The Effect of Mesh Density on the Accuracy of Meld Line Predictions

Edward D. Groninger
Sr. Manufacturing Engineer
Manufacturing Engineering
General Motors Company

David A. Okonski
Staff Research Engineer
Research & Development Center
General Motors Company

© 2012 Autodesk

Class Summary

In this class you will be presented with what problems knit lines create in the development of a vehicle and why accurate prediction is required. Several meshing variables that do and do not effect the weld and meld line prediction plot will be presented and how those predictions match actual molded samples will be shown.

© 2012 Autodesk

Learning Objectives

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

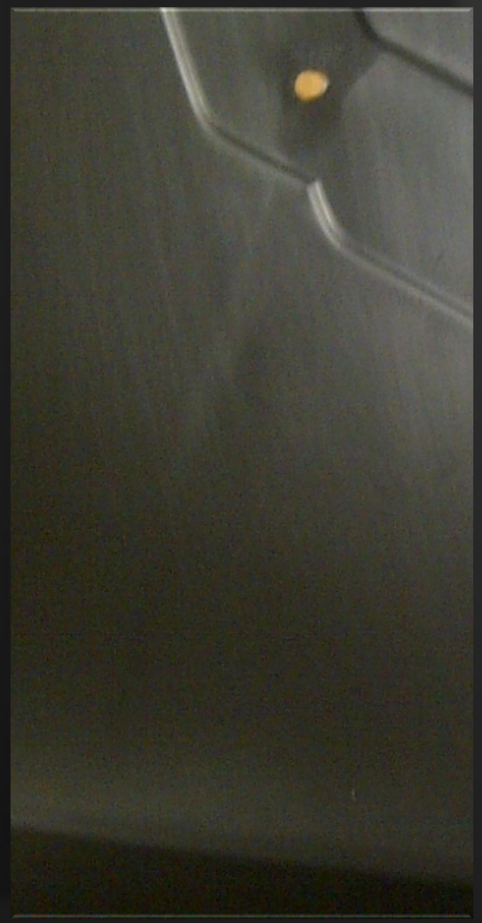
- Better understand the effects of mesh on meld line prediction
- Utilize chord angle controls and mesh match setting to improve prediction
- Interpret additional plots to better predict meld line quality

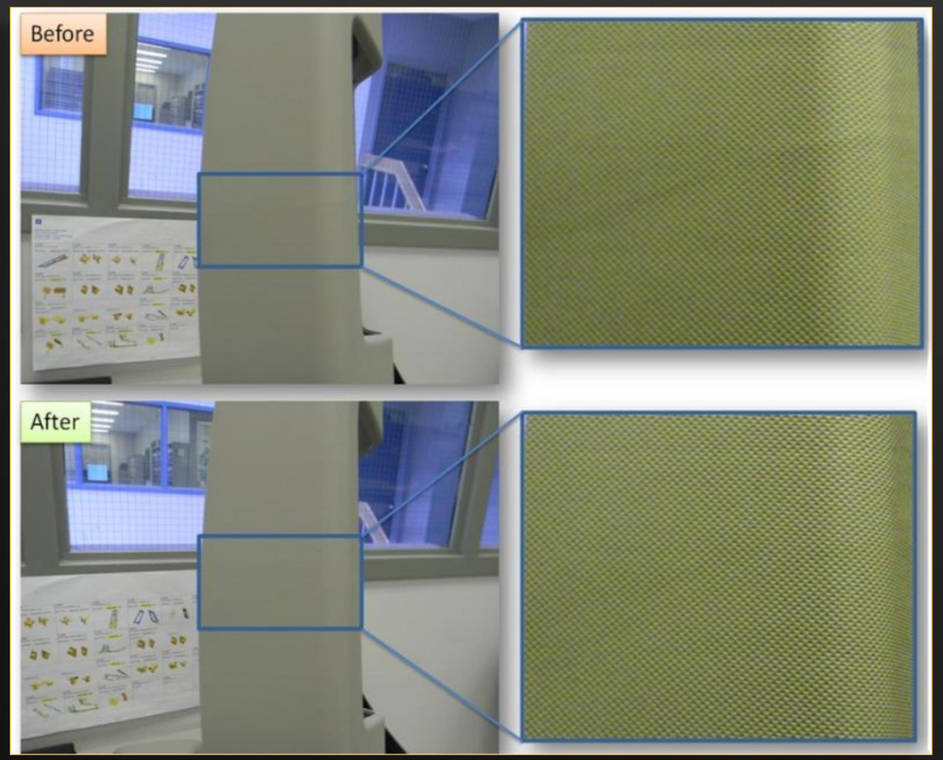
© 2012 Autodesk

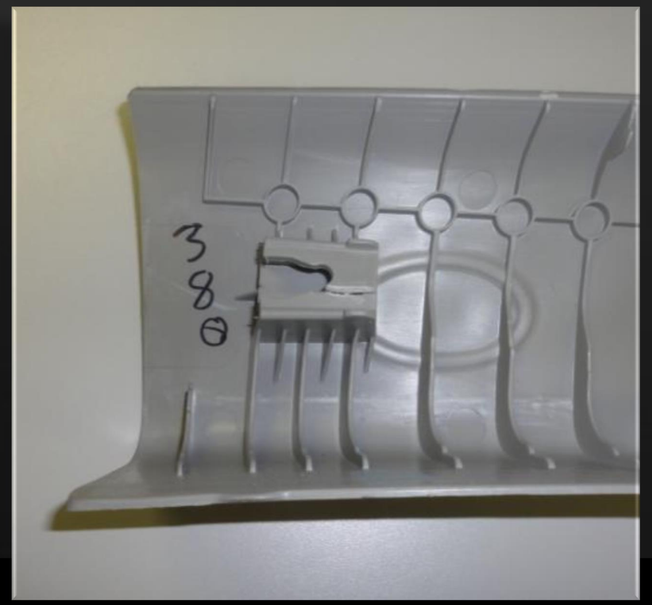
Problem Statement

© 2012 Autodesk

Poorly placed meld lines cost GM time and $

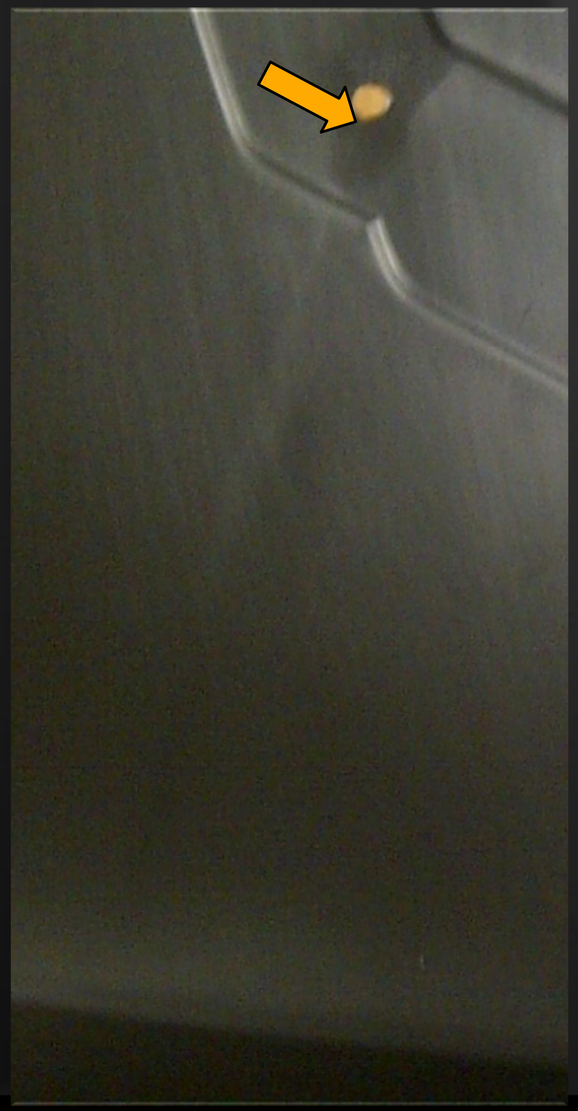


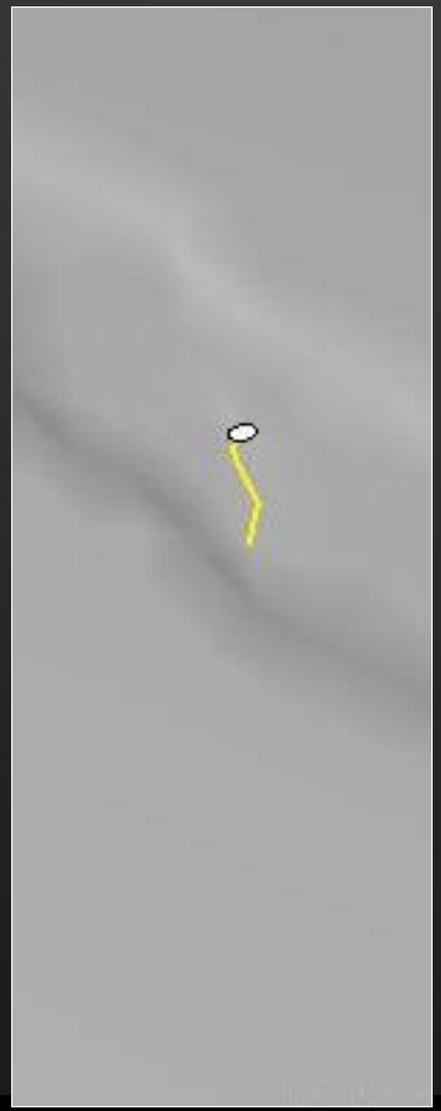




© 2012 Autodesk

Prediction of knit line ending behind a feature

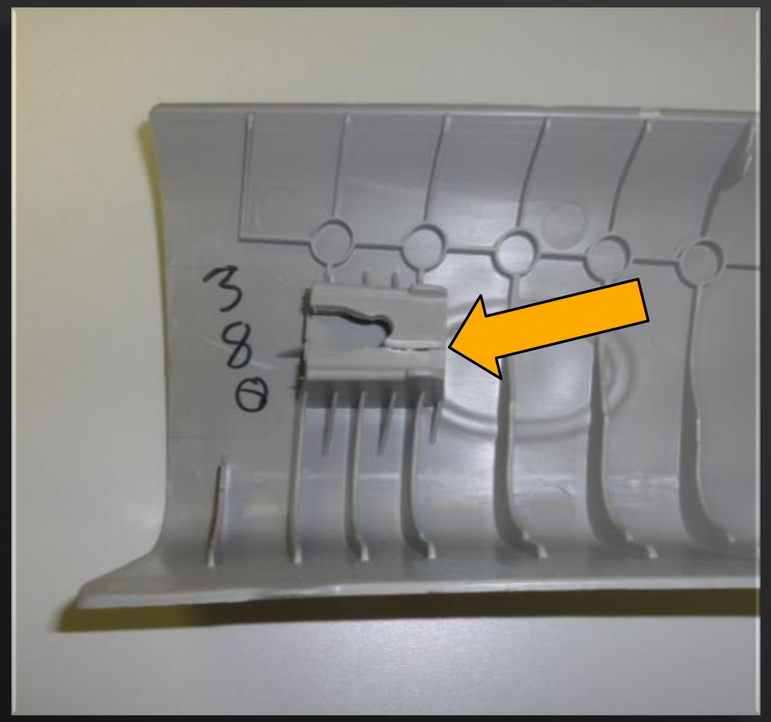


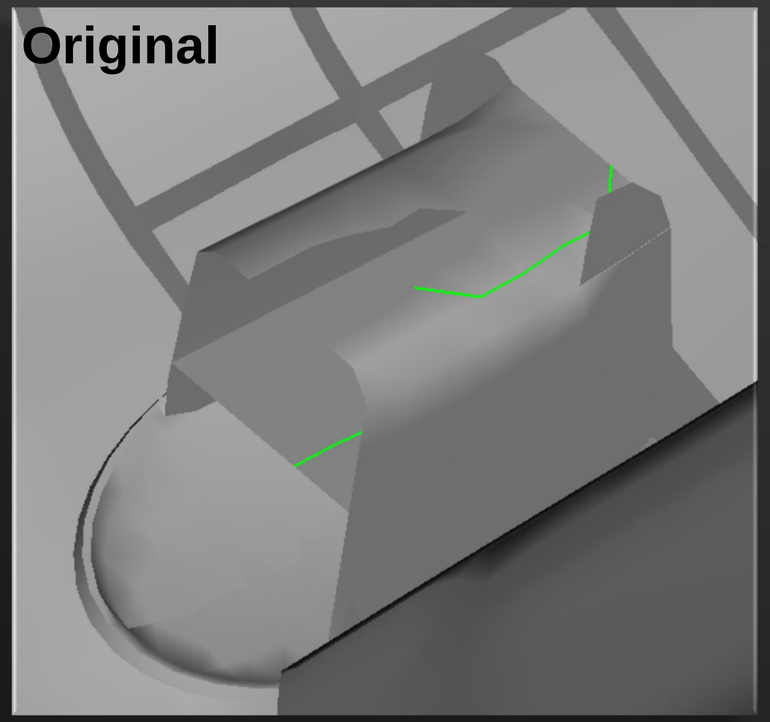


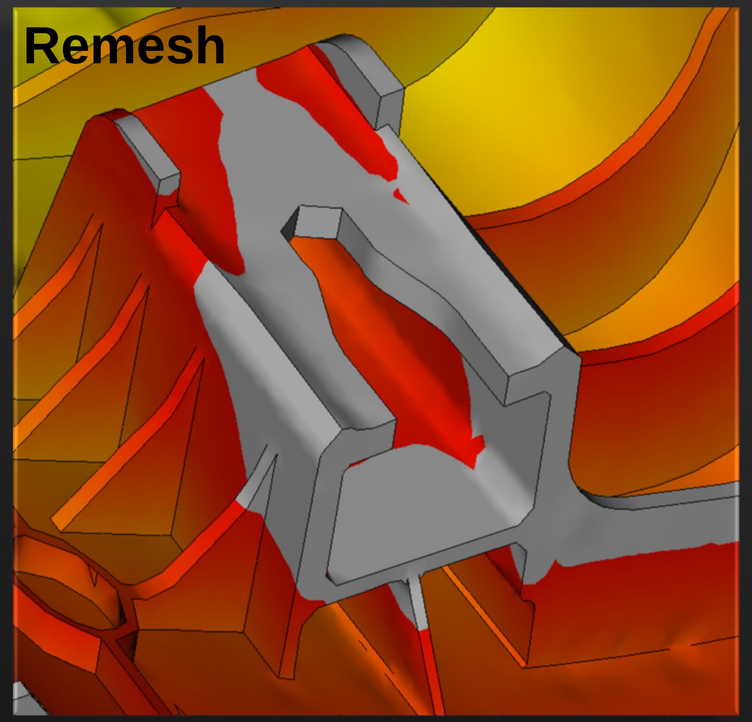
- Length and position are incorrect
- Several processing trials
- Remove pins in tool
- Add secondary punch

© 2012 Autodesk

Acceptable Prediction / Inadequate Interpretation?



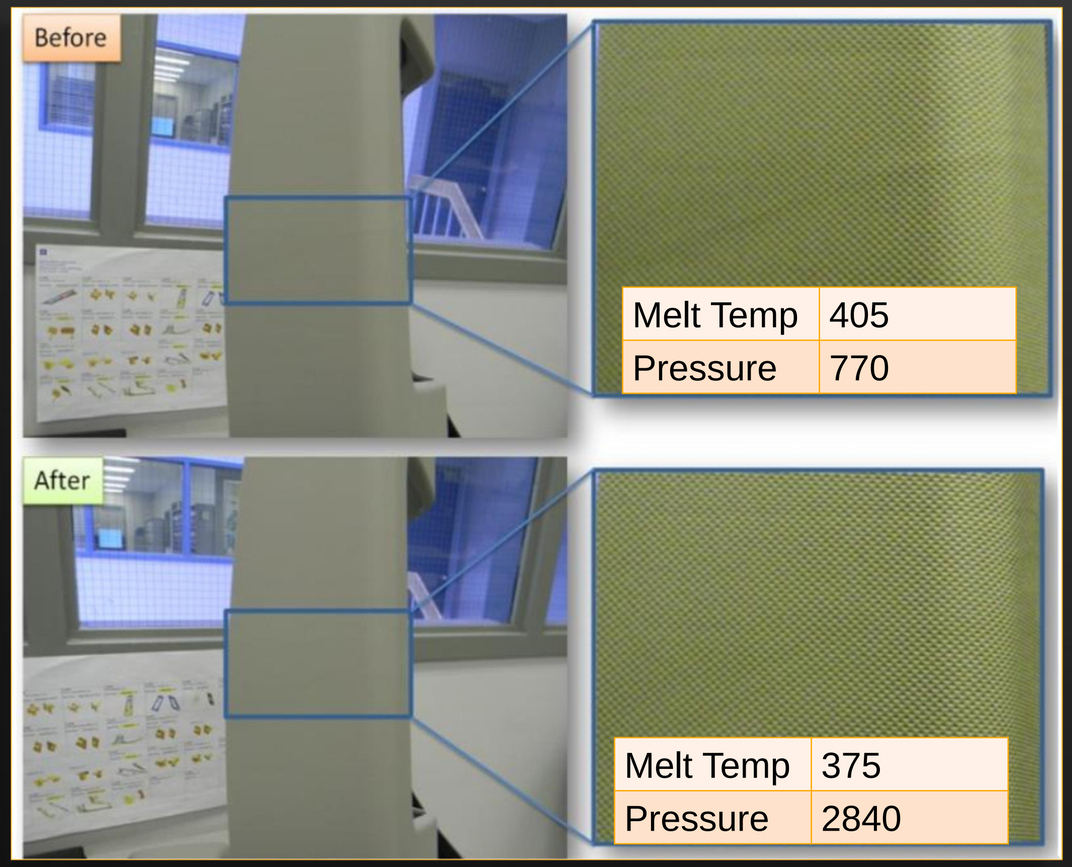




- Additional Validation
- Several additional processing trials
- Several tool “tunings”

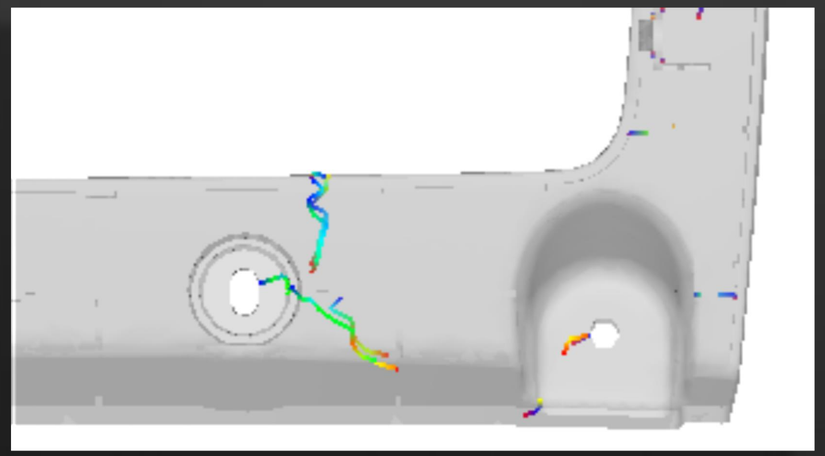
© 2012 Autodesk

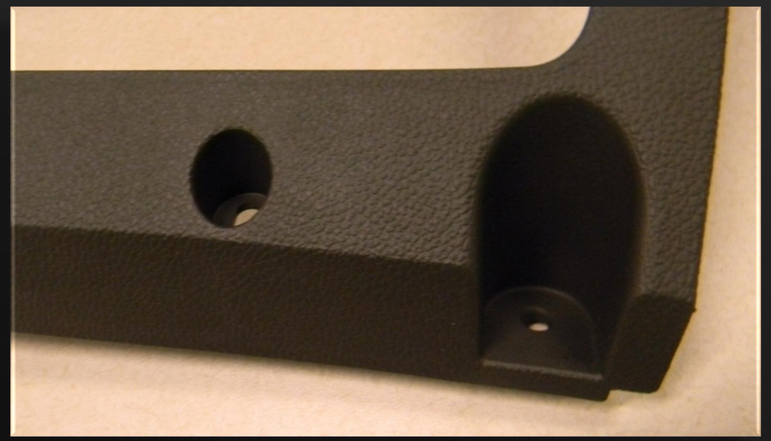
Predicting Quality and Length

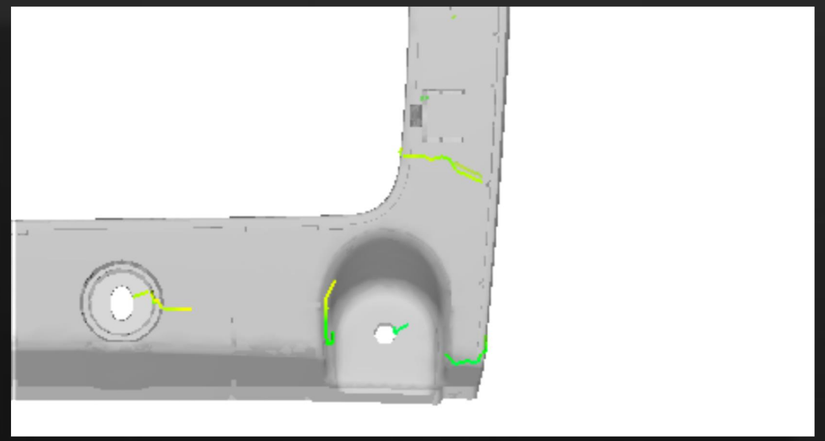


© 2012 Autodesk

No upfront analysis on engineering change







- Several processing trials
- Several buyoff meetings
- Runner system changes

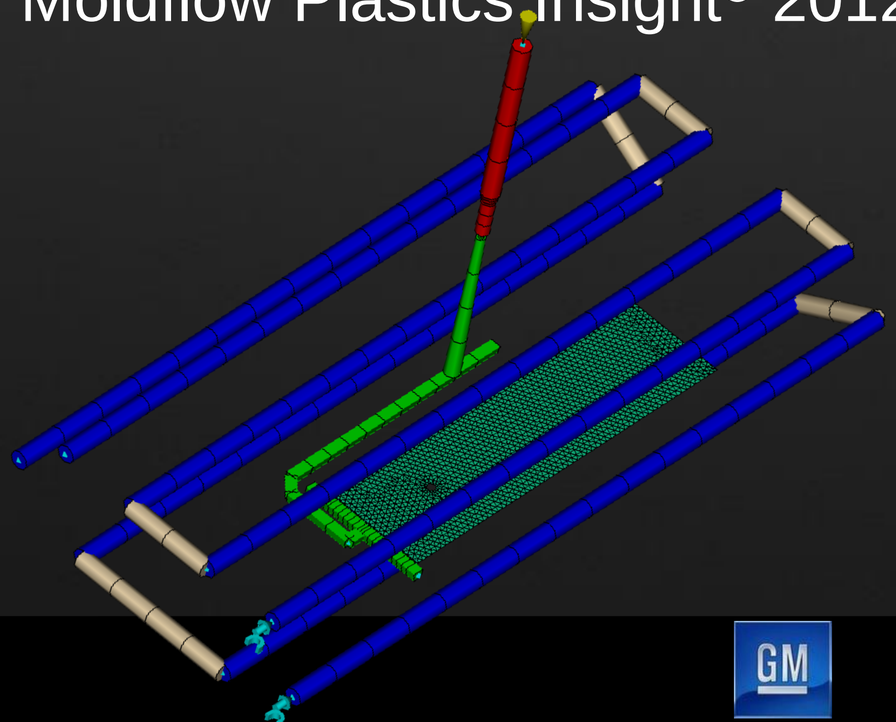
© 2012 Autodesk

Project Outline

© 2012 Autodesk

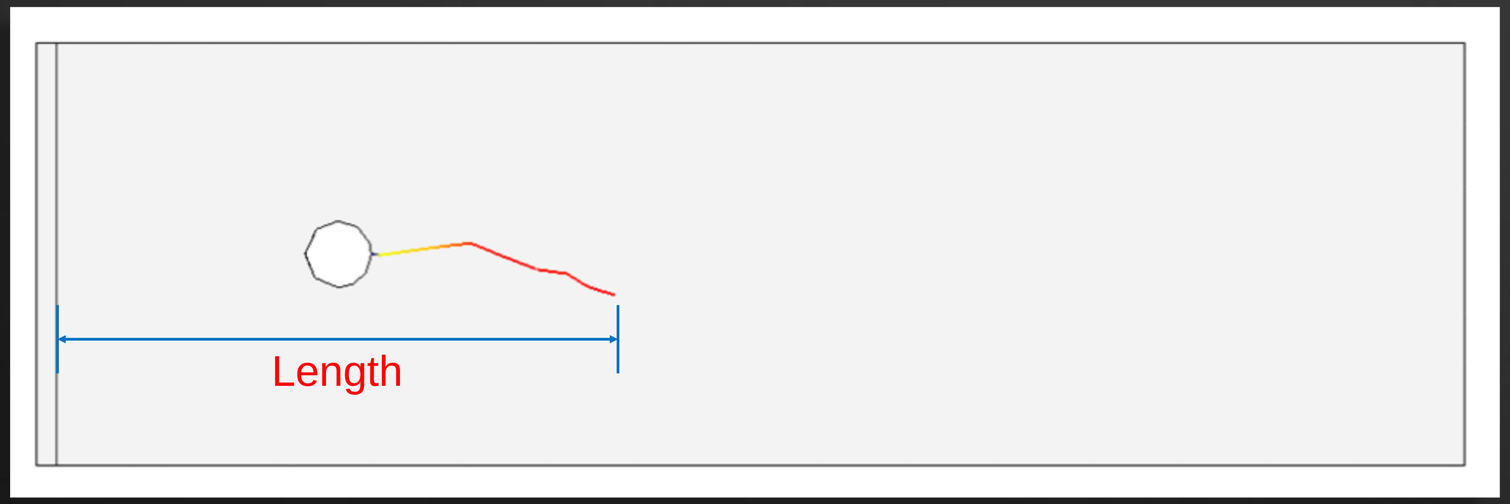
Effects on Knit Line Length and Position

- Compare molded samples to simulation
  - GM R&D 3x10 Plaque
  - Autodesk® Moldflow Plastics Insight® 2012

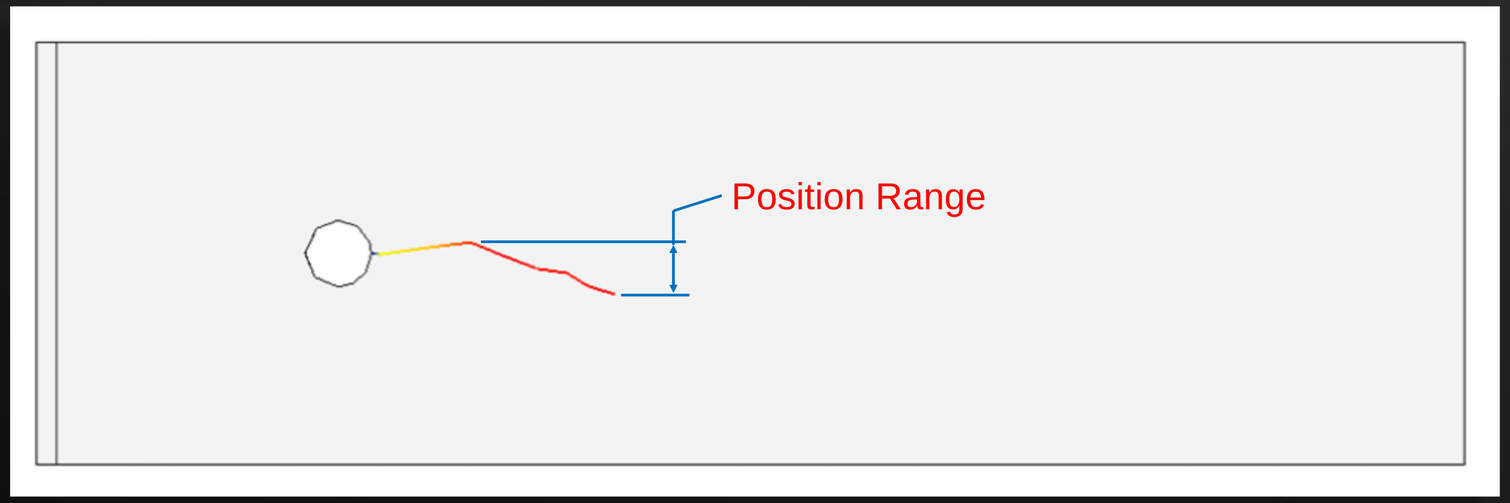


© 2012 Autodesk

Knit Line Length and Position Definition



- Length
  - Distance from part edge to end of objectionable appearance



- Position
  - +/- range from linear knit line

© 2012 Autodesk

GM R&D 3 x 10 Plaque

- 27 Sample Runs
  - 3 Materials: TPO (15% Talc), PP (Unfilled), PC+ABS
  - 3 Fill Speeds: 3in/sec, 1in/sec, 0.4in/sec
  - 3 Pin Diameters: 12mm, 6mm, 2mm

- 15 short shots per combination
- 10 plaques run at equilibrium

© 2012 Autodesk

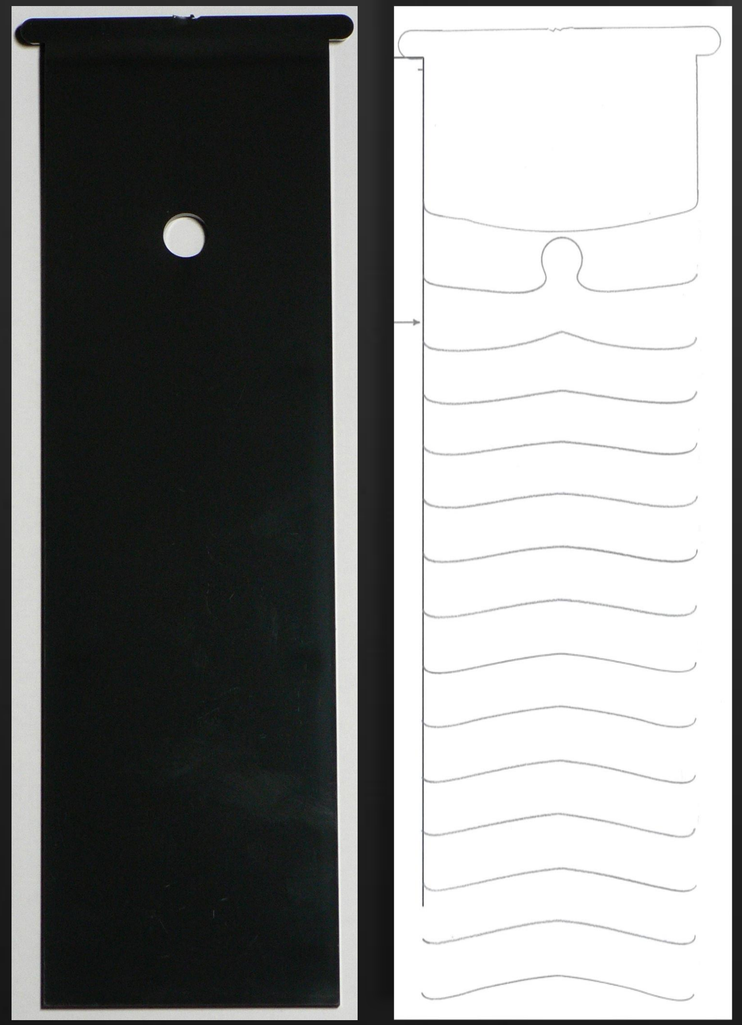
Simulation Variables

- Mid-Plane, Dual-Domain, 3D
- 12 – 1mm Global Edge Lengths
- 60 - 4 Chord Angle
- Analysis Sequence
- Solver Settings
  - Flow & temp convergence, single noded growth, # of layers

© 2012 Autodesk

Actual

12mm Pin

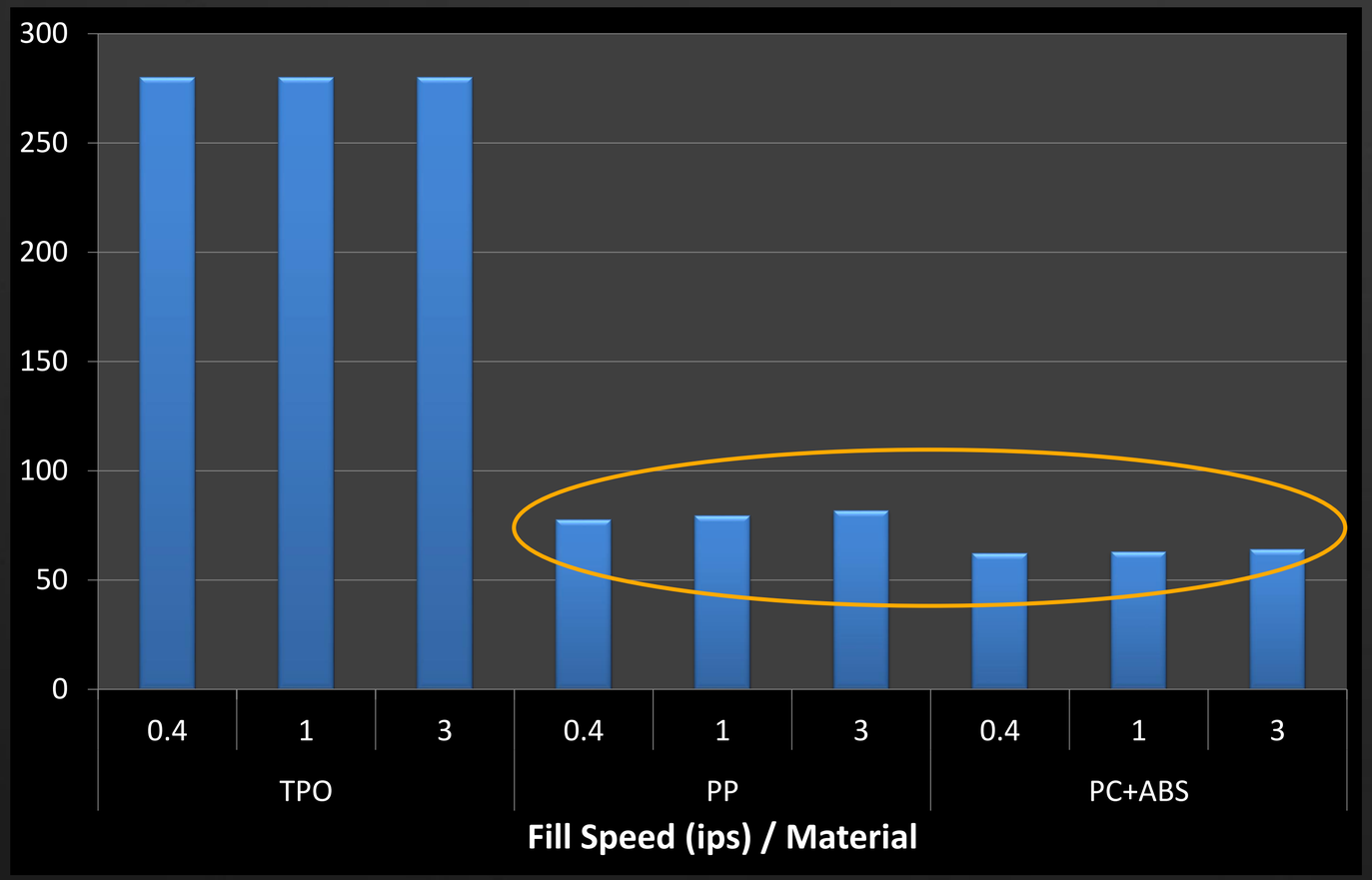


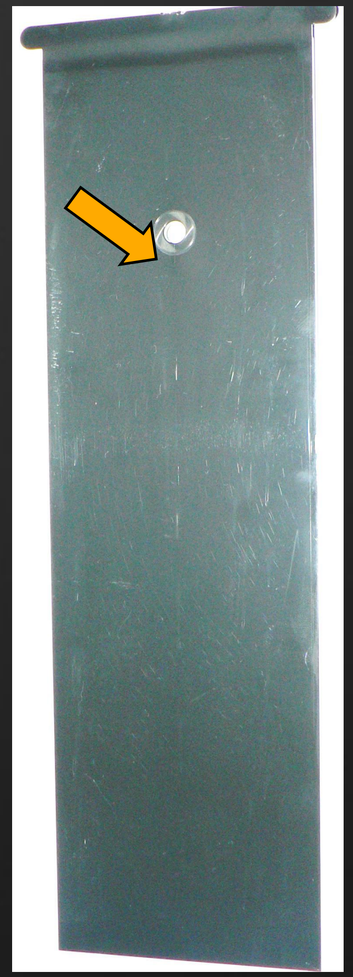
6mm Pin

2mm Pin

© 2012 Autodesk

Visible Knit Line Length – 6mm Pin

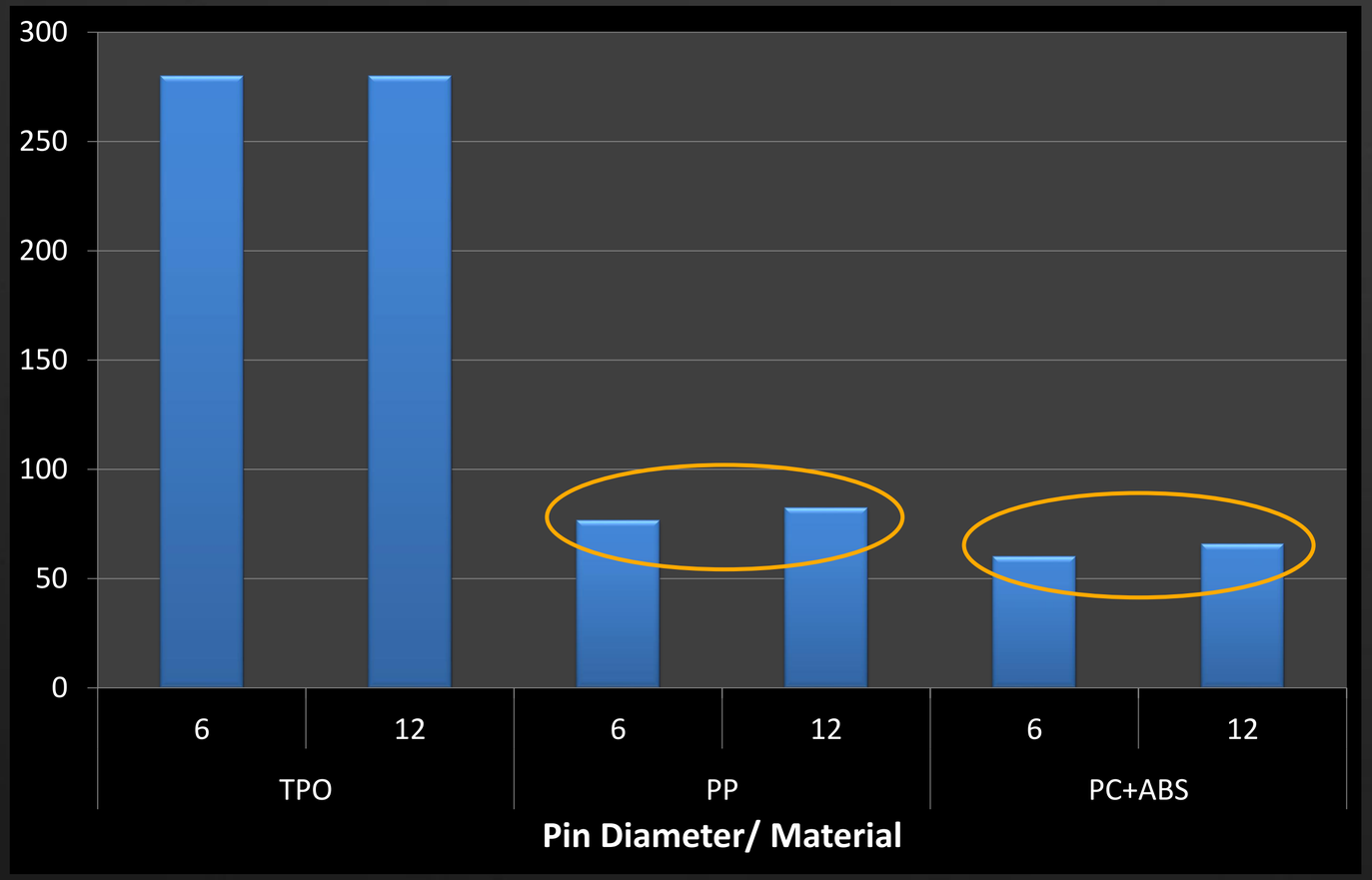


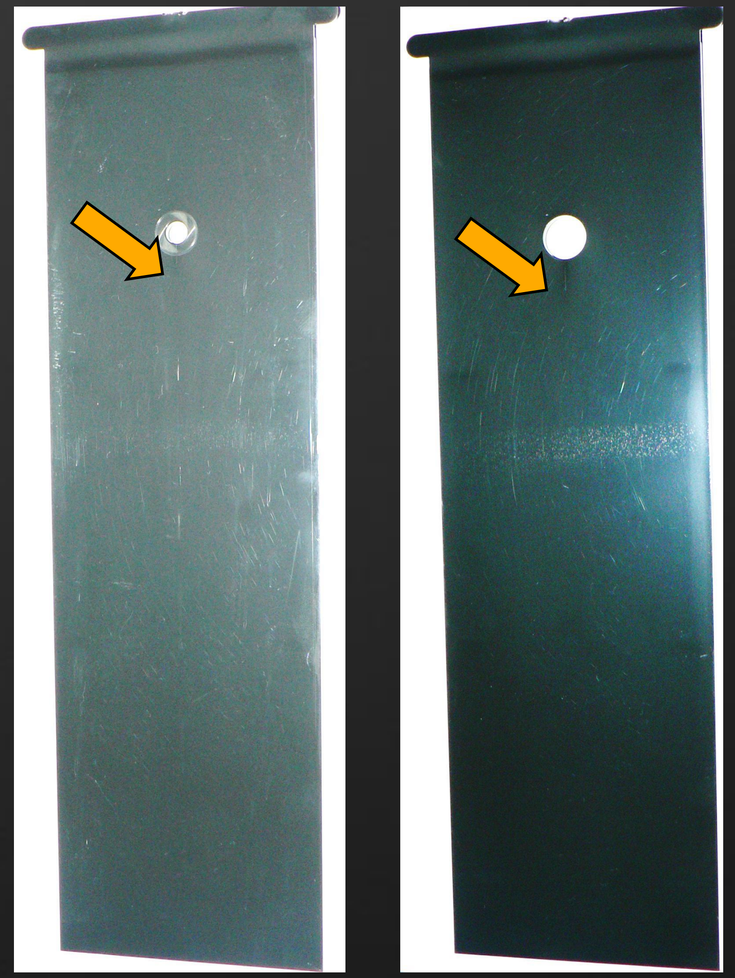


- 17mm average difference between PP and PC+ABS
- TPO: Objectionable appearance runs entire length of plaque.

© 2012 Autodesk

Visible Knit Line Length





- 6mm average difference between 12mm and 6mm pins

© 2012 Autodesk

Predicted Results

© 2012 Autodesk

DOE

- Looked at 6 possible Factors
  - Dual Domain Model

- 2 Significant Factors
  - Global Edge Length
  - Chord Angle

Factors	Low Value	High Value
Single Node Growth	Multiple	Single
No. of Layers	12	20
Global Edge Length	2	8
Chord Angle	15	60
Temp Convergence Setting	Tight	Default
Flow Convergence Setting	Tight	Default

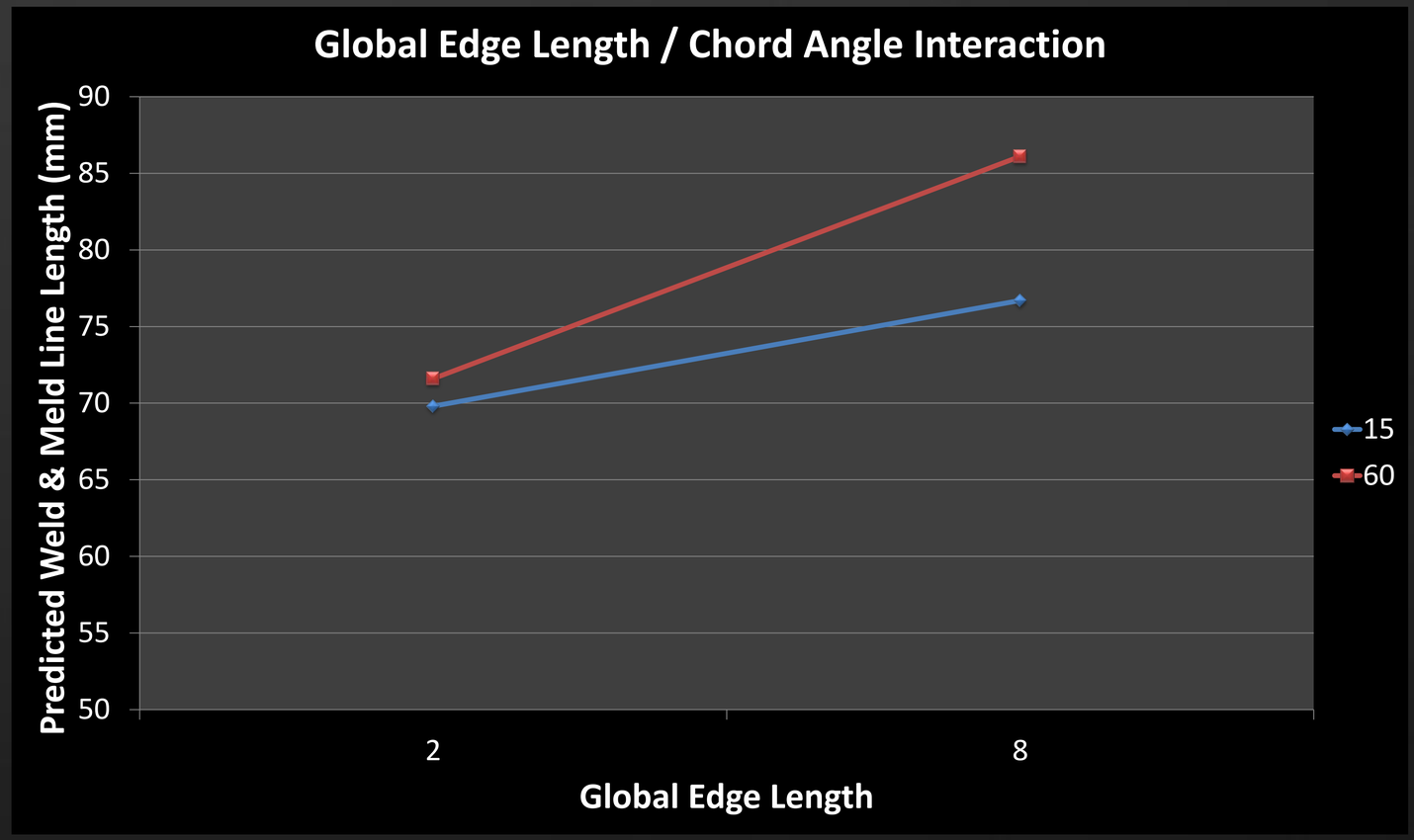
Run #	Treatment	Factors						Measurement
		Single Node Growth	# of Layers	Global Edge Length	Chord Angle	Temp Conv	Flow Conv	
1	(1)	-1	-1	**-1**	**-1**	-1	-1	**69.8**
2	ae	1	-1	**-1**	**-1**	1	-1	**69.8**
3	bef	-1	1	**-1**	**-1**	1	1	**69.8**
4	abf	1	1	**-1**	**-1**	-1	1	**69.8**
5	cef	-1	-1	**1**	**-1**	1	1	**76.7**
6	acf	1	-1	**1**	**-1**	-1	1	**76.7**
7	bc	-1	1	**1**	**-1**	-1	-1	**76.7**
8	abce	1	1	**1**	**-1**	1	-1	**76.7**
9	df	-1	-1	**-1**	**1**	-1	1	**71.6**
10	adef	1	-1	**-1**	**1**	1	1	**71.6**
11	bde	-1	1	**-1**	**1**	1	-1	**71.6**
12	bde	1	1	**-1**	**1**	-1	-1	**71.6**
13	cde	-1	-1	**1**	**1**	1	-1	**86.1**
14	acd	1	-1	**1**	**1**	-1	-1	**86.1**
15	bcdf	-1	1	**1**	**1**	-1	1	**86.1**
16	abcdef	1	1	**1**	**1**	1	1	**86.1**

© 2012 Autodesk

DOE Results

- Significant Interaction Effect
  - Global Edge Length
  - Chord Angle

- Lower chord angle reduces the effect of global edge length

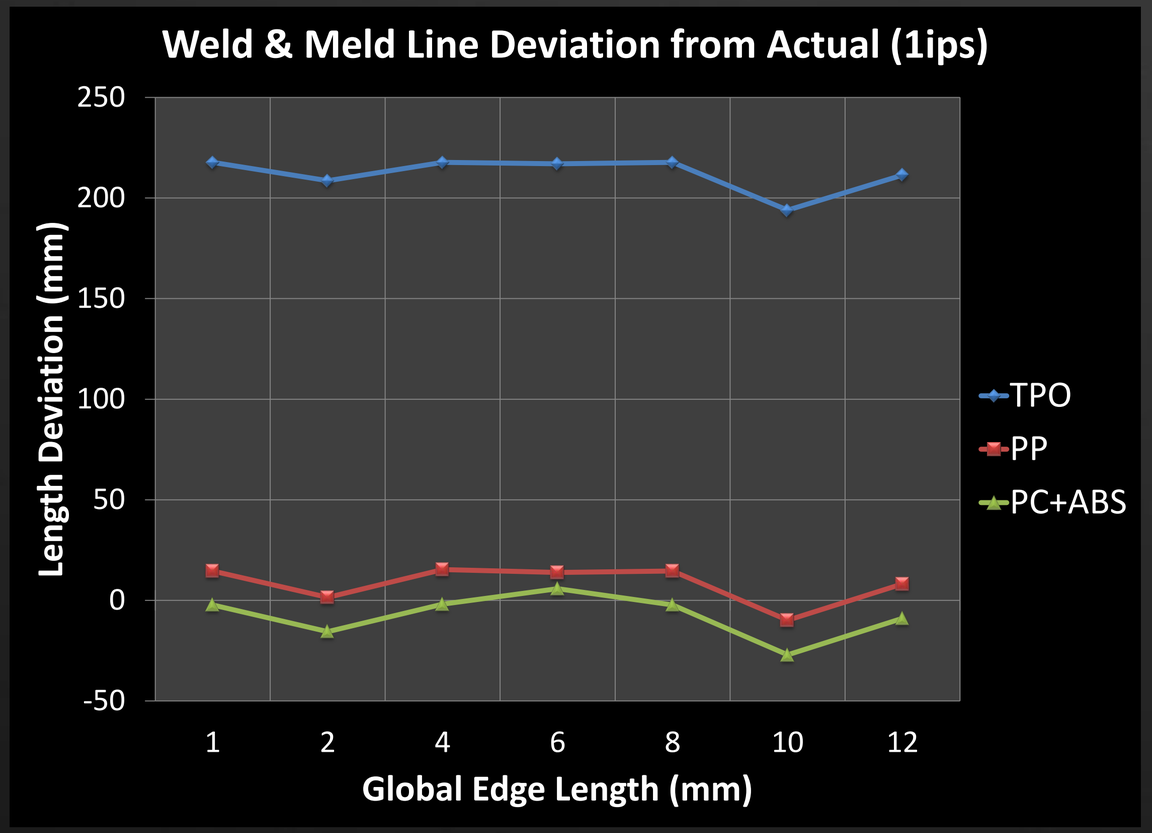


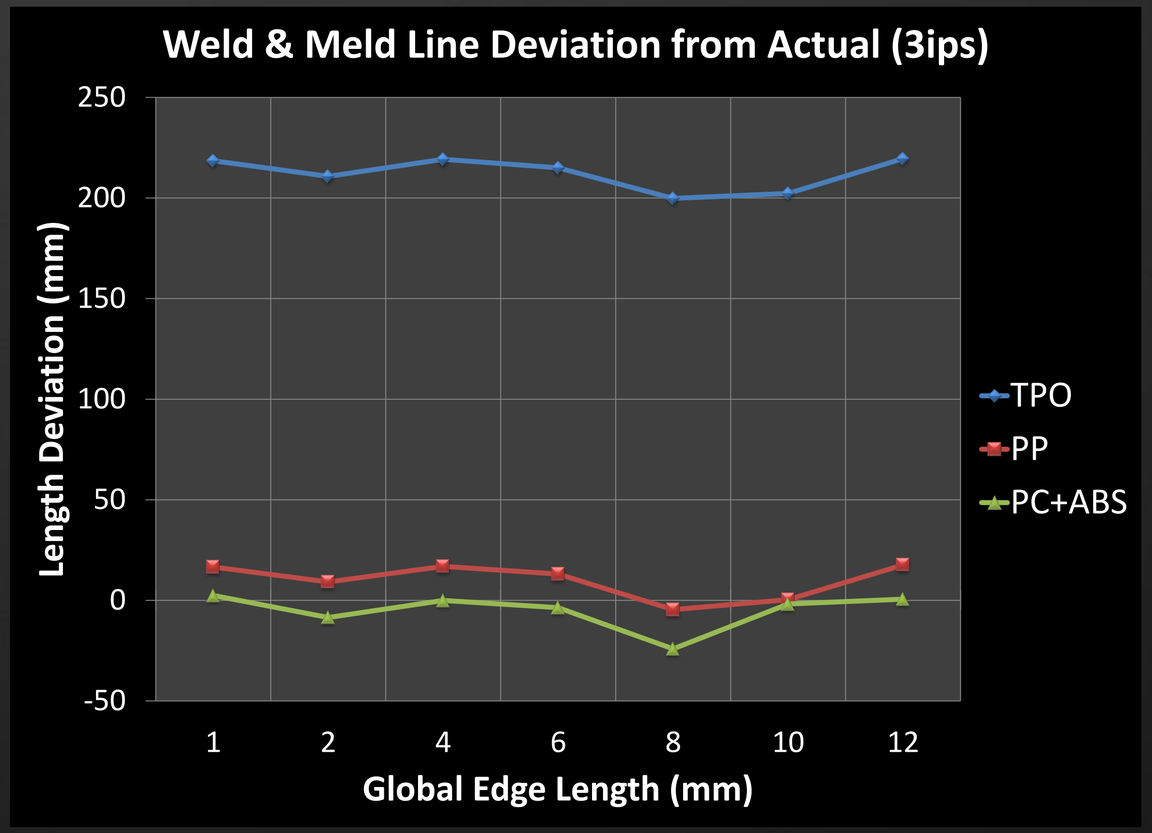
© 2012 Autodesk

Dual-Domain (DD) Mesh Results

© 2012 Autodesk

DD Default Settings – 6mm Pin

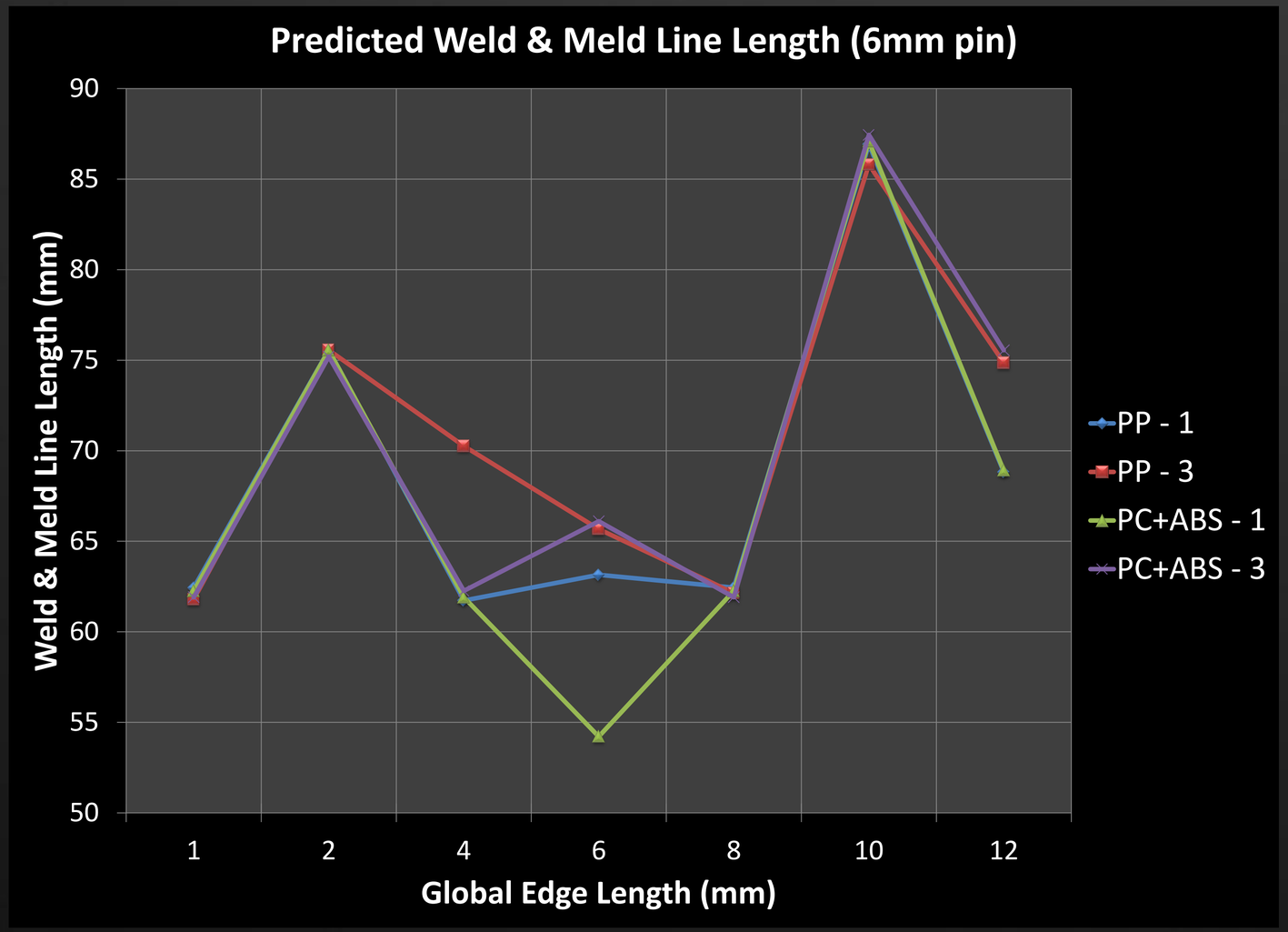




- Prediction deviates from actual -27mm to +17mm
- Deviation in TPO is 200mm +

© 2012 Autodesk

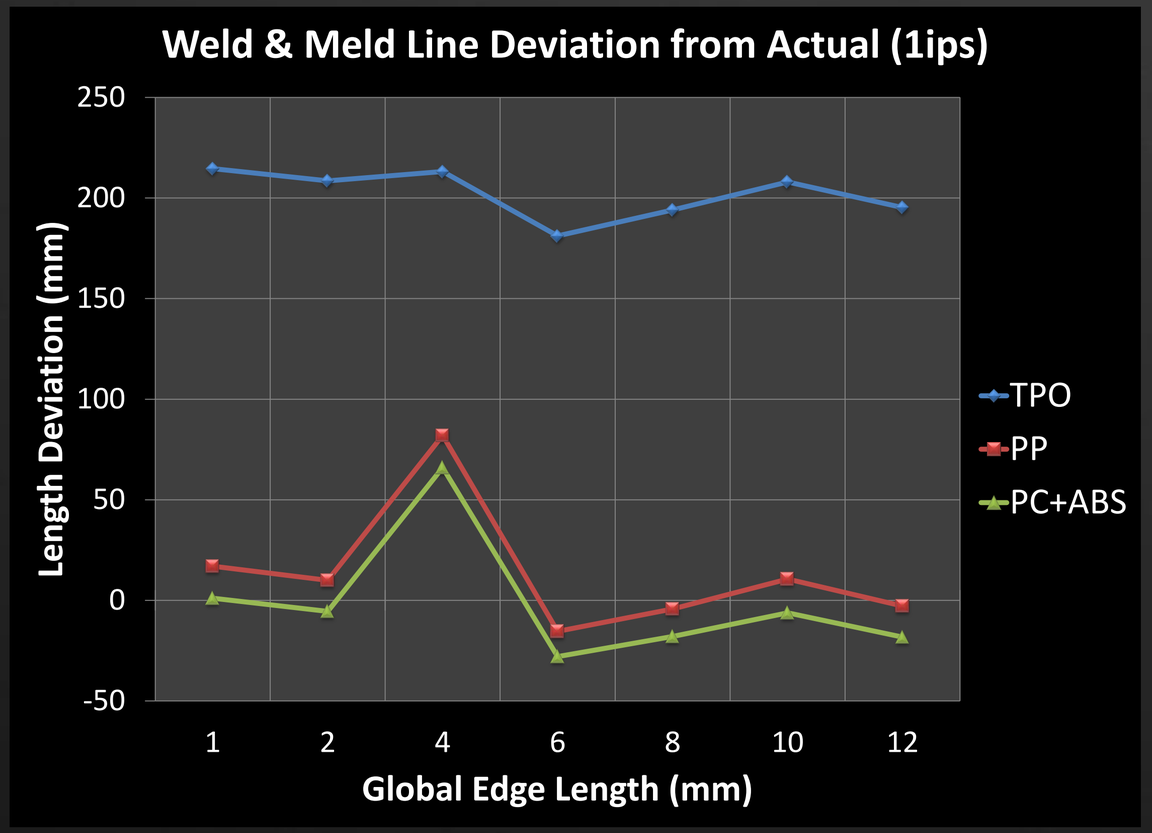
DD – 6mm Pin – Material Difference

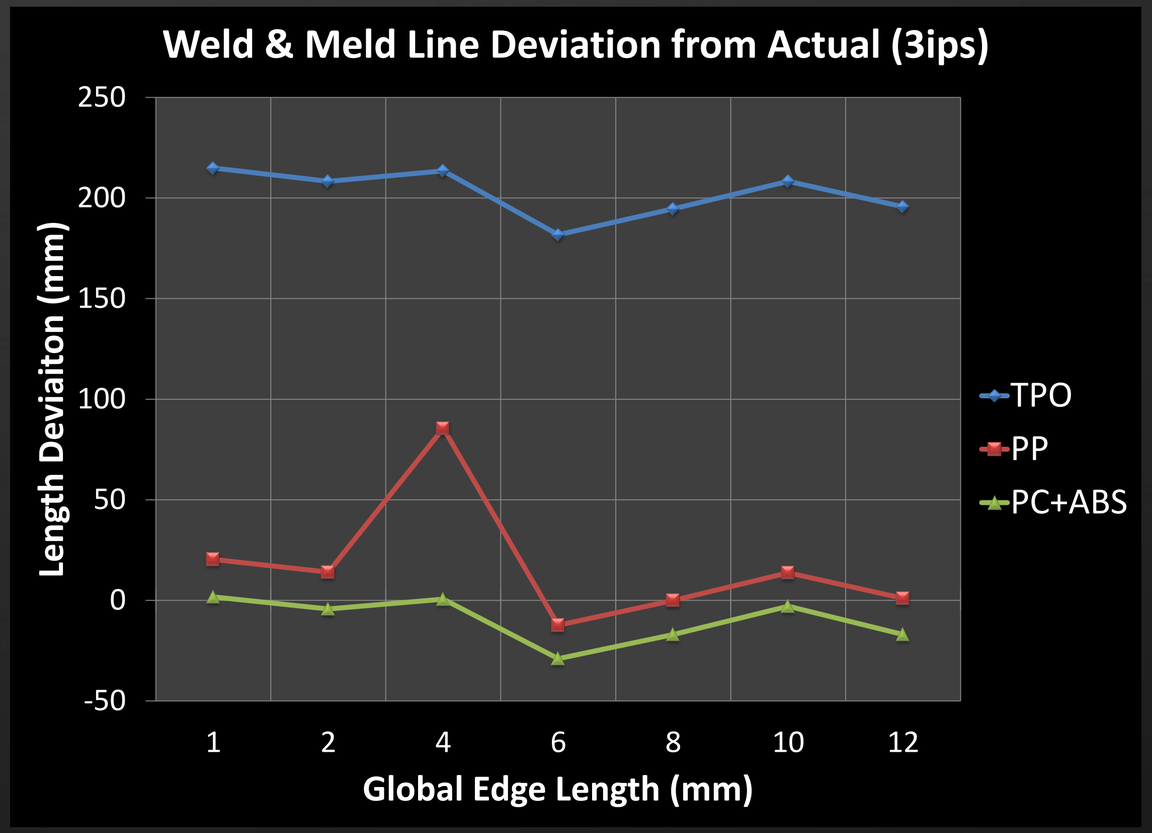


- Predictions do not capture difference between materials

© 2012 Autodesk

DD Default Settings – 12mm Pin

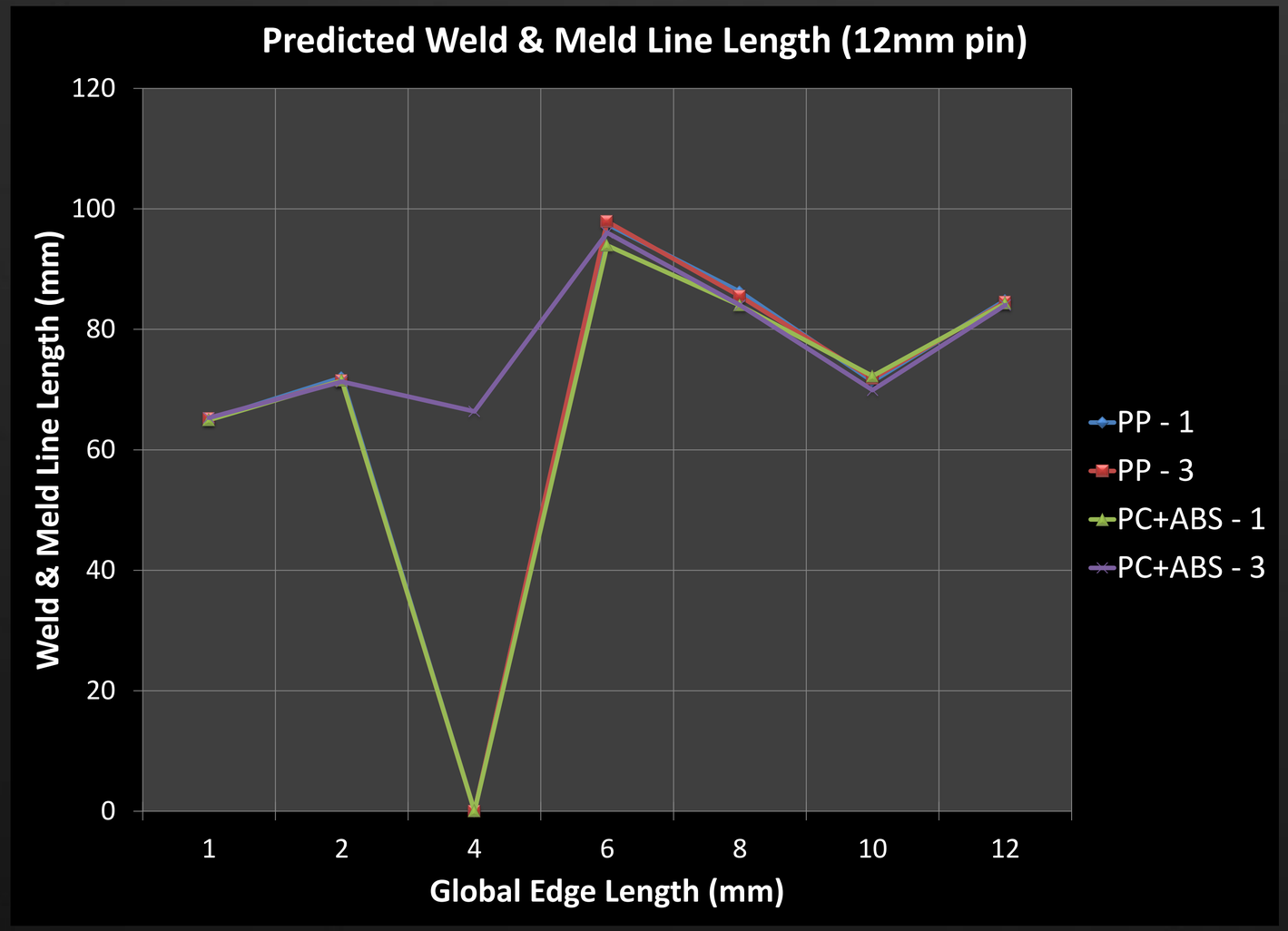




- Prediction deviates from actual -27mm to +85mm
- Deviation in TPO is 180mm +

© 2012 Autodesk

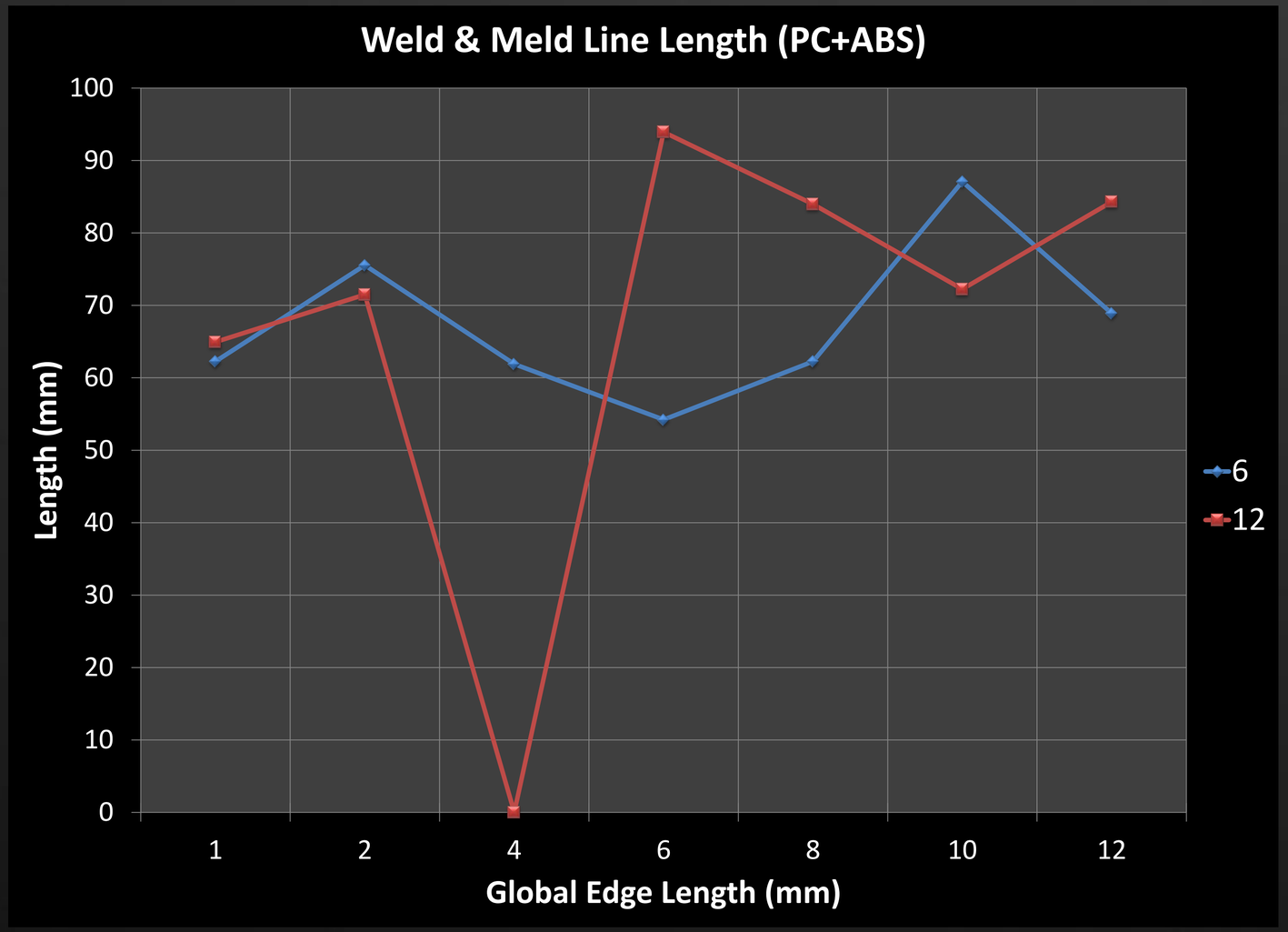
DD – 12mm Pin – Material Difference



- Predictions do not capture difference between materials
- Knit line is not captured consistently at GEL = 4

© 2012 Autodesk

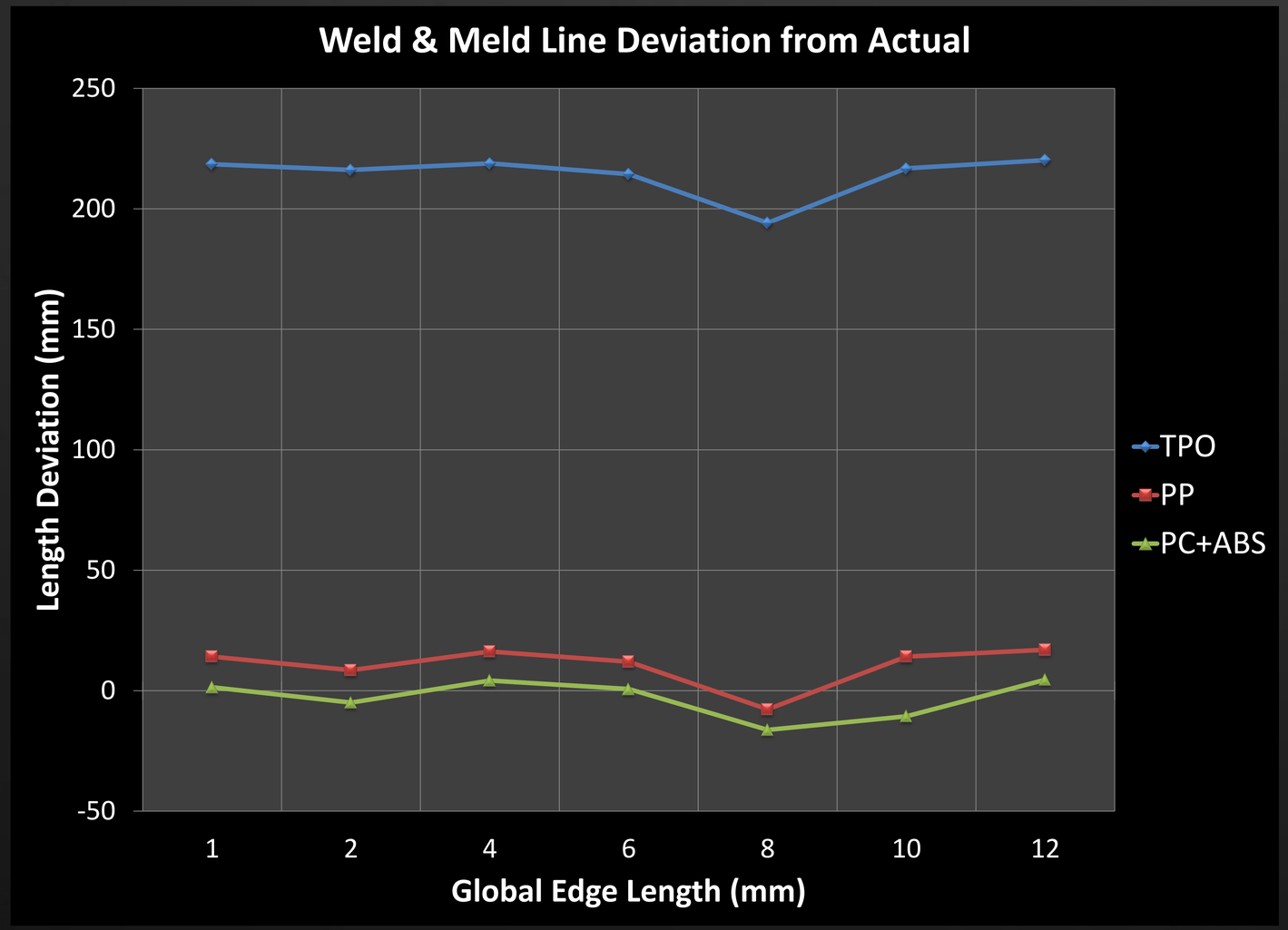
DD – Difference Between Pin Diameters



- With default mesh settings the length difference between pin diameters is not accurately captured
- Knit line not consistently captured at GEL = 4

© 2012 Autodesk

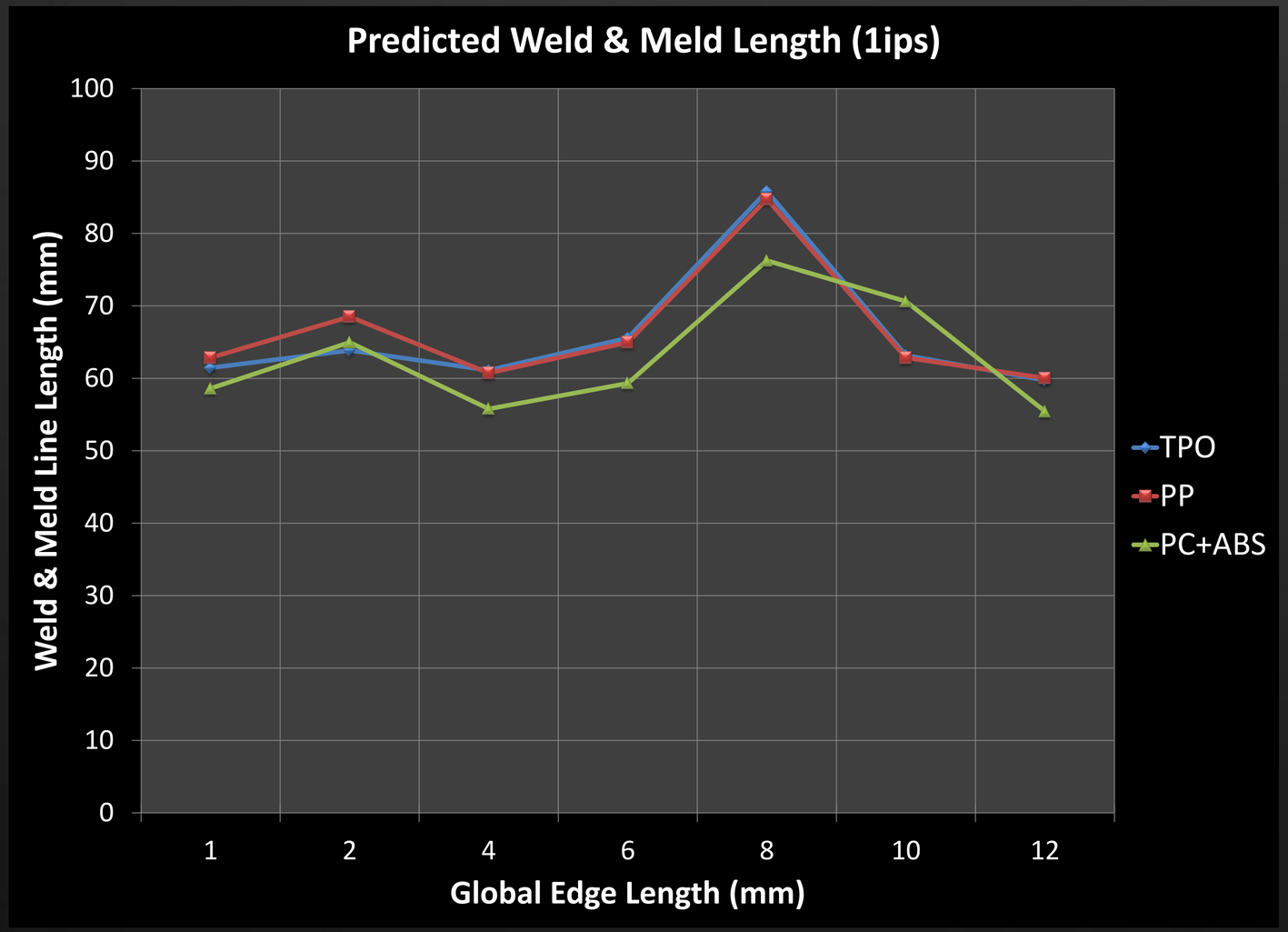
DD – Chord Angle of 15



- TPO deviation is 200mm +
- Predictions deviate from actual -16mm to +16mm

© 2012 Autodesk

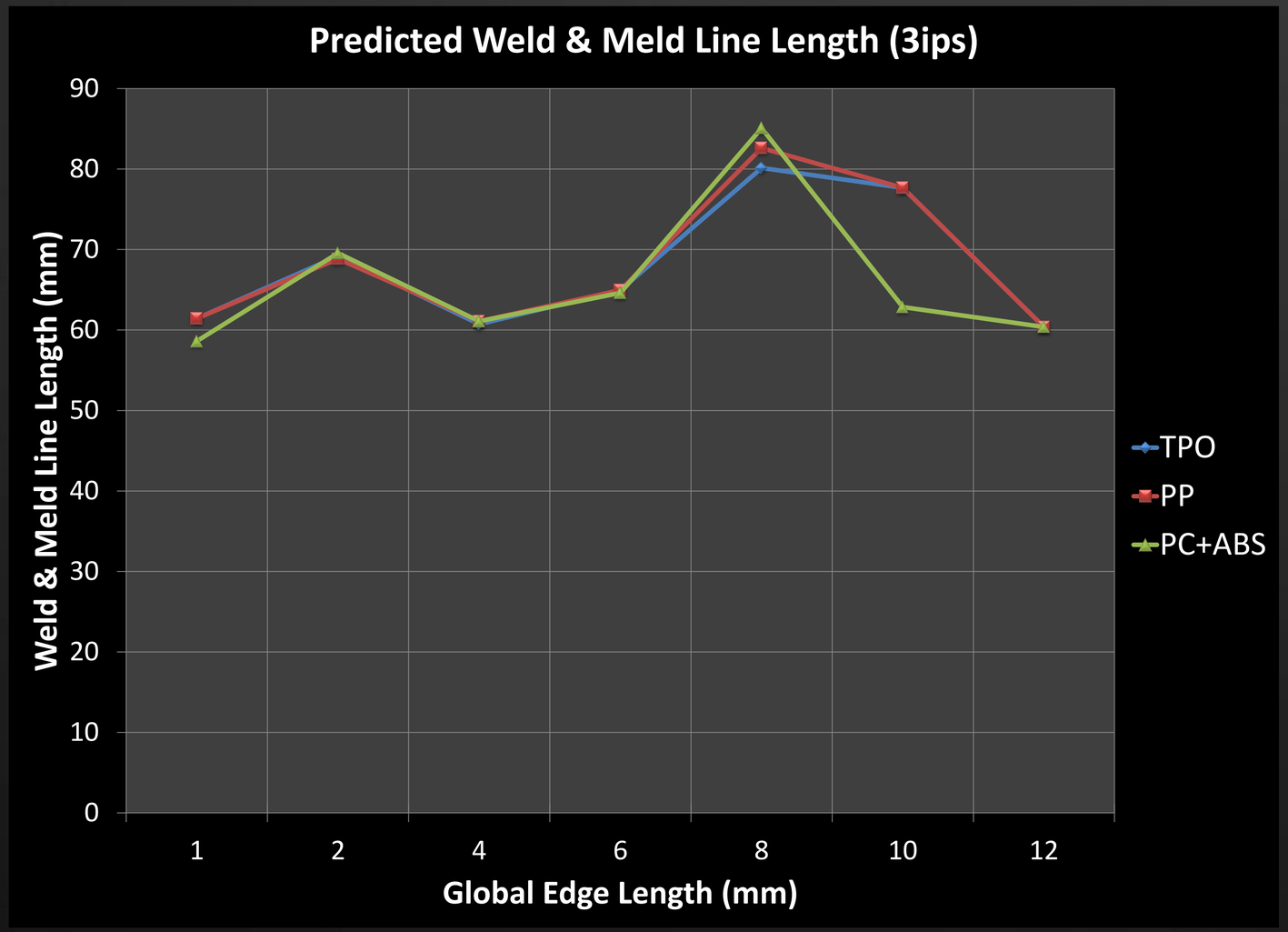
DD – Chord Angle of 15 – Fill Speed 1ips



- A difference between PP and PC+ABS is captured in prediction

© 2012 Autodesk

DD – Chord Angle of 15 – Fill Speed 3ips



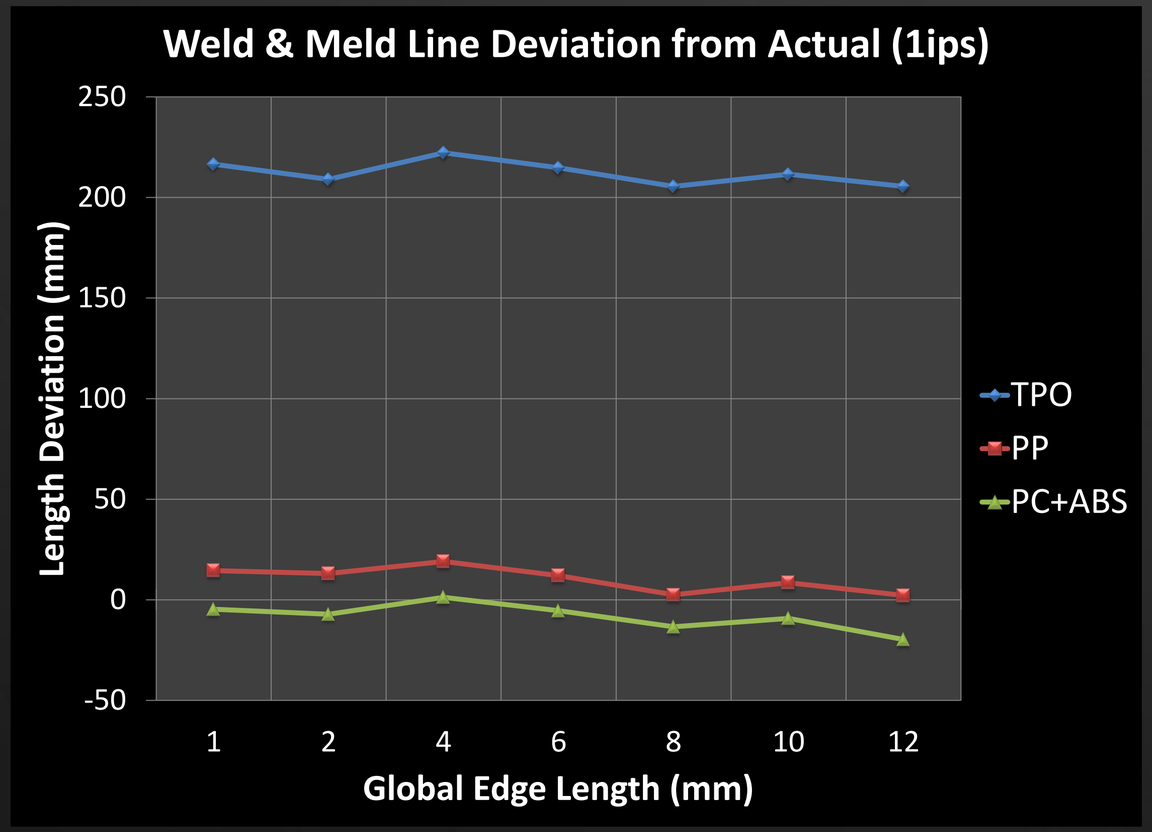
- Difference between PP and PC+ABS is lost at the higher fill speed

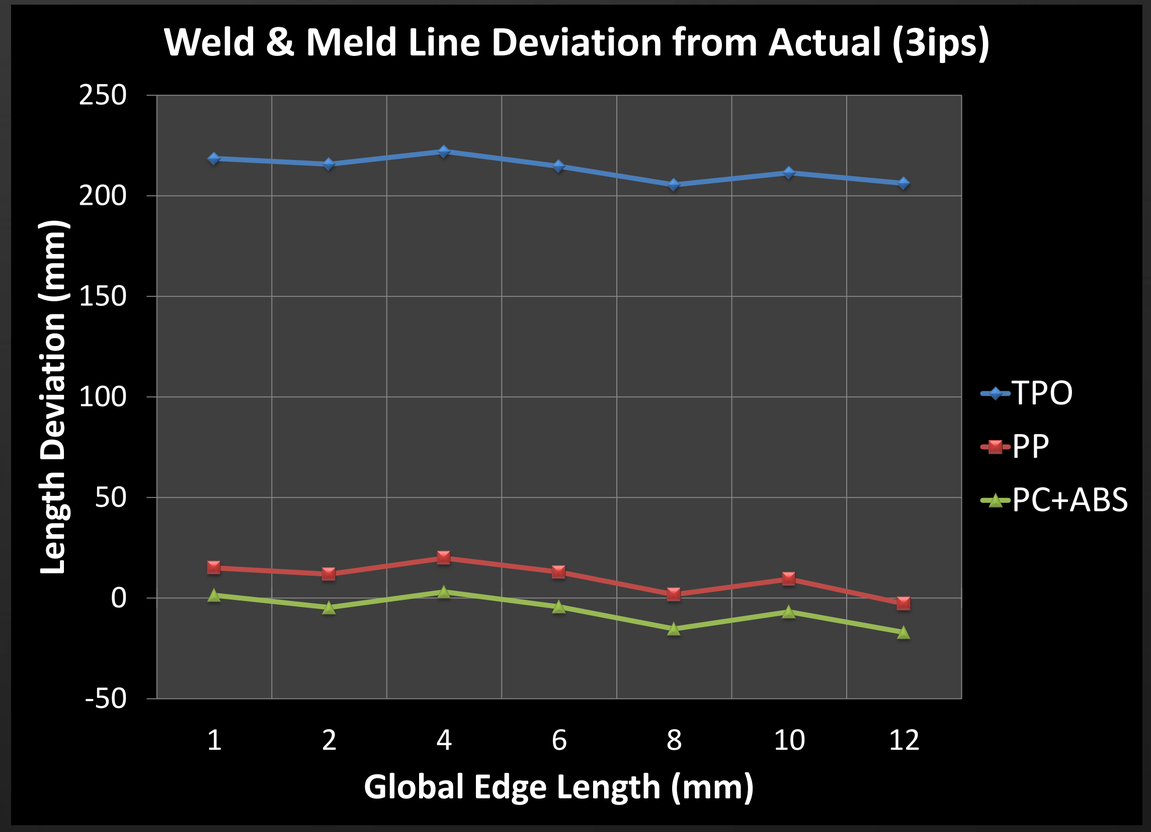
© 2012 Autodesk

Mid-Plane (MP) Mesh Results

© 2012 Autodesk

MP Default Settings – 6mm Pin

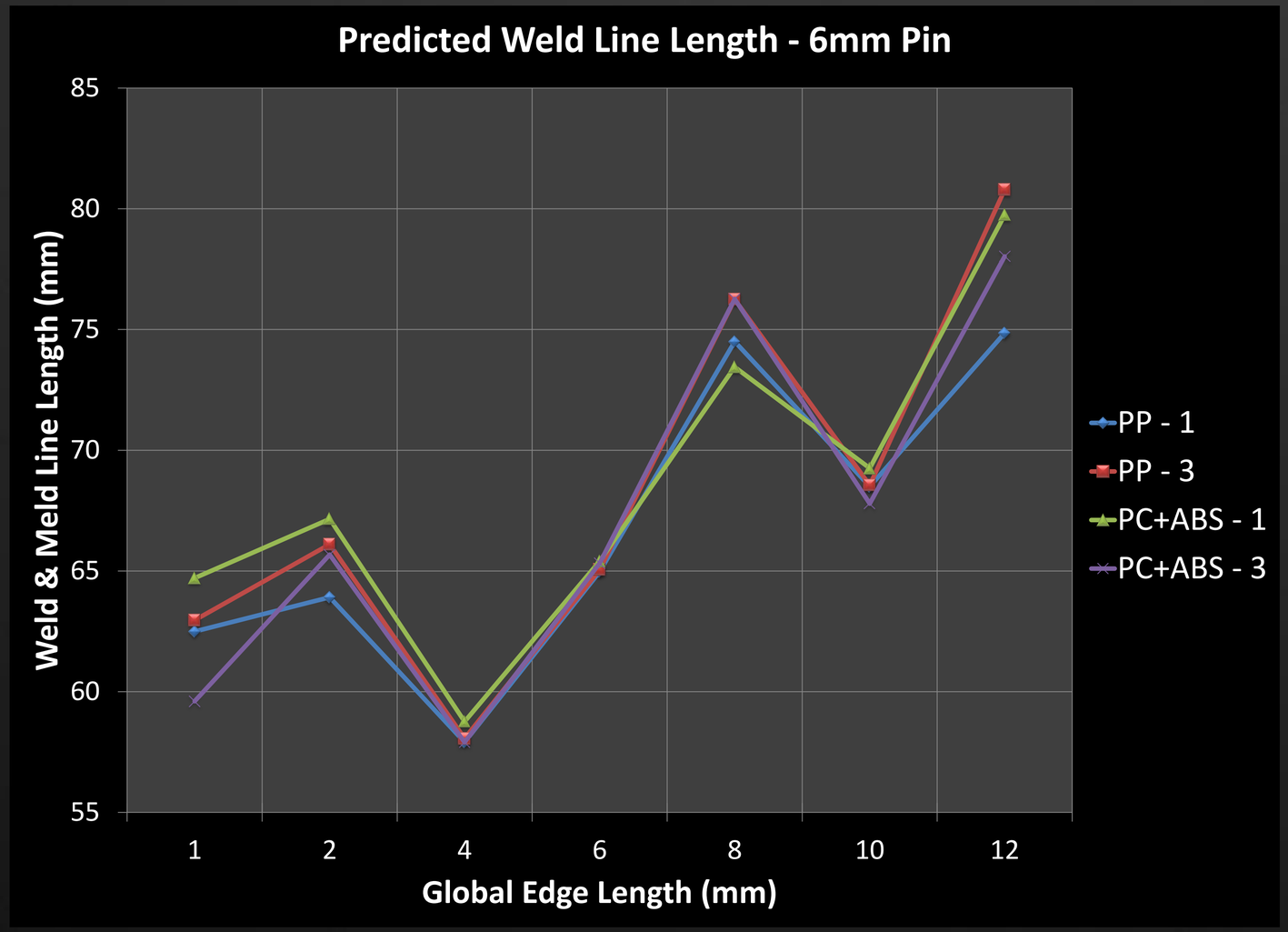




- Global Edge Length not effecting weld and meld predicted length

© 2012 Autodesk

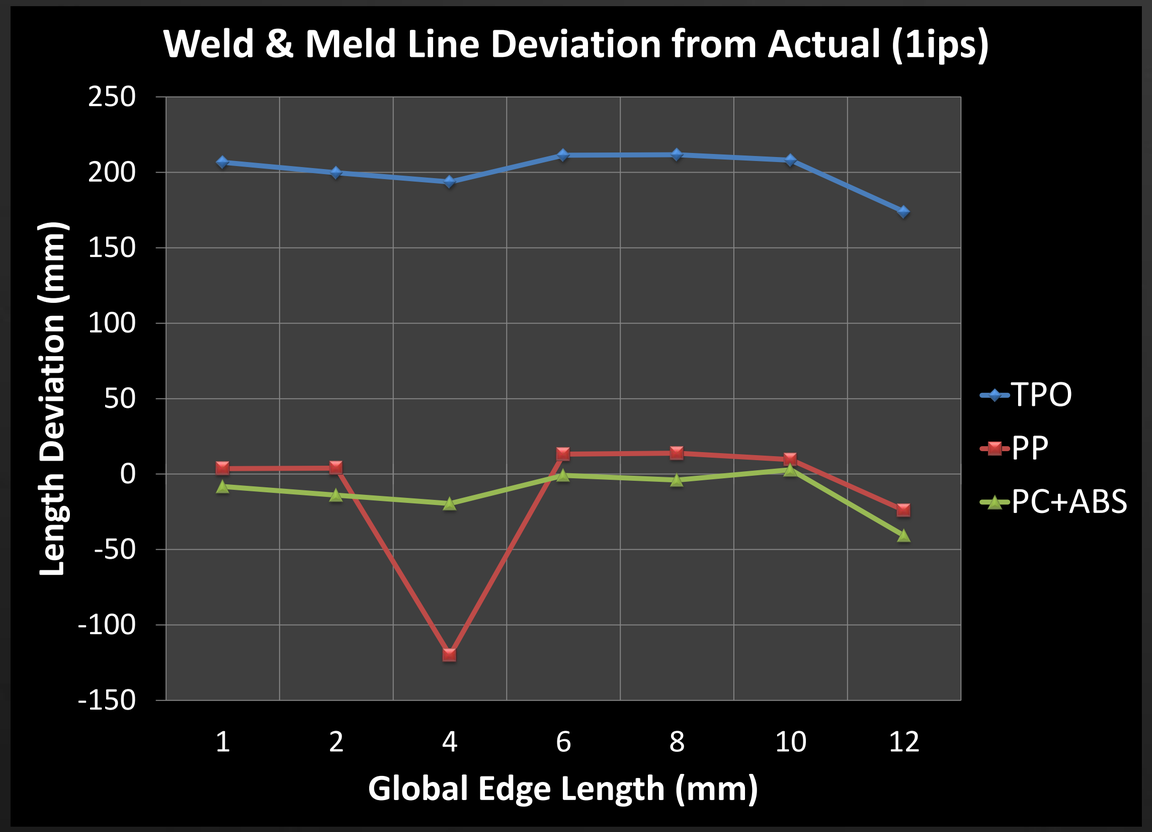
MP – 6mm Pin – Material Difference

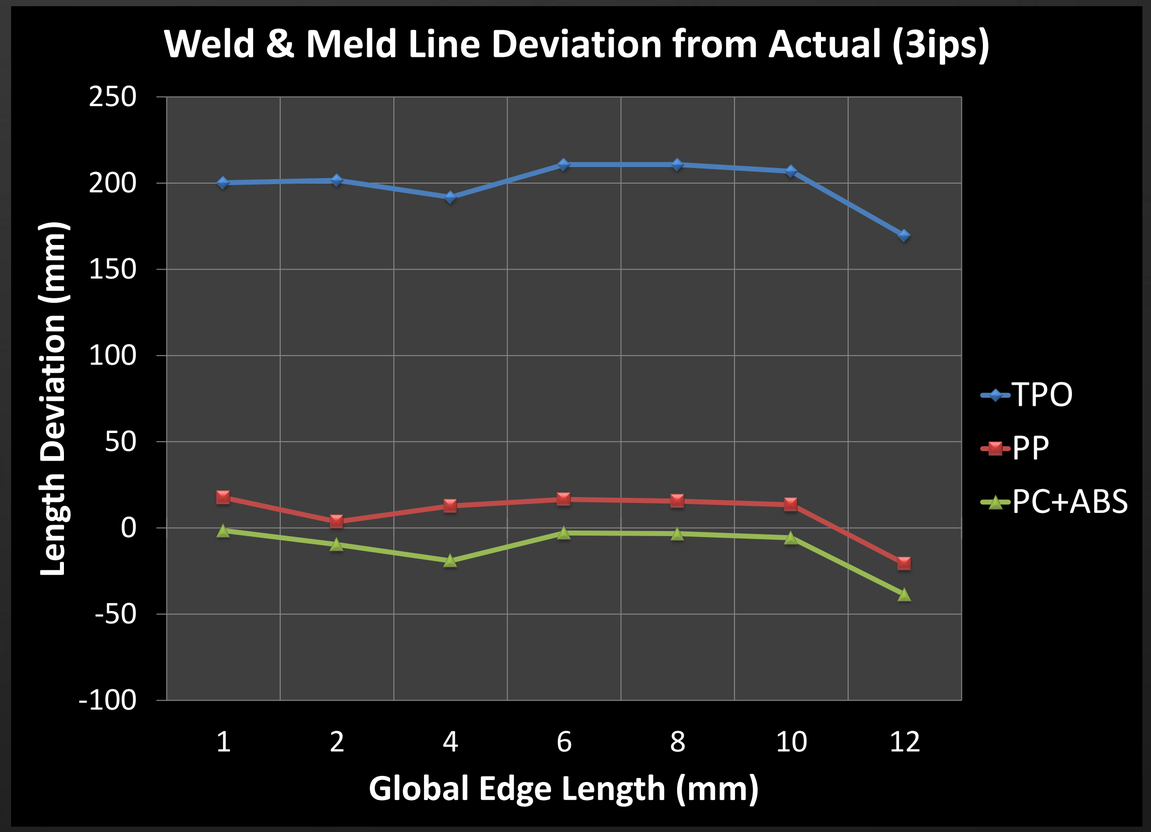


- Predictions do not capture difference between materials

© 2012 Autodesk

MP Default Settings – 12mm Pin

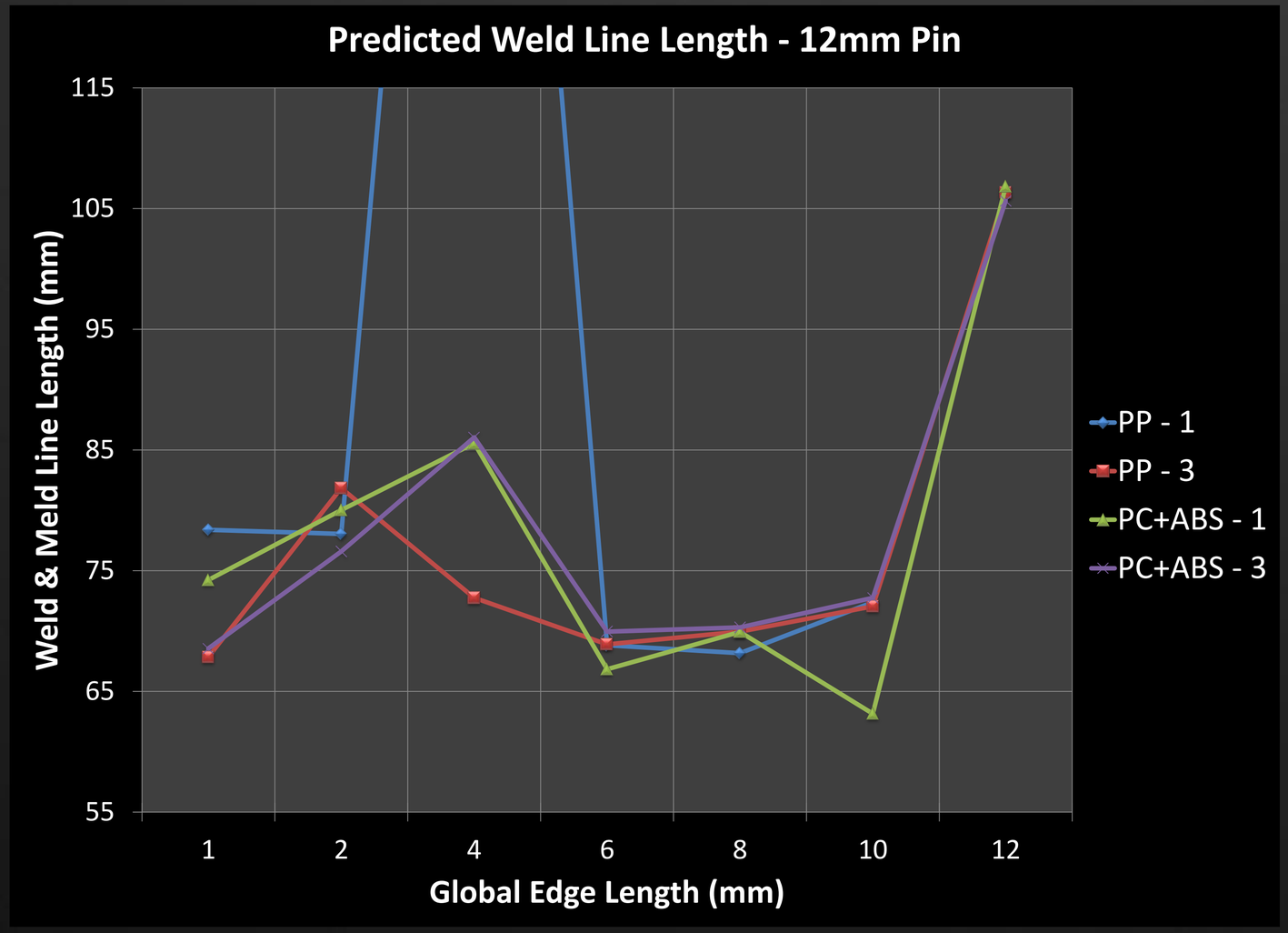




- Global Edge Length not effecting weld and meld predicted length

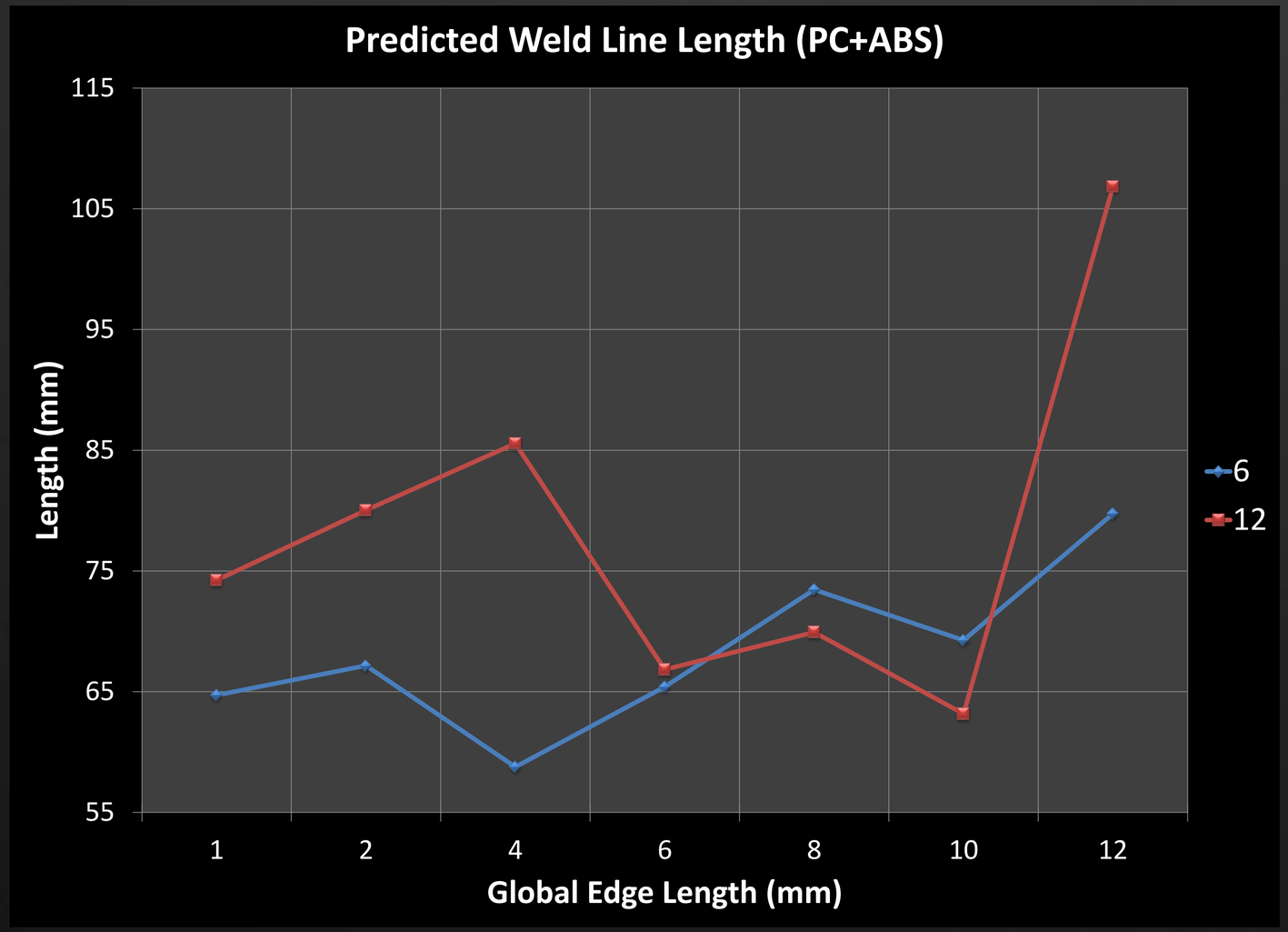
© 2012 Autodesk

MP – 12mm Pin – Material Difference



© 2012 Autodesk

MP – Difference Between Pin Diameters



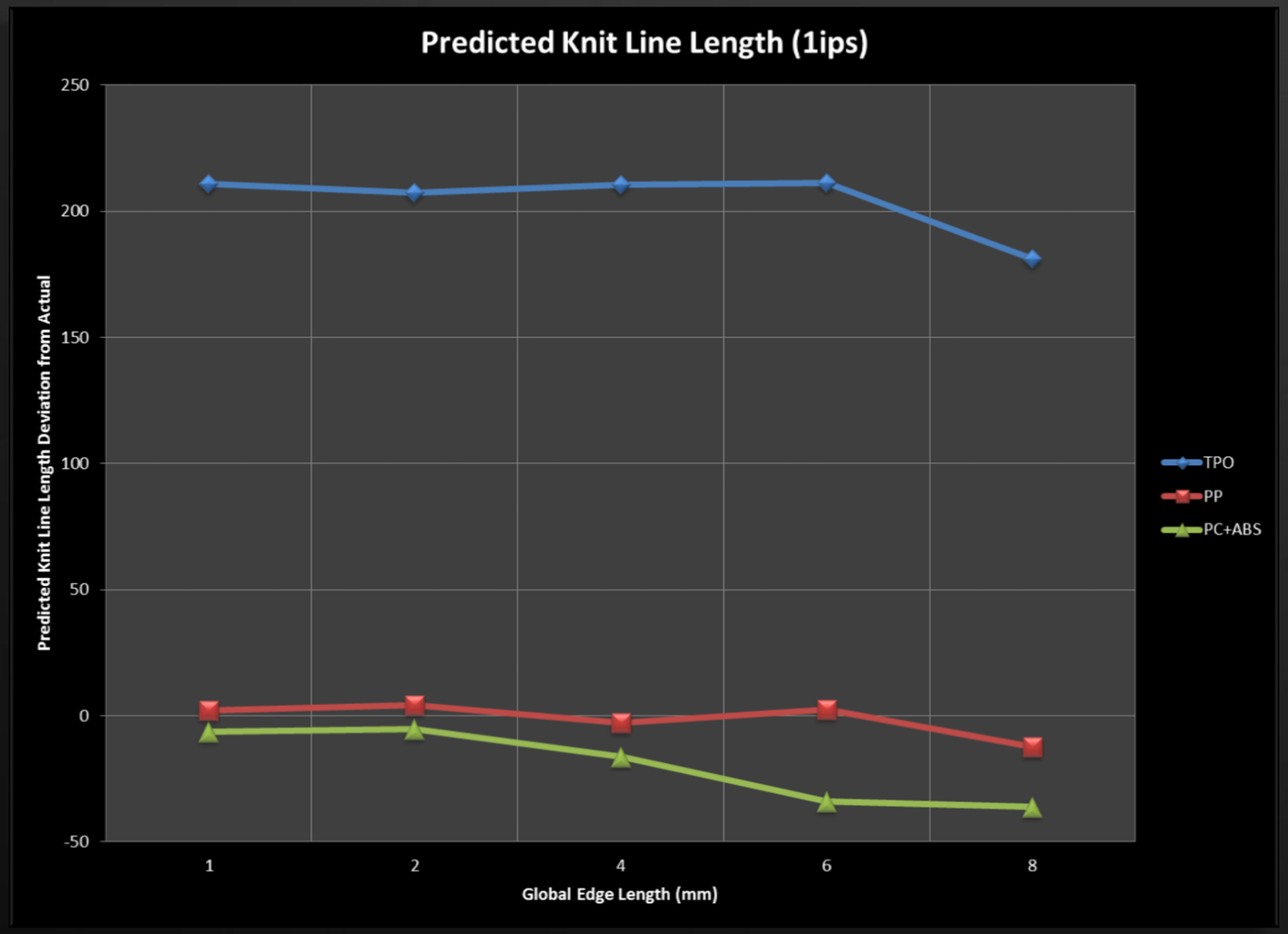
- GEL ≤ 6
  - Relative difference between pins captured
- GEL = 1
  - Error on difference is within 15% of length

© 2012 Autodesk

3D Mesh Results

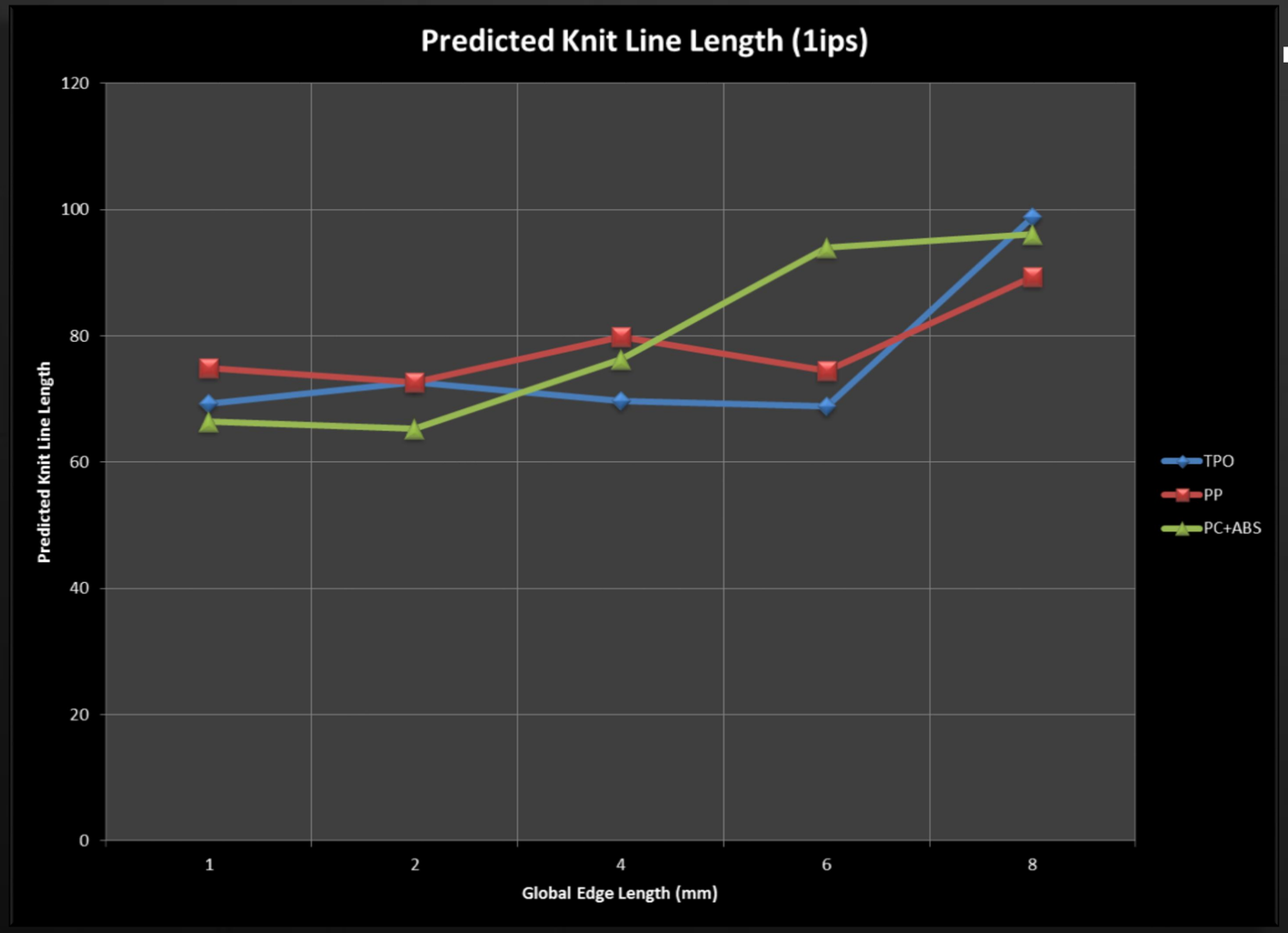
© 2012 Autodesk

3D Mesh – 6mm Pin



© 2012 Autodesk

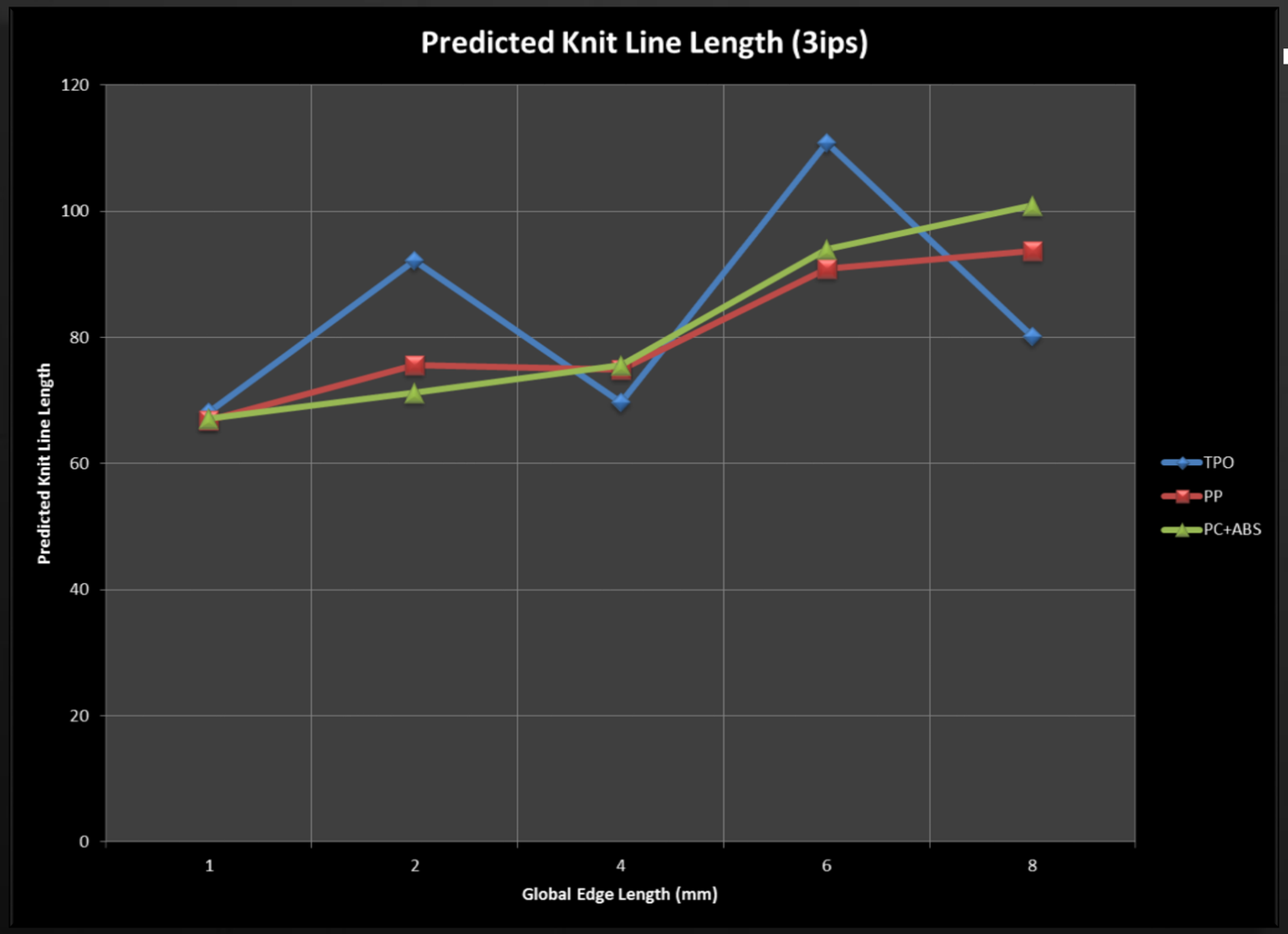
3D Mesh – 6mm Pin



- At edge lengths <= 4 the difference between PP and PC+ABS is captured

© 2012 Autodesk

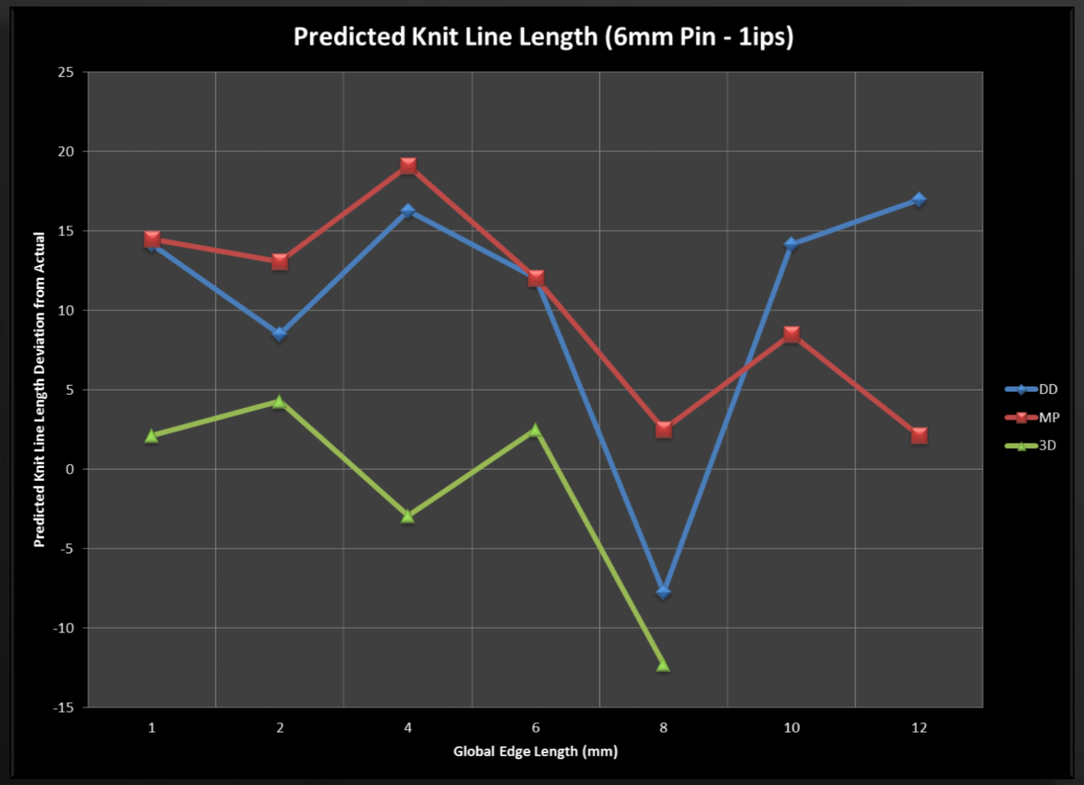
3D Mesh – 6mm Pin

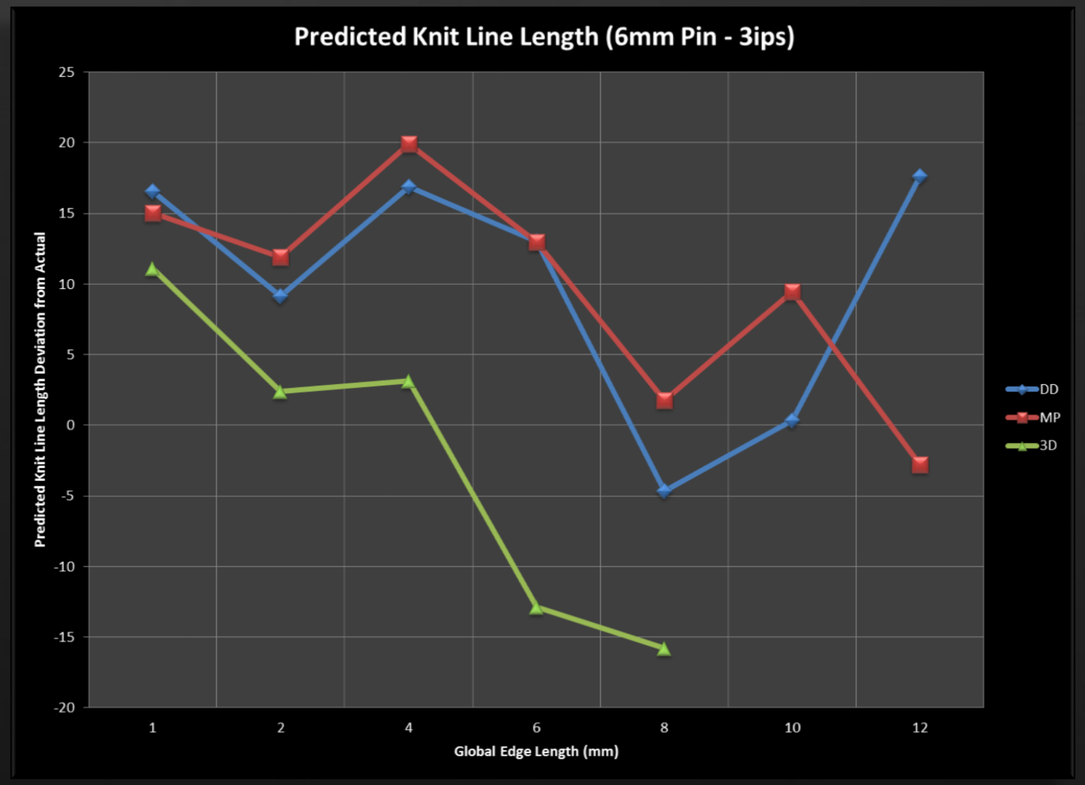


- Similar to the DD models, PP – PC+ABS difference is lost at higher injection speeds

© 2012 Autodesk

PP Summary

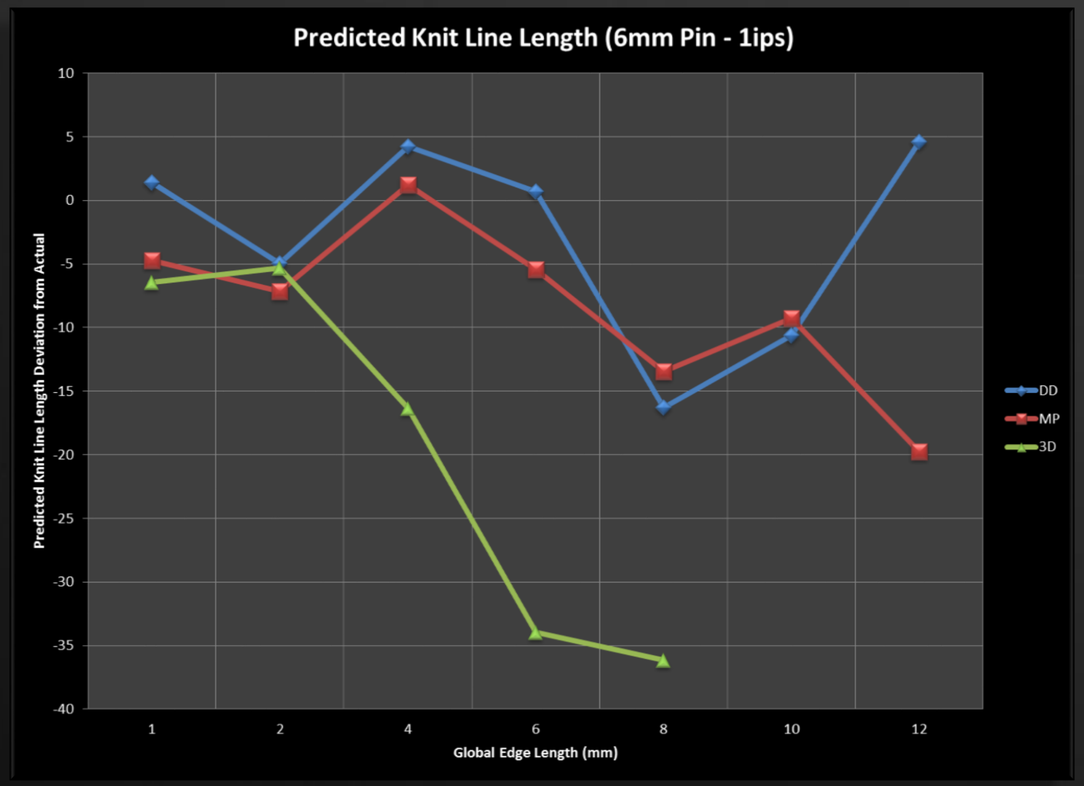


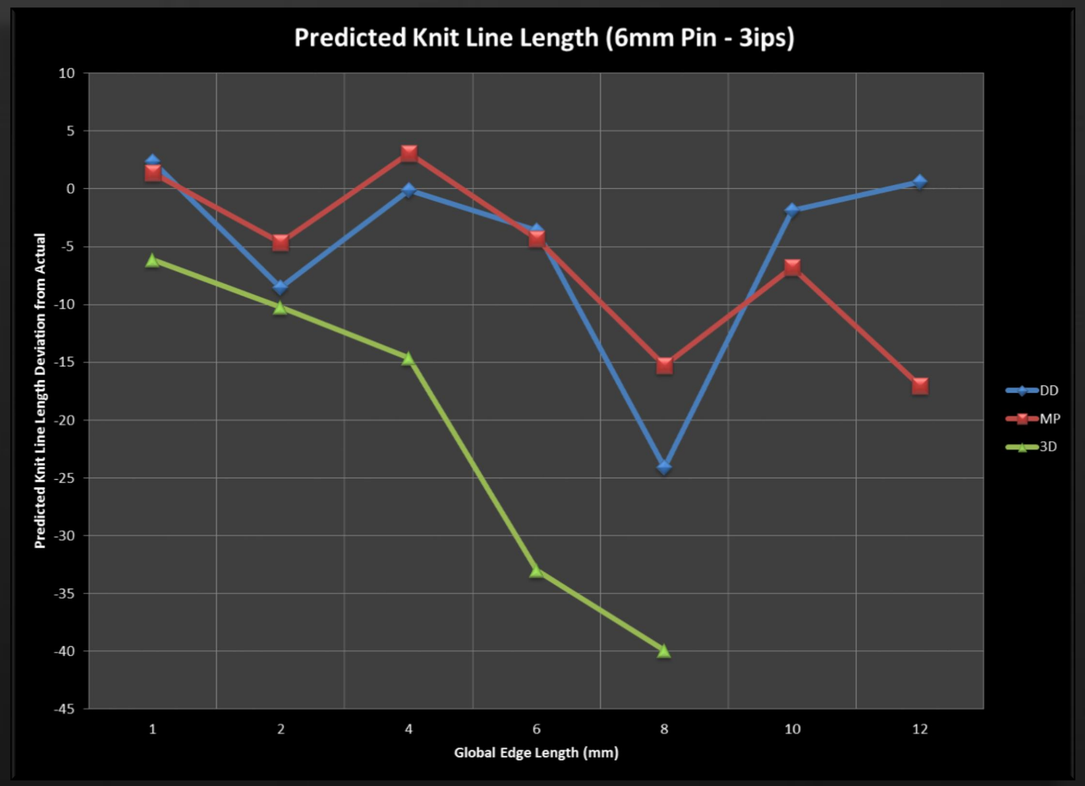


- 3D mesh results in less error than other meshes

© 2012 Autodesk

PC+ABS Summary

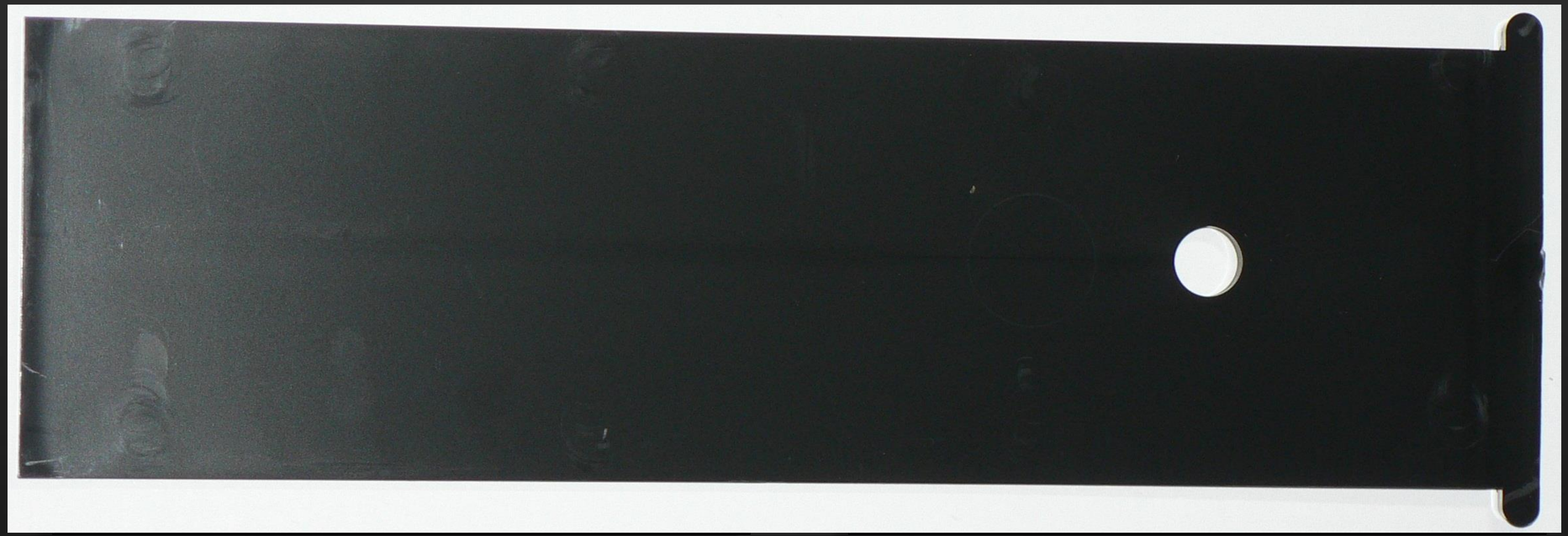




- Most accurate regardless of mesh
- 3D results are sensitive to global edge length

© 2012 Autodesk

TPO Summary



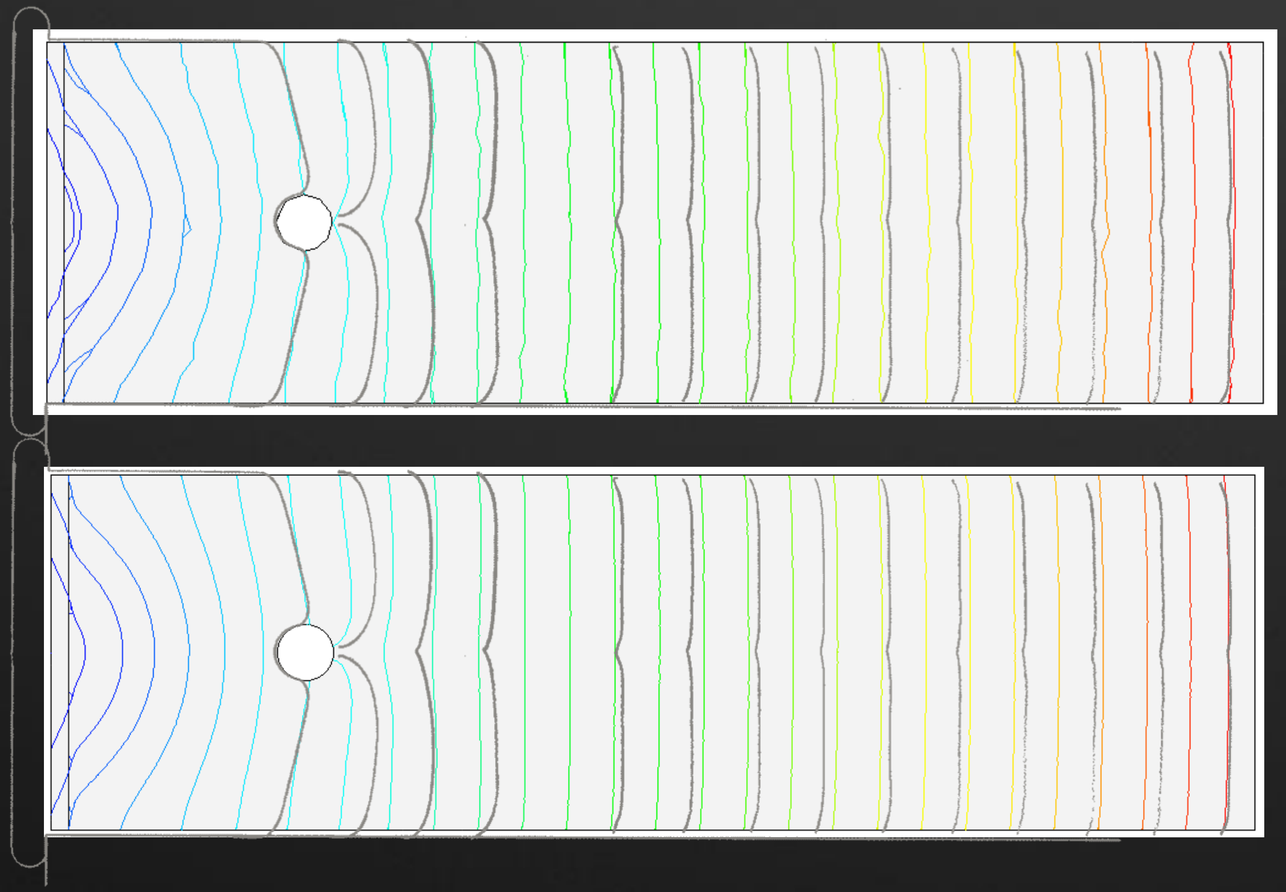
- No mesh type captures the length

© 2012 Autodesk

Contour Overlays

© 2012 Autodesk

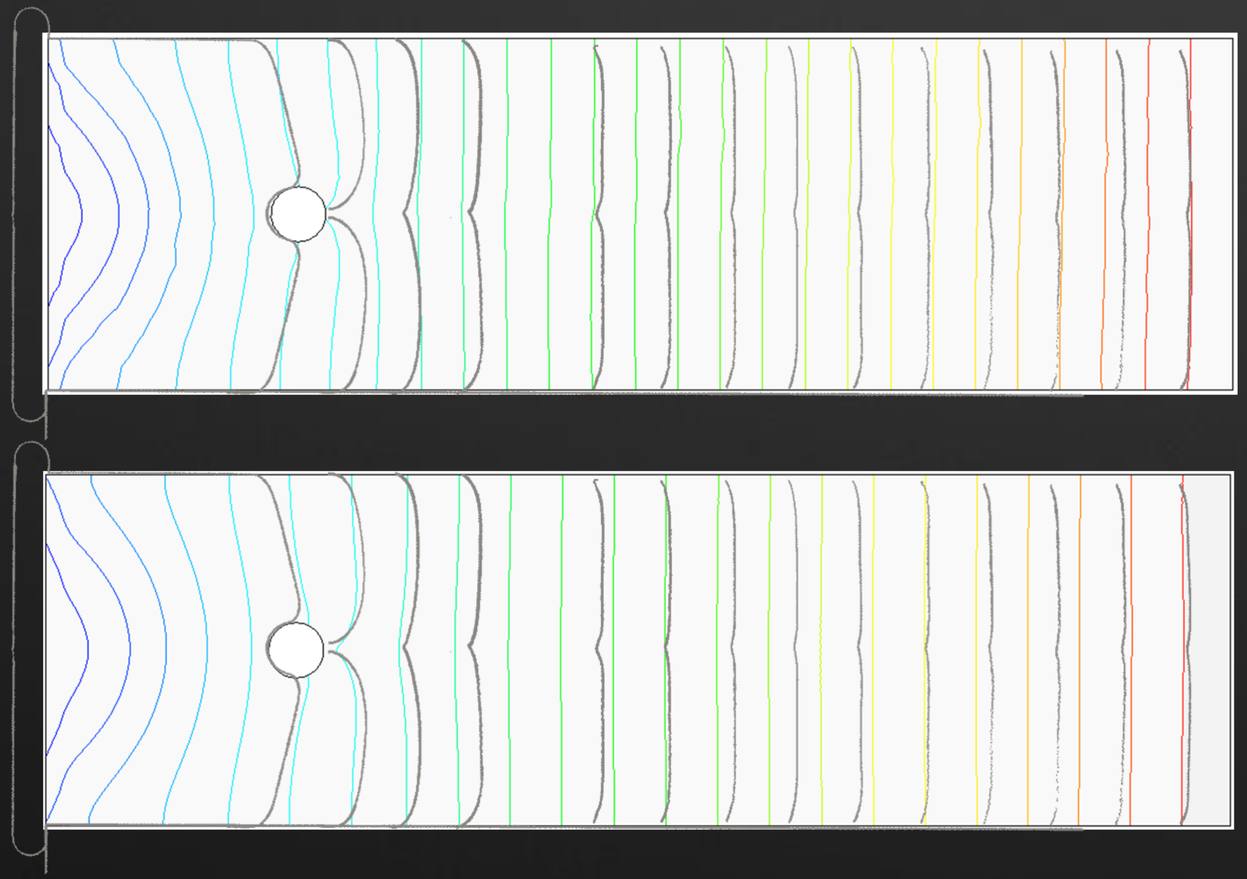
Dual-Domain Contour Overlays - TPO



- 6mm vs 1mm mesh
- Better flow front refinement
- Does not capture slip at side walls
- Both contours “flat” at same distance

© 2012 Autodesk

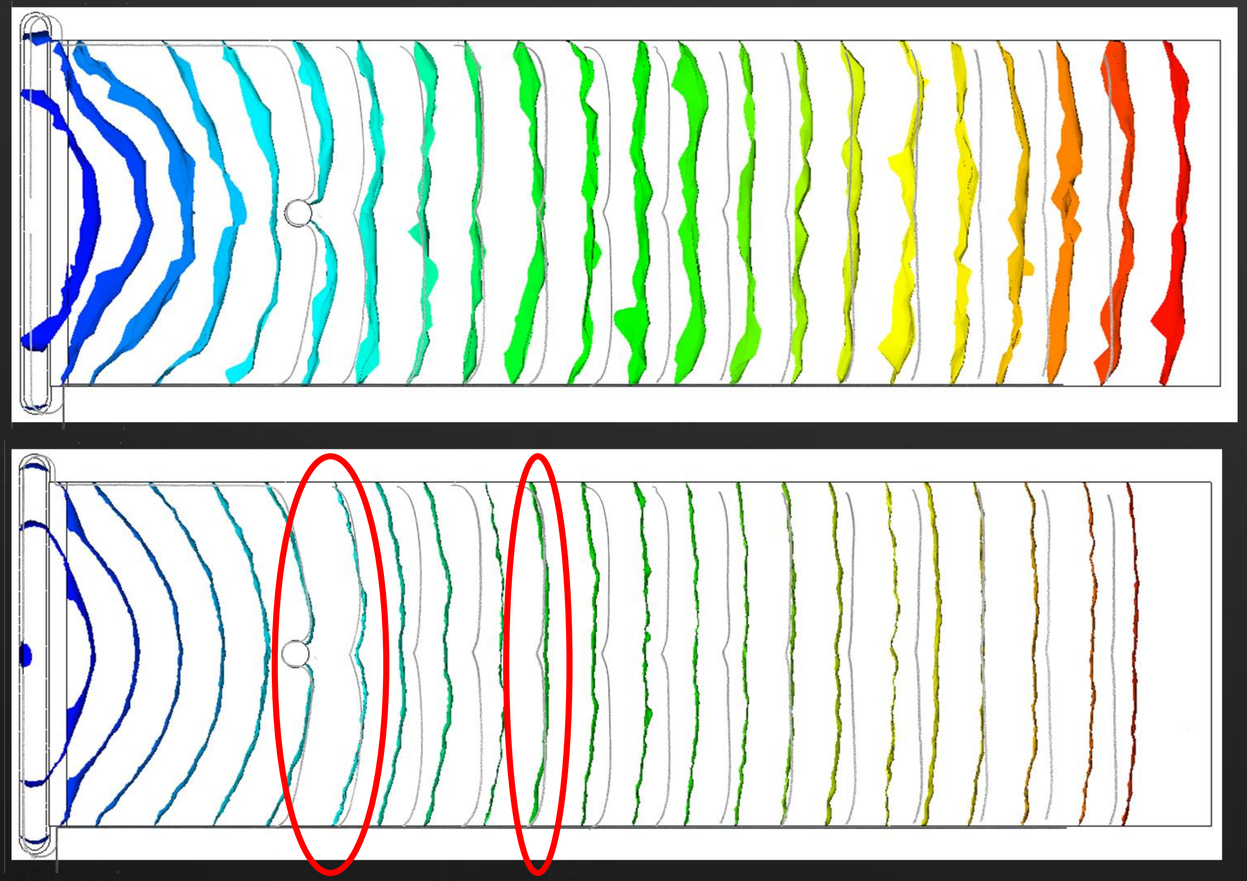
Mid Plane Contour Overlays - TPO



- 6mm vs 1mm mesh
- Better flow front refinement
- Does not capture slip at side walls
- 1mm mesh – longer distance to “flat”

© 2012 Autodesk

3D Contour Overlays - TPO



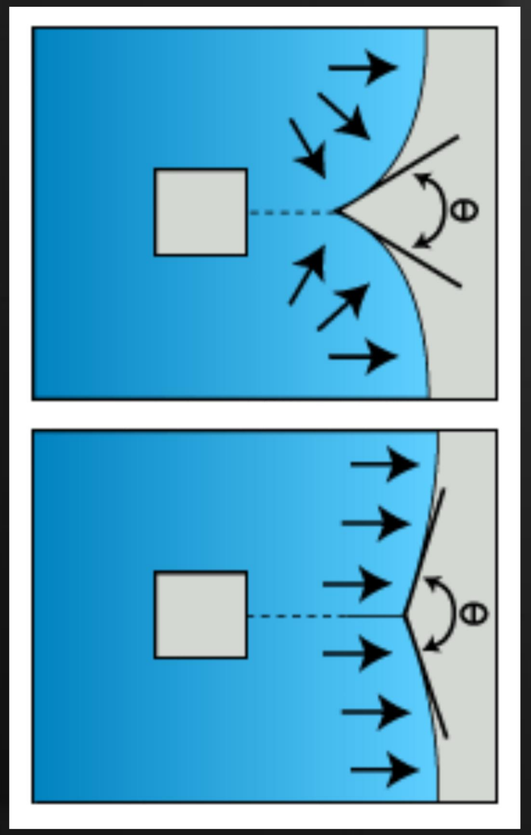
- 6mm vs 1mm mesh
- 8 layers thru thickness
- 6mm 3D – better than MP/DD

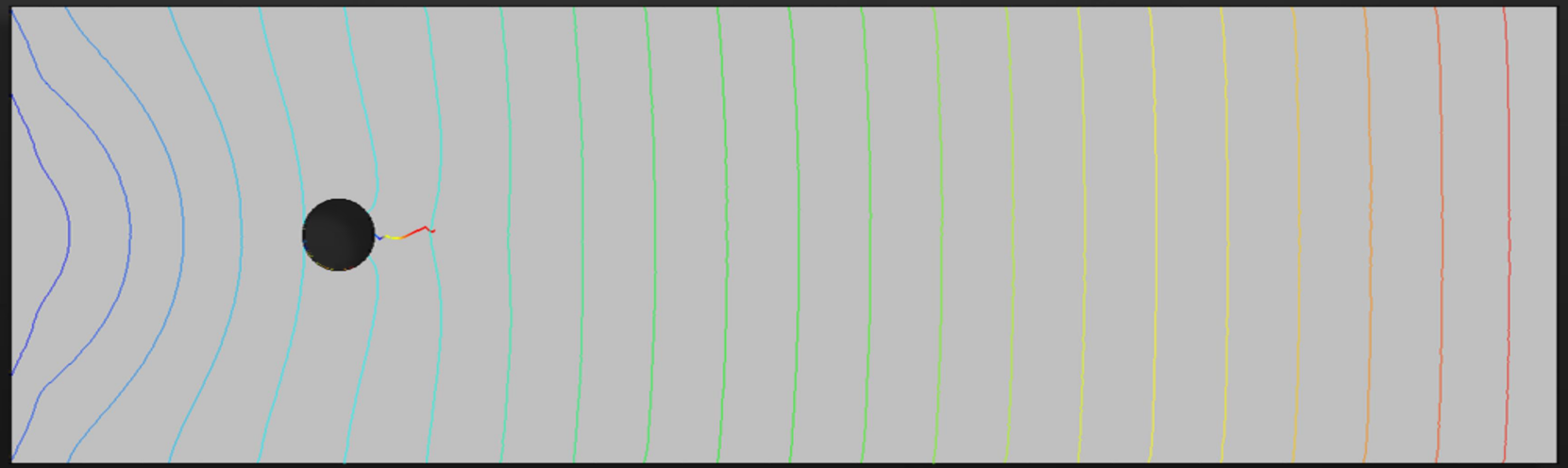
- 1mm mesh
  - Captures slip at pin very well
  - Slip at sidewall slightly captured
  - 1st contour – excellent correlation
  - Flow front flattens too quickly

© 2012 Autodesk

Why is the length not predicted as accurately as we would like?

- Prediction is based solely on the angle of the flow front at each node

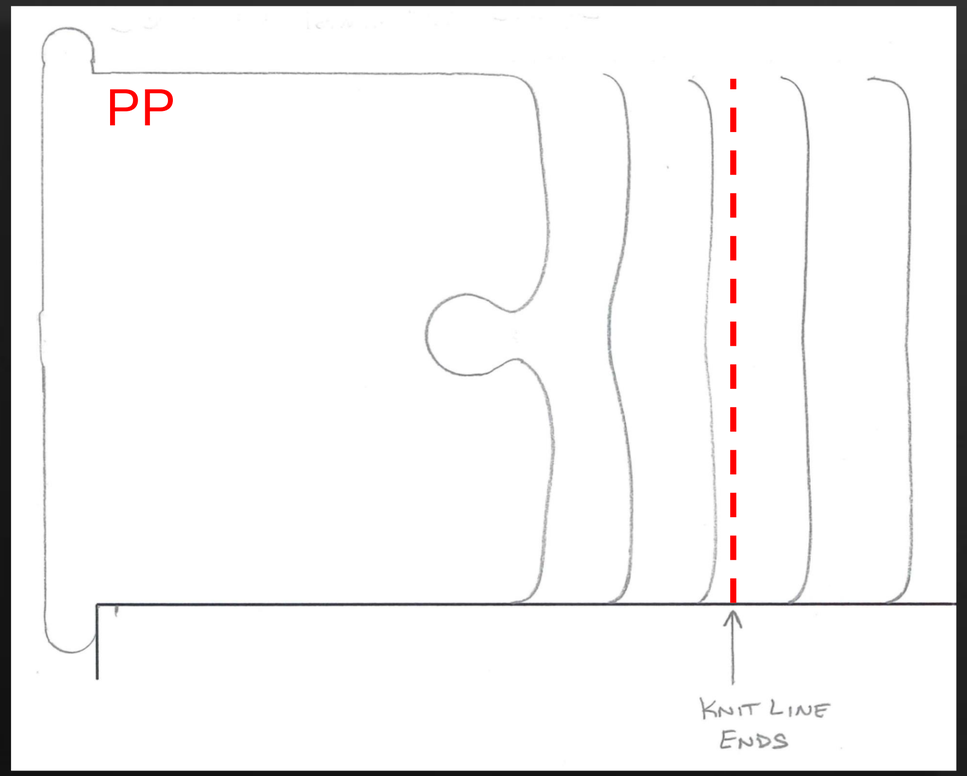


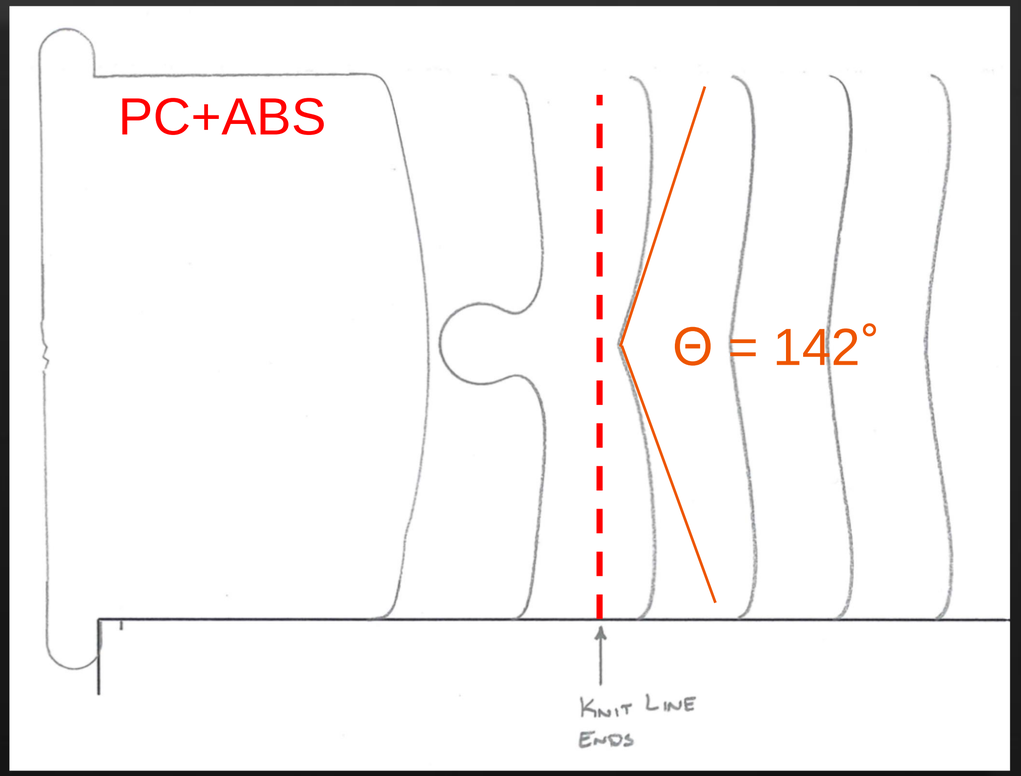


© 2012 Autodesk

Why is the length not predicted as accurately as we would like?

- The actual visible knit line does not correlate to the flow front angle.

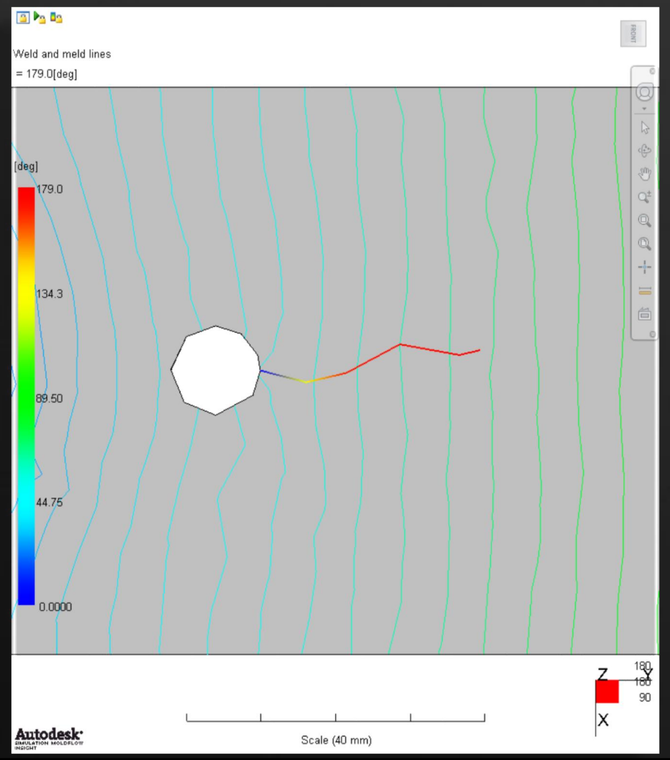


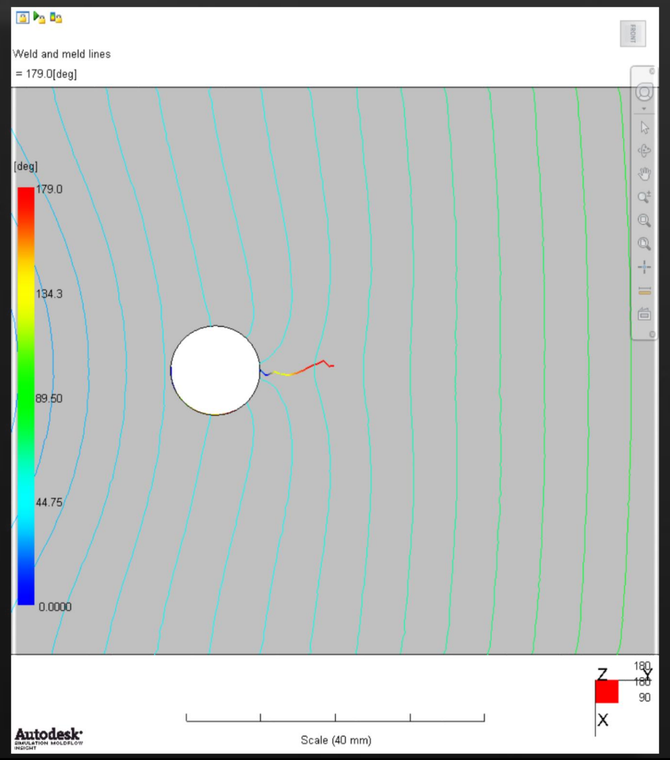


© 2012 Autodesk

Why is the length not as sensitive to edge length as thought?

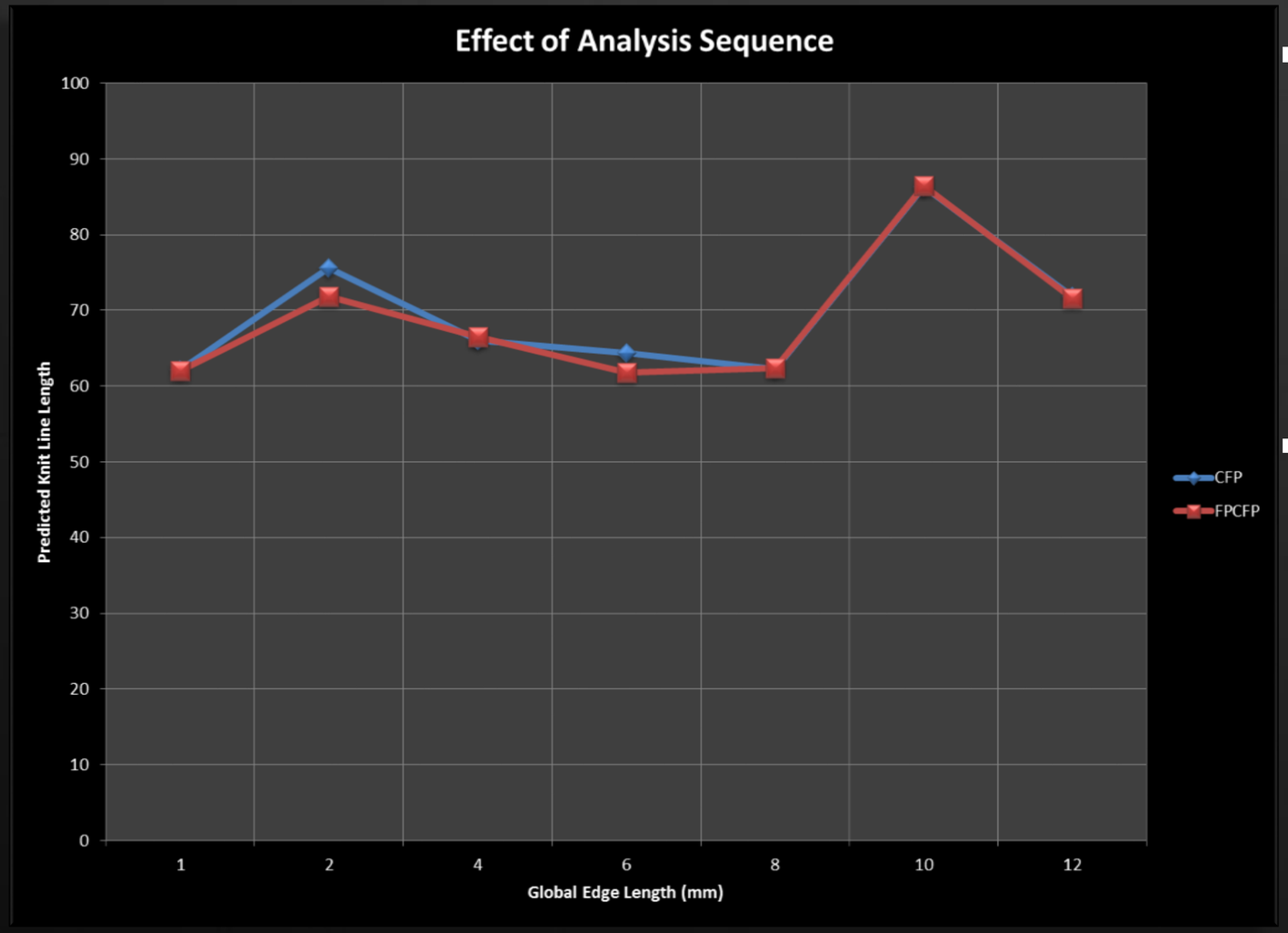
- While edge length improves flow front shape. The “angle” at each node is decreased, which the “Weld and meld lines” plot is based on.





© 2012 Autodesk

Analysis Sequence Effect



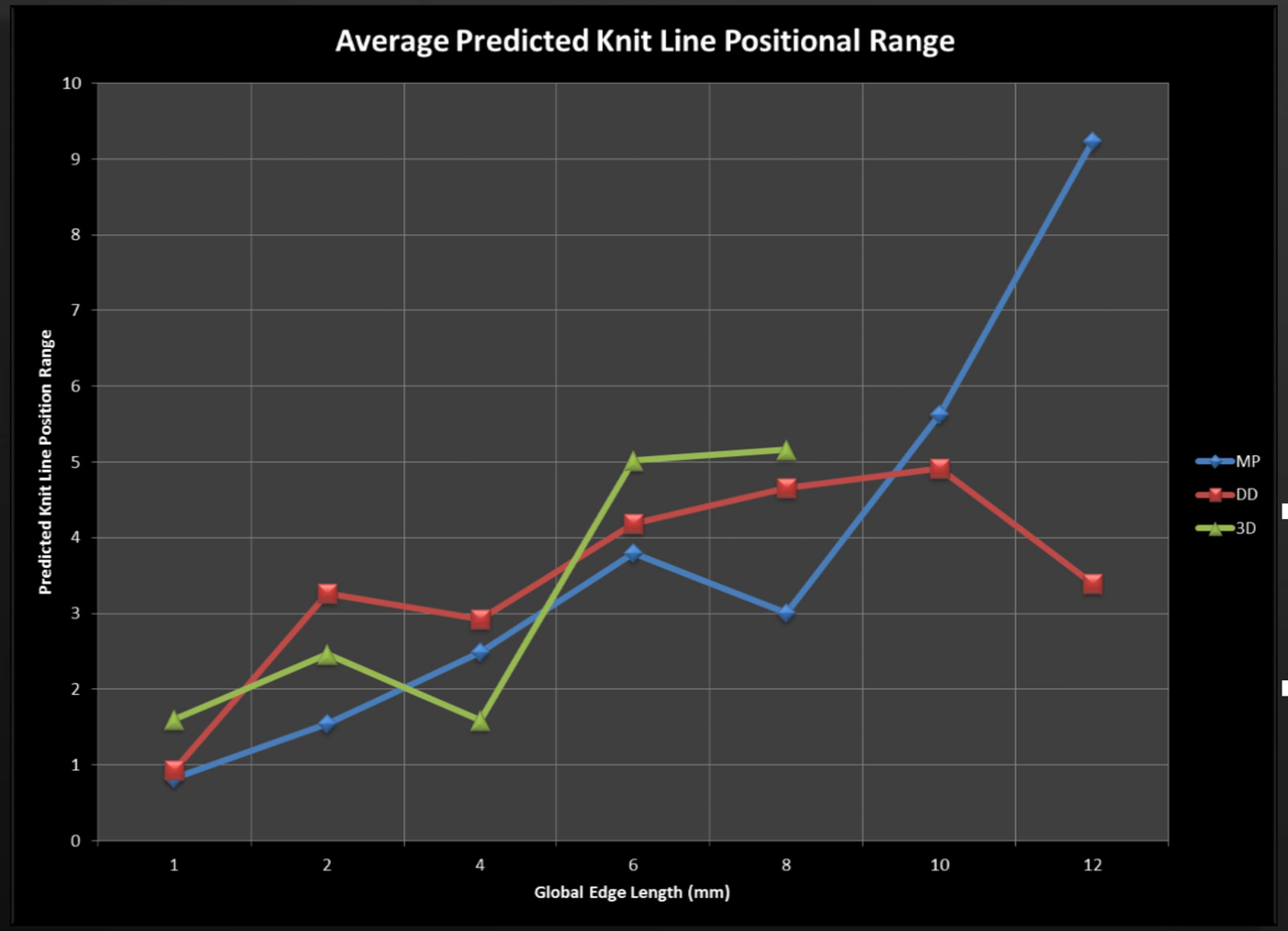
- No significant difference between:
  - Cool + Fill + Pack
  - Fill + Pack + Cool + Fill + Pack
- Finding may not transfer to more complicated geometries

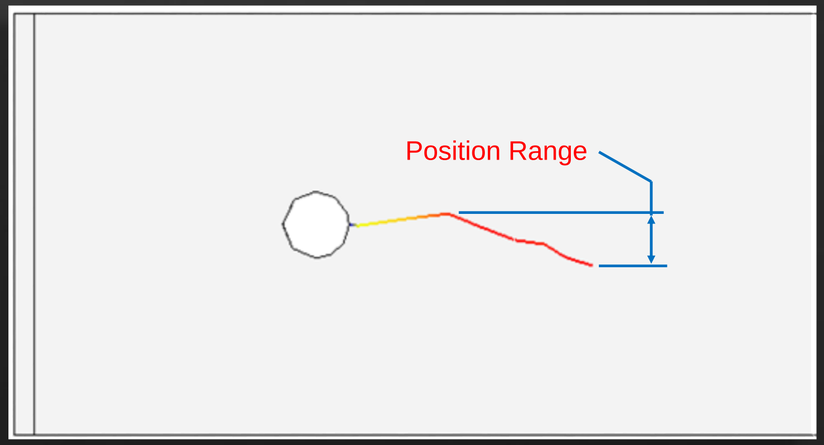
© 2012 Autodesk

Knit Line Position

© 2012 Autodesk

Mesh Type Effect on Predicted Position

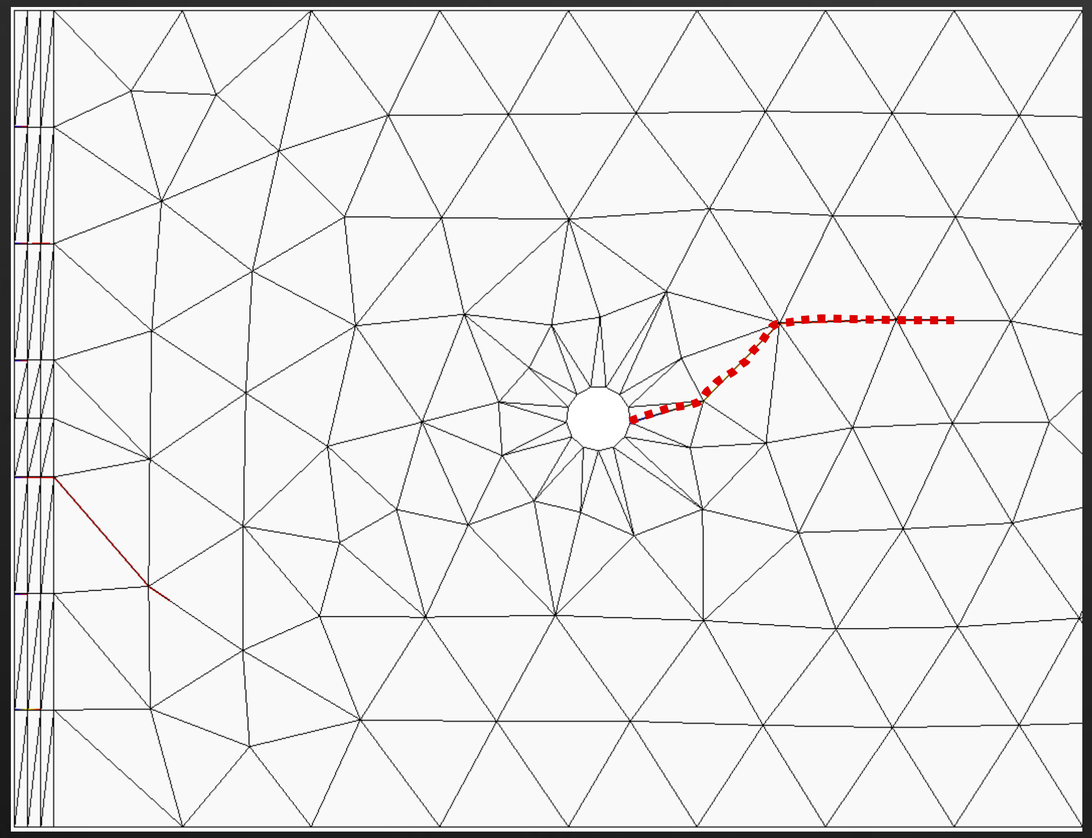


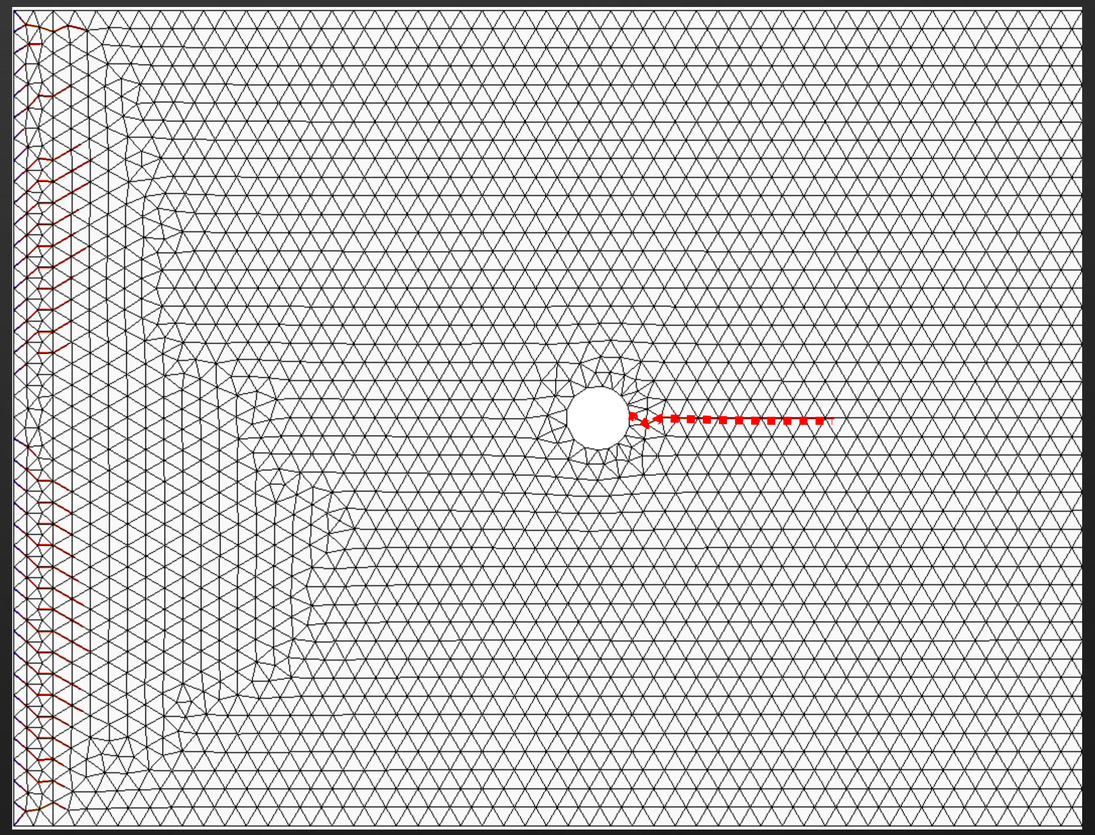


- Target is a range of zero
- Position is controlled by mesh size.
  - Node location

© 2012 Autodesk

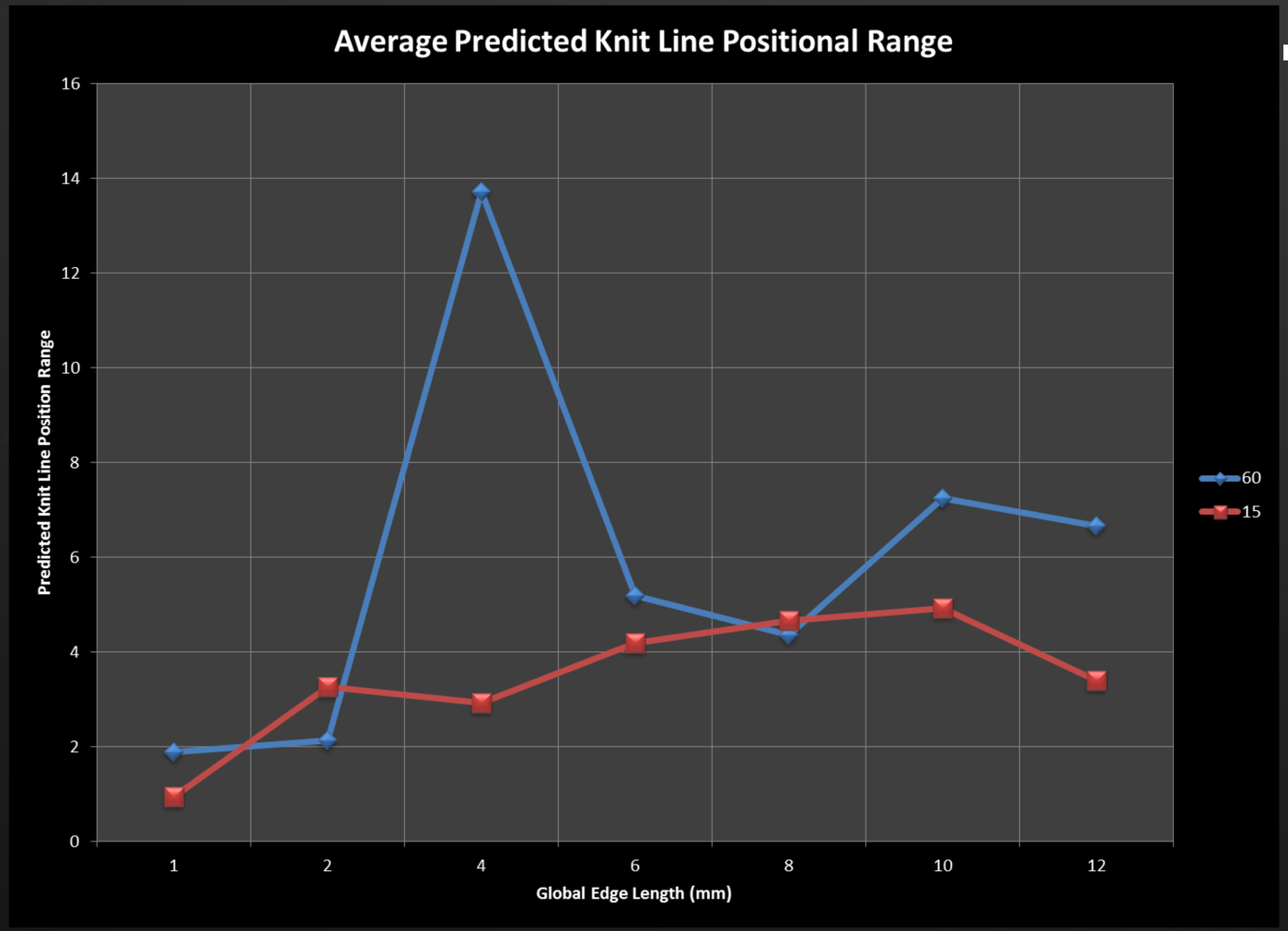
Knit Line position follows the node





© 2012 Autodesk

Chord Angle Effect on Predicted Position



- Again, lower chord angle reduces the effect of mesh size.

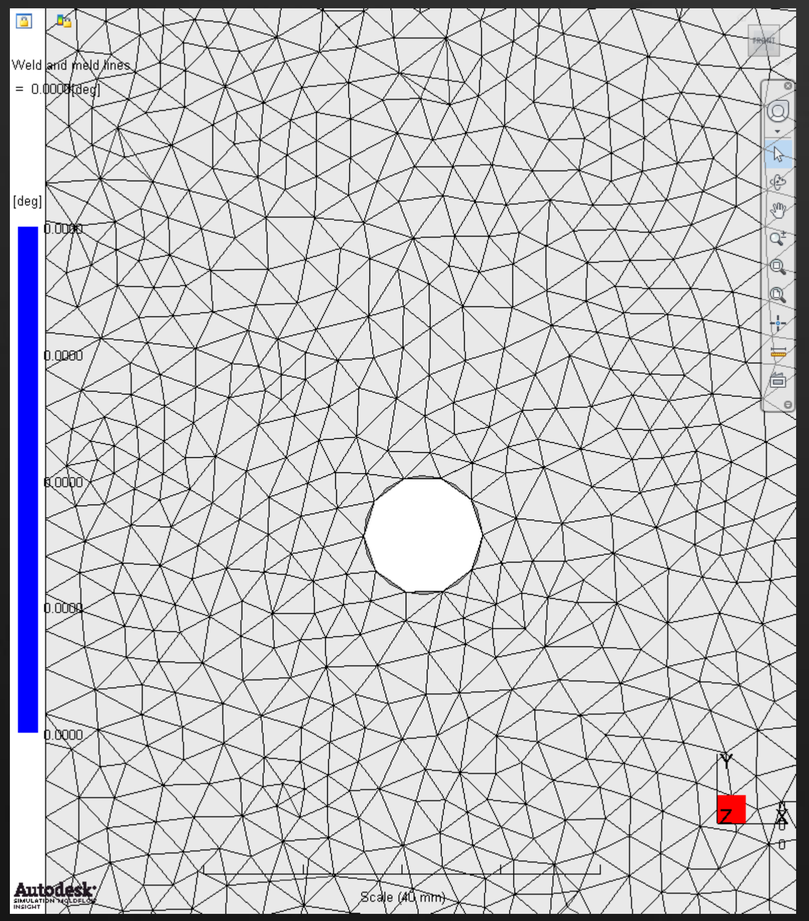
© 2012 Autodesk

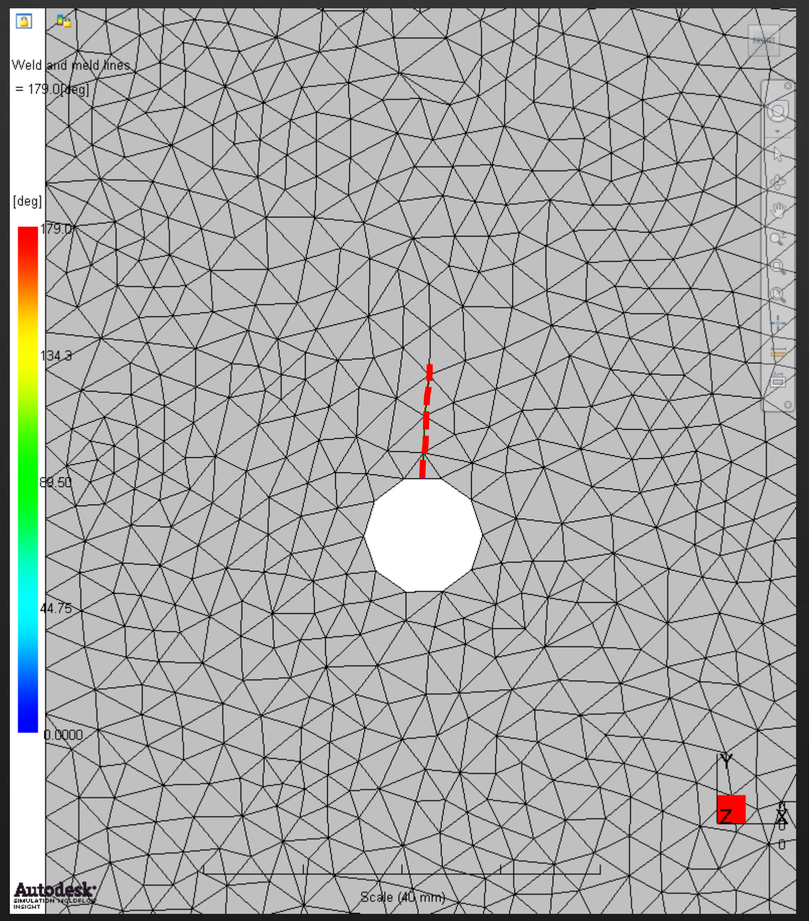
Additional Mesh Issues

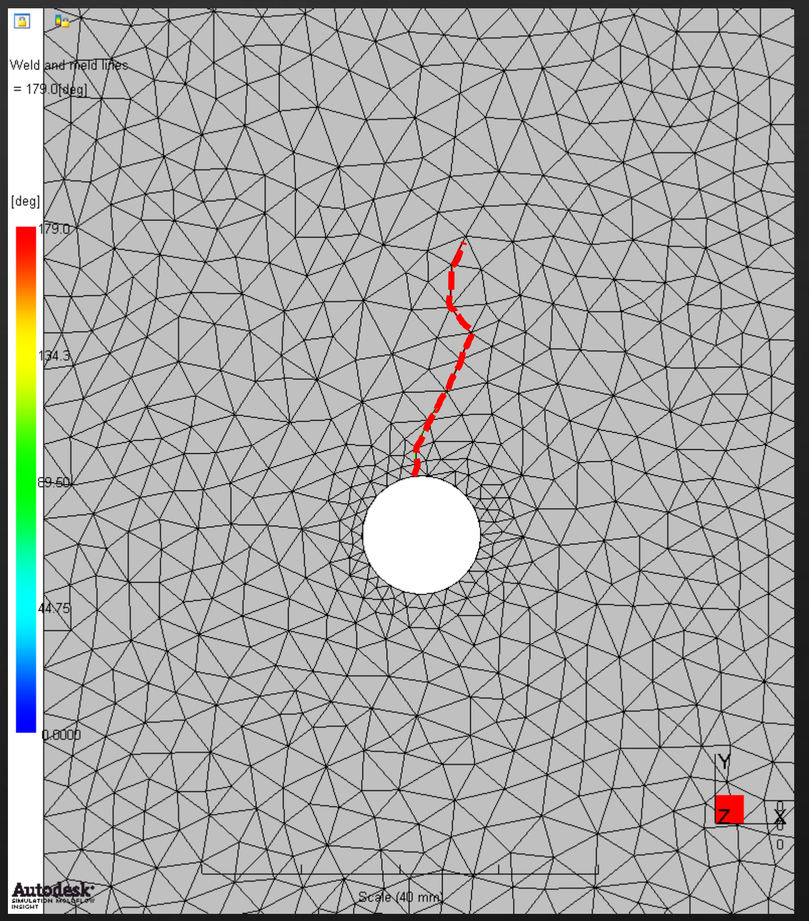
© 2012 Autodesk

Missing the knit line all together

- Global Edge Length and Chord Angle



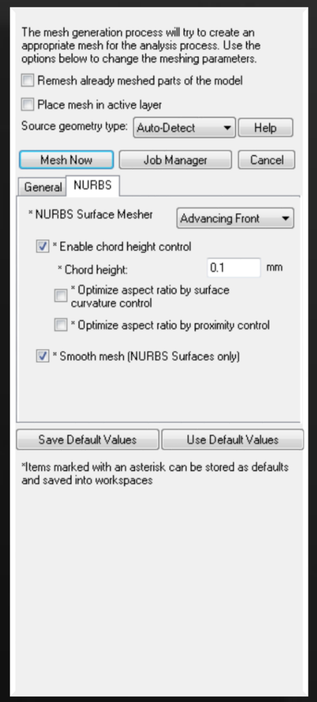


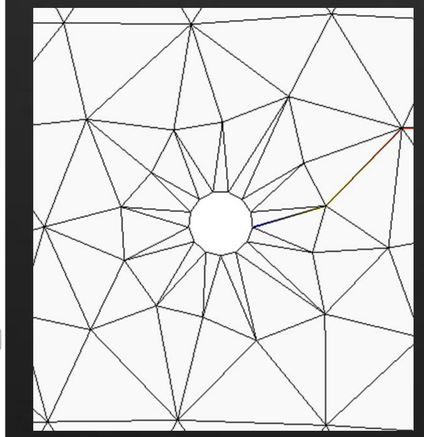


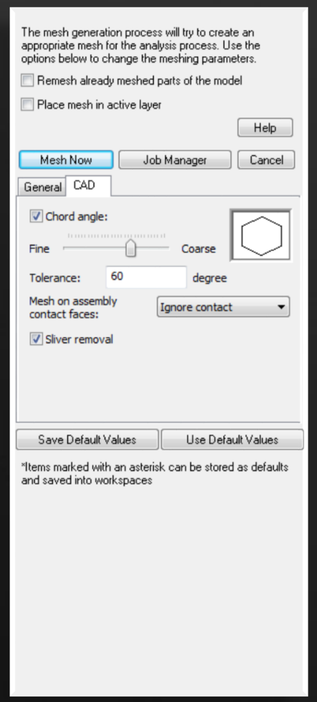
© 2012 Autodesk

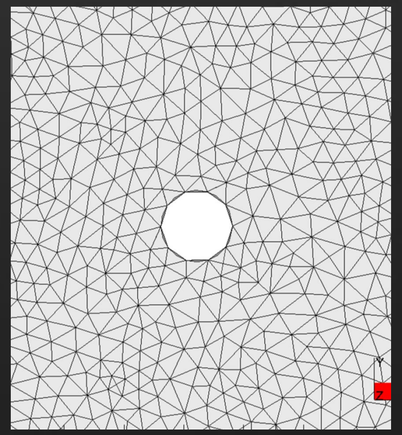
Prevent missing the knit line altogether

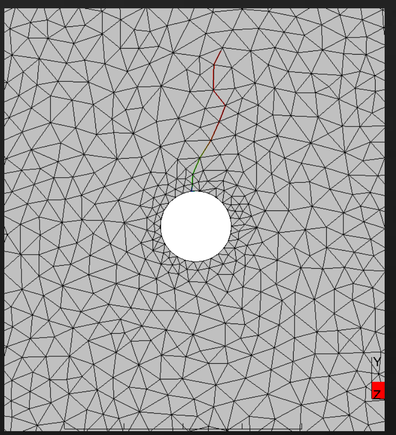
- Utilize the chord height or chord angle controls
- Chord angle default of 60 is too course. 15 is recommended.







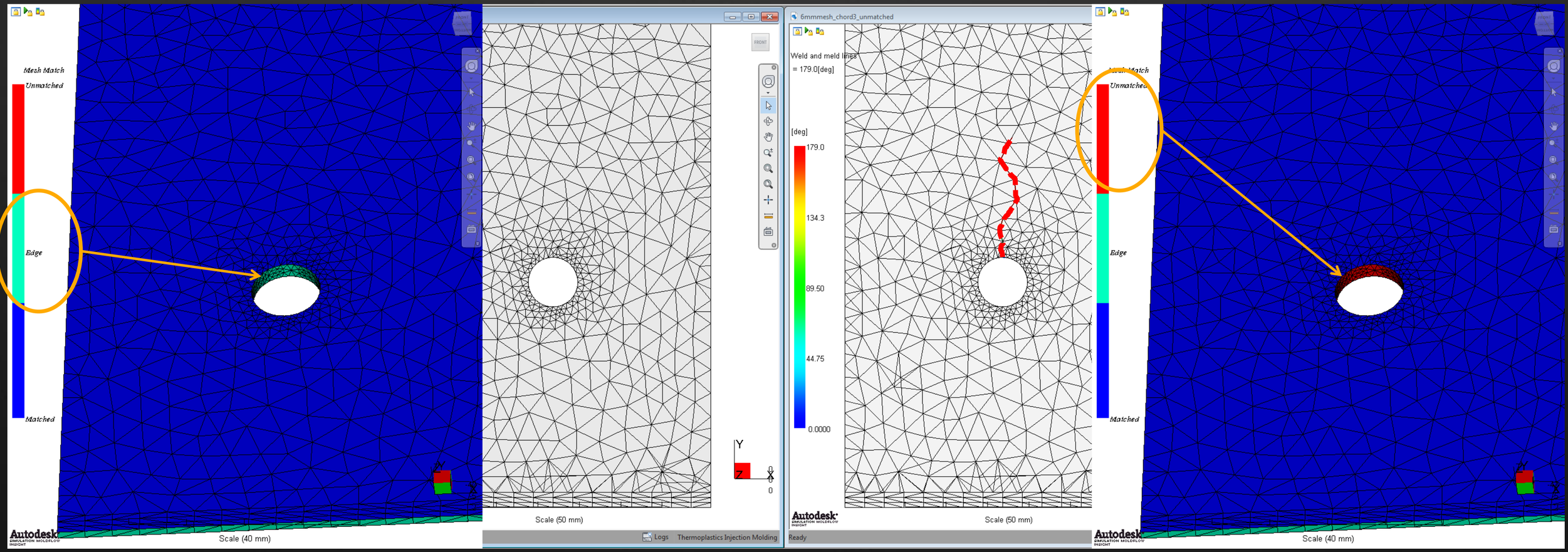




© 2012 Autodesk

Missing the knit line all together

- Edge vs Unmatched Dual-Domain Element



© 2012 Autodesk

Recommended Best Practices

- Chord Angle ≤ 15
- Chord Height ≤ 0.1
- Global Edge Length ≤ Feature Diameter

© 2012 Autodesk

In Conclusion

- The meld and weld line plots cannot be used as an absolute answer
- The plots provide directional guidance on knit line location
- The chord angle or chord height mesh control are an efficient method to improve knit line prediction and prevent “false negatives”

© 2012 Autodesk

Special Thanks

- Franco Costa
  - Autodesk
- Jeff Higgins
  - Autodesk
- Hanno Van Raalte
  - Autodesk

© 2012 Autodesk

Autodesk, AutoCAD* [*if/when mentioned in the pertinent material, followed by an alphabetical list of all other trademarks mentioned in the material] are registered trademarks or trademarks of Autodesk, Inc., and/or its subsidiaries and/or affiliates in the USA and/or other countries. All other brand names, product names, or trademarks belong to their respective holders. Autodesk reserves the right to alter product and services offerings, and specifications and pricing at any time without notice, and is not responsible for typographical or graphical errors that may appear in this document. © 2012 Autodesk, Inc. All rights reserved.