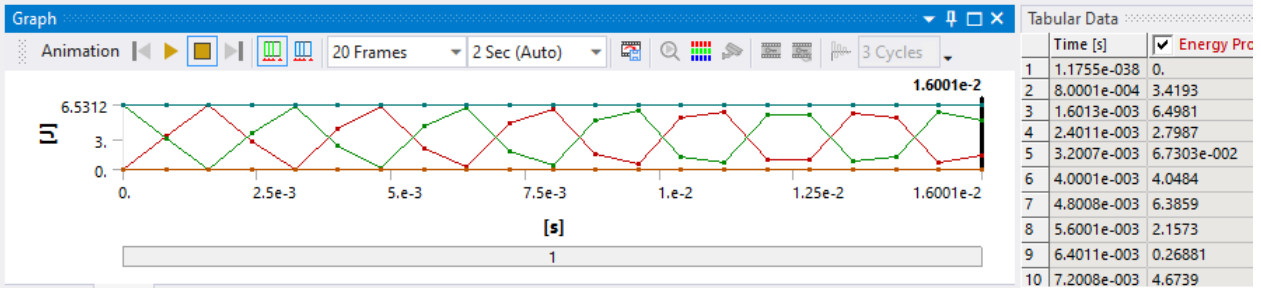
- Comprobación

6.67[J] OK



Details of "Energy Probe"

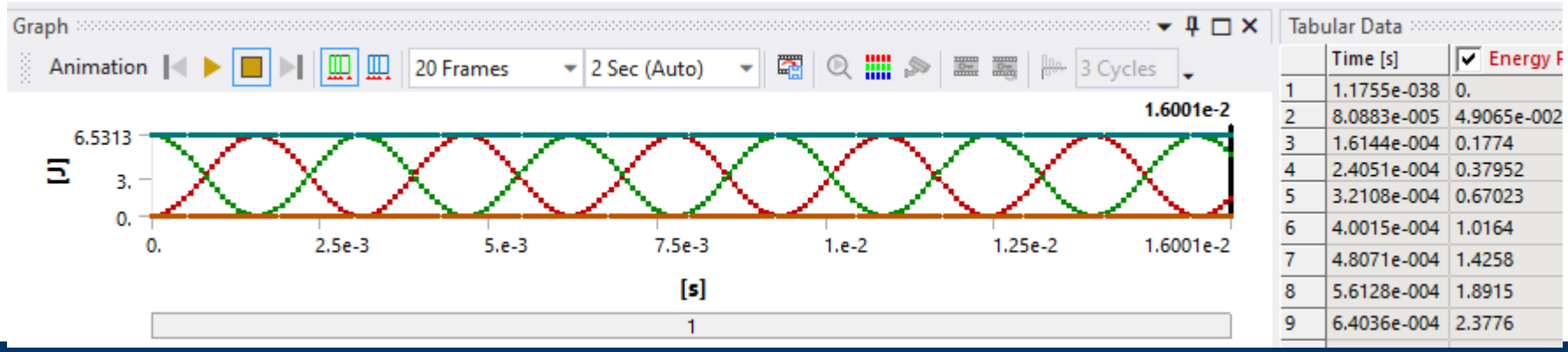
Definition	
Type	Energy
Geometry	1 Body
Suppressed	No
Options	
Result Selection	All
Display Time	End Time
Results	
Maximum Value Over Time	
Internal	6.4981 J
Kinetic	6.5232 J
Plastic Work	0. J
Hourglass	1.8582e-003 J
Contact	0. J
Total	6.5312 J



Tabular Data

	Time [s]	Energy Pro
1	1.1755e-038	0.
2	8.0001e-004	3.4193
3	1.6013e-003	6.4981
4	2.4011e-003	2.7987
5	3.2007e-003	6.7303e-002
6	4.0001e-003	4.0484
7	4.8008e-003	6.3859
8	5.6001e-003	2.1573
9	6.4011e-003	0.26881
10	7.2008e-003	4.6739

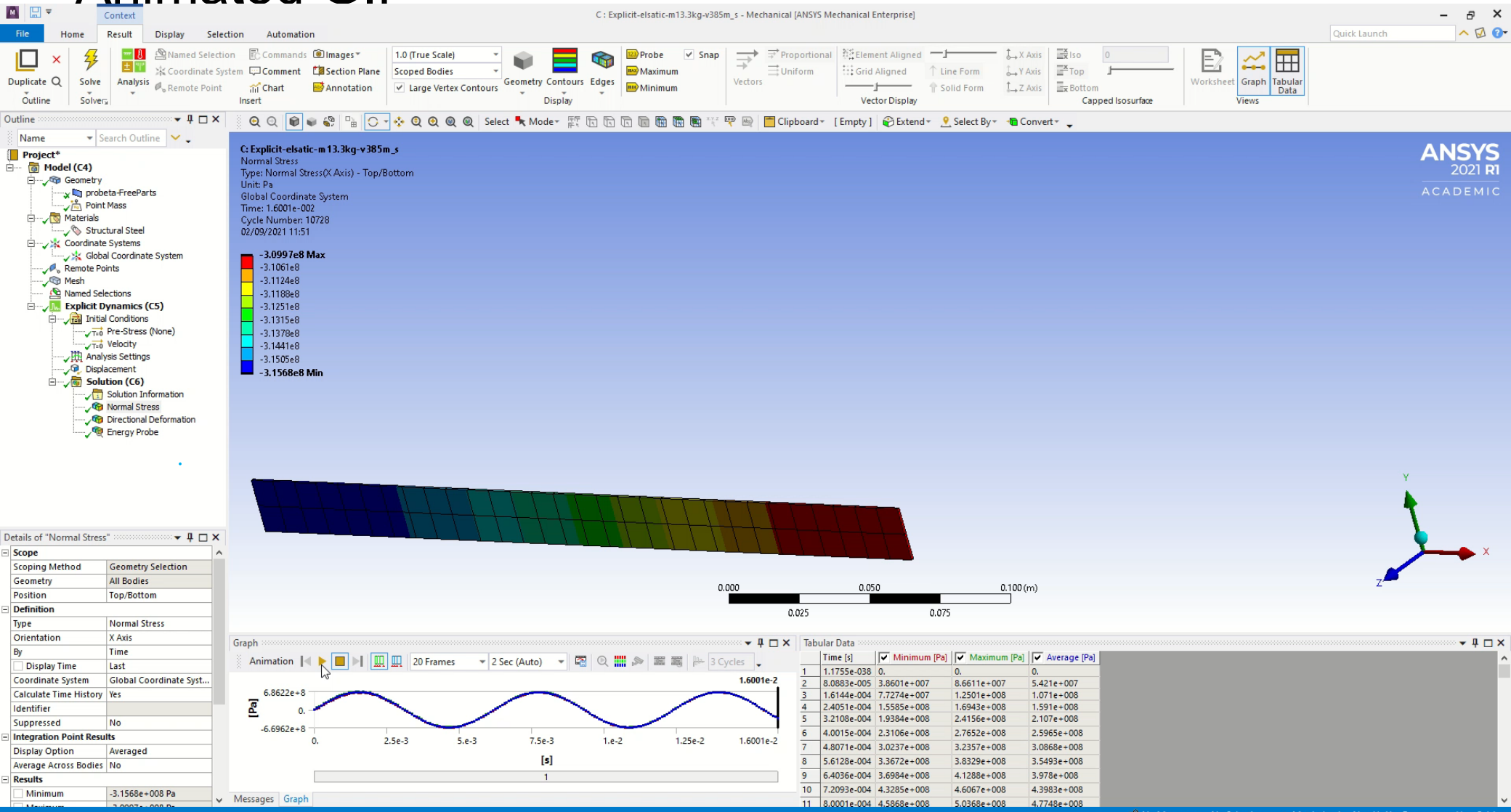
Output Controls	
Step-aware Output Controls	No
Save Results on	Equally Spac...
Result Number Of Points	200



Tabular Data

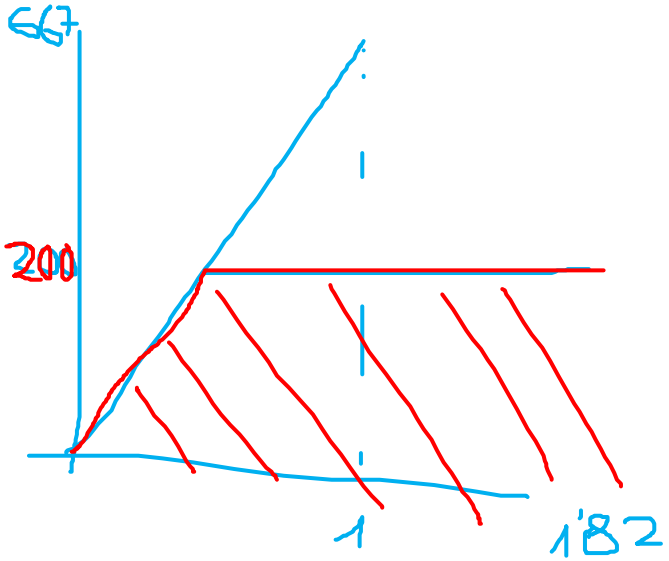
	Time [s]	Energy F
1	1.1755e-038	0.
2	8.0883e-005	4.9065e-002
3	1.6144e-004	0.1774
4	2.4051e-004	0.37952
5	3.2108e-004	0.67023
6	4.0015e-004	1.0164
7	4.8071e-004	1.4258
8	5.6128e-004	1.8915
9	6.4036e-004	2.3776

- Animated GIF



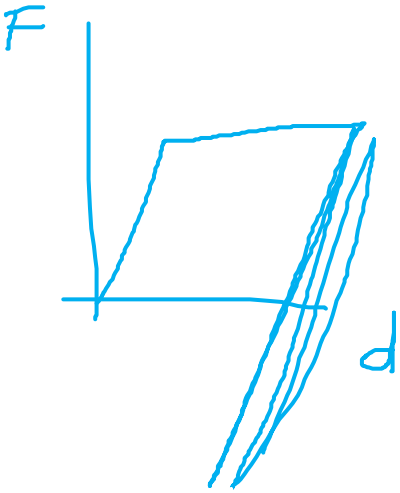
- Repetir el proceso pero con yield 200 MPa

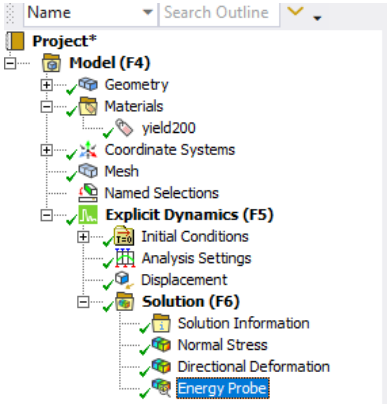
Ahora esa energía de 6.67[J] tendremos un desplazamiento de 1.82[mm] de la parte elástica más la plástica. (Si aproximamos d=E/F sale 6.67/4000=1.67[mm]). Tendremos un pequeño rebote de unos 0.3[mm] de la parte elástica. El tiempo para parar será t=v/(F/m)=1/(4000/13.3)=3.33[ms].

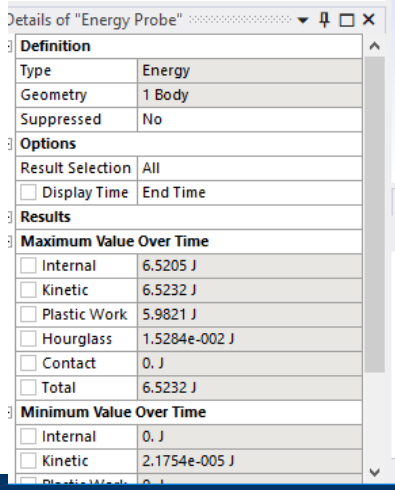


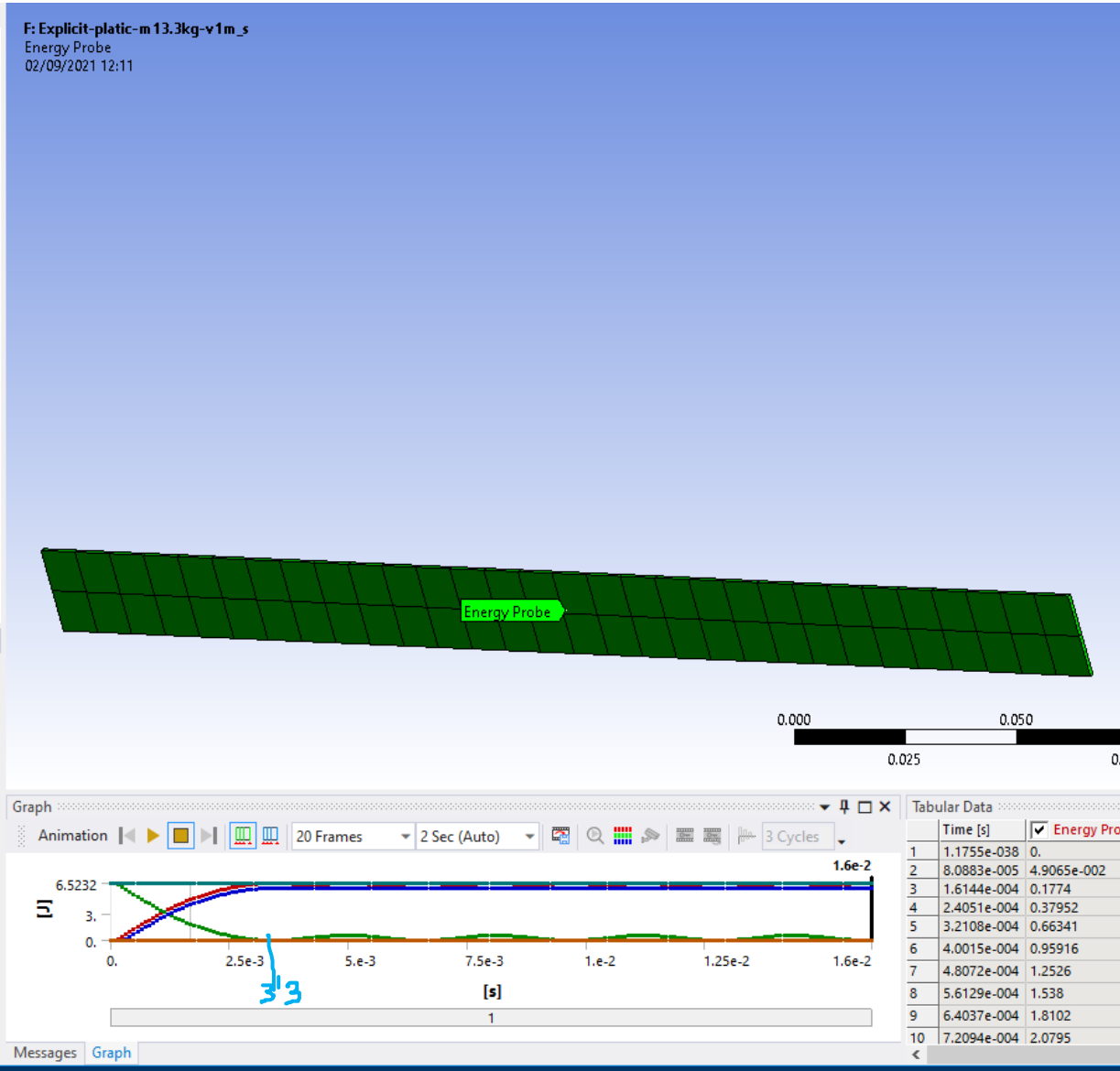
- Comprobaciones

6.67[J] OK
3.33[ms] OK



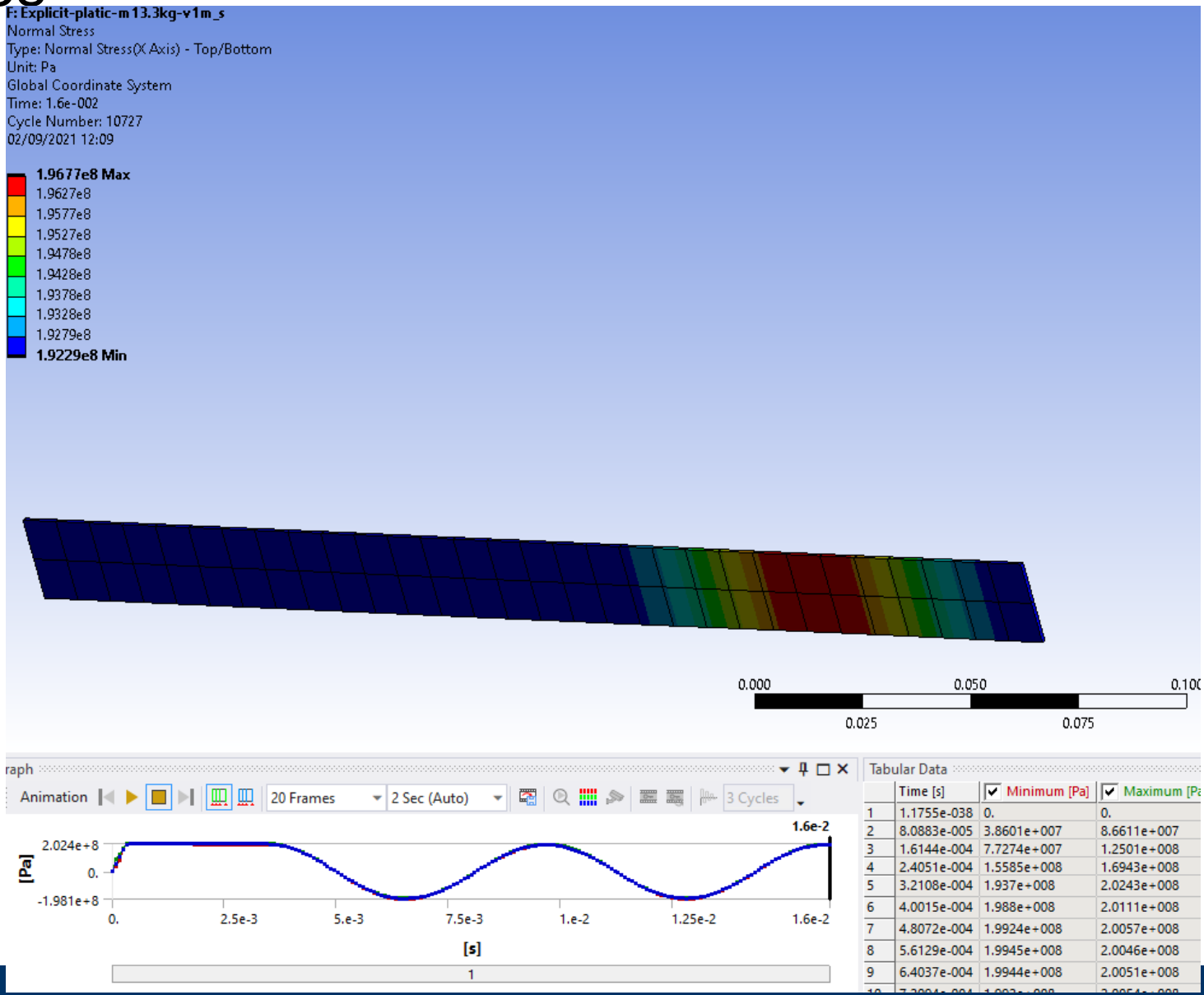






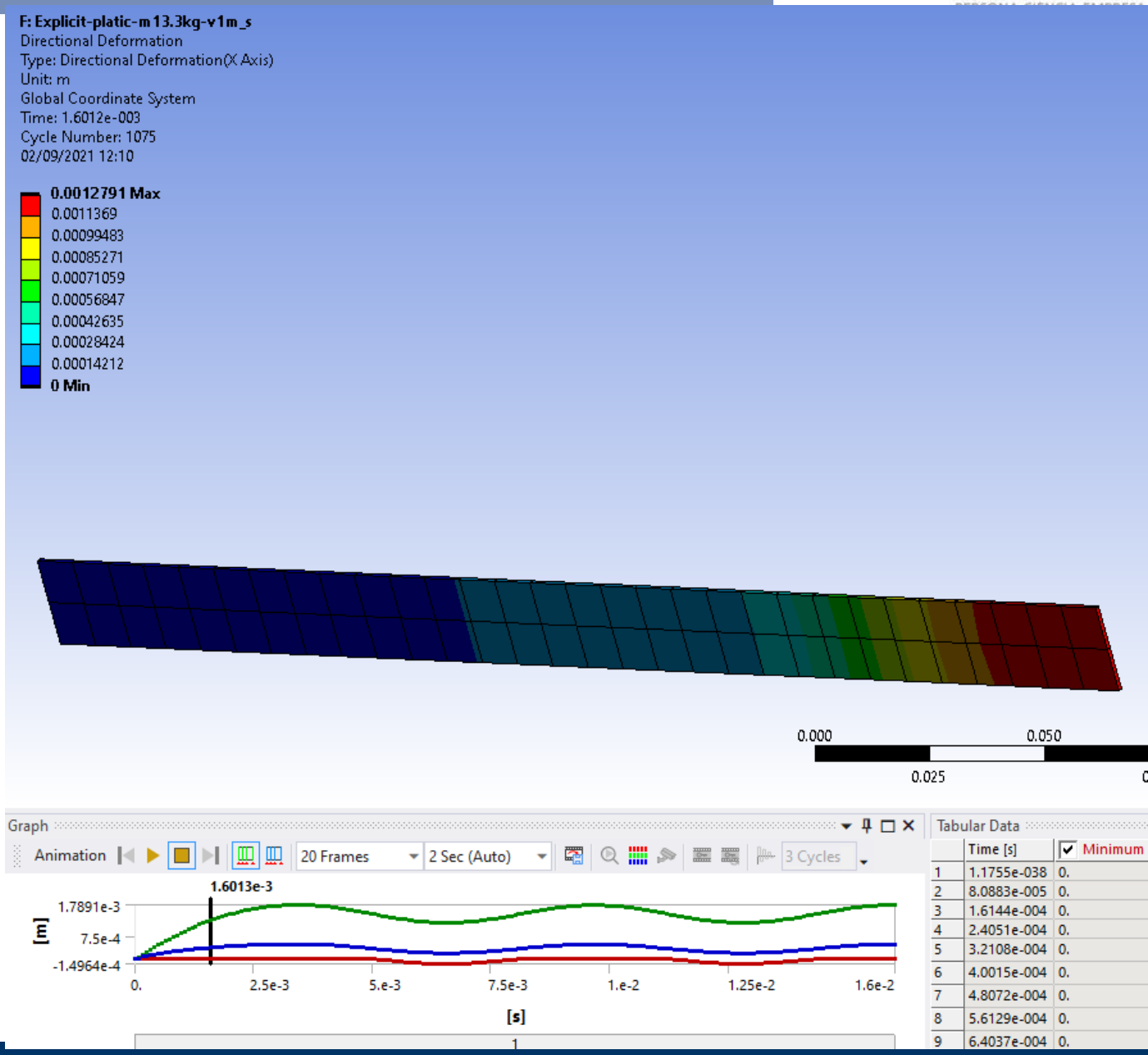
- Comprobaciones

2e8[MPa] OK



- Comprobaciones

1.82 [mm] OK



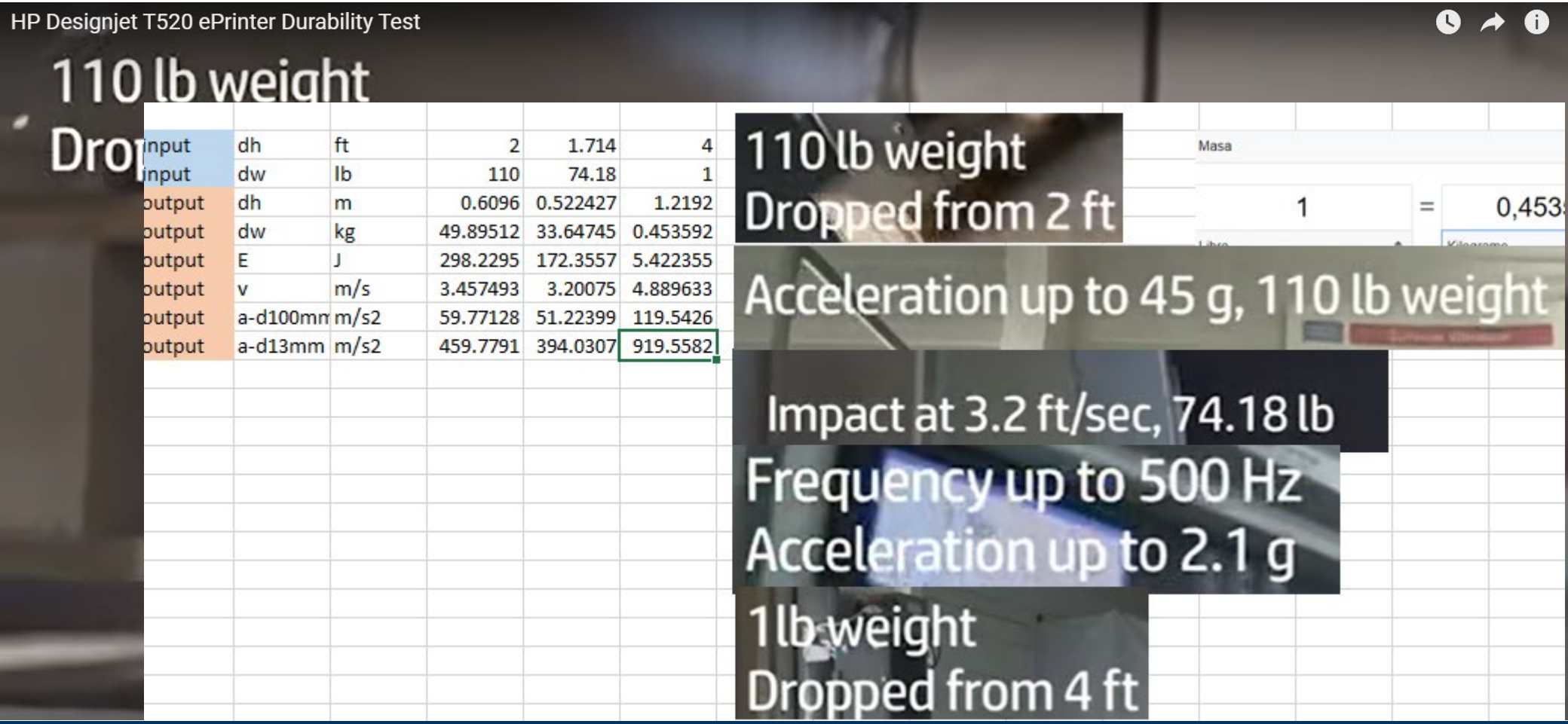
- Ejercicio

Realizar la misma simulación con espesor 2 y razonar que pasa.

	A	B	C	D	E
1	input	E	Pa	2.00E+11	2.00E+11
2	input	un	-	3.00E-01	3.00E-01
3	input	Lx	m	0.3	0.3
4	input	Ly	m	0.02	0.02
5	input	Lz	m	0.002	0.001
6	output	F-z1mm	N	1.19E+00	1.48E-01
7	output	s-z1mm	Pa	2.67E+07	1.33E+07
8	output	E-z1mm	J	1.58E+07	9.88E+05
9	output	k-z1mm	N/m	1.19E+03	1.48E+02
10	output	F-x1mm	N	2.67E+04	1.33E+04
11	output	s-x1mm	Pa	6.67E+08	6.67E+08
12	output	E-x1mm	J	1.33E+01	6.67E+00
13	output	k-x1mm	N/m	2.67E+07	1.33E+07
14	input	mp	kg	2.67E+01	1.33E+01
15	output	w	rad/s	1.00E+03	1.00E+03
16	output	w	hz	1.59E+02	1.59E+02
17	output	T	s	6.28E-03	6.28E-03
18	output	v	m/s	1.00E+00	1.00E+00
19	output	E-yield20(	J	1.33E+01	6.67E+00
20	output	F-yield20(	N	8.00E+03	4.00E+03
21	output	d-yield20(	m	3.00E-04	3.00E-04
22	output	dp-yield2(	m	1.67E-03	1.67E-03
23	output	dt-yeld20(	m	1.82E-03	1.82E-03
24	output	t-tield200	s	3.33E-03	3.33E-03
25					
26	output	e-x300mm	-	0.693147	0.693147
27	output	s-x300mm	Pa	1.39E+11	1.39E+11
28	output	F-x300mm	N	2.37E+06	1.18E+06
29	output	E-x300mm	J	3.55E+05	1.78E+05

- Ejercicio

Hacer el cálculo del peso y velocidad del ensayo documentado de HP en https://www.youtube.com/watch?v=chTfre8-v5I

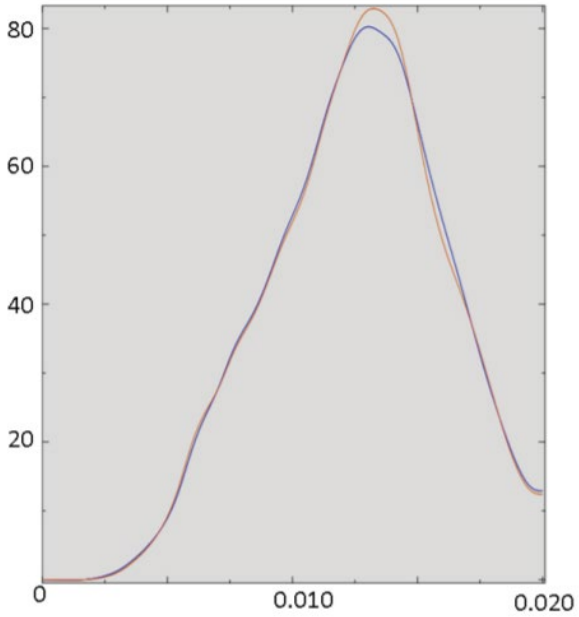


input	dh	ft	2	1.714	4
input	dw	lb	110	74.18	1
output	dh	m	0.6096	0.522427	1.2192
output	dw	kg	49.89512	33.64745	0.453592
output	E	J	298.2295	172.3557	5.422355
output	v	m/s	3.457493	3.20075	4.889633
output	a-d100mm	m/s2	59.77128	51.22399	119.5426
output	a-d13mm	m/s2	459.7791	394.0307	919.5582

- Ejercicio

Buscar información relacionada con los ensayos. Por ejemplo http://www.ata-e.com/wp-content/uploads/2019/01/HP-Drop-Test-Case-Study_2019.pdf

Otro ejemplo general https://mpe.researchmfg.com/shipping-carton-dropimpact-test-condition/



Simulated print-bar acceleration due to drop

Gross weight, m Kg (lbs.)	Drop height cm (in)
0.0 (0) < m ≦ 9.1 (20)	91 (36)
9.1 (20) < m ≦ 18.2 (40)	76 (30
18.2 (40) < m ≦ 27.2 (60)	61 (24)
27.2 (60) < m	46 (18)

- Resumen.

➢ Análisis de largas deformaciones

➢ Introducción de plasticidad

➢ Impacto elástico y frecuencias

➢ Impacto plástico y retorno elástico

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S03t.- Contactos.

Mejora 2122…

- Repaso última sesión

Cálculo con largos desplazamientos.

Cálculo con plasticidad.

Impacto con energía de masa y velocidad elástico y vibraciones y periodos.

Impacto con plasticidad y pequeño retorno elástico

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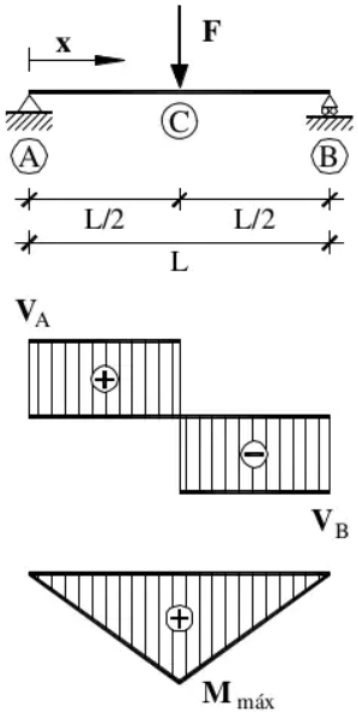
• Impacto a flexión

Vamos a hacer un impacto a 3 puntos a flexión de una masa y una velocidad. Si el impacto es elástico podemos saber cuanto se va a deformar la viga a flexión.

$k = 48EI/L^3 = 12Ebh^3/L^3$.

Empezamos con:
m=1[kg]
v=0.1[m/s]
L=0.25[m] distancia apoyos
h=0.001[m] espesor Lz
b=0.020[m] ancho Ly
Lx=0.300[m] longitud total

VIGA SIMPLE APOYADA: carga puntual $\mathbf{F}$ centrada.



Reacciones y solicitaciones

Reacciones: $R_A = R_B = \frac{F}{2}$

Cortantes: $V_{AC} = \frac{F}{2}$ $V_{CB} = -\frac{F}{2}$

Flectores: $M_{AC} = \frac{F}{2}x$ $M_{CB} = \frac{F}{2}(L-x)$

$M_{máx} = M_C = \frac{FL}{4}$ para $x = \frac{L}{2}$

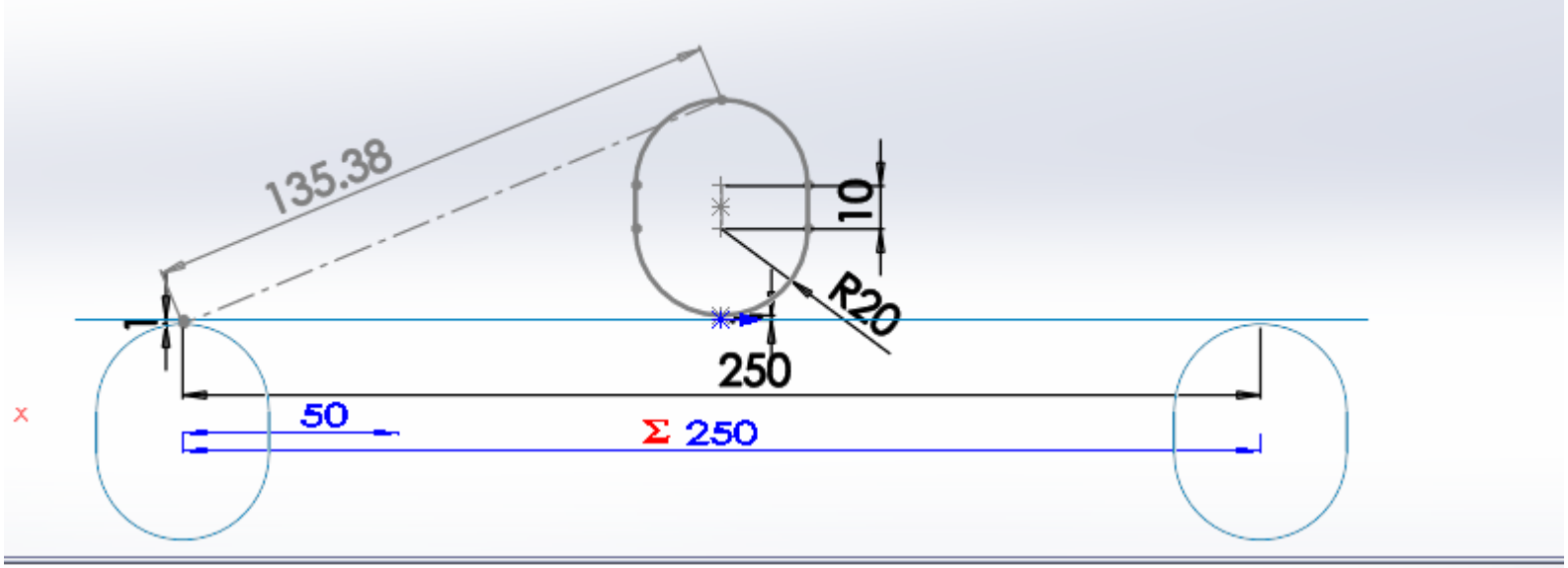
Deformaciones

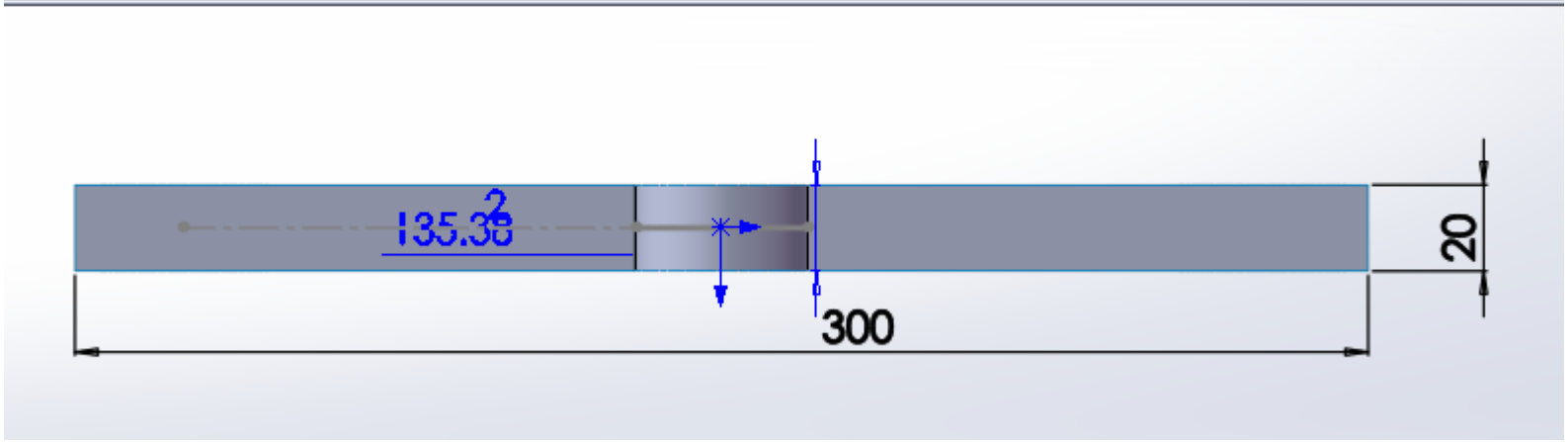
Giros: $\varphi_A = -\frac{FL^2}{16EI}$ $\varphi_B = \frac{FL^2}{16EI}$ $\varphi_C = 0$

Elástica: $y_{AC} = \frac{FL^2x}{16EI}\left(1 - \frac{4}{3}\frac{x^2}{L^2}\right)$ $y_{CB} = \frac{FL^2(L-x)}{12EI}\left(\frac{3}{4} - \frac{(L-x)^2}{L^2}\right)$

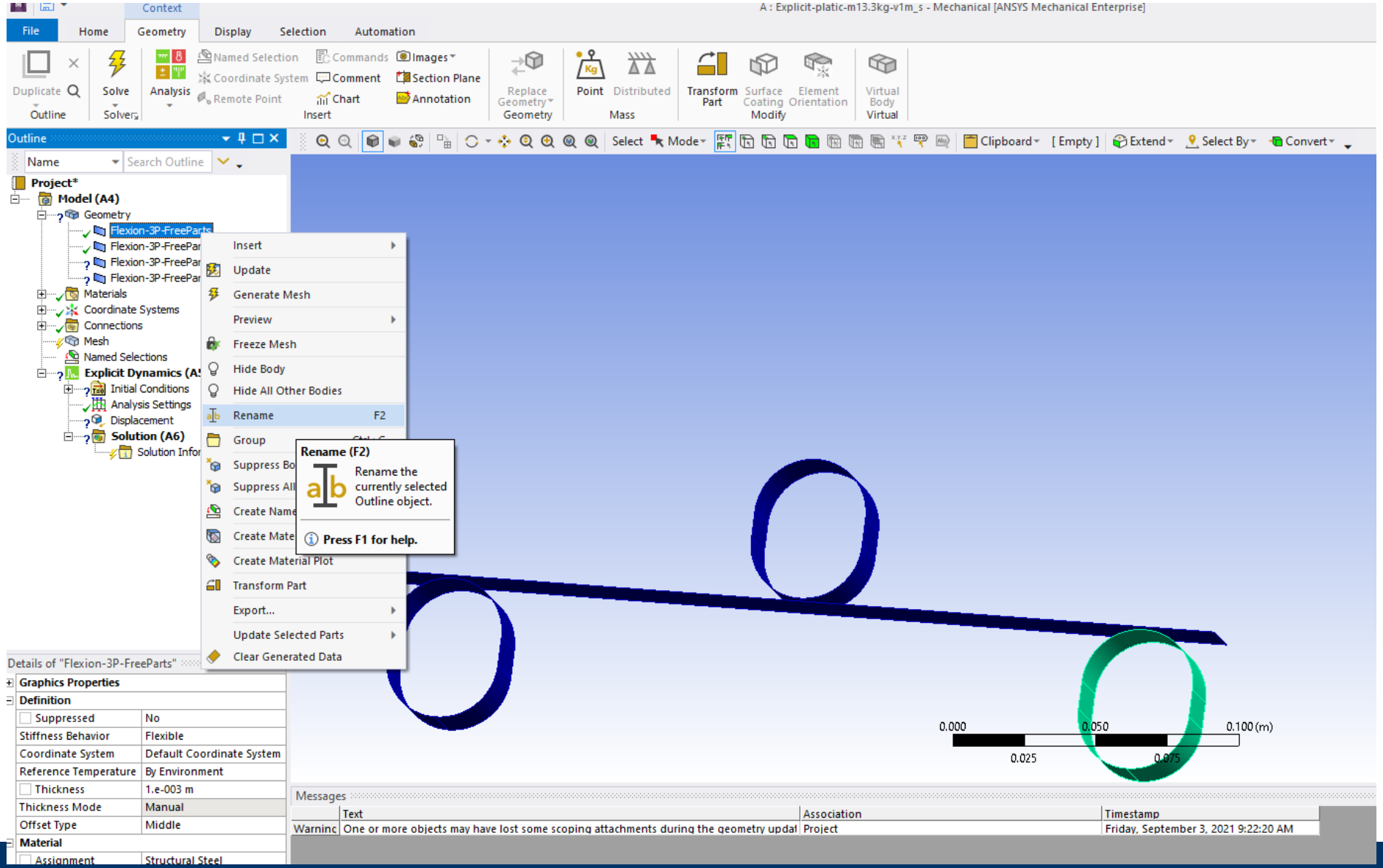
Flecha máxima: $y_{máx} = y_C = \frac{FL^3}{48EI}$ para $x = \frac{L}{2}$

- Geometría impactador a flexión

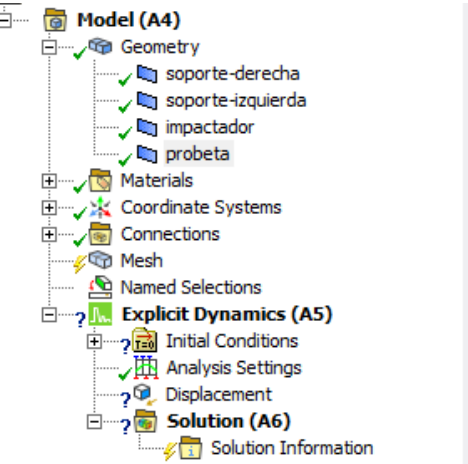


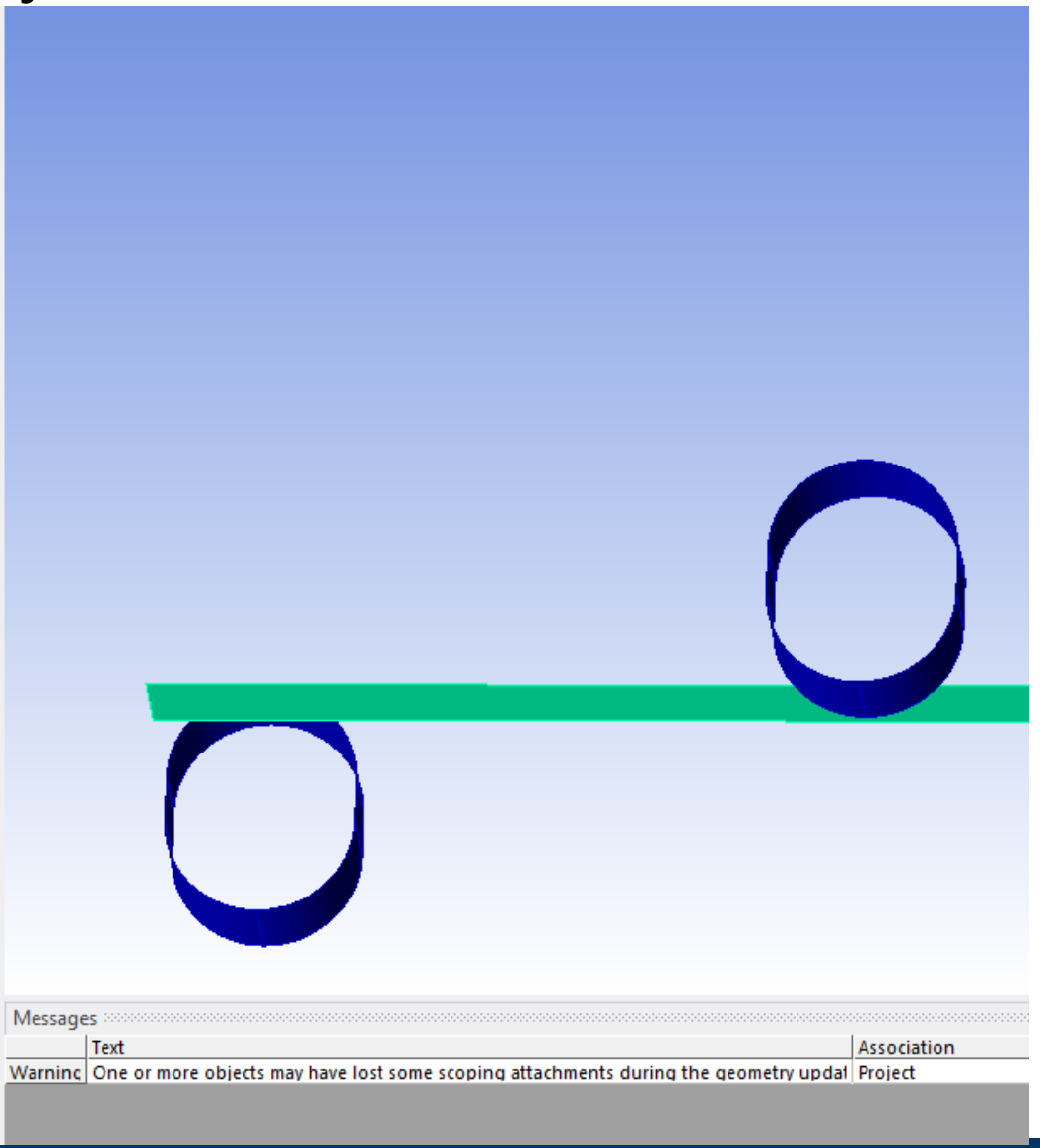


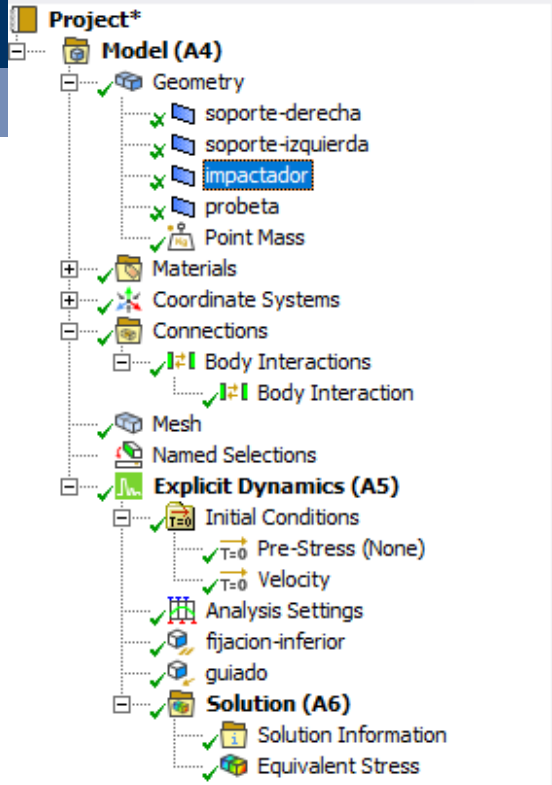
- Renombrar


A : Explicit-platic-m13.3kg-v1m_s - Mechanical [ANSYS Mechanical Enterprise]
Context
File
Home
Geometry
Display
Selection
Automation
Duplicate
Solve
Analysis
Named Selection
Coordinate System
Remote Point
Commands
Comment
Chart
Images
Section Plane
Annotation
Replace Geometry
Point
Distributed
Transform Part
Surface Coating
Element Orientation
Virtual Body
Outline
Solvers
Insert
Geometry
Mass
Modify
Virtual
Outline
Name
Search Outline
Project*
Model (A4)
Geometry
Flexion-3P-FreeParts
Materials
Coordinate Systems
Connections
Mesh
Named Selections
Explicit Dynamics (A5
Initial Conditions
Analysis Settings
Displacement
Solution (A6)
Solution Infor
Insert
Update
Generate Mesh
Preview
Freeze Mesh
Hide Body
Hide All Other Bodies
Rename F2
Group
Suppress Bo
Suppress All
Create Name
Create Mate
Create Material Plot
Transform Part
Export...
Update Selected Parts
Clear Generated Data
Rename (F2)
Rename the currently selected Outline object.
Press F1 for help.
Select
Mode
Clipboard
[Empty]
Extend
Select By
Convert
Details of "Flexion-3P-FreeParts"
Graphics Properties
Definition
Suppressed No
Stiffness Behavior Flexible
Coordinate System Default Coordinate System
Reference Temperature By Environment
Thickness 1.e-003 m
Thickness Mode Manual
Offset Type Middle
Material
Assignment Structural Steel
0.000
0.050
0.100 (m)
0.025
0.075
Messages
Text
Association
Timestamp
Warning
One or more objects may have lost some scoping attachments during the geometry updat
Project
Friday, September 3, 2021 9:22:20 AM

- Espesores y materiales







Details of "probeta"

Graphics Properties	
Definition	
Suppressed	No
Stiffness Behavior	Flexible
Coordinate System	Default Coordinate System
Reference Temperature	By Environment
Thickness	1.e-003 m
Thickness Mode	Manual
Offset Type	Middle
Material	
Assignment	yield200

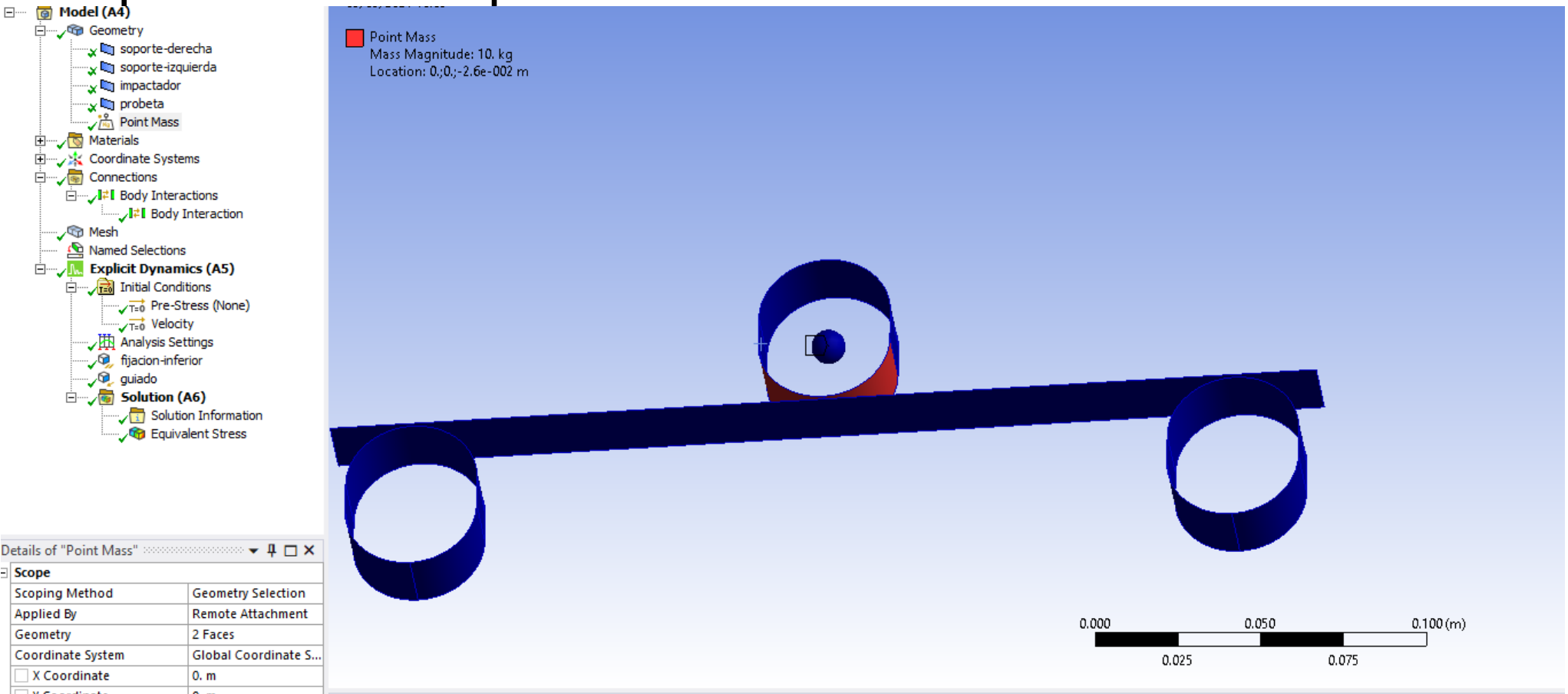
Messages

	Text	Association
Warning	One or more objects may have lost some scoping attachments during the geometry updat	Project

Details of "impactador"

Graphics Properties	
Definition	
Suppressed	No
Stiffness Behavior	Flexible
Coordinate System	Default Coordinate System
Reference Temperature	By Environment
Thickness	1.e-003 m
Thickness Mode	Manual
Offset Type	Middle
Material	
Assignment	Structural Steel

- Aplicar masa impactador



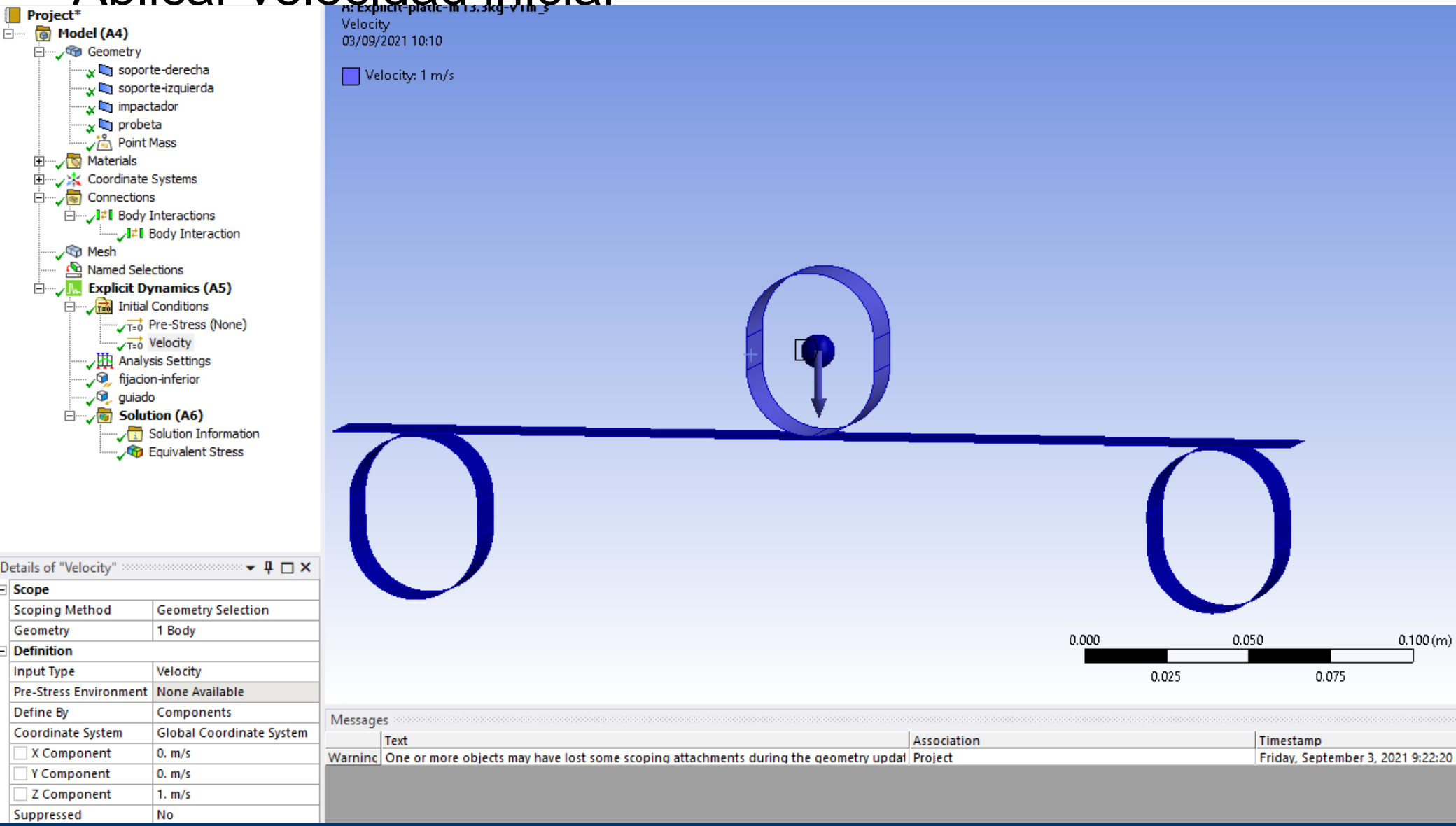
Details of "Point Mass"

Scope	
Scoping Method	Geometry Selection
Applied By	Remote Attachment
Geometry	2 Faces
Coordinate System	Global Coordinate S...
X Coordinate	0. m
Y Coordinate	0. m
Z Coordinate	-2.6e-002 m
Location	Click to Change
Definition	
Mass	10. kg
Mass Moment of Inertia X	1. kg·m²
Mass Moment of Inertia Y	1. kg·m²
Mass Moment of Inertia Z	1. kg·m²
Suppressed	No
Behavior	Rigid
Pinball Region	All

Messages

	Text	Association	Timestamp
Warninc	One or more objects may have lost some scoping attachments during the geometry updat	Project	Friday, September 3, 2021 9:22:20 AM

- Aplicar velocidad inicial



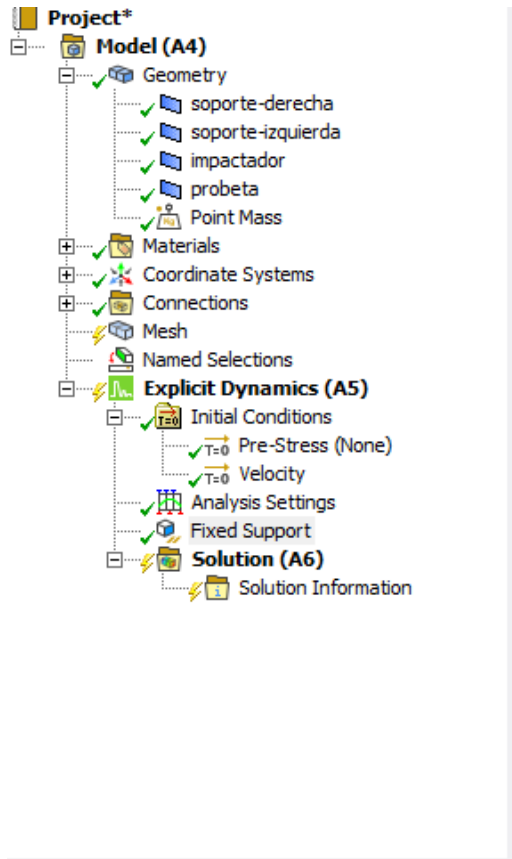
Details of "Velocity"

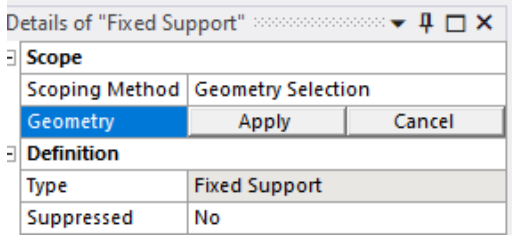
Scope	
Scoping Method	Geometry Selection
Geometry	1 Body
Definition	
Input Type	Velocity
Pre-Stress Environment	None Available
Define By	Components
Coordinate System	Global Coordinate System
X Component	0. m/s
Y Component	0. m/s
Z Component	1. m/s
Suppressed	No

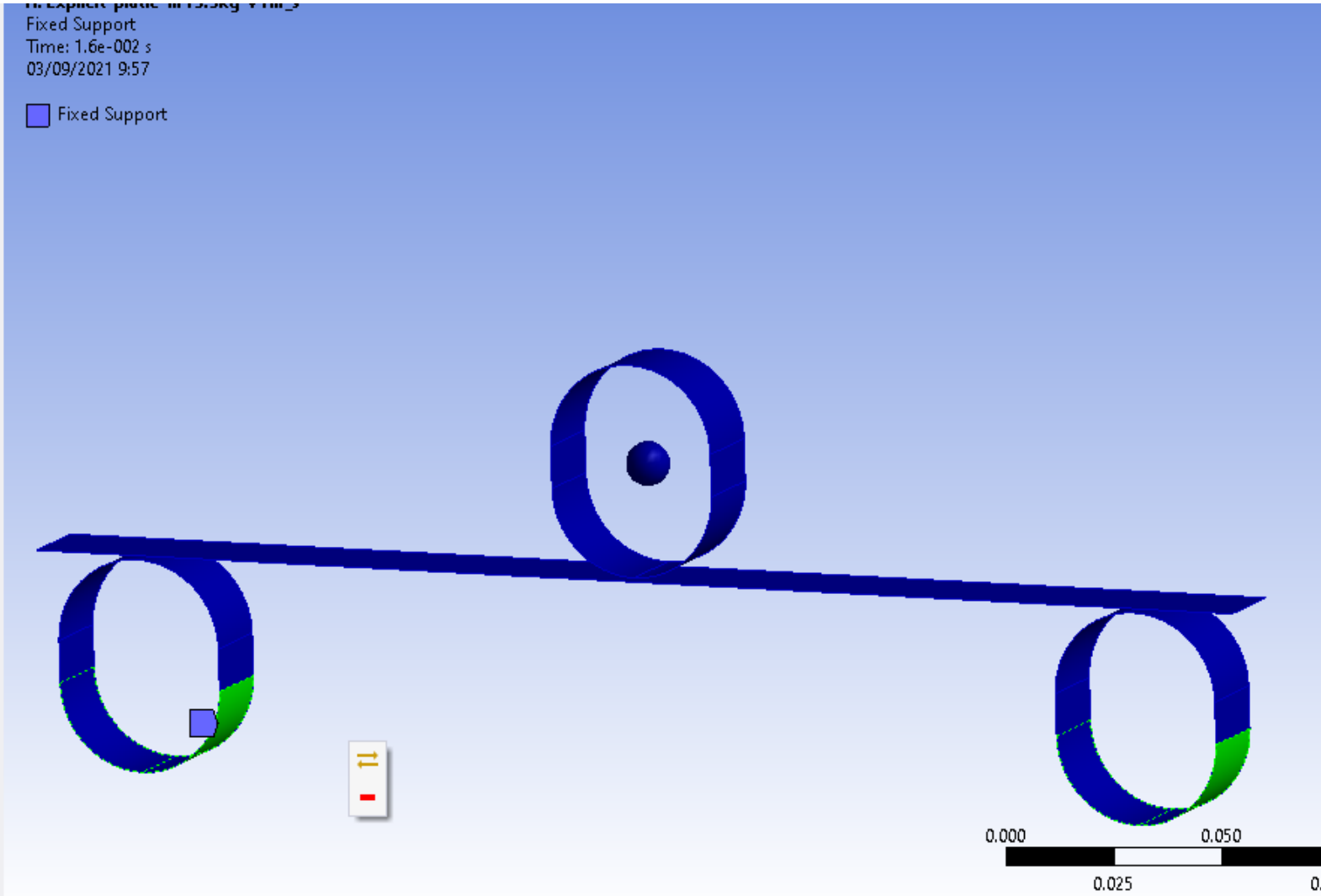
Messages

	Text	Association	Timestamp
Warninc	One or more objects may have lost some scoping attachments during the geometry updat	Project	Friday, September 3, 2021 9:22:20

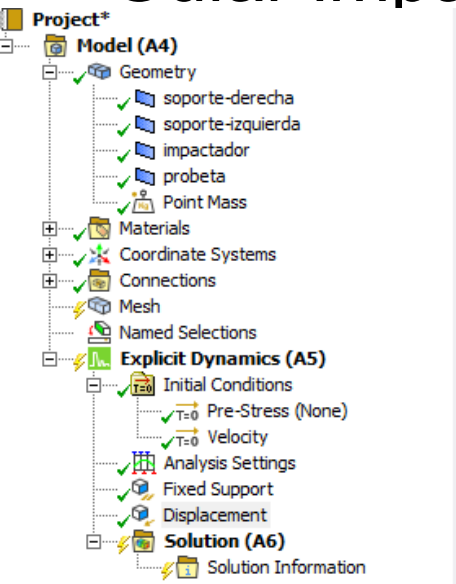
- Aplicar fijaciones

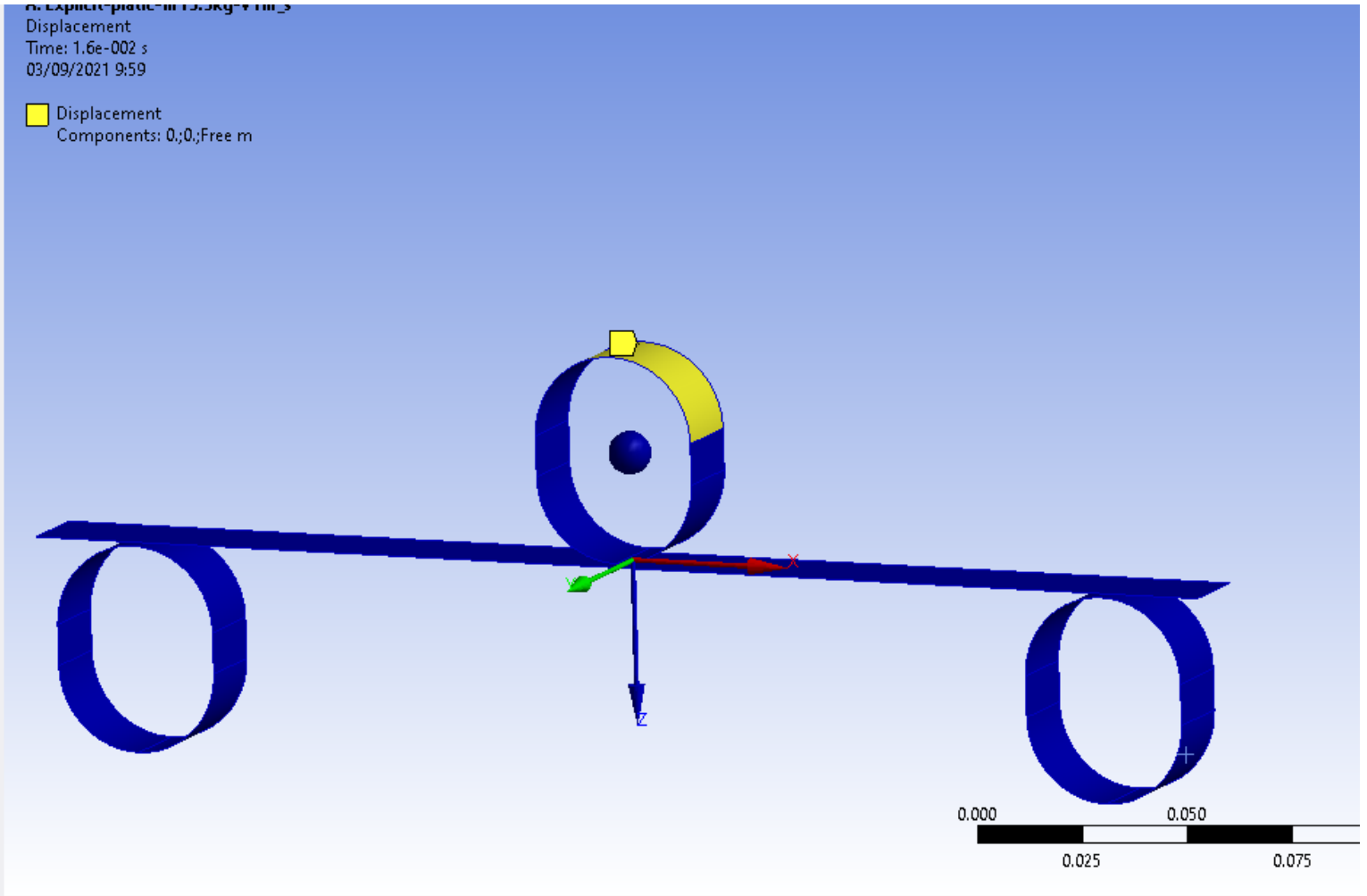






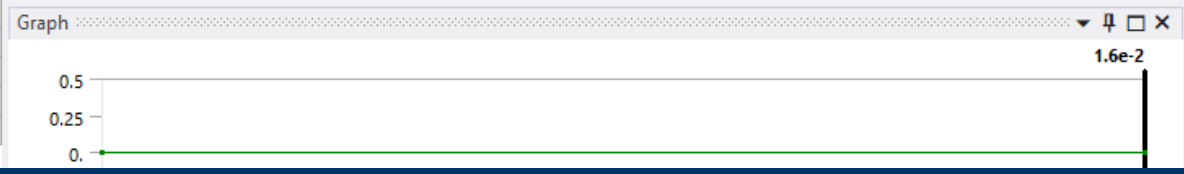
- Guiar impactador





Details of "Displacement"

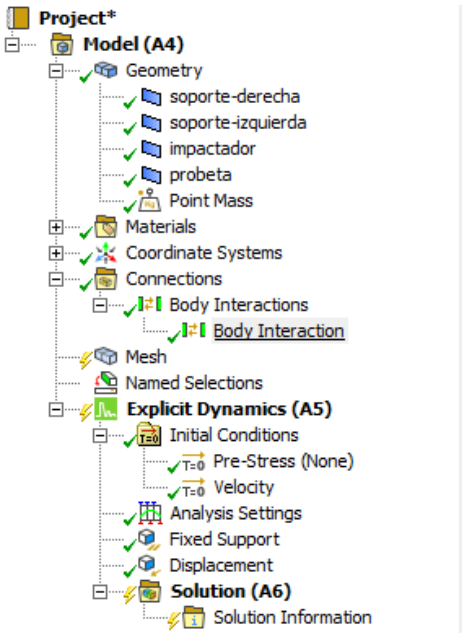
Scope	
Scoping Method	Geometry Selection
Geometry	2 Faces
Definition	
Type	Displacement
Define By	Components
Coordinate System	Global Coordinate System
X Component	0. m (ramped)
Y Component	0. m (ramped)
Z Component	Free
Suppressed	No



Tabular Data

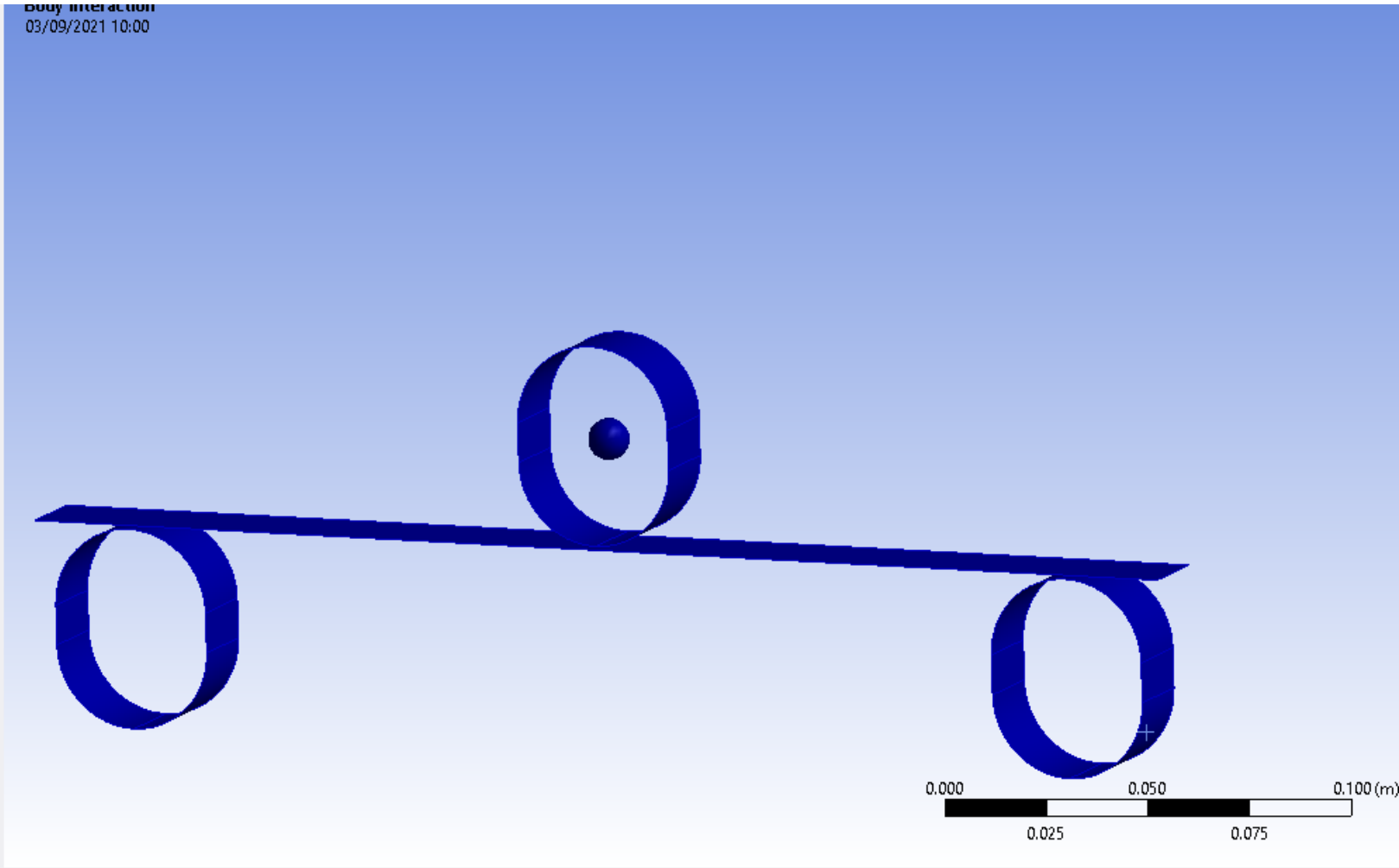
	Steps	Time [s]	X [m]	Y [m]
1	1	0.	0.	0.
2	1	1.6e-002	0.	0.
*				

- Contactos y fricción



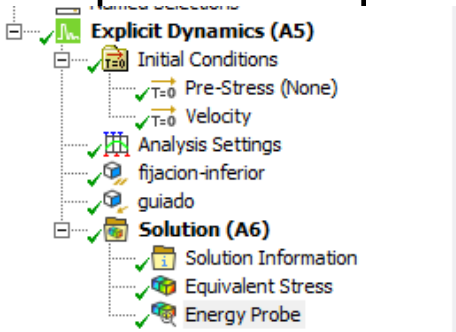
Details of "Body Interaction"

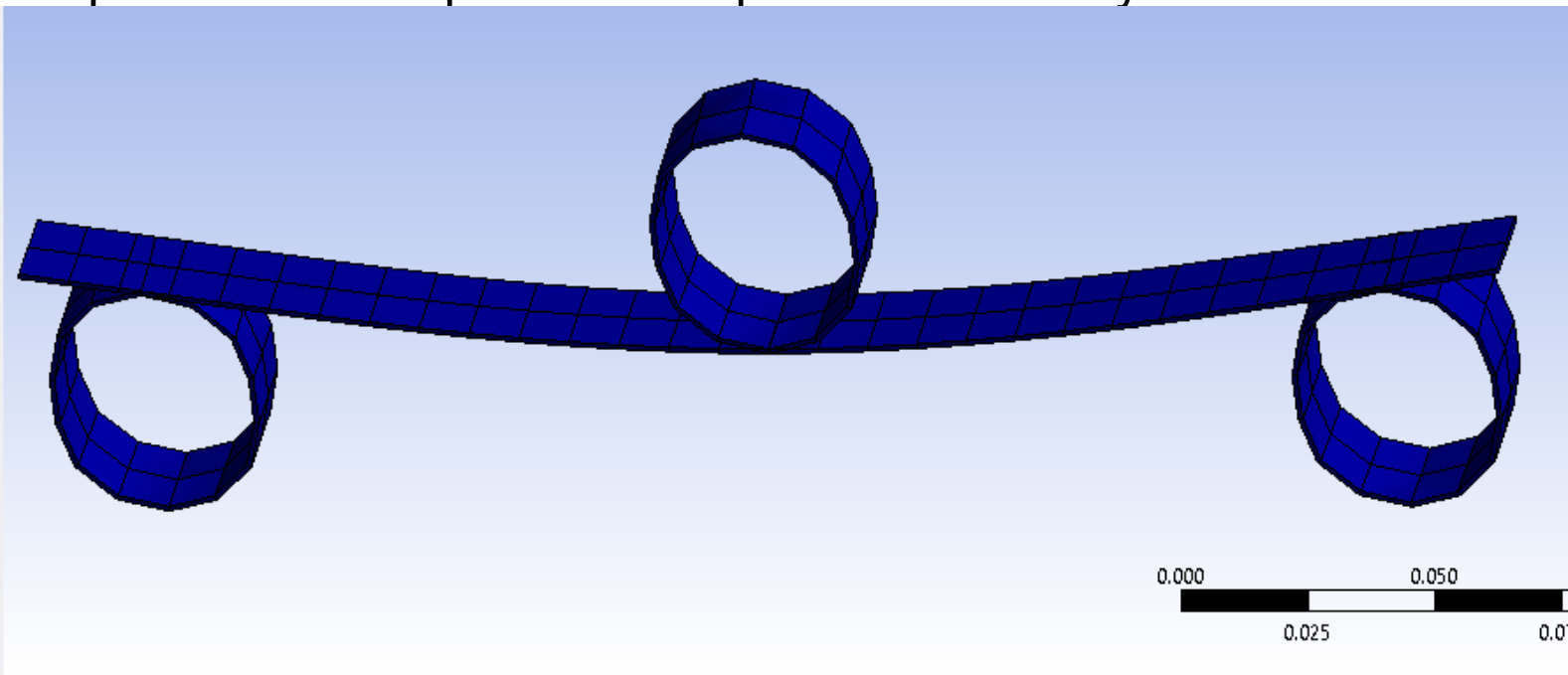
Scope	
Scoping Method	Geometry Selection
Geometry	All Bodies
Definition	
Type	Frictional
Friction Coefficient	0.1
Dynamic Coefficient	0.
Decay Constant	0.
Suppressed	No



- Resultados

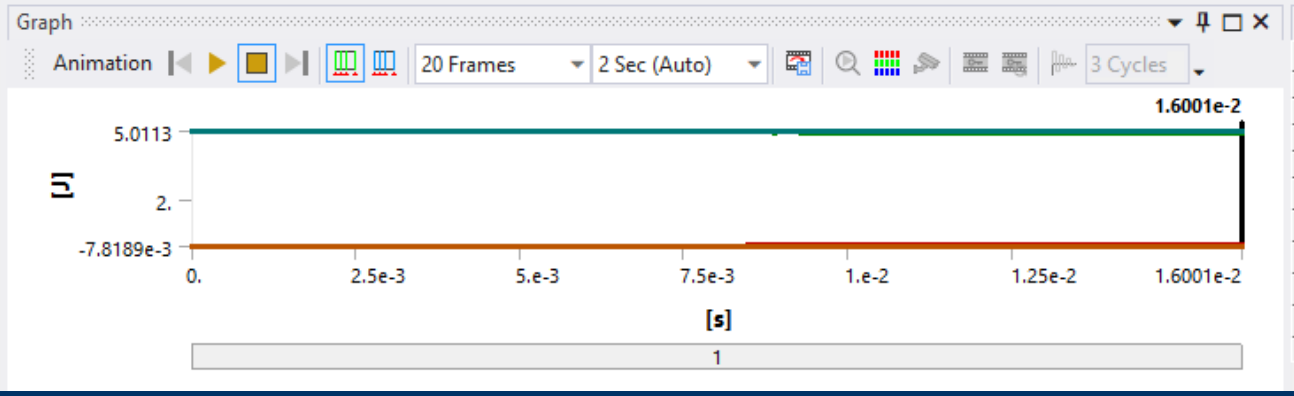
Se puede comprobar que con este espesor no se para esta masa y velocidad





Details of "Energy Probe"

Definition	
Type	Energy
Geometry	System Energy
Suppressed	No
Options	
Result Selection	All
Display Time	End Time
Results	
Maximum Value Over Time	
Internal	0.10537 J
Kinetic	5.0113 J
Plastic Work	1.1762e-002 J
Hourglass	1.0695e-003 J
Contact	0. J
Total	5.0113 J
Minimum Value Over Time	
Internal	0. J
Kinetic	4.8974 J



Tabular Data

	Time [s]	Energy P
1	1.1755e-038	0.
2	8.0661e-005	1.4564e-034
3	1.61e-004	4.3169e-034
4	2.4133e-004	8.5384e-034
5	3.2018e-004	1.4868e-033
6	4.0052e-004	2.2128e-033
7	4.8086e-004	2.4505e-033
8	5.6119e-004	3.792e-033
9	6.4004e-004	5.8384e-033
10	7.2038e-004	7.5361e-033

- Repetimos con v=0.1[m/s]

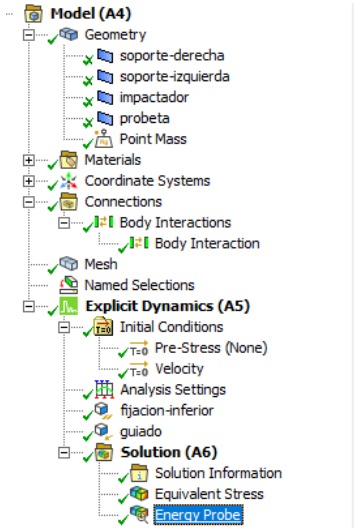
Ahora la energía es un 1%, o sea, 0.05[J] y vamos a calcular 1[s] para dar tiempo a acabar. Ahora vemos que necesitamos 1/1.49e-6= 671000 paso de cálculo y ya tarda en poder resolverse un tiempo considerable de uno 8[min] dependiendo del ordenador y número de CPU que utilicemos

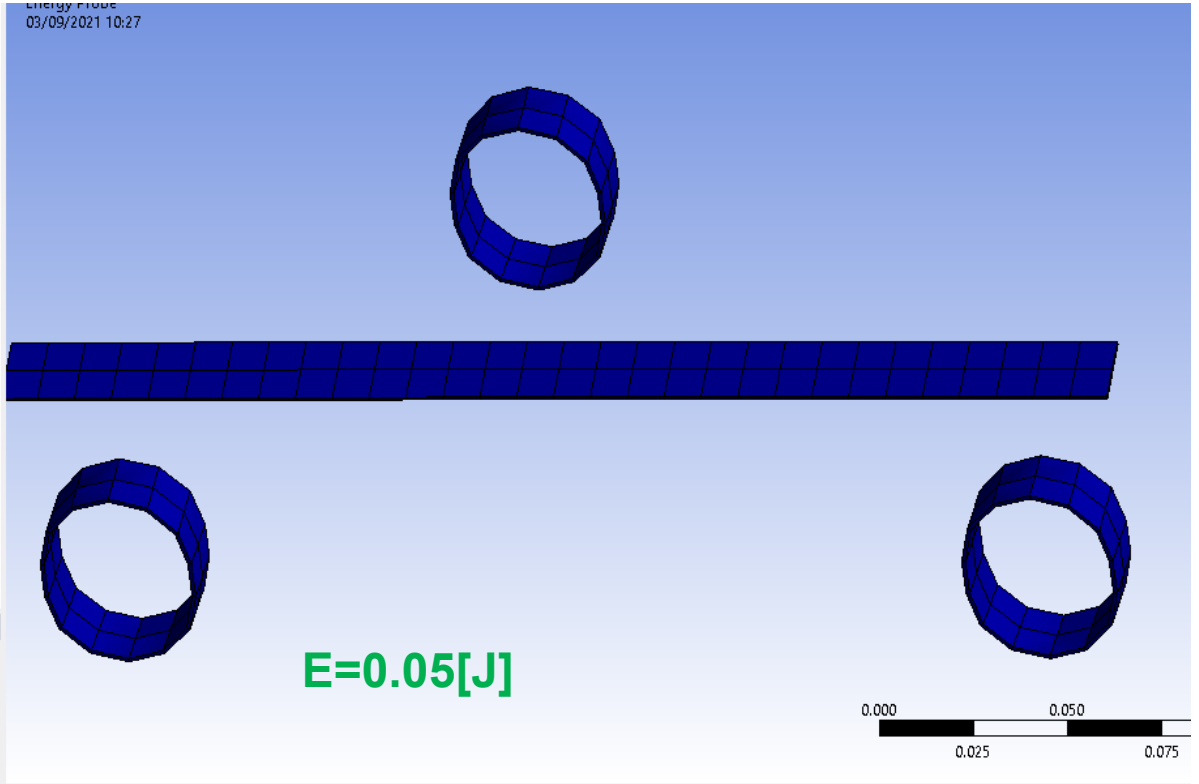
```
Cycle:   672174, Time:  1.000E+00s, Time Inc.: 1.488E-06s, Progress: 100.00%, Est. Cl
Cycle:   672175, Time:  1.000E+00s, Time Inc.: 1.488E-06s, Progress: 100.00%, Est. Cl


SIMULATION ELAPSED TIME SUMMARY

EXECUTION FROM CYCLE        0 TO   672175
ELAPSED RUN TIME IN SOLVER =      7.52017E+00 Minutes
TOTAL ELAPSED RUN TIME     =      7.92983E+00 Minutes
JOB RAN OVER     2 WORKERS
JOB RAN USING Intel MPI
JOB RAN USING DECOMPOSITION AUTO

Problem terminated .... wrapup time reached

 ******************************************
```

	A	B	C	D
1	input	E	Pa	2.00E+11
2	input	nu	-	3.00E-01
3	input	Lx	m	0.3
4	input	Ly	m	0.02
5	input	Lz	m	0.001
6	input	D	m	0.25
7	input	m	kg	10
8	input	v	m/s	0.1
9	output	E	J	5.00E-02
10	output	k	N/m	1.02E+03
11	output	xmax-elas	m	0.00988212
12	output	w-elas	rad/s	10.1192885
13	output	w-elas	hz	1.61053479
14	output	t/2-elas	s	0.31045588
15	output	amax-elas	m/s2	1.01192885
16	output	Fmax-elas	N	10.1192885
17	output	smax-elas	Pa	1.90E+08

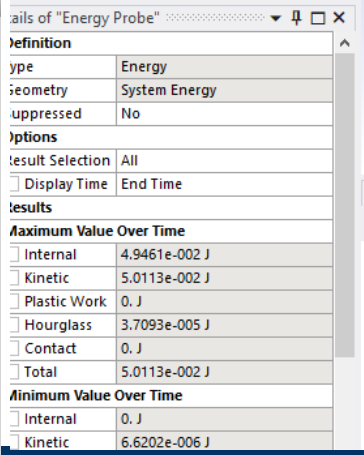
• Resultados

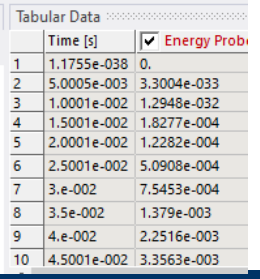
Con tan poca energía el impacto ha sido elástico y tiene un rebote. Con 0.3[s] tendríamos suficiente.





	A	B	C	D
1	input	E	Pa	2.00E+11
2	input	nu	-	3.00E-01
3	input	Lx	m	0.3
4	input	Ly	m	0.02
5	input	Lz	m	0.001
6	input	D	m	0.25
7	input	m	kg	10
8	input	v	m/s	0.1
9	output	E	J	5.00E-02
10	output	k	N/m	1.02E+03
11	output	xmax-elas	m	0.00988212
12	output	w-elas	rad/s	10.1192885
13	output	w-elas	hz	1.61053479
14	output	t/2-elas	s	0.31045588
15	output	amax-elas	m/s2	1.01192885
16	output	Fmax-elas	N	10.1192885
17	output	smax-elas	Pa	1.90E+08

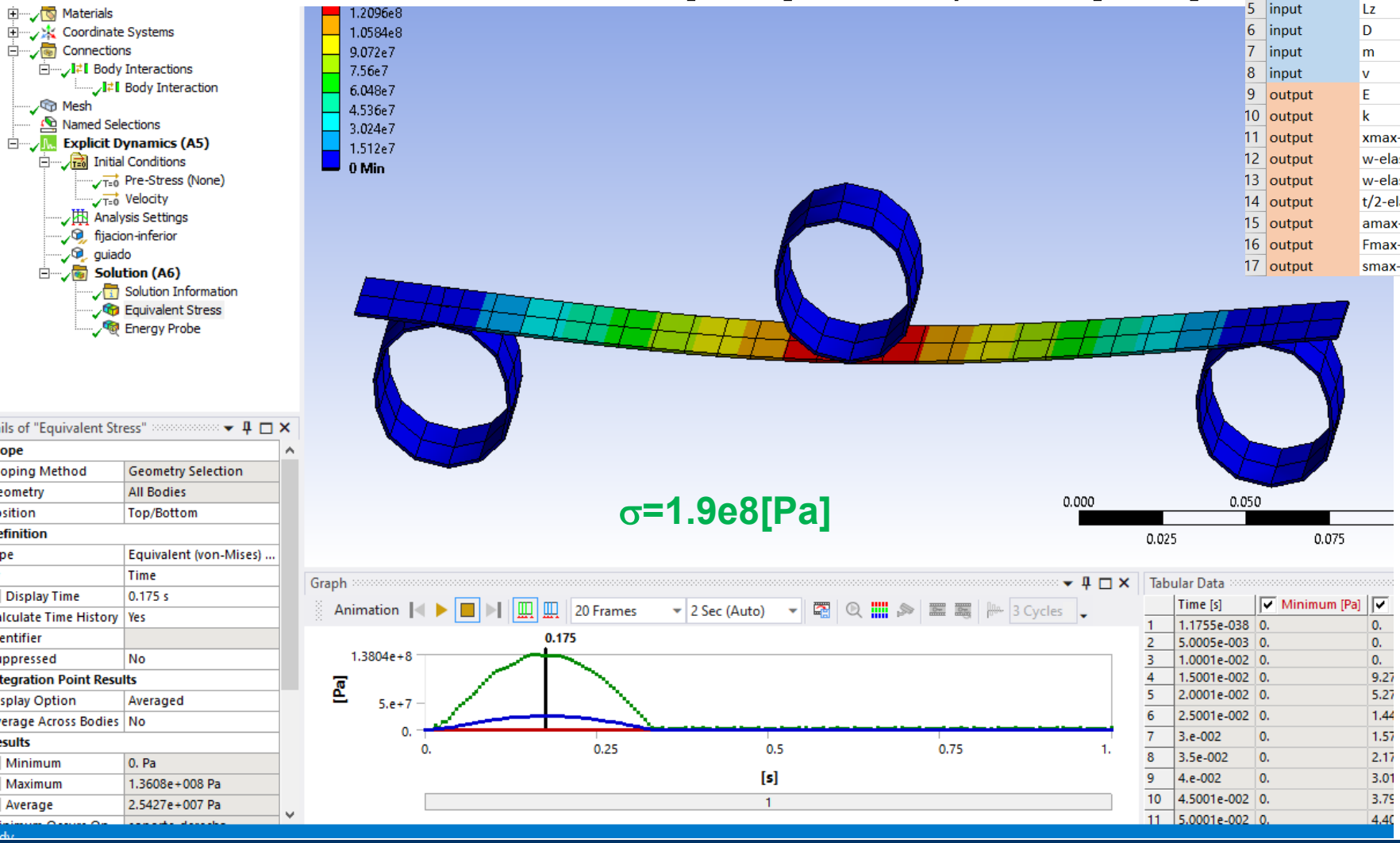




- Resultados

La máxima tensión es de unos 138[MPa] menor que 200[MPa]

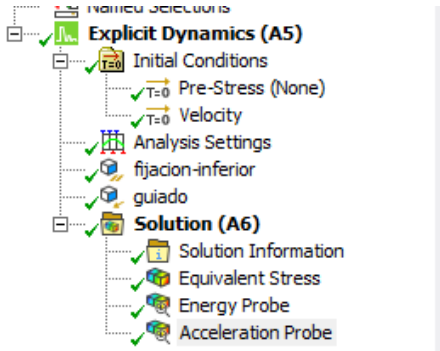
	A	B	C	D
1	input	E	Pa	2.00E+11
2	input	nu	-	3.00E-01
3	input	Lx	m	0.3
4	input	Ly	m	0.02
5	input	Lz	m	0.001
6	input	D	m	0.25
7	input	m	kg	10
8	input	v	m/s	0.1
9	output	E	J	5.00E-02
10	output	k	N/m	1.02E+03
11	output	xmax-elas	m	0.00988212
12	output	w-elas	rad/s	10.1192885
13	output	w-elas	hz	1.61053479
14	output	t/2-elas	s	0.31045588
15	output	amax-elas	m/s2	1.01192885
16	output	Fmax-elas	N	10.1192885
17	output	smax-elas	Pa	1.90E+08

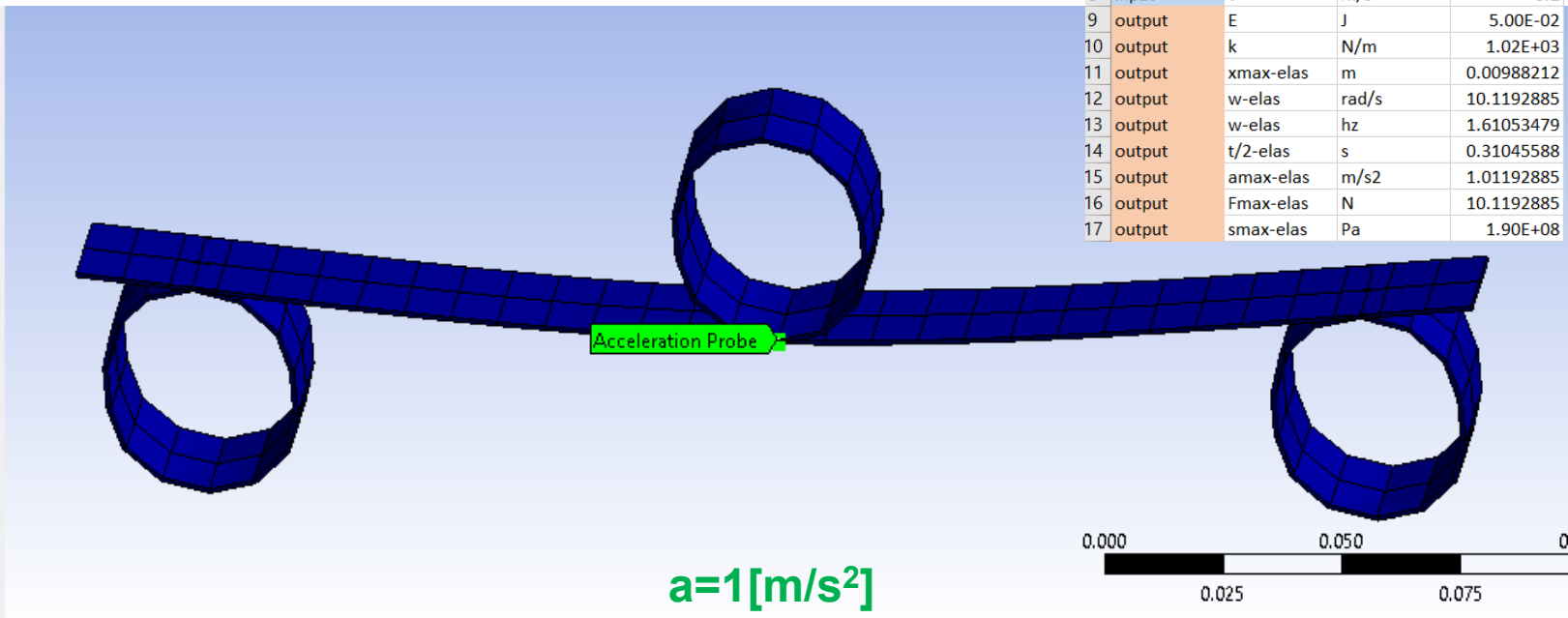


• Resultados

La aceleración es pequeña de 1[m/s²]≈0.1[g].

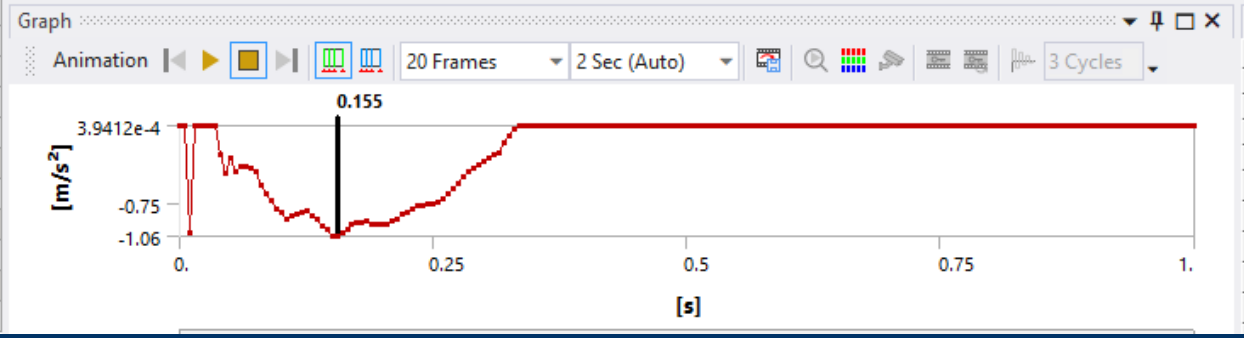
	A	B	C	D
1	input	E	Pa	2.00E+11
2	input	nu	-	3.00E-01
3	input	Lx	m	0.3
4	input	Ly	m	0.02
5	input	Lz	m	0.001
6	input	D	m	0.25
7	input	m	kg	10
8	input	v	m/s	0.1
9	output	E	J	5.00E-02
10	output	k	N/m	1.02E+03
11	output	xmax-elas	m	0.00988212
12	output	w-elas	rad/s	10.1192885
13	output	w-elas	hz	1.61053479
14	output	t/2-elas	s	0.31045588
15	output	amax-elas	m/s2	1.01192885
16	output	Fmax-elas	N	10.1192885
17	output	smax-elas	Pa	1.90E+08





Details of "Acceleration Probe"

Definition	
Type	Acceleration
Location Method	Geometry Selection
Geometry	1 Vertex
Orientation	Global Coordinate System
Suppressed	No
Options	
Result Selection	Z Axis
Display Time	0.155 s
Spatial Resolution	Use Maximum
Results	
Z Axis	-1.06 m/s²
Maximum Value Over Time	
Z Axis	3.9412e-004 m/s²
Minimum Value Over Time	
Z Axis	-1.06 m/s²
Information	



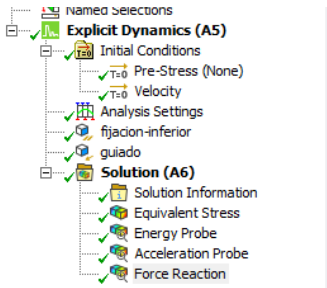
Tabular Data

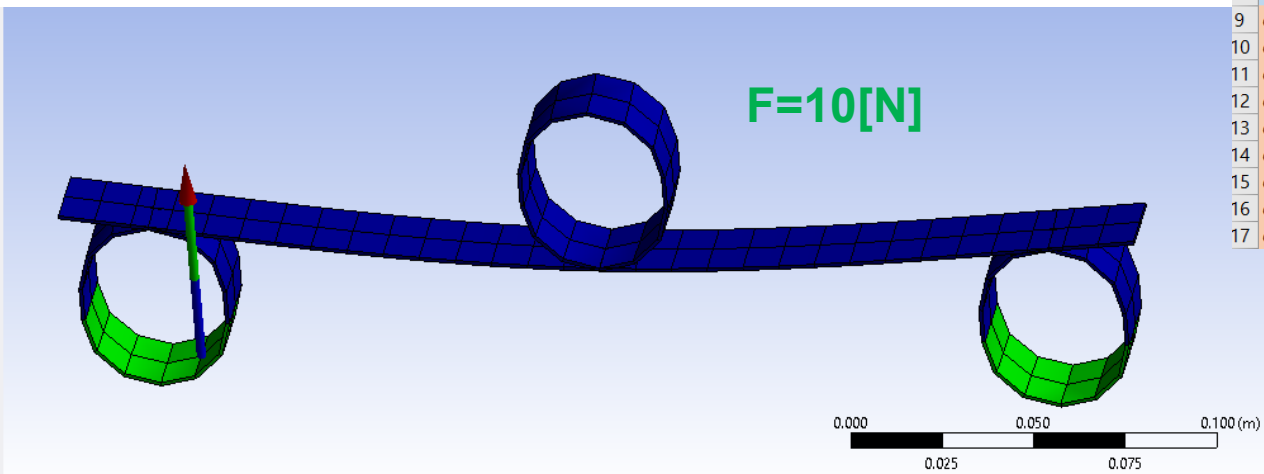
	Time [s]	Acceleration Probe (Z
1	1.1755e-038	0.
2	5.0005e-003	0.
3	1.0001e-002	-1.0196
4	1.5001e-002	-1.5259e-004
5	2.0001e-002	1.1237e-005
6	2.5001e-002	1.572e-004
7	3.e-002	-2.7125e-004
8	3.5e-002	3.9412e-004
9	4.e-002	-0.27331

- Resultados

La fuerza de reacción equivale a la masa * aceleración ≈ 10*1=10[N]

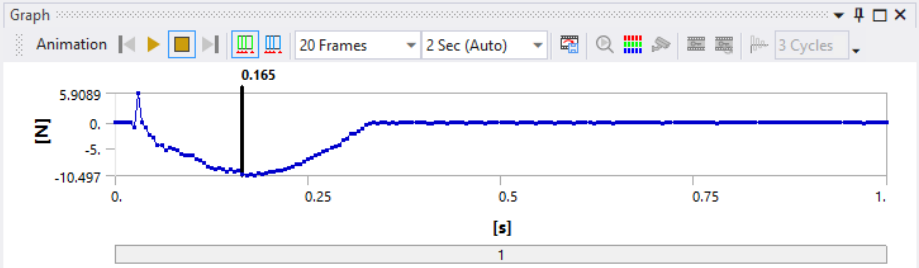
	A	B	C	D
1	input	E	Pa	2.00E+11
2	input	nu	-	3.00E-01
3	input	Lx	m	0.3
4	input	Ly	m	0.02
5	input	Lz	m	0.001
6	input	D	m	0.25
7	input	m	kg	10
8	input	v	m/s	0.1
9	output	E	J	5.00E-02
10	output	k	N/m	1.02E+03
11	output	xmax-elas	m	0.00988212
12	output	w-elas	rad/s	10.119288
13	output	w-elas	hz	1.6105347
14	output	t/2-elas	s	0.3104558
15	output	amax-elas	m/s2	1.0119288
16	output	Fmax-elas	N	10.119288
17	output	smax-elas	Pa	1.90E+08





Details of "Force Reaction"

Definition	
Type	Force Reaction
Location Method	Boundary Condition
Boundary Condition	fijacion-inferior
Orientation	Global Coordinate System
Suppressed	No
Options	
Result Selection	All
Display Time	0.165 s
Results	
X Axis	5.1387e-002 N
Y Axis	0.10872 N
Z Axis	-10.249 N
Total	10.249 N
Maximum Value Over Time	
X Axis	0.37587 N
Y Axis	3.8996 N
Z Axis	5.9089 N

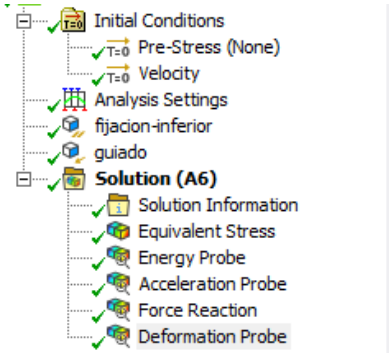


Tabular Data

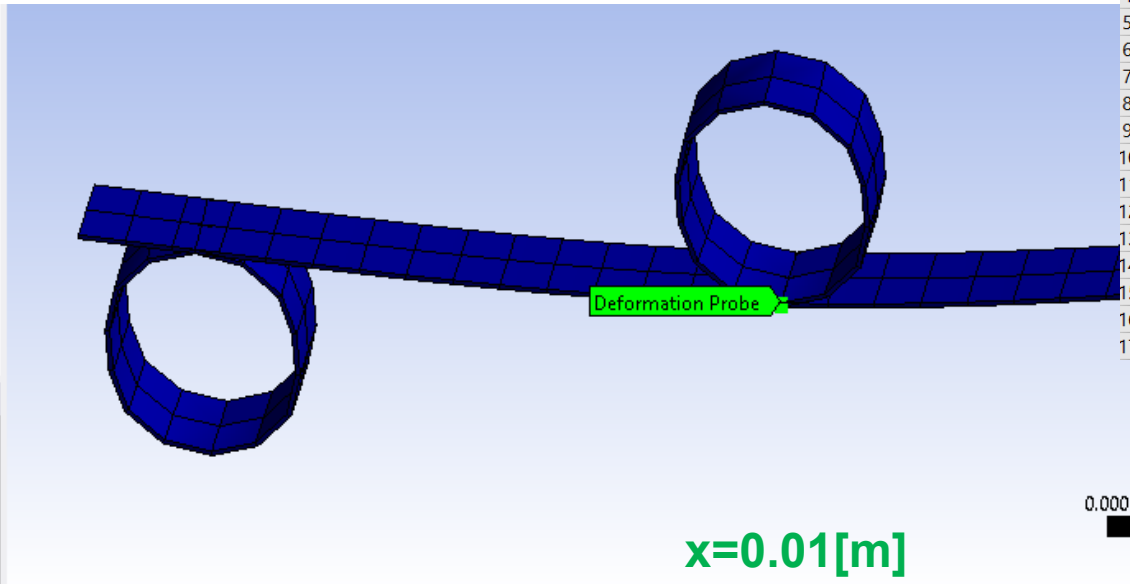
	Time [s]	Force Reaction (X) [N]	Force Reaction (Y) [N]	Force Reaction (Z) [N]	Force Reaction (Tota
1	1.1755e-038	0.	0.	0.	0.
2	5.0005e-003	0.	0.	0.	0.
3	1.0001e-002	0.	0.	0.	0.
4	1.5001e-002	0.	0.	0.	0.
5	2.0001e-002	0.	0.	0.	0.
6	2.5001e-002	0.24534	3.8996	-0.85942	4.0007
7	3.e-002	0.37587	1.5493	5.9089	6.1202
8	3.5e-002	3.3161e-002	-1.5813	-6.2428e-003	1.5816
9	4.e-002	-0.21275	-0.53407	-0.82803	1.008
10	4.5001e-002	-0.42602	0.93114	-2.5006	2.7022
11	5.0001e-002	0.3414	0.18776	-2.9584	2.9839

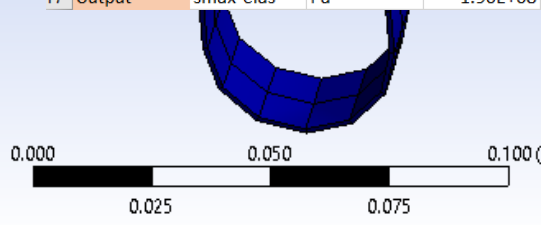
• Resultados

El desplazamiento lo podríamos encontrar como la doble integral de la aceleración y da unos 10[mm] de acuerdo con la rigidez.



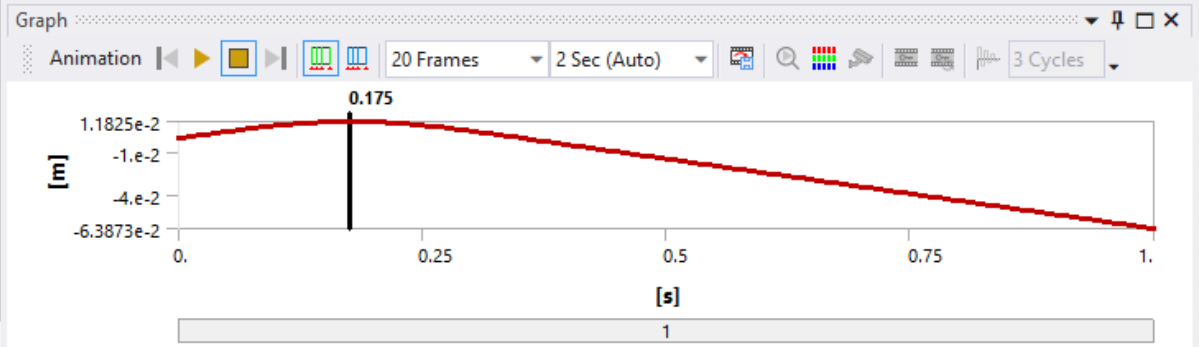
A	B	C	D
1 input	E	Pa	2.00E+11
2 input	nu	-	3.00E-01
3 input	Lx	m	0.3
4 input	Ly	m	0.02
5 input	Lz	m	0.001
6 input	D	m	0.25
7 input	m	kg	10
8 input	v	m/s	0.1
9 output	E	J	5.00E-02
10 output	k	N/m	1.02E+03
11 output	xmax-elas	m	0.00988212
12 output	w-elas	rad/s	10.1192885
13 output	w-elas	hz	1.61053479
14 output	t/2-elas	s	0.31045588
15 output	amax-elas	m/s2	1.01192885
16 output	Fmax-elas	N	10.1192885
17 output	smax-elas	Pa	1.90E+08





Details of "Deformation Probe"

Definition	
Type	Deformation
Location Method	Geometry Selection
Geometry	1 Vertex
Orientation	Global Coordinate System
Suppressed	No
Options	
Result Selection	Z Axis
Display Time	0.175 s
Spatial Resolution	Use Maximum
Results	
Z Axis	1.1825e-002 m
Maximum Value Over Time	
Z Axis	1.1825e-002 m
Minimum Value Over Time	
Z Axis	-6.3873e-002 m
Information	

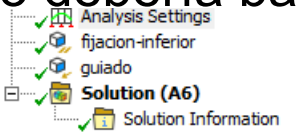


Tabular Data

	Time [s]	Deformation Probe (Z) [m]
1	1.1755e-038	0.
2	5.0005e-003	5.0005e-004
3	1.0001e-002	1.0001e-003
4	1.5001e-002	1.4987e-003
5	2.0001e-002	1.9962e-003
6	2.5001e-002	2.4927e-003
7	3.e-002	2.9877e-003
8	3.5e-002	3.4803e-003
9	4.e-002	3.969e-003
10	4.5001e-002	4.4527e-003
11	5.0001e-002	4.93e-003

- Mass scaling

Como el cálculo tarda mucho vamos a hacer “trampas peligrosas” y escalar la masa para que el time step pase de 1.5e-6 a 1e-5[s] con lo que la masa de cada pieza se aumentará $x(1e\text{-}5/1.5e\text{-}6)^2 \approx 40$ y tendremos 100000 pasos y el tiempo debería baiar.



Vemos que el resultado se puede ver alterado pues la probeta pasará a pesar 1.6[kg] no despreciable respecto a los 10[kg] del impactador que se le añadirán 0.8[kg]

Details of "probeta"

Coordinate System	Default Coordinate S
Reference Temperature	By Environment
Thickness	1.e-003 m
Thickness Mode	Manual
Offset Type	Middle
Material	
Assignment	yield200
Bounding Box	
Properties	
Volume	6.e-006 m³
Mass	4.71e-002 kg
Centroid X	0. m
Centroid Y	0. m
Centroid Z	0. m
Moment of Inertia Ip1	1.57e-006 kg·m²
Moment of Inertia Ip2	3.5325e-004 kg·m²
Moment of Inertia Ip3	3.5482e-004 kg·m²
Surface Area(approx.)	6.e-003 m²

Details of "impactador"

Graphics Properties	
Definition	
Suppressed	No
Stiffness Behavior	Flexible
Coordinate System	Default Coordinate S.
Reference Temperature	By Environment
Thickness	1.e-003 m
Thickness Mode	Manual
Offset Type	Middle
Material	
Assignment	Structural Steel
Bounding Box	
Properties	
Volume	2.9123e-006 m³
Mass	2.2861e-002 kg
Centroid X	-3.9818e-017 m
Centroid Y	-5.8556e-020 m
Centroid Z	-2.6e-002 m

Details of "Analysis Settings"

Number Of Steps	1
Current Step Number	1
Load Step Type	Explicit Time Integratio
End Time	1.
Resume From Cycle	0
Maximum Number of Cycles	1e+07
Maximum Energy Error	0.1
Reference Energy Cycle	0
Initial Time Step	1.e-005 s
Minimum Time Step	1.e-005 s
Maximum Time Step	1.e-004 s
Time Step Safety Factor	0.9
Characteristic Dimension	Opposing Faces
Automatic Mass Scaling	Yes
Minimum CFL Time Step	1.e-004 s
Maximum Element Scaling	1000.
Maximum Part Scaling	1000.
Update Frequency	0

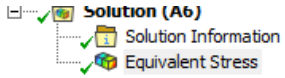
- Resultados

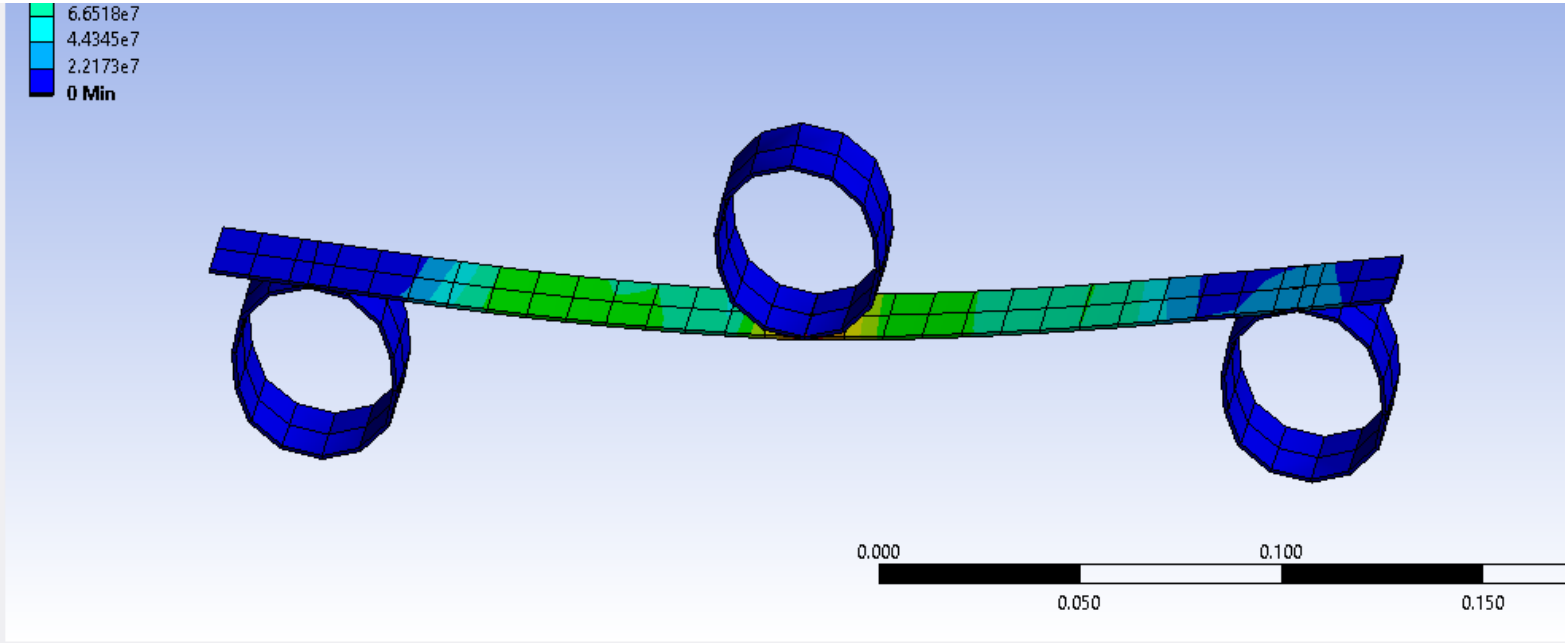
Ahora ha ido mucho más rápido pero hay que vigilar las subidas de masa

```
Cycle:    21263, Time:  1.000E+00s, Time Inc.: 4.705E-05s, Progress: 100.00%, Est. Clock Time Remaining: 0s
Cycle:    21264, Time:  1.000E+00s, Time Inc.: 4.705E-05s, Progress: 100.00%, Est. Clock Time Remaining: -


SIMULATION ELAPSED TIME SUMMARY

EXECUTION FROM CYCLE        0 TO    21264
ELAPSED RUN TIME IN SOLVER =      2.21000E-01 Minutes
TOTAL ELAPSED RUN TIME     =      2.51217E-01 Minutes
JOB RAN OVER     2 WORKERS
JOB RAN USING Intel MPI
JOB RAN USING DECOMPOSITION AUTO

Problem terminated .... wrapup time reached
```

• Resultados

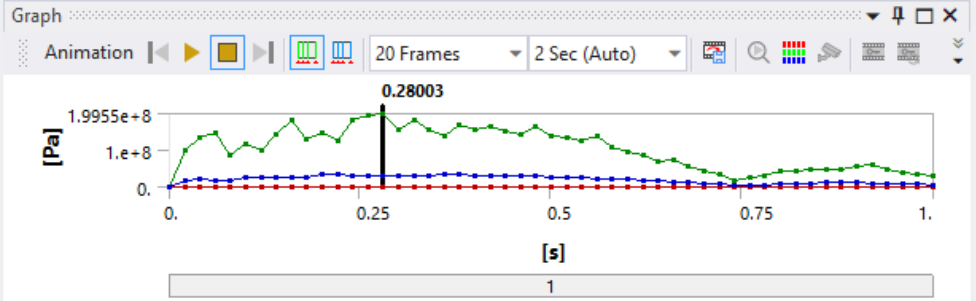
Parece ser que la subida de masa hace que plastifique pasando de 138[MPa] a 200[Mpa]





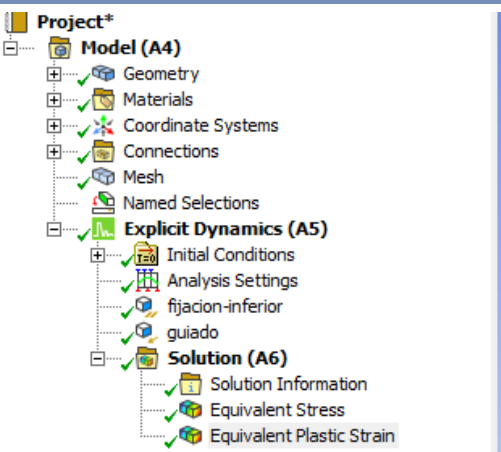
Details of "Equivalent Stress"

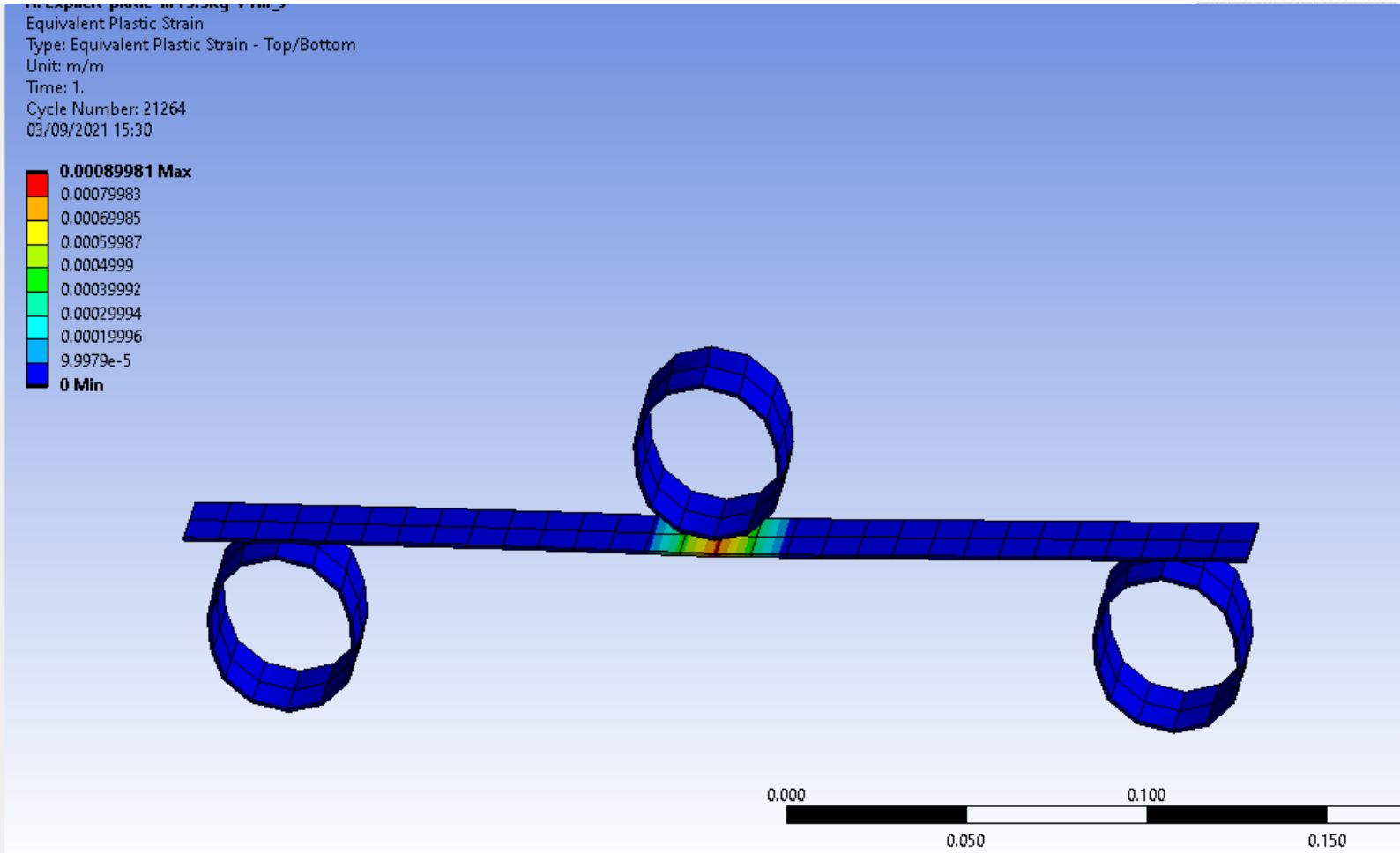
Scope	
Scoping Method	Geometry Selection
Geometry	All Bodies
Position	Top/Bottom
Definition	
Type	Equivalent (von-Mises) Stress
By	Time
Display Time	0.28003 s
Calculate Time History	Yes
Identifier	
Suppressed	No
Integration Point Results	
Display Option	Averaged
Average Across Bodies	No
Results	
Minimum	0. Pa
Maximum	1.9955e+008 Pa
Average	3.0366e+007 Pa
Minimum Occurs On	soporte-derecha
Maximum Occurs On	probeta
Minimum Value Over Time	



Tabular Data

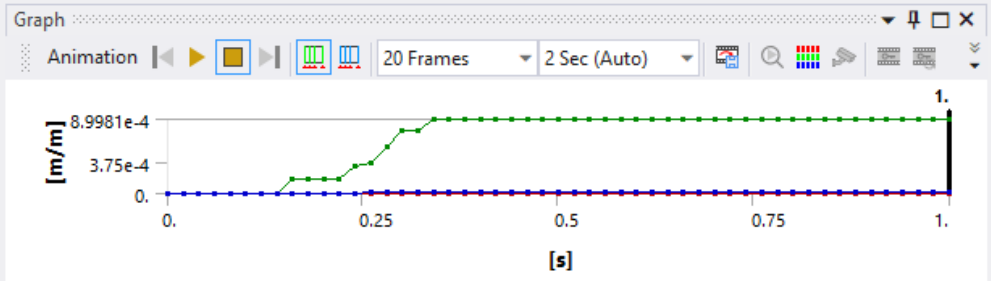
	Time [s]	Minimum [Pa]	Maximum [Pa]	Average [Pa]
1	1.1755e-038	0.	0.	0.
2	2.0013e-002	0.	1.0157e+008	1.6018e+007
3	4.0008e-002	0.	1.3554e+008	2.2711e+007
4	6.0002e-002	0.	1.4622e+008	1.5195e+007
5	8.0044e-002	0.	8.6385e+007	1.8491e+007
6	0.10004	0.	1.1901e+008	2.4522e+007
7	0.12003	0.	9.9445e+007	2.5295e+007
8	0.14003	0.	1.4379e+008	2.4882e+007
9	0.16002	0.	1.8316e+008	2.5289e+007





Details of "Equivalent Plastic Strain"

Scope	
Scoping Method	Geometry Selection
Geometry	All Bodies
Position	Top/Bottom
Definition	
Type	Equivalent Plastic Strain
By	Time
Display Time	Last
Calculate Time History	Yes
Identifier	
Suppressed	No
Integration Point Results	
Display Option	Averaged
Average Across Bodies	No
Results	
Minimum	0. m/m
Maximum	8.9981e-004 m/m
Average	2.4855e-005 m/m
Minimum Occurs On	soporte-derecha
Maximum Occurs On	probeta

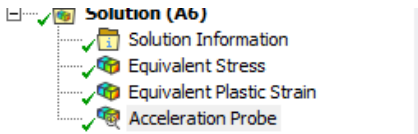


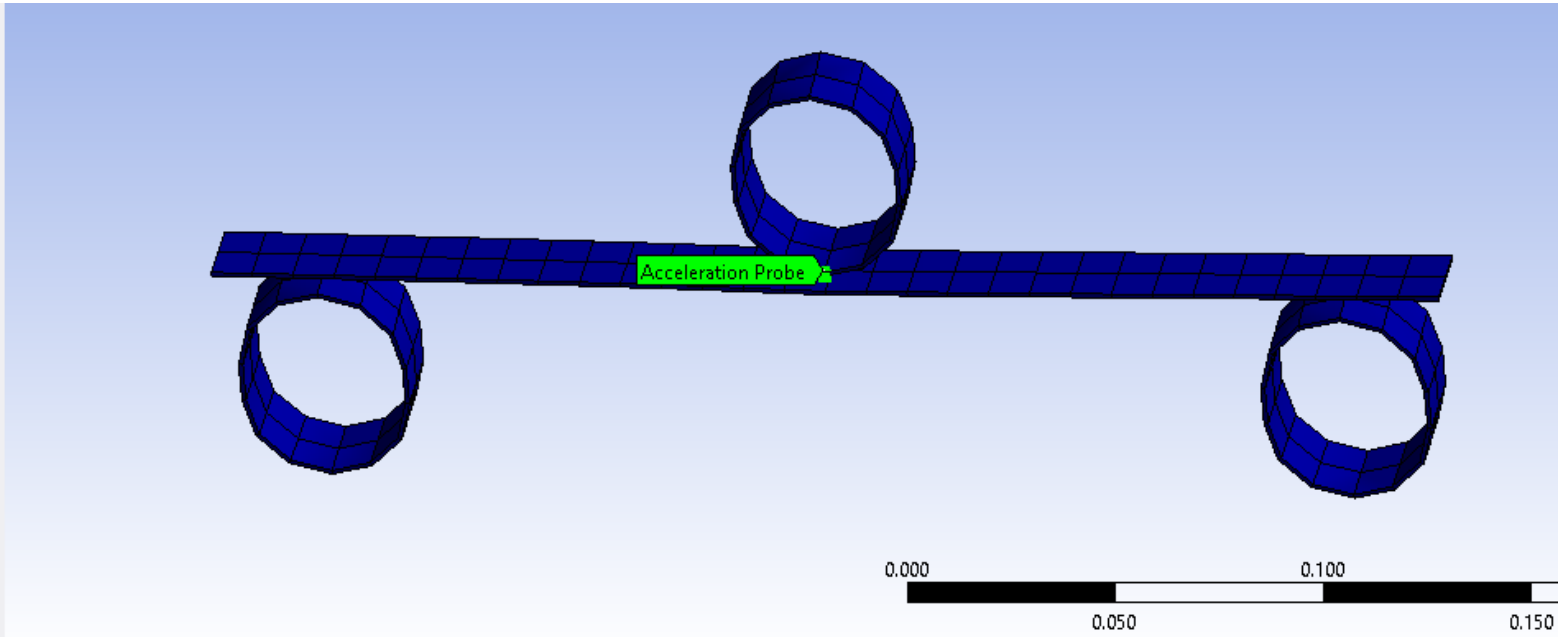
Tabular Data

	Time [s]	Minimum [m/m]	Maximum [m/m]	Average
1	1.1755e-038	0.	0.	0.
2	2.0013e-002	0.	0.	0.
3	4.0008e-002	0.	0.	0.
4	6.0002e-002	0.	0.	0.
5	8.0044e-002	0.	0.	0.
6	0.10004	0.	0.	0.
7	0.12003	0.	0.	0.
8	0.14003	0.	0.	0.

- Resultados

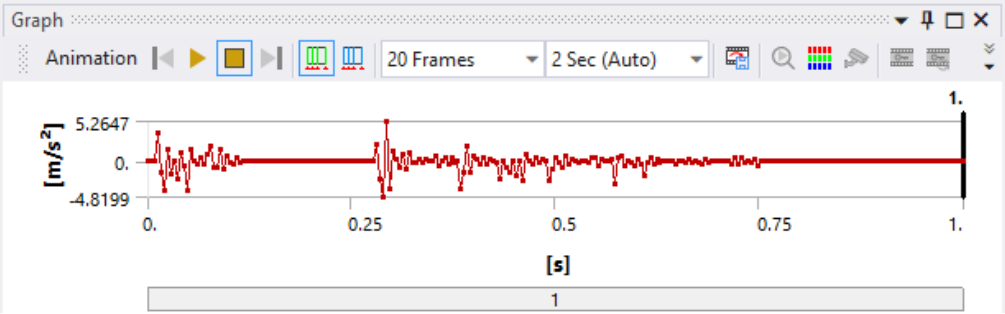
La aceleración pasa de 1[m/s^2] a -5[m/s^2] con forma irregular





Details of "Acceleration Probe"

Definition	
Type	Acceleration
Location Method	Geometry Selection
Geometry	1 Vertex
Orientation	Global Coordinate System
Suppressed	No
Options	
Result Selection	Z Axis
Display Time	End Time
Spatial Resolution	Use Maximum
Results	
Maximum Value Over Time	
Z Axis	5.2647 m/s²
Minimum Value Over Time	
Z Axis	-4.8199 m/s²
Information	

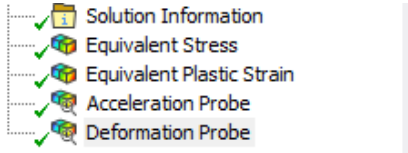


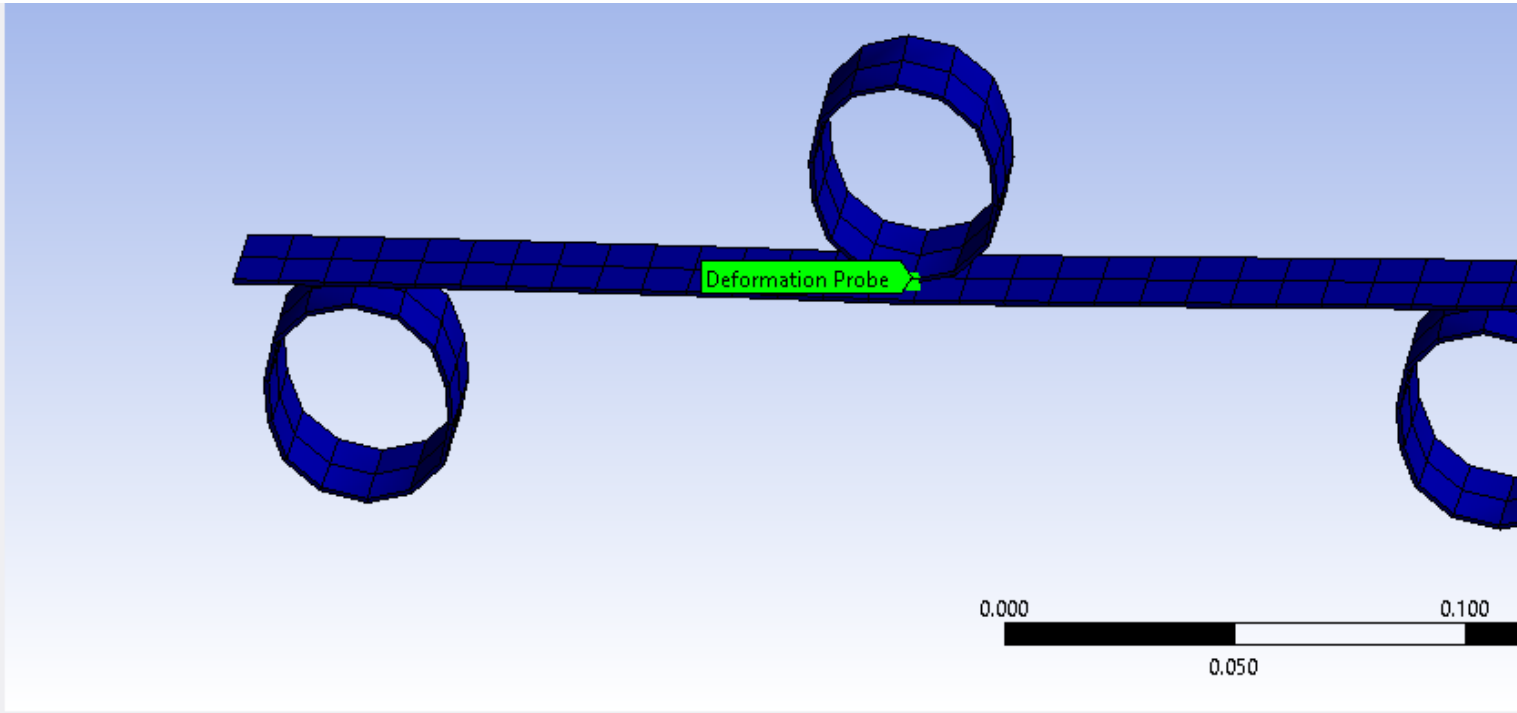
Tabular Data

	Time [s]	Acceleration Probe (Z) [m/s²]
1	1.1755e-038	0.
2	4.018e-003	0.
3	8.0168e-003	0.
4	1.2016e-002	3.7837
5	1.6015e-002	-1.4663
6	2.0013e-002	-3.9395
7	2.4012e-002	1.5686
8	2.8011e-002	-1.7938
9	3.201e-002	-0.10056

- Resultados

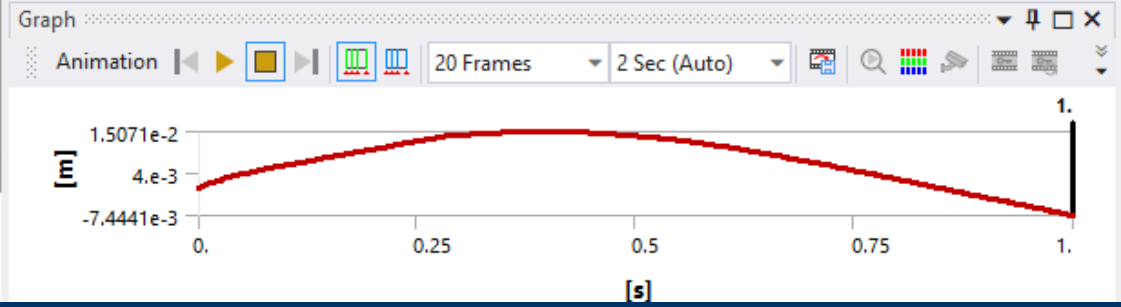
El desplazamiento pasa de 10[mm] a 15[mm] con forma irregular





Details of "Deformation Probe"

Definition	
Type	Deformation
Location Method	Geometry Selection
Geometry	1 Vertex
Orientation	Global Coordinate System
Suppressed	No
Options	
Result Selection	Z Axis
Display Time	End Time
Spatial Resolution	Use Maximum
Results	
Maximum Value Over Time	
Z Axis	1.5071e-002 m
Minimum Value Over Time	
Z Axis	-7.4441e-003 m
Information	

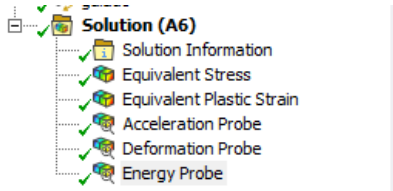


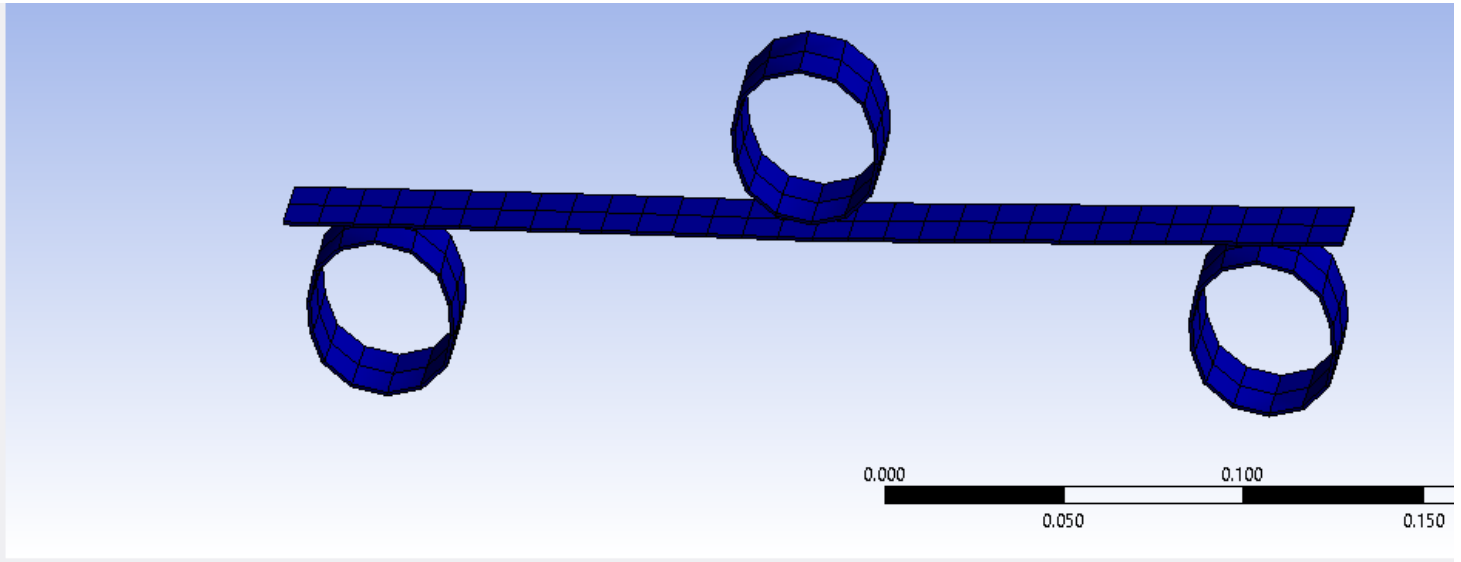
Tabular Data

	Time [s]	Deformation Probe
1	1.1755e-038	0.
2	4.018e-003	4.018e-004
3	8.0168e-003	8.0168e-004
4	1.2016e-002	1.1801e-003
5	1.6015e-002	1.5081e-003
6	2.0013e-002	1.8126e-003
7	2.4012e-002	2.1002e-003
8	2.8011e-002	2.3748e-003

• Resultados

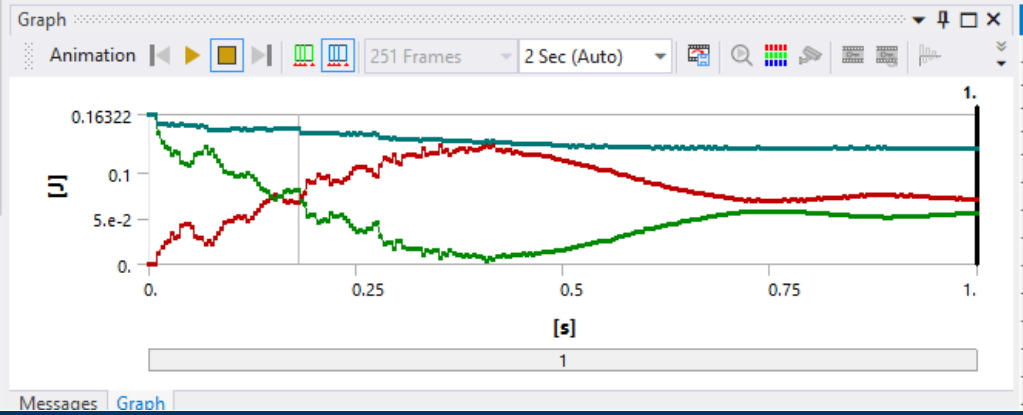
La curva más importante es la de energía donde se observa el riesgo de incrementar la masa pasando de 0.05[J] a 0.16[J] (triplicando energía)





Details of "Energy Probe"

Definition	
Type	Energy
Geometry	System Energy
Suppressed	No
Options	
Result Selection	All
Display Time	End Time
Results	
Internal	7.0865e-002 J
Kinetic	5.6133e-002 J
Plastic Work	4.0706e-002 J
Hourglass	1.0331e-003 J
Contact	3.0666e-002 J
Total	0.127 J
Maximum Value Over Time	
Internal	0.12987 J
Kinetic	0.16322 J
Plastic Work	4.0706e-002 J
Hourglass	4.4383e-003 J
Contact	5.9937e-002 J
Total	0.16322 J
Minimum Value Over Time	



Tabular Data

	Time [s]	Energy Probe (Internal) [J]	E
1	1.1755e-038	0.	0.163
2	4.018e-003	3.0996e-033	0.163
3	8.0168e-003	1.8128e-032	0.163
4	1.2016e-002	1.097e-002	0.142
5	1.6015e-002	1.9266e-002	0.133
6	2.0013e-002	2.3822e-002	0.128
7	2.4012e-002	2.6059e-002	0.125
8	2.8011e-002	3.4023e-002	0.119
9	3.201e-002	2.9016e-002	0.123
10	3.6009e-002	3.0922e-002	0.120
11	4.0008e-002	4.2216e-002	0.110
12	4.4007e-002	4.3199e-002	0.109
13	4.8006e-002	4.3208e-002	0.107

- Ejercicio

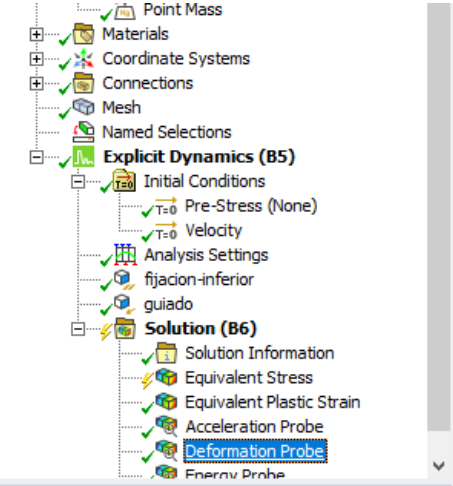
Hacer una simulación para espesor 3[mm] en el que tengamos un impacto elástico de unos 10[mm] con velocidad inicial de 1[m/s^2].
Ahora necesitamos menos tiempo de cálculo:

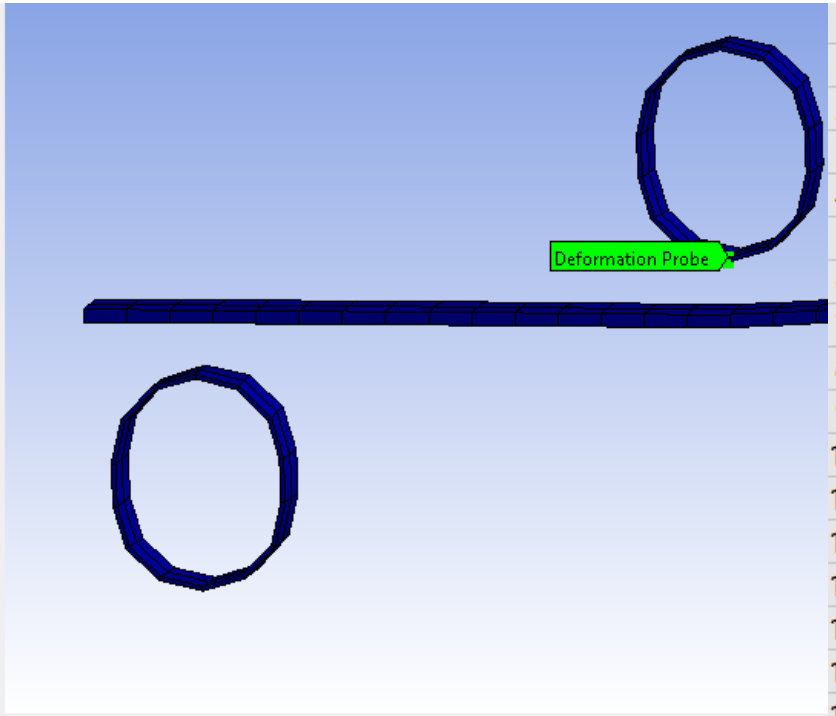
```
Cycle:    53774, Time:  8.000E-02s, Time Inc.: 1.488E-06s, Progress: 100
Cycle:    53775, Time:  8.000E-02s, Time Inc.: 1.488E-06s, Progress: 100


SIMULATION ELAPSED TIME SUMMARY

EXECUTION FROM CYCLE        0 TO    53775
ELAPSED RUN TIME IN SOLVER =      4.46317E-01 Minutes
TOTAL ELAPSED RUN TIME     =      4.76733E-01 Minutes
JOB RAN OVER     2 WORKERS
JOB RAN USING Intel MPI
JOB RAN USING DECOMPOSITION AUTO

Problem terminated .... wrapup time reached

 ******************************************
```

	A	B	C	D	E
1	input	d	kg/m3	7.85E+03	7.85E+03
2	input	E	Pa	2.00E+11	2.00E+11
3	input	nu	-	3.00E-01	3.00E-01
4	input	Lx	m	3.00E-01	3.00E-01
5	input	Ly	m	2.00E-02	2.00E-02
6	input	Lz	m	1.00E-03	3.00E-03
7	input	D	m	2.50E-01	2.50E-01
8	input	m	kg	1.00E+01	3.00E+00
9	input	v	m/s	1.00E-01	1.00E+00
10	input	mesh	m	1.00E-02	1.00E-02
11	input	damp	-	2.00E-01	2.00E-01
12	output	ts-auto	s	1.58E-06	1.58E-06
13	output	E	J	5.00E-02	1.50E+00
14	output	k	N/m	1.02E+03	2.76E+04
15	output	xmax-elas	m	9.88E-03	1.04E-02
16	output	w-elas	rad/s	1.01E+01	9.60E+01
17	output	w-elas	hz	1.61E+00	1.53E+01
18	output	t/2-elas	s	3.10E-01	3.27E-02
19	output	amax-elas	m/s2	1.01E+00	9.60E+01
20	output	Fmax-elas	N	1.01E+01	2.88E+02
21	output	smax-elas	Pa	1.90E+08	6.00E+08
22	input	ts-forced	s	1.00E-05	1.00E-05
23	input	mass-increase	-	3.98E+01	3.98E+01

• Resultados

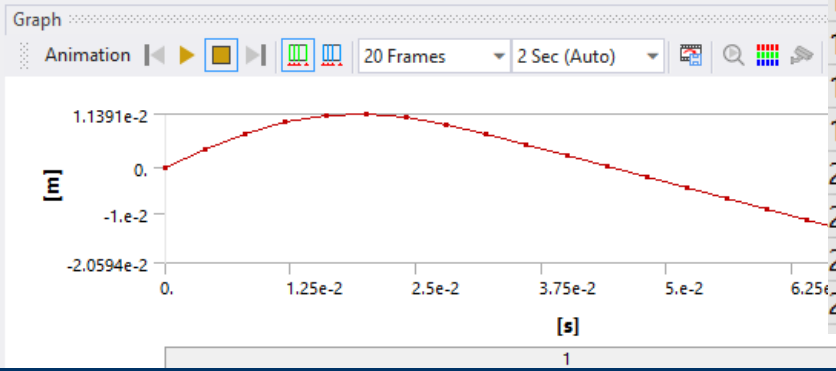
Desplazamiento de 15[mm] en primera simulación con 3[kg] y se ajusta a 2[kg] para la





Details of "Deformation Probe"

Definition	
Type	Deformation
Location Method	Geometry Selection
Geometry	1 Vertex
Orientation	Global Coordinate System
Suppressed	No
Options	
Result Selection	Z Axis
Display Time	End Time
Spatial Resolution	Use Maximum
Results	
Maximum Value Over Time	
Z Axis	1.1391e-002 m
Minimum Value Over Time	
Z Axis	-2.0594e-002 m
Information	

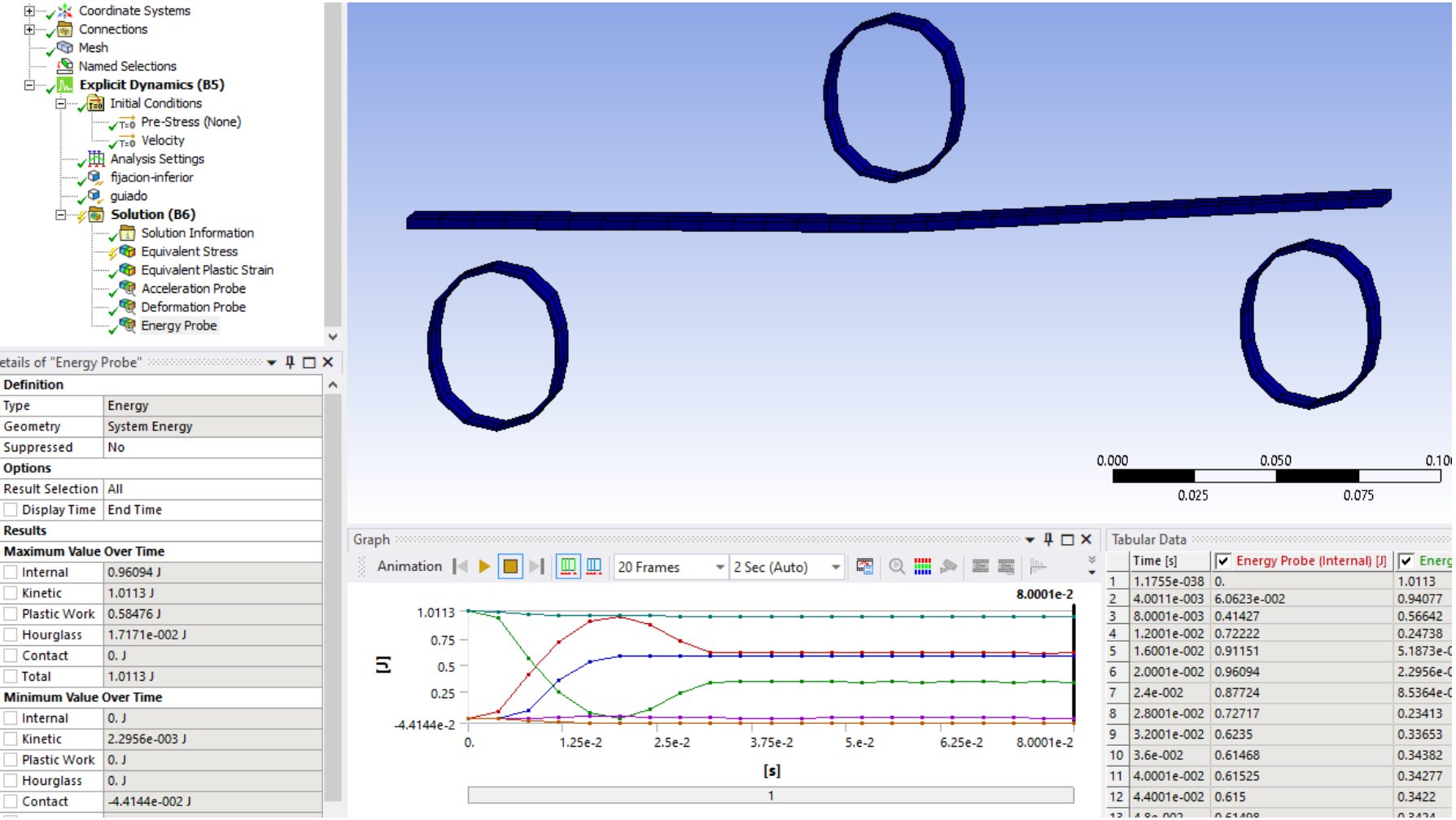


	A	B	C	D	E
1	input	d	kg/m3	7.85E+03	7.85E+03
2	input	E	Pa	2.00E+11	2.00E+11
3	input	nu	-	3.00E-01	3.00E-01
4	input	Lx	m	3.00E-01	3.00E-01
5	input	Ly	m	2.00E-02	2.00E-02
6	input	Lz	m	1.00E-03	3.00E-03
7	input	D	m	2.50E-01	2.50E-01
8	input	m	kg	1.00E+01	3.00E+00
9	input	v	m/s	1.00E-01	1.00E+00
10	input	mesh	m	1.00E-02	1.00E-02
11	input	damp	-	2.00E-01	2.00E-01
12	output	ts-auto	s	1.58E-06	1.58E-06
13	output	E	J	5.00E-02	1.50E+00
14	output	k	N/m	1.02E+03	2.76E+04
15	output	xmax-elas	m	9.88E-03	1.04E-02
16	output	w-elas	rad/s	1.01E+01	9.60E+01
17	output	w-elas	hz	1.61E+00	1.53E+01
18	output	t/2-elas	s	3.10E-01	3.27E-02
19	output	amax-elas	m/s2	1.01E+00	9.60E+01
20	output	Fmax-elas	N	1.01E+01	2.88E+02
21	output	smax-elas	Pa	1.90E+08	6.00E+08
22	input	ts-forced	s	1.00E-05	1.00E-05
23	input	mass-increase	-	3.98E+01	3.98E+01

12	4.4001e-002	1.5218e-004

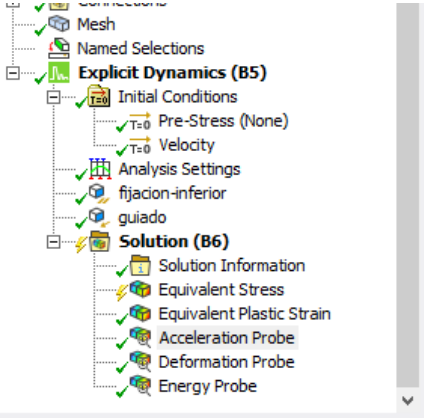
- Resultados

Comprobamos energías y vemos se respeta bien el tener 1[J]



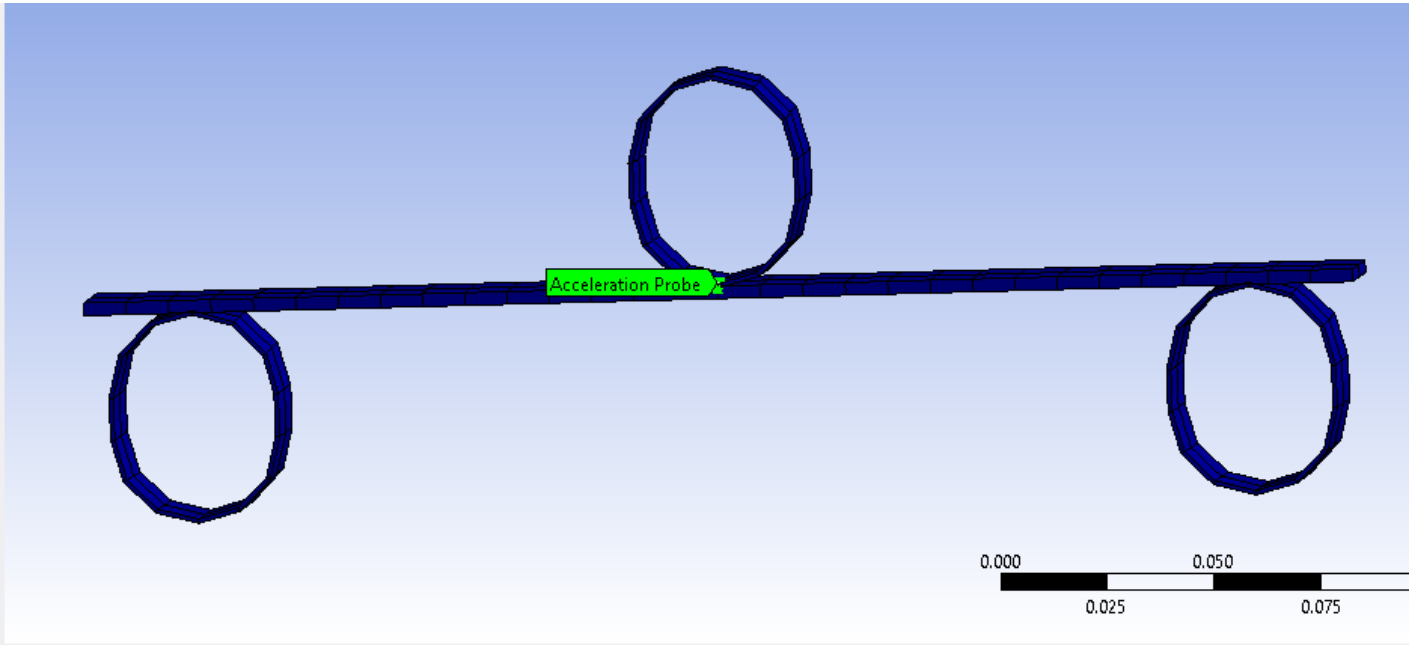
• Resultados

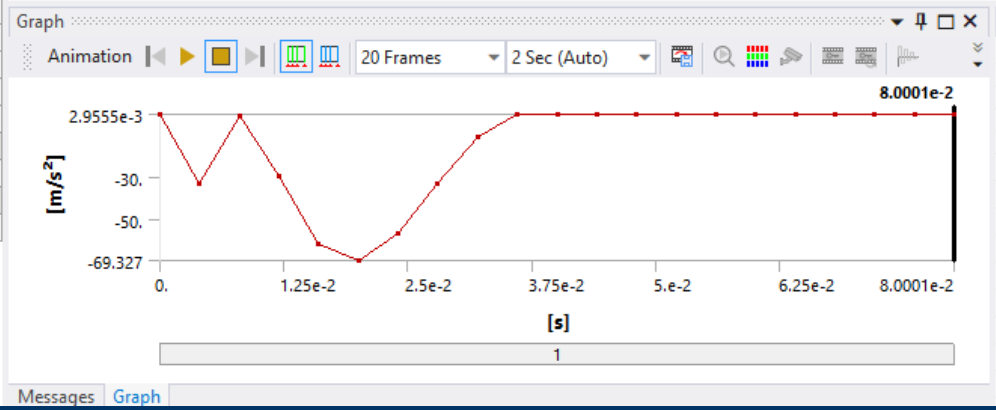
La aceleración llega a unos 7[g]



etails of "Acceleration Probe"

Definition	
Type	Acceleration
Location Method	Geometry Selection
Geometry	1 Vertex
Orientation	Global Coordinate System
Suppressed	No
Options	
Result Selection	Z Axis
Display Time	End Time
Spatial Resolution	Use Maximum
Results	
Maximum Value Over Time	
Z Axis	2.9555e-003 m/s²
Minimum Value Over Time	
Z Axis	-69.327 m/s²
Information	



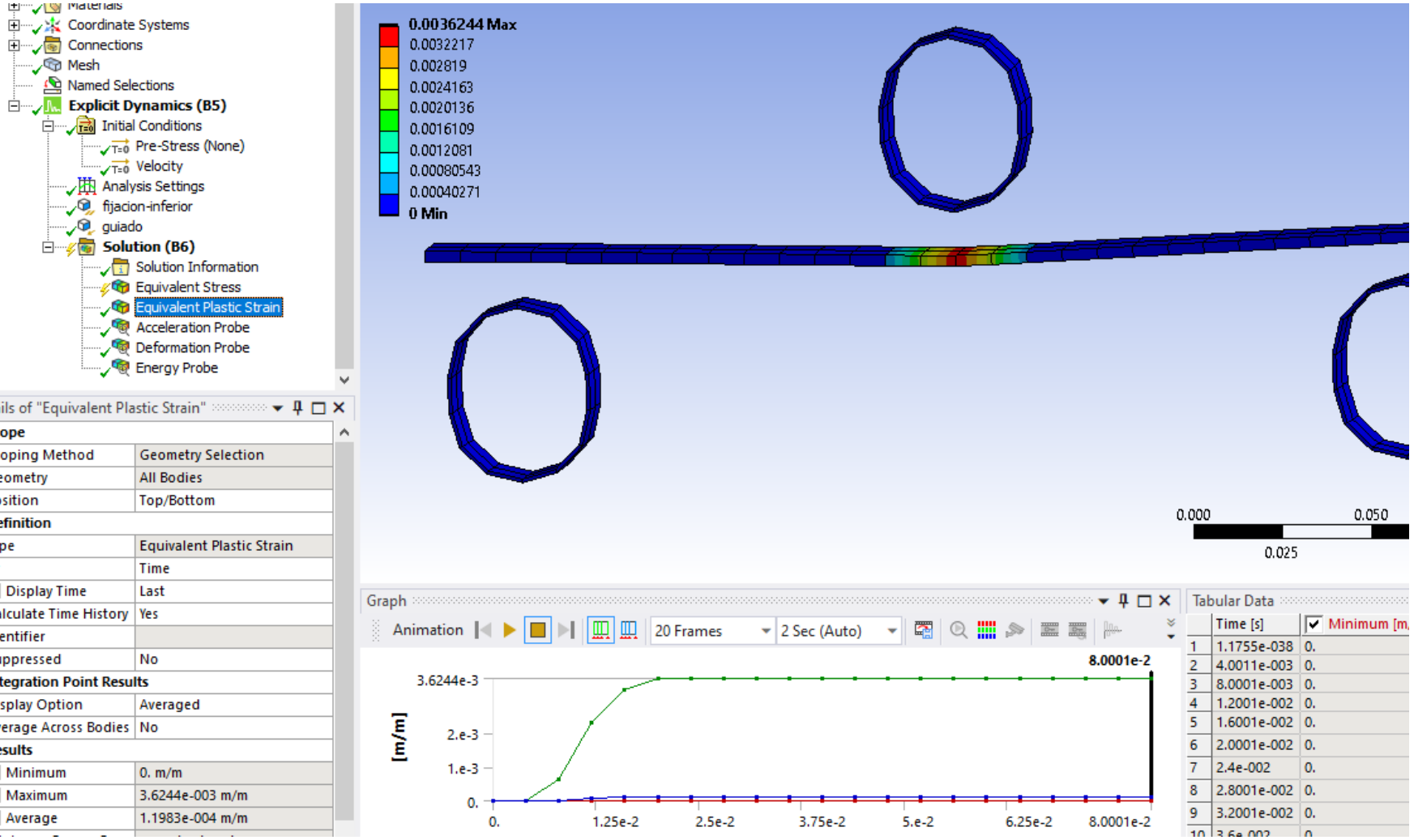


Tabular Data

	Time [s]	Acceleration Probe (Z) [m/s²]
1	1.1755e-038	0.
2	4.0011e-003	-32.973
3	8.0001e-003	-0.58827
4	1.2001e-002	-29.488
5	1.6001e-002	-61.265
6	2.0001e-002	-69.327
7	2.4e-002	-56.59
8	2.8001e-002	-32.82
9	3.2001e-002	-10.847
10	3.6e-002	-3.383e-004
11	4.0001e-002	-1.8255e-003
12	4.4001e-002	-1.8425e-003
13	4.8e-002	-2.7621e-003

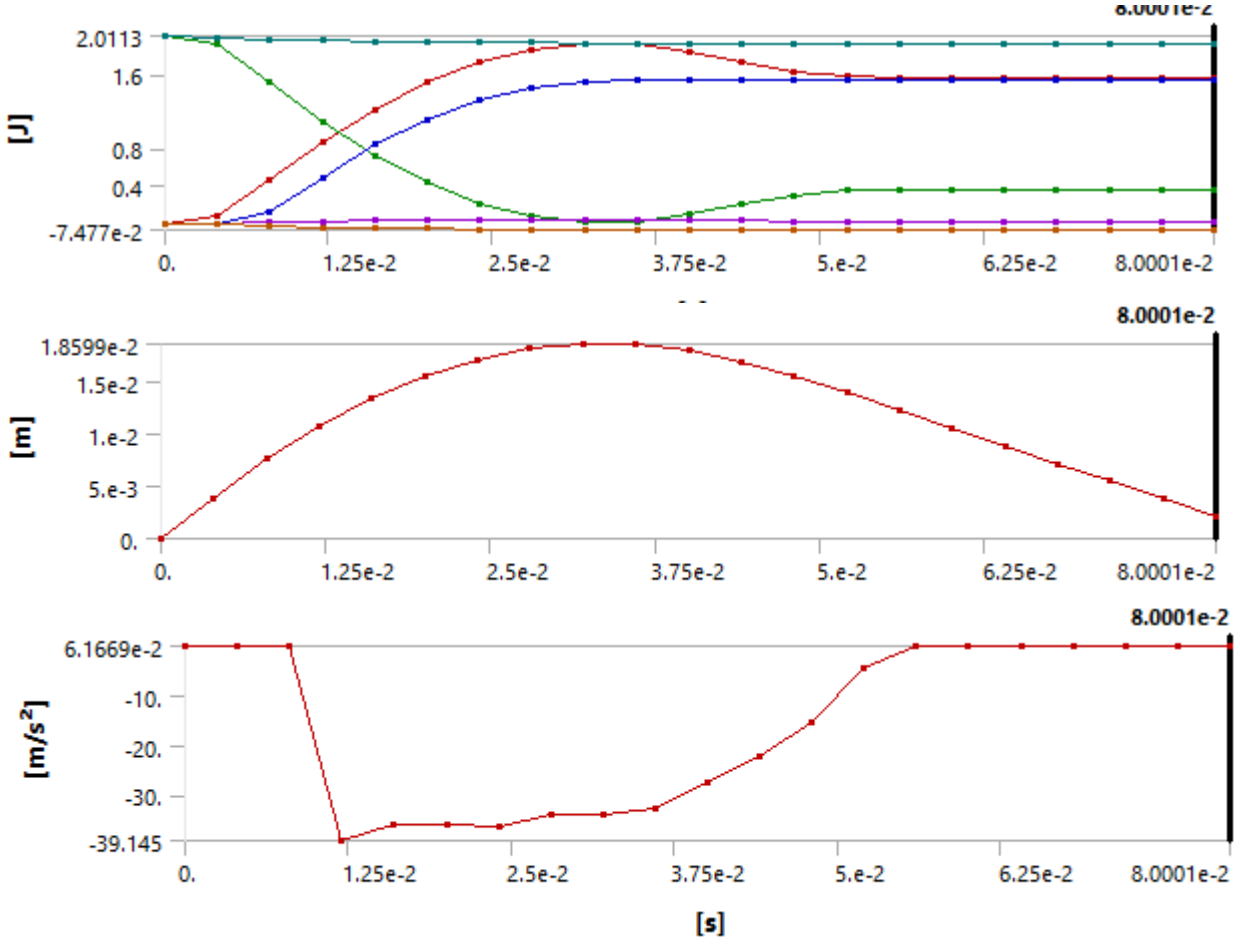
- Resultados

Hay una ligera zona de deformación plástica.



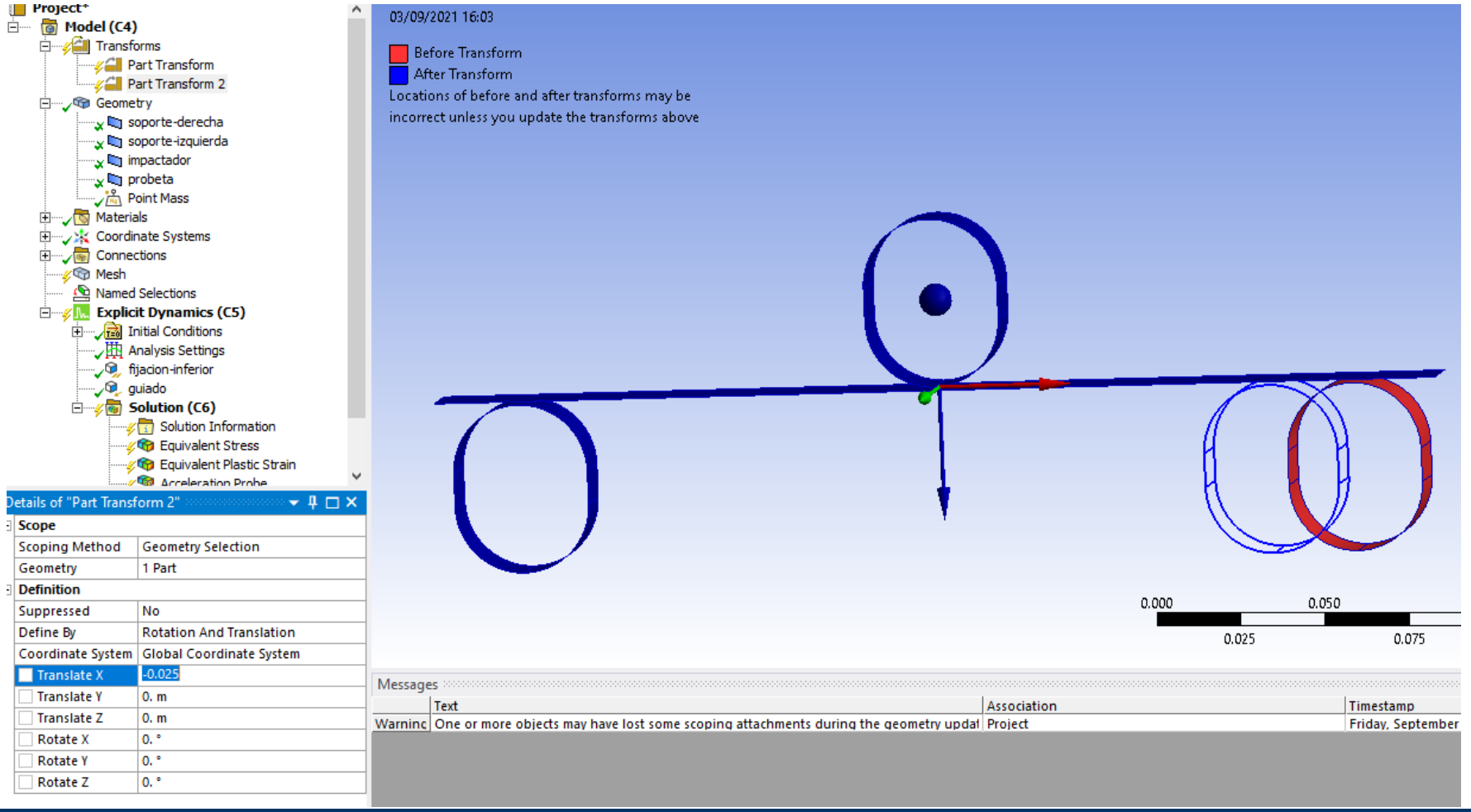
- Duplicar masa

Si ponemos el doble de masa y energía entonces plastifica más y se pasa de 10[mm] a 18.6[mm] con una aceleración que baja de 7 a 4[g].



- Juntar apoyos

Si juntamos los apoyos de 250[mm] a 200[mm] será más rígido con m=2[kg], v1=[m/s] y t=1[mm]



- Resultados

Si juntamos los apoyos de 250[mm] a 200[mm] será más rígido

A	B	C	D	E	F
input	d	kg/m3	7.85E+03	7.85E+03	7.85E+03
input	E	Pa	2.00E+11	2.00E+11	2.00E+11
input	nu	-	3.00E-01	3.00E-01	3.00E-01
input	Lx	m	3.00E-01	3.00E-01	3.00E-01
input	Ly	m	2.00E-02	2.00E-02	2.00E-02
input	Lz	m	1.00E-03	3.00E-03	1.00E-03
input	D	m	2.50E-01	2.50E-01	2.00E-01
input	m	kg	1.00E+01	3.00E+00	2.00E+00
input	v	m/s	1.00E-01	1.00E+00	1.00E+00
input	mesh	m	1.00E-02	1.00E-02	1.00E-02
input	damp	-	2.00E-01	2.00E-01	2.00E-01
output	ts-auto	s	1.58E-06	1.58E-06	1.58E-06
output	E	J	5.00E-02	1.50E+00	1.00E+00
output	k	N/m	1.02E+03	2.76E+04	2.00E+03
output	xmax-elas	m	9.88E-03	1.04E-02	3.16E-02
output	w-elas	rad/s	1.01E+01	9.60E+01	3.16E+01
output	w-elas	hz	1.61E+00	1.53E+01	5.03E+00
output	t/2-elas	s	3.10E-01	3.27E-02	9.93E-02
output	amax-elas	m/s2	1.01E+00	9.60E+01	3.16E+01
output	Fmax-elas	N	1.01E+01	2.88E+02	6.32E+01
output	smax-elas	Pa	1.90E+08	6.00E+08	9.49E+08
input	ts-forced	s	1.00E-05	1.00E-05	1.00E-05
input	mass-increase	-	3.98E+01	3.98E+01	3.98E+01

- Resumen.

➢ Hemos realizado un primer cálculo multipieza con contactos.

➢ Este cálculo nos sirve para poder validar haciendo ensayos si nuestro material es capaz de absorber energía

➢ Transformaciones para poder hacer ensayos con diferentes distancias entre apoyos

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S04t.- Crash box.

Mejora 2122…

- Repaso última sesión

Cálculo impacto a flexión

Introducción de contacto y fricción

Posibilidades de Mass Scaling

Multipiezas y colocación de dichas piezas

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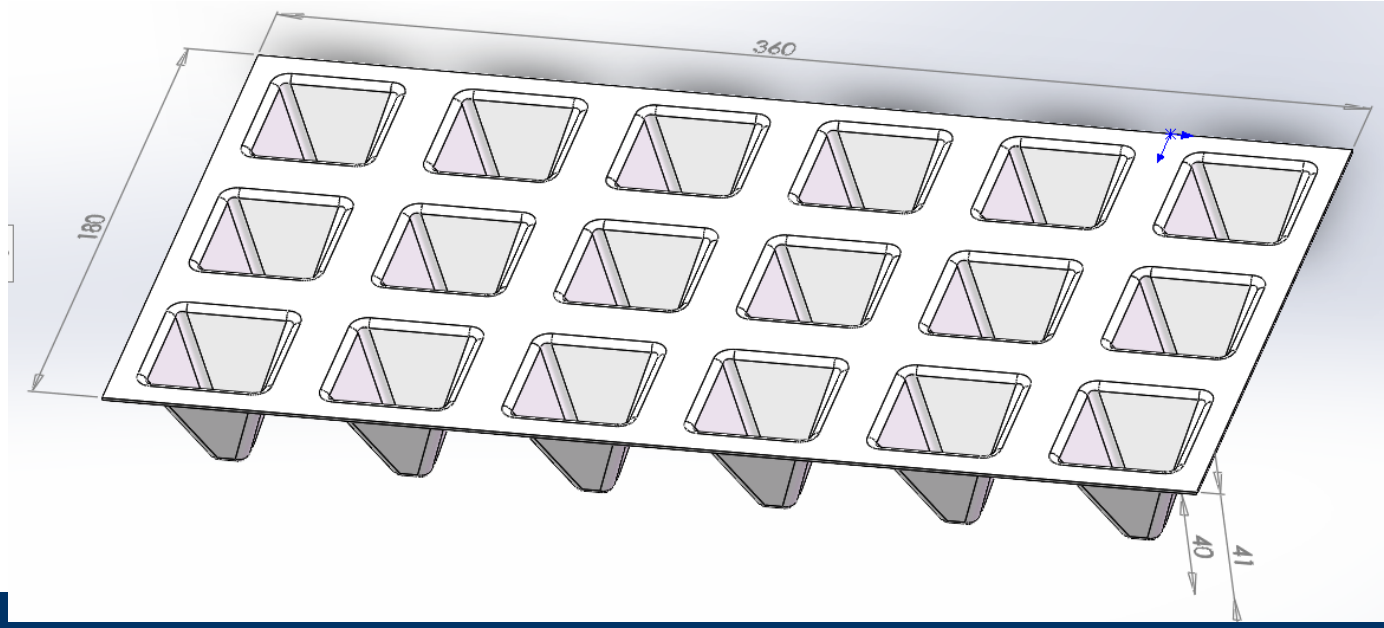
• Crash box

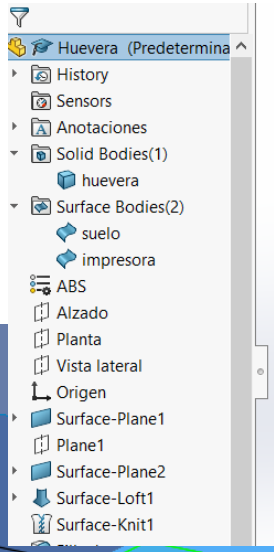
Vamos a intentar parar en menos de 40[mm] un paquete de 50[kg] que cae con una velocidad de 3.5[m/s]. Como factor de seguridad digamos que usamos sólo 20[mm] por lo que necesitaremos una aceleración de unos 31.2[g] ($a=v^2/(2s)$) en unos 12[ms] ($t=v/a$) con fuerzas de 15.3[kN] ($F=ma$)

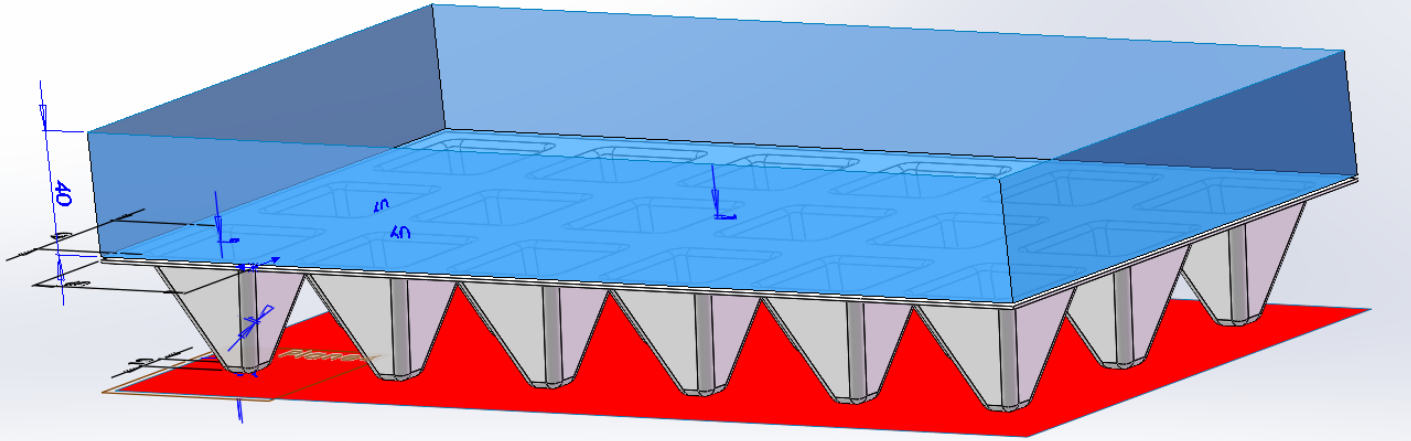
Todos estos números son orientativos pues asumen que la aceleración es constante y seguro no lo va a ser.

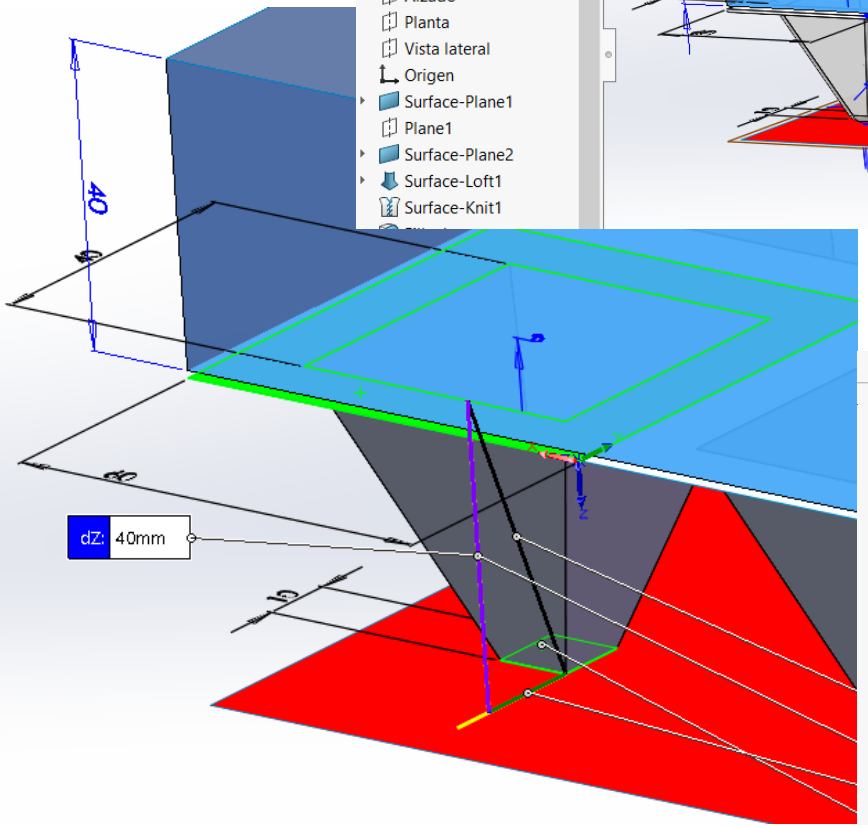
La huevera ocupa 6x60=360[mm] x 3x60=180[mm] con los comentados 40[mm] más el espesor de 1[mm].

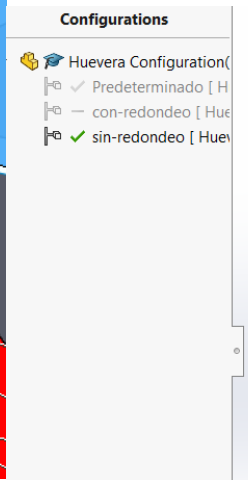


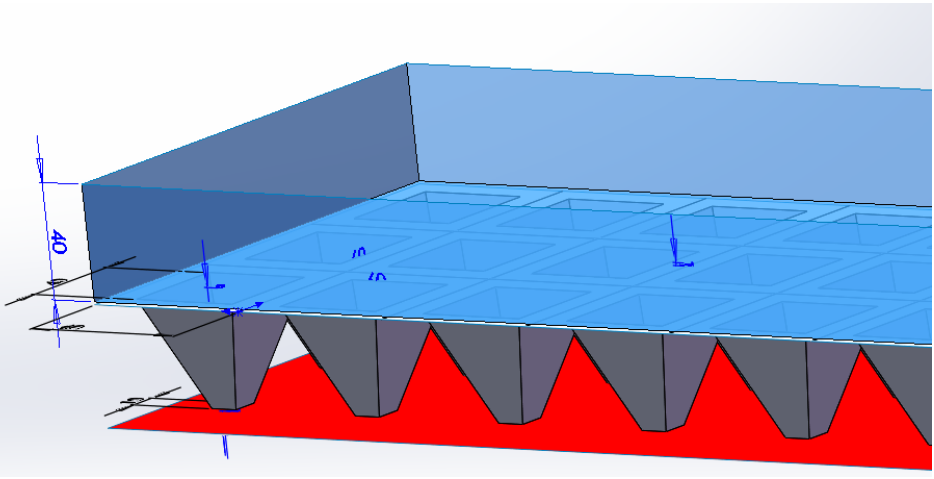
- Geometría


Huevera (Predetermina
History
Sensors
Anotaciones
Solid Bodies(1)
huevera
Surface Bodies(2)
suelo
impresora
ABS
Alzado
Planta
Vista lateral
Origen
Surface-Plane1
Plane1
Surface-Plane2
Surface-Loft1
Surface-Knit1


40

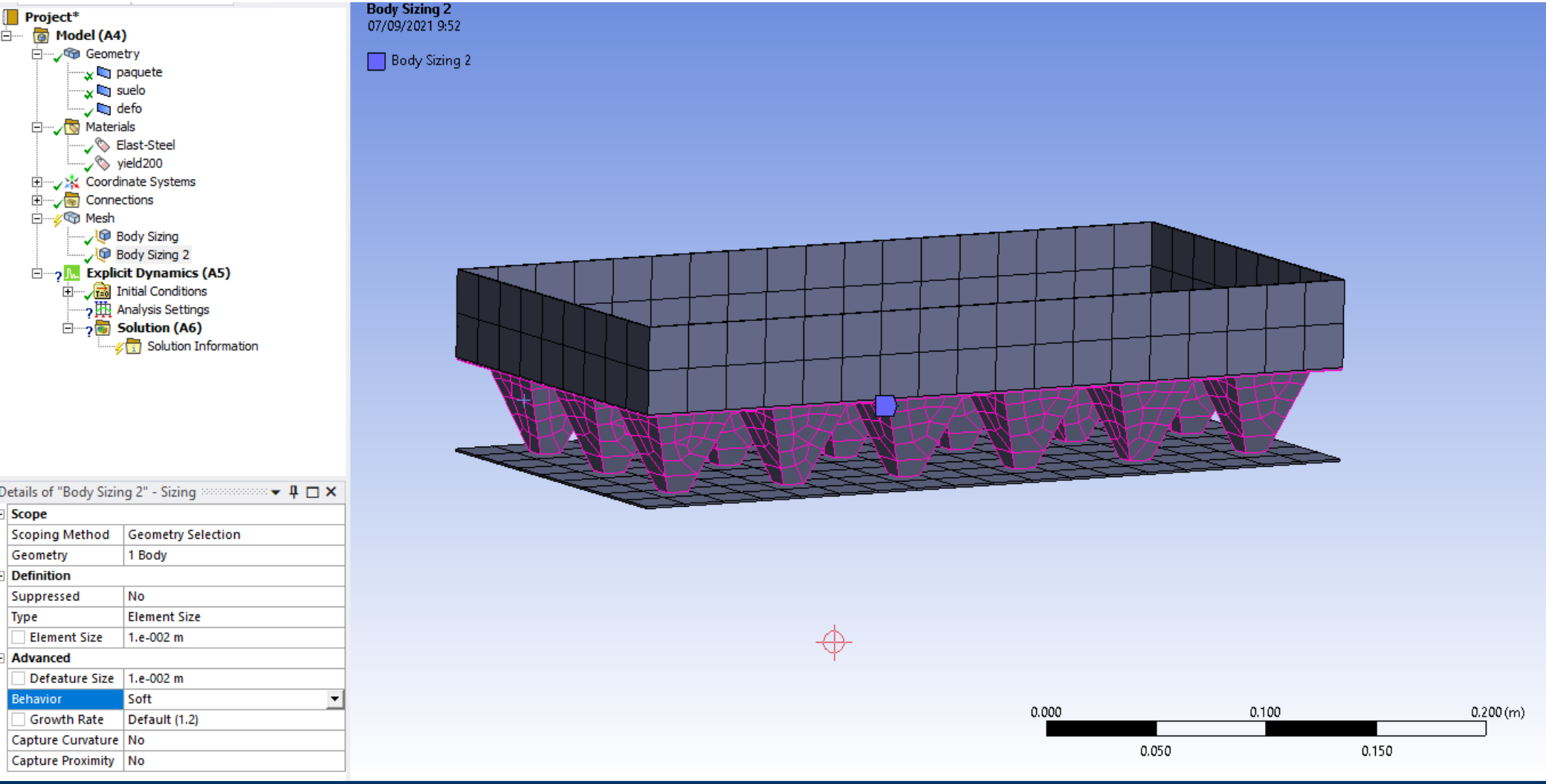

40
dZ: 40mm


Configurations
Huevera Configuration(
Predeterminado [H
con-redondeo [Hue
sin-redondeo [Huev


40

- Ponemos espesores y materiales

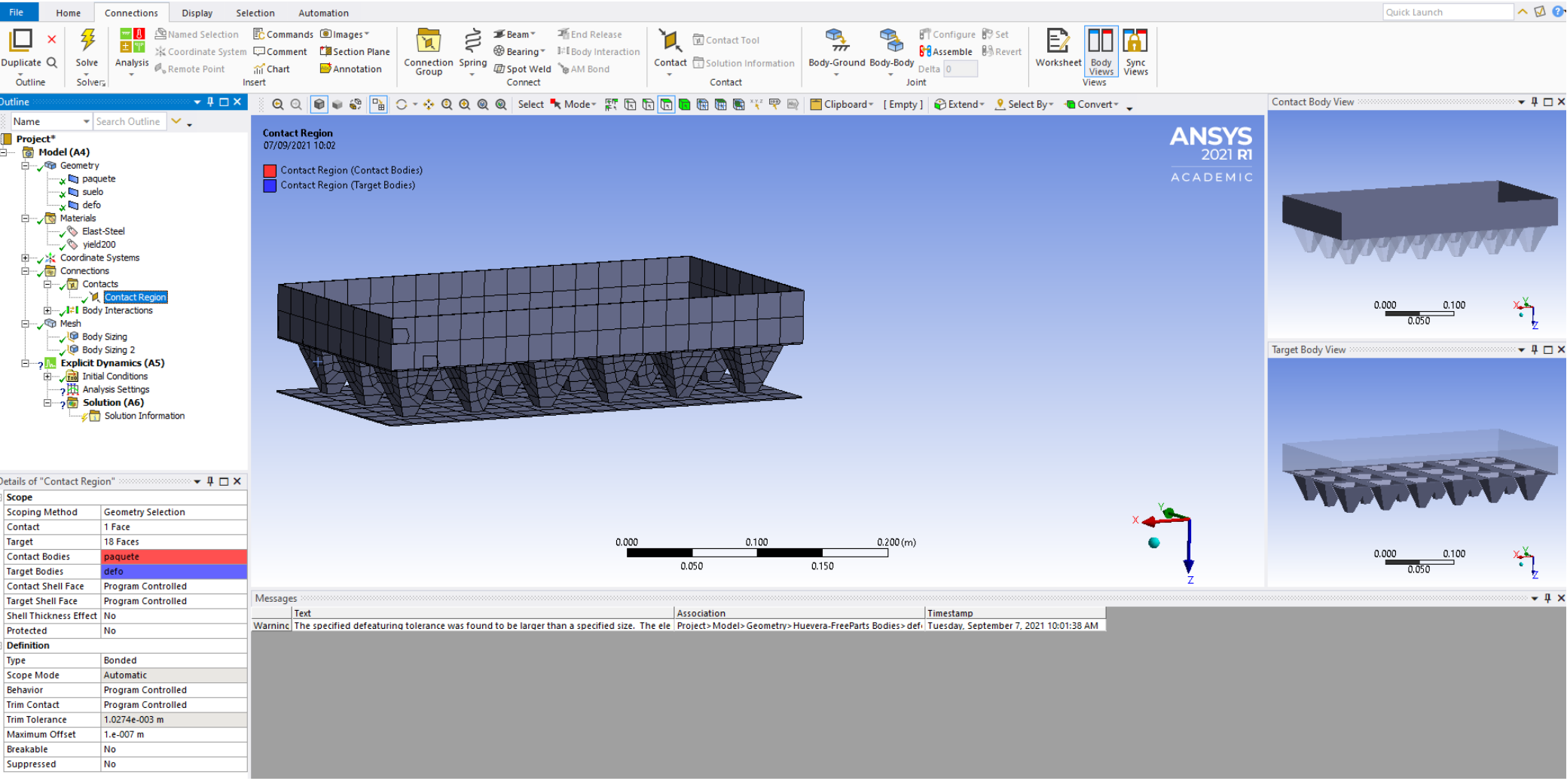
Para empezar con malla de 10mm.



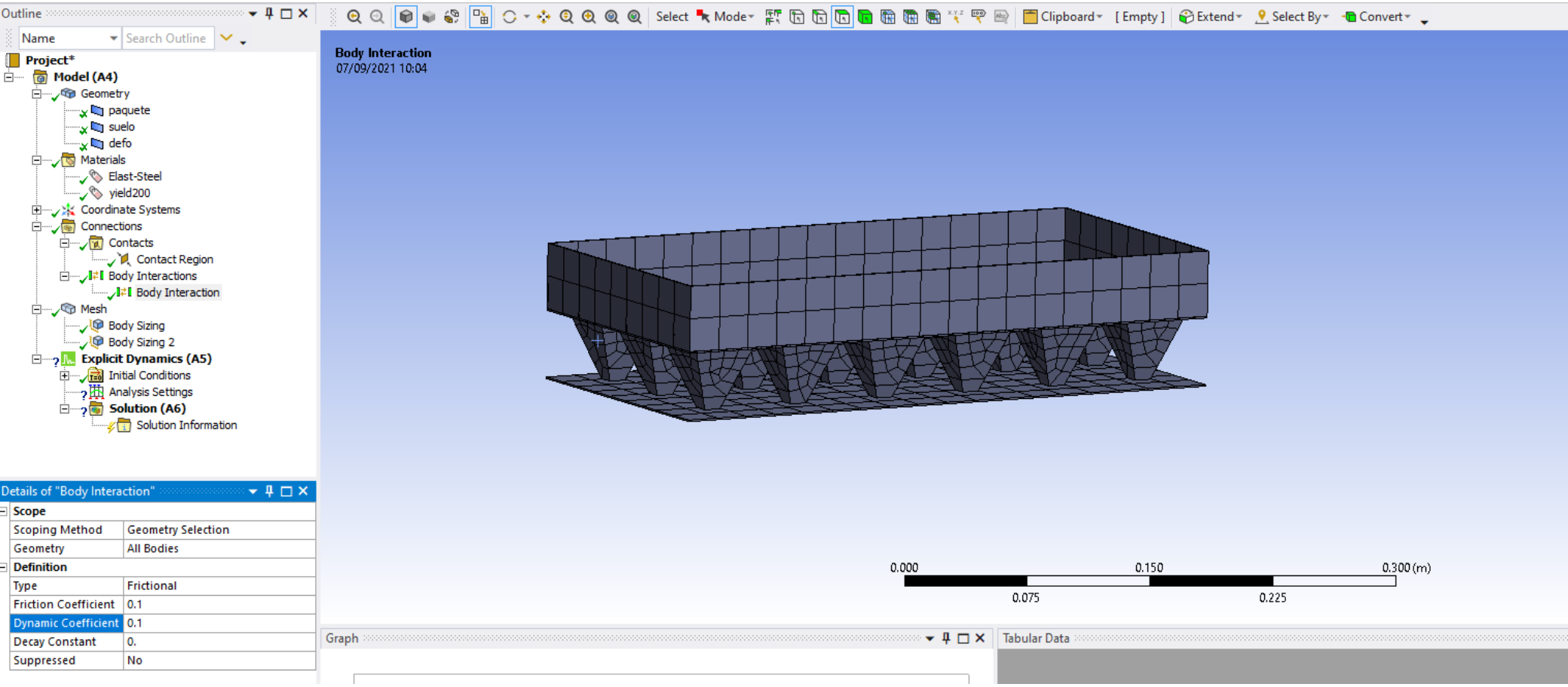
Details of "Body Sizing 2" - Sizing

Scope	
Scoping Method	Geometry Selection
Geometry	1 Body
Definition	
Suppressed	No
Type	Element Size
Element Size	1.e-002 m
Advanced	
Defeature Size	1.e-002 m
Behavior	Soft
Growth Rate	Default (1.2)
Capture Curvature	No
Capture Proximity	No

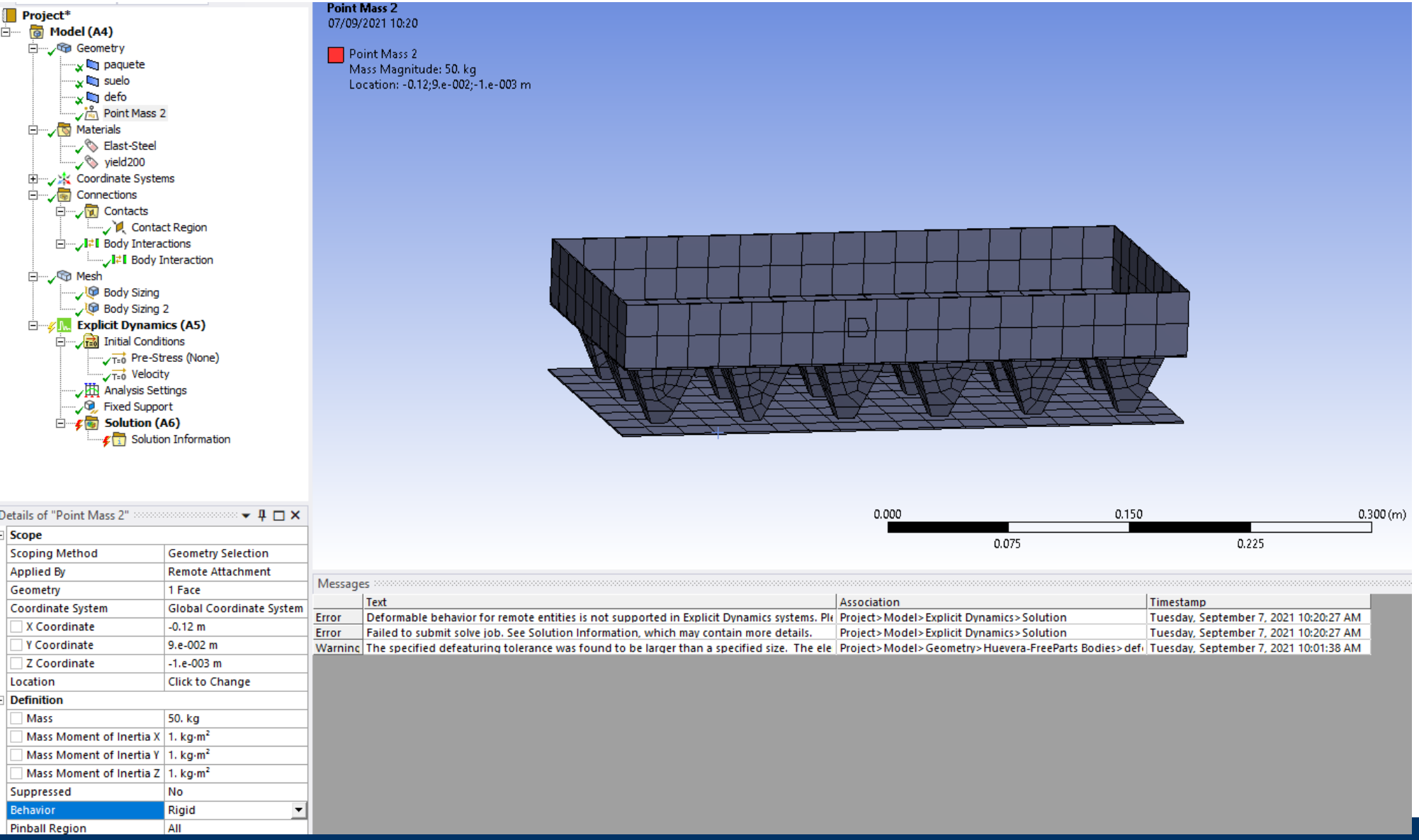
- Pegar paquete a defo



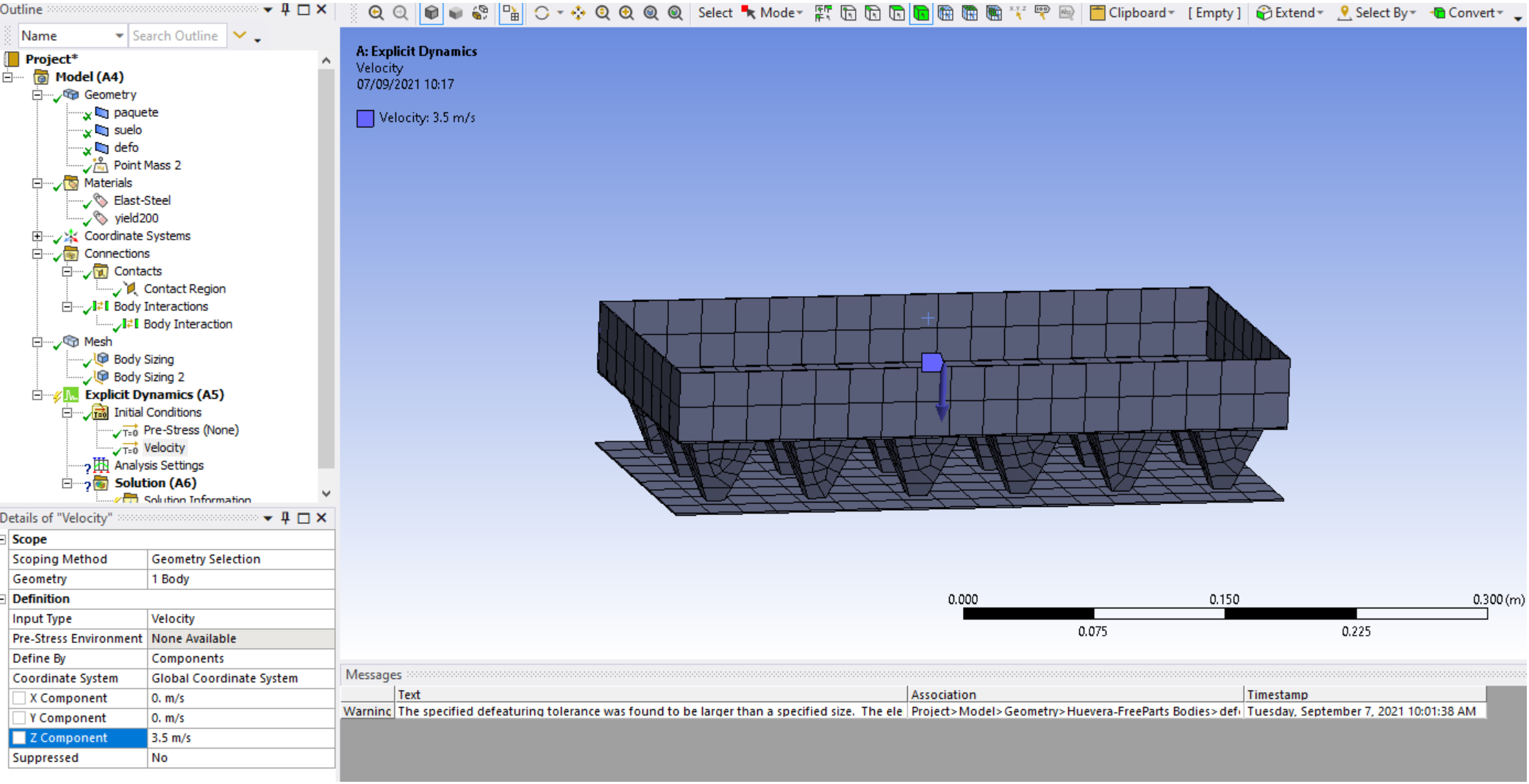
- Contacto inferior



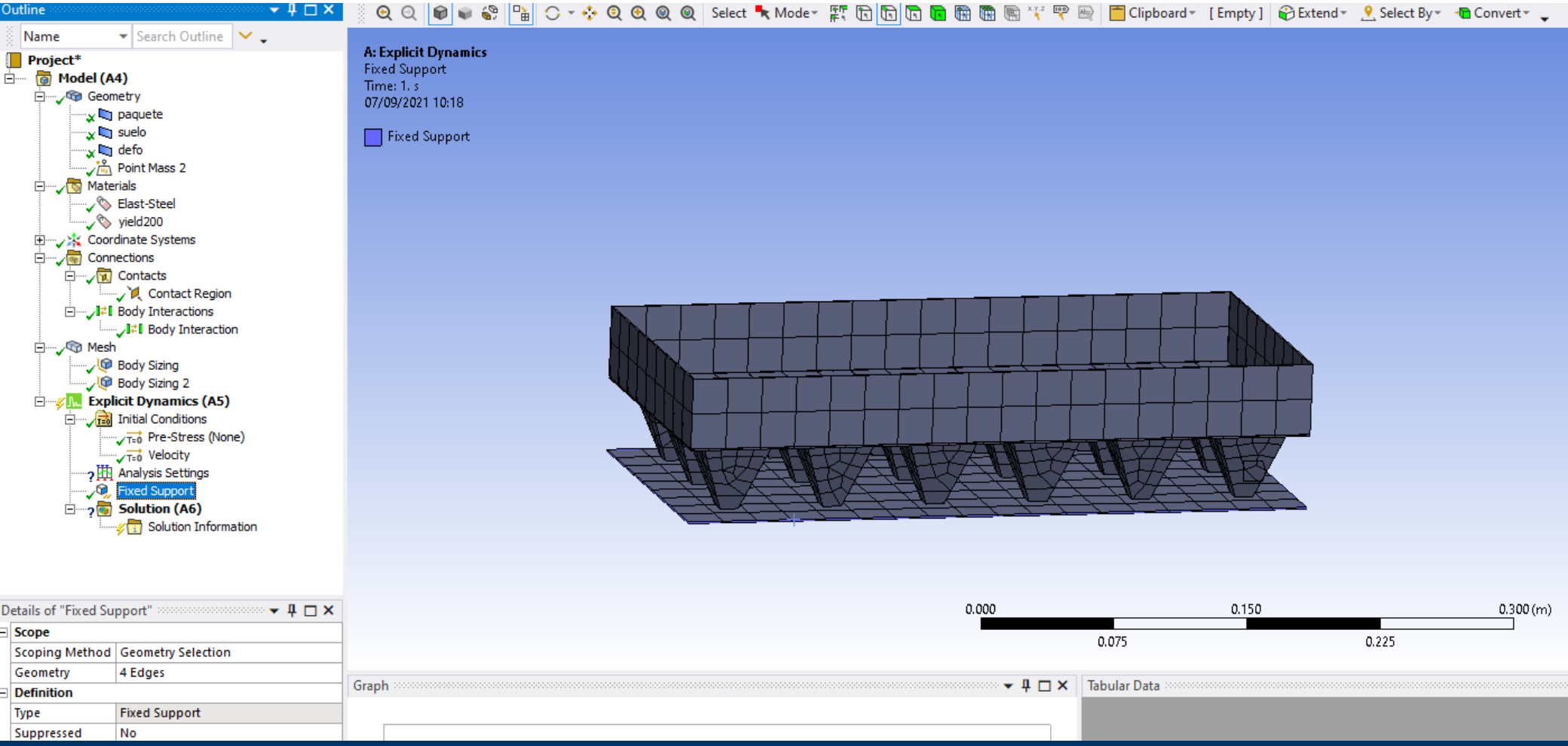
- Ponemos la masa



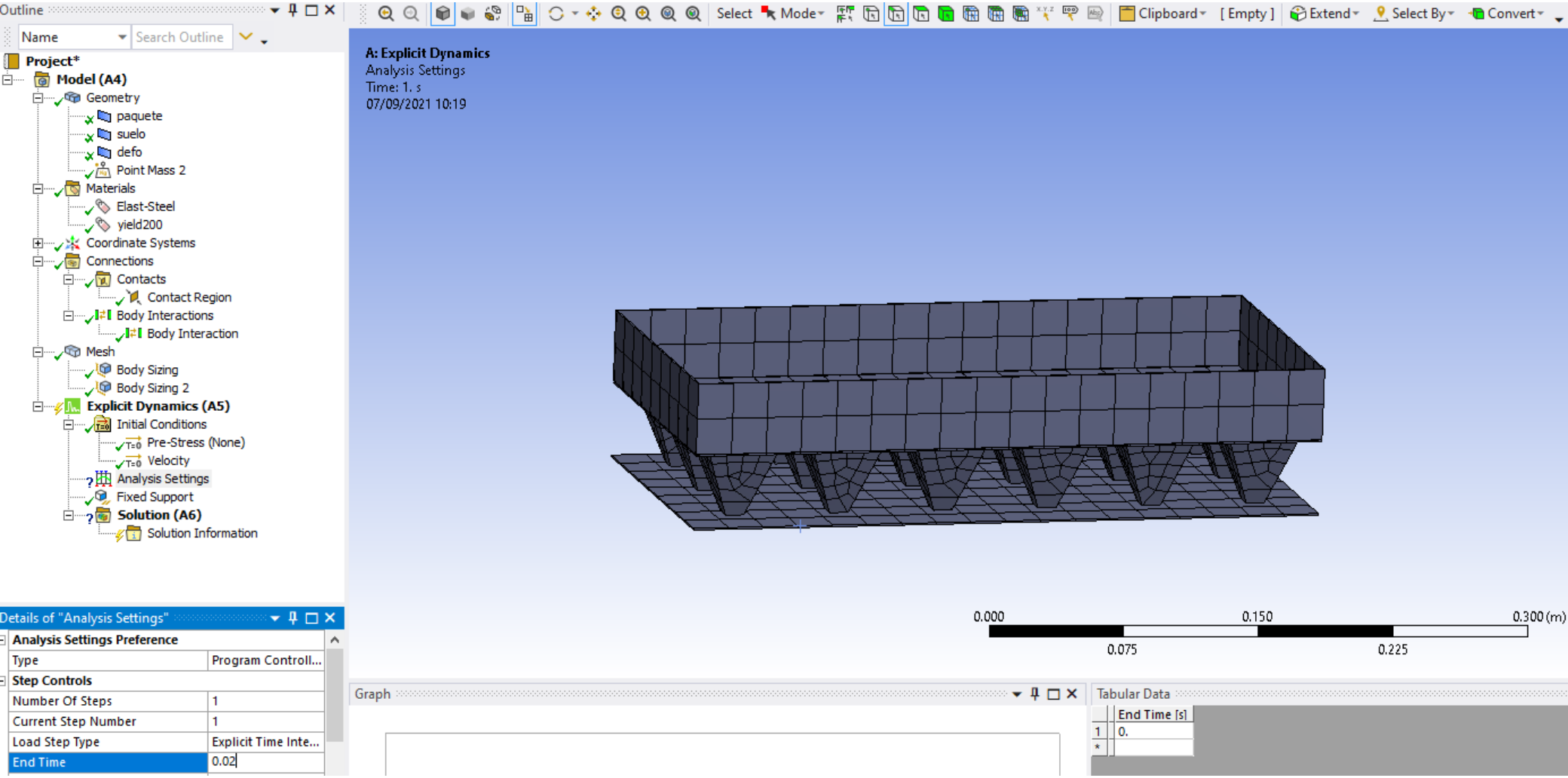
- Velocidad inicial



- Fijamos contorno



- Tiempo de simulación



• Cálculo inicial

Vemos que el time step no es de 1.5e-6 como hasta ahora. Ahora tenemos algún elemento más pequeño en el defo que hace que trabajemos con un time step de 6.1e-7 que hace que tengamos un tiempo de cálculo aproximadamente x2.5

```
Cycle:    32161, Time:  2.000E-02s, Time Inc.: 6.880E-07s, Progress: 100.00%, Est. Clock Time Remaining: 0s
Cycle:    32162, Time:  2.000E-02s, Time Inc.: 6.152E-07s, Progress: 100.00%, Est. Clock Time Remaining: -


SIMULATION ELAPSED TIME SUMMARY

EXECUTION FROM CYCLE        0 TO    32162
ELAPSED RUN TIME IN SOLVER =      1.97292E+00 Minutes
TOTAL ELAPSED RUN TIME     =      2.04545E+00 Minutes
JOB RAN OVER     2 WORKERS
JOB RAN USING Intel MPI
JOB RAN USING DECOMPOSITION AUTO

Problem terminated .... wrapup time reached

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```
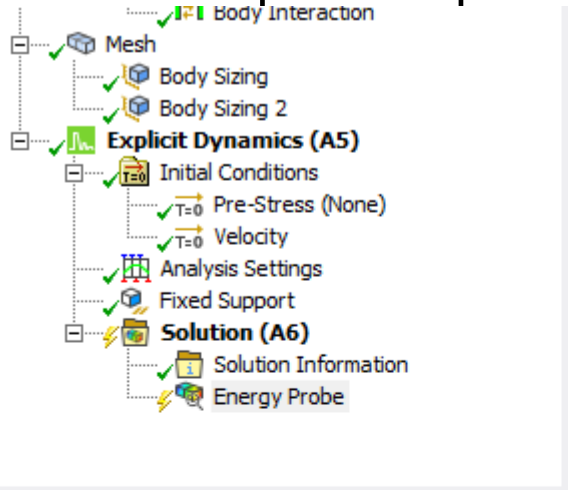
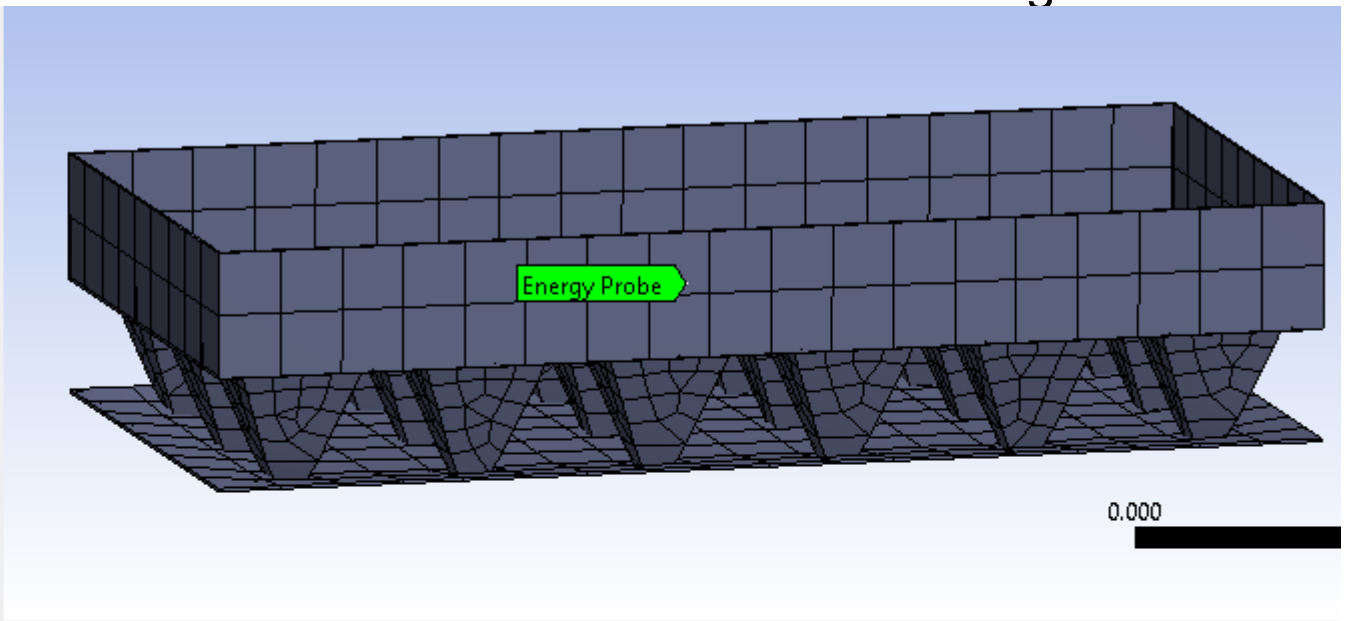

• Energías

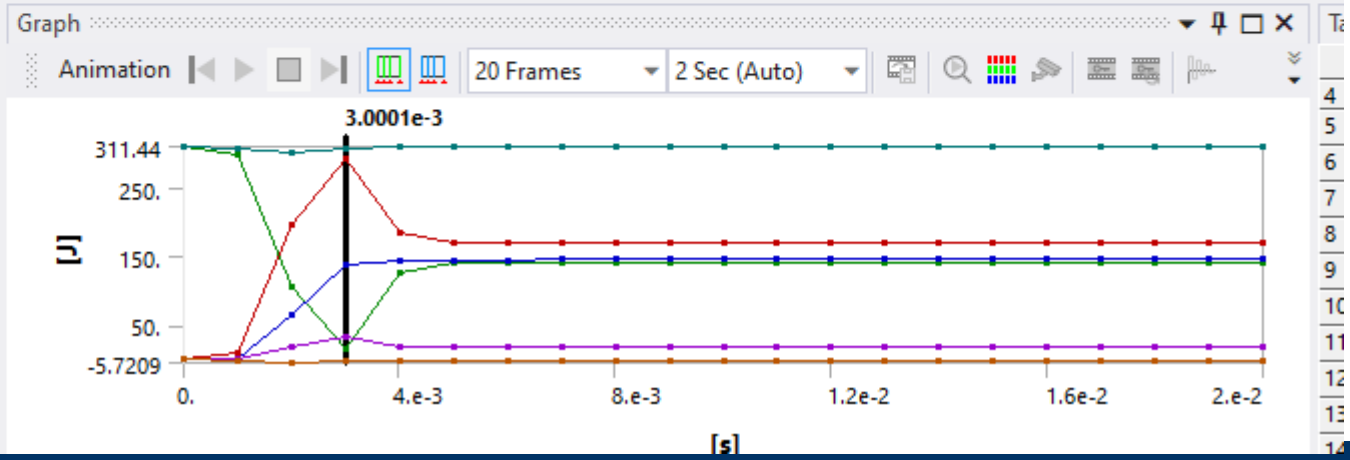
Vemos que el impacto ha sido casi elástico retornando 50% energía.





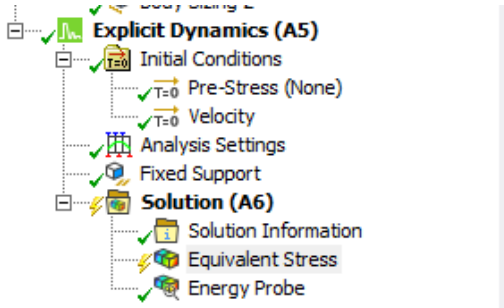
ils of "Energy Probe"

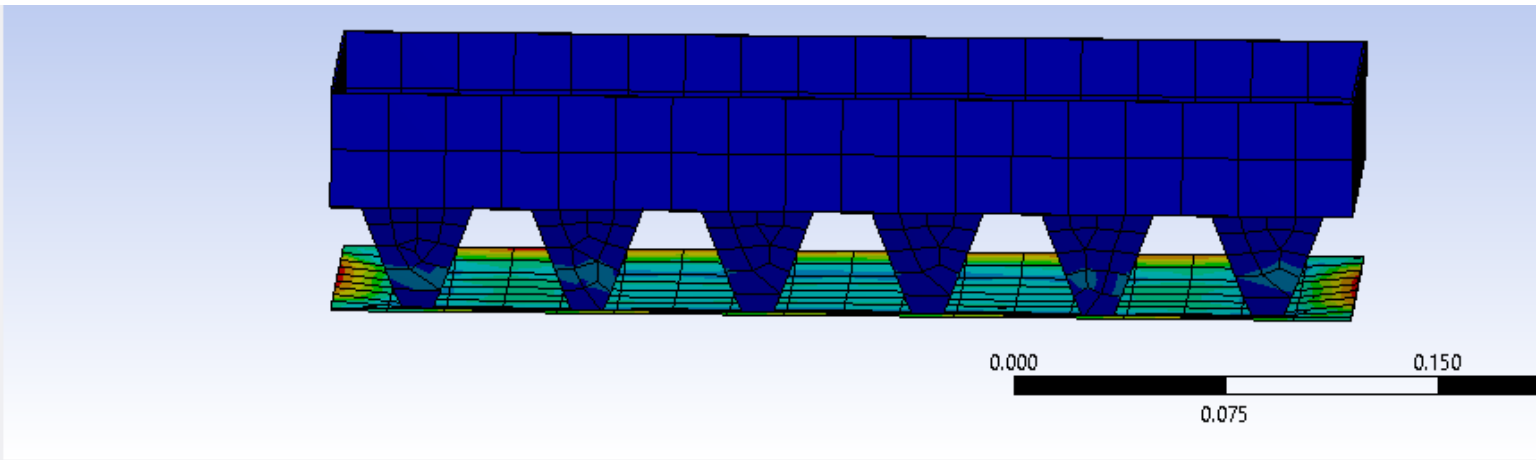
efinition	
pe	Energy
eometry	3 Bodies
ppressed	No
ptions	
sult Selection	All
Display Time	3.0001e-003 s
sults	
aximum Value Over Time	
Internal	292.41 J
Kinetic	311.44 J
Plastic Work	145.58 J
Hourglass	31.631 J
Contact	0. J
Total	311.44 J



- Tensiones

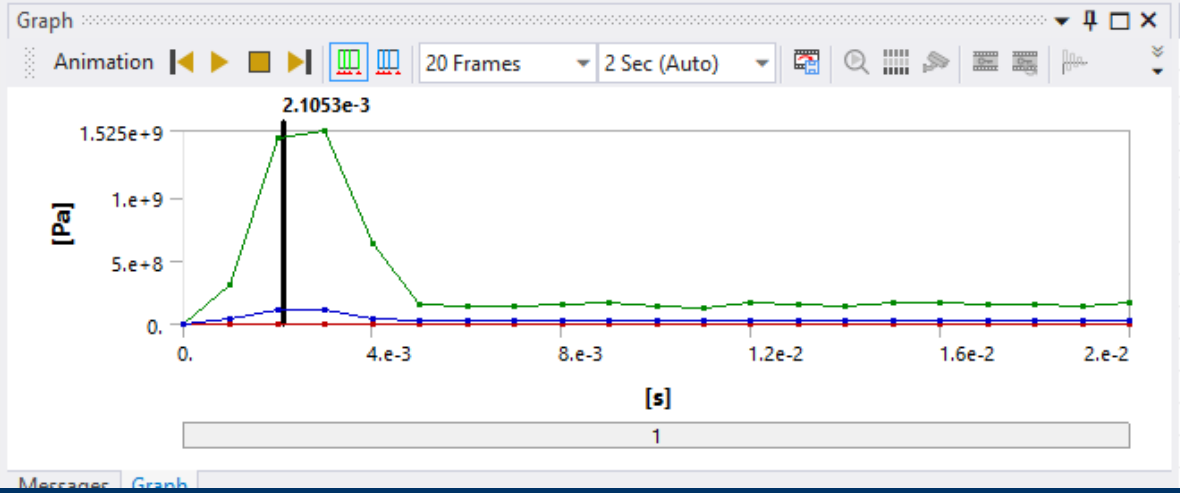
Con esta configuración la base elástica es la que tiene la tensión alta





Details of "Equivalent Stress"

Scope	
Scoping Method	Geometry Selection
Geometry	All Bodies
Position	Top/Bottom
Definition	
Type	Equivalent (von-Mises) Stress
By	Time
Display Time	3.0001e-003 s
Calculate Time History	Yes
Identifier	
Suppressed	No
Integration Point Results	
Display Option	Averaged
Average Across Bodies	No
Results	
Minimum	0. Pa
Maximum	1.682e+008 Pa
Average	2.3203e+007 Pa

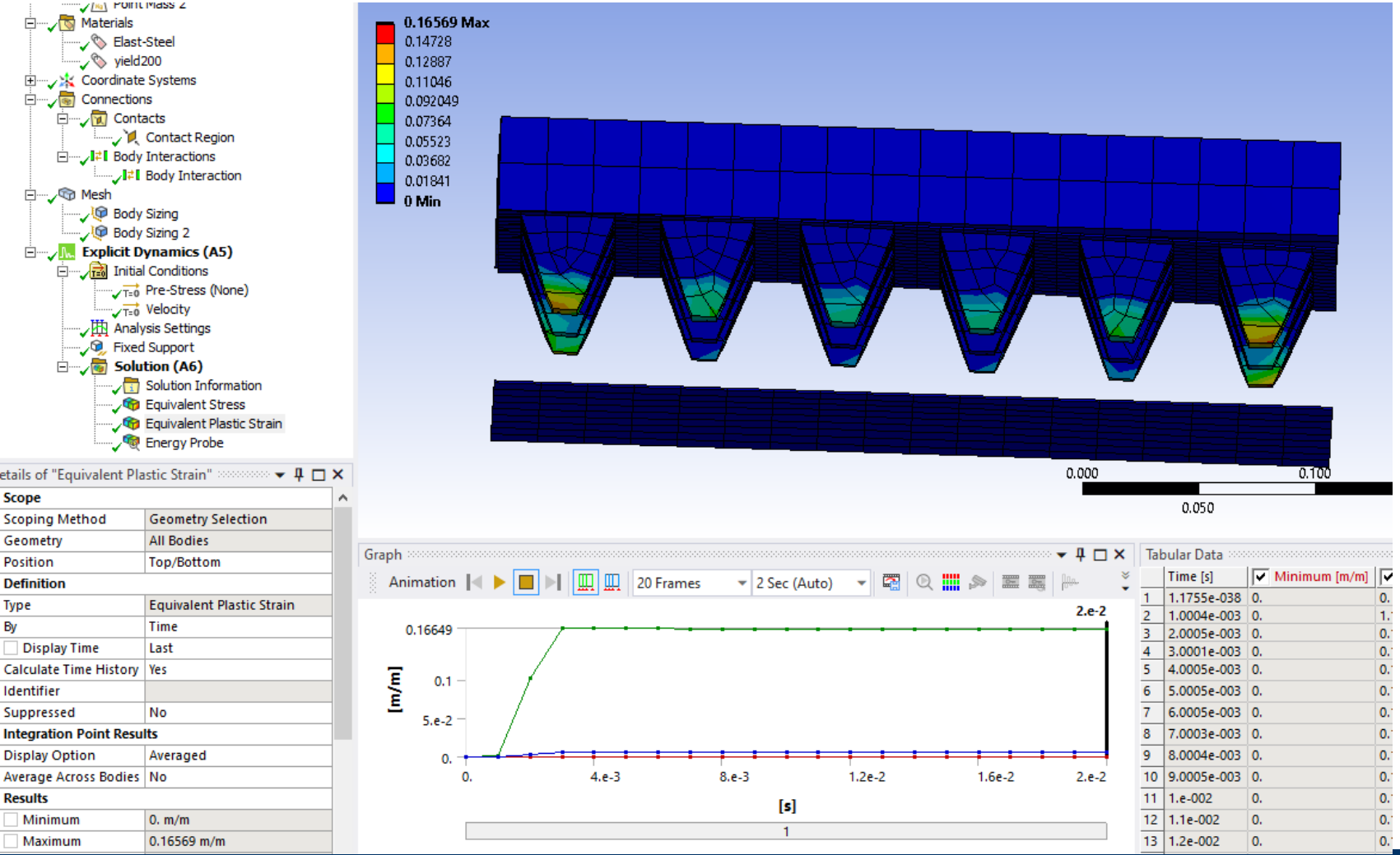


Tabular Data

	Time [s]	Minimum [Pa]	
1	1.1755e-038	0.	0.
2	1.0004e-003	0.	3.6
3	2.0005e-003	0.	1.4
4	3.0001e-003	0.	1.5
5	4.0005e-003	0.	6.3
6	5.0005e-003	0.	1.6
7	6.0005e-003	0.	1.4
8	7.0003e-003	0.	1.4
9	8.0004e-003	0.	1.5
10	9.0005e-003	0.	1.6
11	1.e-002	0.	1.4
12	1.1e-002	0.	1.3
13	1.2e-002	0.	1.6
14	1.3e-002	0.	1.5

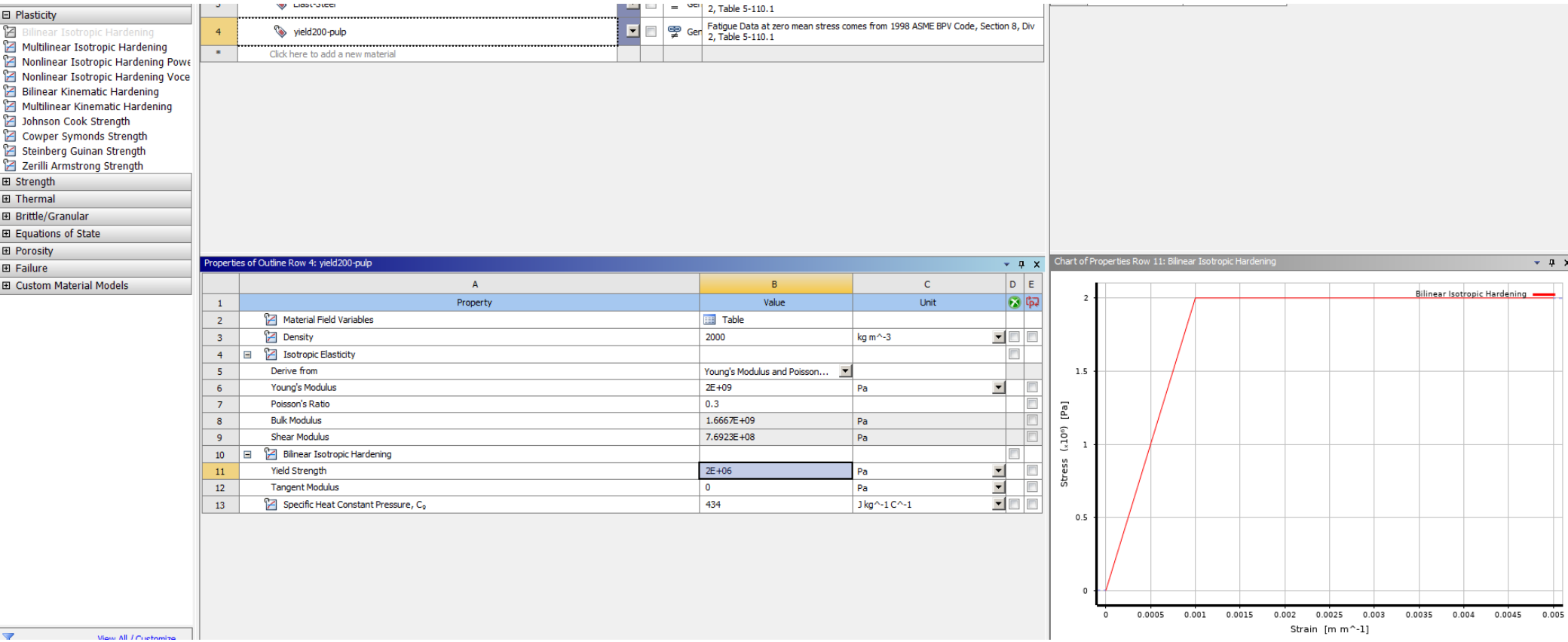
- Deformación plástica

El defo tiene algo de deformación plástica pero no ha hecho su trabajo



- Reasignación de propiedades

Primero vamos a poner la pared de abajo toda restringida y no sólo en el contorno. Luego para el defo vamos a hacer un material con propiedades divididas por 100 de módulo Young y Yield para que deforme más y no estropee el time step.



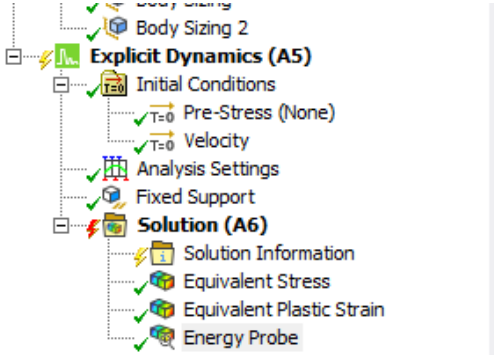
- Resultados

Ahora puede ir con un time step grande y corre rápido.

```
Cycle:     7374, Time:  1.623E-02s, Time Inc.: 1.889E-06s, Progress:  81.15%, Est. Clock Time Remaining: 9s


SIMULATION ELAPSED TIME SUMMARY

EXECUTION FROM CYCLE        0 TO     7374
ELAPSED RUN TIME IN SOLVER =      6.50100E-01 Minutes
TOTAL ELAPSED RUN TIME     =      6.97833E-01 Minutes
JOB RAN OVER     2 WORKERS
JOB RAN USING Intel MPI
JOB RAN USING DECOMPOSITION AUTO

Problem terminated .... energy error too large
Problem terminated .... energy error too large

 ****************************************
```

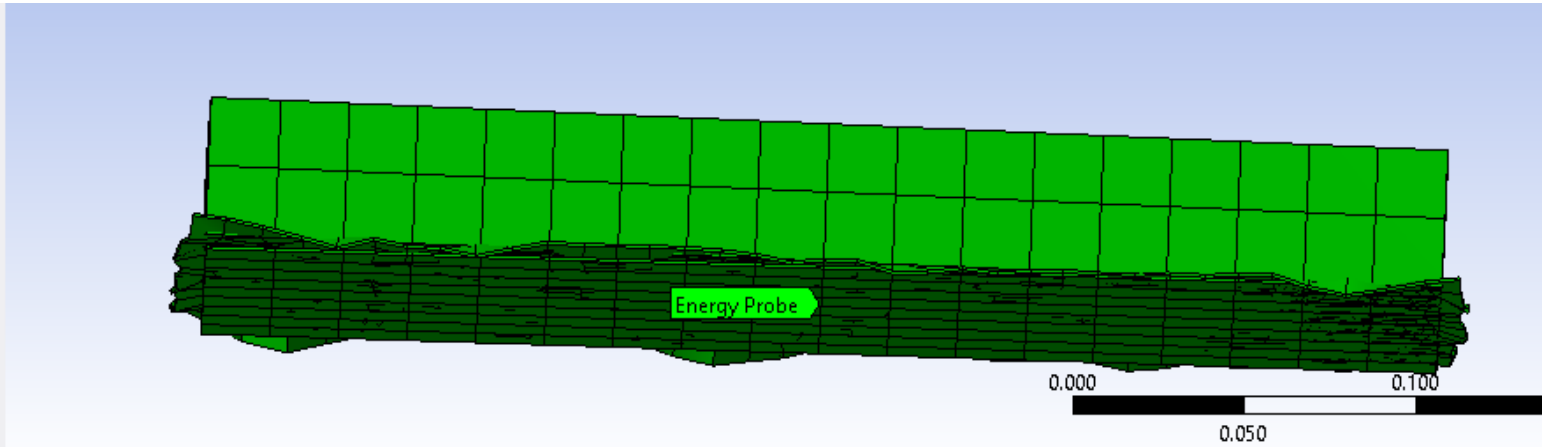
• Energías

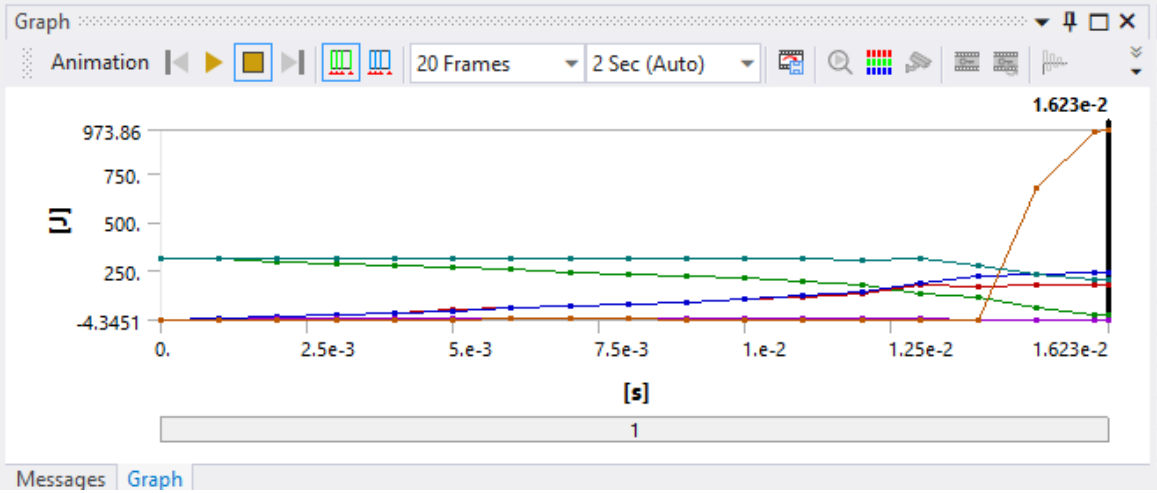
Como se puede ver ahora es demasiado débil con espesor 1[mm] y por tanto no frena a tiempo colapsando el defo



Details of "Energy Probe"

Definition	
Type	Energy
Geometry	3 Bodies
Suppressed	No
Options	
Result Selection	All
Display Time	End Time
Results	
Maximum Value Over Time	
Minimum Value Over Time	
Information	



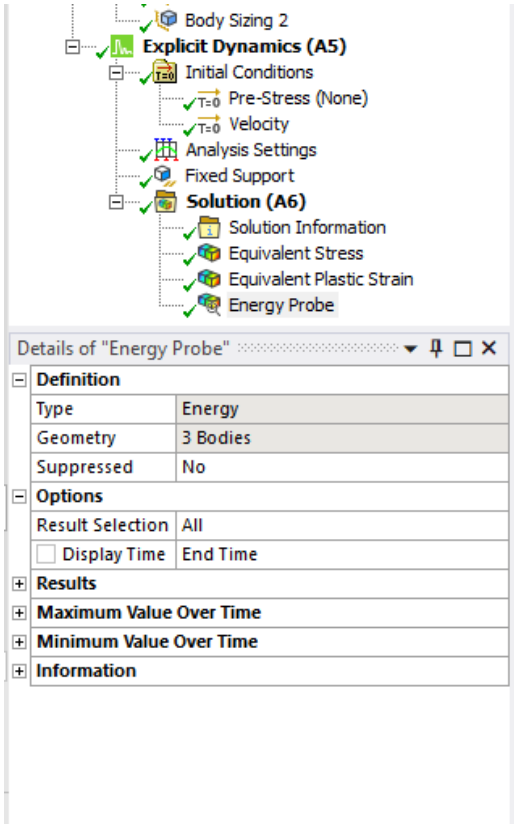


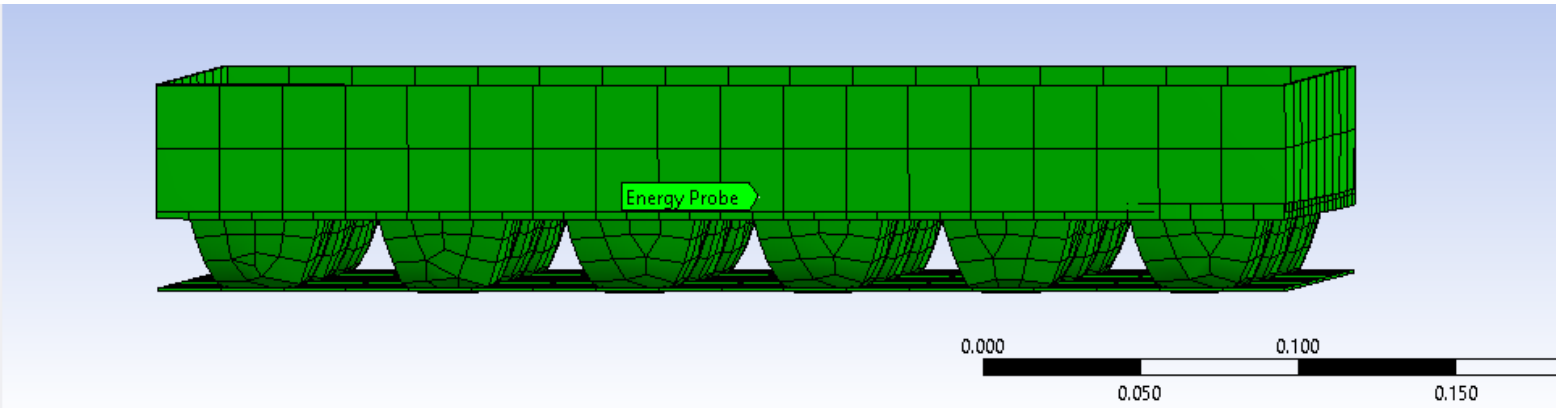
Tabular Data

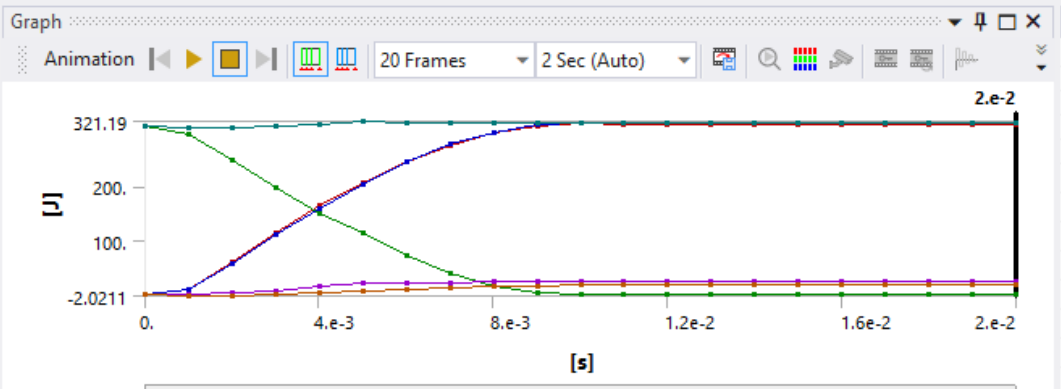
	Time [s]	Energy Probe (Intern
1	1.1755e-038	0.
2	1.0027e-003	2.2333
3	2.0002e-003	12.79
4	3.0006e-003	24.788
5	4.0026e-003	35.837
6	5.0027e-003	46.799
7	6.001e-003	56.86
8	7.0013e-003	66.377
9	8.0005e-003	78.926
10	9.0014e-003	86.269
11	1.0002e-002	100.72
12	1.1002e-002	115.55
13	1.2e-002	134.82

- Juego con espesores

Repetimos el cálculo jugando con espesores hasta un máximo que podamos fabricar. Con 5[mm] vemos que ya paramos la caja pero usando poco espacio y por tanto mucha fuerza y aceleración.





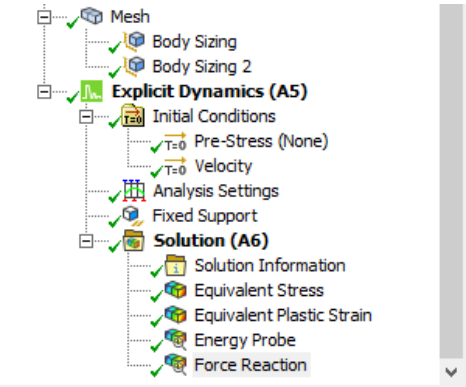


Tabular Data

	Time [s]	Energy Probe (Internal) [J]	Energy
1	1.1755e-038	0.	311.44
2	1.0027e-003	10.557	298.41
3	2.0002e-003	60.251	248.78
4	3.0006e-003	114.02	197.64
5	4.0003e-003	164.94	151.58
6	5.0016e-003	207.37	113.82
7	6.0012e-003	245.54	73.734
8	7.0018e-003	277.07	40.336
9	8.0013e-003	300.19	16.852
10	9.0005e-003	313.43	3.6282
11	1.0002e-002	317.09	5.7342e-00
12	1.1001e-002	316.59	0.66987

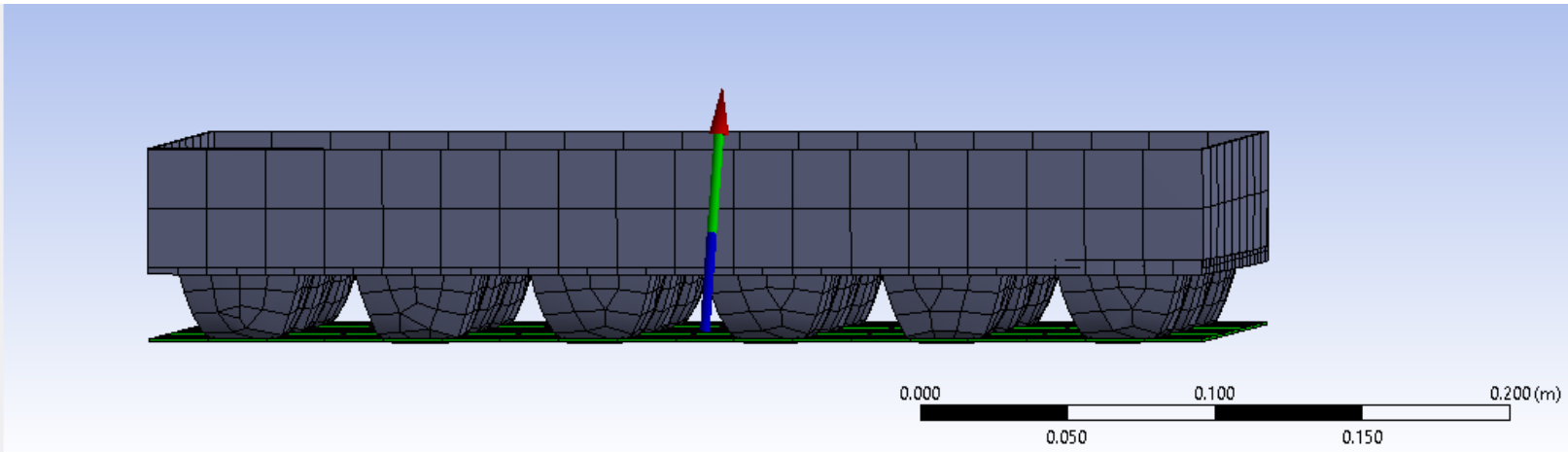
• Fuerza reacción

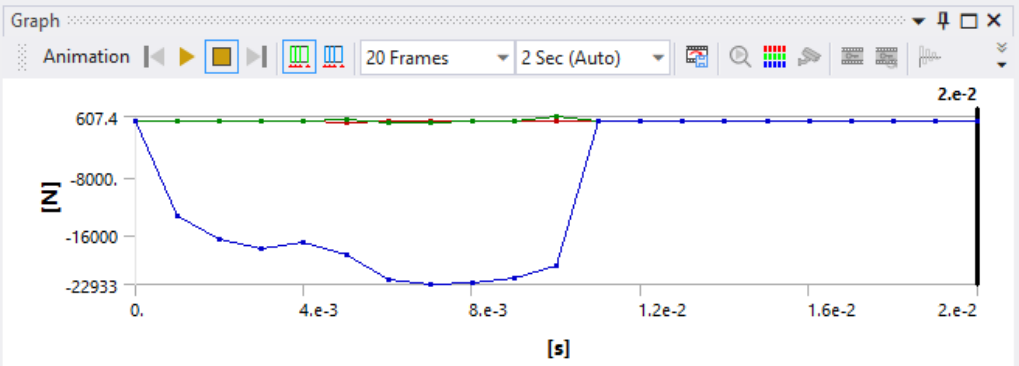
Buscábamos una fuerza de reacción de unos 15[kN] y tenemos unos 23[kN] por lo que usamos menos espacio



Details of "Force Reaction"

Definition	
Type	Force Reaction
Location Method	Boundary Condition
Boundary Condition	Fixed Support
Orientation	Global Coordinate System
Suppressed	No
Options	
Result Selection	All
Display Time	End Time
Results	
Maximum Value Over Time	
Minimum Value Over Time	
Information	



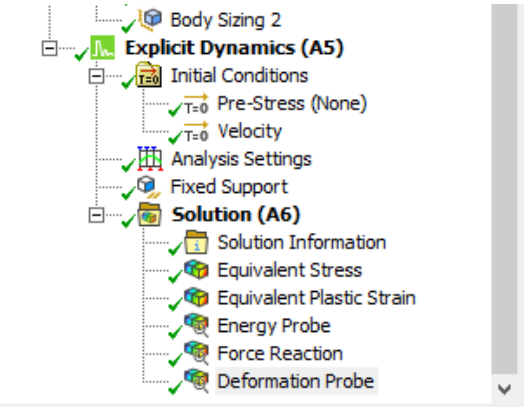


Tabular Data

	Time [s]	Force Reaction (X) [N]	Force Reaction (Y) [N]	
1	1.1755e-038	0.	0.	0.
2	1.0027e-003	12.01	-16.434	-13
3	2.0002e-003	34.765	-98.729	-16
4	3.0006e-003	32.962	-137.49	-17
5	4.0003e-003	-7.7809	-60.32	-17
6	5.0016e-003	-171.84	151.19	-18
7	6.0012e-003	20.203	-247.28	-22
8	7.0018e-003	-29.098	-203.3	-22
9	8.0013e-003	-24.929	-109.6	-22
10	9.0005e-003	18.858	4.1354	-22
11	1.0002e-002	61.899	607.4	-20

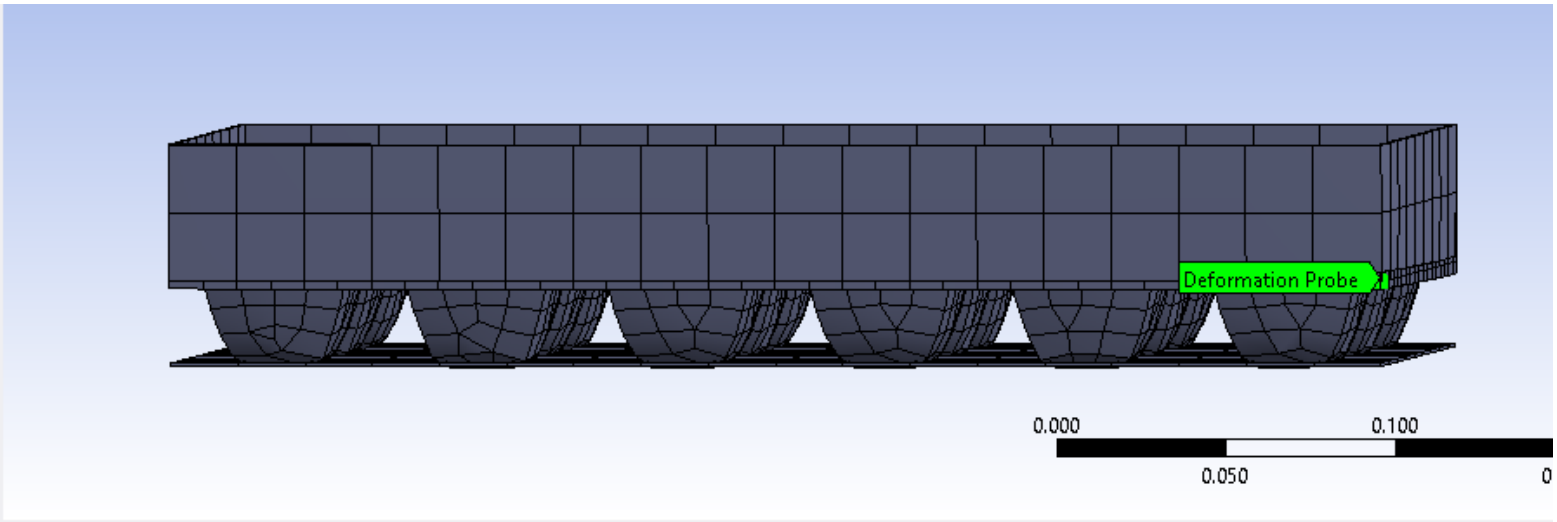
- Espacio utilizado

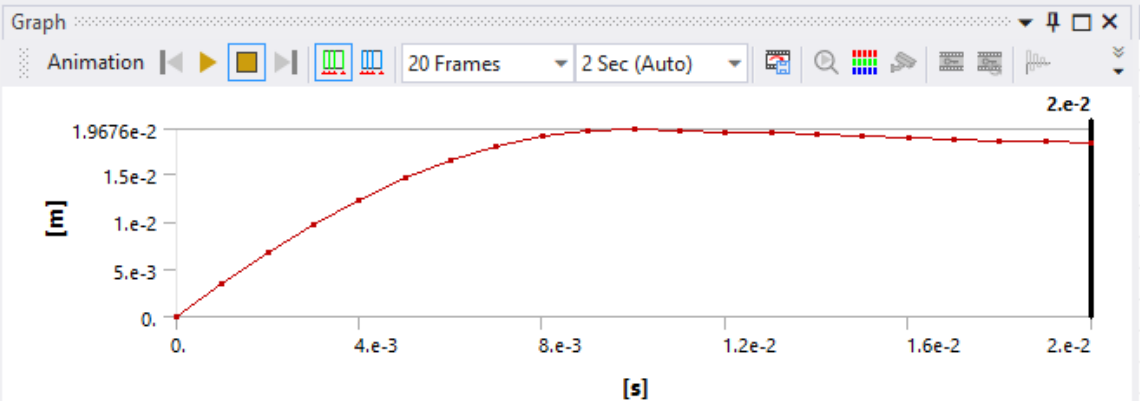
Buscábamos usar unos 20[mm] para llegar a usar más si es más débil sin problema.



Details of "Deformation Probe"

Definition	
Type	Deformation
Location Method	Geometry Selection
Geometry	1 Vertex
Orientation	Global Coordinate System
Suppressed	No
Options	
Result Selection	Z Axis
Display Time	End Time
Spatial Resolution	Use Maximum
Results	
Maximum Value Over Time	
Minimum Value Over Time	
Information	



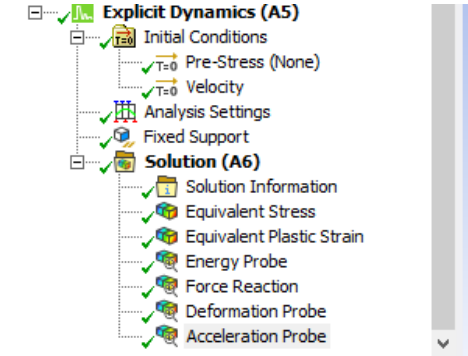


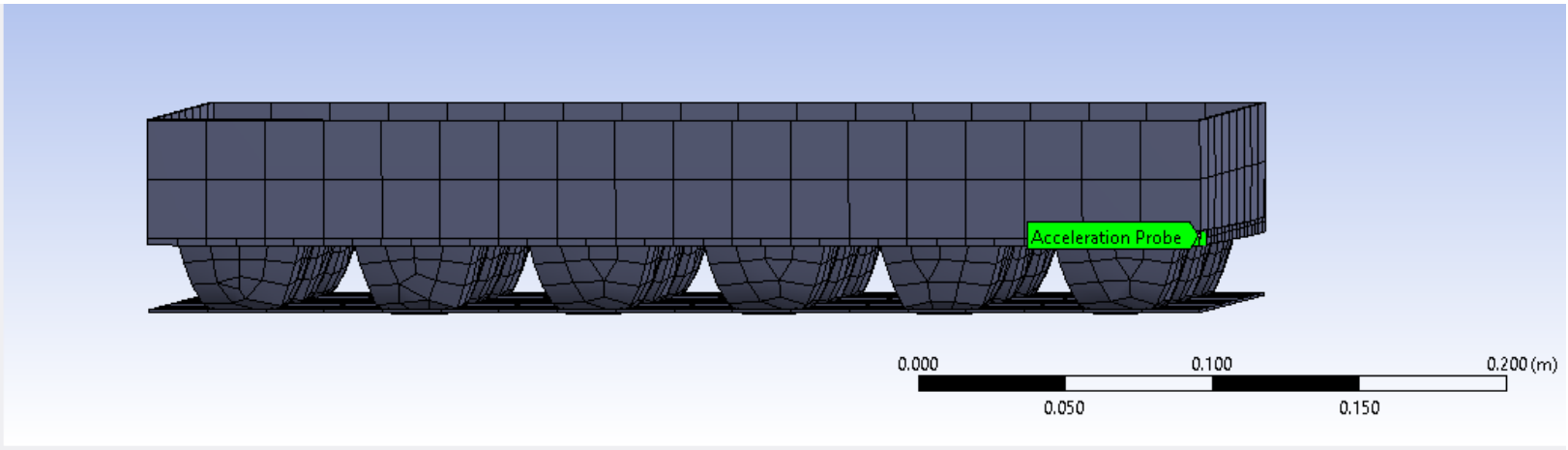
Tabular Data

	Time [s]	Deformation Probe (Z) [m
1	1.1755e-038	0.
2	1.0027e-003	3.4487e-003
3	2.0002e-003	6.6942e-003
4	3.0006e-003	9.6273e-003
5	4.0003e-003	1.2217e-002
6	5.0016e-003	1.4486e-002
7	6.0012e-003	1.6391e-002
8	7.0018e-003	1.7868e-002
9	8.0013e-003	1.8903e-002
10	9.0005e-003	1.9501e-002
11	1.0002e-002	1.9676e-002

• Aceleración

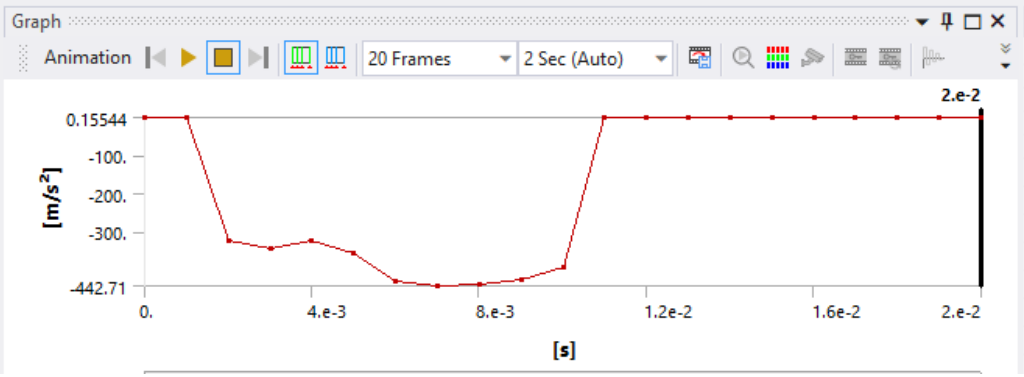
Todo el diseño se basa en tener una aceleración constante de unos 31[g] pero la obtenida se parece a un impacto elástico al principio y luego está en torno a los 44[g].





etails of "Acceleration Probe"

Definition	
Type	Acceleration
Location Method	Geometry Selection
Geometry	1 Vertex
Orientation	Global Coordinate System
Suppressed	No
Options	
Result Selection	Z Axis
Display Time	End Time
Spatial Resolution	Use Maximum
Results	
Maximum Value Over Time	
Minimum Value Over Time	
Information	

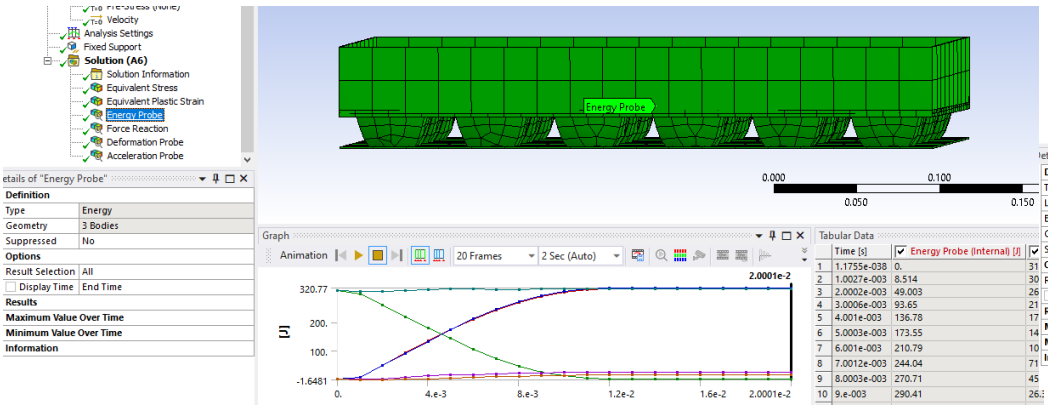


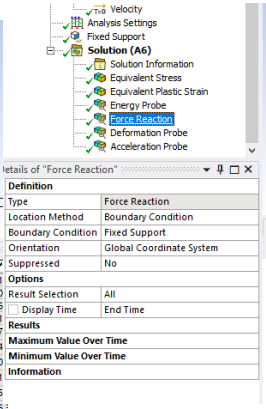
Tabular Data

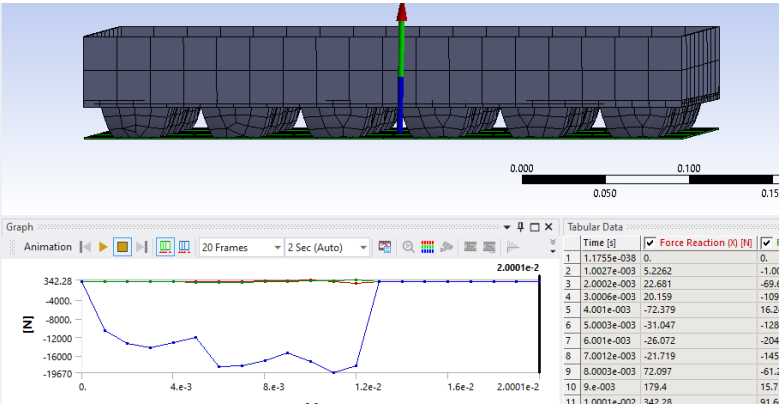
	Time [s]	Acceleration Probe (Z) [m/s²]
1	1.1755e-038	0.
2	1.0027e-003	-6.5779e-002
3	2.0002e-003	-325.49
4	3.0006e-003	-343.
5	4.0003e-003	-324.83
6	5.0016e-003	-358.45
7	6.0012e-003	-432.33
8	7.0018e-003	-442.71
9	8.0013e-003	-437.02
10	9.0005e-003	-424.61
11	1.0002e-002	-393.11
12	1.1001e-002	0.15544

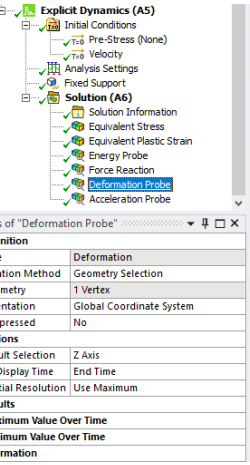
- Cambio a espesor 4[mm]

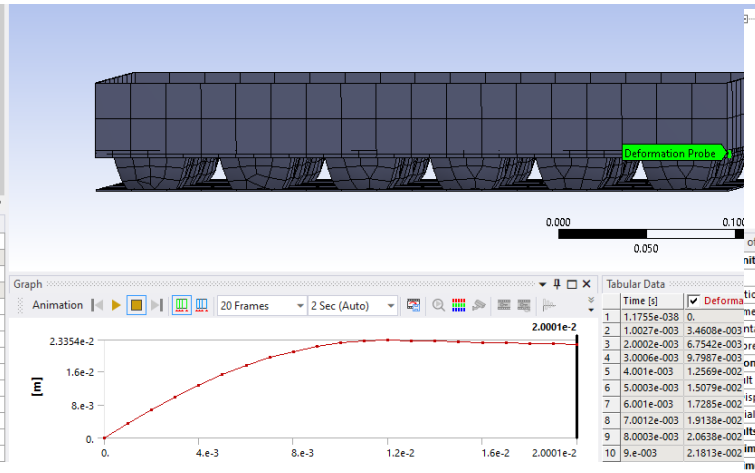
Haremos una tabla de espesores y valores de fuerza, desplazamiento y aceleración para valorar.

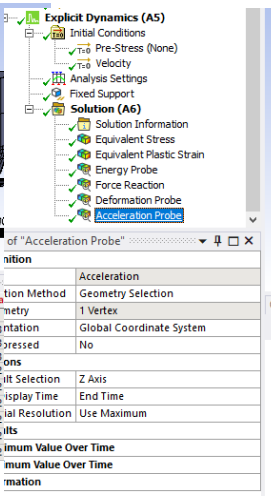


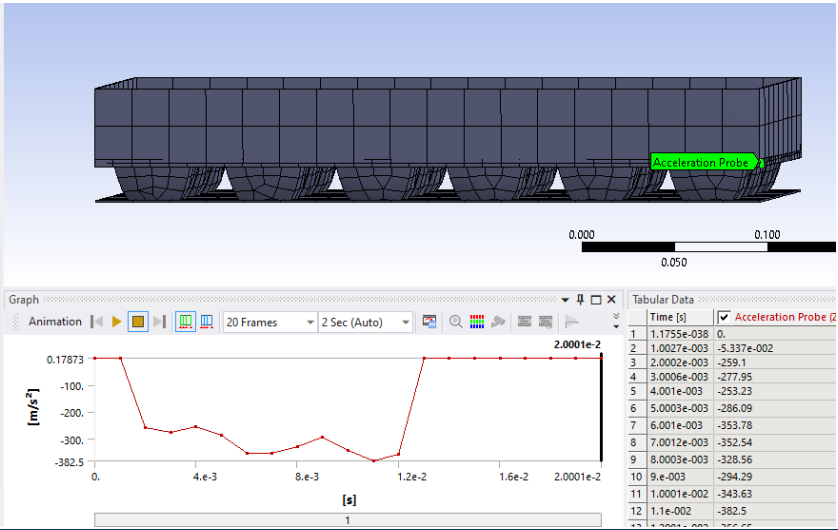






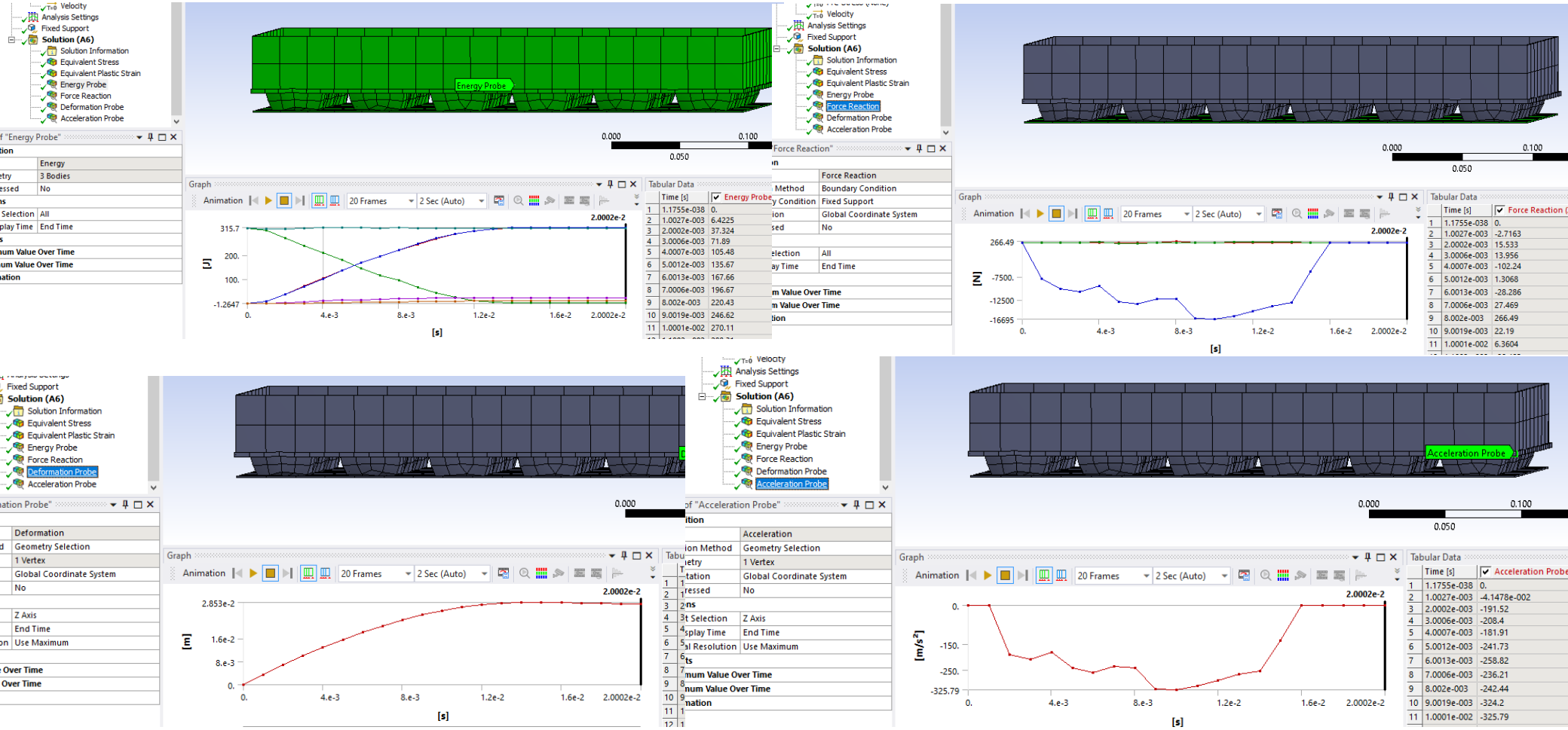




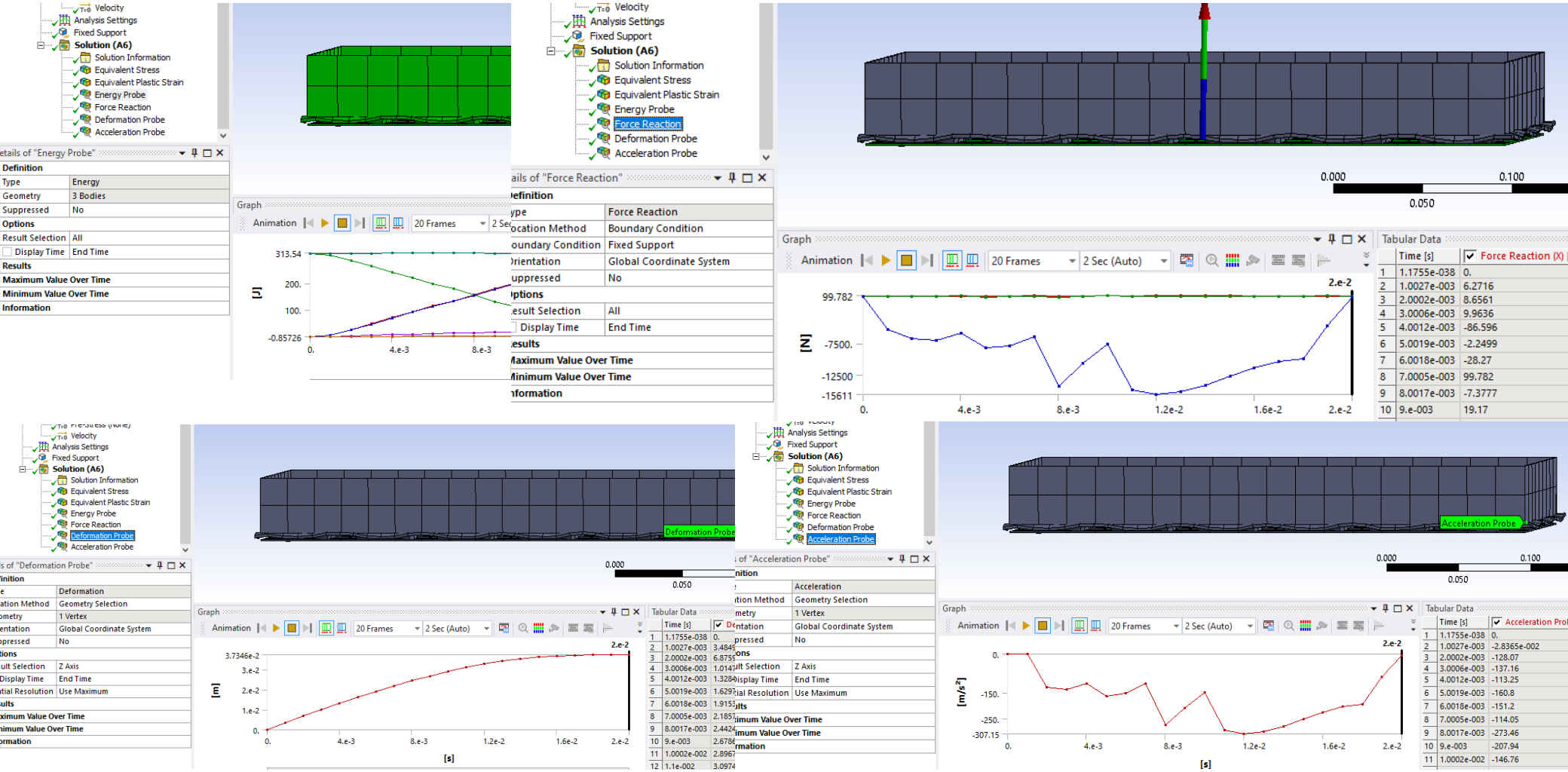


- Cambio a espesor 3[mm]

Repetimos

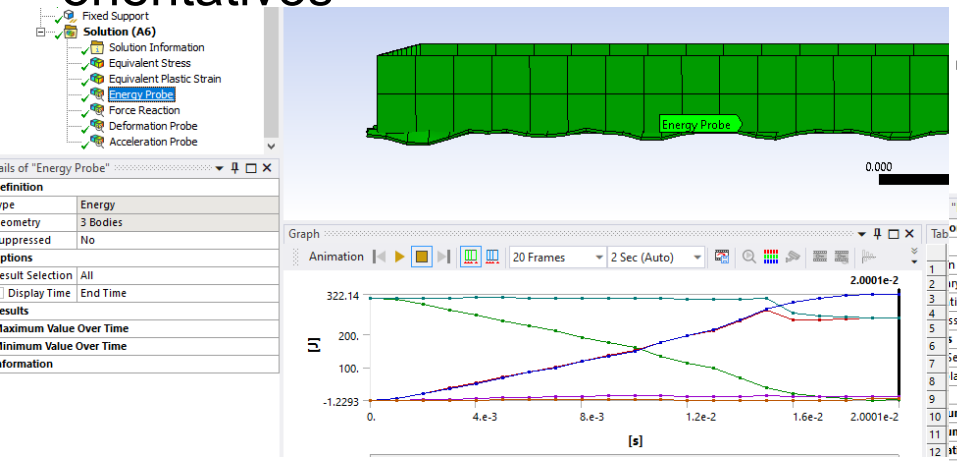


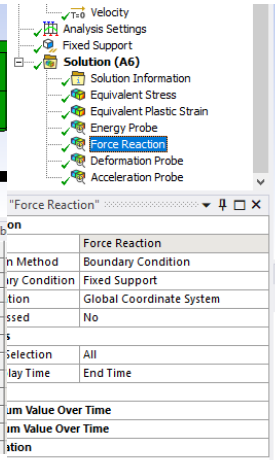
- Cambio a espesor 2[mm]

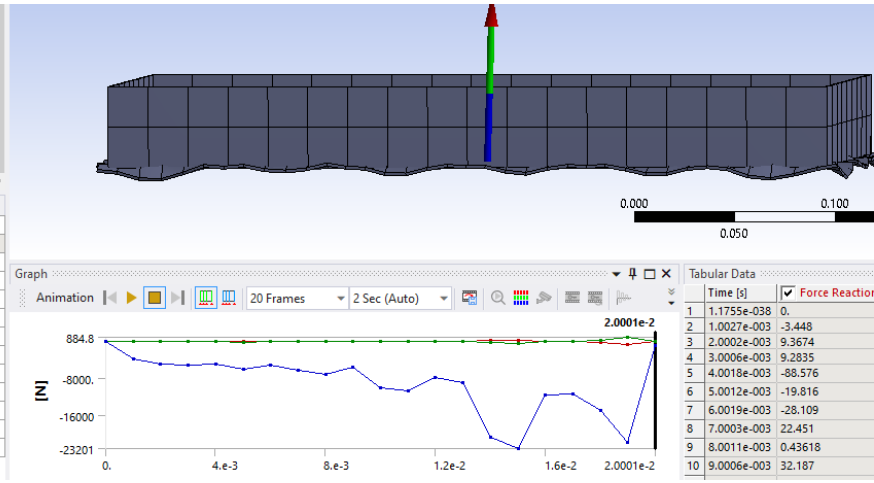


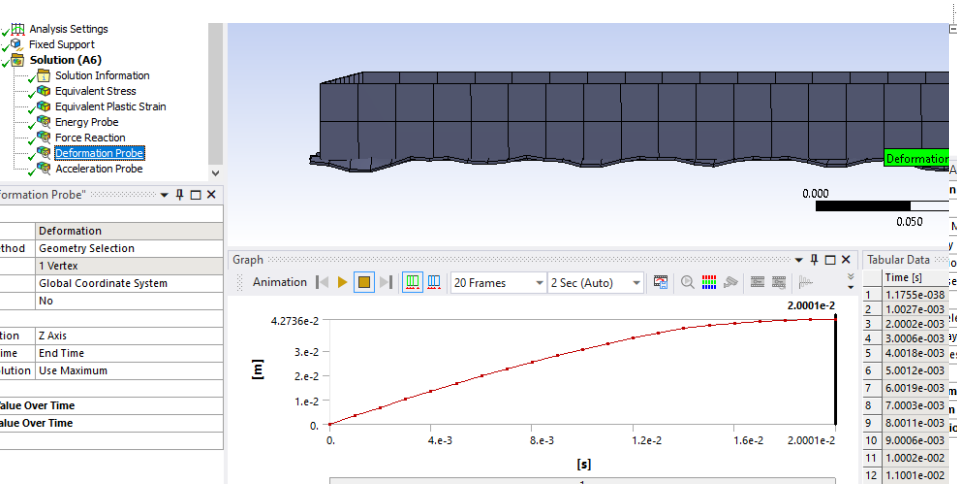
- Cambio espesor 1.5[mm]

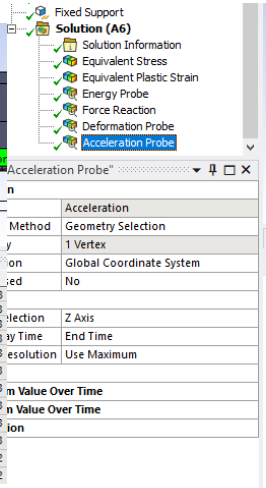
Este es un valor donde se impacta la base y se disparan fuerzas. Valores sólo orientativos

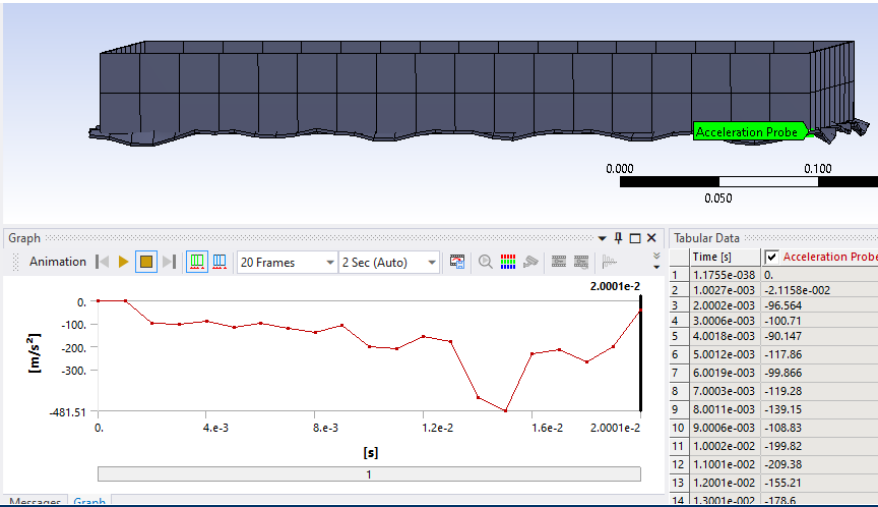






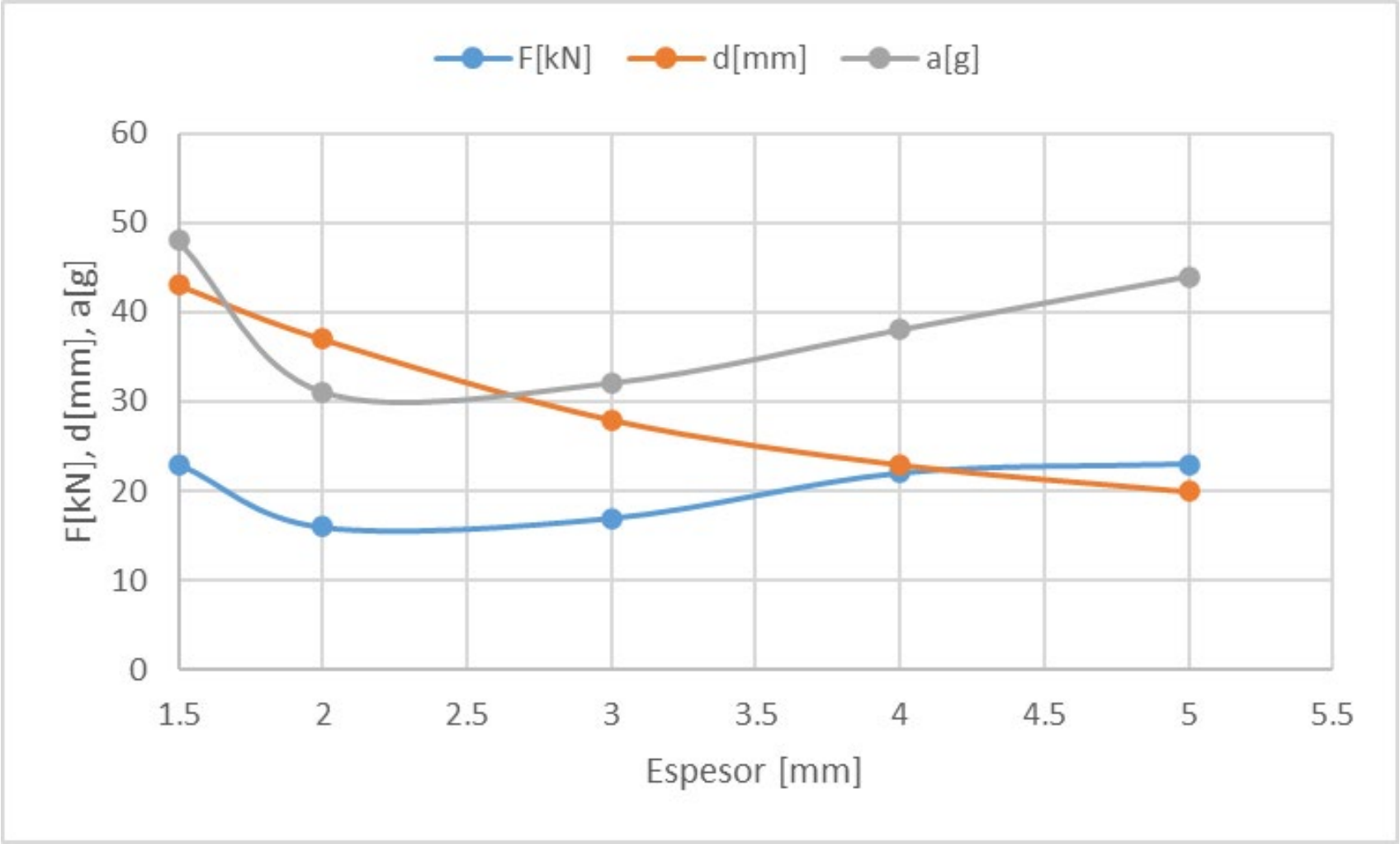




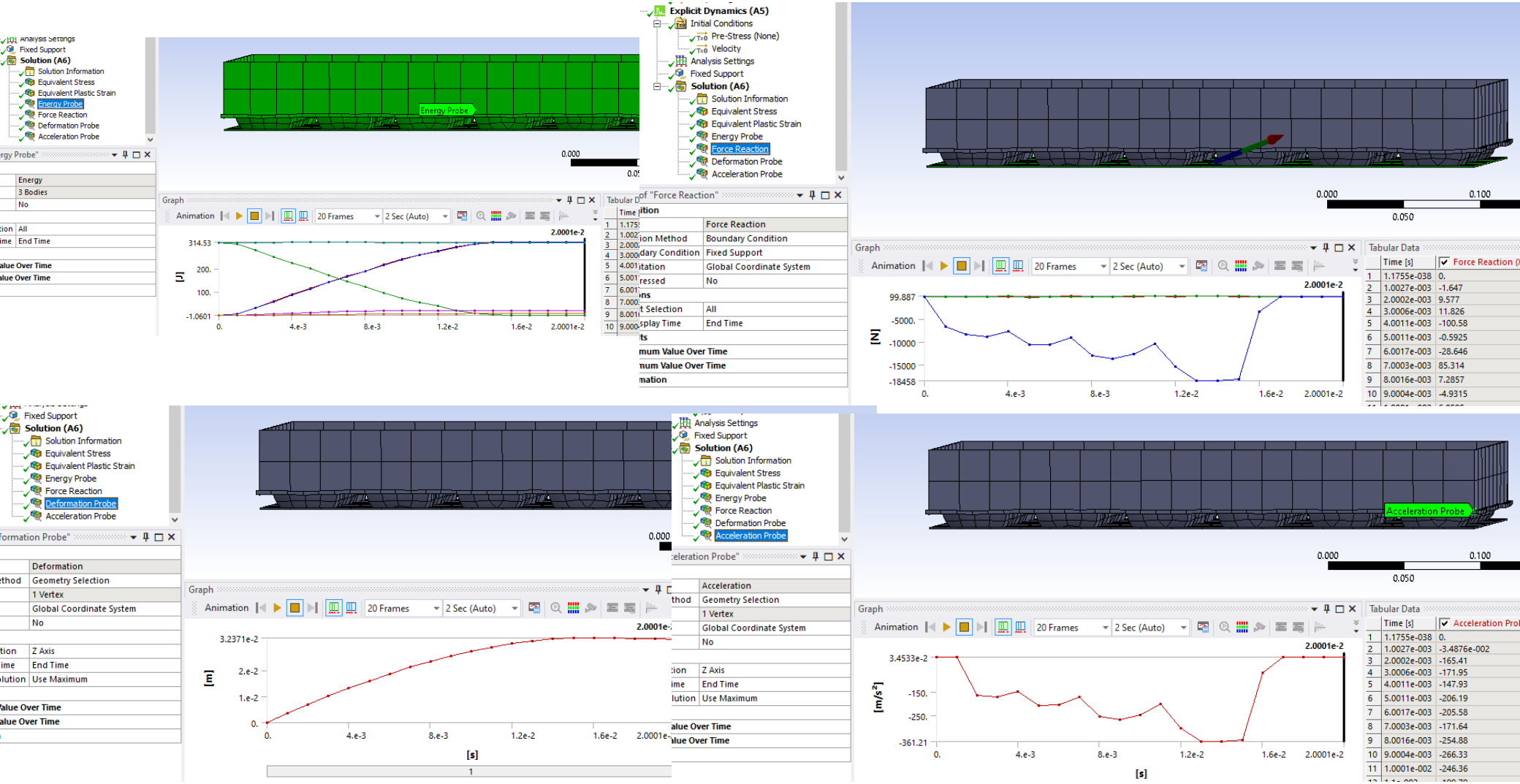


- Análisis

Si plotemaos vemos el óptimo puede estar entre 2 y 3[mm]



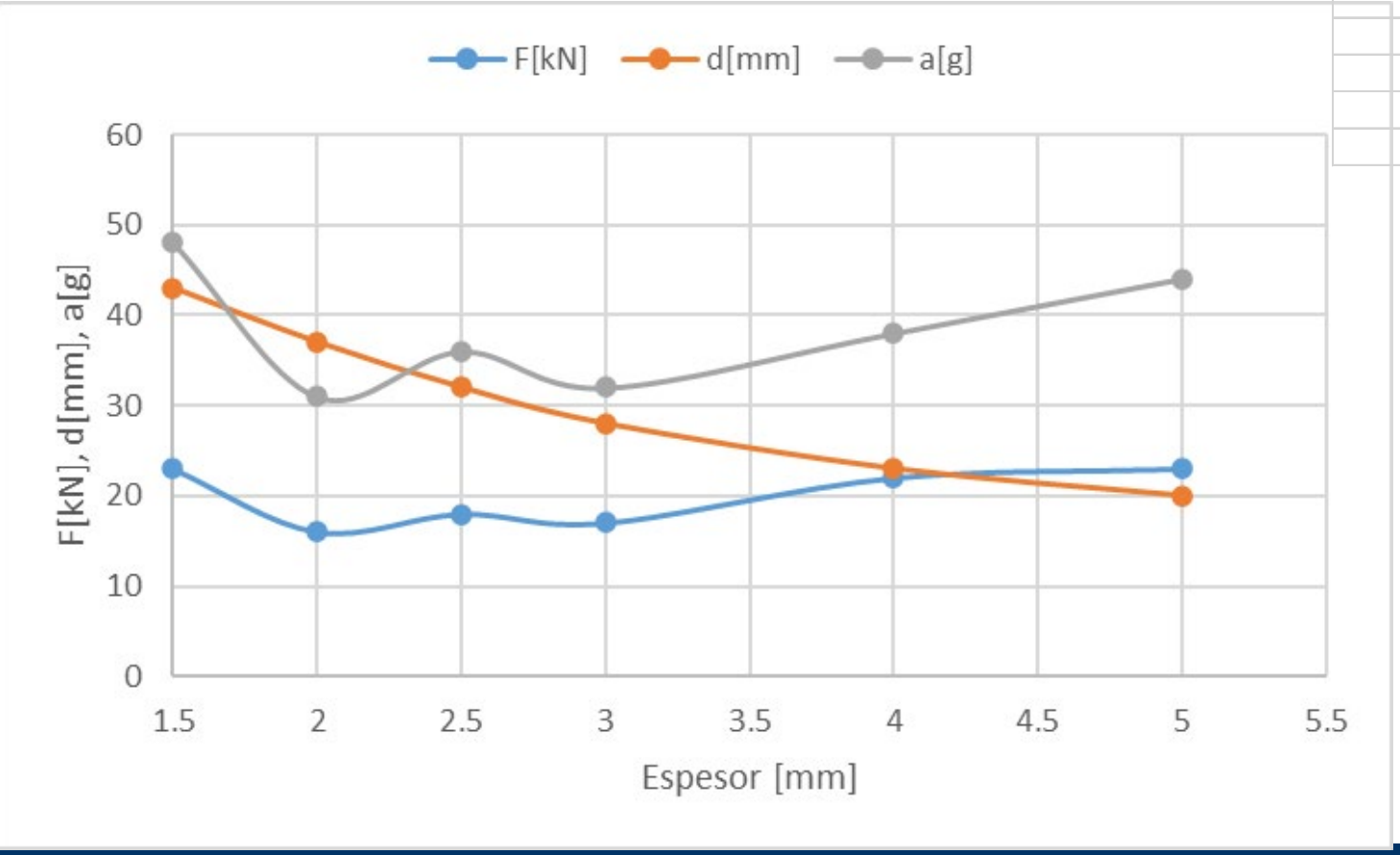
- Repetimos para 2.5[mm]



• Análisis

Si diseñamos con un espesor de 2.5[mm] puede que tengamos valores entre 2 y 3[mm]

espesor	F	d	a
mm	kN	mm	g
1.5	23	43	48
2	16	37	31
2.5	18	32	36
3	17	28	32
4	22	23	38
5	23	20	44



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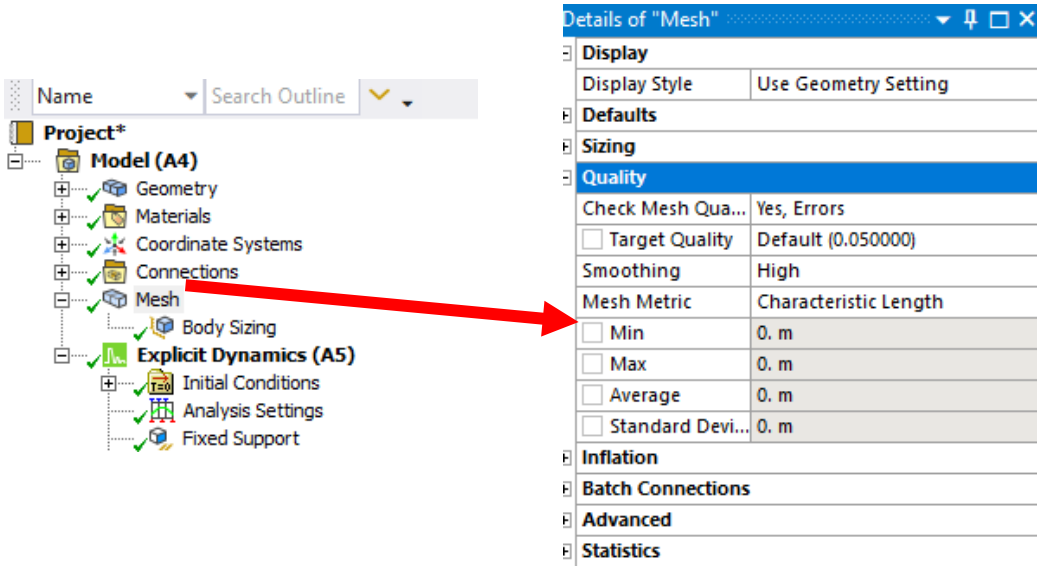
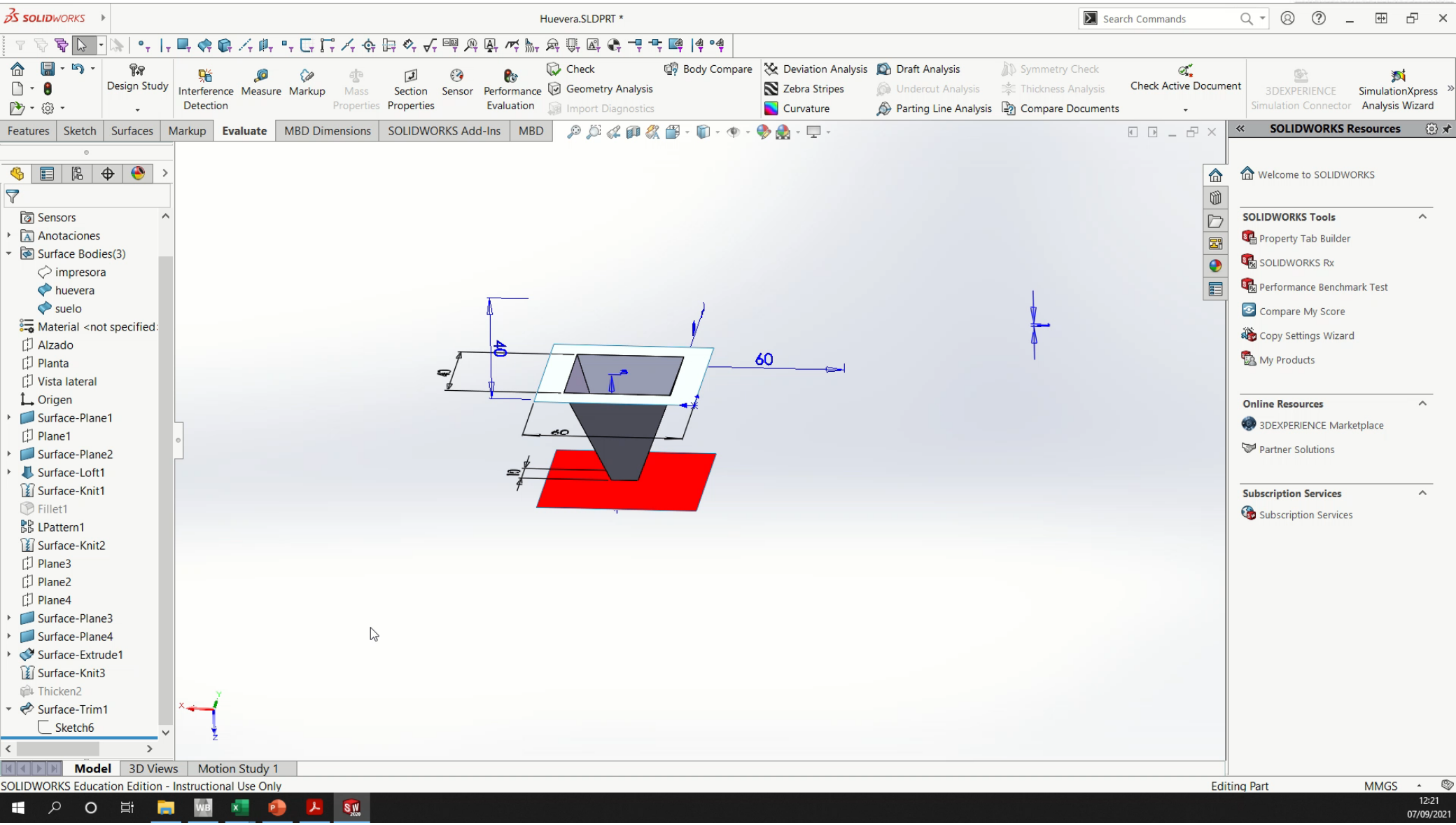
- Modelo sencillo

Para entender el modelo podemos colapsar una única huevera-defo de las 18 que hay. Para ello pondremos 50/18=2.78[kg] para ver si nos da una fuerza de 15/18=0.833[kN]




Huevera.SLDPRT *
Search Commands
Design Study
Interference Detection
Measure
Markup
Mass Properties
Section Properties
Sensor
Performance Evaluation
Check
Geometry Analysis
Import Diagnostics
Body Compare
Deviation Analysis
Zebra Stripes
Curvature
Draft Analysis
Undercut Analysis
Parting Line Analysis
Symmetry Check
Thickness Analysis
Compare Documents
Check Active Document
3DEXPERIENCE Simulation Connector
SimulationXpress Analysis Wizard
Features
Sketch
Surfaces
Markup
Evaluate
MBD Dimensions
SOLIDWORKS Add-Ins
MBD
Sensors
Anotaciones
Surface Bodies(3)
impresora
huevera
suelo
Material <not specified>
Alzado
Planta
Vista lateral
Origen
Surface-Plane1
Plane1
Surface-Plane2
Surface-Loft1
Surface-Knit1
Fillet1
LPattern1
Surface-Knit2
Plane3
Plane2
Plane4
Surface-Plane3
Surface-Plane4
Surface-Extrude1
Surface-Knit3
Thicken2
Surface-Trim1
Sketch6
60
40
SOLIDWORKS Resources
Welcome to SOLIDWORKS
SOLIDWORKS Tools
Property Tab Builder
SOLIDWORKS Rx
Performance Benchmark Test
Compare My Score
Copy Settings Wizard
My Products
Online Resources
3DEXPERIENCE Marketplace
Partner Solutions
Subscription Services
Subscription Services
Model
3D Views
Motion Study 1
SOLIDWORKS Education Edition - Instructional Use Only
Editing Part
MMGS
12:21
07/09/2021

- Resumen.

➢ Diseño de un defo para tener unas fuerzas de unos 15[kN]

➢ Cálculos con muchos espesores para determinar el óptimo.

➢ Cálculo con un solo defo para ver el espesor óptimo en cálculo rápido.

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S05t.- Automatización.

Mejora 2122…

• Repaso última sesión

Cálculo de una huevera para poder frenar un paquete de manera plástica obteniendo un espesor óptimo.

Realización de un cálculo sencillo de una única huevera para poder ir rápido en la optimización

Recordar:

Para el modelo sencillo poner 3.5[m/s] pero la masa 50/18=2.778[kg]

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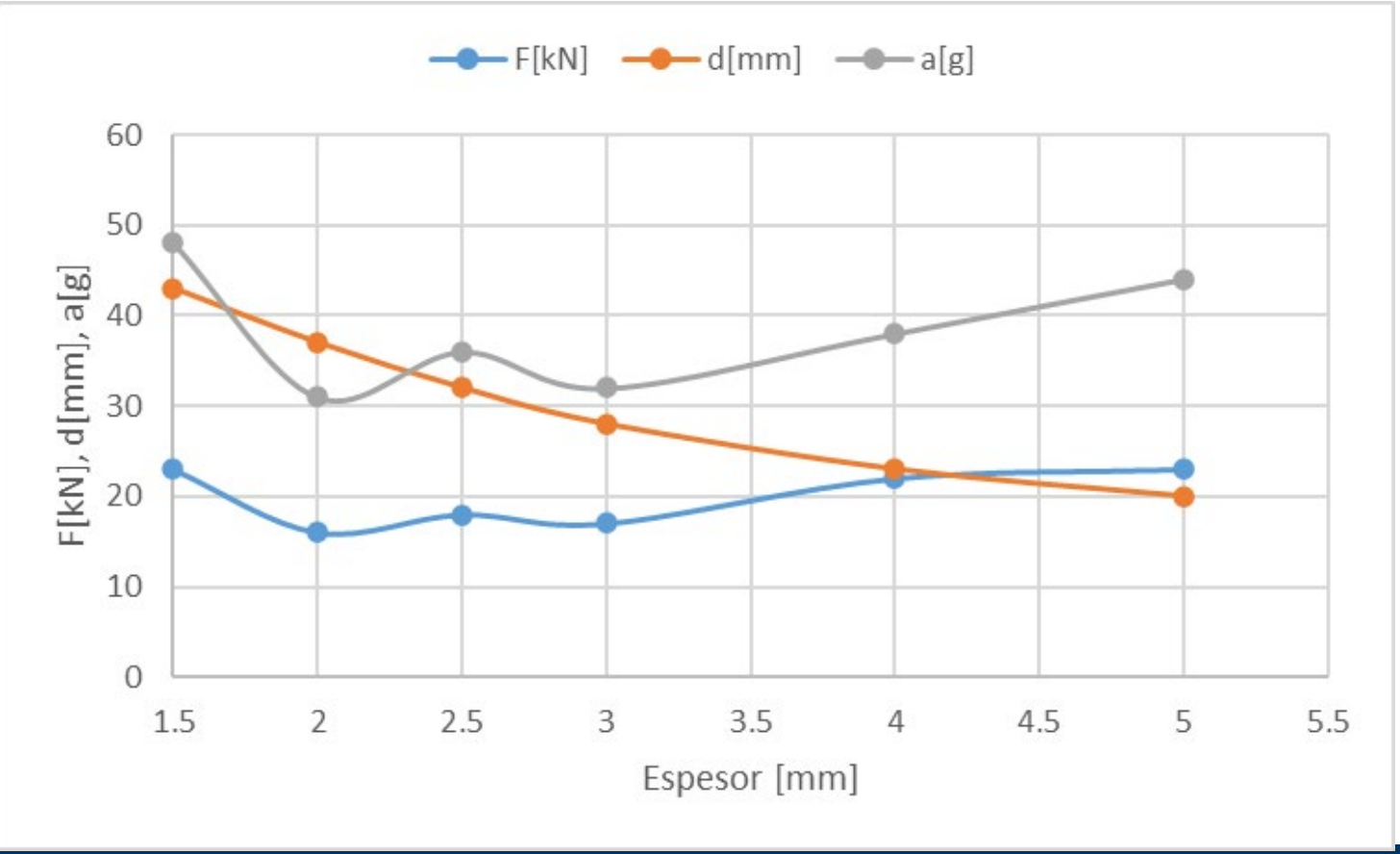
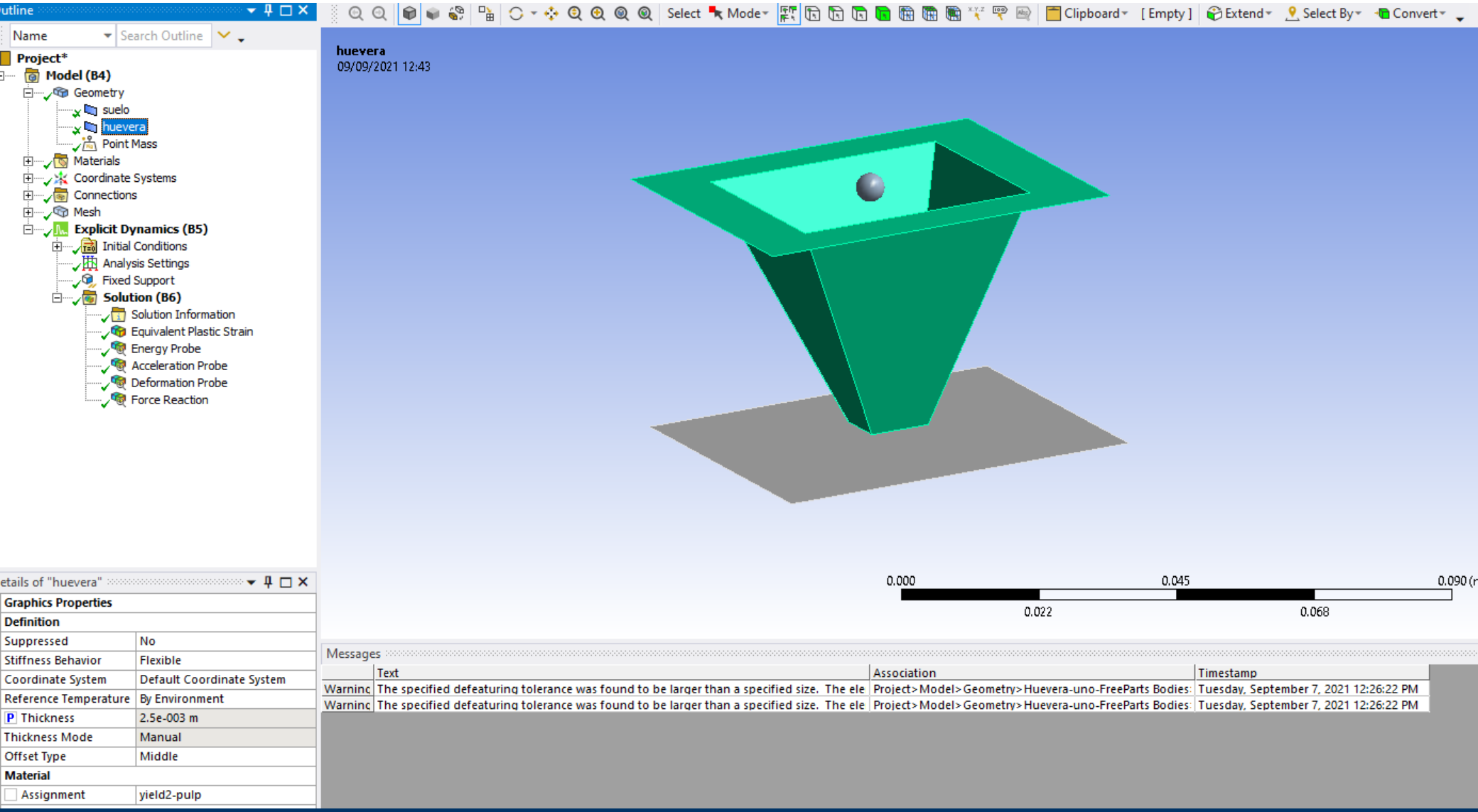
• Automatización

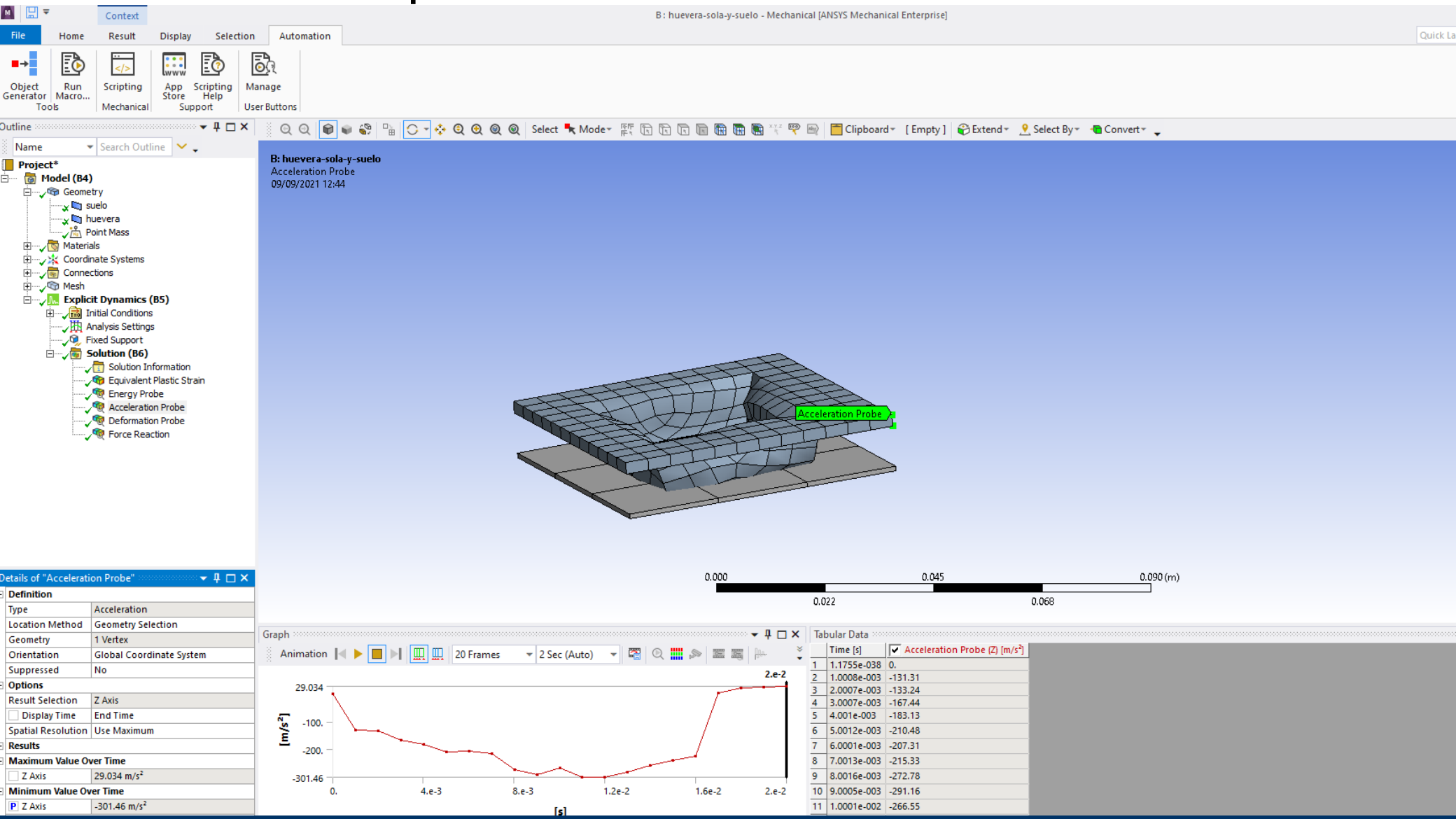
Hemos ido realizando simulaciones variando el espesor hasta tener el espesor óptimo. La idea es poder optimizar este proceso para llegar al mejor espesor o diseño de una manera automática.



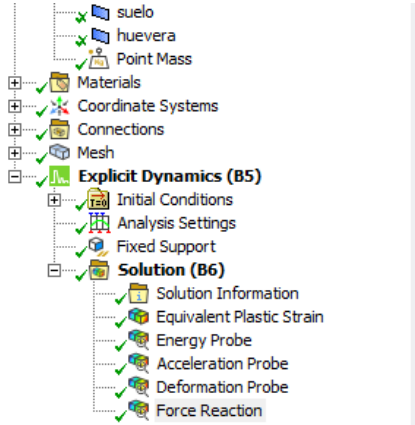
- Parámetro input espesor

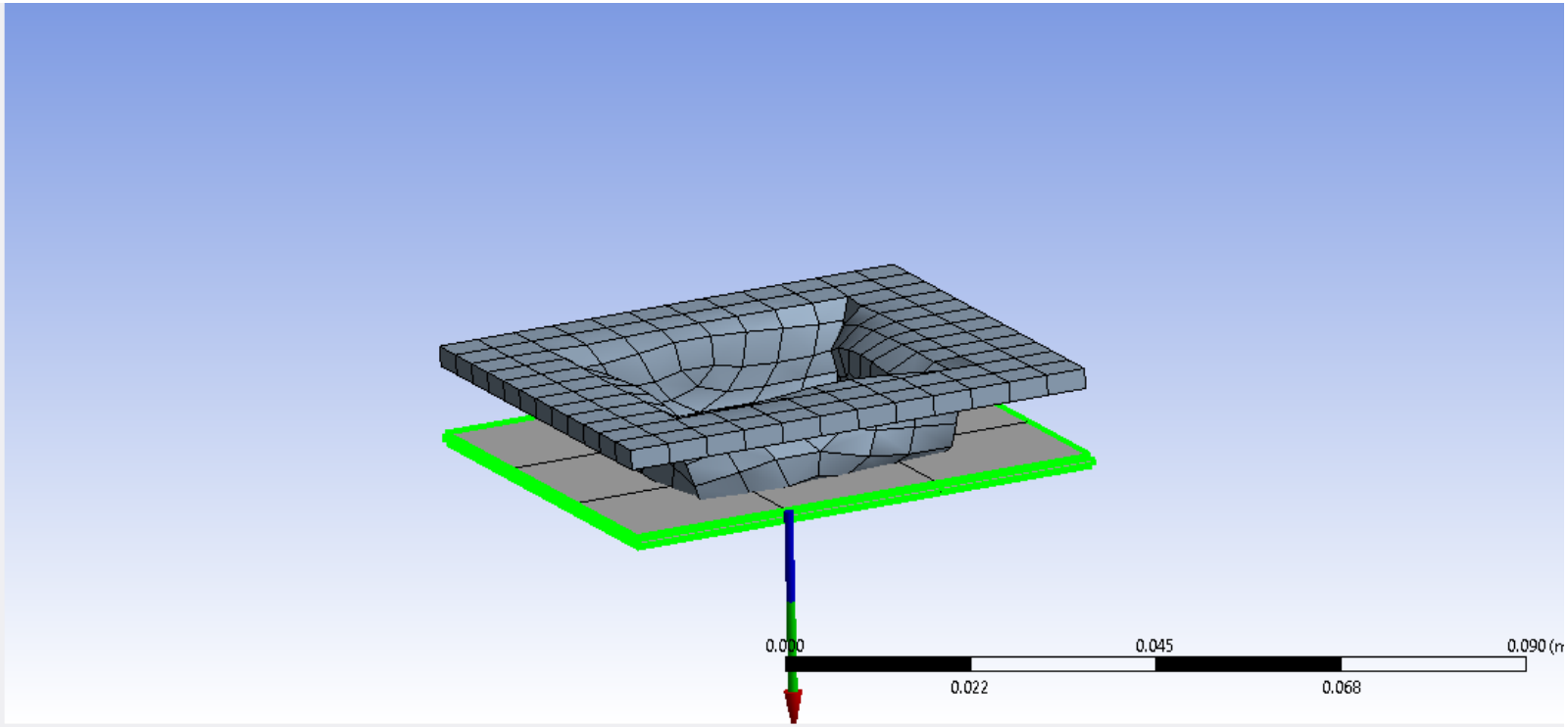


- Parámetro output aceleración



- Parámetro output fuerza



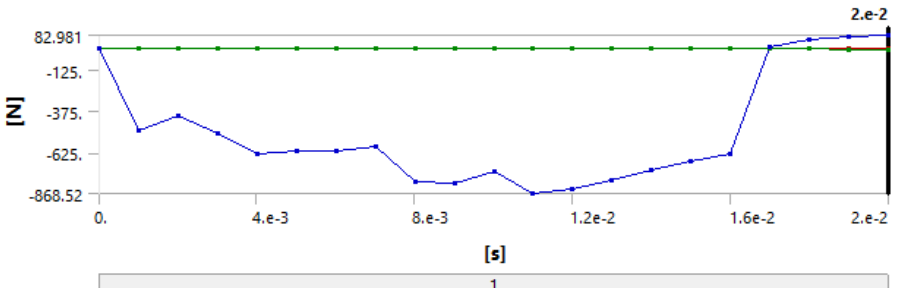


Details of "Force Reaction"

Definition	
Type	Force Reaction
Location Method	Boundary Condition
Boundary Condition	Fixed Support
Orientation	Global Coordinate System
Suppressed	No
Options	
Result Selection	All
Display Time	End Time
Results	
Maximum Value Over Time	
Minimum Value Over Time	
X Axis	-3.6742e-002 N
Y Axis	-3.0847 N
Z Axis	-868.52 N
Total	0. N

Graph

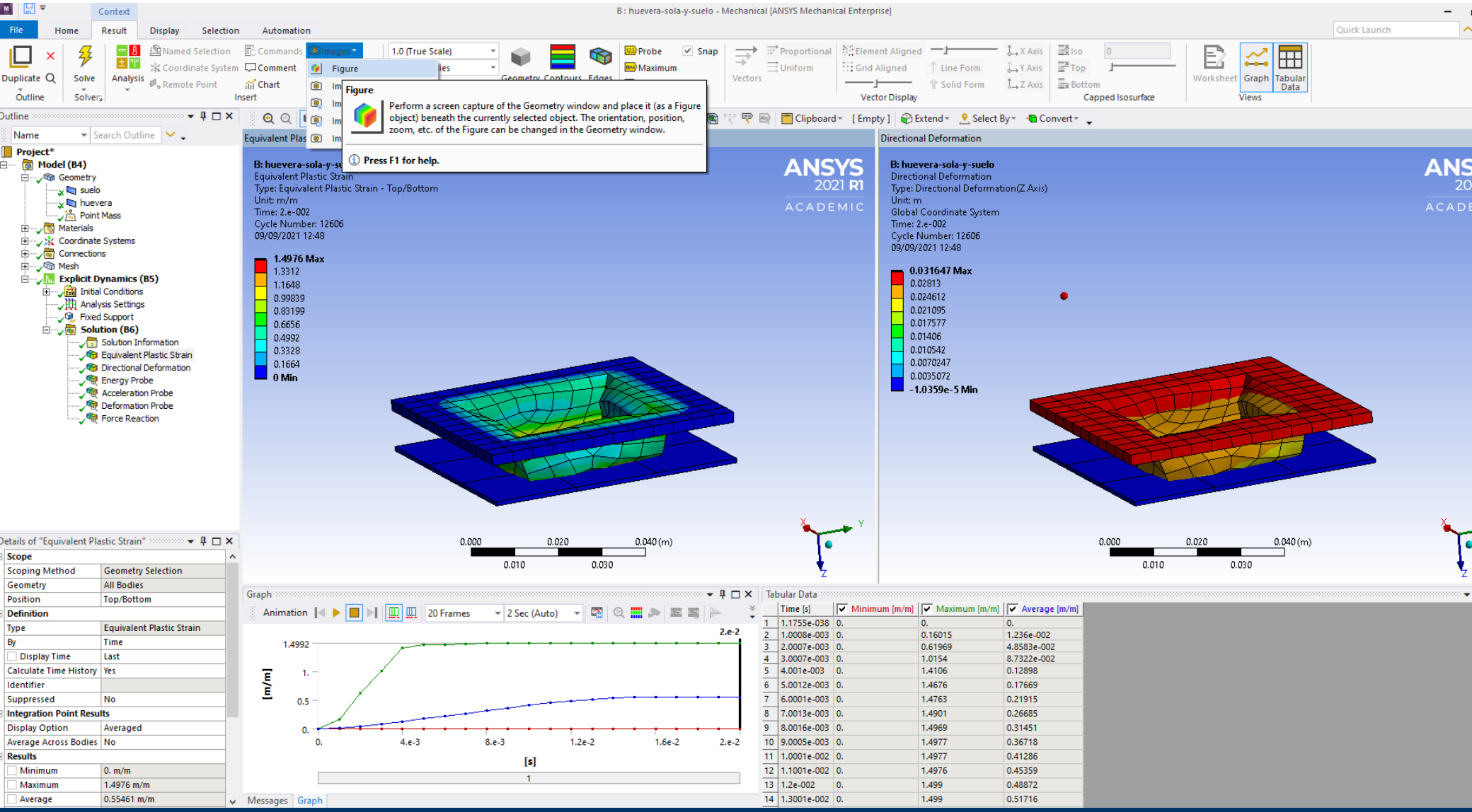
Animation | 20 Frames | 2 Sec (Auto)



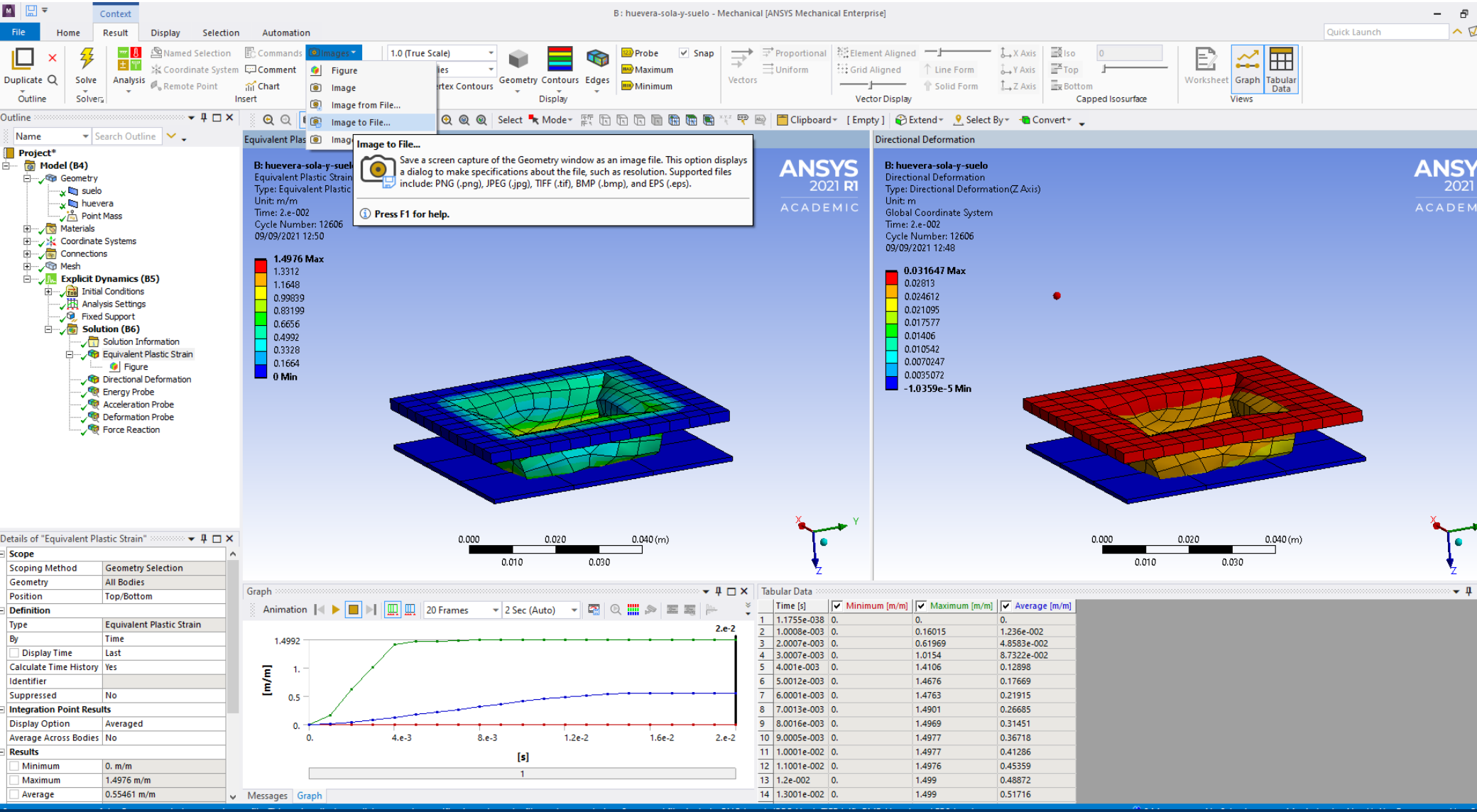
Tabular Data

	Time [s]	Force Reaction (X) [N]	Force Reaction (Y) [N]	Force Rea
1	1.1755e-038	0.	0.	0.
2	1.0008e-003	1.2469e-003	-2.8515e-003	-491.86
3	2.0007e-003	5.2475e-003	-1.7332e-002	-401.76
4	3.0007e-003	6.4773e-002	4.6746e-002	-508.4
5	4.001e-003	-3.6742e-002	-9.8522e-003	-629.21
6	5.0012e-003	5.3319e-002	0.16531	-609.05
7	6.0001e-003	5.8061e-002	4.6879	-610.36
8	7.0013e-003	0.31552	1.1107e-002	-582.84
9	8.0016e-003	0.59346	0.16518	-795.4
10	9.0005e-003	0.40785	5.2067e-002	-808.69
11	1.0001e-002	0.54916	-1.7556e-002	-736.99
12	1.1001e-002	0.33454	9.092e-002	-868.52

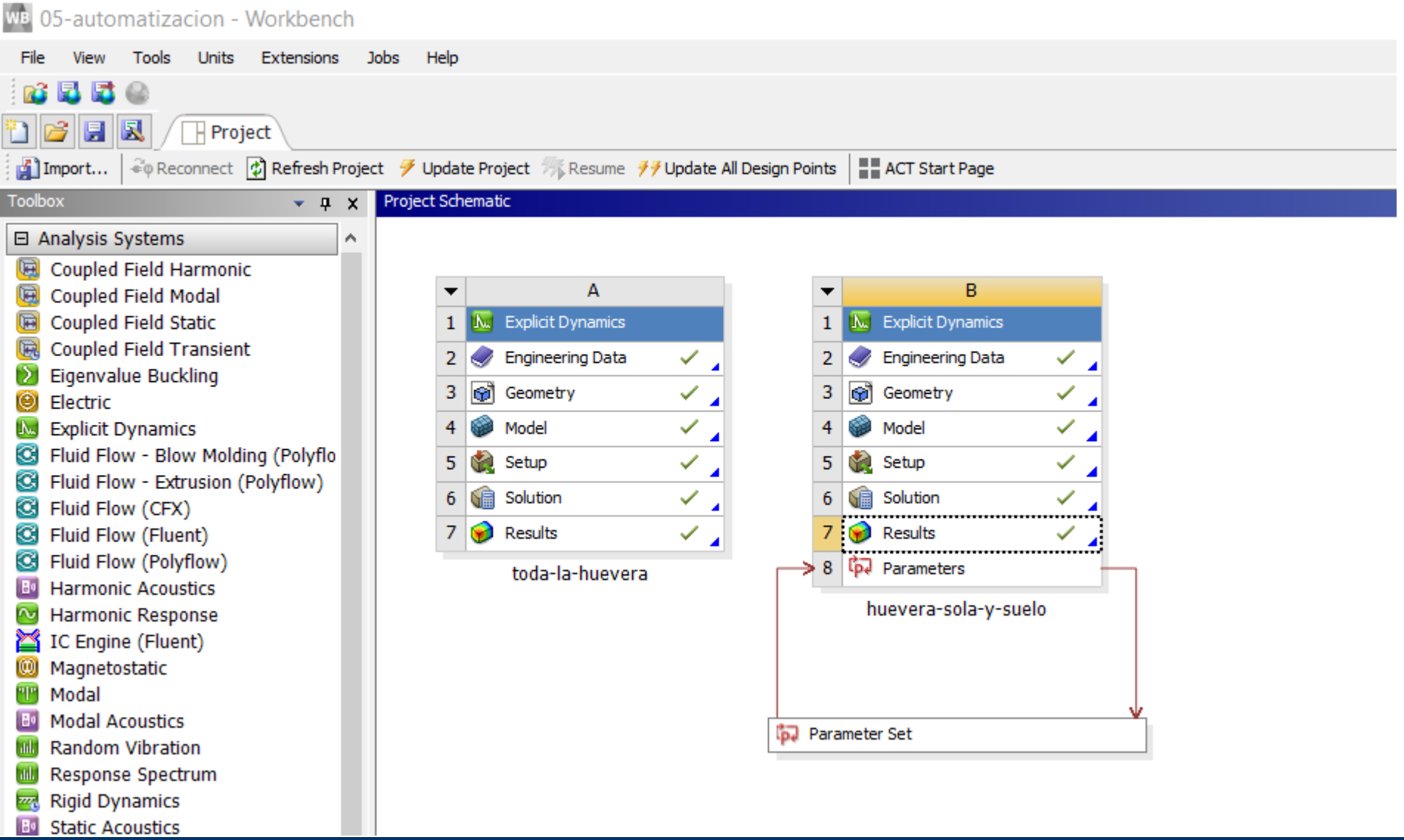
- Crear imágenes



- Crear imágenes



- Parámetros en Workbench



- Escenarios de diseño

05-automatizacion - Workbench

File Edit View Tools Units Extensions Jobs Help

Project | Parameter Set ×

Resume | Update All Design Points

Toolbox

Update All Design Points

No toolbox items are applicable for the current selection.

Outline of All Parameters

	A	B	C	D
1	ID	Parameter Name	Value	Unit
2	Input Parameters			
3	huevera-sola-y-suelo (B1)			
4	P1	huevera Thickness	0.0025	m
*	New input parameter	New name	New expression	
6	Output Parameters			
7	huevera-sola-y-suelo (B1)			
8	P2	Acceleration Probe Minimum Z Axis	-301.46	m s^-2
9	P3	Force Reaction Minimum Z Axis	-868.52	N
*	New output parameter		New expression	
11	Charts			

Table of Design Points

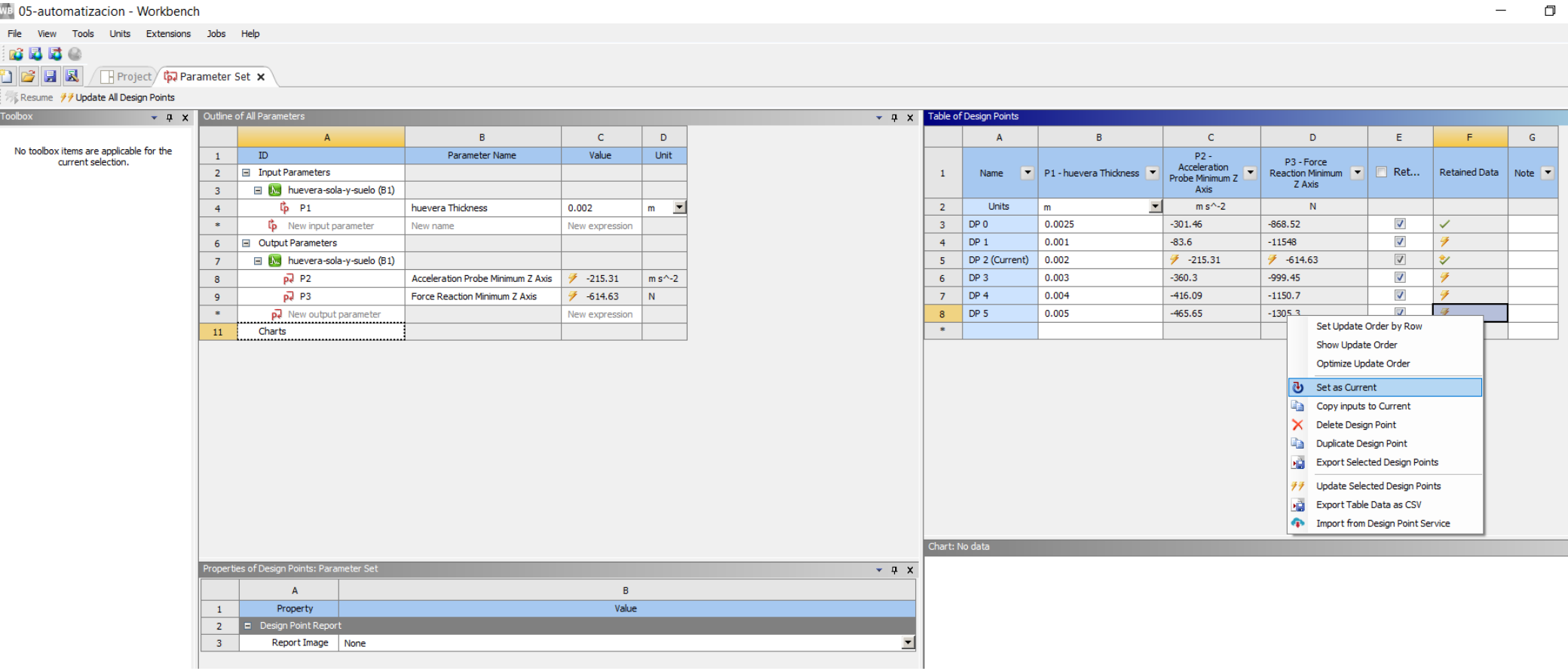
	A	B	C	D	E	F	G
1	Name	P1 - huevera Thickness	P2 - Acceleration Probe Minimum Z Axis	P3 - Force Reaction Minimum Z Axis	Ret...	Retained Data	Note
2	Units	m	m s^-2	N			
3	DP 0 (Current)	0.0025	-301.46	-868.52	☑	✓	
4	DP 1	0.001			☐		
5	DP 2	0.002			☐		
6	DP 3	0.003			☐		
7	DP 4	0.004			☐		
8	DP 5	0.005			☐		
*					☐		

Chart: No data

Properties of Design Points: Parameter Set

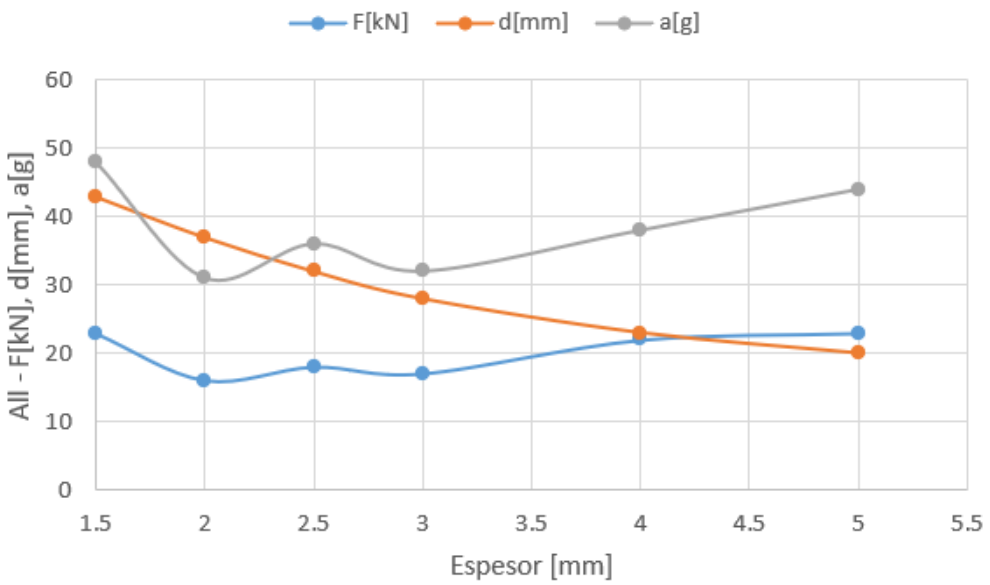
	A	B
1	Property	Value
2	Design Point Report	
3	Report Image	None

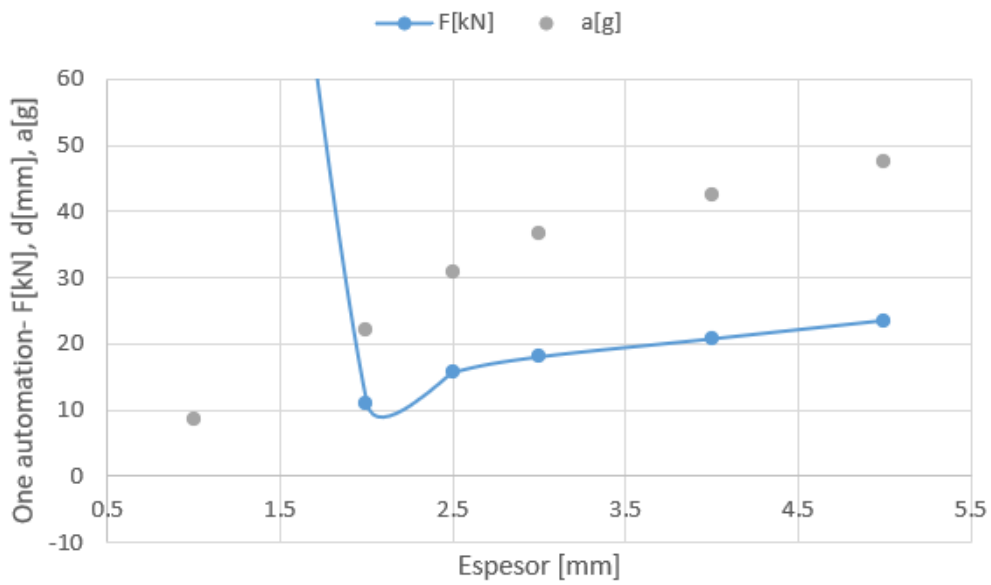
- Escenarios de diseño



- Resultados comparados

Modelo de 18 sin automatizar con modelo de sólo 1 automatizado (La fuerza del gráfico es la F de cálculo multiplicada x18 para comparar). Ahora la aceleración baja para espesores pequeños pues no llega a acabar el cálculo y ver el segundo pico. Cuidado con mínimo y máximo!!





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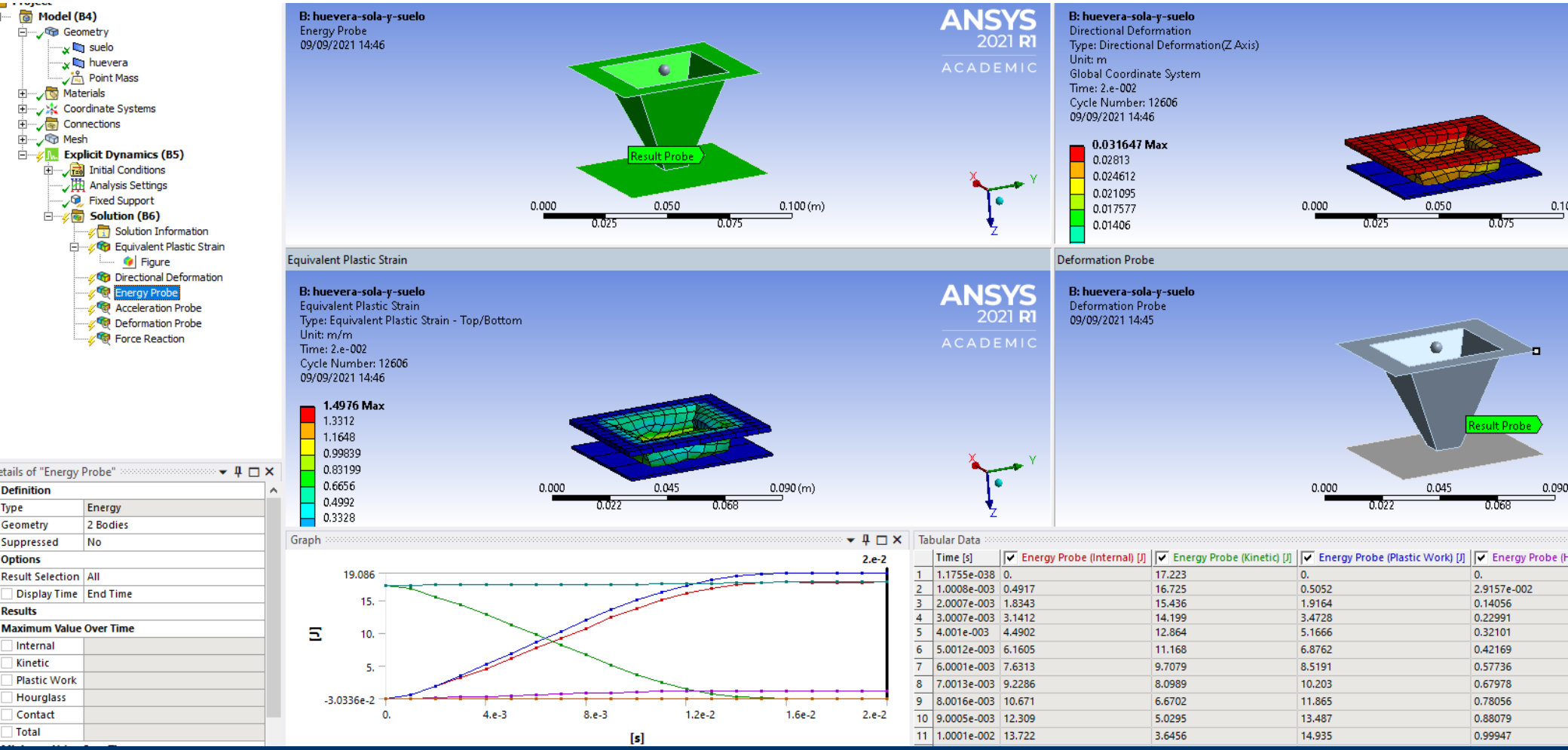
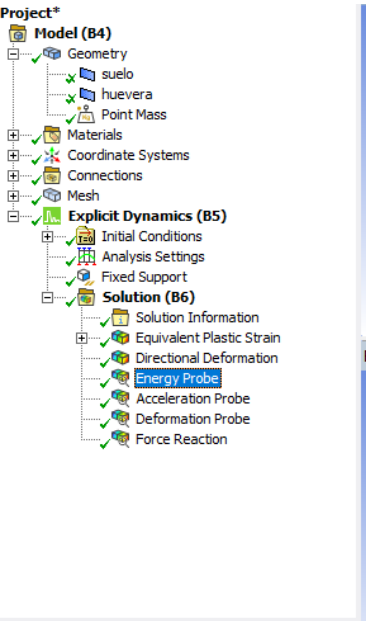
- Comprobación de resultados

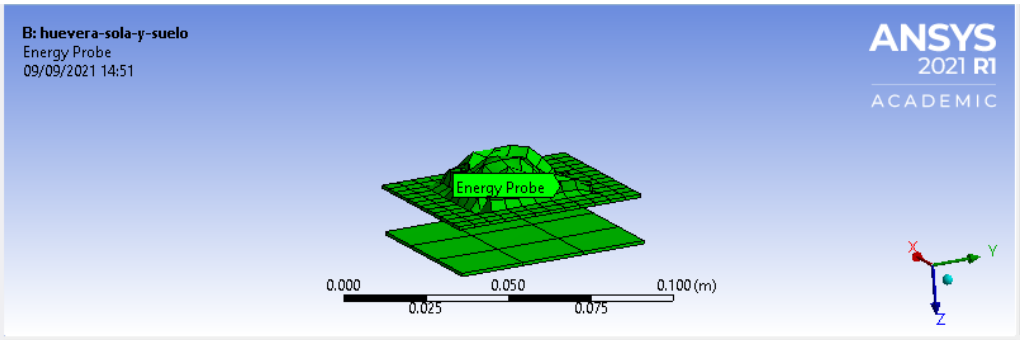
Es necesario mirar los resultados por si hay algún problema. Con 2[mm] hay un poco de Hourglass pero OK.

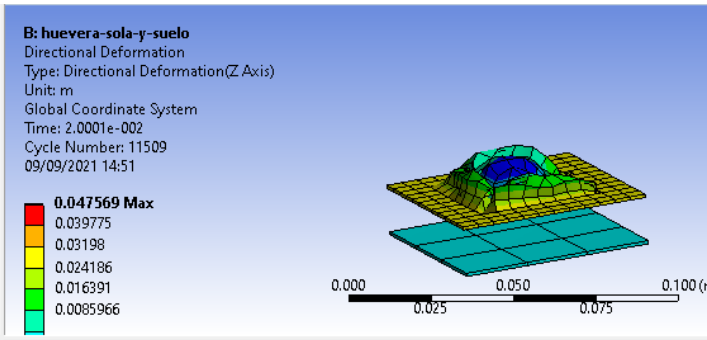


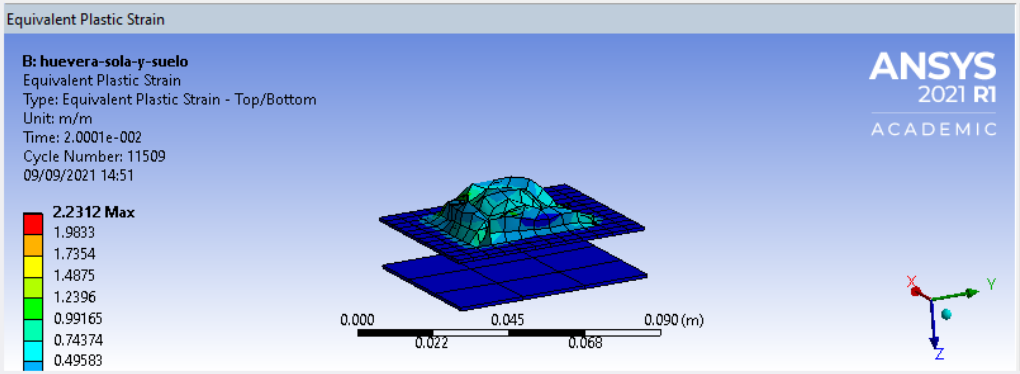
- Comprobación de resultados

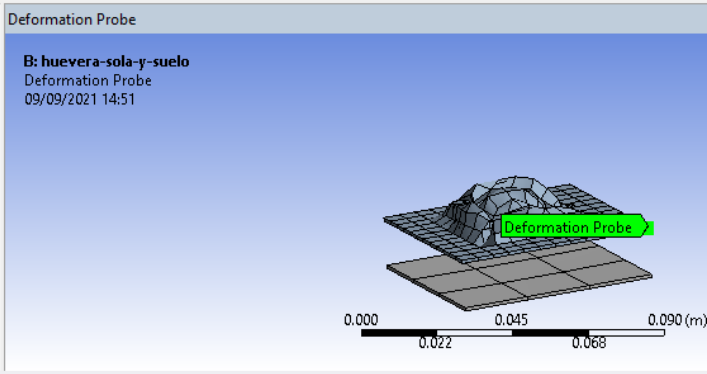
Con 1[mm] se disparan las energías y el cálculo no es válido.

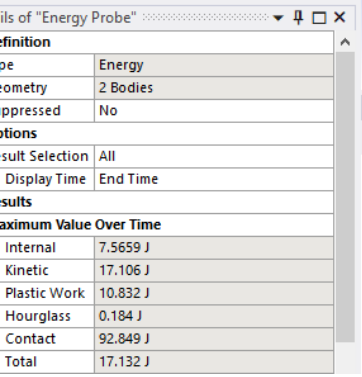


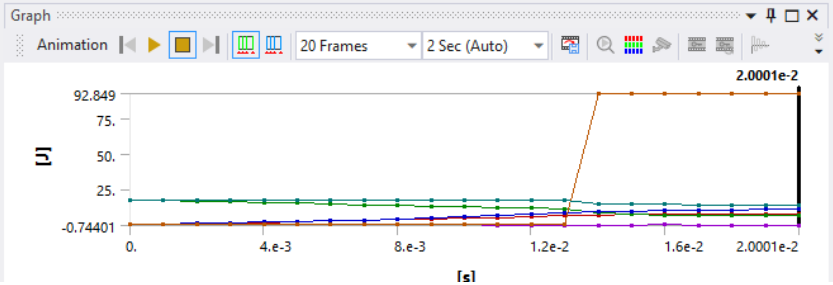










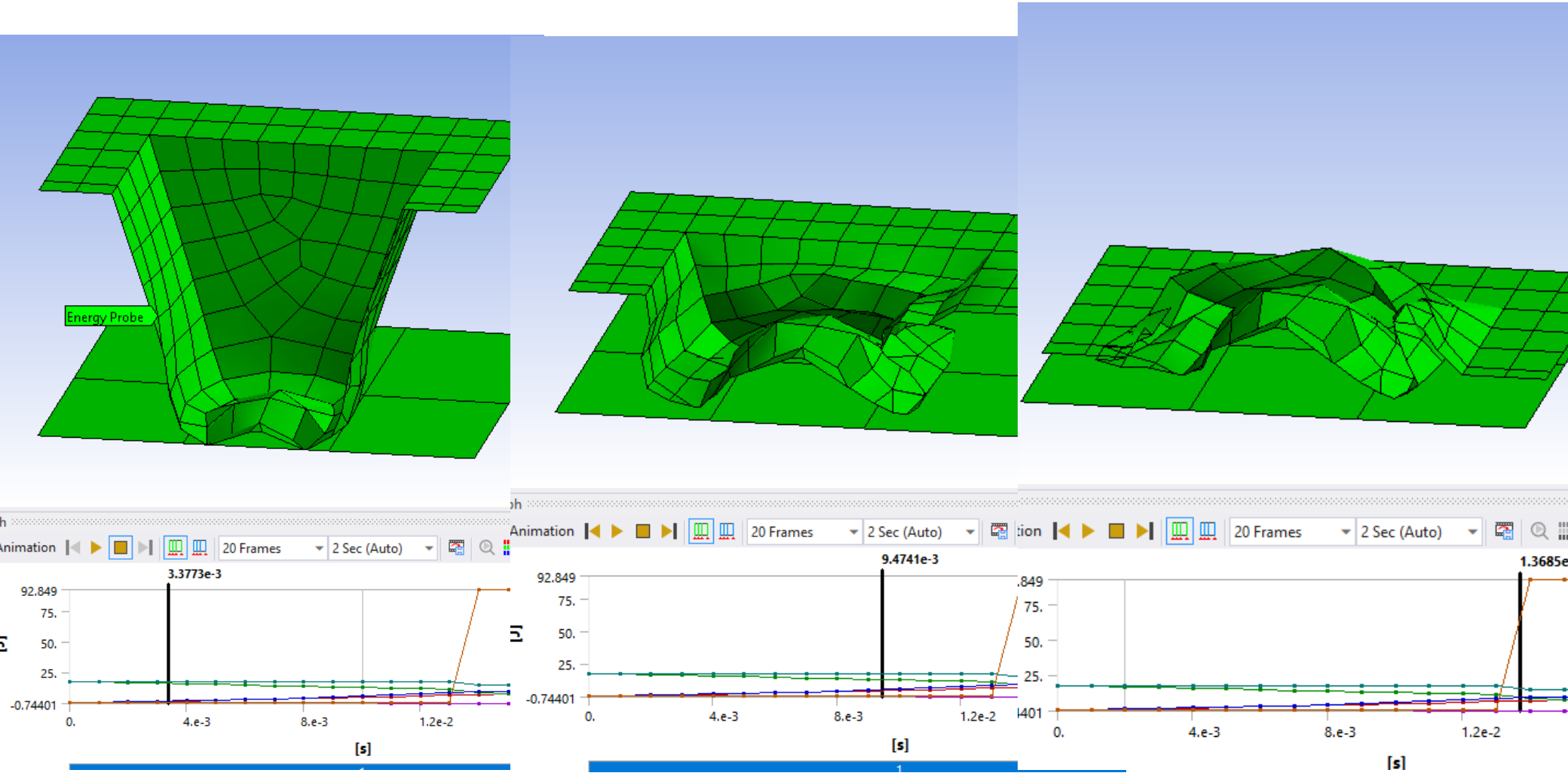


Tabular Data

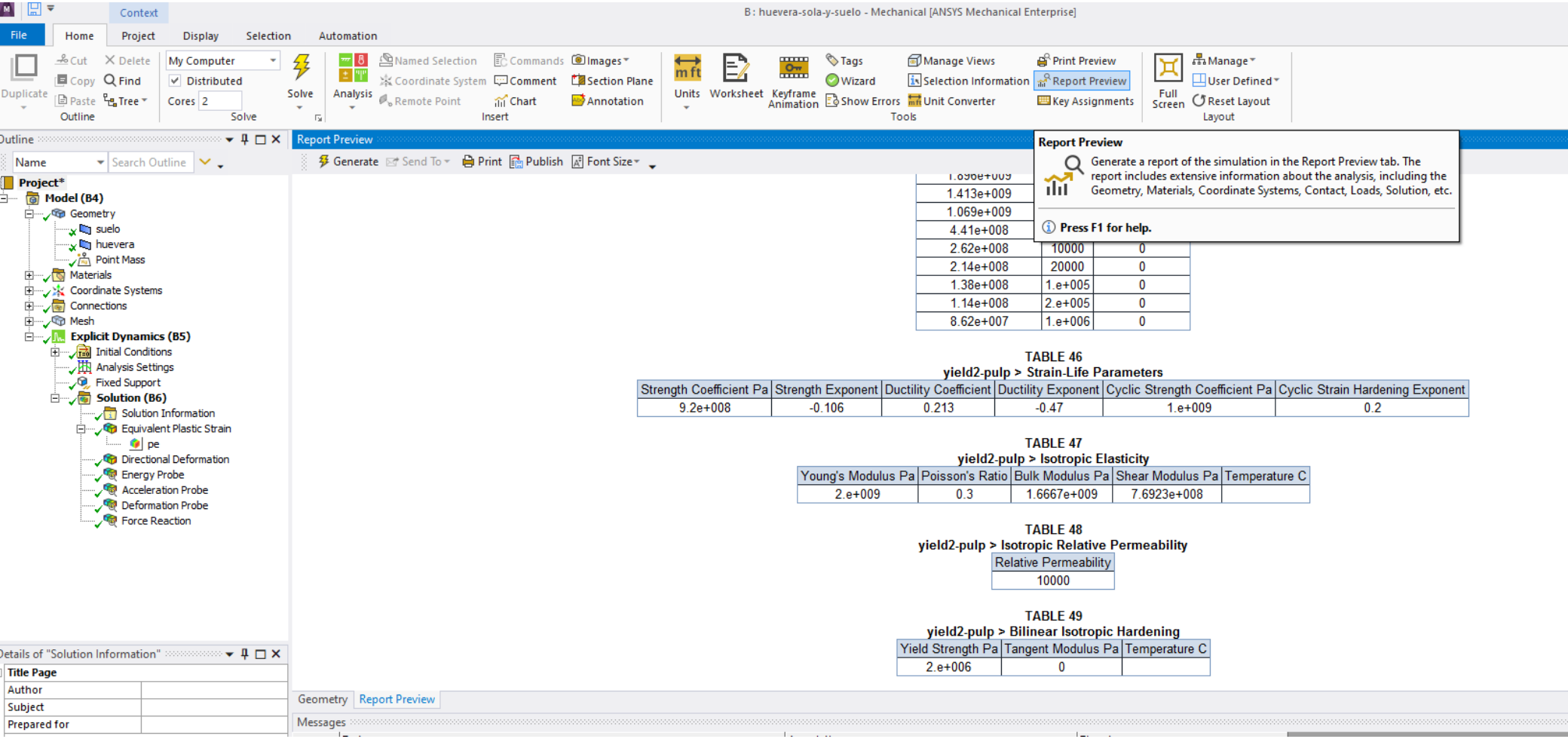
	Time [s]	Energy Probe (Internal) [J]	Energy Probe (Kinetic) [J]	Energy Probe (Plastic Work) [J]	Energy Probe (Hour
1	1.1755e-038	0.	17.106	0.	0.
2	1.0005e-003	0.19732	16.906	0.2043	1.1218e-002
3	2.0001e-003	0.68711	16.427	0.69857	6.1572e-002
4	3.0006e-003	1.0319	16.087	1.0595	0.10109
5	4.0009e-003	1.443	15.675	1.5103	0.11548
6	5.0004e-003	1.8749	15.241	1.9888	0.12413
7	6.0016e-003	2.4538	14.664	2.6101	0.14444
8	7.0015e-003	3.0323	14.086	3.211	0.184
9	8.0001e-003	3.6229	13.509	3.9219	0.15181
10	9.0003e-003	4.0441	13.029	4.8127	-6.7763e-002
11	1.0001e-002	4.4875	12.601	5.5027	-0.23474

- Comprobación de resultados

Con 1[mm] se disparan las energías y el cálculo no es válido.



- Report



1.413e+009		
1.069e+009		
4.41e+008		
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 46
yield2-pulp > 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 47
yield2-pulp > Isotropic Elasticity

Young's Modulus Pa	Poisson's Ratio	Bulk Modulus Pa	Shear Modulus Pa	Temperature C
2.e+009	0.3	1.6667e+009	7.6923e+008	

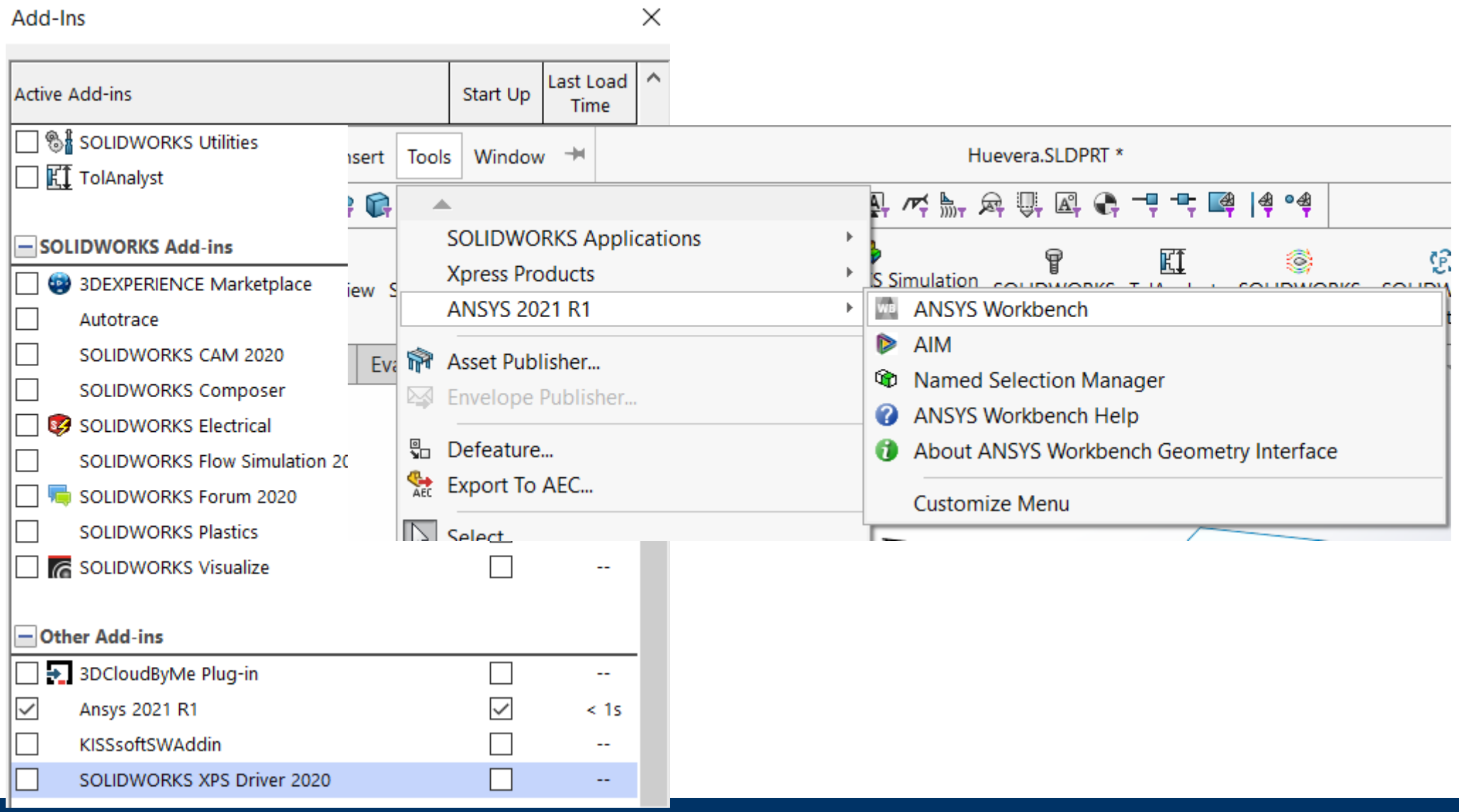
TABLE 48
yield2-pulp > Isotropic Relative Permeability

Relative Permeability
10000

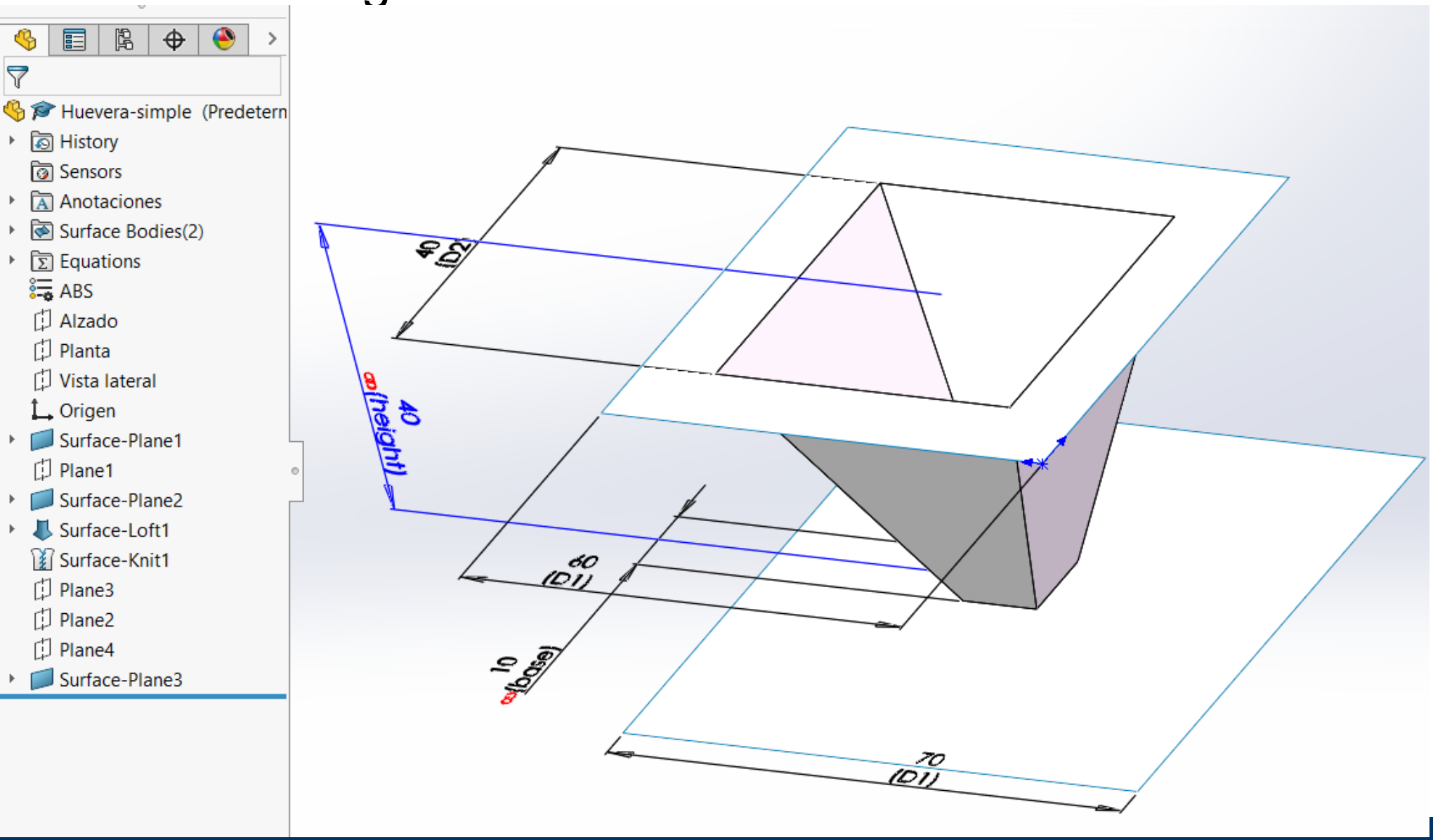
TABLE 49
yield2-pulp > Bilinear Isotropic Hardening

Yield Strength Pa	Tangent Modulus Pa	Temperature C
2.e+006	0	

- Parámetros geométricos desde SolidWorks



- Parámetros geométricos desde SolidWorks



- Propiedades de material como parámetro

Properties of Outline Row 3: pulp-y2

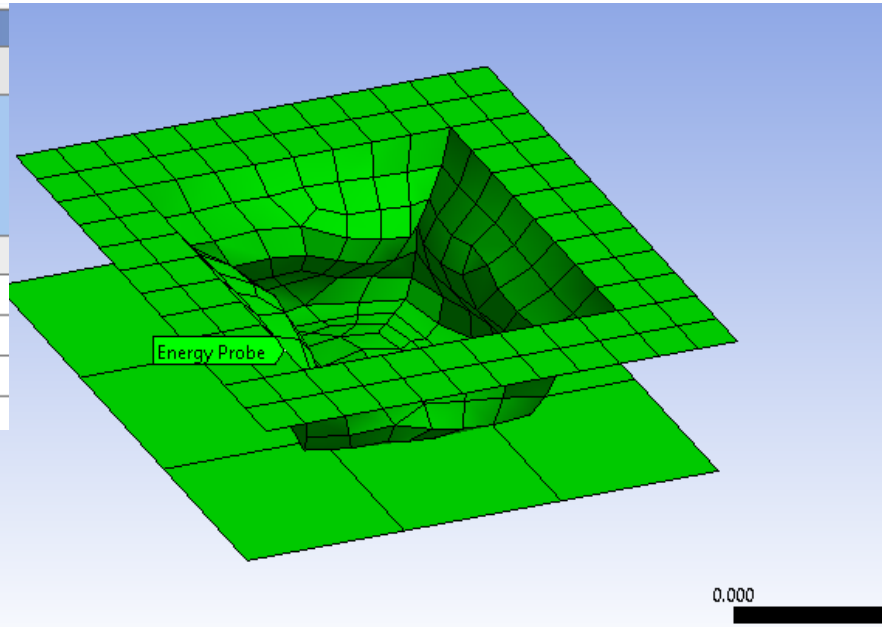
	A	B	C	D	E
1	Property	Value	Unit		
2	Material Field Variables	Table			
3	Density	2000	kg m^-3		
4	Isotropic Elasticity				
5	Derive from	Young's Modulus and Poisson...			
6	Young's Modulus	2E+09	Pa		
7	Poisson's Ratio	0.3			
8	Bulk Modulus	1.6667E+09	Pa		
9	Shear Modulus	7.6923E+08	Pa		
10	Bilinear Isotropic Hardening				
11	Yield Strength	2E+06	Pa		☑
12	Tangent Modulus	0	Pa		
13	Specific Heat Constant Pressure, C_p	434	J kg^-1 C^-1		

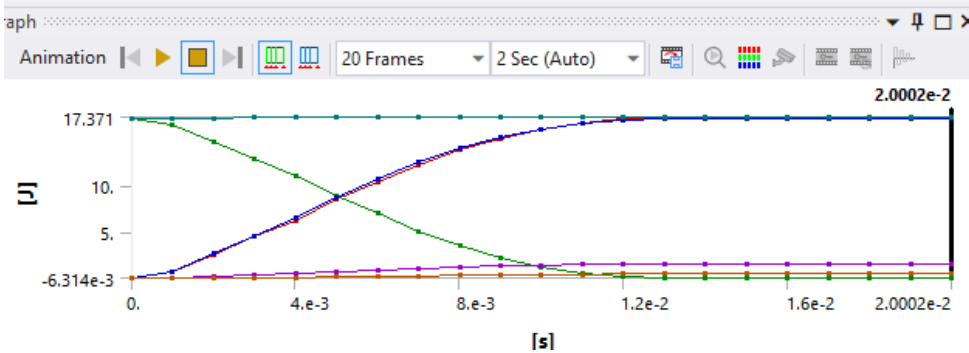
• Automatización con propiedades de material

Generamos variantes de propiedades de material.

Table of Design Points

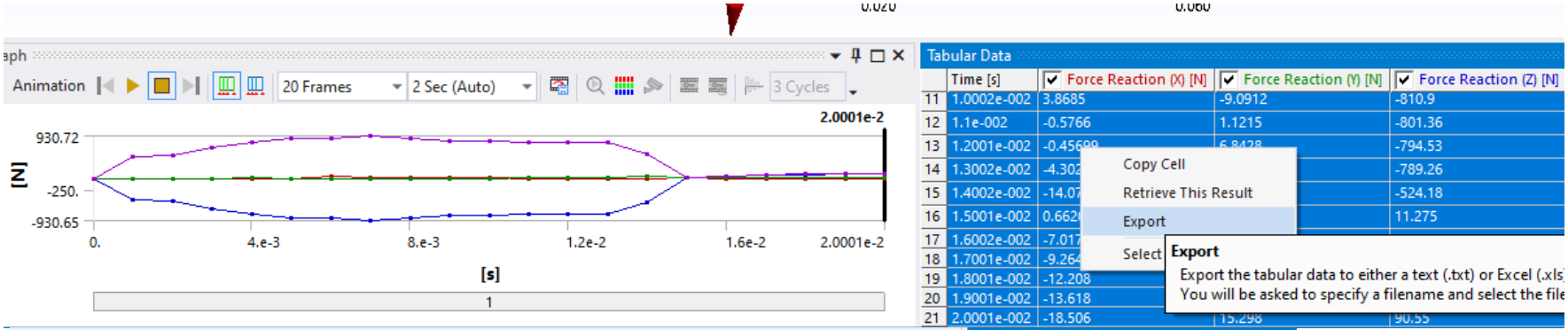
	A	B	C	D	E	F	G
1	Name	P4 - Yield Strength	P5 - Accele... Probe Minimum Z Axis	P6 - Deform... Probe Maximum Z Axis	P7 - Force Reaction Minimum Z Axis	Ret...	Retained Data
2	Units	Pa	m s^-2	m	N		
3	DP 1 (Current)	2E+06	-4306.3	0.042002	-12129	☑	✓
4	DP 2	4E+06	-335.06	0.025717	-937.38	☑	✓
5	DP 3	6E+06	-471.13	0.019781	-1318.5	☑	✓
*						☐	

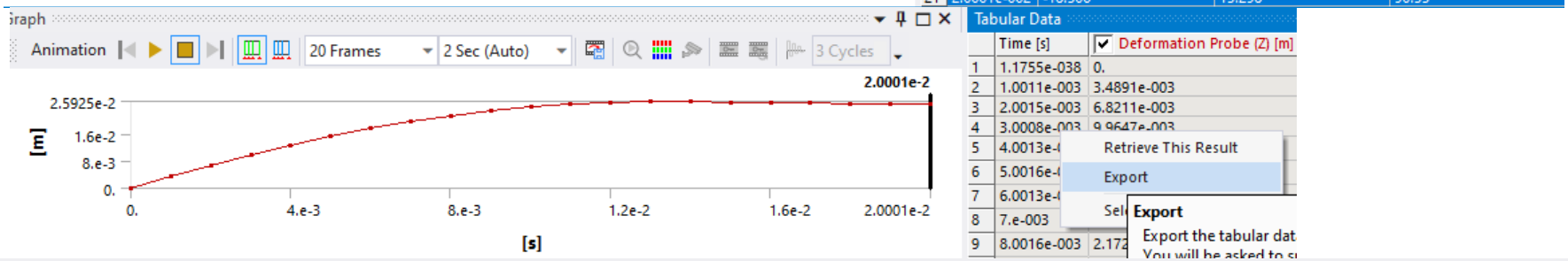


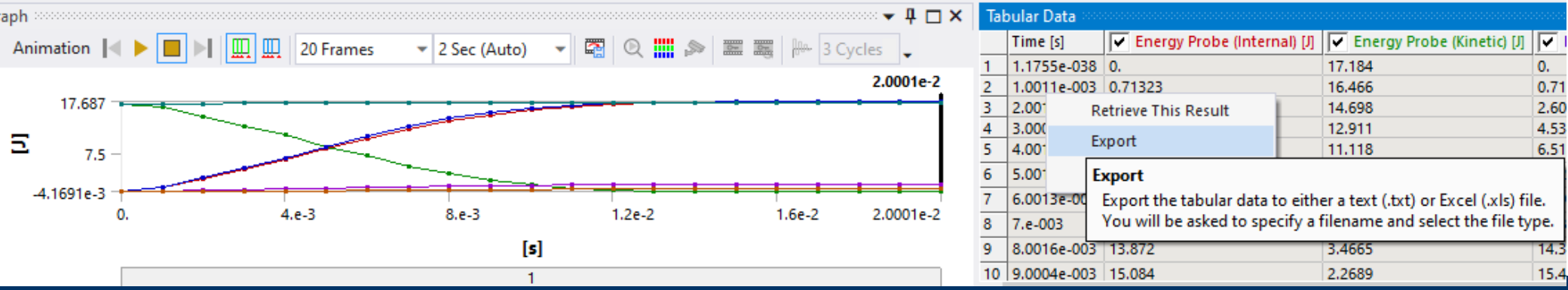


- Fuerza desplazamiento y energía

Generamos la curva de fuerza y desplazamiento .



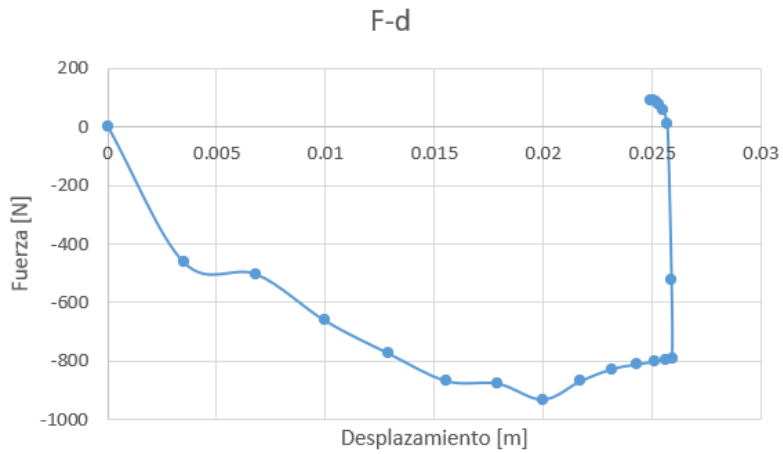


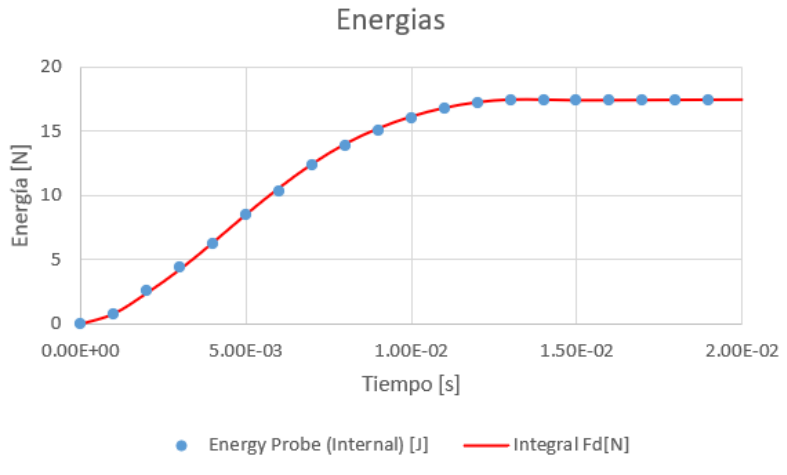


• Trabajo en Excel

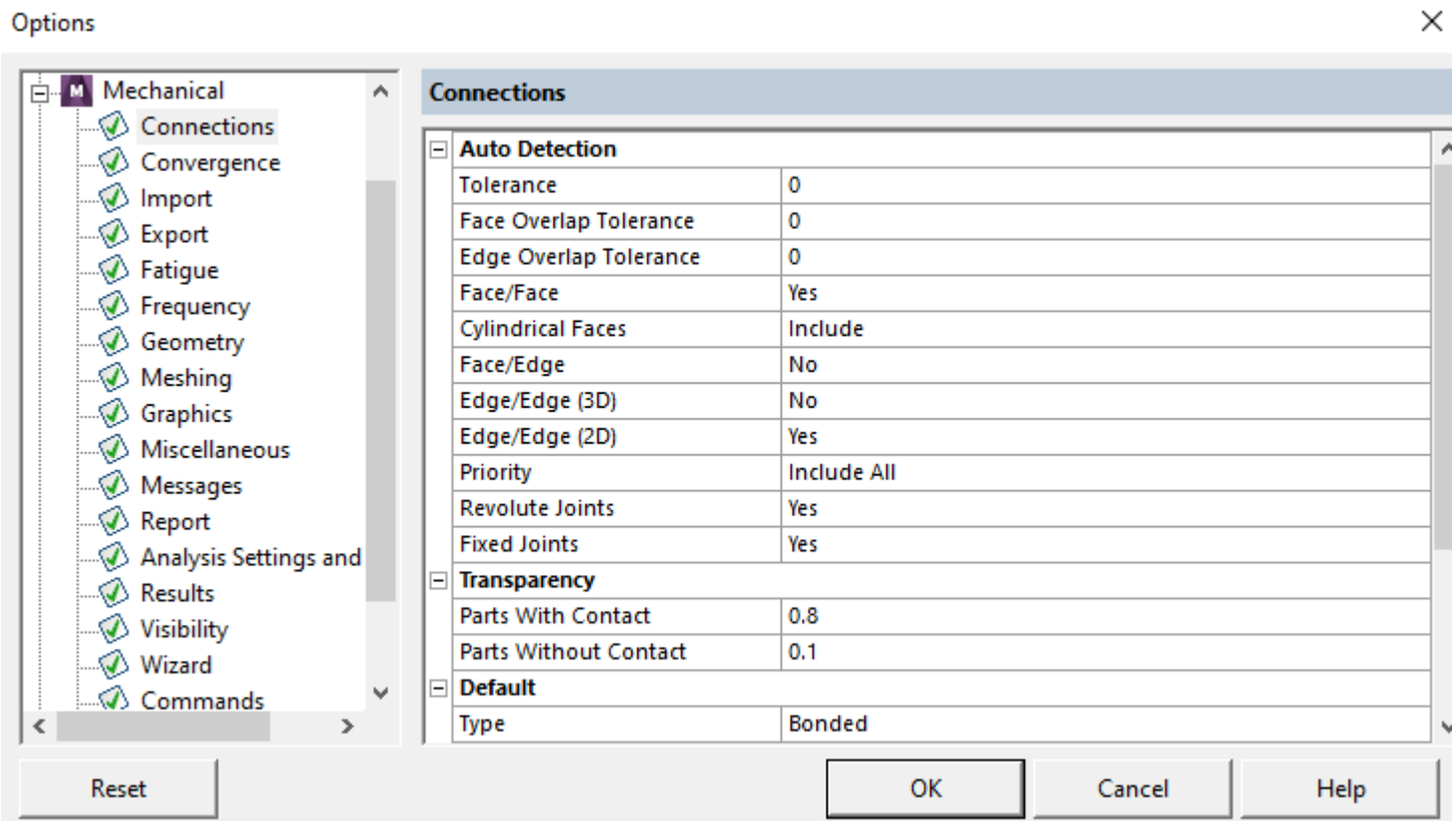
Trabajamos para comparar y practicar a integrar en Excel y ver que la energía es la integral de fuerza-desplazamiento.

T	U	V
		Integral
Energy Probe (Internal) [J]		Integral Fd[N]
0		0
0.71323		8.07E-01
2.5764		2.42E+00
4.422		4.25E+00
6.214		6.34E+00
8.4858		8.53E+00
10.348		1.06E+01
12.309		1.25E+01
13.872		1.40E+01
15.084		1.52E+01
16.025		1.61E+01
16.716		1.68E+01
17.168		1.73E+01
17.385		1.75E+01





- Mechanical, file, options



- Scripts

Un buen lugar para mirar scripts es
https://mapdldocs.pyansys.com/user_guide/index.html

- Bases de datos de materiales

https://paperonweb.com/pulppro.htm

:Untitled - GRANTA EduPack 2020 - [MaterialUniverse:\Hybrids: composites, foams, natural materials\Natural materials]

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Database: Level 1 Change...

paper AND pulp

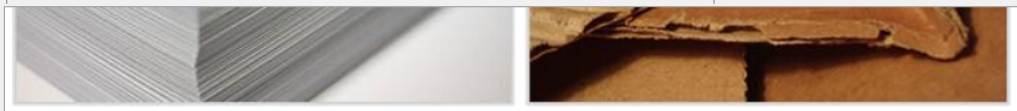
MaterialUniverse (3)

- Paper and cardboard
- Bamboo
- Titanium alloys

Home | Paper and cardboard

Paper and cardboard

Datasheet view: All properties | Show/Hide | Find Similar



Caption

1. Stack of copy paper © Jonathan Joseph Bondhus at en.wikipedia (CC BY-SA 3.0) 2. Corrugated cardboard © Richard Wheeler (Zephyris) at en.wikipedia (CC BY-SA 3.0)

The material

Papyrus, the forerunner of paper, was made from the flower stem of the reed, native to Egypt; it has been known and used for over 5000 years. Paper, by contrast, is a Chinese invention (105 AD). It is made from pulped cellulose fibers derived from wood, cotton or flax. There are many different types of paper and paper board: tissue paper - newsprint, kraft paper for packaging, office paper, fine glazed writing paper, cardboard - and a correspondingly wide range of properties. The data below span the range of newsprint and kraft paper.

Composition (summary)

Cellulose fibers, usually with filler and colorant

General properties

Density	700	-	1.15e3	kg/m^3
Price	* 0.886	-	1.08	EUR/kg

Mechanical properties

Young's modulus	2	-	4	GPa
Yield strength (elastic limit)	15	-	34	MPa
Tensile strength	15	-	34	MPa
Elongation	* 0.38	-	1.7	% strain
Hardness - Vickers	* 6	-	9	HV
Fatigue strength at 10^7 cycles	* 13.8	-	24.8	MPa
Fracture toughness	2	-	3	MPa.m^0.5

Thermal properties

Maximum service temperature	76.9	-	130	°C
Thermal conductor or insulator?	Good insulator			

- Bases de datos de materiales

:Untitled - GRANTA EduPack 2020 - [MaterialUniverse:\Hybrids: composites, foams, honeycombs, natural materials\Composites\Natural material composites\Paper an]

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Database: Level 3 Change...

paper AND pulp

MaterialUniverse (50)

- Paper and cardboard
- Paperboard
- Stainless steel, duplex, Ilium PD, cast, water quenched
- Stainless steel, duplex, Ilium PD, cast, water quenched & age
- Satinwood (l)
- Parana-pine (l)
- Satinwood (t)
- Parana-pine (t)
- Bamboo (longitudinal)
- Bamboo (transverse)
- Bamboo
- Stainless steel, duplex, UNS S33207, annealed
- Palm
- Stainless steel, austenitic, ASTM CH-10, cast, water quenche
- Stainless steel, austenitic, ASTM CN-7MS, cast, water quench
- Duplex (semi-austenitic) stainless steel
- Stainless steel, duplex, ASTM CD-4MCu, cast, water quenche
- Martensitic stainless steel
- Stainless steel, martensitic, ASTM CA-40, cast, tempered at 3
- Stainless steel, martensitic, ASTM CA-40, cast, tempered at 5
- Stainless steel, martensitic, ASTM CA-40, cast, tempered at 6
- Stainless steel, martensitic, ASTM CA-40, cast, tempered at 7
- Stainless steel, martensitic, ASTM CB-7Cu, cast, aged at 480°
- Stainless steel, martensitic, ASTM CB-7Cu, cast, aged at 495°
- Stainless steel, martensitic, ASTM CB-7Cu, cast, aged at 550°
- Stainless steel, martensitic, ASTM CB-7Cu, cast, aged at 580°
- Stainless steel, martensitic, ASTM CB-7Cu, cast, aged at 595°

Home | Paper and cardboard | Paperboard | Links

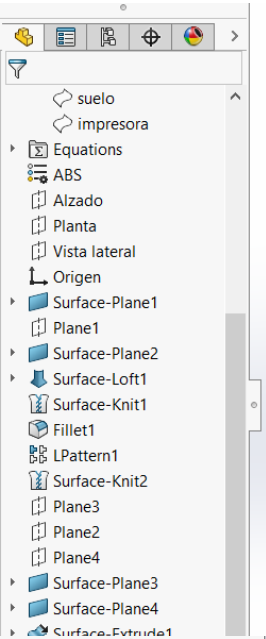
Paperboard

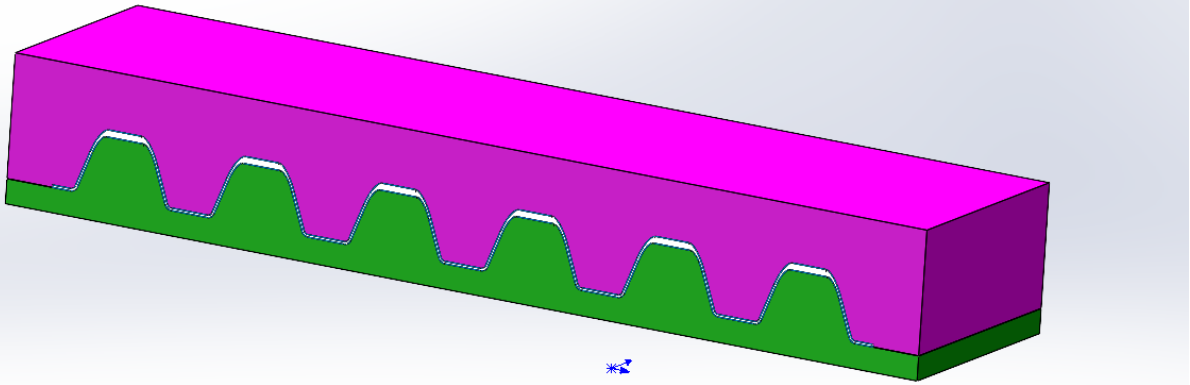
Datasheet view: All attributes | Show/Hide | Find Similar

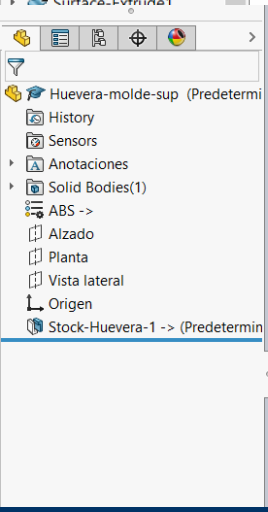
Cellulose

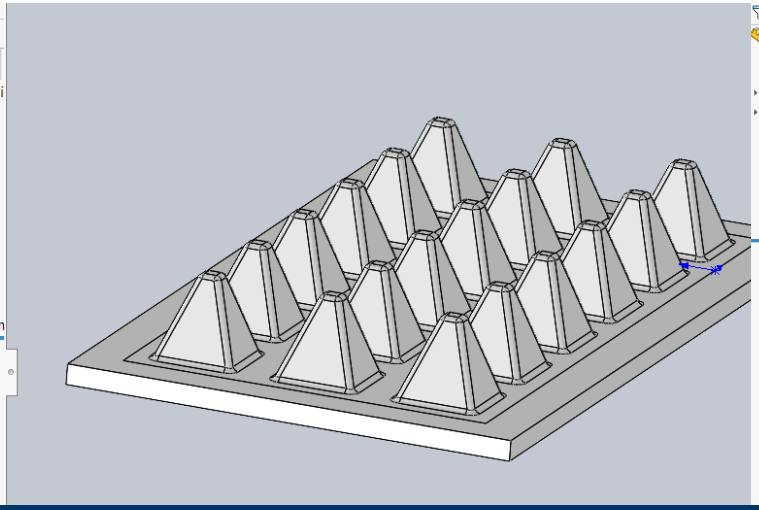
Form		Other			
Material family		Natural			
Base material		Cellulose			
Renewable content		85			%
Price					
Price		* 0.671	-	1.34	EUR/kg
Price per unit volume		* 638	-	1.34e3	EUR/m^3
Physical properties					
Density		950	-	1e3	kg/m^3
Mechanical properties					
Yield strength (elastic limit)		20	-	50	MPa
Tensile strength		20	-	50	MPa
Specific strength		20.5	-	51.3	kN.m/kg
Elongation		* 2.2	-	4	% strain
Compressive strength		* 20	-	50	MPa
Bulk modulus		* 0.1	-	0.5	GPa
Poisson's ratio		* 0.3	-	0.4	
Fatigue strength at 10^7 cycles		* 10	-	20	MPa
Impact & fracture properties					
Fracture toughness		* 4	-	5	MPa.m^0.5
Thermal properties					
Glass temperature		47	-	67	°C
Maximum service temperature		77	-	130	°C
Minimum service temperature		-273			°C
Thermal conductivity		0.1	-	0.15	W/m.°C
Specific heat capacity		1.3e3	-	1.4e3	J/kg.°C
Thermal expansion coefficient		5	-	20	µstrain/°C

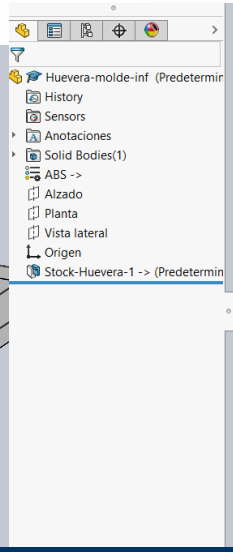
- Moldes y costes

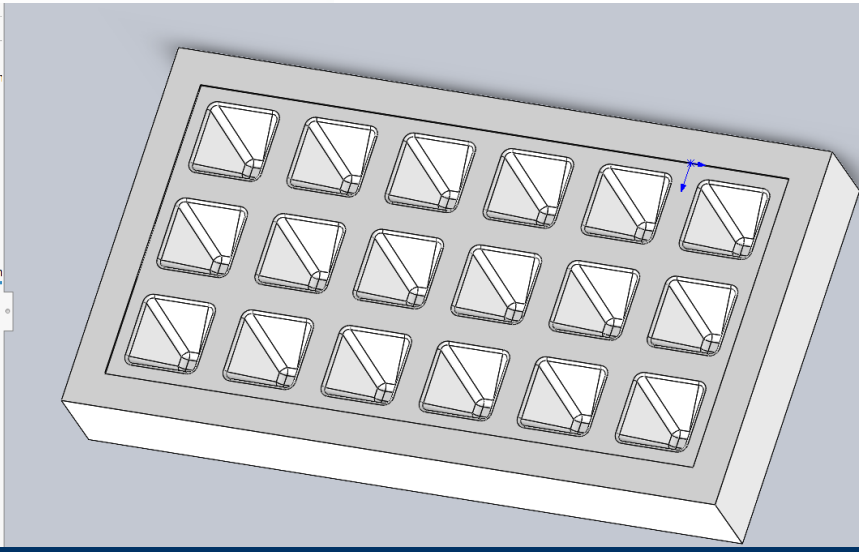




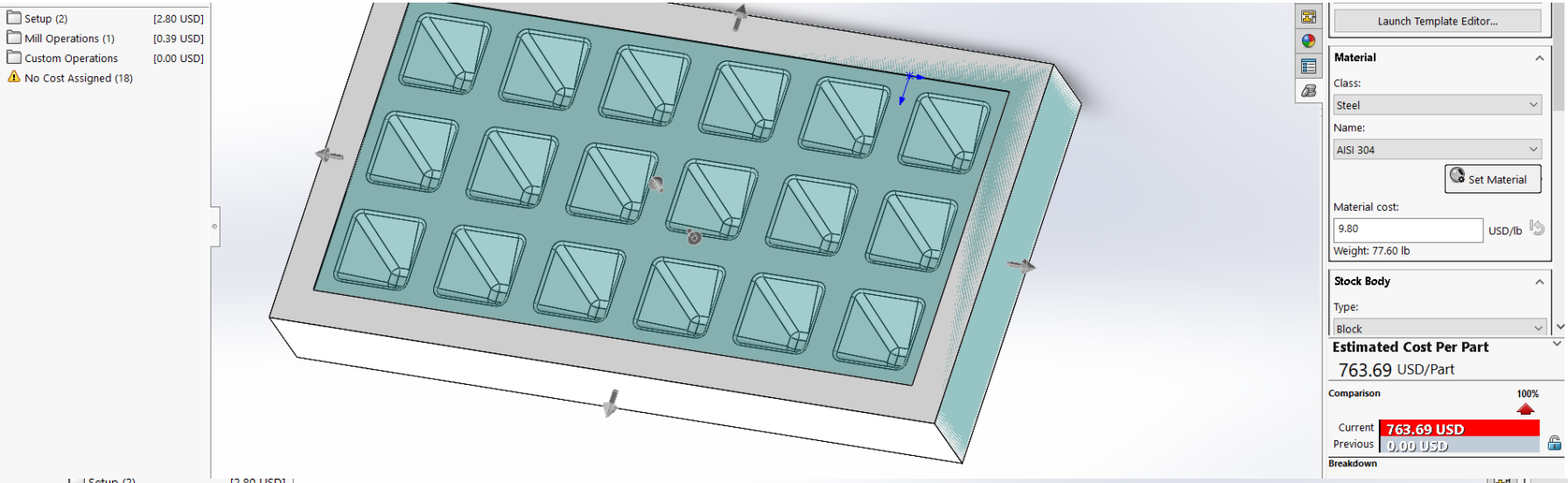


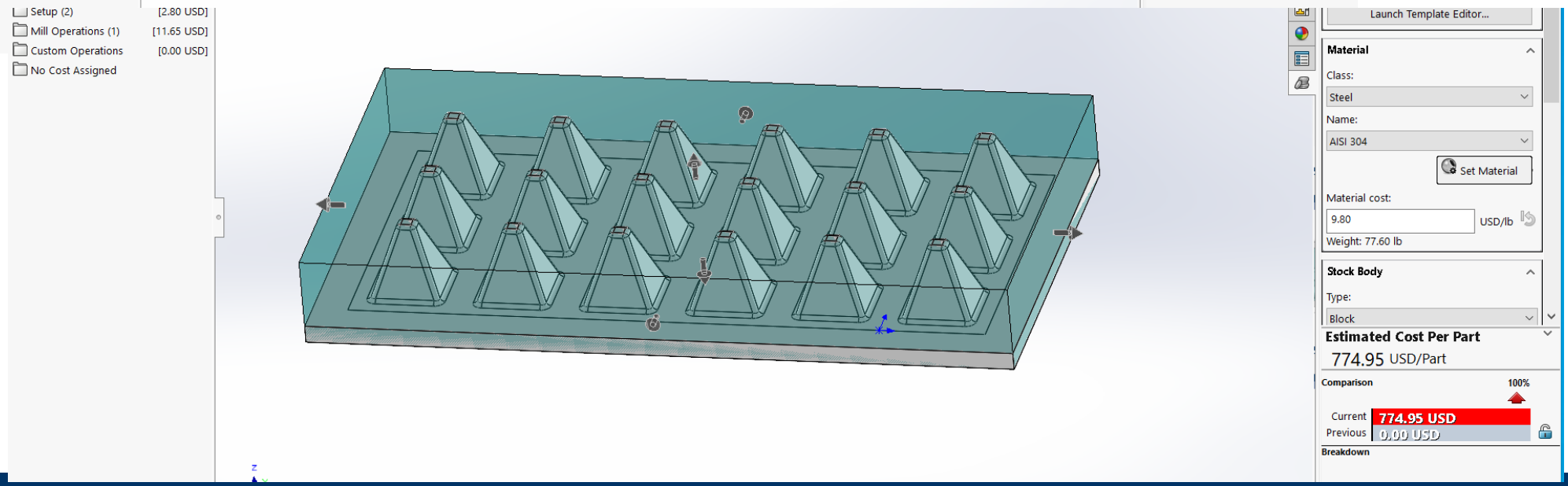






- Moldes y costes





- Ensayos experimentales

Como no tenemos geometría real se va a mirar algo similar usando hueveras comerciales del supermercado. Tomando cuatro muestras de peso vemos una gran variación de 10.70 a 12.29 gramos que indica el poco control de esta técnica.

			sample1	sample2	sample3	sample4	media	max-med	med-min	max-min
medición	peso	gr	11.52	10.70	12.29	11.65	11.54	6.50%	7.28%	14.86%

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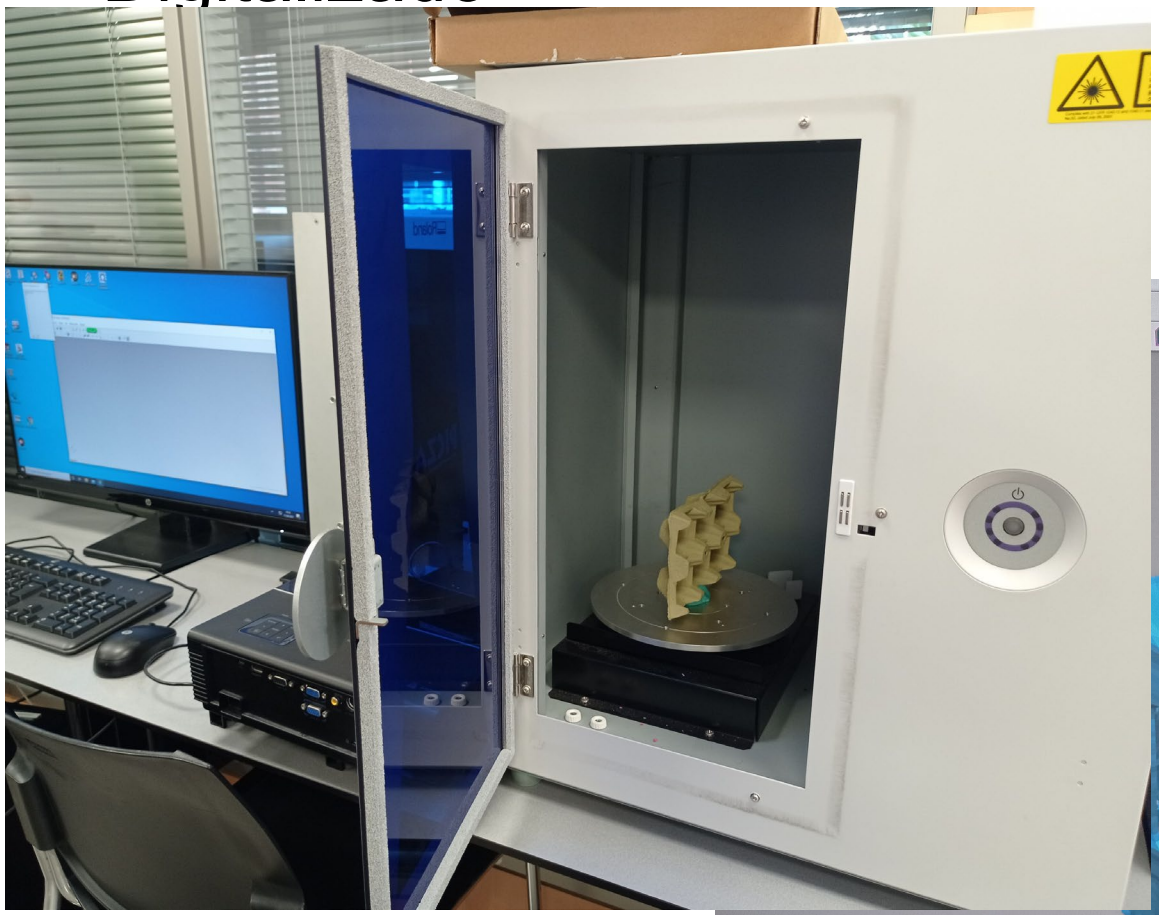
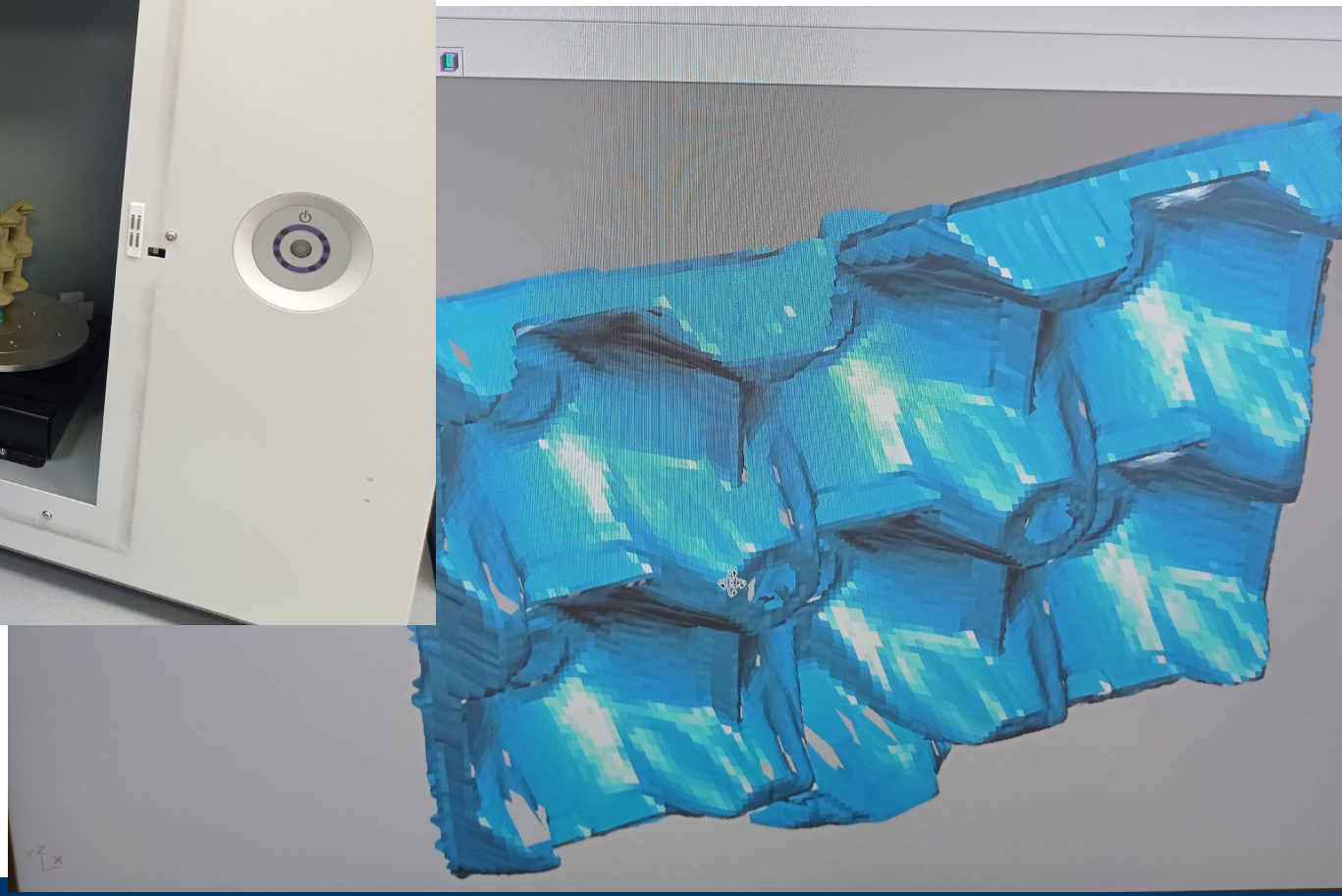
- Digitalizado





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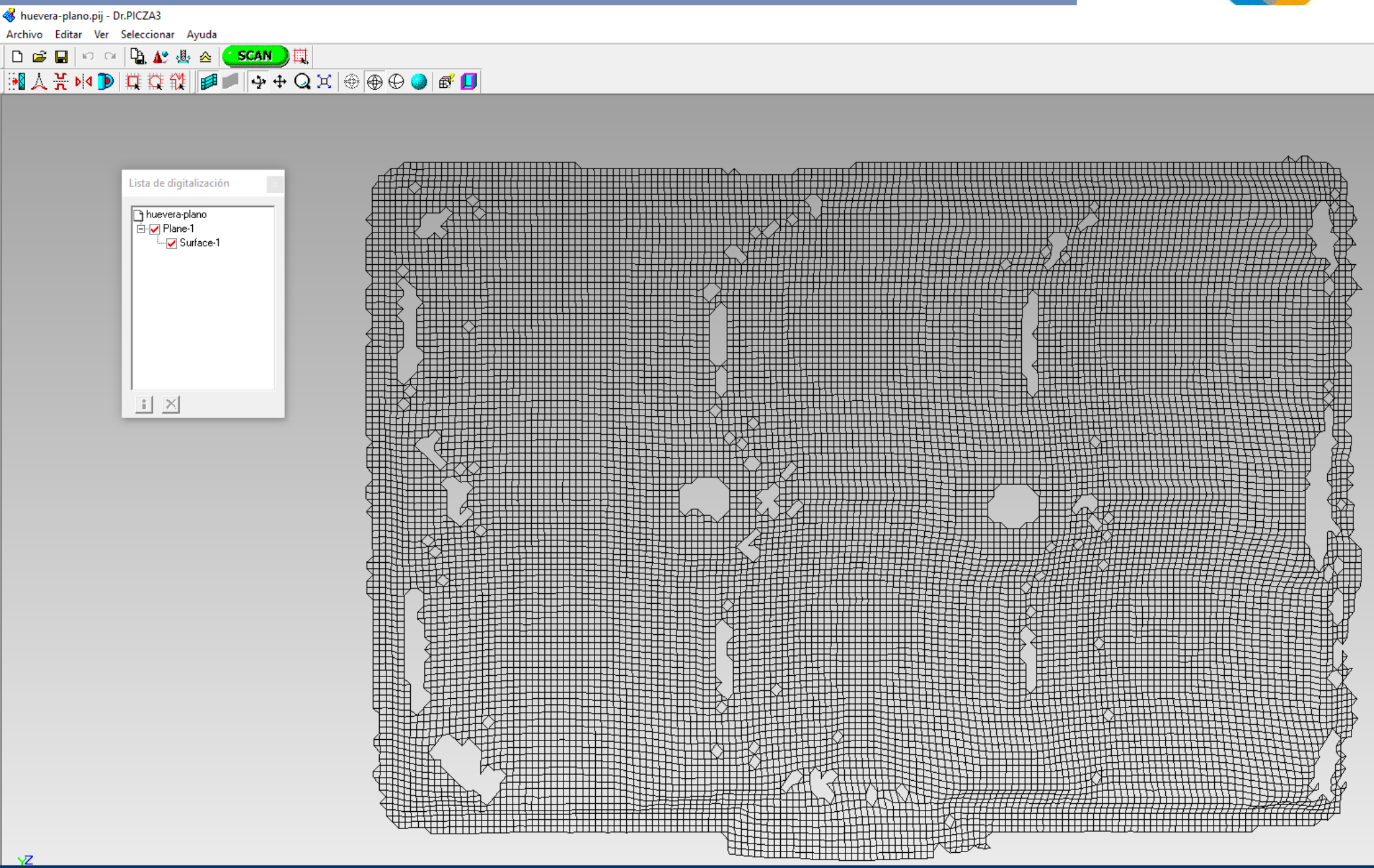
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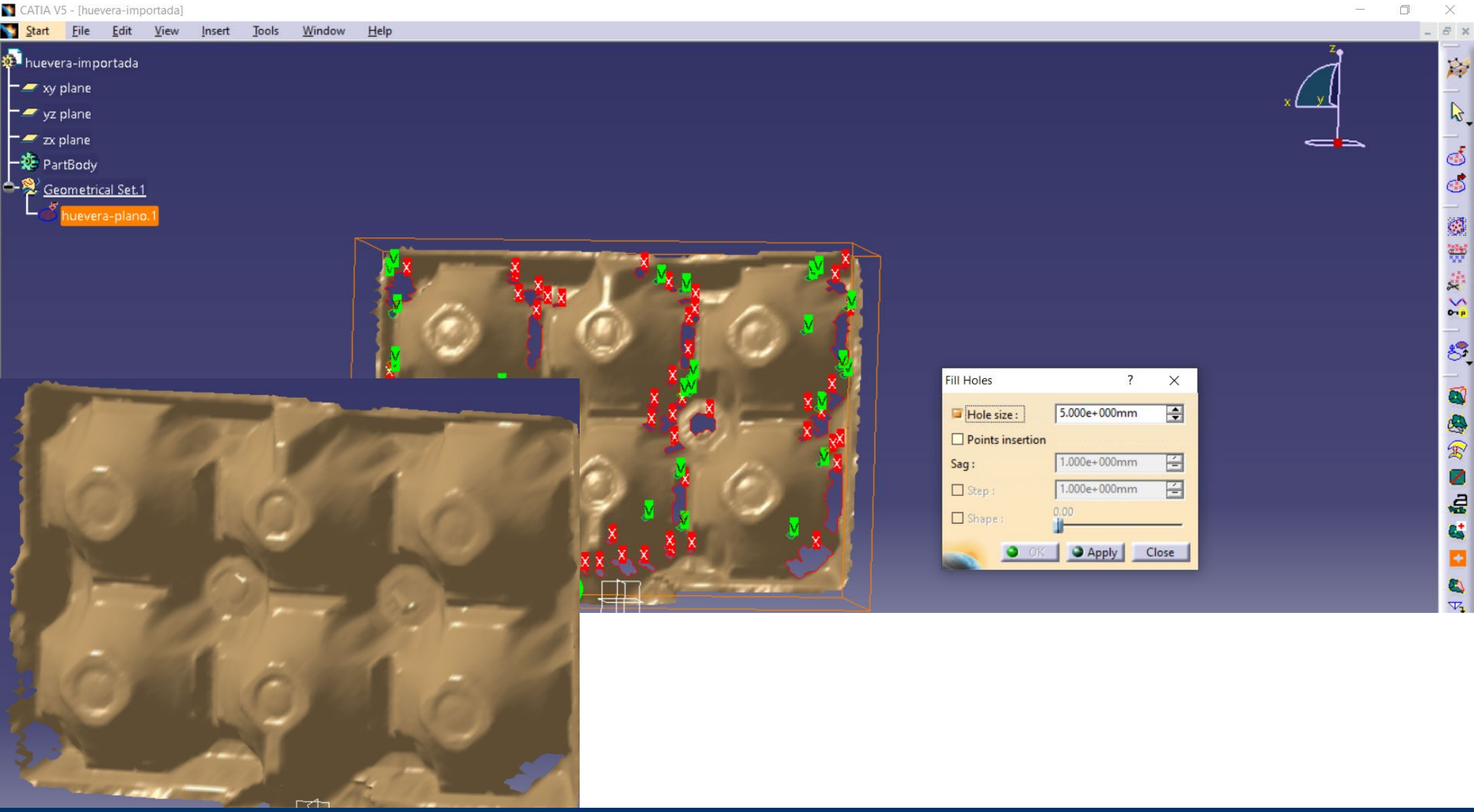
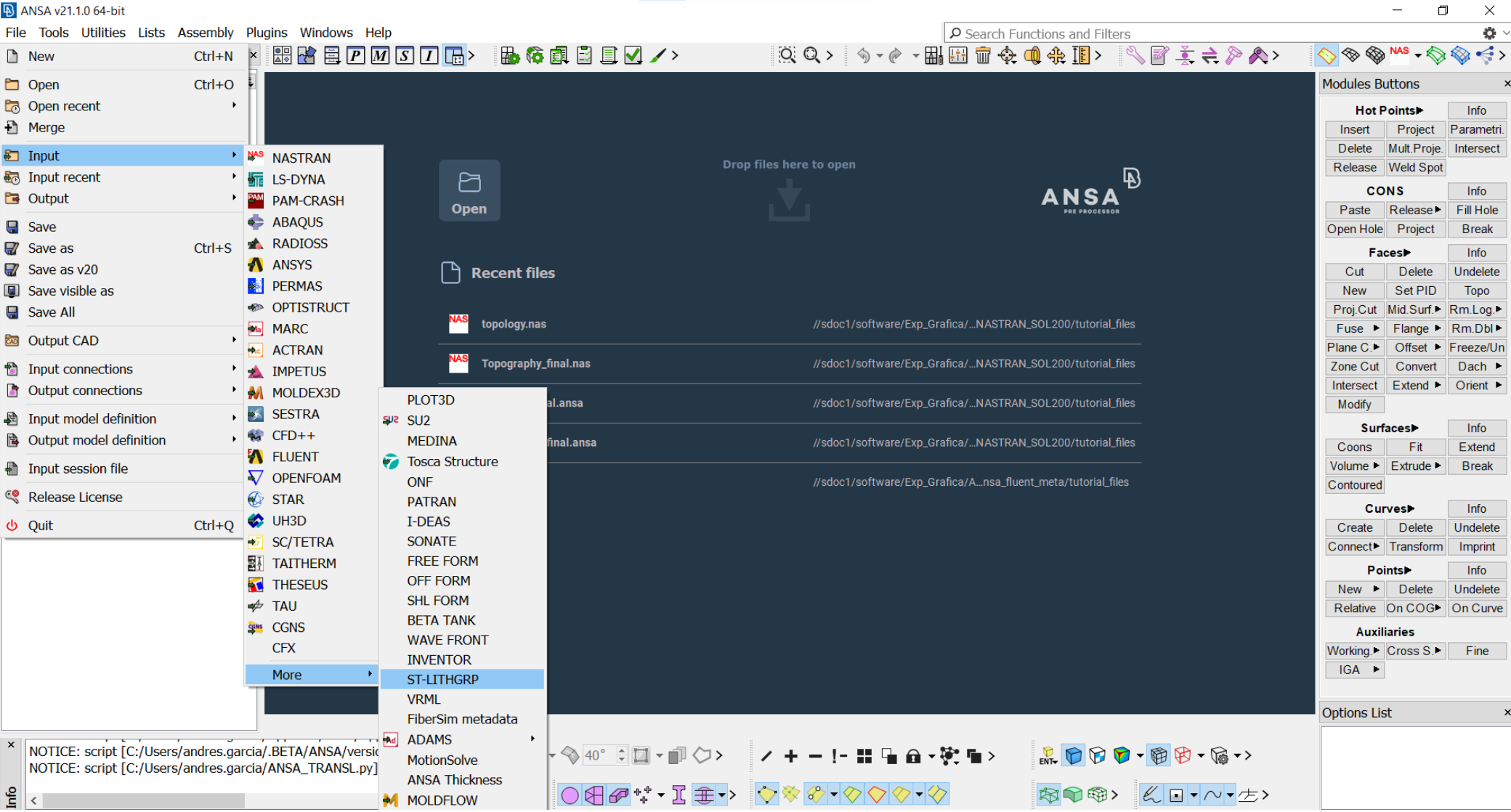
Plane-1
Surface-1

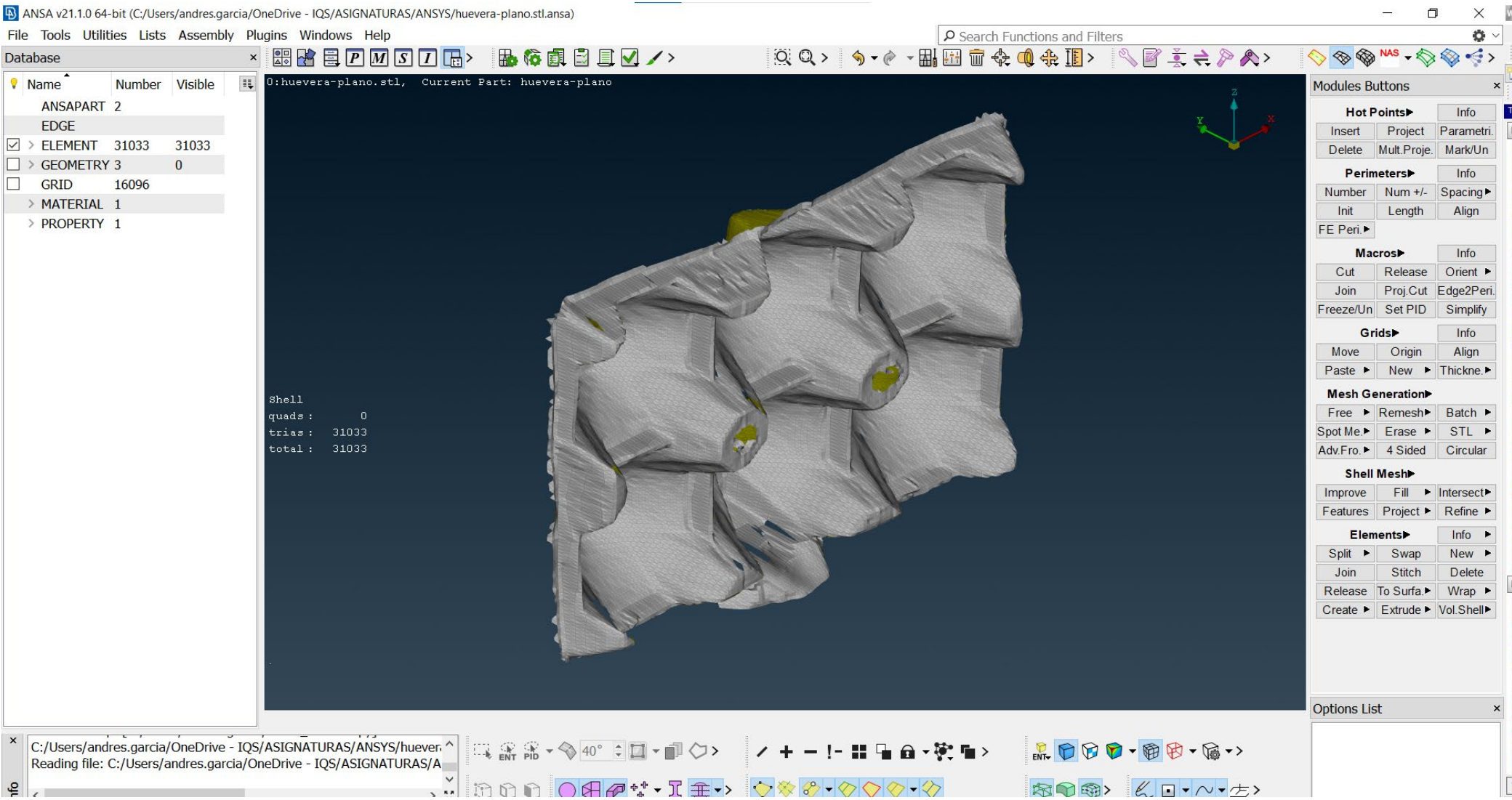
- Arreglamos el mallado en Catia



- Arreglamos el mallado en ANSA



- Arreglamos el mallado en ANSA



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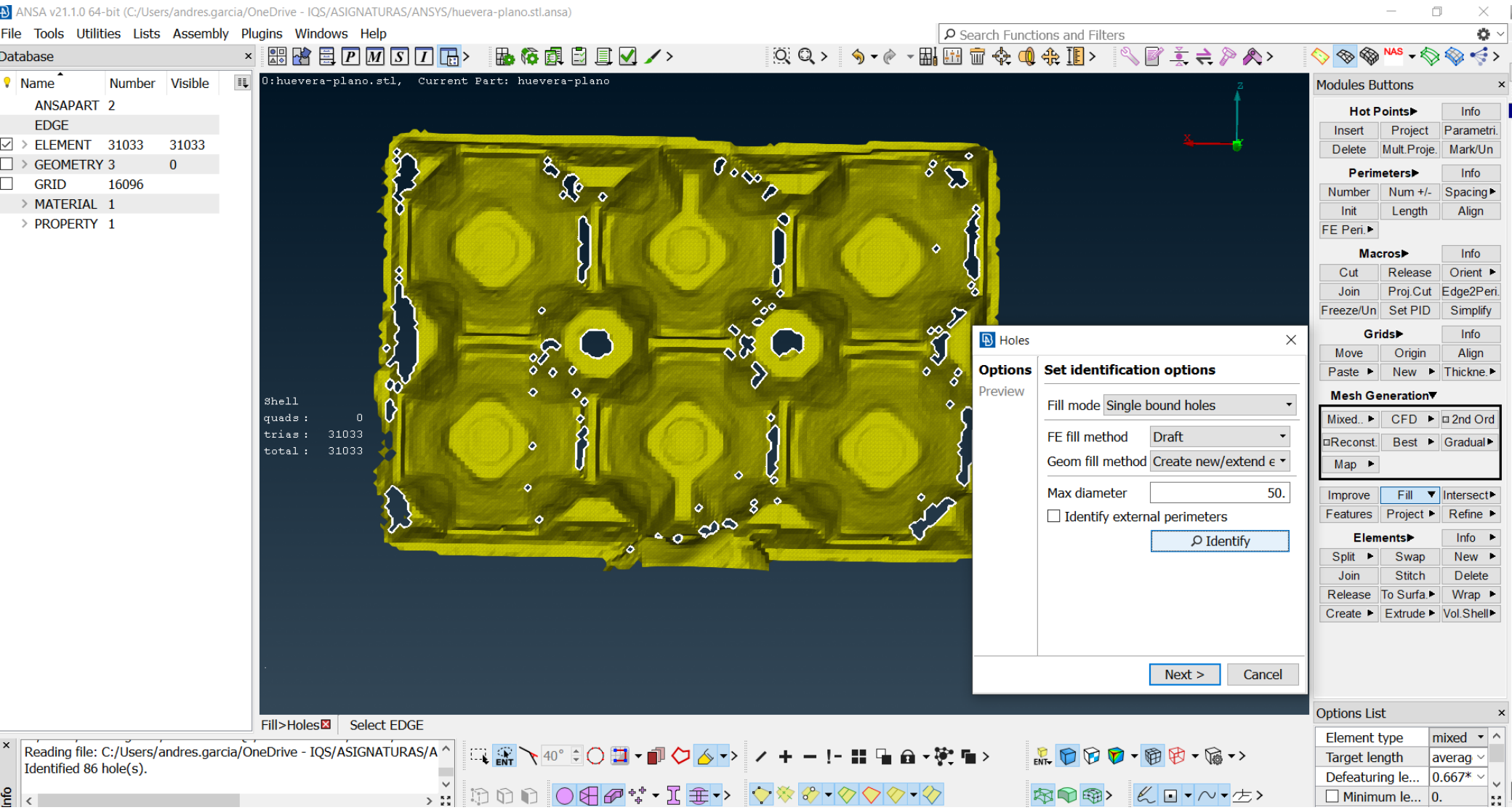
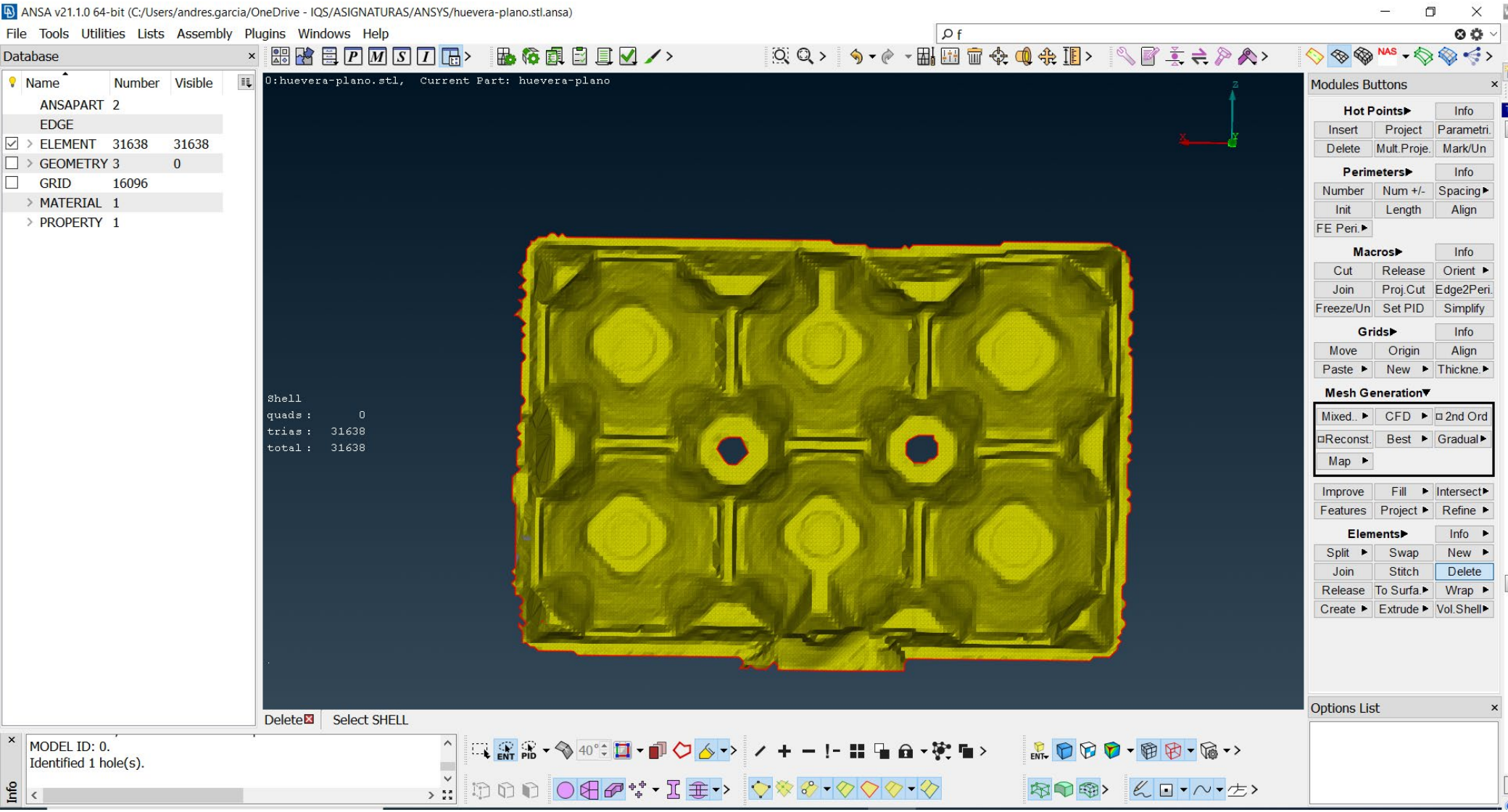
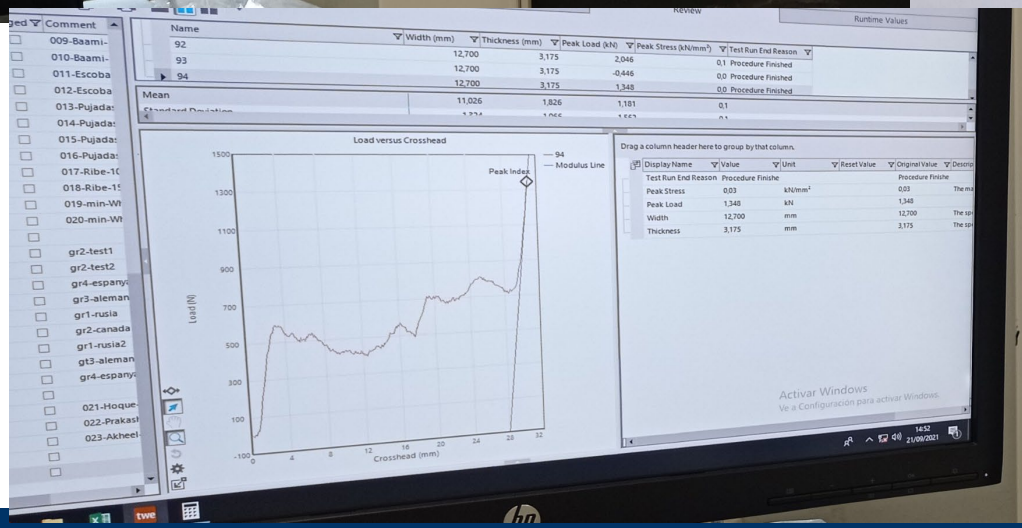


- Arreglamos el mallado en ANSA



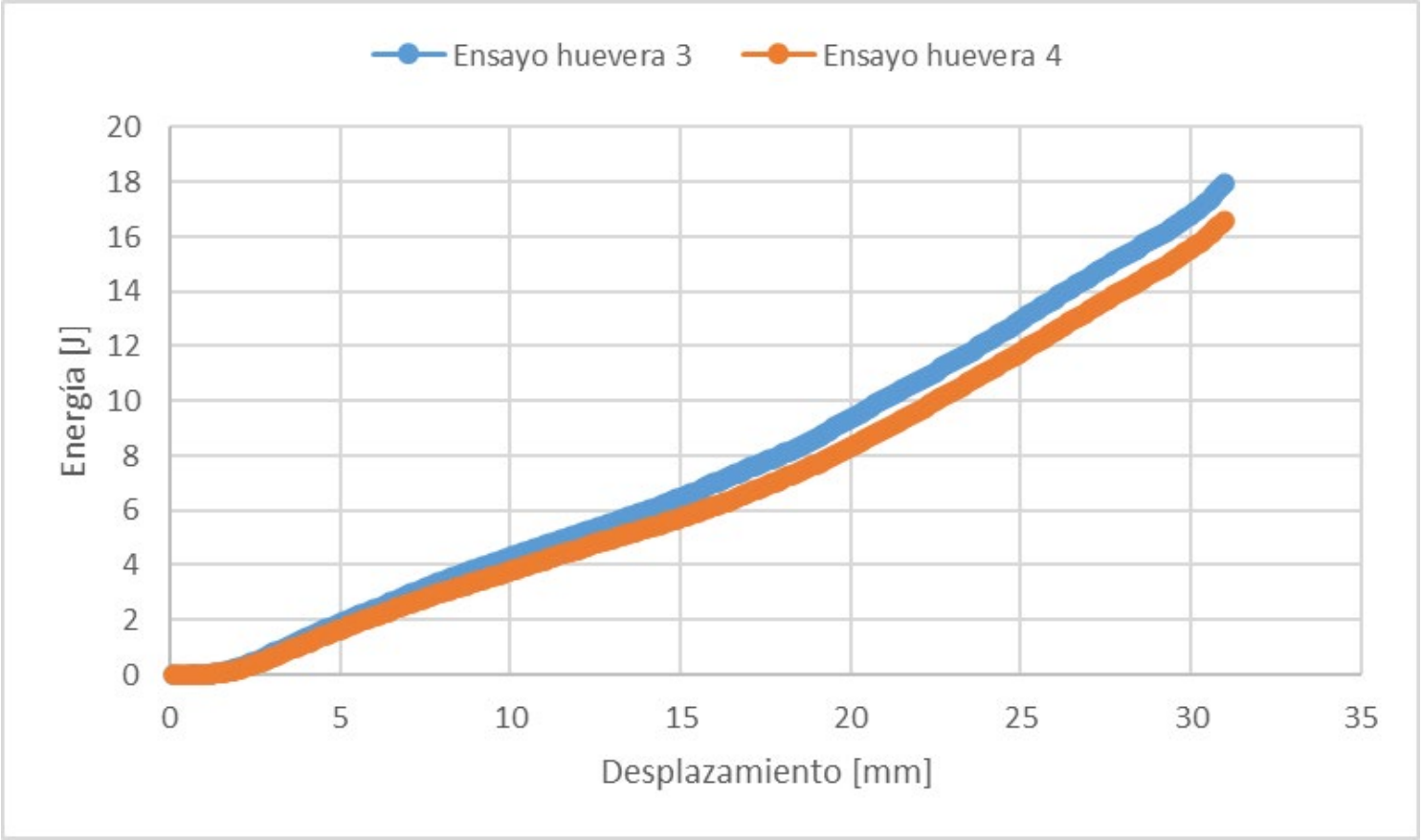
- Ensayos huevera compresión

Primero ensayamos la huevera a compresión para obtener la curva fuerza-desplazamiento y obtener la energía.



- Ensayos huevera compresión

Una vez tenemos el ensayo podemos ver como hacer el impacto



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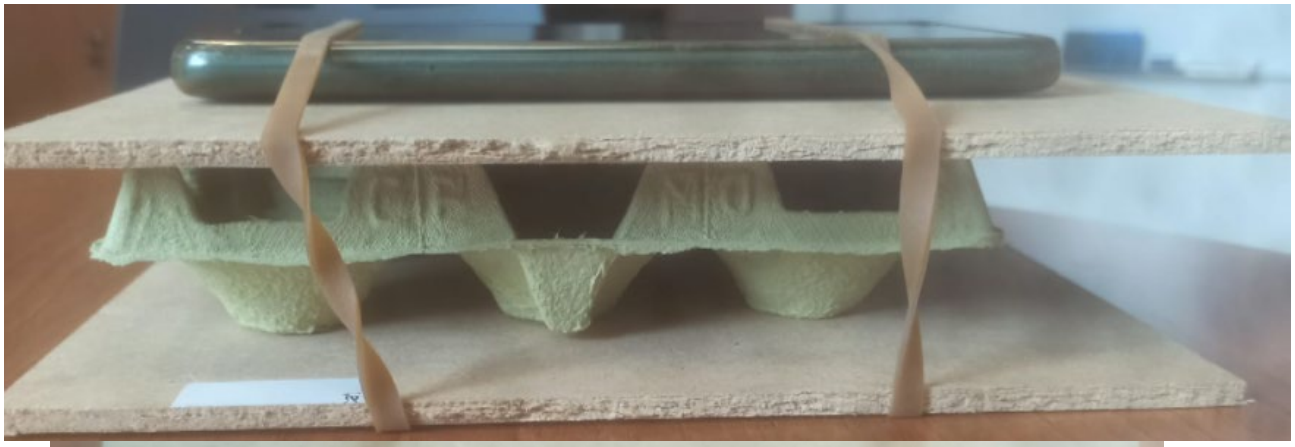
• Ensayos huevera impacto

La masa de cada madera es de 105g y el móvil 230g gomas 1.5 g total 443g. La masa que comprime es de 105+230+1=346g aprox.

Para tener la energía despejamos la velocidad: $v=\sqrt{(2E/m)}$, altura $h=E/(mg)$ y la aceleración máxima esperemos esté entorno a: $a_{max}=F_{max}/m$

El tiempo lo podemos estimar como $t=v/a$

El móvil lee cada 2.5ms por lo que tenemos difícil ver bien el impacto y tan sólo ±15[g].



• Resumen.

- Automatización de cálculos variando espesor o propiedad de material.
- Revisar los cálculos automatizados para no dar un valor con simulación que no ha acabado o problema de energías
- Posibilidad de tener la optimización parametrizada con la geometría CAD bien relacionada.
- Conclusiones de modelo sencillo parecidas al modelo completo de huevera.
- Posibilidad de creación de scripts
- Base de materiales GRANTA
- Costes de moldes
- Ensayos de PaperPulp con hueveras con grandes diferencias en peso
- Escaneo de piezas para hacer ingeniería inversa

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• Resumen CURSO.

➢ Cálculo a tracción para verificar propiedades de material y saber que hacemos bien energías, deformaciones, tensiones, fuerzas…

➢ Impacto para ver como la energía cinética se transforma en energía interna con un pequeño rebote elástico.

➢ Impactos a flexión para poder verificar impactos de manera sencilla.

➢ Importancia del Time step. Par acero de 10[mm] el time step son unos 2[us] por lo que para calcular 20[ms] se necesitan 10000 pasos de cálculo. Si tenemos un elemento de 1[mm] no nos podemos permitir hacer 100000 pasos de cálculo y es importante hacer bien el mass scaling.

➢ Importancia de automatizar para poder lanzar muchos cálculos y evaluar riesgos de si es más duro o más blando.