

COFE Better simulation through better geometry

Short Course Example Problems

February 20, 2020 Provo, UT





Coreform Process Output cards

0110 001001101001011110100110



User-defined in Coreform Process



Created by "build uspline" command

Coreform Process

0110 001001101001011110100110

Displacement Boundary Condition cards



Coreform

User-defined in Coreform Process



Created by "build uspline" command



Coreform Process

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Pressure load cards



User-defined in Coreform Process



Created by "build uspline" command

Coreform Process

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Contact cards



Coreform

User-defined in Coreform Process



Created by "build uspline" command

Problem 1: Simple unstructured solid simulation

Overview



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This tutorial will simulate the dynamic pressure loading of the part shown on the left. The pressure graphed on the right will be applied to the inside of the part, and the resulting displacement will be observed.

The problem will be modelled using half of the given part, with symmetry boundary conditions.



coreform





Learning Objectives

Tutorial participants will:

- Mesh a swept solid in Trelis and build a smooth spline over the mesh
- Set up and run a simple simulation on a semi-unstructured solid



Open Part

y Z

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This file is available at https://coreform.com/shortcourse/PressureVessel/pressurevesselpart.trelis



Webcut part on ZX plane

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- or -

webcut volume 1 with plane yplane



Delete half of the part

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- or -

delete volume 2



Set mesh element size

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- or -

volume 1 size 1

Mesh face

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Coreform

- or -

surface 7 scheme pave
mesh surface 7

Mesh volume as swept surface

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χ. Σ





Coreform

volume 1 scheme sweep source surface 7 target surface 8 mesh volume 1

Create block

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, Y



Coreform



- Or block 1 add volume 1

block 1 name "Pressure Vessel"

Create sidesets – symmetry boundary

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Entity - Sidesets FFF 🐺 🍘 🌏 Action - Create sideset 🔀 🗞 🗟 🌒 🌒 81 🗙 Sideset ID Sideset Name Symmetry Boundary Select O Face Surface O Edge Curve O Tri Group ID(s) 78 With Respect To wrt Surface Direction Forward Reset All Sidesets (i) 1 Apply

Coreform

Mode - Analysis Groups and Materials

ØX

Command Panel

sideset 1 add surface 7 8
sideset 1 name "Symmetry Boundary"

Create sidesets – pressurized surface





Sideset ID 2		
Sideset Name Pres	surized Surface	
Select		
Surface	🔘 Fac	e
O Curve	🔘 Edg	le
⊖ Group	🔿 Tri	
ID(s) 9 10 12		
With Respect To		
() wrt Surface		O wrt Hex
O wrt Volume		🔿 wrt Tet
		🔿 wrt Tri
	all	
Direction		
Forward		
O Reverse		
Reset All Sidese	ts	Reset
(i) 9		Apply

The mesh at this point is available at https://coreform.com/shortcourse/PressureVessel/pressurevesselmesh.trelis



Command Line	ØX
Trelis>sideset 2 name "Pressurized Surface" Journaled Command: sideset 2 name "Pressurized Surface"	^
Trelis>undo group end Journaled Command: undo group end	
Trelis>build uspline from mesh	
Script Command Error History	•

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Build is finished when Trelis> prompt returns.

Select "Simulation Cards" tab in bottom right

Command Panel	Flex Workflow	Simulation Cards	

The simulation cards tab should now look like this:

coreform

Simulation Cards			Ø
F			G
🔲 10001 - basis_	uspline		
🔲 20001 - basis_	uspline		
1 - basis_usplir	ne_tensor_product		
1 - domain_spl	ine_solid		
I - patch	elems - Pressure	Vessel	
2 - subdomain	elems - Symmetr	v Boundary	
3 - subdomain	elems - Pressuriz	ed Surface	
version			
c 15 1	Else Marshellser		



Adding Cards

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11 Q







Add material and formulation cards

material_isotropic_linear_elastic		
desc	Steel	
material_id	1	
 E E_time_depend E_temperature 	1000 dent_function_temporal_id e_dependent_function_temporal_id	
nu	0.3	
rho	100	
thermal_expansion	0	
	ଚ	Apply

formulation_sol	id
desc	Linear elastic 3d solid
formulation_id	1
formulation_type	solid_3d 🗸 🗸
quadrature	QP1 •
material_id	1 - material_isotropic_linear_elastic
	Apply



Add part card

<u>0110 α01001101001011110100110</u>

part			Select an Id 🛛 😣
desc	Pressure Vessel		Search
part_id	1		1 - Pressure Vessel 2 - Symmetry Boundary
formulation_id	1 - Linear elastic 3d solid		3 - Pressurized Surface
subdomain_ids	🛨 🗙		
1 - Pressure Ve	ssel		
			ØK X Cancel
temperature_id	•		
	Apply <	,	



Add timestep cards

control_time_integration_newmark		
desc	Trapezoidal integration scheme	
control_time_integration_id	1	
beta	0.25	
gamma	0.5	
	9	Apply <

control_timestep_implicit	t_dynamic_2nd_order	-
desc	implicit dynamic timestep	
control_timestep_id	1	
control_time_integration_id	1 - Trapezoidal integration scheme	<u>}</u>
predictor_type	CONSTANT_DISPLACEMENT *	
max_corrector_step_n	10	
newton_tol_abs	1e-32	
newton_tol_rel	1e-06	
delta_tol_abs	1e-32	
delta_tol_rel	0.001	
line_search		
line_search_tol	0.5	
	Apply	

Coreform

Add problem and control_model cards

problem		-
desc	Pressurization of Vessel	
problem_id	1	
part_ids	+ X	
1 - Pressure Vessel		
control_timestep_id	1 - control_timestep_implicit_dynamic_2nd_order	-
coupled_problems	💠 🗶	
control_linear_solve	r	•
	Apply	<

control_model		*
desc	Global Parameters	
control_time		
initial_time_step 0.1		
termination_time 1		
adaptive_timestep		
iteration_optimal		
iteration_window		
growth_factor		
reduction_factor		
delta_t_min		
delta_t_max		
control_problem	1 - problem	~
enable parent basis		



Add temporal functions

function_temporal_constant		
desc	Always and Forever	
function_temporal_id	1	
value	1	
birth	0	
death	1000000000	
tol	1e-10	
	Apply 🗲	

desc	Pressure var	iation with tin	nel
function_temporal_id	2		
birth	0		
death	100000000	0	
tol	1e-10		
graph			4 X
1	:		f(t)
1 0		0	
2 1	~	1	~



Add symmetry boundary condition

subdomain_nodal_dva	
desc	Symmetry Boundary Condition
subdomain_nodal_value_id	1
subdomain_id	2 - Symmetry Boundary 🗧 👻
dva_type	DISPLACEMENT 🔷 🗸
UX	0
✓ UY <	0
UZ	0
RX	0
RY	0
RZ	0
 function_temporal_id 	1 - Always and Forever 🛛 🖛 🔻
O function_spatial_temp	oral_id 🗸 🗸
	Apply <

problem_boundary_condition				
desc	Associate BCs with problem			
problem_id	1 - problem	*		
subdomain_nodal_value_ids				
1 - Symmetry Boundary Co	ndition			
	4	Apply		



Add pressure load

subdomain_scalar_field	load	
desc	Pressure on inside face	~
subdomain_field_value_id	1	
subdomain_id	3 - Pressurized Surface	
load_type	pressure	-
۲		
magnitude	300	
domain_type	reference	
function_temporal_id	2 - Pressure variation with time	~
O function_spatial_temp	poral_id	~
	9	Apply

	Associate load with problem	
roblem_id	1 - problem	•
ubdomain_field_value_io	ls	4
- subdomain_scalar_fie	ld_load	



Add output

subdomain_output_field	
desc	Data output settings
subdomain_output_id	1
subdomain_ids	4 X
1 - Pressure Vessel	
function_temporal_id	1 - Always and Forever
field_types	
✓ displacement	
velocity	
acceleration	

delta_time delta_step	
file_name_prefix	results
file_type	vtk 🔹
sample_type	BEZIER 🔶 🔹 🔯
 cache_basis_evals 	
✓ include_elem_outlines	
solution_type	current 🔹
bezier_projection_relative_continuity	



Input finished

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Your window should now look like this:





Run Simulation

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Simulation Cards ØX **F** 10001 - basis uspline 20001 - basis uspline 1 - basis uspline tensor product control model - Global Parameters 1 - control time integration newmark - Trapezoidal integration scheme 1 - control timestep implicit dynamic 2nd order - implicit dynamic timeste 1 - domain_spline_solid 1 - formulation solid - Linear elastic 3d solid 1 - function temporal constant - Always and Forever 2 - function temporal linear interpolation - Pressure variation with time 1 - material isotropic linear elastic - Steel 1 - part - Pressure Vessel 1 - patch 1 - problem - Pressurization of Vessel 1 - problem boundary condition - Associate BCs with problem 1 - problem field load - Associate load with problem 1 - subdomain elems - Pressure Vessel 2 - subdomain elems - Symmetry Boundary 3 - subdomain_elems - Pressurized Surface 1 - subdomain nodal dva - Symmetry Boundary Condition 1 - subdomain_output_field - Data output settings 1 - subdomain scalar field load - Pressure on inside face version

Look in:	🚞 /home	e/calebg/Short	Course/Press	ureVessel	-	G	Ο	0	ß	:: =
Computer	-									
File name:	Pressure	/esselSim						_		Save





View Results

<u>0110 001001101001011110100110</u>

Command Line			8 X
	Cancel Job	S Post Process	🂐 Close
====== ACCUMULATED EXECUTION TIME REPORT Total elapsed time (secs): 100.392 Output (secs): 6.45407 (6.4288%) Restart (secs): 0 (0%)			<u> </u>
Report for problem 11 Total problem time (secs): 93.9319 (93.5653%) Time integrator (secs): 93.9051 (93.5652%) Corrector iteration (secs): 93.9051 (93.5386%) External F assembly (secs): 0.701173 (0.701425 %) Internal F assembly (secs): 19.7047 (19.6278 %) Stiffness assembly (secs): 19.7051 (81.513 %) Total assembly (secs): 0.705136 (0.955362 %) ParentBasis: timer 0: 0.959106 (0.955362 %) PatchBasis: timer 0: 17.547 Solver process exited normally with exit code 0 0			Ŧ
Script Command Error History Coreform Analyze - PressureVesselSim			



Set Post Process Executable

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Tools -> Options -> Post Meshing



View Results

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0 10
Delete 2





Warp By Vector

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View Smooth Spline

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WarpByVector1	Search (use Esc to clear text)
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	Use Shader Replacements
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Properties Information	Block Colors
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Search (use Esc to clear text)	Use Data Partitions
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View Mesh

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View Displacements

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ः 💼	resu	ts.pvd												
•	War	oByVe	ctor1											


Play Displacements

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You may need to adjust the color scaling



Problem 2: Deep Rolling



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This tutorial will simulate contact between a disc and a block as shown on the left. The material model used for both parts will allow for plastic deformation

The problem will be modeled as a 2D solid quasi-static simulation



Learning Objectives

Tutorial participants will learn:

- How to manage a simulation with multiple parts
- How to set up displacement boundary conditions
- How to use material models with plasticity
- How to set up contact



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Coreform

- or -

Create surface rectangle width 1 height 1 zplane



Create disc

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Command Panel						Ø
м	ode - Geom	etry				
	J. 🗊		1			
O	peration - C	reate G	eometr	у		
	1	M (v)	۹,	0	¥	
	• ×	==	*			
Er	ntity - Surfac	ces				
	1	r	۲	*		
Circle						•
Specify Circle Usi	ng					
	0.	Center V	ortex	6	Verter	11.4
Radius	0.	concer a	encex		vertex	List
Radius Radius 0.5			FILEX		vertex	List
Radius Radius O.5 XPlane	01	(Plane	ertex.	(ZPlane	List

- or -

Create surface circle radius 0.5 zplane



Move disc

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command raner	만면
Mode - Geometry	
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Operation - Transform Geometry	
1 🖉 🎘 🖓 🏹	
Entity - Surfaces	
Move	¥
Surface ID(s) 2	
✓ Include Merged	
Select Method	
O To Coordinates O To Entity	
Distance General Location	
O In Direction Of Surface Normal	
X Distance	
Y Distance 1	
Z Distance	

- or -

This geometry is available at this address: https://coreform.com/shortcourse/deep_rolling_init.cub

Move surface 2 y 1



Mesh disc

Command Panel M	ode - I	Mesh					8
				-			
E	ntity -	Surfac	e				
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	*						
A	ction -	Mesh					
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		100		E1			
Circle							•
Select Surfaces							
2]
Advanced							
(i) ?							Apply Scheme
Check For Ove	rlappi	ng Sur	faces				
Apply Scheme	Befor	e Mesł	ning				
Scheme: circle							Mesh







Mesh disc





Mesh block

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1 9



Command Panel	6
Mode - Mesh	
👗 🌍 🥞 🖙 🔤 💽	
Entity - Surface	
🎯 🔷 🖍 🔺 🎒 🄛	
☆ ▲ ¤ △ → +	
热	
Action - Intervals	
🖬 🖺 9 🏓 🗱	
Approximate Size	, •
Select Surfaces	
1	
Approximate Size 0.1	
✓ Preview	
	Apply Size
Check For Overlapping Surfaces	
✓ Apply Size Before Meshing	
 ? 	Mesh

- or -Surface 1 size 0.1 Mesh surface 1



Create block sets - Disc

0110 001001101001011110100110





- OC -Block 1 add surface 2 Block 1 name "Disc"



Create block sets - Block

0110 00100110100101111010010



Command Panel ØX Mode - Analysis Groups and Materials 👗 🗊 🗊 🤜 🖬 🗾 Entity - Blocks Action - Create 🍋 泽 🦄 🕂 😭 🧮 🐒 💰 🛠 Teate block Block ID 2 Block Name Block Select O Tet Group O Face Volume 🔘 Tri Surface 🔘 Edge O Curve Vertex O Node Hex ID(s) 1

Allow Blocks to Contain Duplicate Elements

Reset All Blocks

(j) 🔈

Apply

- Ol -Block 2 add surface 1 Block 2 name "Block" 0110 001001101001011110100110

Create side sets bottom of block



Command Panel ØX Mode - Analysis Groups and Materials Entity - Sidesets Ħ Action - Create sideset 🏹 🗞 🔛 8 🔀 Sideset ID 1 Sideset Name Bottom of Block Select Surface Face O Edge Ourve Group 🔘 Tri ID(s) 3 With Respect To wrt Surface Forward Reset All Sidesets (i) **?** Apply - or -

coreform

Sideset 1 add curve 3 Sideset 1 name "Bottom of Block" 0110 001001101001011110100110

Create side sets top of block



Coreform

	Mode - Analysis Groups and Materials	
	Entity - Sidesets	
	Action - Create sideset	
Sideset ID 2		
Sideset Name Top o	of Block	
Select		
 Surface 	○ Face	
Curve	⊖ Edge	
O Group	O Tri	
ID(s) 1		
ID(s) 1 With Respect To		
ID(s) 1 With Respect To wrt Surface	O wrt Hex	
ID(s) 1 With Respect To wrt Surface	O wrt Hex O wrt Tet	
ID(s) 1 With Respect To wrt Surface wrt Volume wrt Face	O wrt Hex O wrt Tet O wrt Tri	
ID(s) 1 With Respect To With Surface With Volume With Volume With Volume With Volume With Volume With Volume With Volume	O wrt Hex O wrt Tet O wrt Tri	
ID(s) 1 With Respect To wrt Surface wrt Volume wrt Face Surface ID(s) Direction	O wrt Hex O wrt Tet O wrt Tri all	
ID(s) 1 With Respect To wrt Surface wrt Volume wrt Face Surface ID(s) Direction Forward	O wrt Hex O wrt Tet O wrt Tri	
ID(s) 1 With Respect To wrt Surface wrt Volume wrt Face Surface ID(s) Direction Forward Reverse	O wrt Hex O wrt Tet O wrt Tri	
ID(s) 1 With Respect To wrt Surface wrt Volume wrt Face Surface ID(s) Direction Forward Reverse Forward/Revers	O wrt Hex O wrt Tet O wrt Tri	
ID(s) 1 With Respect To wrt Surface wrt Volume wrt Face Surface ID(s) Direction Forward Reverse Forward/Reverse Reset All Sidese	O wrt Hex O wrt Tet O wrt Tri all	et

- Or -Sideset 2 add curve 1 Sideset 2 name "Top of Block"



Split disc curve

0110 001001101001011110100110





- Or -Partition create curve 5 node 15 0110 0010010101001011110100110

Create side sets bottom of disc





- OC -Sideset 3 add curve 6 Sideset 3 name "Bottom of Disc"



0 2

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Build is finished when Trelis> prompt returns.

Select "Simulation Cards" tab in bottom left

Command Panel	Flex Workflow	Simulation Cards	

The simulation cards tab should now look like this:

coreform

10001 - basis	uspline		
20001 - basis	uspline		
🔲 1 - basis uspli	ne tensor product		
🔲 1 - domain_sp	ine_solid		
🔲 1 - patch			
1 - subdomain	_elems - Pressure	Vessel	
2 - subdomain	_elems - Symmetr	y Boundary	
subdomain version	_elems - Pressunz	ed surface	



Build U-spline

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Command Line	0 🗙
Finished Command: set node constraint smart	
Finished Command: undo on	
Trelis>build uspline from mesh draw	
Script Command Error History	

Build is finished when Trelis> prompt returns.





View simulation cards

Select "Simulation Cards" tab in bottom right

Command Panel	Flex Workflow	Simulation Cards	

Simulation Cards	0 ×
🔲 1 - basis_uspline	
🔲 2 - basis_uspline	
1 - domain_spline_solid	
2 - domain_spline_solid	
🔲 1 - patch	
🔲 2 - patch	
🔲 1 - subdomain_elems - Disc	
2 - subdomain_elems - Block	
3 - subdomain_elems - Bottom of Block	
4 - subdomain_elems - Top of Block	
5 - subdomain_elems - Bottom of Disc	
version	



Creating Cards

<u>0110 001001101001011110100110</u>





Material definition

desc	Material for b	ooth parts
material_id	1	
• E		1000
 E_time_dependent_f 	function_temporal_id	~
E_temperature_deperature_deperature_deperature	endent_function_temporal	_id
าน	0.3	
nu	0.3	

material_yield_surface_properties_von_mises			
desc	Material for both parts		
material_yield_surface_properties_id	1		
К	0		
yield_stress	2		
saturation_stress			
saturation_exponent	0		



Element Formulation

formulation_solid		
desc	Solid formulation for both parts	
formulation_id	1	
formulation_type	solid_2d 🛶	
quadrature	QP1 -	
material_id	1 - Material for both parts 🖛	

Parts

part	
desc	Disc
part_id	1
formulation_id	1 - Solid formulation for both parts 🖛 🔹
subdomain_ids	💠 🗶
1 - Disc	
temperature_id	

part	
desc	Block
part_id	2
formulation_id	1 - Solid formulation for both parts 🖛
subdomain_ids	🕂 🗶
2 - Block	
temperature_id	

coreform



Control Timestep

control_timestep_quasistatic_pc		
desc		
control_timestep_id	1	
max_corrector_step_n	10 🦛	
newton_tol_abs	1e-32	
newton_tol_rel	1e-06	
delta_tol_abs	1e-32	
delta_tol_rel	0.001	
✓ line_search ←		
line_search_tol	0.5	
line_search_max_iterations	10	



Problem and Control Model

problem		
desc	Deep rolling contact	
problem_id	1	
part_ids		+ X
1 - Disc		
2 - Block		
control timestep id	d 1 - control timestep quasistatic pc 룾	•
coupled_problems		
control_linear_solv	er	
control_linear_solvo	er command_line	

control_model				
desc				
control_time				
initial_time_step 0.01 termination_time 9 adaptive_timestep iteration_optimal iteration_window growth_factor reduction_factor delta_t_min				
delta_t_max				
control_problem □ enable_parent_basis √ enable_output	1 - Deep rolling contact 🔷 🔹			
enable_output_restart				
utput_restart_file_name_prefix result				
output_restart_delta_t	0			
output_restart_delta_time_step	1			
output_restart_based_on_time	e_step			



Downward displacement of disc

function_temporal_linear_interpolation		subdomain_nodal_dva						
desc	Downward displacement of disc	desc	Downward displacement of disc					
function_temporal_id	1	subdomain_nodal_value_id	1	1.0				
birth	0	subdomain_id	1 - Disc 🗸 🗸	1.0				
death	1000000000	dva_type	DISPLACEMENT 🔷	Ê 0.8				
tol	1e-10	UX	0	<u>ٿ</u>				
graph		✓ UY	-0.075	0.0				
	t f(t)		0	ຍຼັ 0.4				
1 0	0	RX	0	spla				
2 1	1		0	ā ^{0.2}				
3 10	1	L RZ		0.0				
		 function_temporal_id function_spatial_temp 	1 - Downward displacement of disc voral_id	Ō	2	4 ó Time (s)	8	10



Right displacement of disc

function_temporal	linear_interpolation					
desc	Right displacement of	f disc	subdomain_nodal_dva			
function_temporal_id	2		desc subdomain_nodal_value_i	Right displacment of Disc	<u><u><u></u></u></u>	
birth	0		subdomain_id	1 - Disc 🗸 🗸	Ē	
death	1000000000		dva_type			
tol	1e-10			0.075	len	
graph		+ >		0	E 4	
	t	f(t)	RX	0		
1 0		0	RY	0	ds 21	
2 1		0	RZ	0		
3 2		1	function_temporal_ie	d 2 - Right displacement of disc *	0.0	2.5 5.0 7.5 10.0
4 10		9 🔶	O function_spatial_tem	nporal_id		Time (s)
					1	



Clamp bottom of block

function_temporal_constant			
desc	Always 1		
function_temporal_id	3		
value	1		
birth	0		
death	100000000		
tol	le-10		

subdomain_nodal_dva	
desc	Clamp bottom of block
subdomain_nodal_value_id	3
subdomain_id	3 - Bottom of Block
dva_type	DISPLACEMENT 🖛
V UX	0
V UY	0 👄
UZ	0
RX	0
RY	0
RZ	0
 function_temporal_id function_spatial_temp 	oral_id



Problem boundary condition

problem_boundary_condition				
desc	Deep rolling boundary conditions			
problem_id	1 - Deep rolling contact 🔶 👻			
subdomain_nodal_value_ids				
1 - Downward displacement	of disc			
2 - Right displacment of Dise				
3 - Clamp bottom of block	—			



Set up contact

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formulation_contact		contact_surface		problem_contact_surface			
desc	Disc to block	desc	Disc to block	desc	Deep rolling - disc to block		
formulation_id	2	contact_surface_id	1	problem_id	1 - Deep rolling contact 🔷 🔹		
formulation_type	contact_gpts_2d 🗸 🗸	formulation id	2 - Disc to block	contact_surface_ids	+ ×		
penalty	100000	- slave subdomain id	4 - Top of Block	1 - Disc to block	—		
use_soft_contact		master subdomain id	E Battom of Dire				
gap_tolerance	1e-06	master_subdomain_id					
nearest_point_tolerance	1e-12						
nearest_point_max_iteration_n	10						
master_seed_points_n	10						
search_sphere_tolerance	0.1						
search_cone_tolerance	0						
master_seeds	QP1 ·						
slave_quadrature	QP1 ·						

coreform

Output

ir 🦉

desc	Displacement and Strain	
subdomain_output_id		
subdomain_ids		4 X
1 - Disc		
2 - Block		
function_temporal_id	3 - Always 1	•
field_types		
✓ displacement <		
velocity		
acceleration		
strain		
stress		
vm_stress		
pressure		
contact pressure		
contact_gap		
⊂ contact_gap ✓ eps		
contact_gap ✓ eps ←		
contact_gap ✓ eps ← ← ← ← ← ← ← ← ← ← ← ← ← ← ← ← ← ← ←		
 contact_gap eps effective_plastic_work effective_driving_energy phase_field 		
 contact_gap eps effective_plastic_work effective_driving_energy phase_field phase_field_rate 		
 contact_gap eps effective_plastic_work effective_driving_energy phase_field phase_field_rate weight 		
 contact_gap eps effective_plastic_work effective_driving_energy phase_field phase_field_rate weight 		
 contact_gap eps effective_plastic_work effective_driving_energy phase_field phase_field_rate weight delta_time 0.1 		
<pre>contact_gap </pre> <pre>ers </pre> effective_plastic_work effective_driving_energy phase_field phase_field_rate weight • delta_time 0.1 • delta_step		
 contact_gap eps effective_plastic_work effective_driving_energy phase_field phase_field_rate weight delta_time 0.1 delta_step file_name_prefix 	results	
 contact_gap contact_gap eps effective_plastic_work effective_driving_energy phase_field phase_field_rate weight delta_time 0.1 delta_step file_name_prefix file type 	results	
 contact_gap eps effective_plastic_work effective_driving_energy phase_field phase_field_rate weight delta_time 0.1 delta_step file_name_prefix file_type sample type 	results vtk BEZIER	
 contact_gap contact_gap eps effective_plastic_work effective_driving_energy phase_field phase_field_rate weight delta_time 0.1 delta_step file_name_prefix file_type sample_type cacha basis evals 	results vtk BEZIER	
 contact_gap eps effective_plastic_work effective_driving_energy phase_field phase_field_rate weight delta_time 0.1 delta_step file_name_prefix file_type sample_type cache_basis_evals include elem outline 	results vtk BEZIER	
 contact_gap veps effective_plastic_work effective_driving_energy phase_field phase_field_rate weight delta_time 0.1 delta_step file_name_prefix file_type sample_type cache_basis_evals include_elem_outlines solution type 	results vtk BEZIER	

subdomain output field



Run Simulation



8	Save c	ards and run analysis						
Look in:	/home/mitch/WIP/short.	g/DeepRollingComplete	- G	0	0	R	::	
Computer WIP mitch	Name				•	Size		T
File name:	DeepRollingComplete						Sav	/e
Files of type:	*.json				Ŧ] 🗙	Can	ce



Run Simulation

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O	ancel Job 🕅 Post Process 🕅 🕅 Cle	
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+ r/s boni • ws Boni starb.		
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> Checking residual for convergence 		
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538766		
47647-007 47142-007		
www.skanneling the stiftens matrix.		
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View Results

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	Cancel Job	Nost Process	💐 Close
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August In provides 1 109.2770%) The integration (uses: 33.5.5.7%) (19.2770%) The integration (uses: 33.5.6%) (19.2770%) Control integration (uses: 33.5.7%) (18.2770%) Filed integration (uses: 33.5.7%) (18.2770%			



Set Post Process Executable

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Tools -> Options -> Post Meshing



View Results

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Properties					(記)
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Properties	(results.pvd)				
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Warp By Vector

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• Instand	


Tessellate

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Filters -> Search -> Tessellate Then click apply



View Displacements

8 -	- 0																_	_						_		
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Play Displacments

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You may need to adjust the color scaling



View eps

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You may need to adjust the color scaling



Problem 3: Flex Cable

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This is a specific industry application that has been proven to be difficult to simulate using traditional FEA. It consists of a flexible cable made up of copper traces surrounded by adhesive and encased in Kapton. The simulation has 2 stages: first cable is bent into a U shape and then a heat load is applied.

A custom workflow has been created to simulate this problem. The first step is to create a U-spline of the cable cross section. The cross section is then extruded to form a 3D solid and the boundary conditions are applied. The extrusion and application of boundary conditions are automated using a Python script



Learning Objectives

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Tutorial participants will learn:

- A custom workflow created for a specific customer application
- How to import multiple cards to add to your simulation



Import geometry

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File->Import

8	Import File				
Look in:	📄 /home/mitch/WIP/Flex 1xample Files/Step Files 🔹 🧿 🔘	0	ø	::	Ξ
Compute	r Name ComplexConforming.stp SimpleConforming.stp SimpleNonComforming.stp	•	Size 95 88 28	KiB KiB	Typ stp stp
					•
Files of type:	STEP (*.stp *.STP *.step *.STEP)	v) X	Ope Can	en cel

Accept import default options

- or-

Import step "<path>" heal

This file is available at https://coreform.com/shortcourse/FlexCable/SimpleConforming.stp



Imprint and merge

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- or -

Imprint all Merge all



Set mesh size then mesh surface



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Command Panel		C 🗙
	Mode - Mesh	
	🚴 🗊 🌍 🤜 🔤 💽	
	Entity - Surface	
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	☆ 📣 ¤ 🛆 +	
	蒸 III	
	Action - Intervals	
	🖬 🔛 🤋 🥟 🍄 🛪	
Approximate Size		•
Select Surfaces		
all		
Approximate Size 5		
✓ Preview		
		Apply Size
✔ Check For Overlapping S	urfaces	
✔ Apply Size Before Meshir	ng	
(j) ?		Mesh

- or -

surface all size 5 Mesh surface all



Setup Trelis Blocks - Copper

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- or -

Block 1 add surface 1 2 3 Block 1 name "Copper"



Setup Trelis Blocks - Adhesive

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Command Panel

Create block

Create block		
Block ID 2		
lock Name Adhesive		
elect		
O Group	⊖ Tet	
🔿 Volume	○ Face	
Surface	🔿 Tri	
O Curve	🔘 Edge	
○ Vertex	🔿 Node	
⊖ Hex		
ID(s) 6 4		
Allow Blocks to Contain Duplic	ate Elements	
Reset All Blocks		Reset
(i) 🥠		Apply

Block 2 add surface 6 4 Block 2 name "adhesive"

- or -



Setup Trelis Blocks - Kapton

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- Or -Block 3 add surface 5 7 8 Block 3 name "kapton"







Imprint mesh onto geometry

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Flex Workflow	Ø×
Steps - Imprint Mesh	
Imprint Mesh onto Body all	
✓ Stitch all bodies	
Compress IDs	
Keep the Mesh	
	Apply

- Or -Imprint mesh onto body all Stitch body all compress



Build U-spline

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Flex Workflow		0 8
Steps - U-spline Commands		
Commands - Build U-spline		
۵ 🔌 🥐		
Body Id(s)	all	
Degree	2	
Default Continuity	1	
Domain Type	solid	•
✓ Convert Blocks to Subdomains		
✔ Crease Subdomain Boundaries		
✔ Draw U-spline		
Show Continuity		
\bigcirc		Build U-spline

- Or -Build uspline body all p 2 c 1 domain "solid" draw



View simulation cards

Simulation Cards		0 🗙
1 - basis_uspline		
1 - domain_spline_solid		
1 - patch		
2 - subdomain_elems - Adhesive		
3 - subdomain_elems - Kapton		
version		
Command Panel Flex Workflow	Simulation Cards	

Coreform

Create card





Add material for adhesive

function_temporal_	linear_interpola	tion					
desc	Adhesive Modul	us 🖛					
function_temporal_id	1						
birth	70						
death	160 🗲	160 🖛					
tol	1e-10						
graph			+ X				
t			f(t)				
1 70		689					
2 100		0.689					
3 160		0.6					

material_isotropic_elastoplas	stic
desc	Adhesive
material_id	1
○ E	
O E_time_dependent_function	n_temporal_id
• E_temperature_dependent	_function_temporal_id 1 - Adhesive modulus
nu	0.34
rho	1.07e-06
thermal_expansion	5e-05
None	
<pre>O function_temporal_id</pre>	
0	
К	
yield_stress	
saturation_stress	
saturation_exponent	
plastic_work_threshold	0
effective_plastic_work_measure	plastic_work
yield_type	J2

Coreform

Add adhesive formulation and part

id
Adhesive
1
solid_3d 🔶
QP1 •
1 - Adhesvie

10100110

part		
desc	Adhesive	
part_id	1	
formulation_id	1 - Adhesive	
subdomain_ids		4)
2 - Adhesive	-	



Import cards for copper and kapton

Simulation Cards	ð X	×	Open JSON Cards file	
		Look in: 📄 /ho	me/mitch/WIP/shorte_feb2020/FlexProblem	0 0 0 🛤 🗉 🗏
 1 - basis_uspline 1 - domain_spline_solid 1 - patch 1 - subdomain_elems - Copper 2 - subdomain_elems - Adhesive 3 - subdomain_elems - Kapton version 		Computer WIP	Name 2dTrial FromChris Images ProblemDefinition Trial4 Trial5 Trial6 TrialRun2 TrialRun2 TrialRun3 CopperKaptonCards.json DemoMatt_R360.json NewNameTest_R10.json PreScript.json Crother Scient	▼ Size T F F F F F F F F F F F F F
		File <u>n</u> ame: Copper Files of type: JSON f	rKaptonCards.json ile (*.json)	✓ Cancel



Associate imported parts with correct subdomain

part		part		
desc Copper		desc	Kapton	
part_id 2		part_id	З	
formulation_id 2 - Copper	•	formulation_i	id 3 - Kapton	•
subdomain_ids	🗣 🗶	subdomain_i	ds	+ ×
1 - Copper		3 - Kapton	—	
temperature_id		temperature	_id	•



Add output cards

function_temporal_constant			
desc	Always 1		
function_temporal_id	2		
value	1		
birth	0		
death	1000000000		
tol	le-10		

subdomain_output_field desc subdomain_output_id subdomain_ids 1 - Copper 2 - Adhesive	
<pre>unction_temporal_id field_types velocity acceleration strain strain stress pressure contact_pressure contact_gap eps effective_plastic_work effective_driving_energy phase_field_rate weight</pre>	2 - Always 1
delta_time delta_step d	results Vtk * BEZIER ()
bezier_projection_relative_continuity	



Export Flex simulation file

Flex Workflow	Ø
Steps - Export Flex Simulation	
1 🖉 🗢 💰	
Bend radii	360
Length of e	extruded cable is set to bend radius * pi
Element size along cable length	50
Element degree along cable length	2
Element continuity along cable length	1
Starting temperature	70
Max temperature	150
Rate of temperature increase	4
Positive X moment	True
Body ID of source geometry	1
(Optional) User-defined variable	
Output file name itch/WIP/shortcourse	feb2020/FlexProblem/ProblemDefinition/ScriptOutput] Browse
(Optional) User-defined python function	·
l	Browse
\bigcirc	Export Input File(s
	Export input lines

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When the users clicks "Export Input File(s)", the simulation cards and the parameters entered into this dialog are input into a python script that will:

- Add a patch_operation_extrude card that will turn the 2d cross section into a 3d solid model*
- Add boundary conditions
- Add other cards required for the simulation (control_model, problem etc)
- Export this modified solid simulation input file that is ready to run in the solver

*Visualization of 3D U-splines is not currently supported in Trelis, so it is not possible to view the solid flex cable model



Import Flex simulation cards

5	Simulation Cards	ð	2
		5	J
	1 - basis_uspline		
	Control model		
	1 - control time integration generalized alpha		
	1 - control_timestep_implicit_dynamic_2nd_order		
	1 - domain_spline_solid		
	1 - formulation_solid - Adhesive		
	2 - formulation_solid - Copper		
	3 - formulation_solid - Kapton		
	1000 - function_spatial_temporal_vector_valued_6		
	2 - function_temporal_constant - Always 1		
	1 - function_temporal_linear_interpolation - Adhesive Modulus		
	2000 - function_temporal_linear_interpolation		
	1 - material_isotropic_elastoplastic - Adhesvie		
	2 - material_isotropic_elastoplastic - Kapton		
	3 - material_isotropic_elastoplastic - Copper		
	🔲 1 - part - Adhesive		
	2 - part - Copper		
	3 - part - Kapton		
	🔲 1 - patch		
	1001 - patch_operation_extrude		
	1 - problem		
	1 - problem_boundary_condition		
	1 - subdomain_elems - Copper		
	2 - subdomain_elems - Adhesive		
	3 - subdomain_elems - Kapton		
	1000 - subdomain_elems - z0		
	2000 - subdomain_elems - z1		
	1000 - subdomain_nodal_dva		
	2000 - subdomain_nodai_dva		
	1 - subdomain_output_field		
	1 - temperature		
	version .		