Moldflow Insight Sensitivity Study
SM2137-P

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Class Summary/Highlights

Theoretical - Laura:

- Manual* DOE creation methods using tcodes, tcodesets, scripts
- Moldflow command shell use
- Study creation & modification
- Result extraction

Experimental - Paul:

- Comparison of theoretical vs. experimental

*This study included some functionality not currently available in the Moldflow Insight DOE module at the time the study was conducted.

Learning Objectives

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

- Recreate a sensitivity study tailored to your product line and commonly used materials
- Reduce design optimization time
- Create modified studies and extract results from studies without using the Autodesk Moldflow Insight user interface
- Enhance an experimental sensitivity study result
- Observe a comparison of predicted parameter sensitivity against measured values

Theoretical Sensitivity Study

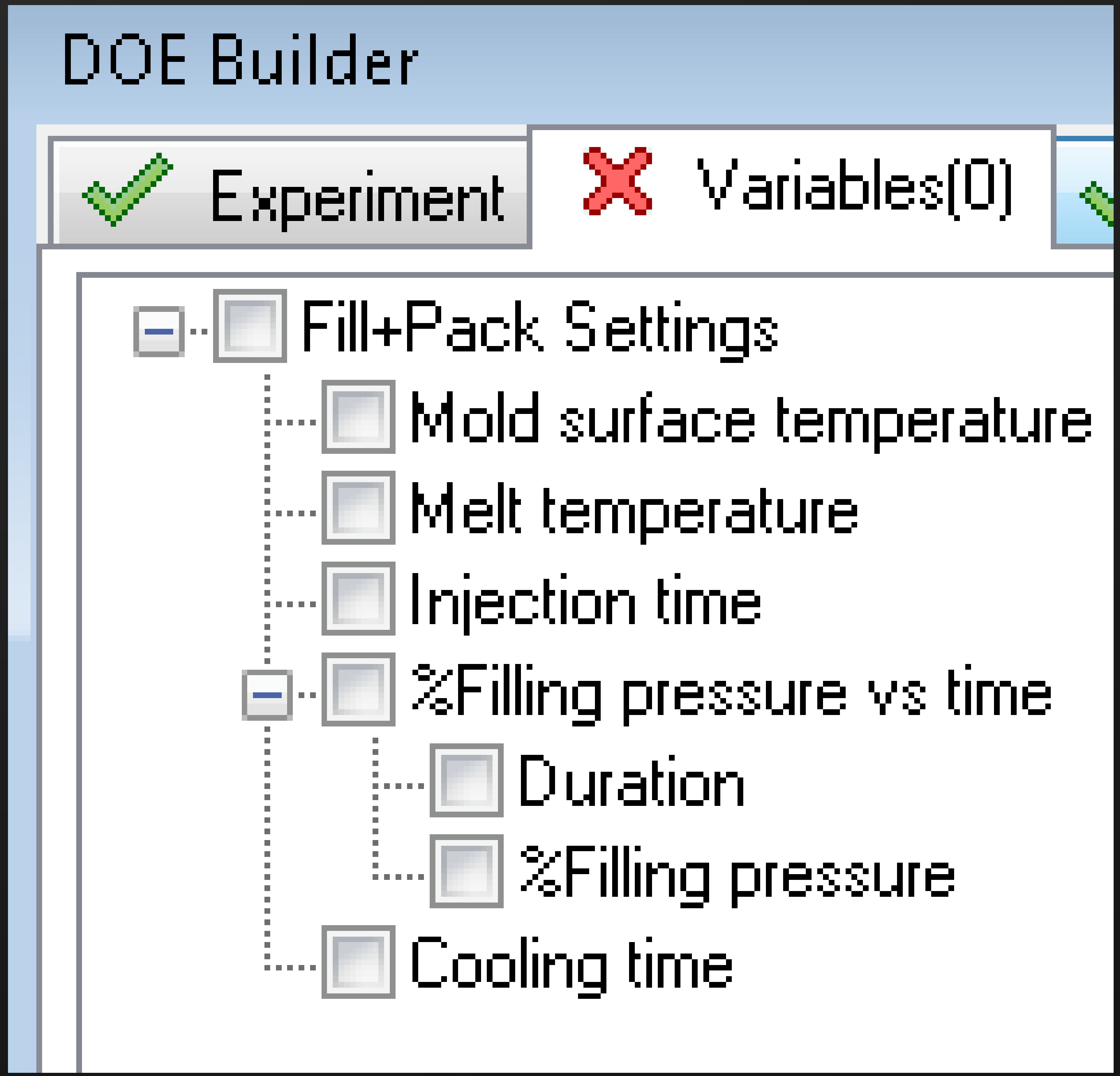
Laura Stuart

Theoretical Study – Motivation vs. Capability

TE Connectivity Internal Debates:

- Fill time vs. flow rate
- Pressure profile increments
- Mold & melt temp
- More

Moldflow Insight DOE Capabilities



- No direct mapping of our desirables

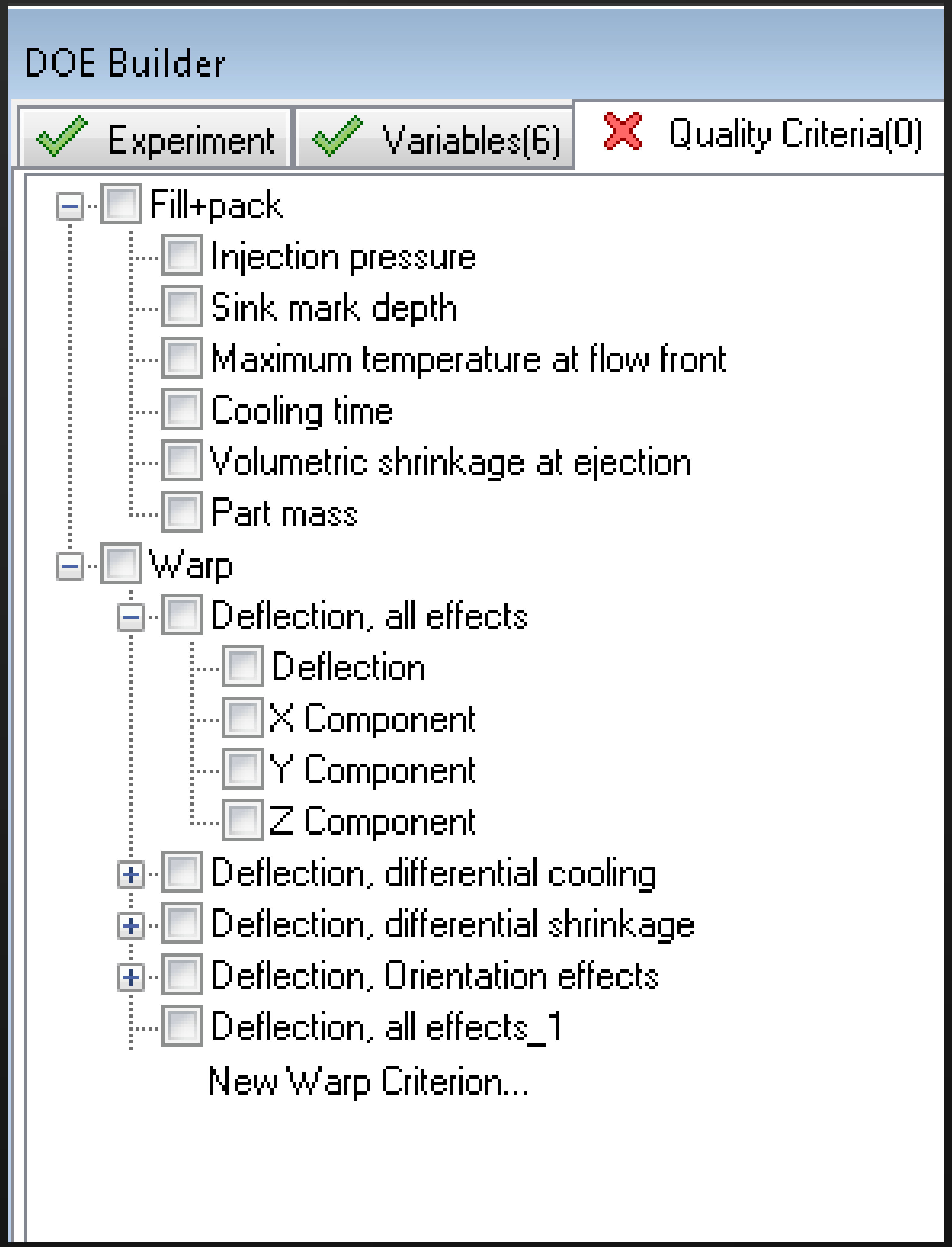
Theoretical Study – Motivation vs. Capability

TE Connectivity Internal Debates:

- Filled & fill time
- Temp at flow front
- Time to ejection temp
- Pressure at end of fill
- Volumetric shrinkage
- Deflection

Moldflow Insight DOE Capabilities

- No direct mapping of our desirables



Theoretical - Overview

Study/Mesh Creation

DOE = L^V

- Variables (V) – e.g. process conditions
- Levels (L) – e.g. high/low

Add:

- Materials (M)
- Geometries (G)

Resultant # of analyses = $M*G*L^V$

RUN	Mold Temp	Melt Temp	Fill Control	Pressure
1	Low	Low	Low	Low
2	High	Low	Low	Low
3	Low	High	Low	Low
4	High	High	Low	Low
5	Low	Low	High	Low
6	High	Low	High	Low
7	Low	High	High	Low
8	High	High	High	Low
9	Low	Low	Low	High
10	High	Low	Low	High
11	Low	High	Low	High
12	High	High	Low	High
13	Low	Low	High	High
14	High	Low	High	High
15	Low	High	High	High
16	High	High	High	High

Theoretical - Overview

Levels (L) = 2

“High” vs. “Low”

Variables (V) = 4

Melt & Mold temp, Fill & Pack Control

Materials (M) = 4

2 PBT & 2 Nylon with varying glass content

Geometries (G) = 2 varying geometries

RUN	Mold Temp	Melt Temp	Fill Control	Pressure
1	Low	Low	Fill Time	Fine
2	High	Low	Fill Time	Fine
3	Low	High	Fill Time	Fine
4	High	High	Fill Time	Fine
5	Low	Low	Flow Rate	Fine
6	High	Low	Flow Rate	Fine
7	Low	High	Flow Rate	Fine
8	High	High	Flow Rate	Fine
9	Low	Low	Fill Time	Coarse
10	High	Low	Fill Time	Coarse
11	Low	High	Fill Time	Coarse
12	High	High	Fill Time	Coarse
13	Low	Low	Flow Rate	Coarse
14	High	Low	Flow Rate	Coarse
15	Low	High	Flow Rate	Coarse
16	High	High	Flow Rate	Coarse

Resultant # of analyses = $M*G*L^V$ = **128**

Theoretical - Benefits

ACCURACY

- Will you *accurately* create 128 Moldflow studies manually?

EFFICIENCY

- Do you have the time to create, launch, & review 128 studies?
- Why *manually* create when you can *automate*?

SOLUTION

- Scripting

Theoretical – Scripting Used

- Python (programming language user choice)
- Batch Files
- Moldflow Commands
  - Studymod.exe
  - Studyrlt.exe
  - Runstudy.exe

Administrator: Moldflow Insight 2012 Command Line

```
NAME:
  Studymod - Modify a study File

SYNOPSIS:
  C:\EngApps\Autodesk\2012\Insight\bin\studymod.exe  <InputStudy> <OutputStudy>
<ModifierFile>

DESCRIPTION:
  <InputStudy>      Name of the original study file
  <OutputFile>      Name of the modified study file
  <ModifiedFile>    Name of the file containing the modifications to make
```

```
   runstudy - Command line launching of Moldflow analyses
-----------------------------------------------------------
SYNOPSIS:
runstudy
    [-help]
    [-project project_file]
    [-temp temp_dir]
    [-keeptmp]
    study_name
```

Theoretical – Scripting Used

To access the Moldflow commands (studymod, studyrlt, runstudy):

1. Select Start > All Programs > Autodesk Moldflow Insight 2012
2. Open either "Autodesk Moldflow 2012 Synergy Command Shell" or "Autodesk Moldflow 2012 Insight Command Shell"
3. Enter Moldflow command (*studymod, studyrlt, runstudy*) at the command prompt

Theoretical - Solution

5 Basic Steps (details for each to follow)

1. Create the CSV file defining DOE
2. Create the Moldflow model
3. Create the Sensitivity Study script
4. Launch the batch file
5. Extract the results

Theoretical – Solution Step 1

Create CSV file defining DOE with properties to be changed

– i.e. DOE table with one row per trial

<u>Examples</u>:

- Melt temp
- Mold temp
- Cool time
- Injection profile
- Pack profile
- And more!

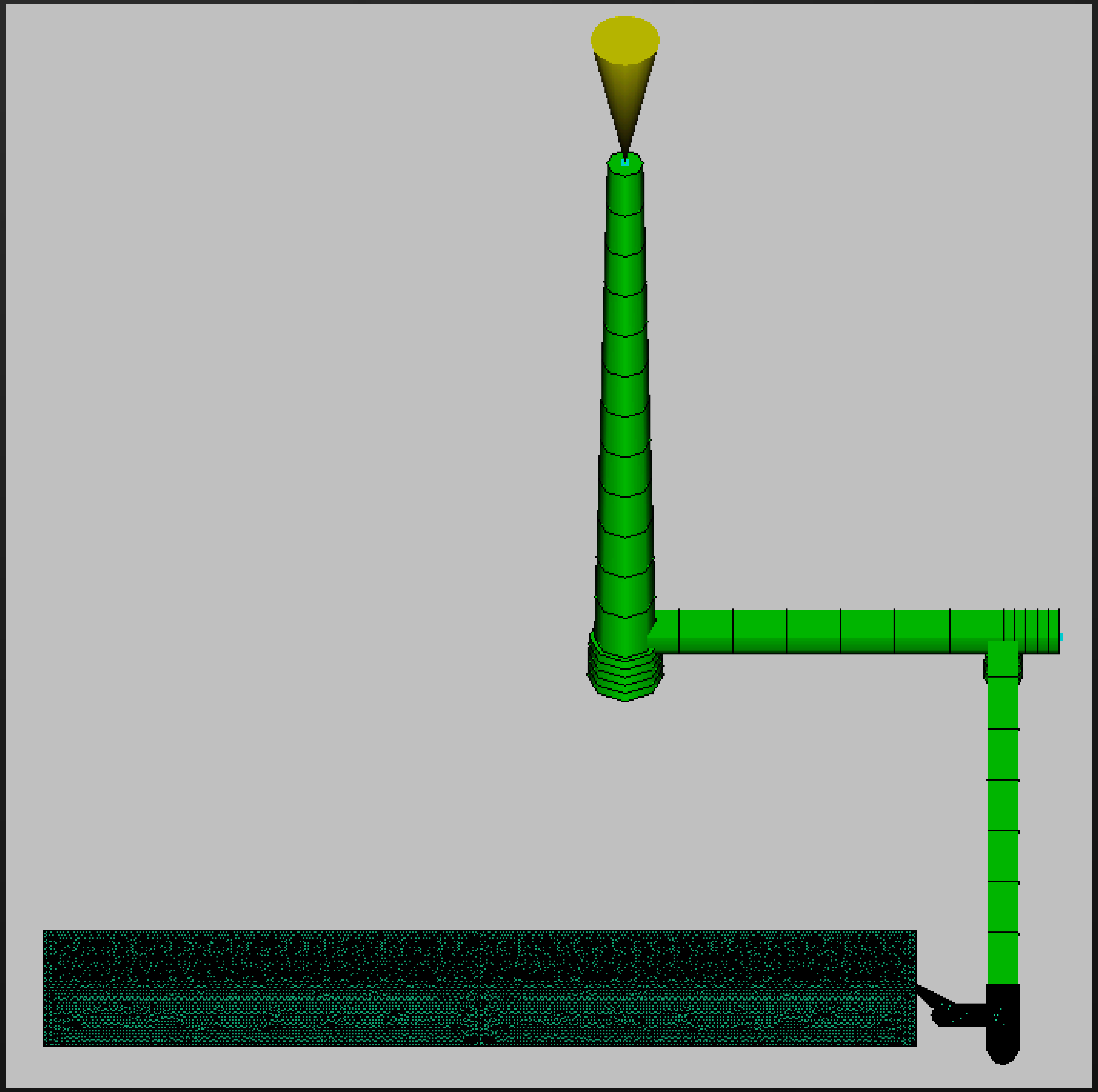
RUN	Mold Temp	Melt Temp	Fill Control	Pressure
1	Low	Low	Fill Time	Fine
2	High	Low	Fill Time	Fine
3	Low	High	Fill Time	Fine
4	High	High	Fill Time	Fine
5	Low	Low	Flow Rate	Fine
6	High	Low	Flow Rate	Fine
7	Low	High	Flow Rate	Fine
8	High	High	Flow Rate	Fine
9	Low	Low	Fill Time	Coarse
10	High	Low	Fill Time	Coarse
11	Low	High	Fill Time	Coarse
12	High	High	Fill Time	Coarse
13	Low	Low	Flow Rate	Coarse
14	High	Low	Flow Rate	Coarse
15	Low	High	Flow Rate	Coarse
16	High	High	Flow Rate	Coarse

Theoretical – Solution Step 2

Create Moldflow model

Define:

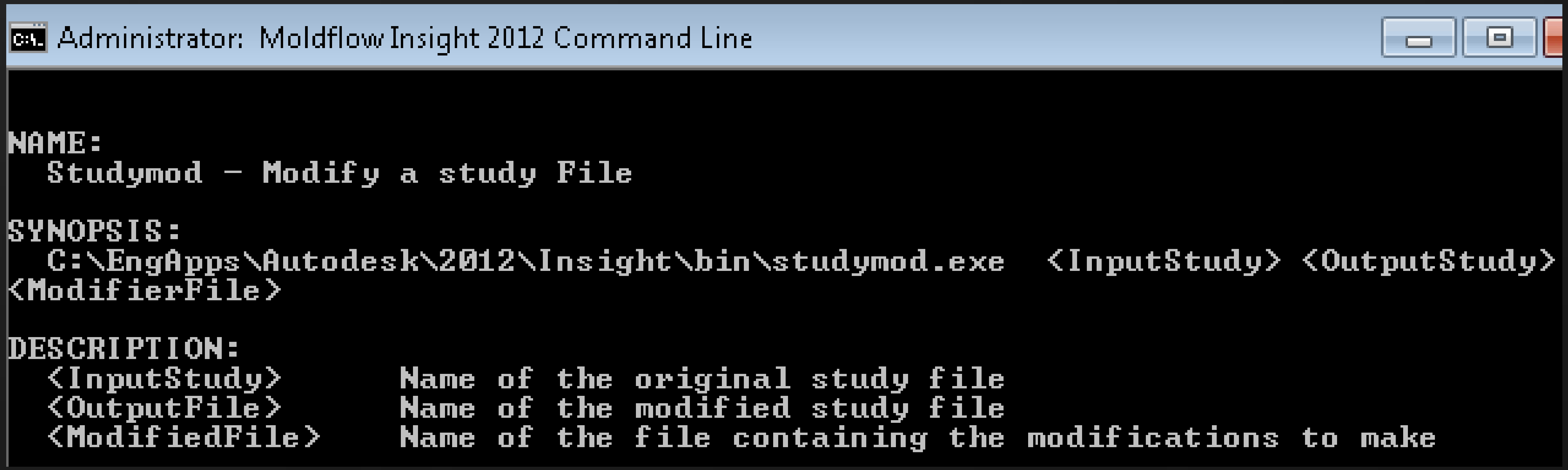
- Injection locations
- Mesh
- Material
- Anything not in DOE variables



Theoretical - Solution Step 3

Create Sensitivity Study script to perform the following:

1. Define template xml file w/variables for replaceable elements
   -e.g. properties, tset, tcode
2. Open CSV file
3. For each trial/row:
   a) Parse rows into values
   b) Replace values in xml template
   c) Write to xml file
   d) Call studymod.exe to generate new study w/xml file replacements



Theoretical – *XML File Example Code*

```
xml='''\
<?xml version="1.0" encoding="utf-8"?>
<StudyMod title="Autodesk StudyMod" ver="1.00">
  <UnitSystem>Metric</UnitSystem>
  <Property>
    <TSet>
          <!--Process controller defaults-->
          <ID>30011</ID>
          <SubID>1</SubID>
        <TCode>
            <!-- Mold Surface Temperature -->
            <ID>11108</ID>
            <Value>${MoldTemp}</Value>
        </TCode>
        <TCode>
            <!-- Melt Temperature -->
            <ID>11002</ID>
            <Value>${MeltTemp}</Value>
        </TCode>
        <TCode>
```

```
Profilefine='''     <TCode>
            <!-- Packing pressure vs. Time Fine Profile
            <ID>10707</ID>
            <Value>0.000 45.59</Value>
            <Value>0.028 43.37</Value>
            <Value>0.034 41.16</Value>
            <Value>0.038 38.95</Value>
            <Value>0.046 36.74</Value>
            <Value>0.052 34.53</Value>
            <Value>0.061 32.32</Value>
            <Value>0.073 30.10</Value>
            <Value>0.085 27.89</Value>
            <Value>0.095 25.68</Value>
            <Value>0.111 23.47</Value>
            <Value>0.125 21.26</Value>
            <Value>0.146 19.05</Value>
            <Value>0.173 16.84</Value>
            <Value>0.208 14.62</Value>
            <Value>0.247 12.41</Value>
            <Value>0.290 10.20</Value>
            <Value>0.339 7.99</Value>
        </TCode>
```

Theoretical - Solution Step 3 (continued)

Sensitivity Study script also needs to perform the following:

4. Create windows batch file with the following for each new study:
   a) Runstudy.exe command
   b) Create a new directory named by <studyname>
   c) Copy into that directory the study file and all results

Theoretical - Solution Step 4

Run batch file

runstudies.bat

```
C:\ENGapps\AutodeskMoldflow\Insight2012\bin\runstudy.exe Trial001.sdy
mkdir X:\us076676\SS\Trial001
copy Trial001.sdy X:\us076676\SS\Trial001
copy testxml* X:\us076676\SS\Trial001
C:\ENGapps\AutodeskMoldflow\Insight2012\bin\runstudy.exe Trial002.sdy
mkdir X:\us076676\SS\Trial002
copy Trial002.sdy X:\us076676\SS\Trial002
copy testxml* X:\us076676\SS\Trial002
```

```
C:\>C:\ENGapps\AutodeskMoldflow\Insight2012\bin\runstudy.exe Trial031.sdy
C:\>mkdir X:\us076676\SS\Trial031
C:\>copy Trial031.sdy X:\us076676\SS\Trial031
C:\>copy testxml* X:\us076676\SS\Trial031
```

Theoretical - Solution Step 5

Obtain results

1	study	Defl	Defl: X max	Defl: X min	Defl: Y max	Defl: Y min	Defl: Z max	Defl: Z min

1. Create new CSV file for results with column headers & row names
2. For each subdirectory (i.e. study):
   a) Open the out file corresponding with Flow result, then:
      - If line starts with message id (tcode):
        - 304007, record "Filled"
        - 304008, record "Shorted" + value filled

```
304007
0
```

```
304008
0
6
0.7211796
62.606609
```

Theoretical - Solution Step 5 (continued)

Obtain results (continued)

2. For each subdirectory (i.e. study):
   b) For each desired result value:
      i. Build studyrlt.exe command line with appropriate result tcode
      ii. Run studyrlt.exe
      iii. Read result from the .val file and record value
   c) Write all results to a row of the CSV file

	A	J	K	L	M	N	O	P	Q	R
1	study	Defl	Defl: X max	Defl: X min	Defl: Y max	Defl: Y min	Defl: Z max	Defl: Z min	Defl shrink max	Defl orient max
2	Trial001	1.3257	0.0593917	-0.217107	0.00321003	-1.3222	0.28832	-0.426783	1.9162	0.605008

Theoretical – Studyrlt Format

```
NAME:
  Studyrlt - Result Extraction Utility

SYNOPSIS:
  studyrlt  <study> -message <sequence>  <message ID> <occurrence> <item> [-unit SI|Metric|English]
      <study> -xml <result ID>
      <study> -exportpatran
      <study> -result <result ID>  -min|-max|-average|-stddev|-node <node number>|-element <element number>
                           [-cavity|-gate|-runner|-sprue]
                           [-component <number> [-anchor <node1> <node2> <node3>]
                           [-unit SI|Metric|English]

DESCRIPTION:
  -message             Extract Results from Screen output
  <sequence>           Which Analysis Sequence to extract results from.
                       (1 = First analysis in sequnece)
  <message ID>         Message ID number as defines in cmmesage.dat
  <occurrence>         Get the specified occurrence of the message ID
  <item>               Get the specified Data Item
  -unit                Show results in Visible unit SI(default), Metric or English

  -exportpartan        Export a Patran file based on the specific study file

  -xml <result ID>      Extract specified result set in XML format

  -result <result ID>          Extract a numerical value from the specified result set
```

Note: See the Moldflow help “tcodeset reference” & “tcode reference” for tcodesets & tcodes

Theoretical – Studyrlt Format

```
-result <result ID>       Extract a numerical value from the specified result set
-min                      Get the Minimum value of the result data set
-max                      Get the Maximum value of the result data set
-average                  Get the Average value of the result data set
-stddev                   Get the Standard Deviation value of the result data set
-node <node number>       Get the Result at a specified node (example -node 57)
-element <element number> Get the Result at a specified element (example -element 23)
-cavity                   Only Consider Results in the cavity region
-gate                     Only Consider Results in the gate region
-runner                   Only Consider Results in the runner region
-sprue                    Only Consider Results in the Sprue region
-component <number>       Component to extracted  0 = Magnitude (default),
                                                  1 = X
                                                  2 = Y
                                                  3 = Z
                          (only applicable to vector based results)
-anchor <Node1> <Node2> <Node3>   Apply Anchor plane defined by Nodes 1,2 and 3
                                  (only applicable to warpage results)
-unit                     Show results in Visible unit SI(default), Metric or English

Note:  Argument order is important please follow the argument order provided.
```

Note: See the Moldflow help “tcodeset reference” & “tcode reference” for tcodesets & tcodes

Theoretical –*Extraction* Example Code & Cmds

```
#Temperature, part
row.append(studyrlt(file,'-result 5600 -max -unit Metric'))
row.append(studyrlt(file,'-result 5600 -min -unit Metric'))

#Temperature, mold
row.append(studyrlt(file,'-result 5702 -max -unit Metric'))
row.append(studyrlt(file,'-result 5702 -min -unit Metric'))

#Deflection, all effects: Deflection
row.append(studyrlt(file,'-result 6250 -max -anchor N218516 N223934 N213104 -unit Metric'))
row.append(studyrlt(file,'-result 6250 -min -anchor N218516 N223934 N213104 -unit Metric'))

#Deflection, all effects: X Component
row.append(studyrlt(file,'-result 6250 -max -component 1 -anchor N218516 N223934 N213104 -unit Metric'))
row.append(studyrlt(file,'-result 6250 -min -component 1 -anchor N218516 N223934 N213104 -unit Metric'))
```

Note: See the Moldflow help “tcodeset reference” & “tcode reference” for tcodesets & tcodes

Theoretical – Result of *Extraction* Code

	A	B	C	D	E	F	G	H	I
1	study	Filled?	Fill t	T.a.f.f. max	Taff min	Time to Eject T	P at Fill End	Vol Shr max	Vol Shr min
2	Trial001	Filled	0.404509	278.37	250	7.01185	39.7114	16.9497	1.39257
3	Trial002	Filled	0.377385	276.327	250	8.7004	41.16	16.9768	3.08214
4	Trial003	Filled	0.339218	285.012	275	7.51296	43.6788	17.3507	1.40125
5	Trial004	Filled	0.332493	286.349	275	9.32421	44.0614	17.2601	3.1292
6	Trial005	Filled	0.405106	270.807	250	7.02315	39.7196	16.9552	1.39272
7	Trial006	Filled	0.376337	268.274	250	8.70368	41.2098	16.9573	3.08168
8	Trial007	Filled	0.338986	284.877	275	7.53845	43.6841	17.3974	1.40184
9	Trial008	Filled	0.333453	289.233	275	9.32732	43.9751	17.2748	3.12949
10	Trial009	Filled	0.41627	278.37	250	7.1692	31.1488	17.0726	1.5047
11	Trial010	Filled	0.397526	276.327	250	8.99491	33.2877	17.0578	3.18078
12	Trial011	Filled	0.340366	285.012	275	7.78763	41.3485	17.5989	1.47009
13	Trial012	Filled	0.333079	286.349	275	9.74581	42.3408	17.5792	3.14145
14	Trial013	Filled	0.393919	270.807	250	7.17677	34.1368	16.9807	1.5062
15	Trial014	Filled	0.379026	268.274	250	8.95661	35.6453	17.1576	3.18247
16	Trial015	Filled	0.34013	284.877	275	7.812	41.3613	17.6288	1.46985

Theoretical – Result of *Extraction* Code

	A	J	K	L	M	N	O	P	Q	R
1	study	Defl	Defl: X max	Defl: X min	Defl: Y max	Defl: Y min	Defl: Z max	Defl: Z min	Defl shrink max	Defl orient max
2	Trial001	1.3257	0.0593917	-0.217107	0.00321003	-1.3222	0.28832	-0.426783	1.9162	0.605008
3	Trial002	1.29971	0.0654299	-0.212253	0.00192779	-1.29625	0.309121	-0.44158	1.8787	0.594316
4	Trial003	1.19155	0.0610909	-0.179825	0.0190543	-1.18845	0.268584	-0.45871	1.71711	0.539481
5	Trial004	1.22053	0.0574776	-0.180649	0.0293268	-1.21574	0.295618	-0.46375	1.75995	0.551622
6	Trial005	1.32248	0.0608128	-0.221244	0.00334289	-1.31993	0.287575	-0.424993	1.91247	0.603634
7	Trial006	1.30051	0.0658182	-0.215005	0.00165632	-1.29684	0.307539	-0.438668	1.87894	0.592906
8	Trial007	1.20332	0.0603428	-0.186652	0.0138539	-1.19939	0.275387	-0.464293	1.73294	0.543456
9	Trial008	1.22265	0.0551836	-0.191846	0.0280583	-1.21724	0.296465	-0.466228	1.76176	0.551602
10	Trial009	1.44939	0.0502245	-0.247702	0.072431	-1.44348	0.299397	-0.387645	2.10256	0.666544
11	Trial010	1.46685	0.049197	-0.257344	0.0918578	-1.45937	0.302105	-0.366589	2.13197	0.678363
12	Trial011	1.43552	0.0574172	-0.214227	0.125185	-1.43139	0.286191	-0.359073	2.07882	0.654905
13	Trial012	1.46878	0.0501933	-0.221439	0.142533	-1.46149	0.294462	-0.331774	2.13096	0.673574
14	Trial013	1.4655	0.0500777	-0.25534	0.0703169	-1.46021	0.300977	-0.382052	2.12485	0.672732
15	Trial014	1.4585	0.0454843	-0.275384	0.096719	-1.45051	0.30101	-0.358123	2.11983	0.673809
16	Trial015	1.43727	0.0560972	-0.219514	0.122839	-1.43194	0.286208	-0.364511	2.08021	0.654247

Experimental Sensitivity Study

Paul Brincat, Autodesk
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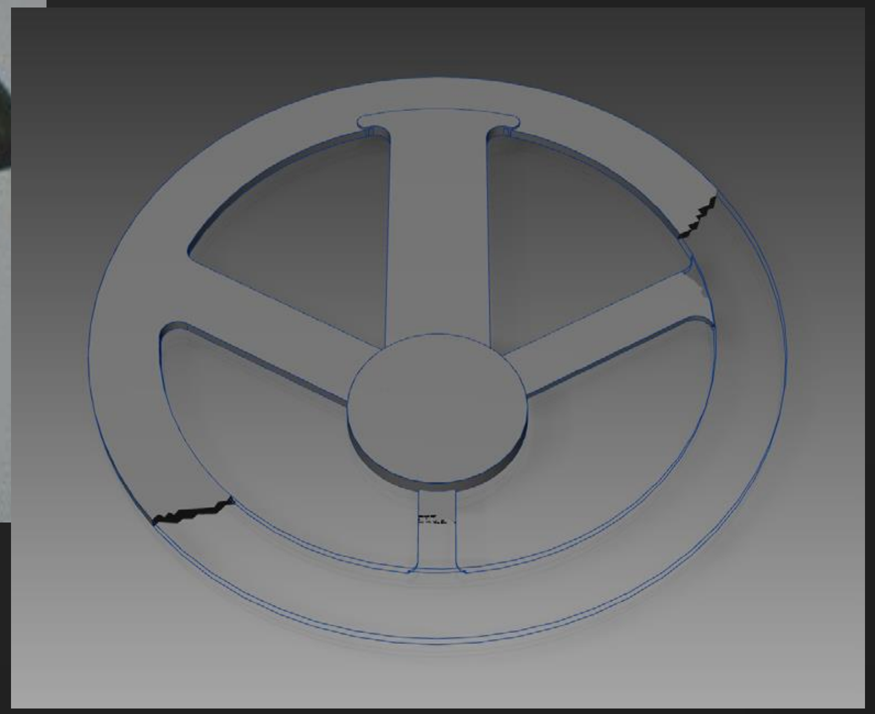
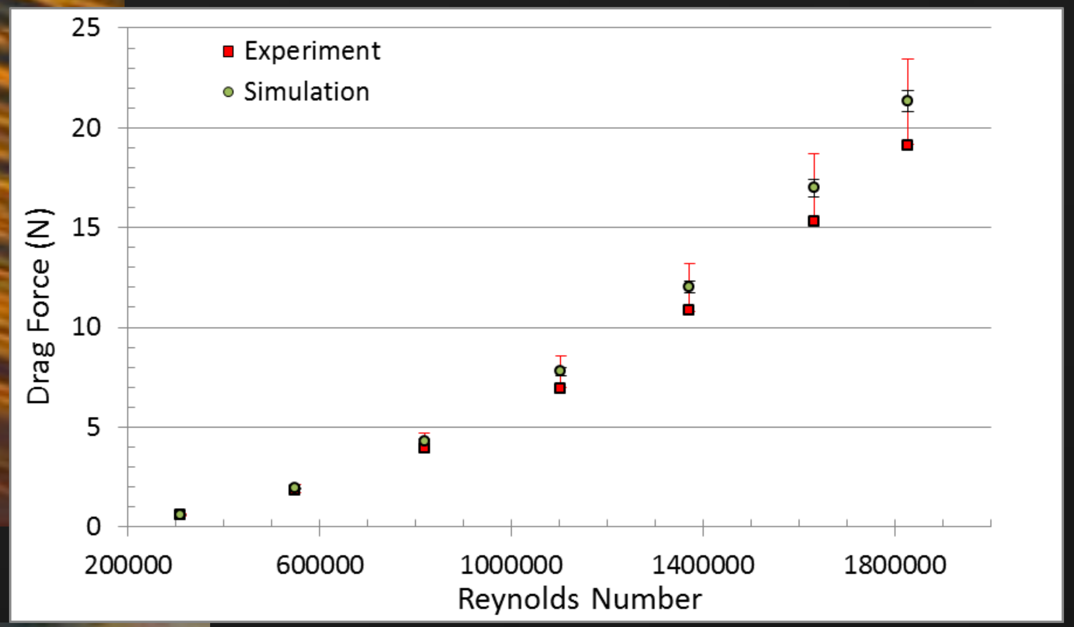
Section Summary

In this section of the class Autodesk® Simulation Moldflow® Insight predictions for a parameter sensitivity study will be shown against a test case to firstly highlight aspects to consider and also demonstrate Insight's alignment with the measured responses.

Introduction

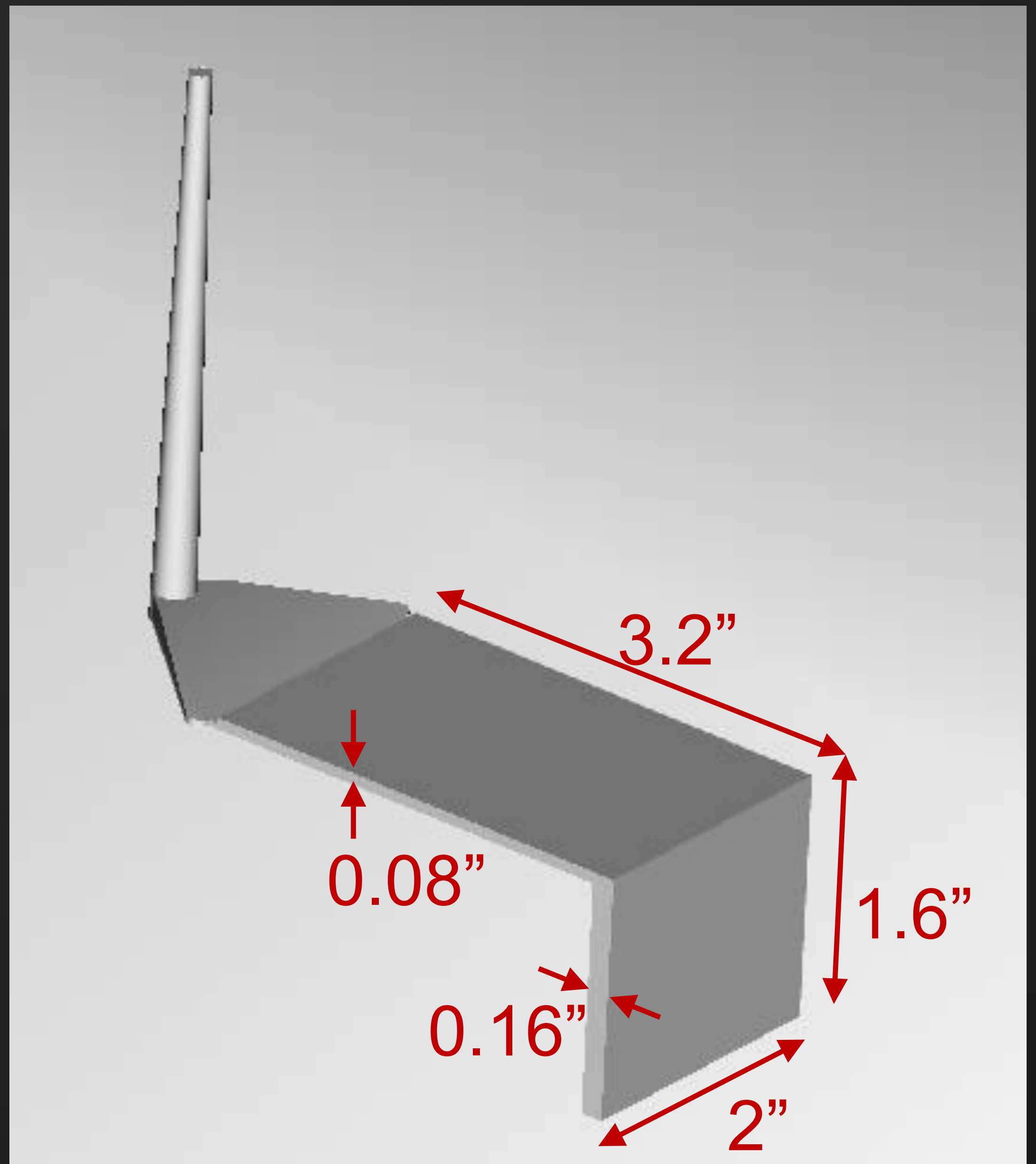
- Simulation Validation Group is responsible for quantifying the accuracy of:
  - Autodesk Simulation Moldflow
  - Autodesk Simulation CFD
  - Autodesk Simulation Mechanical





Experimental Sensitivity Study

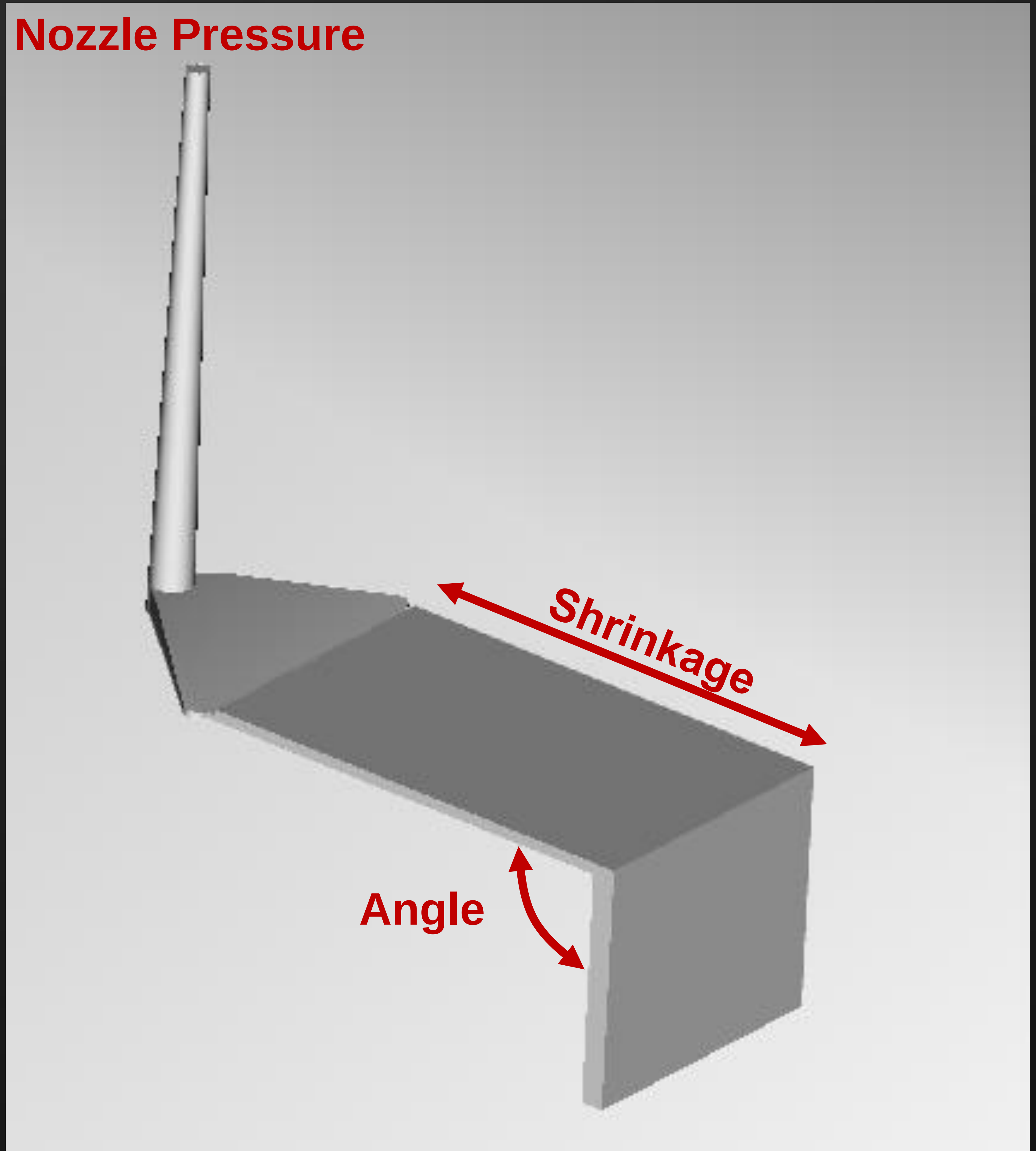
- Corner geometry
- Polypropylene (Basell Moplen EP301K)
- The parameters varied:
  - Melt temperature
  - Mold temperature (uniformly)
  - Pack pressure



Experiment Number	Melt Temperature (°F)	Mold Temperature (°F)	Pack Pressure (psi)
1	390	85	2900
2	390	85	5075
3	390	140	2900
4	390	140	5075
5	445	85	2900
6	445	85	5075
7	445	140	2900
8	445	140	5075

Experimental Sensitivity Study (continued)

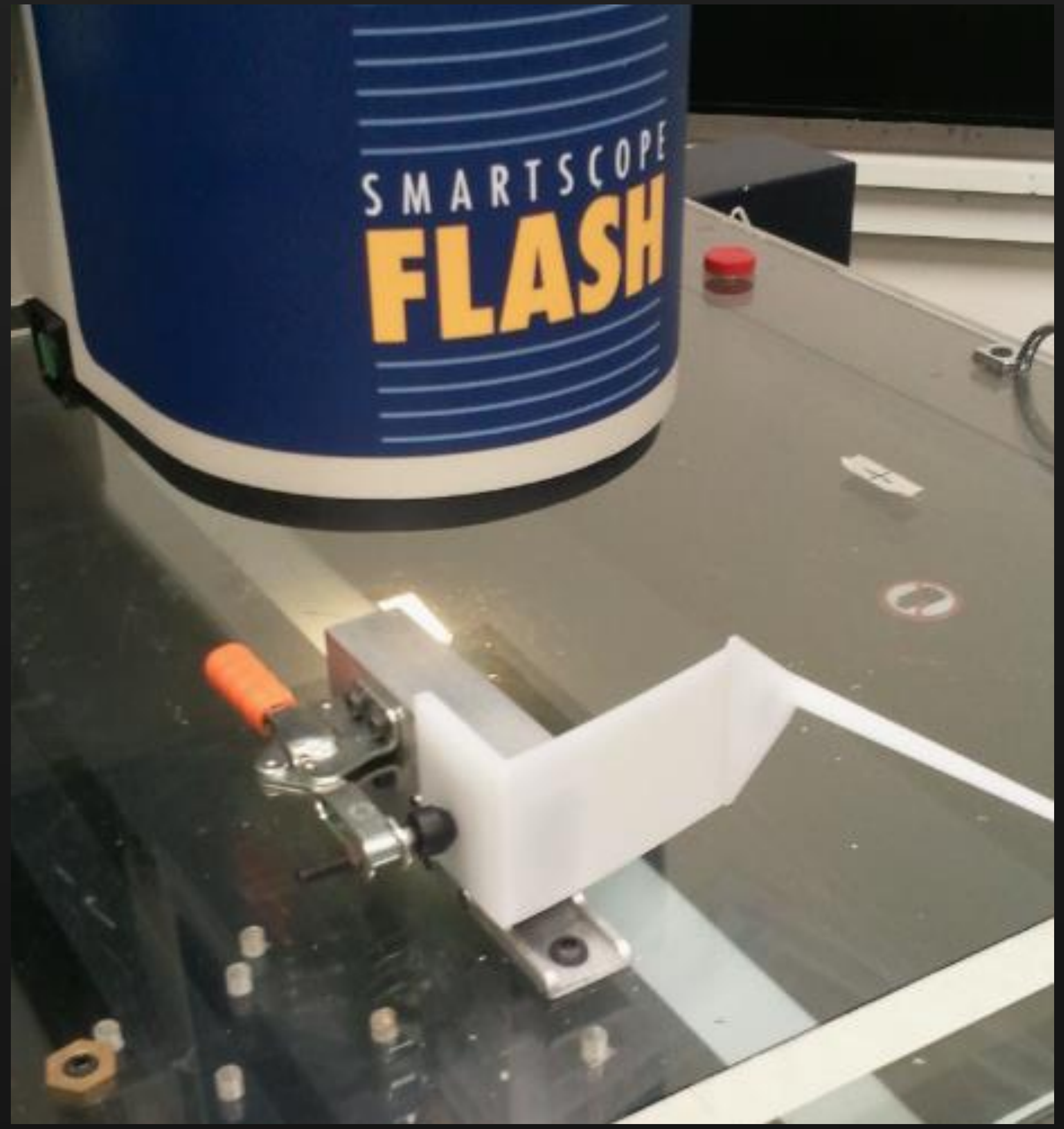
- The outputs measured:
  - End of injection pressure
  - Part linear shrinkage
  - Corner angle



Experimental Equipment

- Data acquisition device to capture displacement, pressure and temperature values

- Part dimensions measured optically



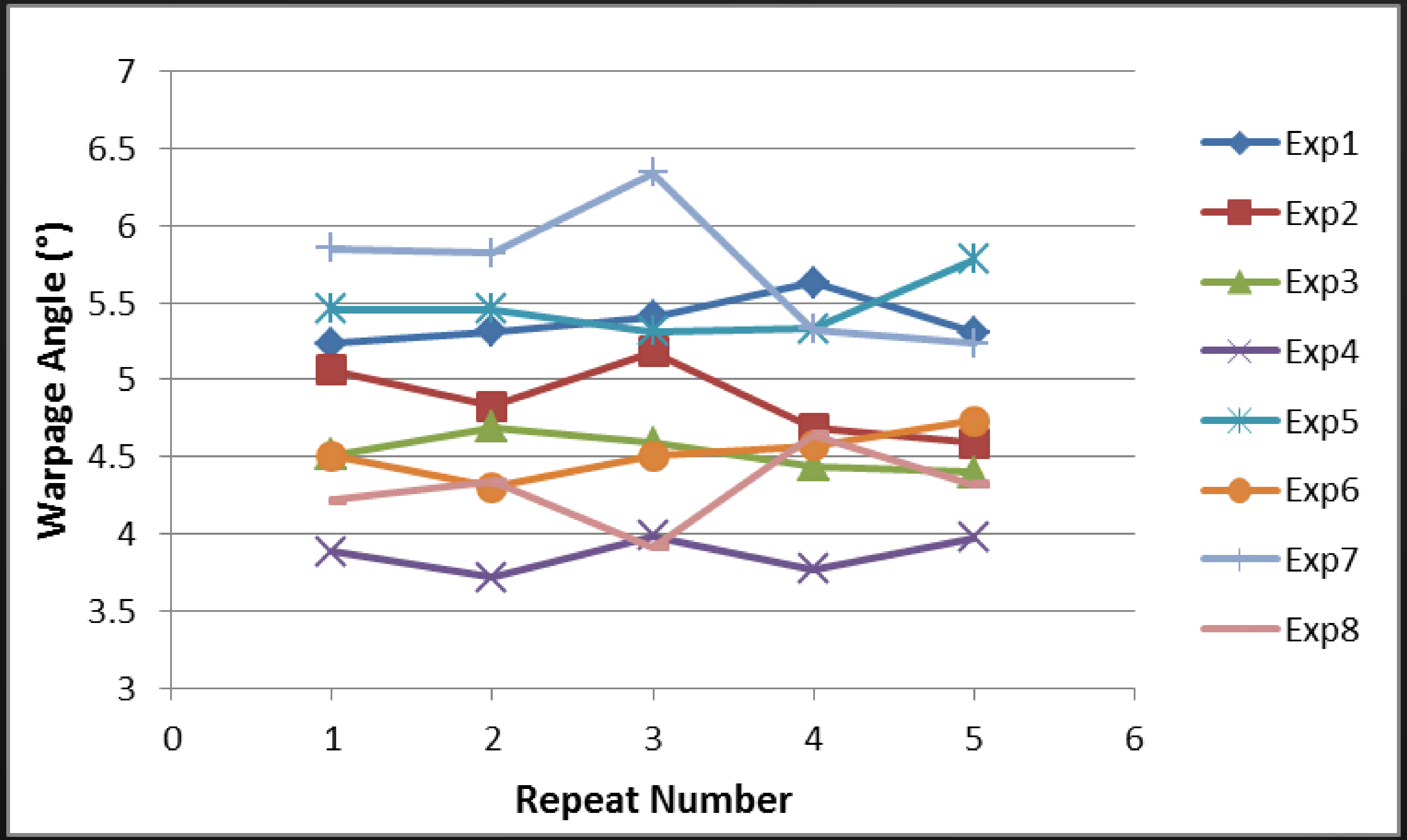
Steps to Enhance an Experimental Sensitivity Study Result

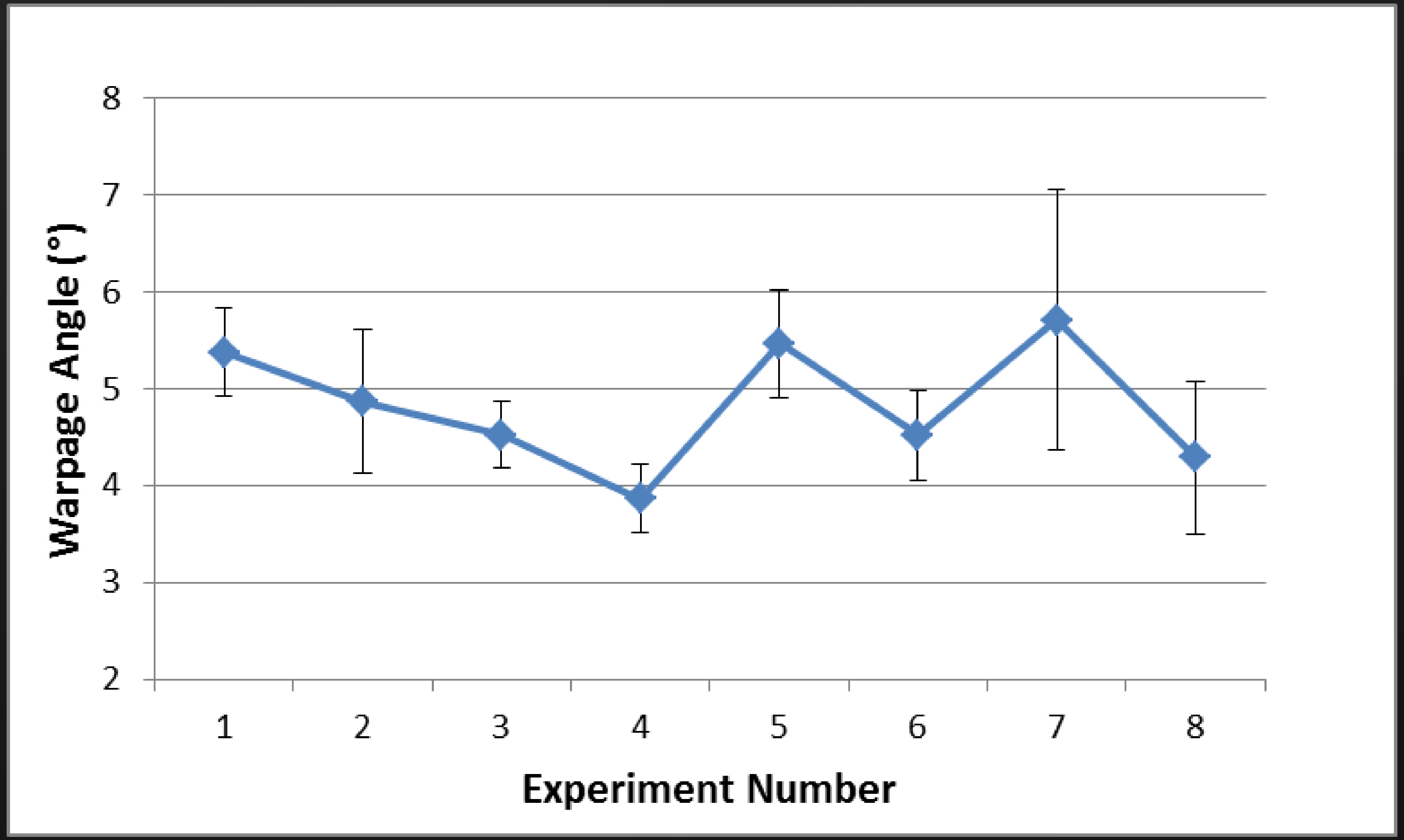
Experimental Uncertainties

- To establish an accurate input parameter to output measurement relationship, it is important to:
  - minimize experimental variation by ensuring stable conditions
  - quantify the experimental uncertainty through the use of repeats

Experimental Uncertainties (continued)

- Measurement variations can then be observed on parameter influences, for example Warpage Angle

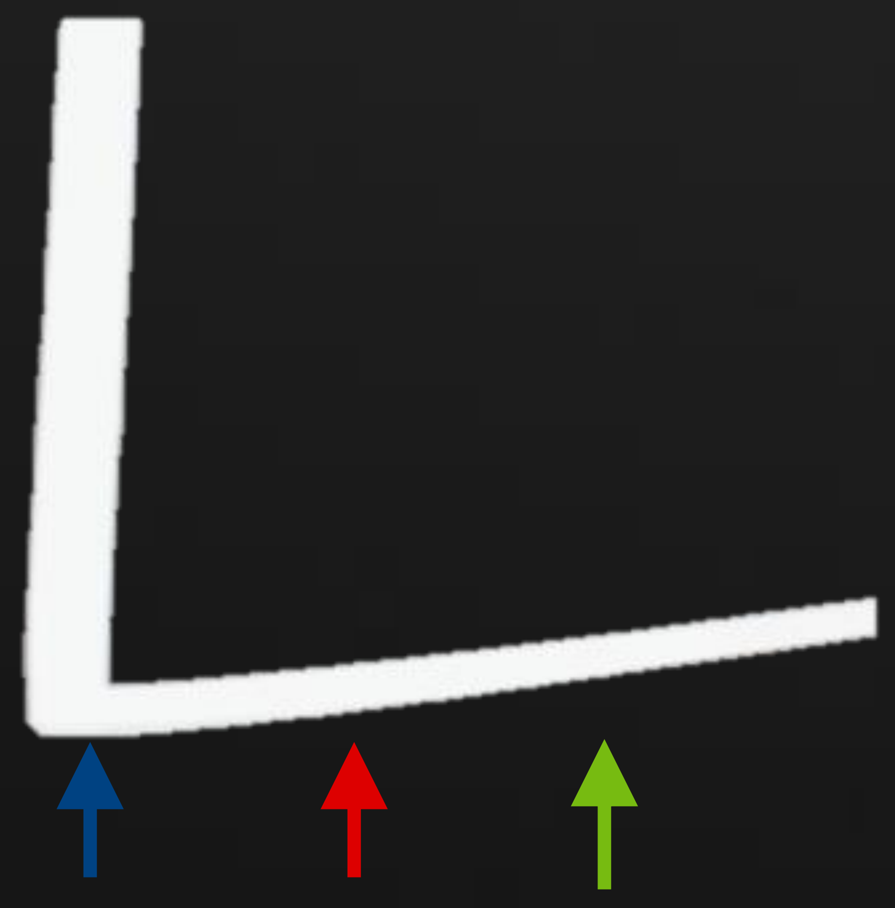


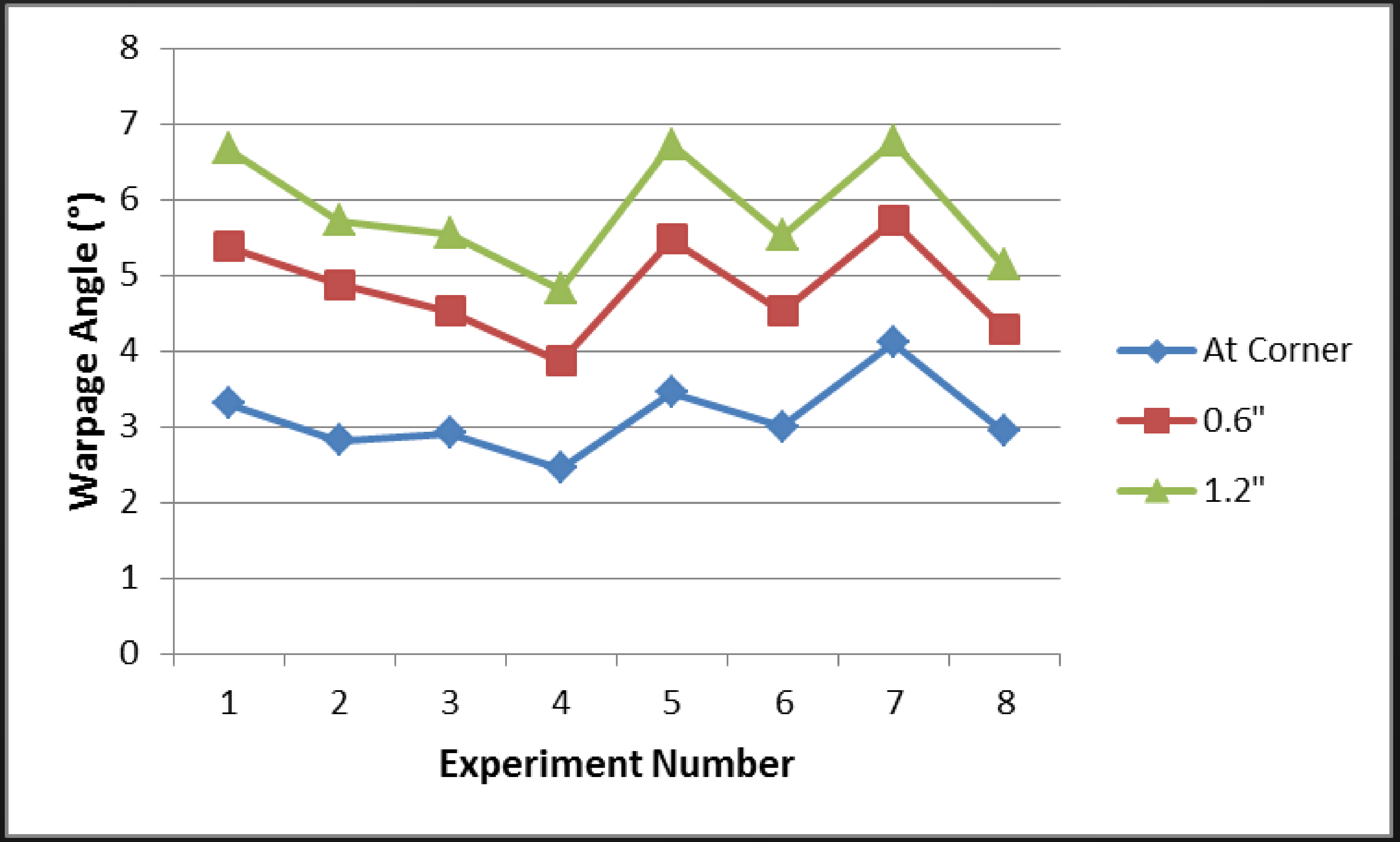


Experimental Uncertainties (continued)

- Being aware of local measurement variations, such as some corner curvature
- Key is to ensure that trend is captured

Scan of corner part



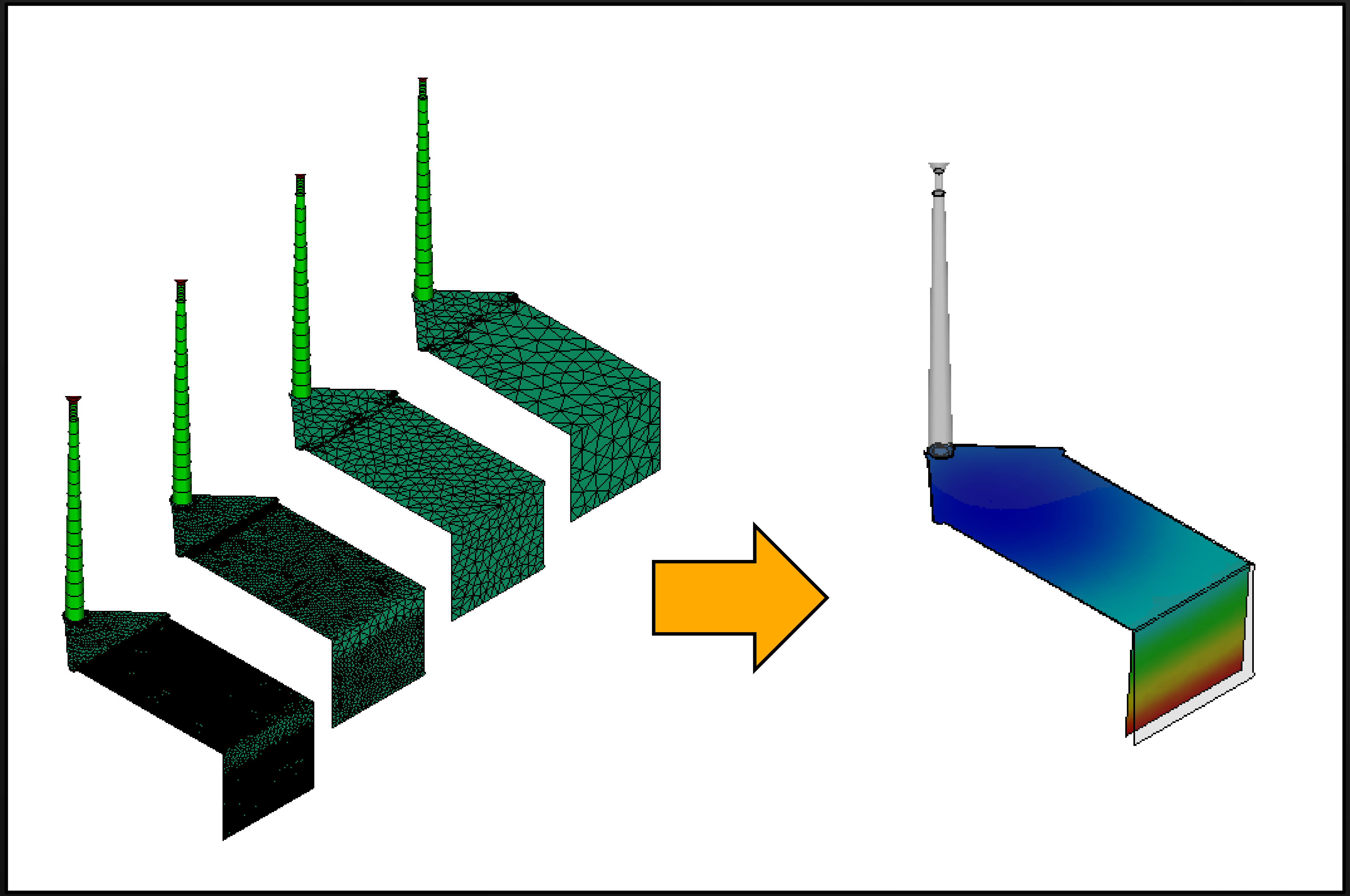


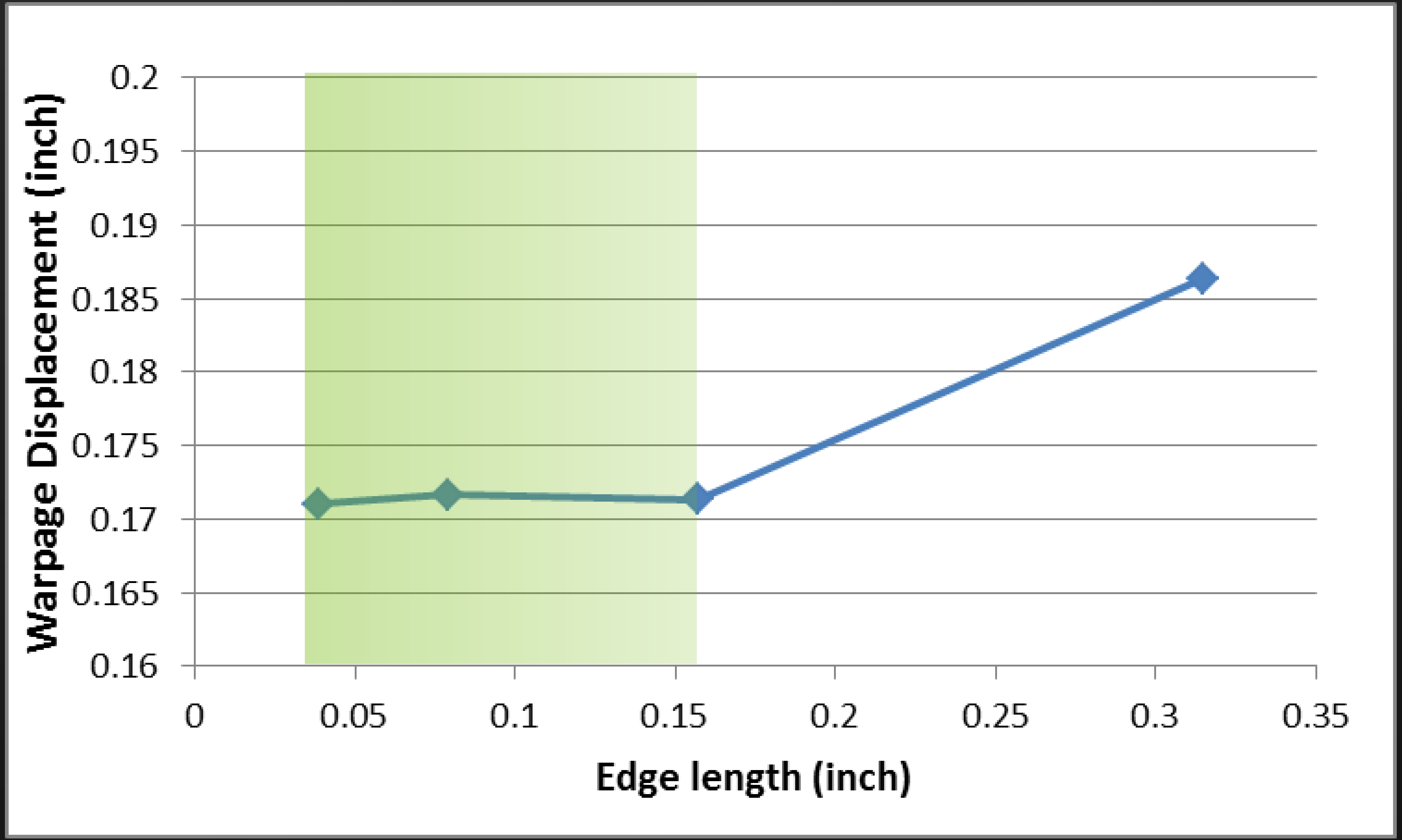
Simulation Uncertainties

- Like Experimental variation, the Simulation uncertainty should be minimized as well through an:
  - Accurate representation of the geometry
  - Appropriate selection of simulation parameters, such as mesh and parameter settings

Simulation Uncertainties (continued)

- Selection of mesh edge length based on mesh sensitivity test

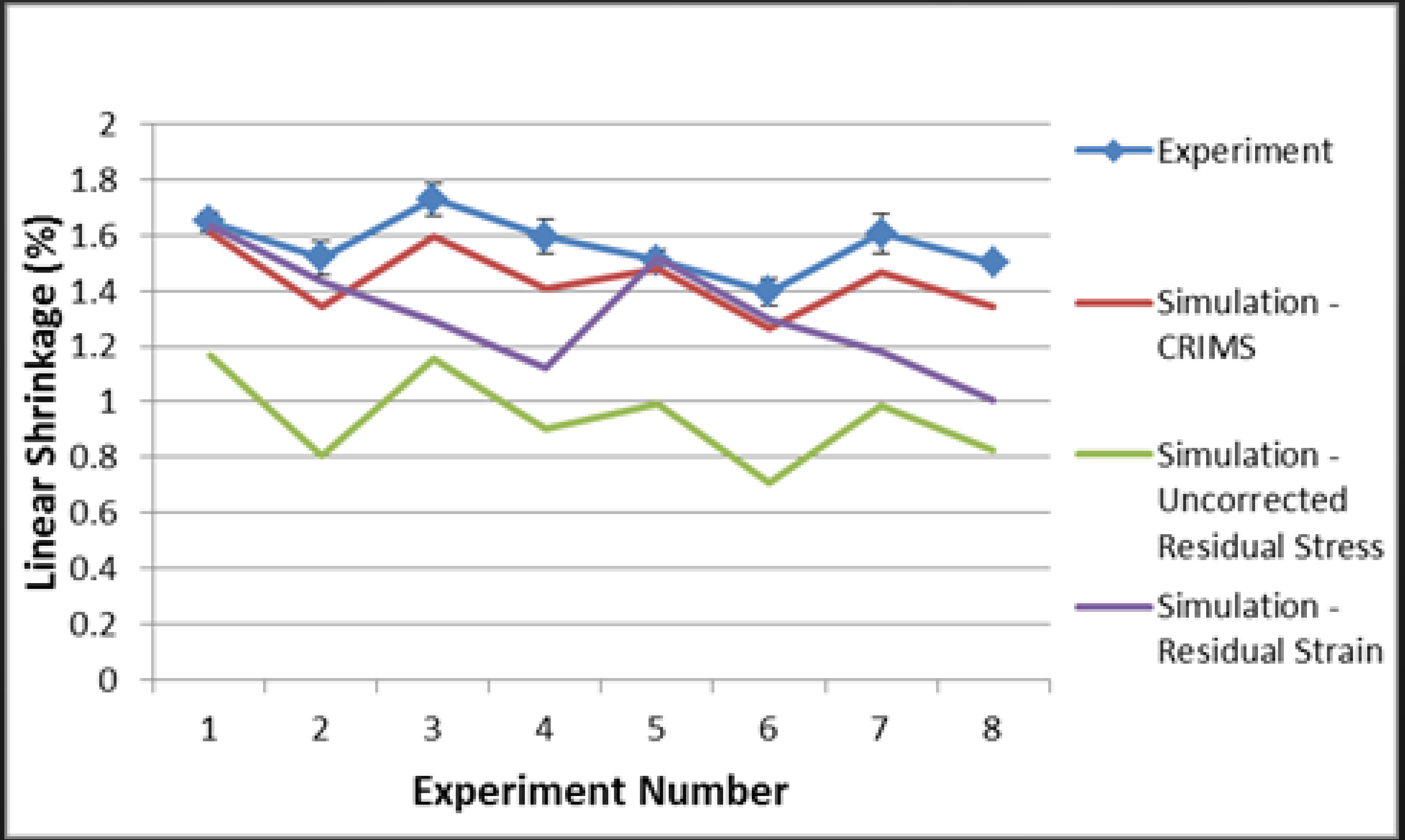




Simulation Uncertainties (continued)

- Variations such as Material model parameters can impact the sensitivity results

- If available CRIMS Shrinkage model can enhance linear shrinkage prediction



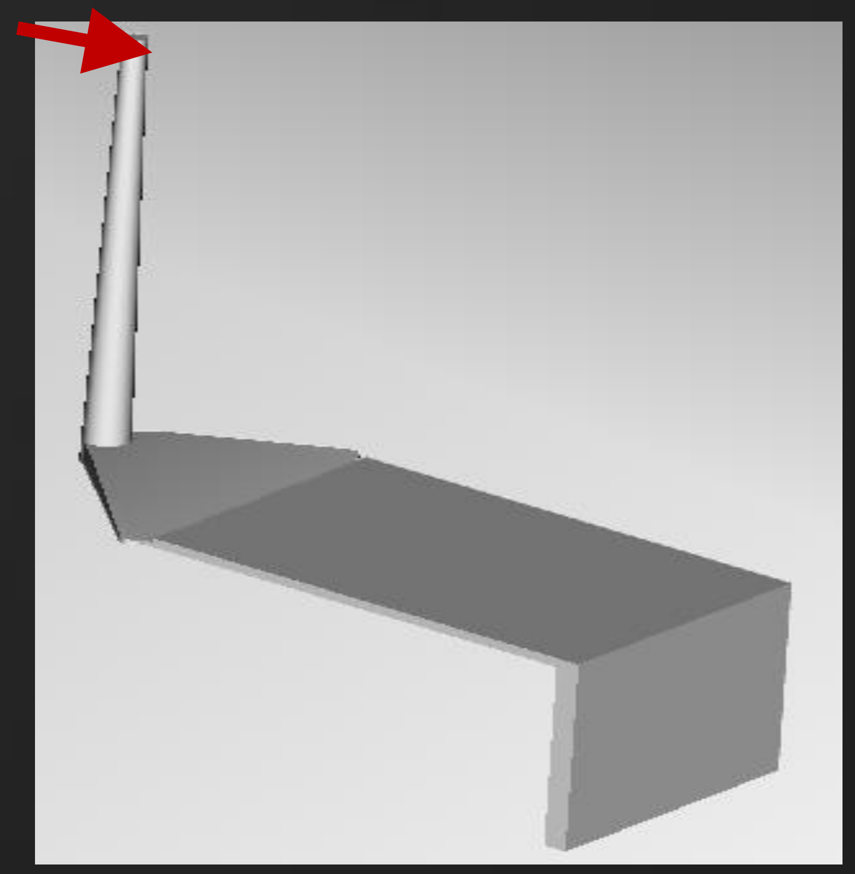
Sensitivity Study Results

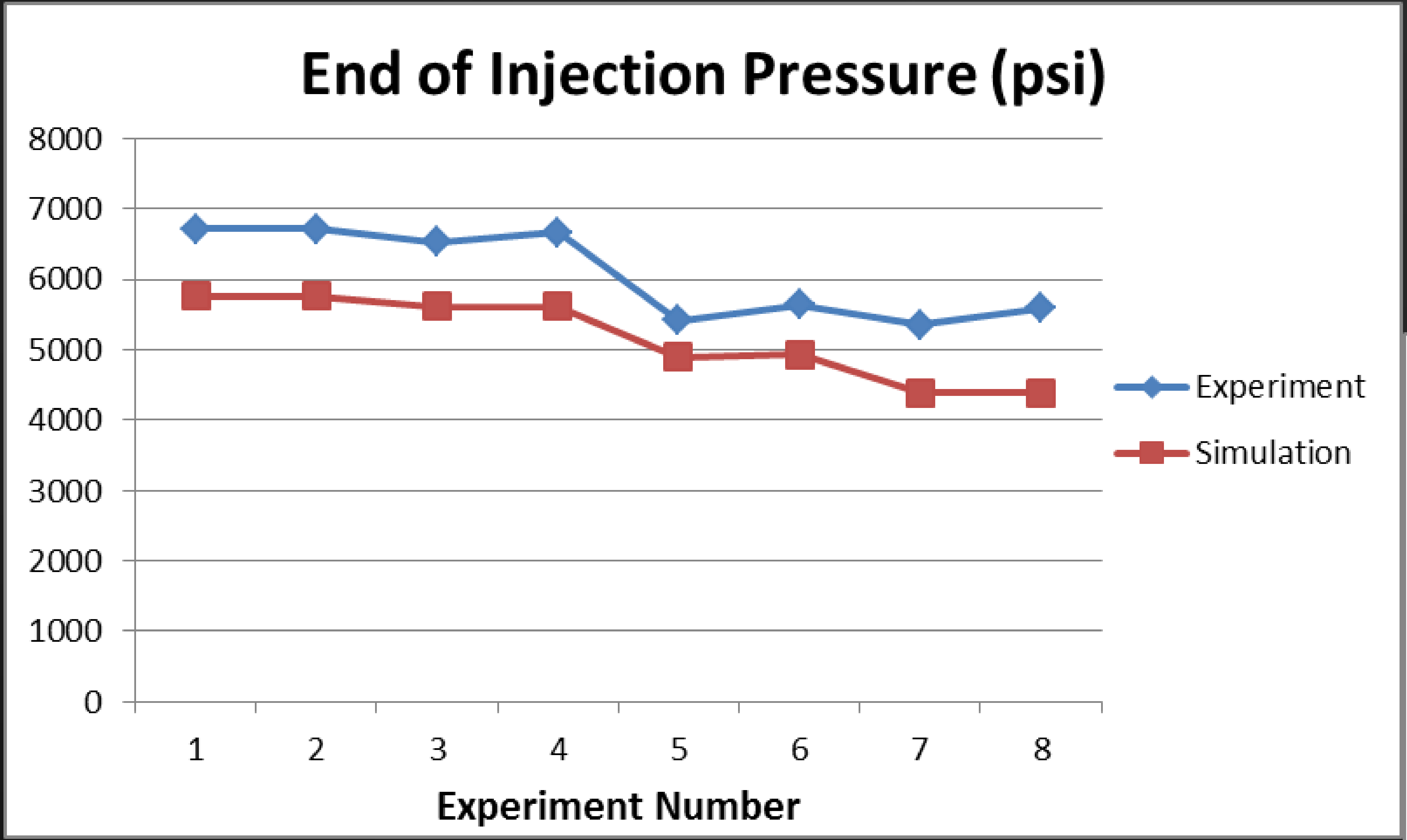
Sensitivity Study Results

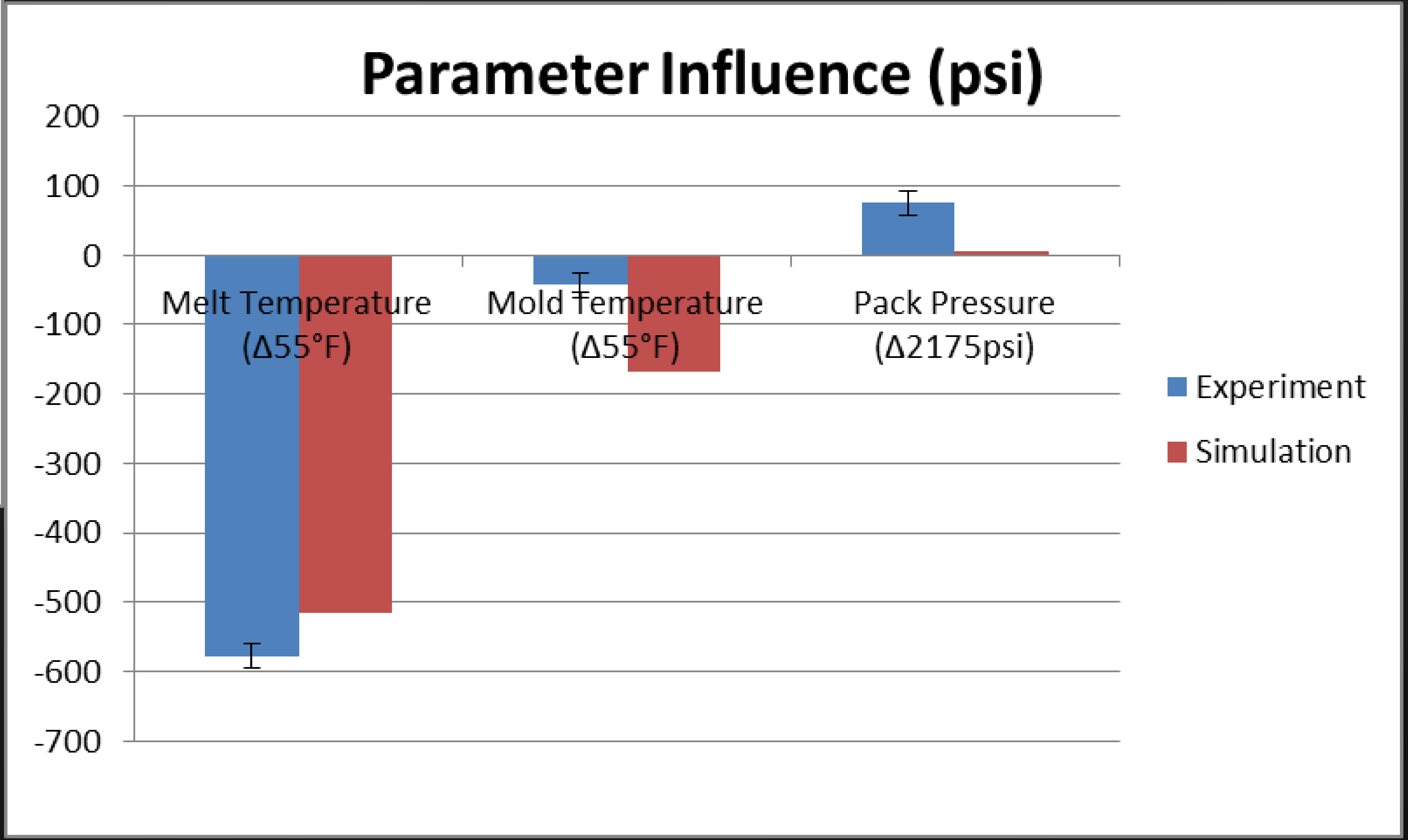
- It would be ideal to get close to measured values but key aspects of a sensitivity study are to observe:
  - the size of variation
  - parameter trends

- All simulations are done using:
  - Autodesk Simulation Moldflow Insight 2013
  - Mid-plane mesh
  - Cool + Fill + Pack + Warp sequence

End of Injection Pressure

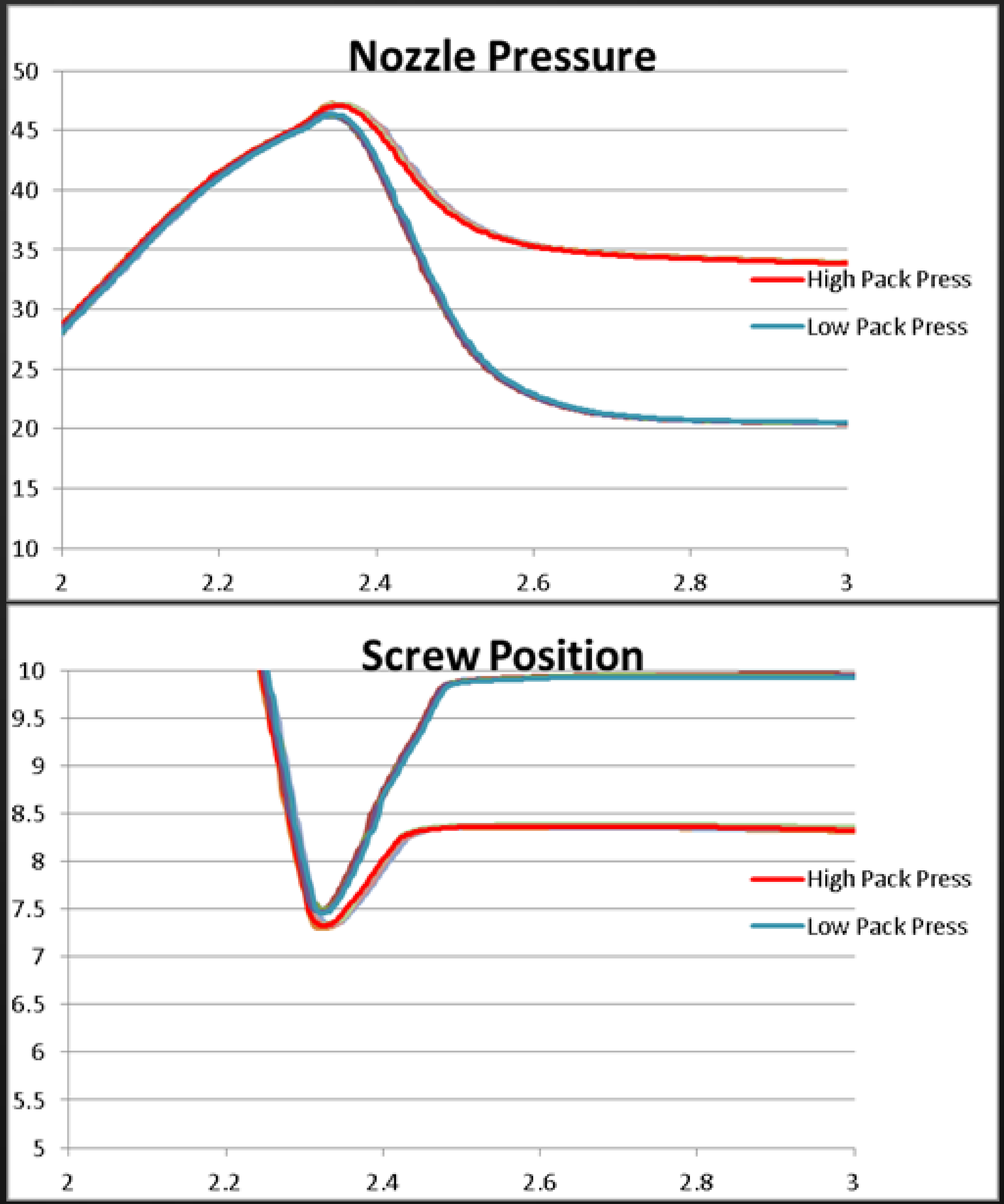




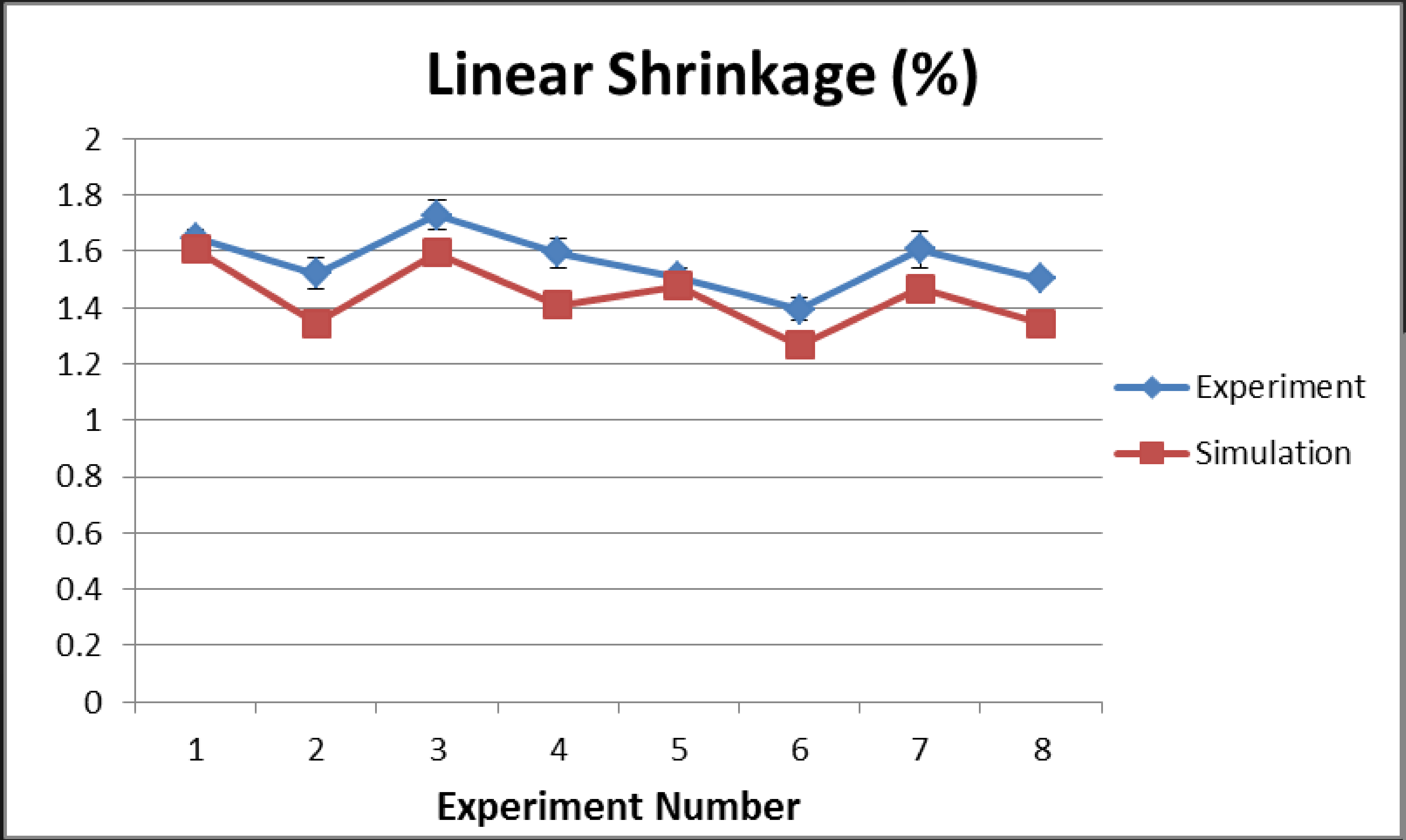


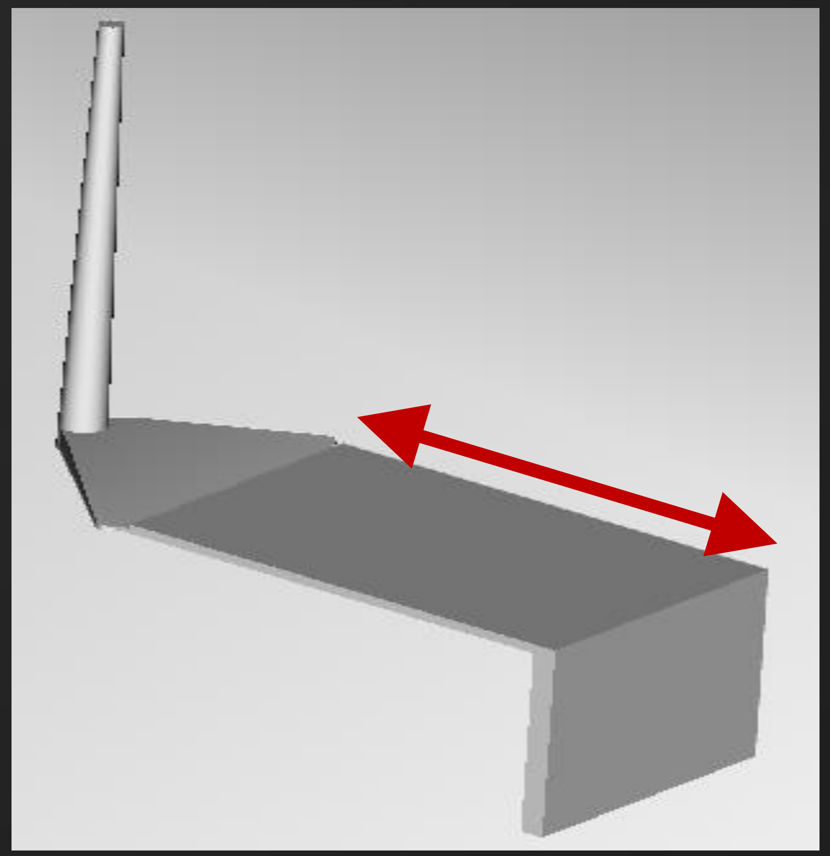
End of Injection Pressure (continued)

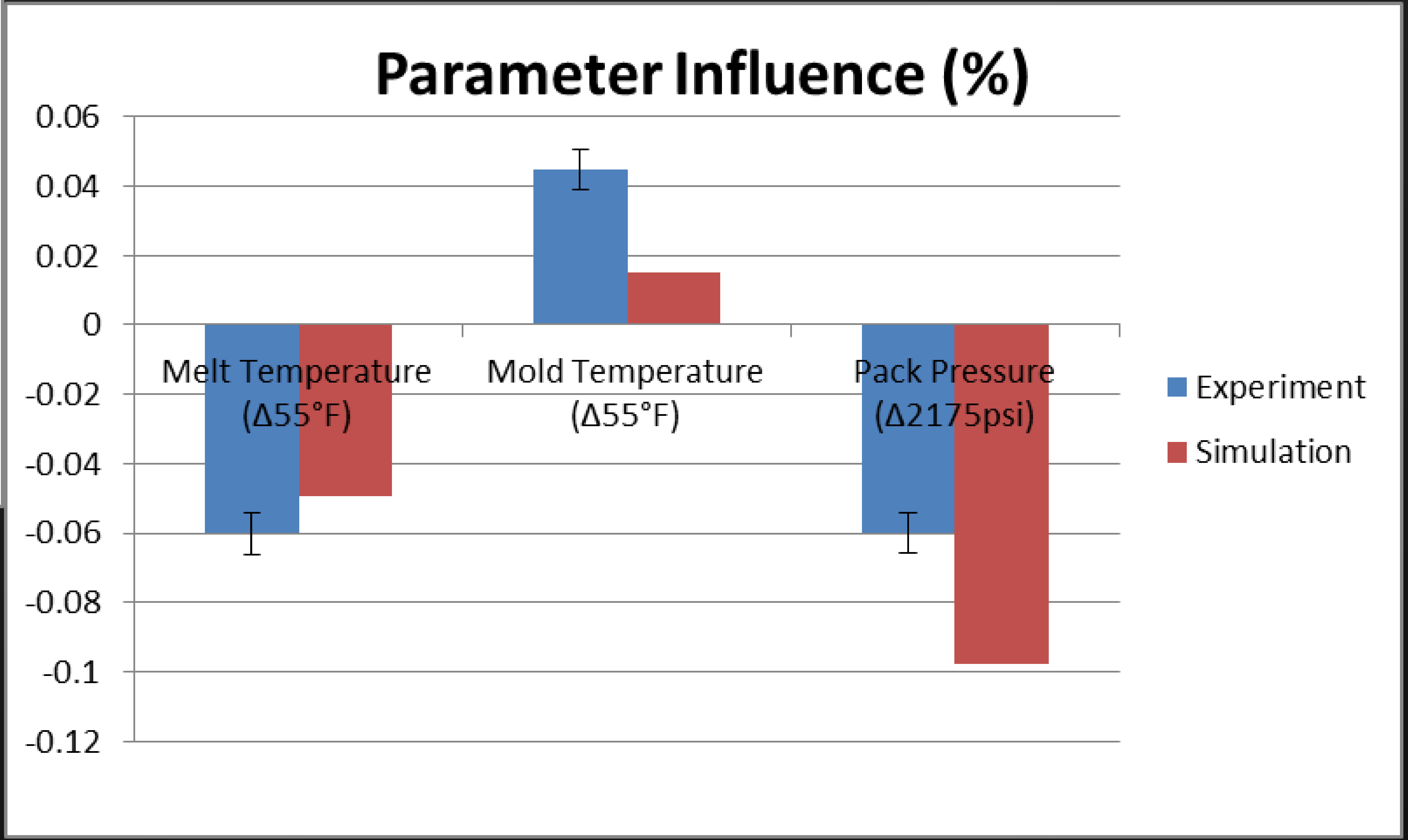
- Unexpected Pack Pressure influence
- Shows that machine dynamics can have an impact on measured responses



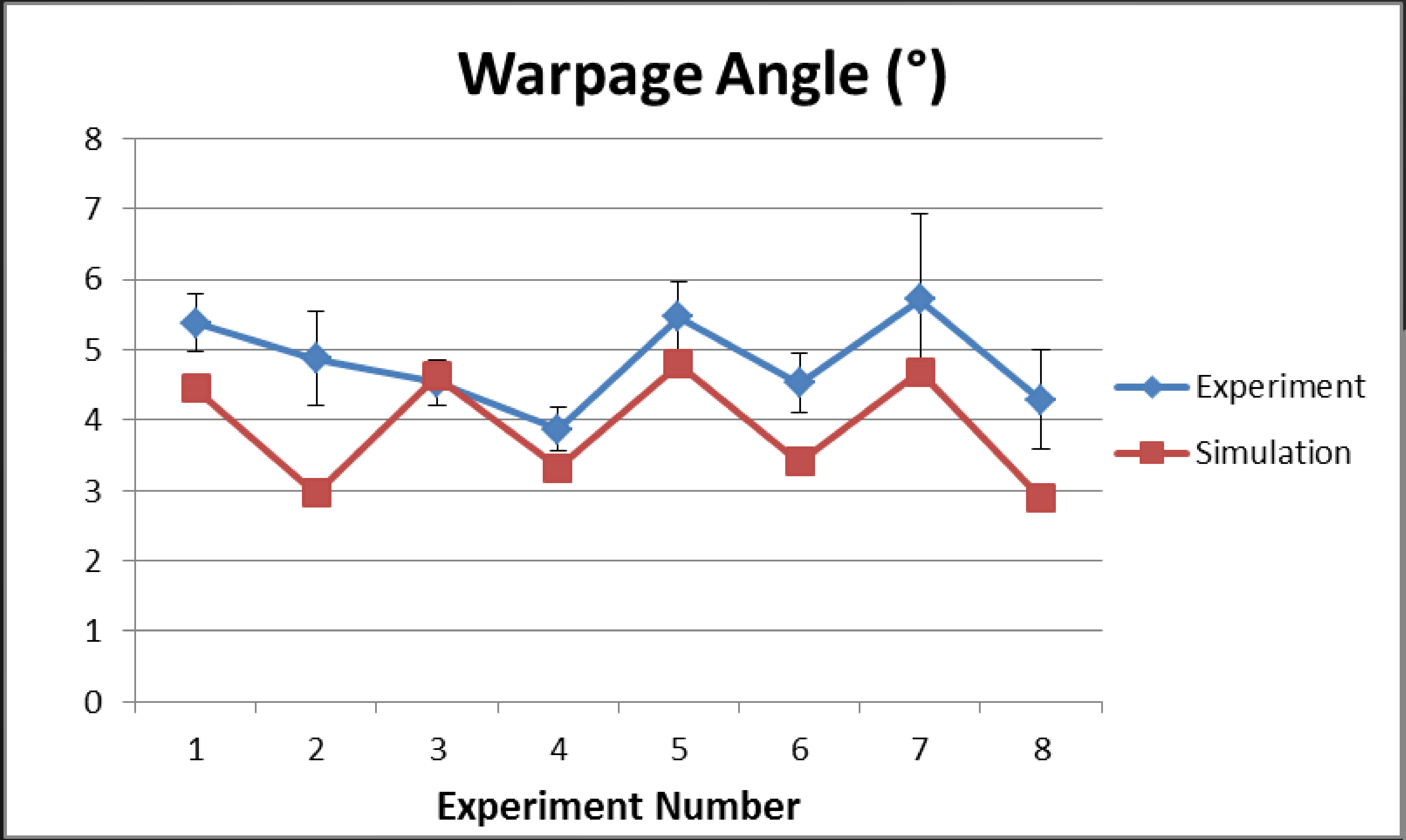
Part Linear Shrinkage

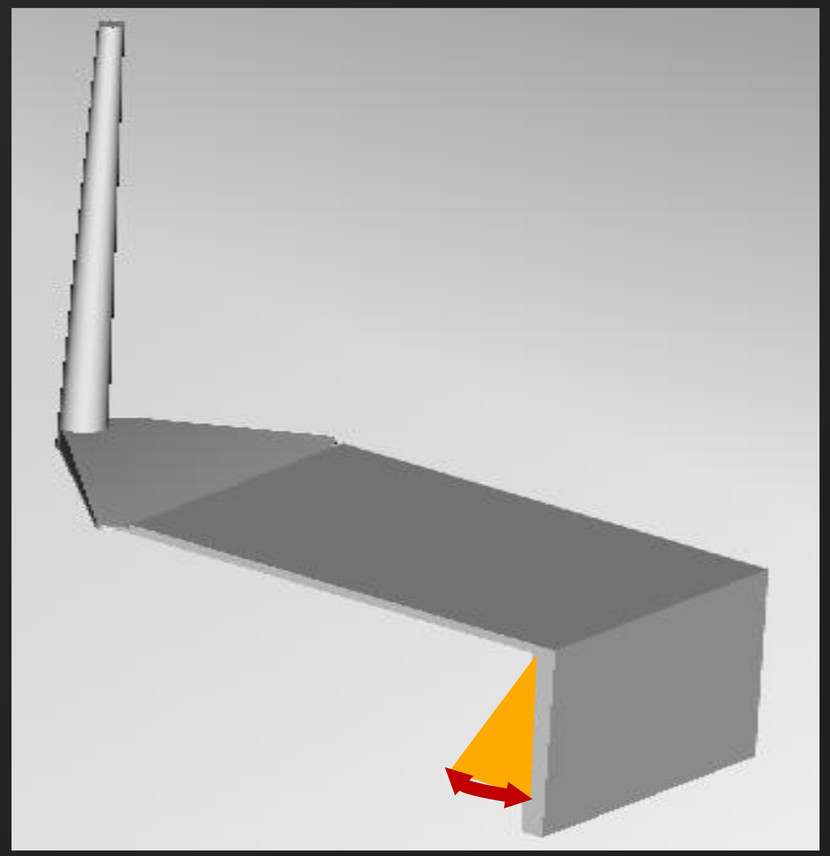


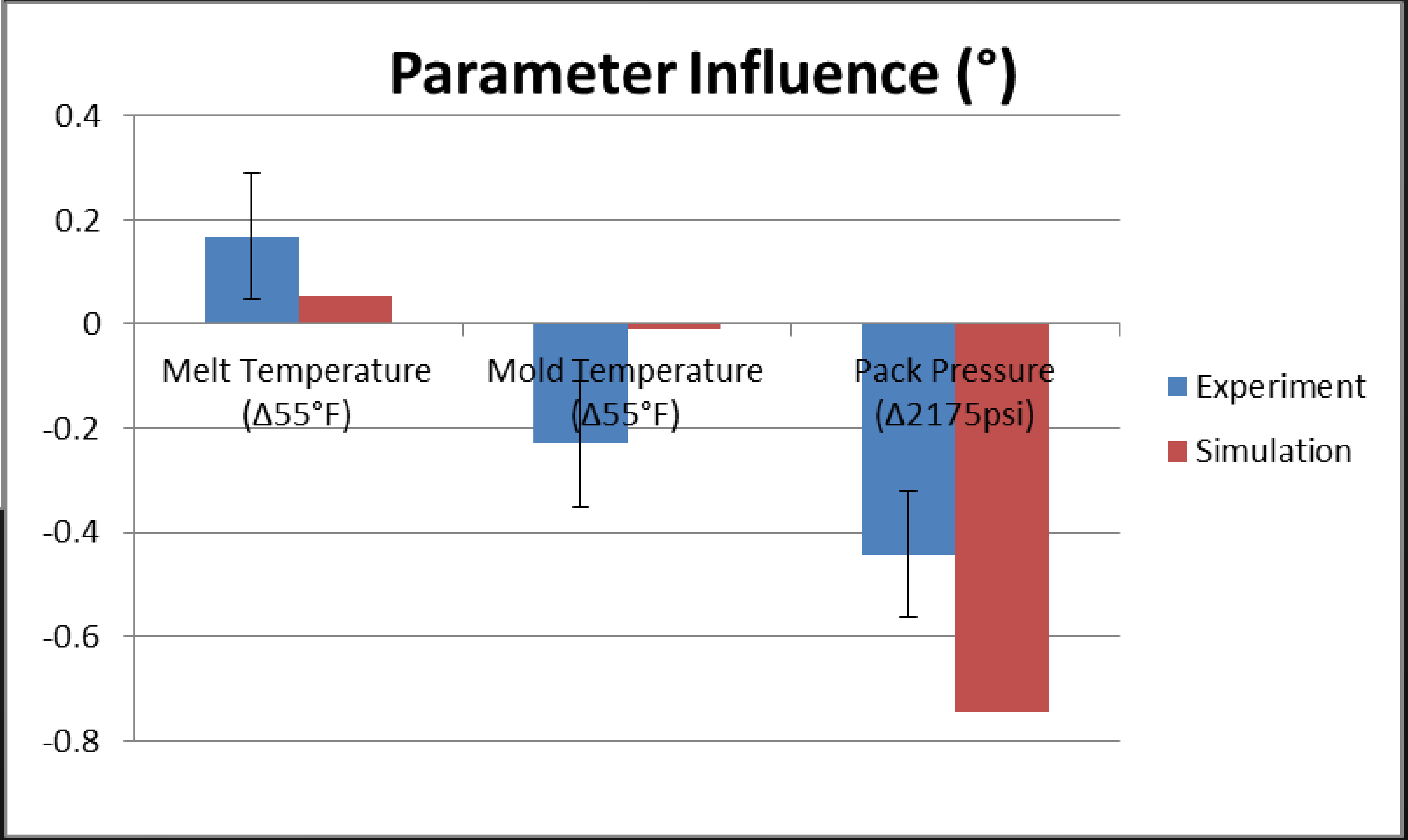




Part Warpage







Summary

- Important to consider uncertainties both in the experiment and simulation as they can provide a clearer picture of the confidence in your results

- Simulation sensitivity studies provide much more than single simulation results, namely the expected:
  - Size of variation
  - Parameter influences

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