Optimization of Weld Line with Moldflow and Helius PFA

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Class summary

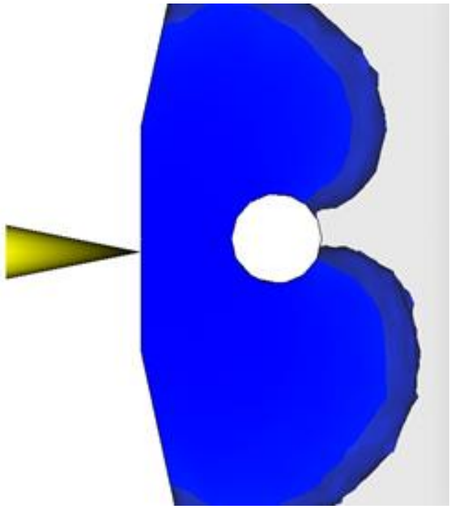
Weld lines can negatively affect part performance as well as aesthetics. In this class, show a case study demonstrating how to improve a weld line formation after an obstacle by using localized thickness changes and discuss new developments around weld line strength prediction.

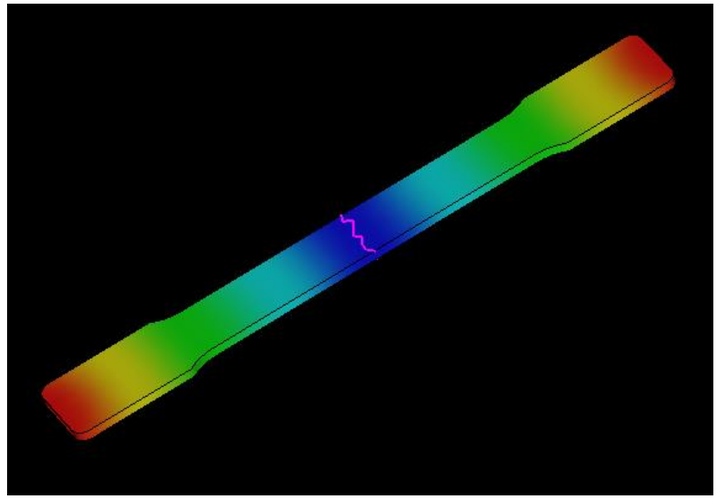
Key learning objectives

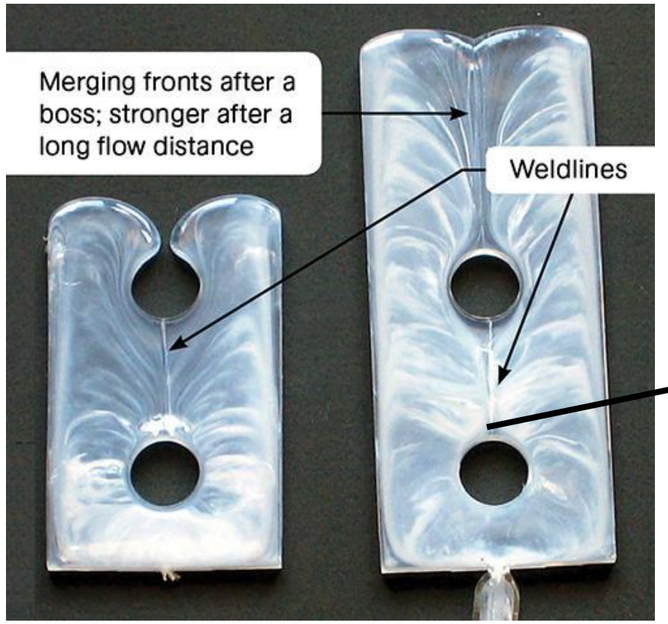
At the end of this class, you will be able to:

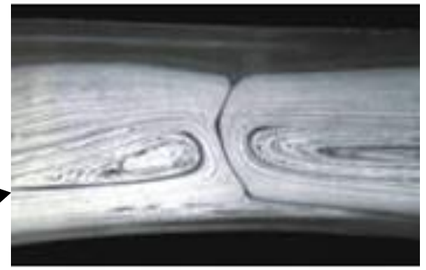
- Use Command Line API to automate Autodesk Moldflow Insight
- Understand DOE utilization
- Learn how to use Simulation Moldflow software more efficiently
- Learn how to use Helius PFA to predict weld line strength

Weld Lines









X-section View

Image Source: www.ptonline.com

Why We Should Care About Weld Lines…

Amorphous Resin	Reinf.	%	Filler	%	η % (UTS)
PC	-	-	-	-	99
PC	GF	10	-	-	90
PC	GF	30	-	-	65
PC	GF	40	-	-	55
PC	-	-	Milled Gl	30	92
PC	GF	30	PTFE	15	60
SAN	-	-	-	-	80
SAN	GF	30	-	-	40
SAN	GF	30	Flame Ret	10	45
PSU	-	-	-	-	100
PSU	GF	30	-	-	62

Crystalline Resin	Reinf.	%	Filler	%	η % (UTS)
PA66	-	-	-	-	97
PA66	GF	10	-	-	93
PA66	GF	30	-	-	61
PA66	GF	40	-	-	52
PA66	LGF	30	-	-	58
PA66	CF	30	-	-	47
PA66	-	-	Glass Bd	30	95
PP	-	-	-	-	86
PP	GF	30	-	-	34
PPS	-	-	-	-	83
PPS	GF	40	-	-	20

Reference: Cloud et al., “Reinforced Thermoplastics: Understanding Weld-Line Integrity”, Plastics Technology, 22, 48, (1976).

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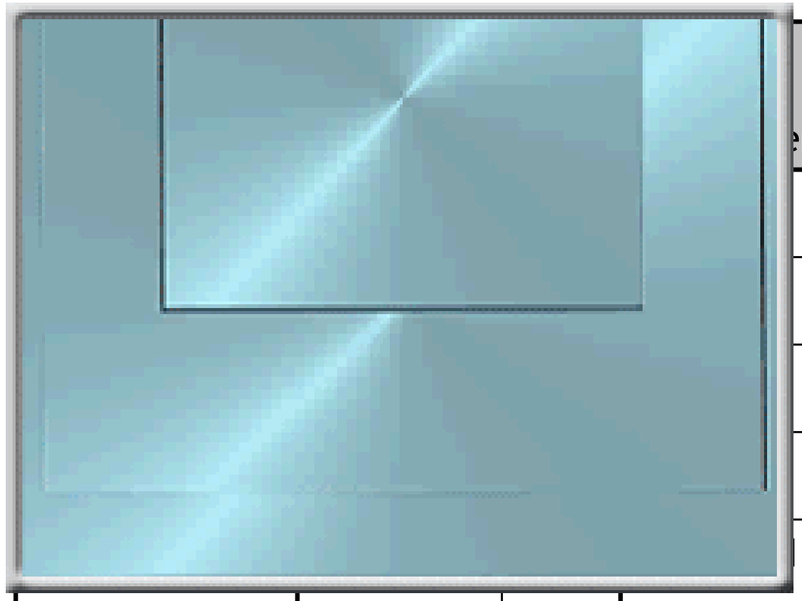

			er	%	η % (UTS)
				-	99
				-	90
				-	65
				-	55
			l Gl	30	92
PC	GF	30	PTFE	15	60
SAN	-	-	-	-	80
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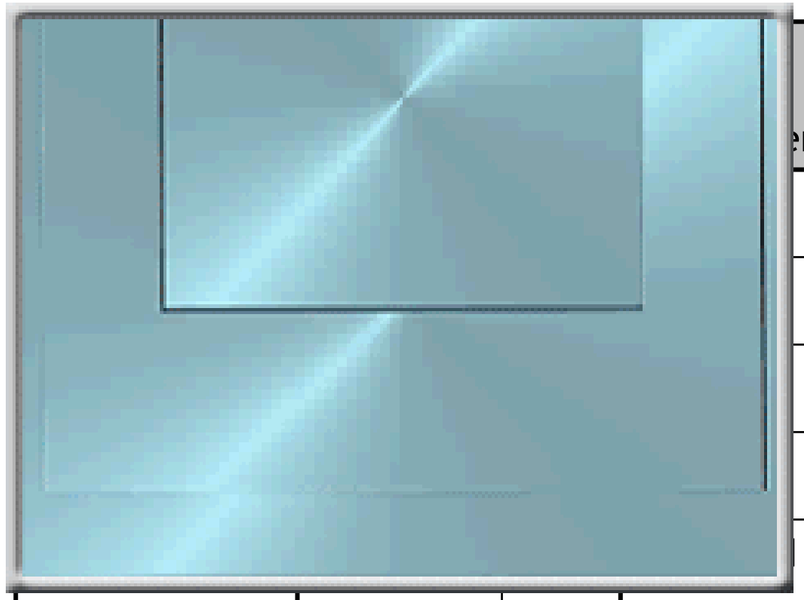

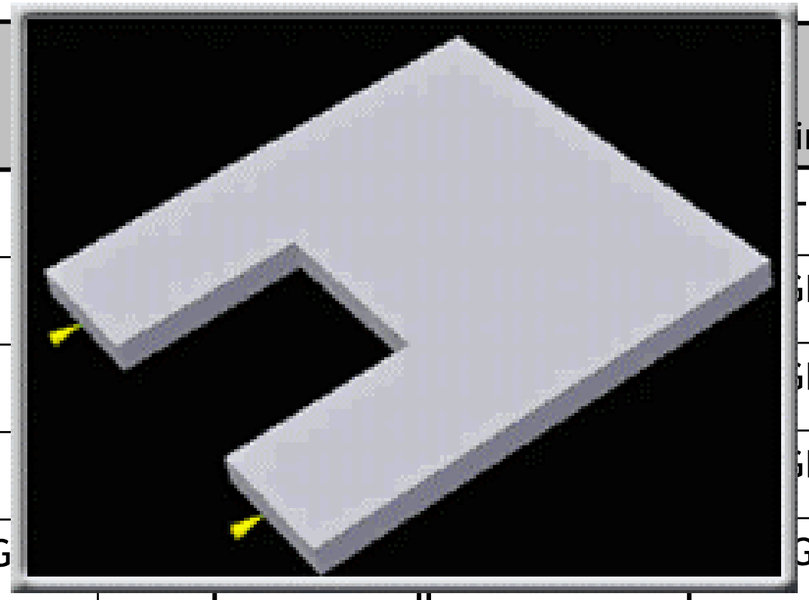

							inf.	%	Filler	%	η % (UTS)
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							GF	30	-	-	61
							GF	40	-	-	52
						G		GF	30	-	-	58
PC	GF	30	PTFE	15	60	PA66	CF	30	-	-	47
SAN	-	-	-	-	80	PA66	-	-	Glass Bd	30	95
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PSU	-	-	-	-	100	PPS	-	-	-	-	83
PSU	GF	30	-	-	62	PPS	GF	40	-	-	20

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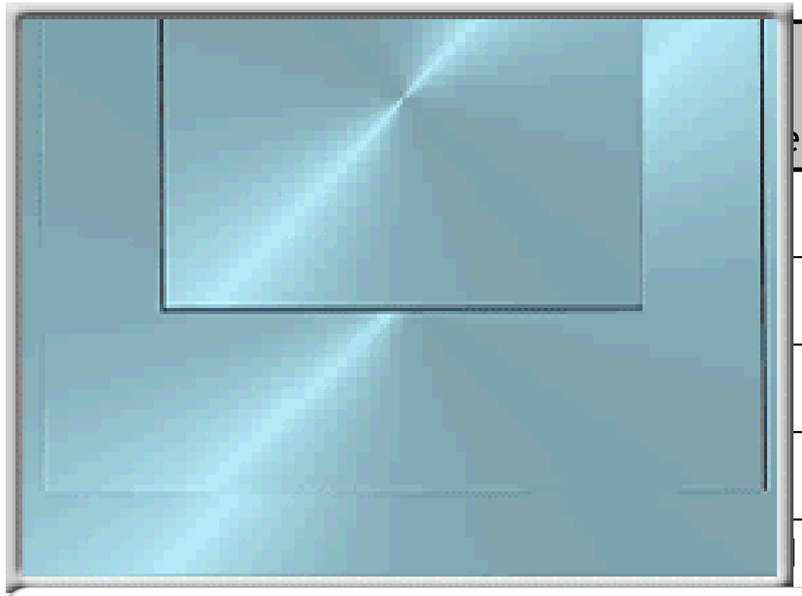
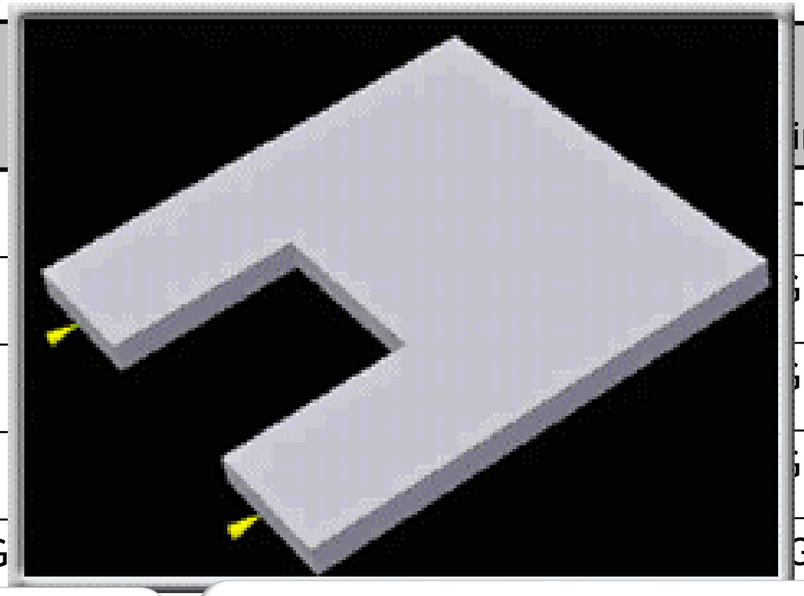
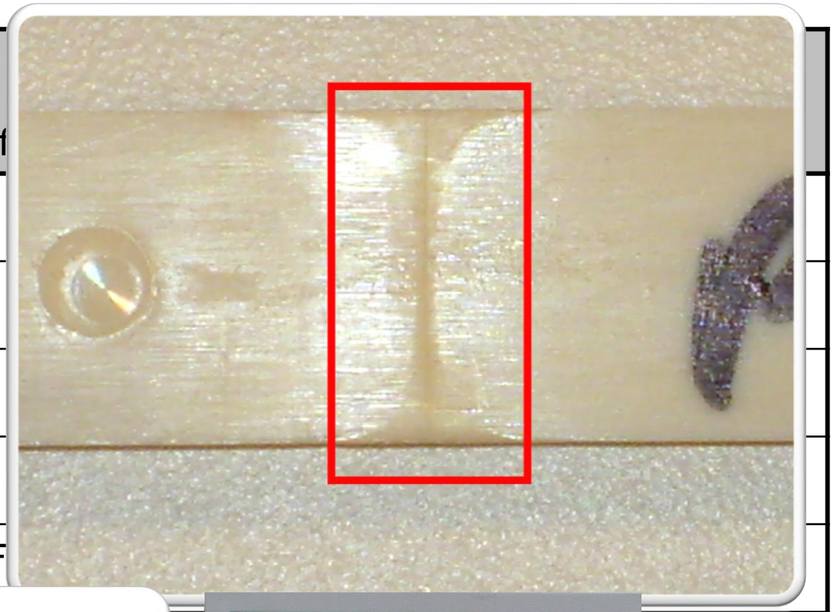
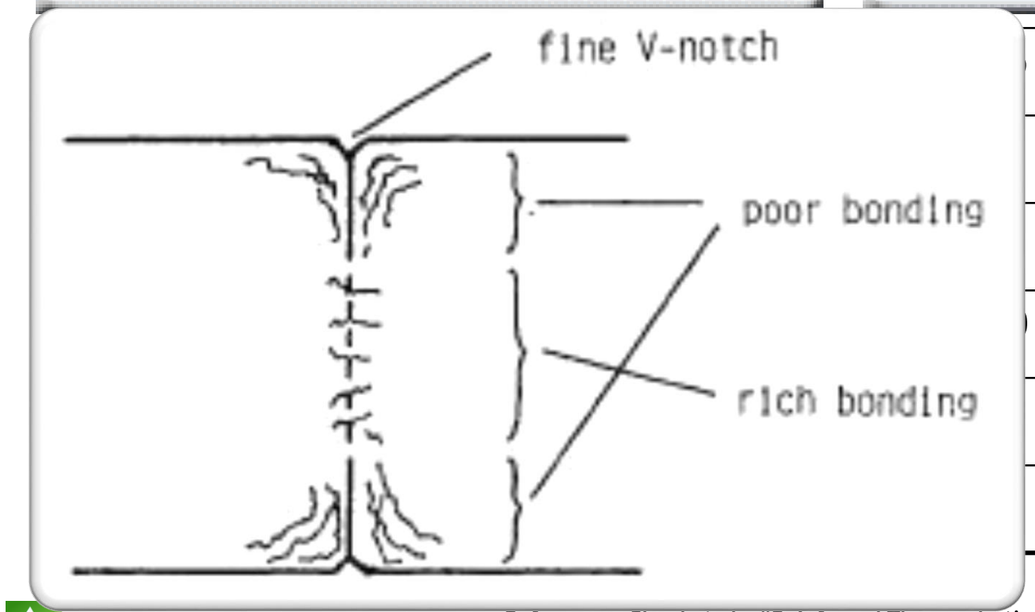
Why We Should Care About Weld Lines…









	47
	95
	86
	34
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	20

Reference: Cloud et al., "Reinforced Thermoplastics: Understanding Weld-Line Integrity", Plastics Technology, 22, 48, (1976).

The case

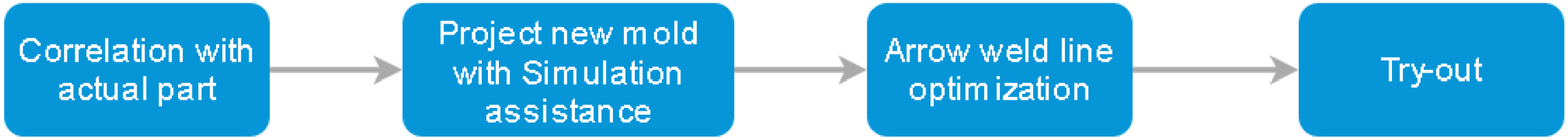
The case

- IP Cluster
- Aesthetic part
- The part is painted
- The main goal was:
  - Use simulation to improve the overall surface quality
  - Reduce weld line after arrow hole feature

The surfaces problem

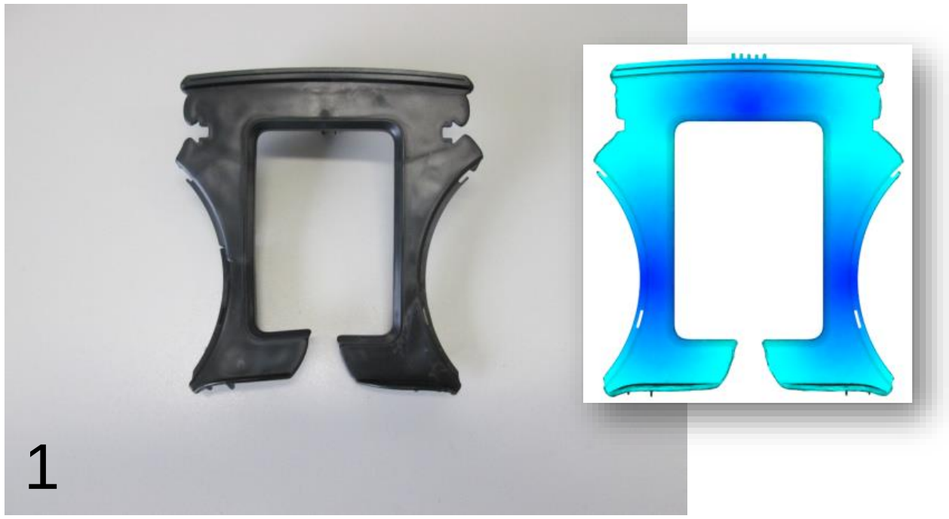
- The part has:
  - Marks on the top of the part
  - Weld line after arrows
- The part is painted

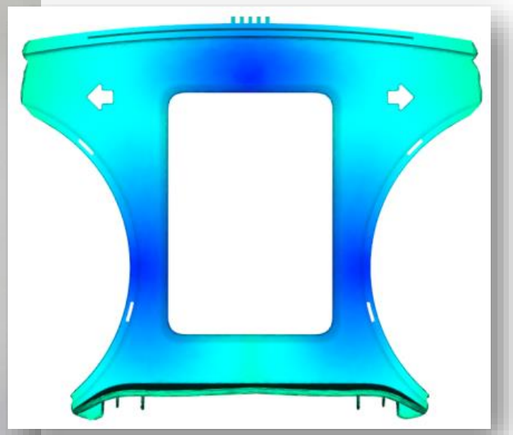
Methodology

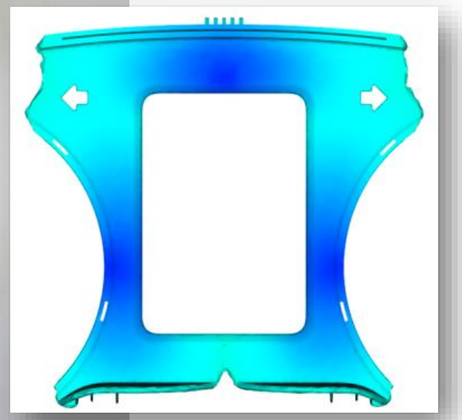


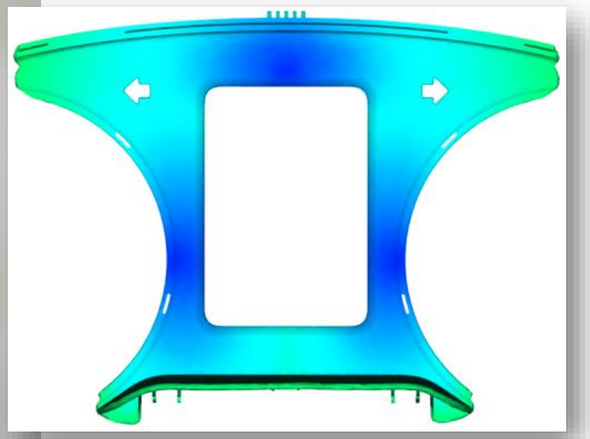
- First we need to guarantee the simulation results are similar to real part
- Second we worked on the overall quality
- Finally we worked on a specific issue

Correlation with actual part

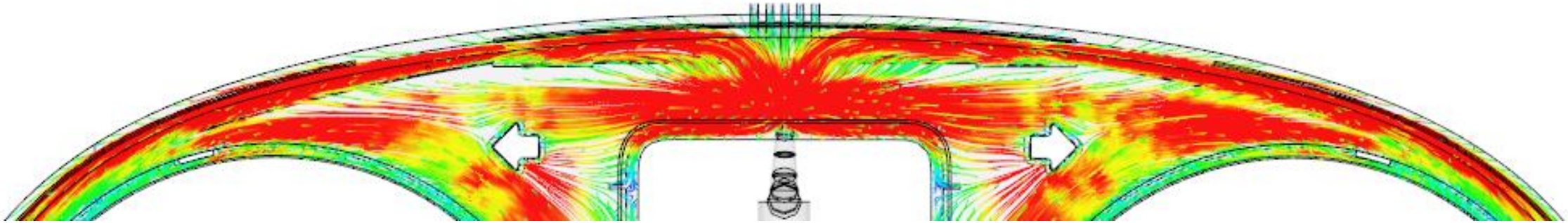






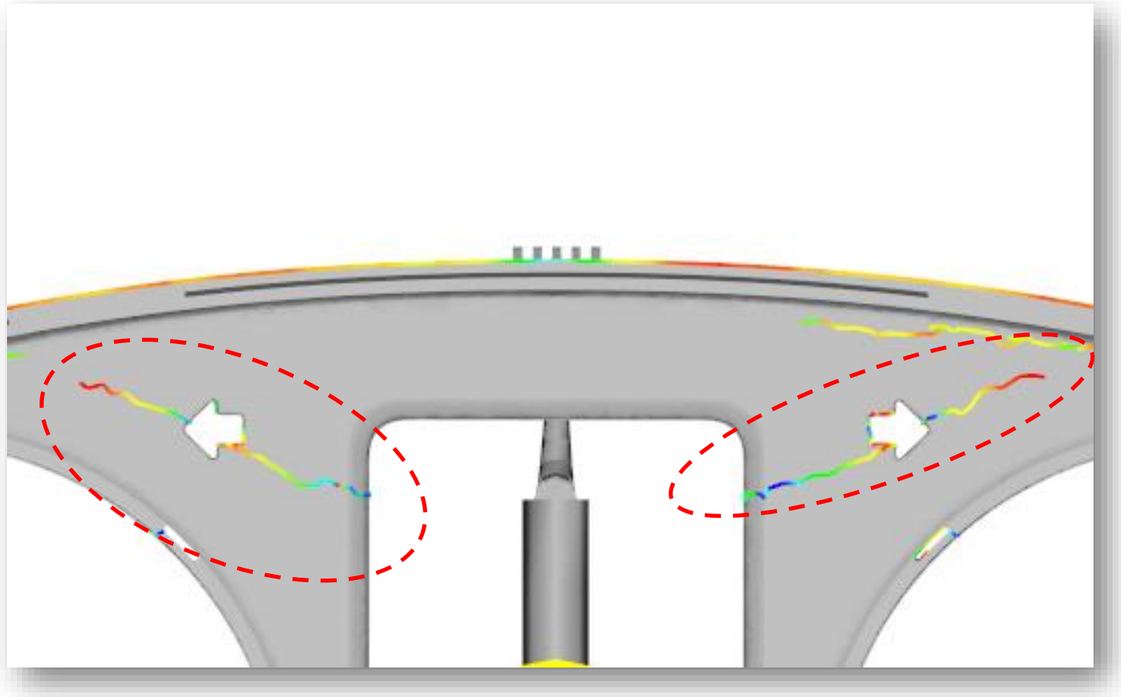


Correlation with actual part - Marks



We use path line with velocity and temperature results
Path line was introduced in Moldflow 2016

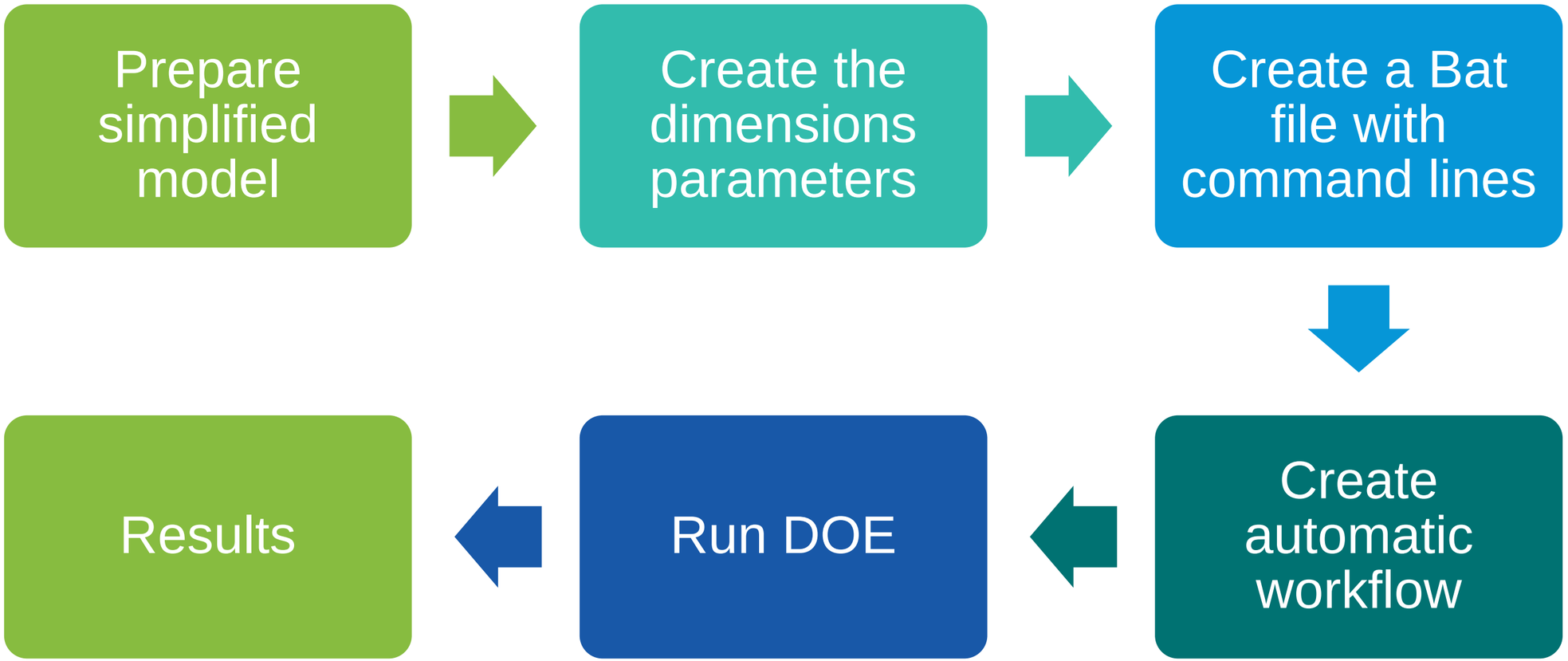
Correlation with actual part weld line



Optimization of weld line

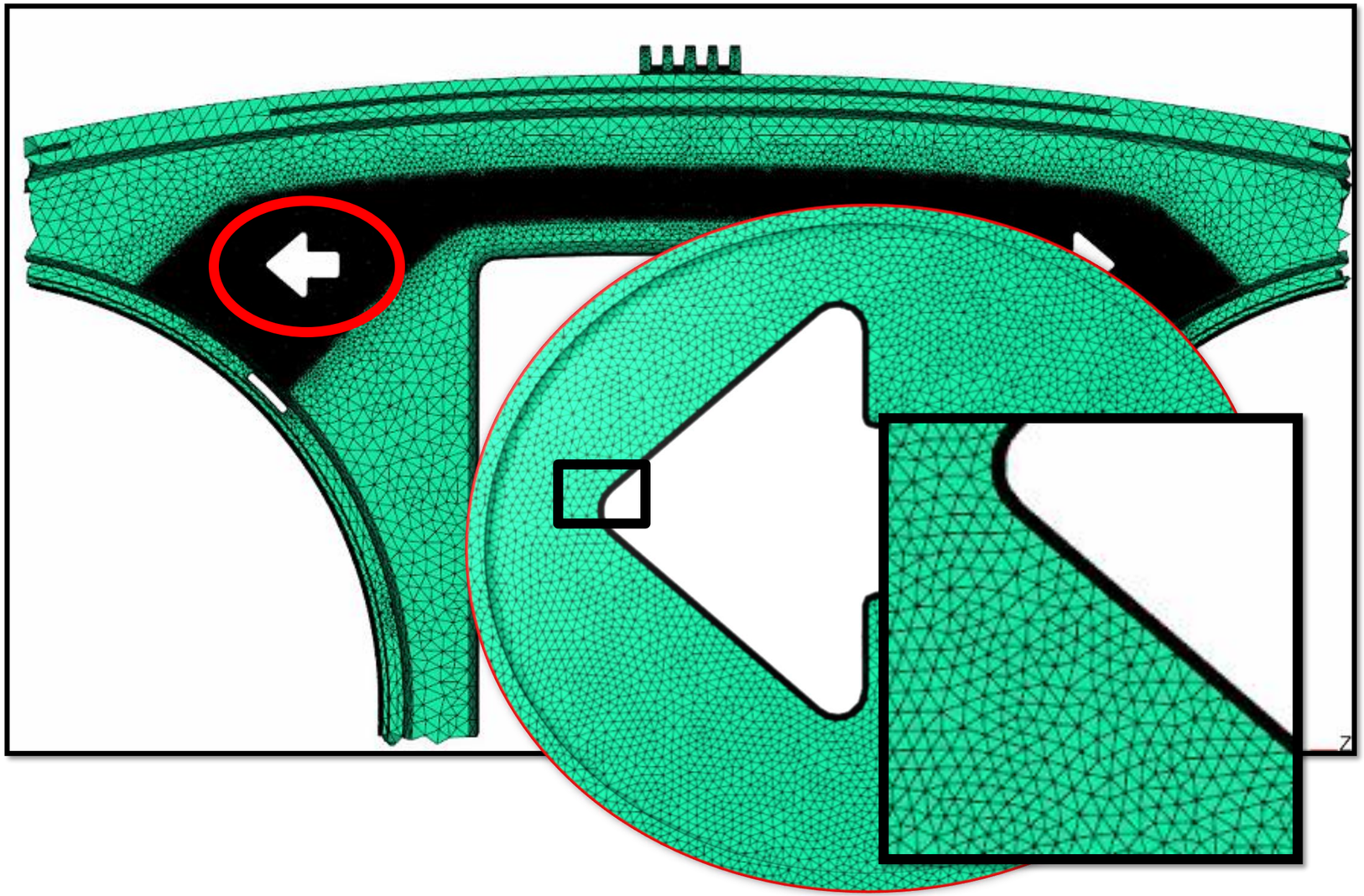
- The main goal:
  - By changing the thickness around the arrow we can change the flow pattern and reduce the length of the weld line

Optimization - Methodology

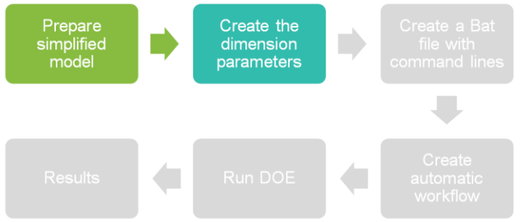


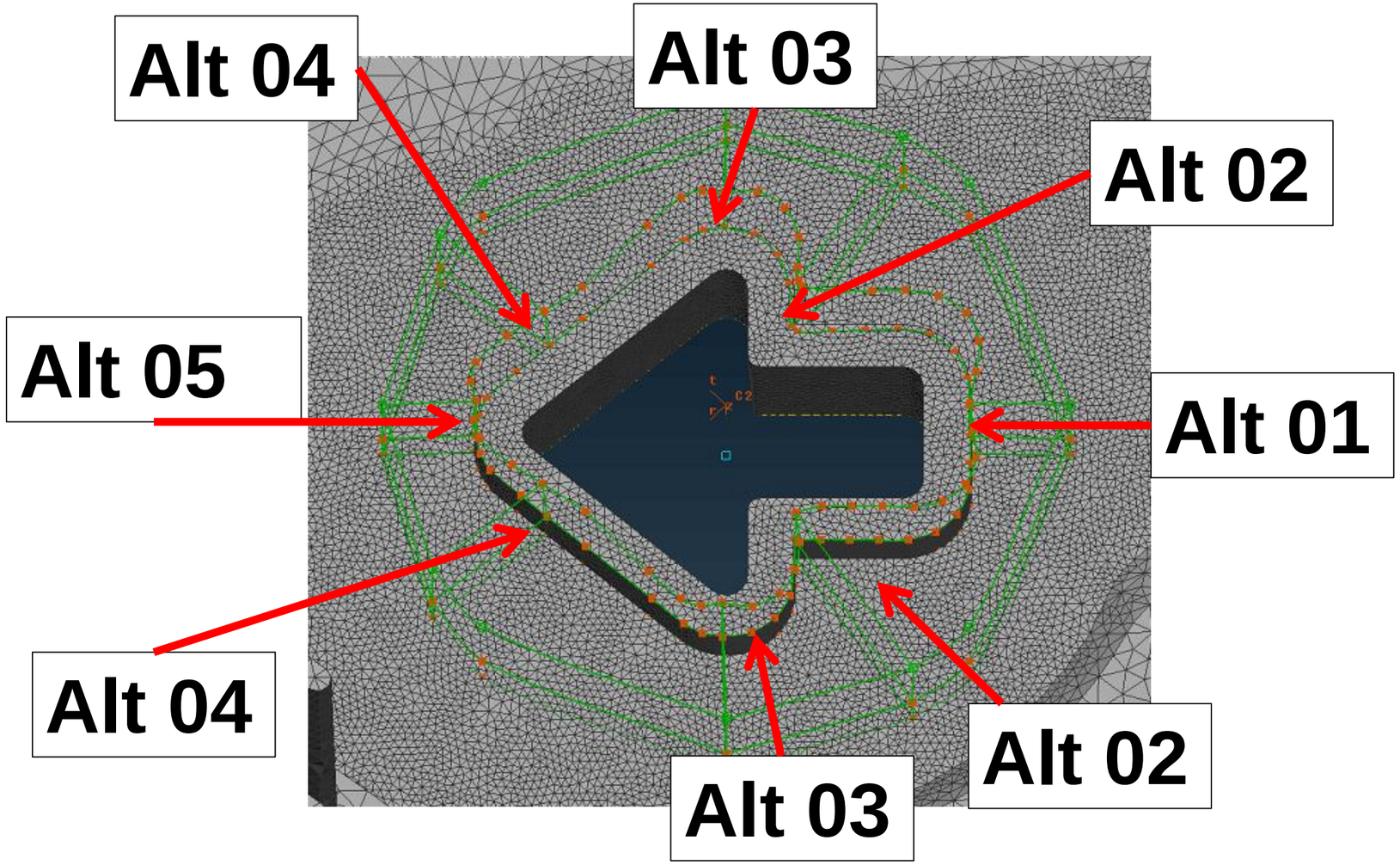
Prepare Simplified model

- Mesh result from ANSA



Create the dimension parameters





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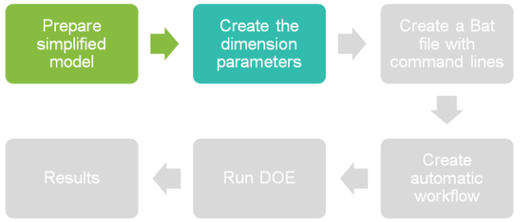
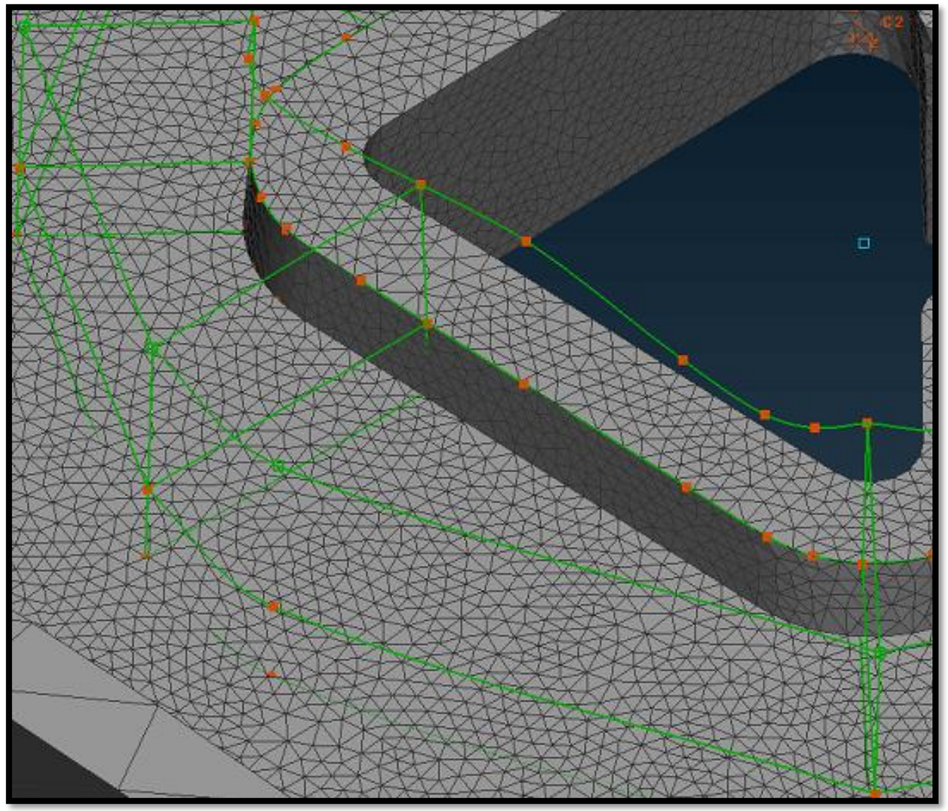
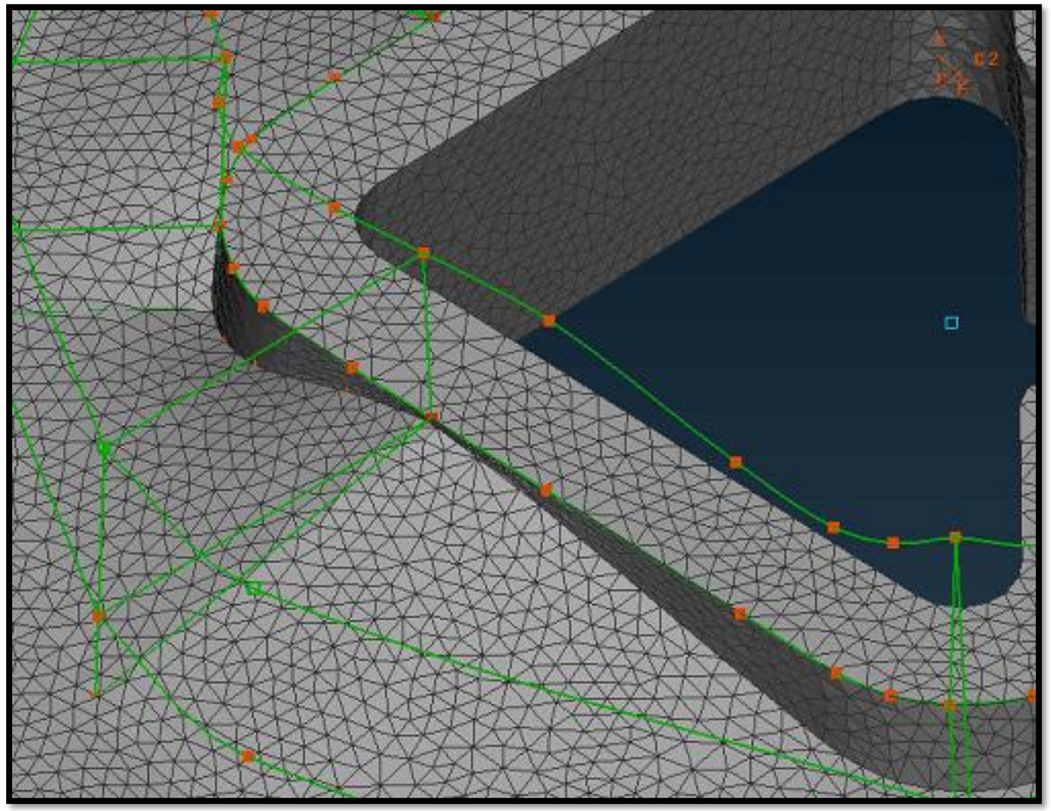
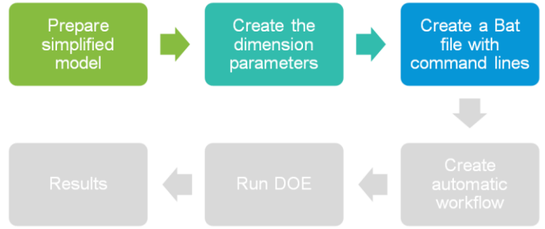






Create a Bat file with command lines

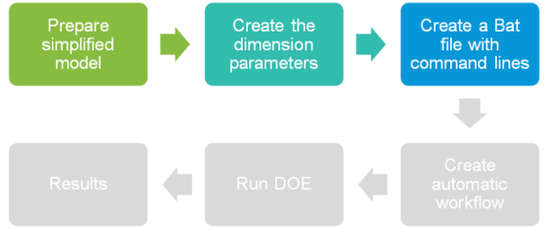


bat.bat - Bloco de notas

Arquivo Editar Formatar Exibir Ajuda

```
studymod isight.sdy isight_modDD.sdy studymod.xml
synmesh isight_modDD.sdy
studymod isight.sdy isight_mod3D.sdy studymod2.xml
runstudy isight_mod3D.sdy
studyrlt isight_mod3D.sdy -result 1732 -count
studyrlt isight_mod3D.sdy -exportoutput 1 -output log.txt -unit SI
```

Create a Bat file with command lines



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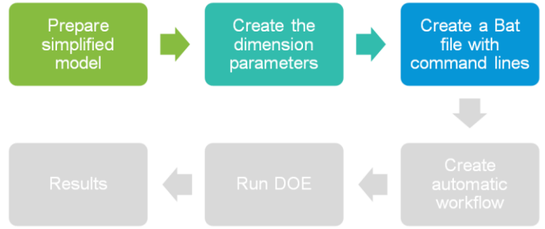

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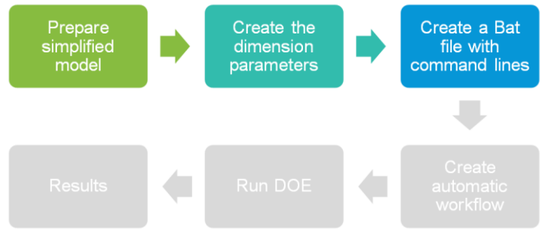

bat.bat - Bloco de notas

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```
studymod isight.sdy isight_modDD.sdy studymod.xml
synmesh isight_modDD.sdy
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runstudy isight_mod3D.sdy
studyrlt isight_mod3D.sdy -result 1732 -count
studyrlt isight_mod3D.sdy -exportoutput 1 -output log.txt -unit SI
```

isight_mod3D.val - Bloco de notas

Arquivo Editar Formatar Exibir Ajuda

```
243
```

log.txt - Bloco de notas

Arquivo Editar Formatar Exibir Ajuda

```
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(C)2009 2010 2011 2012 2013 2014
Portions of this software are covered by U.S. Patent Numbers 5,287,408 and 6,096,088.

Coupled 3D Flow Solver.

Version: ami2015-promethium_compile_windows-x64  (Build 14394-769)
         64-bit build

Analysis running on host: SMT-CAE-04
        Operating System: Windows 7 Service Pack 1
          Processor type: GenuineIntel Intel64 Family 6 Model 62 Stepping 4 ~3400 MHz
    Number of Processors: 12
   Total Physical Memory: 32682 MBytes


Analysis commenced at        Wed Jun 10 17:24:25 2015
Mesh and boundary conditions file name : isight_mod3D.udm
Results files core name                : isight_mod3d~3

   Core shift calculation : ON
--------------------------------------------------------------------------------

Solver Parameters:
==================

   Solver setup:
   -------------
   Solver                                        = Coupled 3D
   Solution type                                 = Stokes
   Simulate inertia effect                       = No
   Simulate gravity effect                       = No
   Gate diameter at cavity injection locations   = Automatic
```
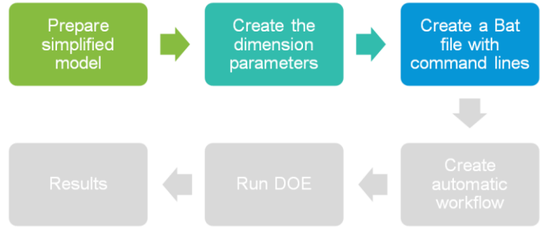

XML files



bat.bat - Bloco de notas

Arquivo Editar Formatar Exibir Ajuda

```
studymod isight.sdy isight_modDD.sdy studymod.xml
synmesh isight_modDD.sdy
studymod isight.sdy isight_mod3D.sdy studymod2.xml
```

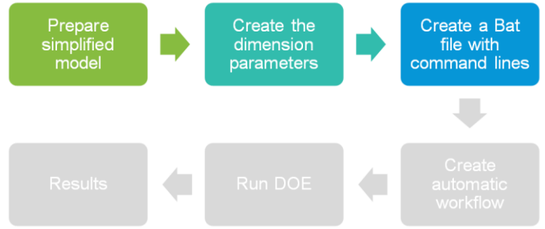
studymod.xml - Bloco de notas

Arquivo Editar Formatar Exibir Ajuda

```
<?xml version="1.0" encoding="utf-8"?>
<StudyMod title="Weldline" ver="1.00">
  <UnitSystem>Metric</UnitSystem>
  <Mesh cmd="Import">
    <MeshType>3D</MeshType>
    <MeshUnit>mm</MeshUnit>
    <FileName>modelosimplificado.udm</FileName>
  </Mesh>
  <Mesh cmd="Generate">
    <Option>
      <Name>Mesher3D</Name>
      <Value>AdvancingFront</Value>
    </Option>
  </Mesh>
  <BoundaryCondition>
    <InjLocation cmd="Create">
      <CoordinatesAbsolute>-0.180 -60.640 0.760</CoordinatesAbsolute>
      <TSetID>40000</TSetID>
      <Vector>0.0 0.0 -1.0</Vector>
    </InjLocation>
  </BoundaryCondition>
</StudyMod>
```

It will import Dual Domain model and it will set the mesh parameters

XML files



bat.bat - Bloco de notas

Arquivo Editar Formatar Exibir Ajuda

```
studymod isight.sdy isight_modDD.sdy studymod.xml
synmesh isight_modDD.sdy
studymod isight.sdy isight_mod3D.sdy studymod2.xml
```

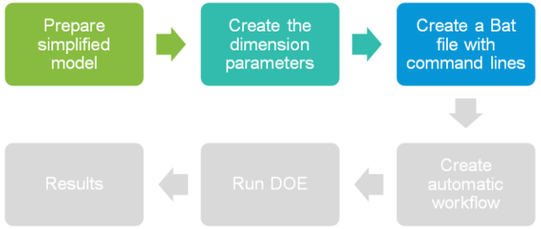
studymod.xml - Bloco de notas

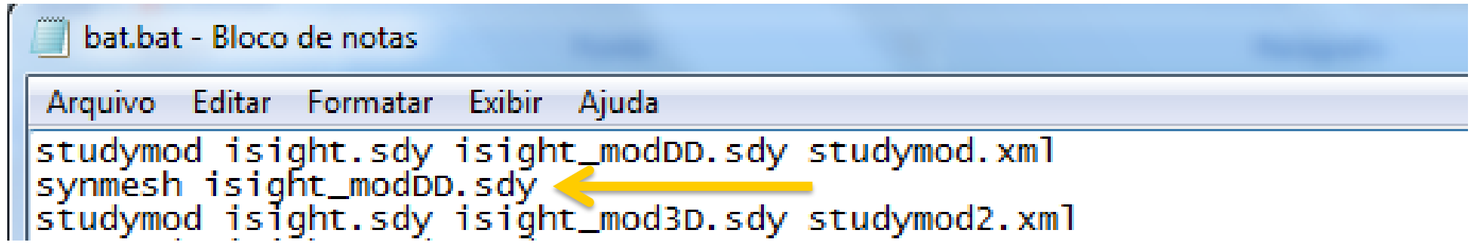
Arquivo Editar Formatar Exibir Ajuda

```
<?xml version="1.0" encoding="utf-8"?>
<StudyMod title="Weldline" ver="1.00">
  <UnitSystem>Metric</UnitSystem>
  <Mesh cmd="Import">
    <MeshType>3D</MeshType>
    <MeshUnit>mm</MeshUnit>
    <FileName>modelosimplificado.udm</FileName>
  </Mesh>
  <Mesh cmd="Generate">
    <Option>
      <Name>Mesher3D</Name>
      <Value>AdvancingFront</Value>
    </Option>
  </Mesh>
  <BoundaryCondition>
    <InjLocation cmd="Create">
      <CoordinatesAbsolute>-0.180 -60.640 0.760</CoordinatesAbsolute>
      <TSetID>40000</TSetID>
      <Vector>0.0 0.0 -1.0</Vector>
    </InjLocation>
  </BoundaryCondition>
</StudyMod>
```

Define the injection point

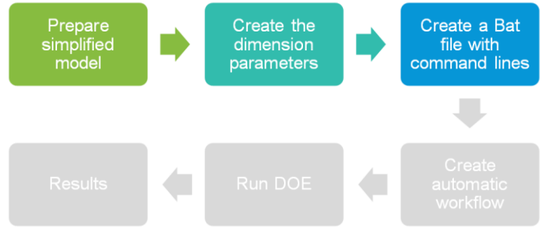
XML files





- Synmesh is the command that generates mesh
- It will generate the mesh in this sdy file
- There isn’t any documentation or information about it
- It works similar to runstudy command

XML files



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Arquivo Editar Formatar Exibir Ajuda

```
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synmesh isight_modDD.sdy
studymod isight.sdy isight_mod3D.sdy studymod2.xml
```

studymod2.xml - Bloco de notas

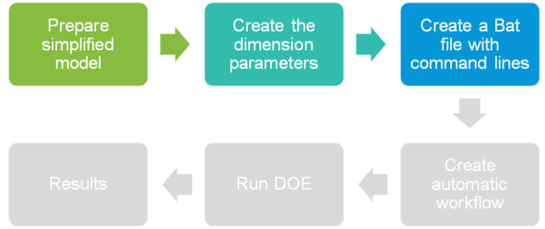
Arquivo Editar Formatar Exibir Ajuda

```
<?xml version="1.0" encoding="utf-8"?>
<StudyMod title="Weldline" ver="1.00">
  <UnitSystem>Metric</UnitSystem>
  <Mesh cmd="Import">
    <MeshType>3D</MeshType>
    <MeshUnit>mm</MeshUnit>
    <FileName>isight_modDD.udm</FileName>
  </Mesh>
</StudyMod>
```

- Import 3d mesh
- All parameters were set up before at “isight_mod3d.sdy”

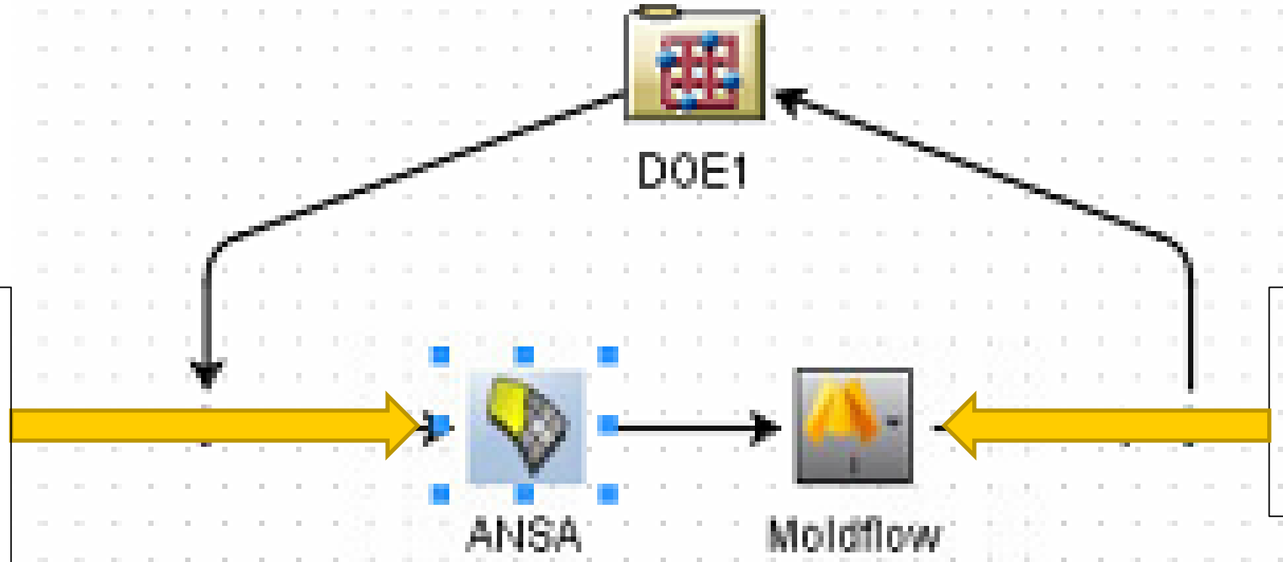
Now If I change the initial geometry, I only execute the bat file and the setup and mesh will be done automatically

Create automatic workflow



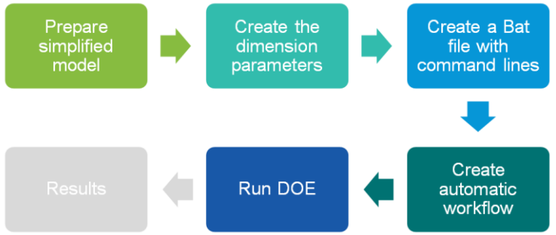
Using Isight program we did a workflow

ANSA changes the FEM model



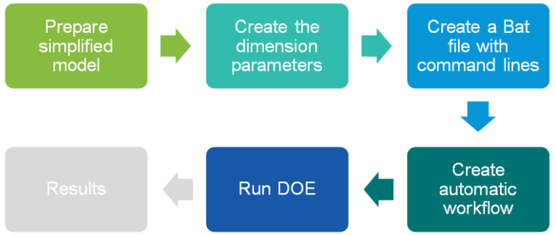
Moldflow runs bat file

Run DOE



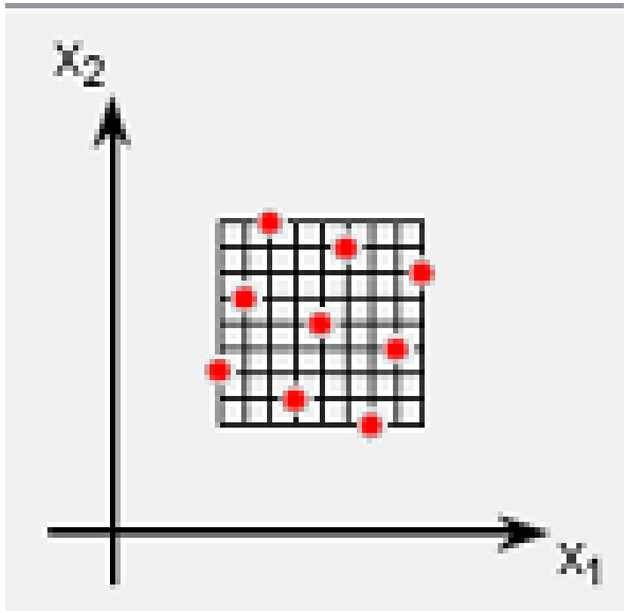
- Why we use DOE:
  - Know the influence between parameters
  - Create a response surface
  - Study the problem

Run DOE

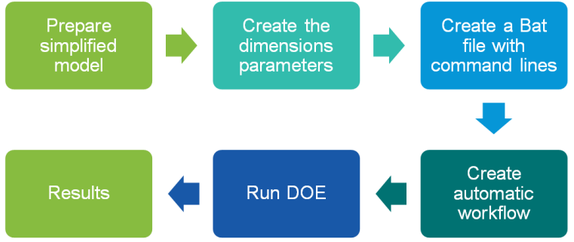


	Alt01	Alt02	Alt03	Alt04	Alt05
1	-0,5	-0,0474	-0,316	-0,158	-0,421
2	-0,211	-0,0316	-0,447	-0,316	-0,026
3	-0,184	0,0	-0,395	-0,237	-0,395
4	-0,421	-0,0947	0,0	-0,132	-0,237
5	-0,342	-0,0868	-0,5	-0,421	-0,342
6	-0,316	-0,15	-0,289	-0,105	-0,368
7	-0,158	-0,0632	-0,132	-0,026	-0,447
8	-0,474	-0,1105	-0,342	-0,211	-0,079
9	-0,105	-0,1421	-0,421	-0,342	-0,132
10	-0,395	-0,1342	-0,158	-0,474	-0,289
11	-0,026	-0,1026	-0,368	-0,263	-0,5
12	-0,368	-0,0079	-0,211	-0,079	-0,105
13	-0,447	-0,0158	-0,237	-0,447	-0,184
14	0,0	-0,0237	-0,105	-0,184	-0,158
15	-0,237	-0,0711	-0,474	0,0	-0,211
16	-0,079	-0,1263	-0,026	-0,289	-0,316
17	-0,289	-0,0395	-0,053	-0,368	-0,474
18	-0,263	-0,0789	-0,079	-0,395	0,0
19	-0,132	-0,1184	-0,184	-0,053	-0,053
20	-0,053	-0,0553	-0,263	-0,5	-0,263
Add					

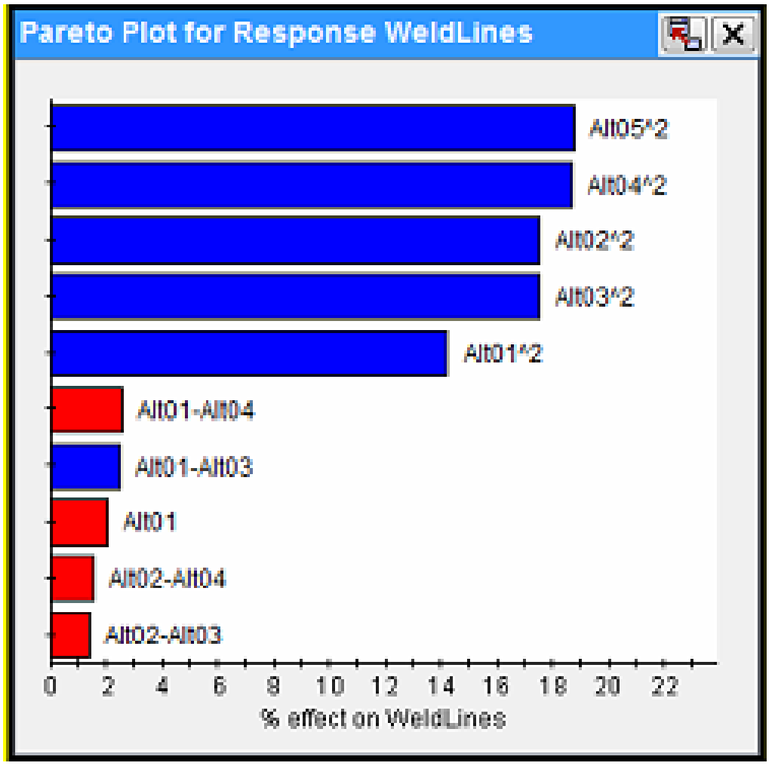
Optimal Latin Hypercube

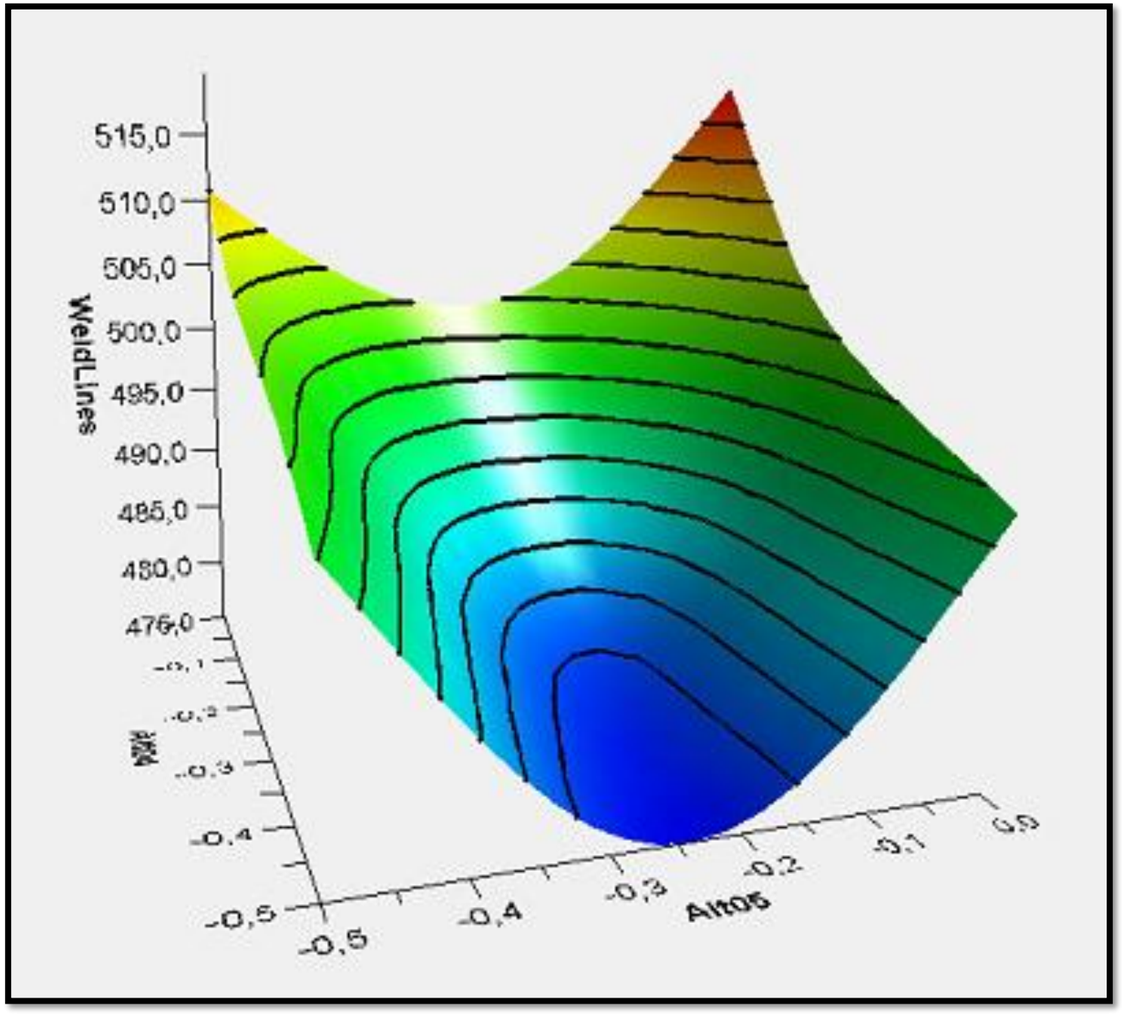


Results

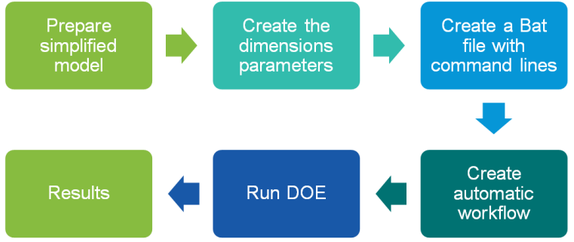


- Response surface
- Pareto Plot





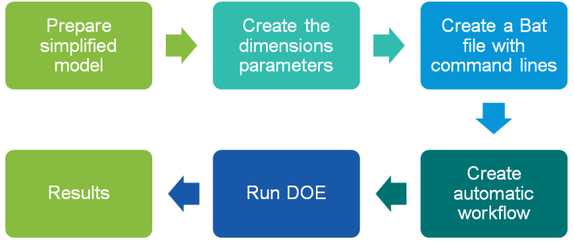
Results

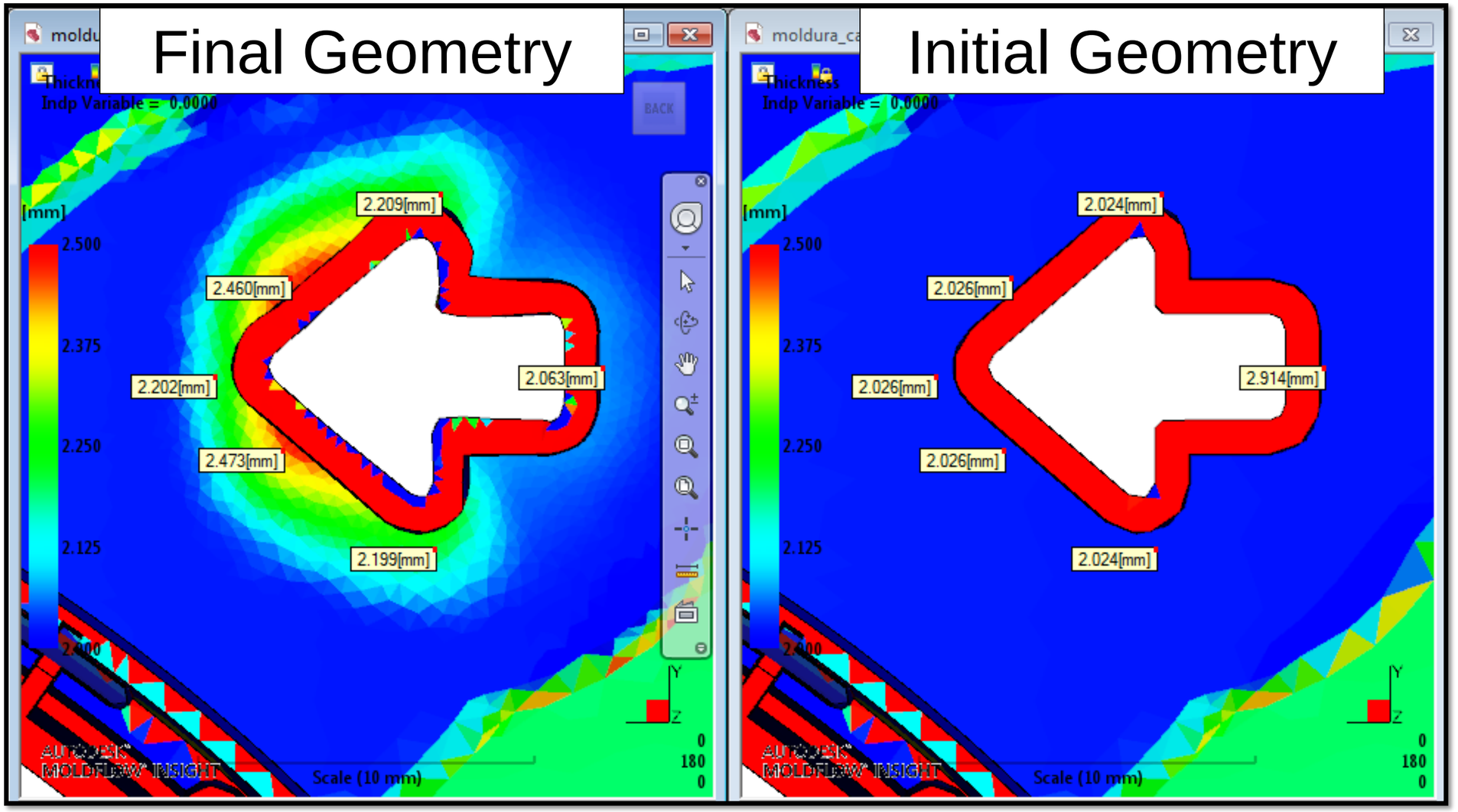


Run Path			Parameters for					
✓			Alt01	Alt02	Alt03	Alt04	Alt05	WeldLines
✓	1	1	-0,5	-0,0474	-0,316	-0,158	-0,421	510,0
✓	1	2	-0,211	-0,0316	-0,447	-0,316	-0,026	577,0
✓	1	3	-0,184	0,0	-0,395	-0,237	-0,395	417,0
✓	1	4	-0,421	-0,0947	0,0	-0,132	-0,237	508,0
✓	1	5	-0,342	-0,0868	-0,5	-0,421	-0,342	481,0
✓	1	6	-0,316	-0,15	-0,289	-0,105	-0,368	519,0
✓	1	7	-0,158	-0,0632	-0,132	-0,026	-0,447	523,0
✓	1	8	-0,474	-0,1105	-0,342	-0,211	-0,079	448,0
✓	1	9	-0,105	-0,1421	-0,421	-0,342	-0,132	438,0
✓	1	10	-0,395	-0,1342	-0,158	-0,474	-0,289	551,0
✓	1	11	-0,026	-0,1026	-0,368	-0,263	-0,5	565,0
✓	1	12	-0,368	-0,0079	-0,211	-0,079	-0,105	551,0
✓	1	13	-0,447	-0,0158	-0,237	-0,447	-0,184	524,0
✓	1	14	0,0	-0,0237	-0,105	-0,184	-0,158	460,0
✓	1	15	-0,237	-0,0711	-0,474	0,0	-0,211	545,0
✓	1	16	-0,079	-0,1263	-0,026	-0,289	-0,316	517,0
✓	1	17	-0,289	-0,0395	-0,053	-0,368	-0,474	592,0
✓	1	18	-0,263	-0,0789	-0,079	-0,395	0,0	569,0
✓	1	19	-0,132	-0,1184	-0,184	-0,053	-0,053	570,0
✓	1	20	-0,053	-0,0553	-0,263	-0,5	-0,263	390,0

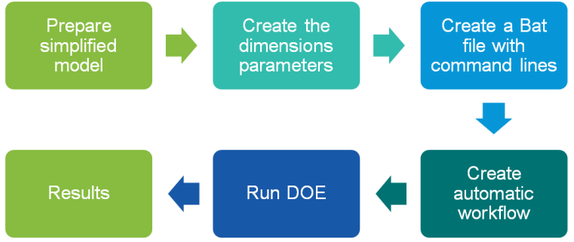
Best weld line

Results

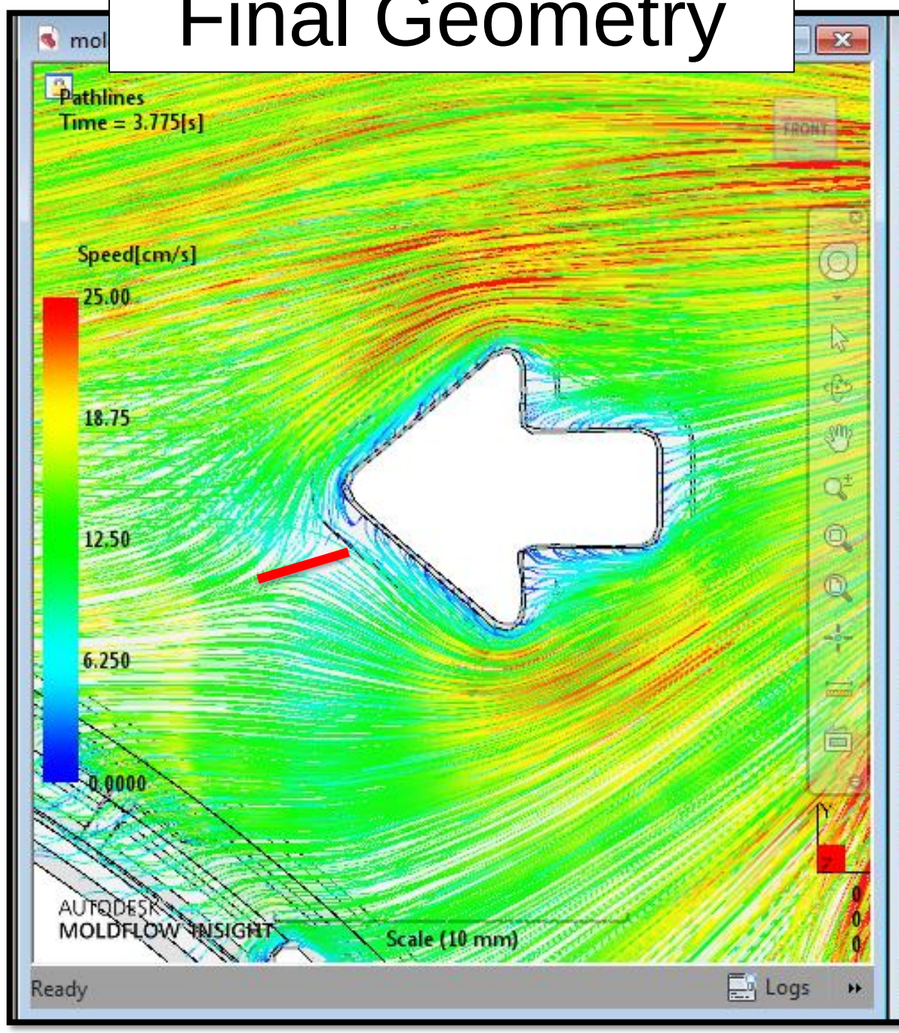

Prepare simplified model
Create the dimensions parameters
Create a Bat file with command lines
Create automatic workflow
Run DOE
Results


Final Geometry
moldu
Thickness
Indp Variable = 0.0000
BACK
[mm]
2.500
2.375
2.250
2.125
2.209[mm]
2.460[mm]
2.202[mm]
2.063[mm]
2.473[mm]
2.199[mm]
AUTODESK MOLDFLOW INSIGHT
Scale (10 mm)
0
180
0
Initial Geometry
moldura_ca
Thickness
Indp Variable = 0.0000
[mm]
2.500
2.375
2.250
2.125
2.024[mm]
2.026[mm]
2.026[mm]
2.914[mm]
2.026[mm]
2.024[mm]
AUTODESK MOLDFLOW INSIGHT
Scale (10 mm)
0
180
0

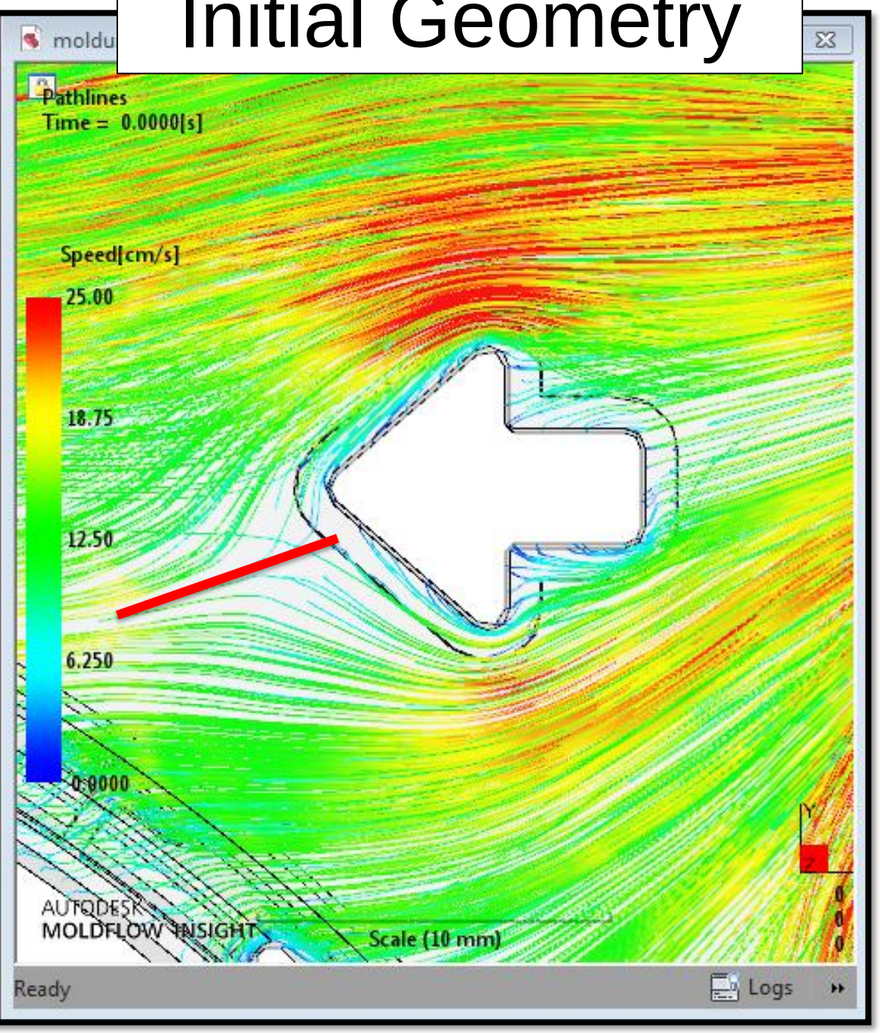
Results



Final Geometry



Initial Geometry



Conclusions

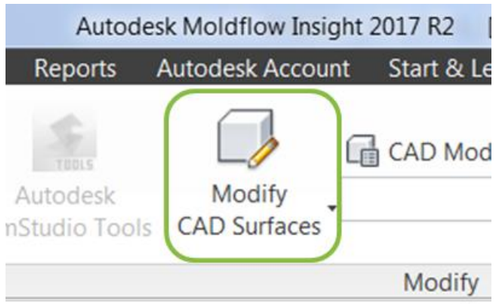
- The command line could help to automate a workflow without knowledge of programming
- DOE technique is an important tool to study the problem
- It is possible to obtain better results when DOE technique was combined with Simulation
- It was possible to improve the part with this methodology

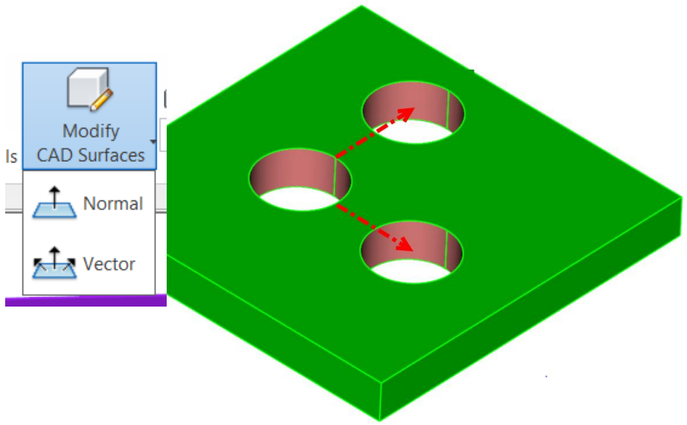
Questions?

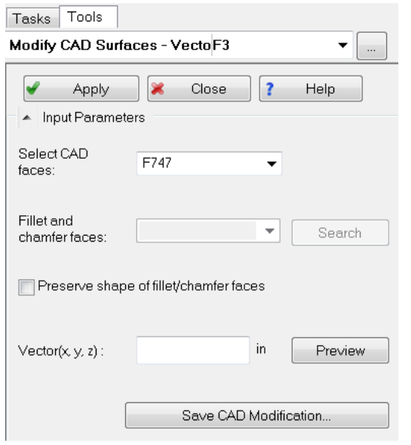
Recent Developments

CAD Geometry Editing Tools

- New modify CAD surfaces Tools
  - Direct Geometry modification in product (Synergy)
  - Increase or reduce the thickness of a part
  - Move an entire section, such as the position of ribs, holes or bosses
  - Change the diameter of a cylinder or a circular section
  - Preserve the shape of fillets and chamfers

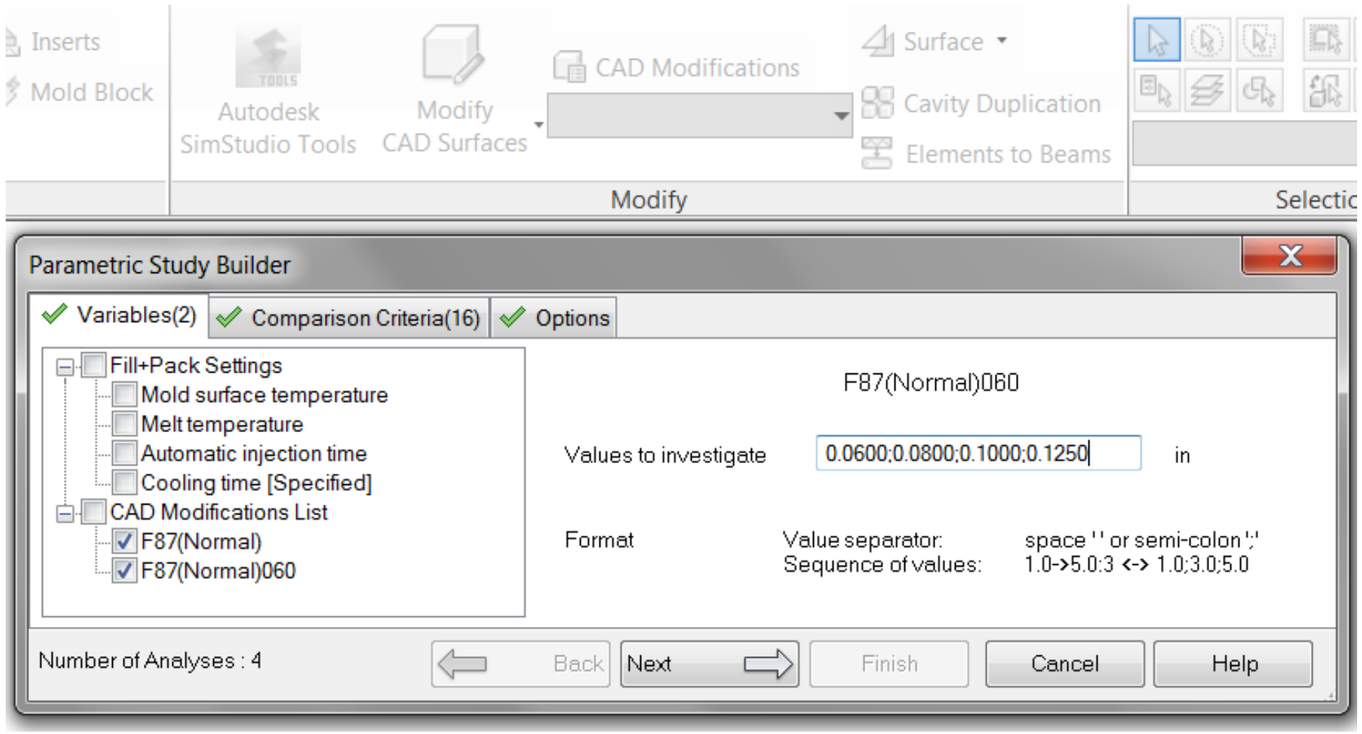






CAD Geometry as Parametric Optimization Variables

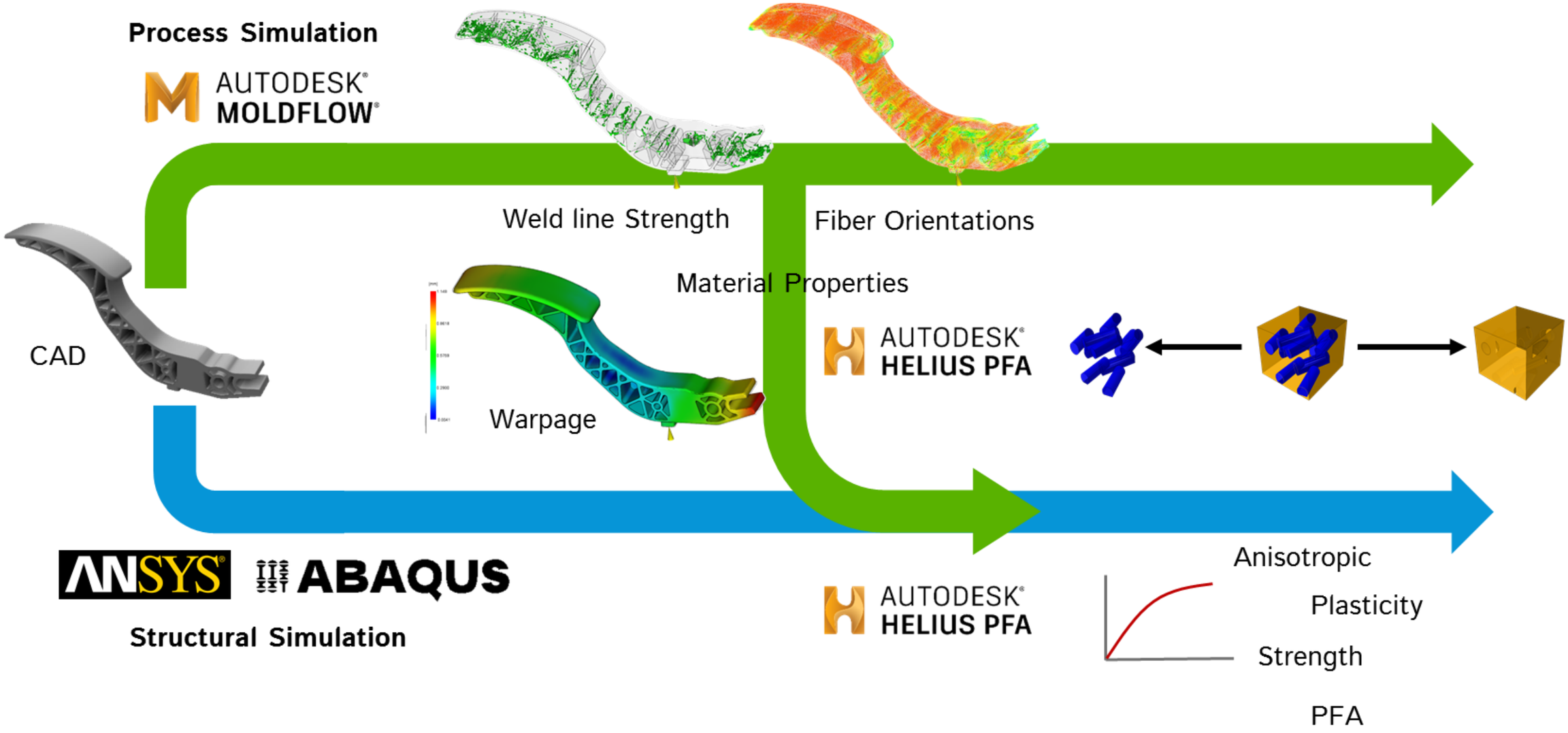
- Changes made with CAD geometry editing tools recognized by DOE Parametric Study builder
- Now able to optimize both process and geometry



Helius PFA

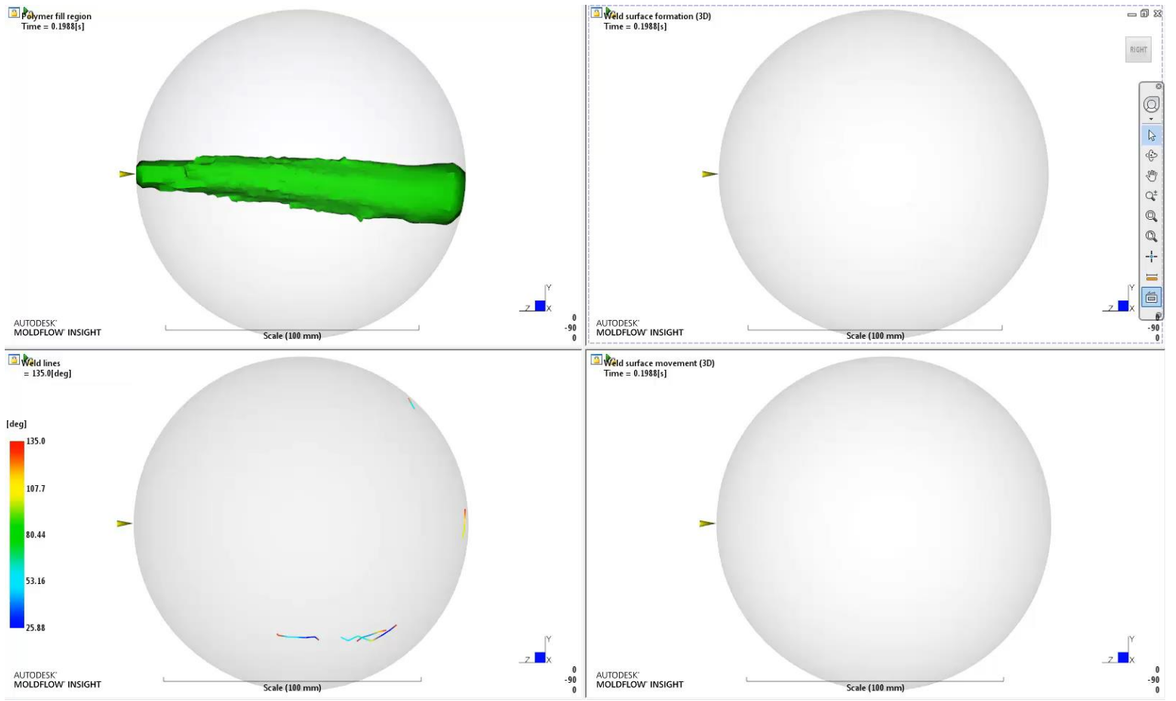
- Helius PFA links Moldflow results to structural (FEA) models
  - Fiber orientation
  - Residual strain (warpage)
  - Filled or non-filled materials
  - 3D Weld surfaces (strength reduction)
  - Elastic plastic or linear elastic material behavior

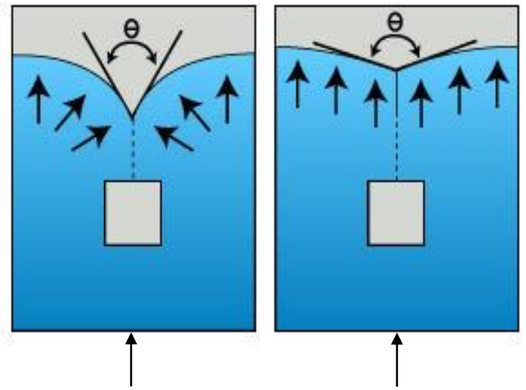
As-Manufactured Simulation Workflow Overview



Simulation Weld Surface Strength Variables

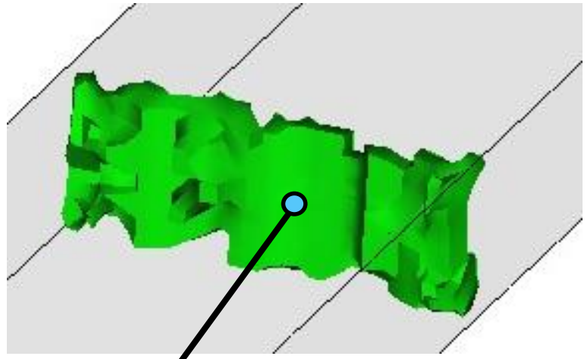
- 3D Weld Surface
  - Initial meeting angle, location and movement

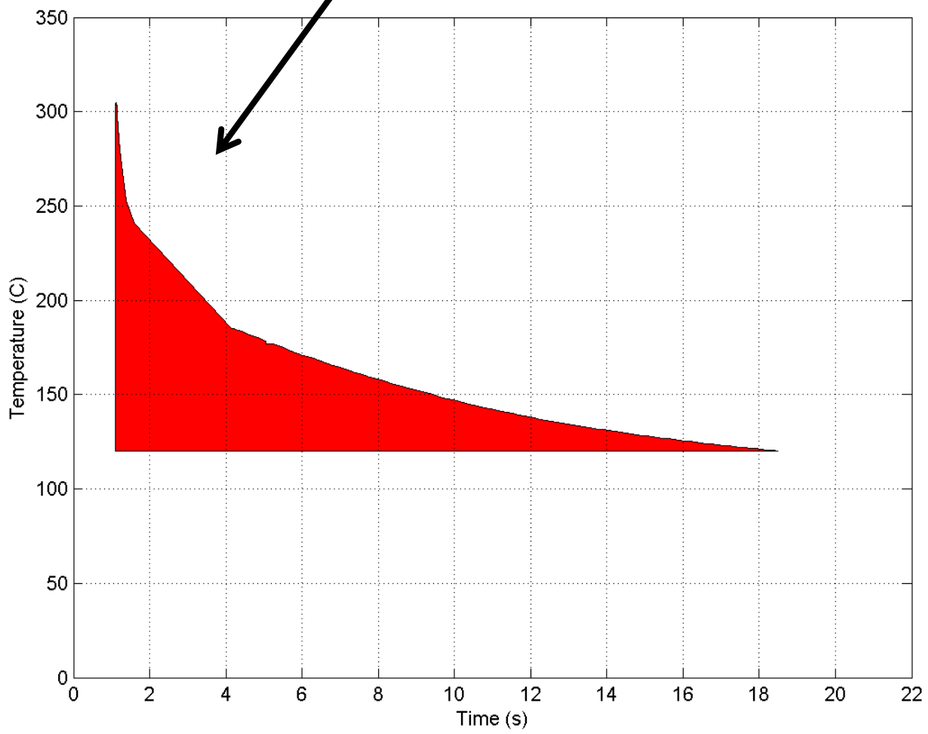




Simulation Weld Surface Strength Variables

- 3D Weld Surface
  - Initial meeting angle, location and movement
- Transient history
  - Pressure and Temperature

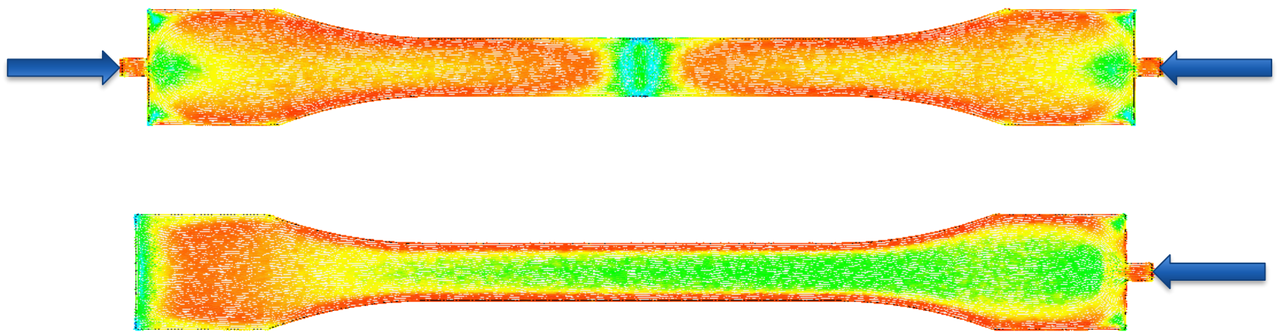




Simulation Weld Surface Strength Variables

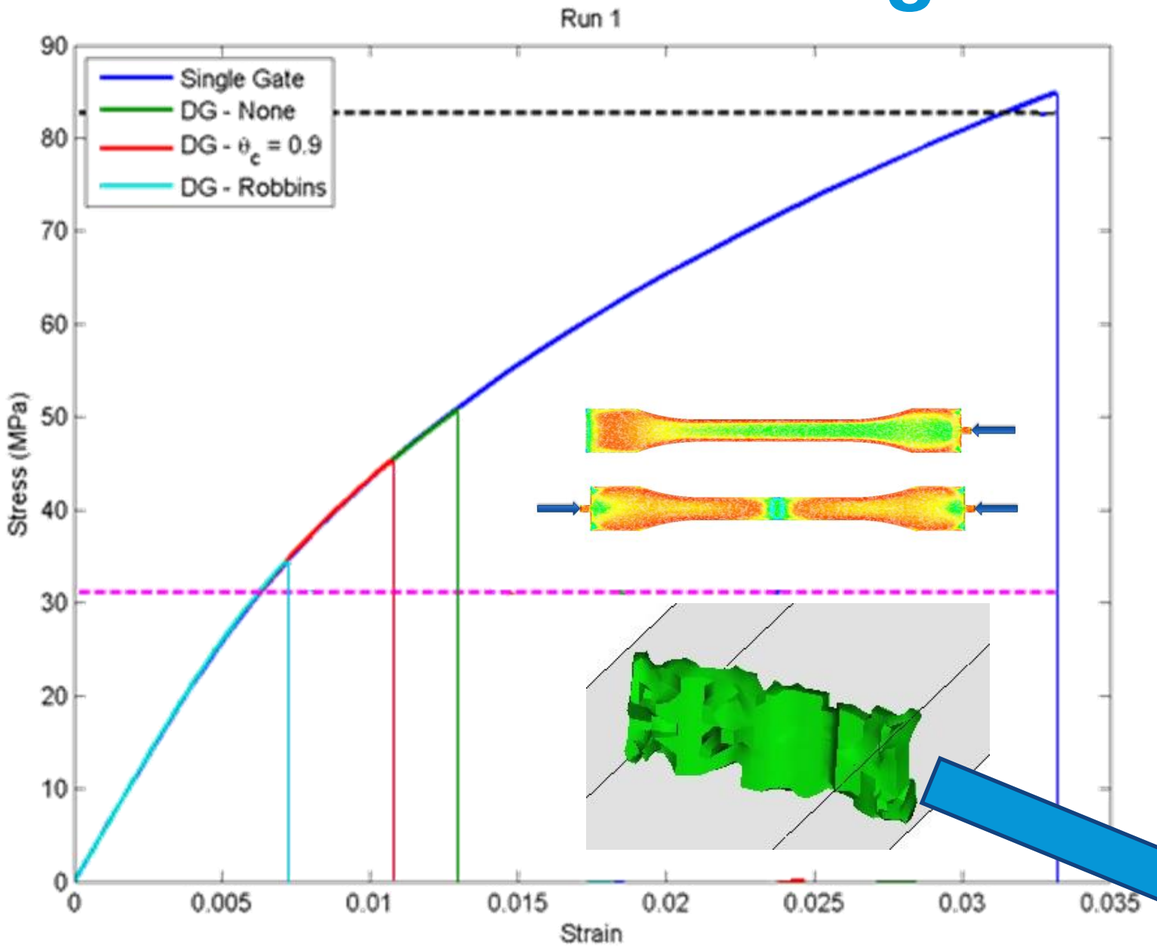
- 3D Weld Surface
  - Initial meeting angle, location and movement
- Transient history
  - Pressure and Temperature
- Fiber Orientation*

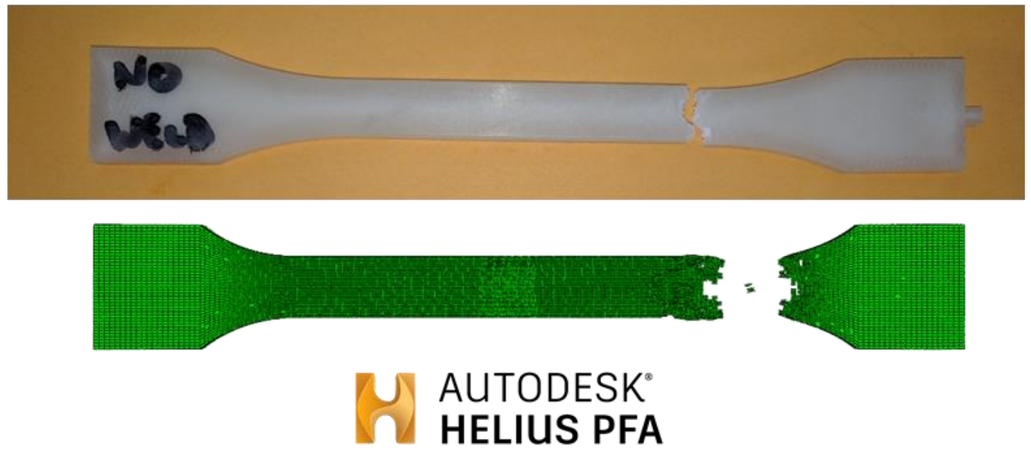
With Weld Line

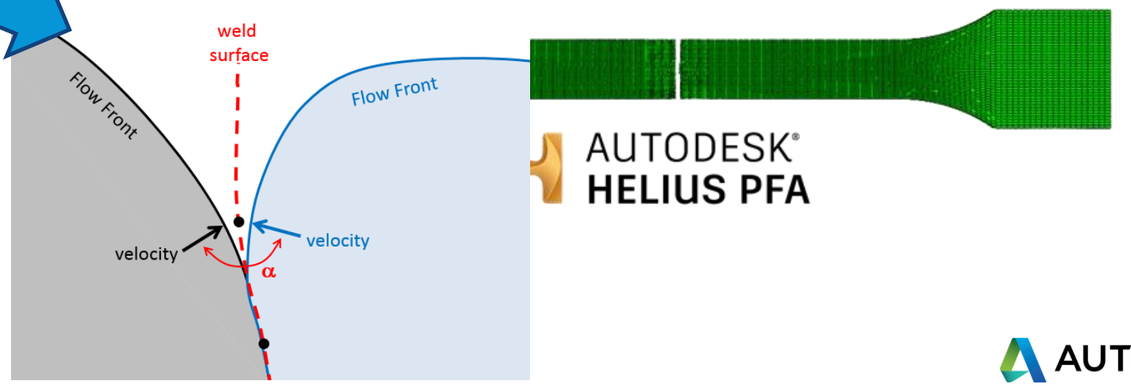


Without Weld Line

Weld Surface Strength - Tensile Test Specimen Example







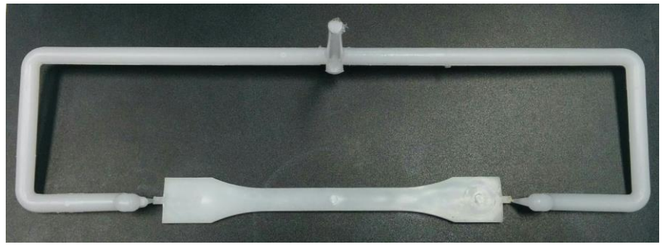
$$d\beta = \beta_{(t)}\left(c_T\left(T_{(t)} - T_g\right) + c_P P_{(t)}\right)dt$$

initial condition $\beta(0) = \left\langle \frac{\alpha_{crit} - \alpha}{\alpha_{crit}} \right\rangle$

Partnership Request

- Weld line material testing project underway
- No charge for weld line coefficient testing

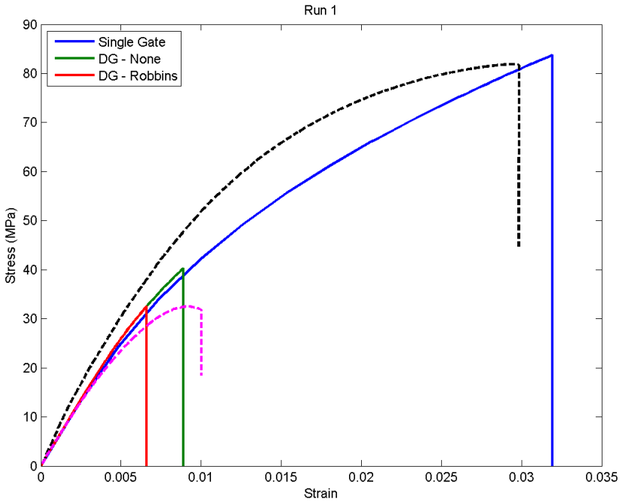
1. The material must be fully characterized for MPL-150 (Filling, Packing, Shrinkage, and Warpage)
2. 50kg of material shipped to our lab
3. DOE weld line strength testing performed
   - Single and dual gate testing specimens
4. Updated udb file is sent, including the Weld Line coefficients
5. Validation data requested back

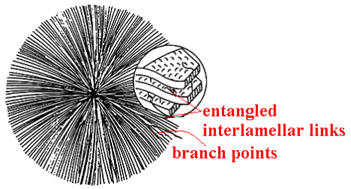


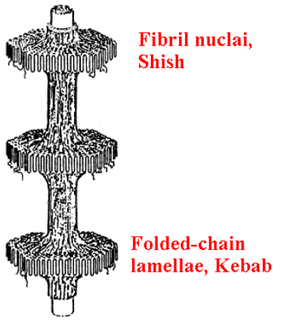
Run	Melt Temp (°C)	Mold Temp (°C)	Injection Rate (cm^3/s)	Pack Pressure (MPa)	Pack Time (s)	Cool Time (s)
1	200	20	40	40	2.5	35
2	200	20	40	70	6	45
3	200	40	80	40	2.5	45
4	200	40	80	70	6	35
5	220	20	80	40	6	35
6	220	20	80	70	2.5	45
7	220	40	40	40	6	45
8	220	40	40	70	2.5	35

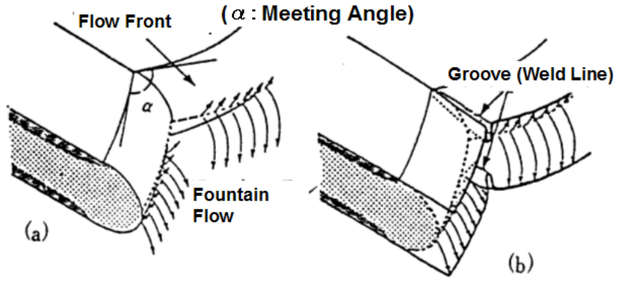
Future & Improvements

- Present validation with partner customer parts*
- Improve prediction curve response
- Include other effects into calculation such as:
  - Higher level bonding/entanglement equations
  - Crystallinity
  - Polymer orientation
  - Polymer blends
  - Additives
  - More comprehensive approach to weld/meld lines threshold



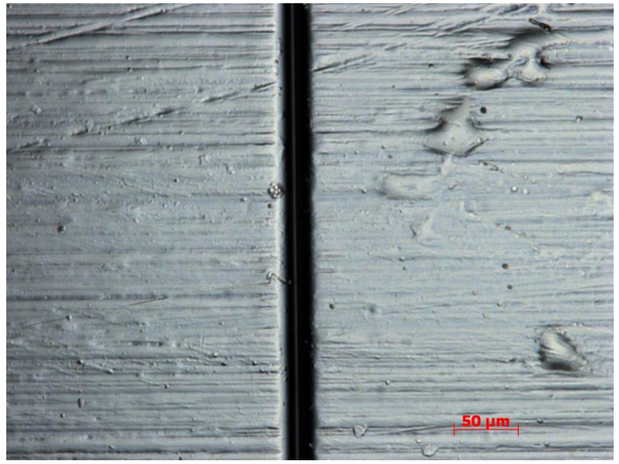


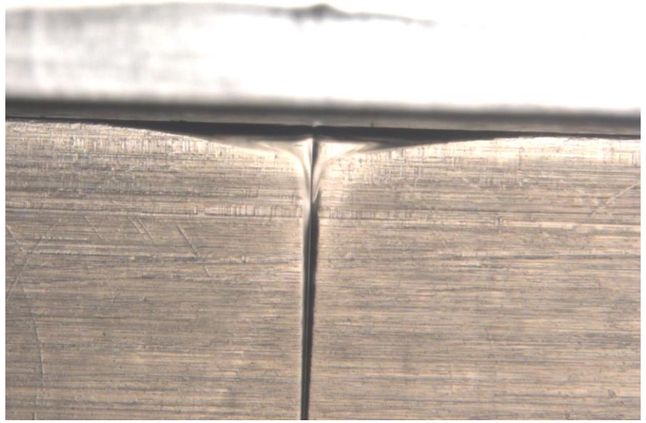


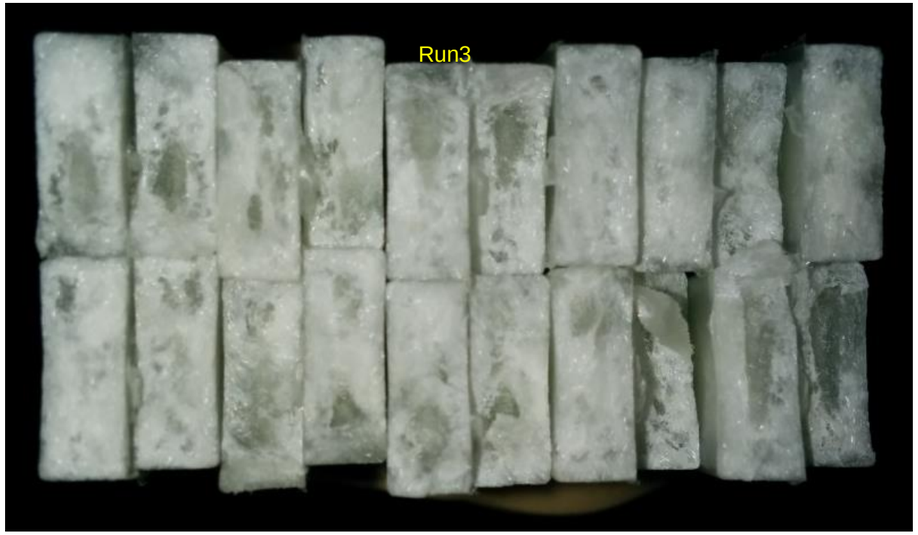


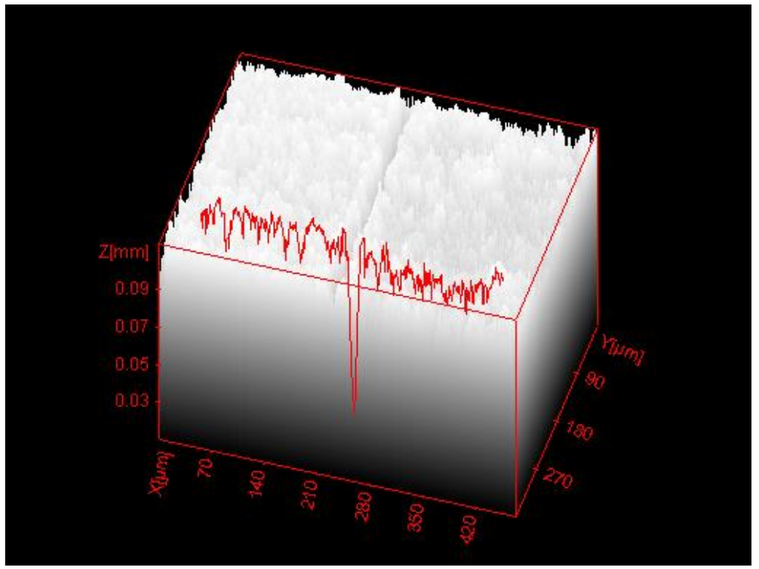
Future & Improvements

- Integrate venting analysis:
  - Vnotch effects
    - Reduction of area/volume
    - Stress concentration
  - Air traps









Questions?

How did we do?

- Your class feedback is critical. Fill out a **class survey** now
- Use the AU mobile app or fill out a class survey online
- Give feedback after each session
- AU speakers will get feedback in real-time
- **Your feedback results in better classes and a better AU experience**

More Questions? Visit the AU Answer Bar

- Seek answers to all of your technical product questions by visiting the **Answer Bar**
- Open daily from **8am-6pm Tuesday** and **Wednesday**; **8am-4:30pm Thursday**
- Located outside **Hall C, Level 2**
- Meet Autodesk developers, testers, & support engineers ready to help with your most challenging technical questions