Solving Polymer Processing Problems with Computer Simulation

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Compuplast Canada Inc.

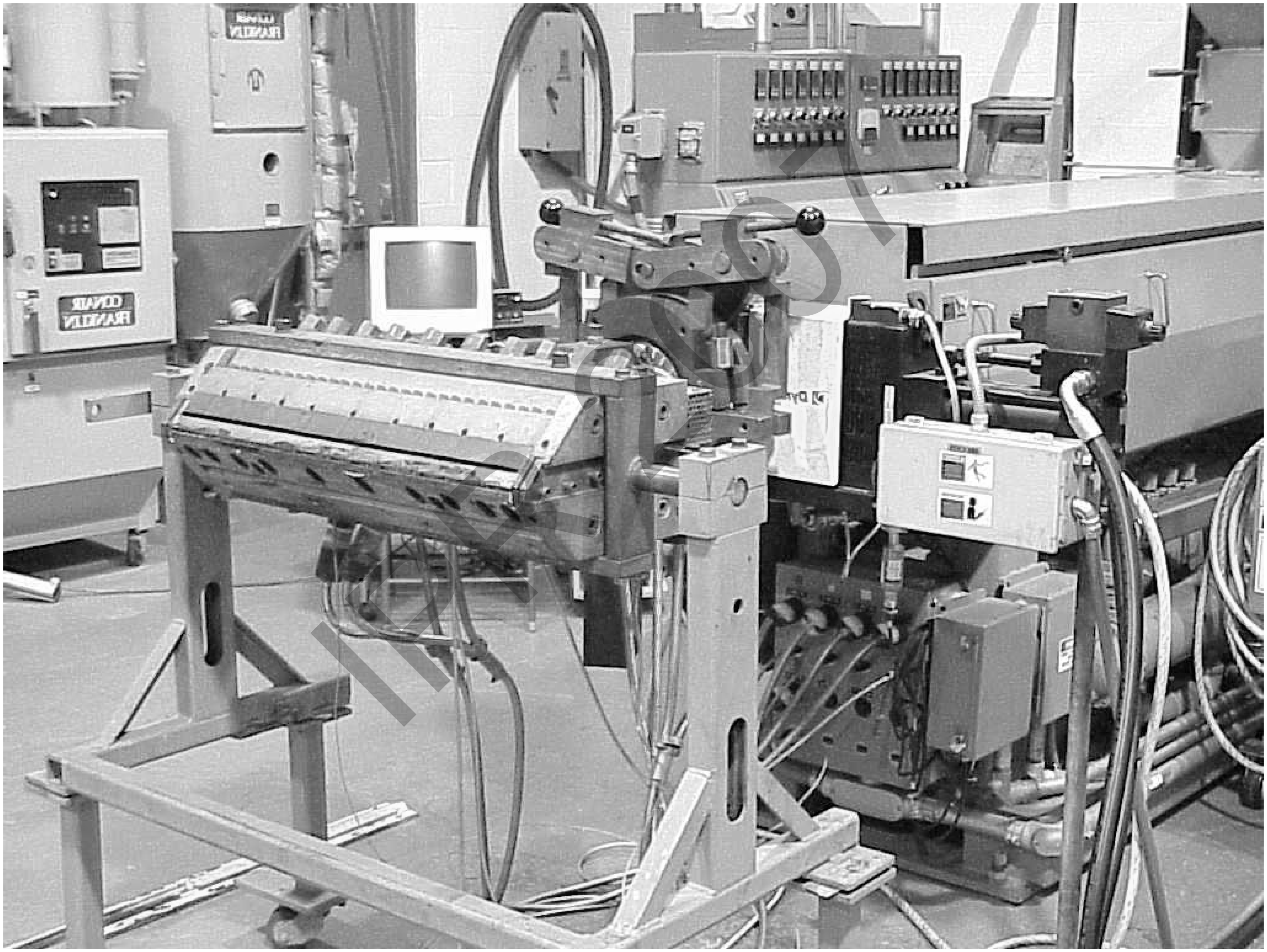
Objectives

- **Demonstrate the application of CAE/CFD/Simulation in polymer processing**
- **Show how simulation can be used to troubleshoot/optimize a process/design**
- **Explain certain observations or phenomena with the aid of simulation**

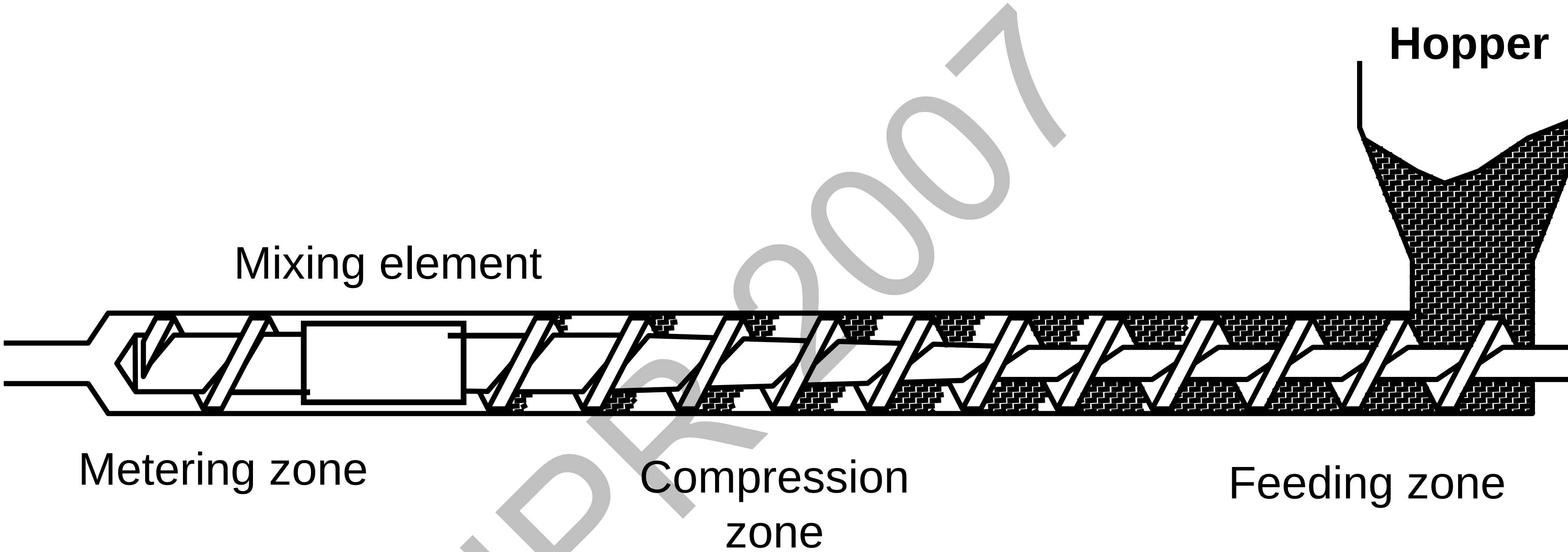
Problem: Particles/Gels in Film Sample

- **In this system, periodic "showers" of gels or particles were observed in the film sample.**

Film/Sheet Extrusion



Single Screw Extruder
Conventional screw



Comprehensive Tests with the Macro Glass Window Extruder

Song, Perdikoulias and Planeta, ANTEC 2000

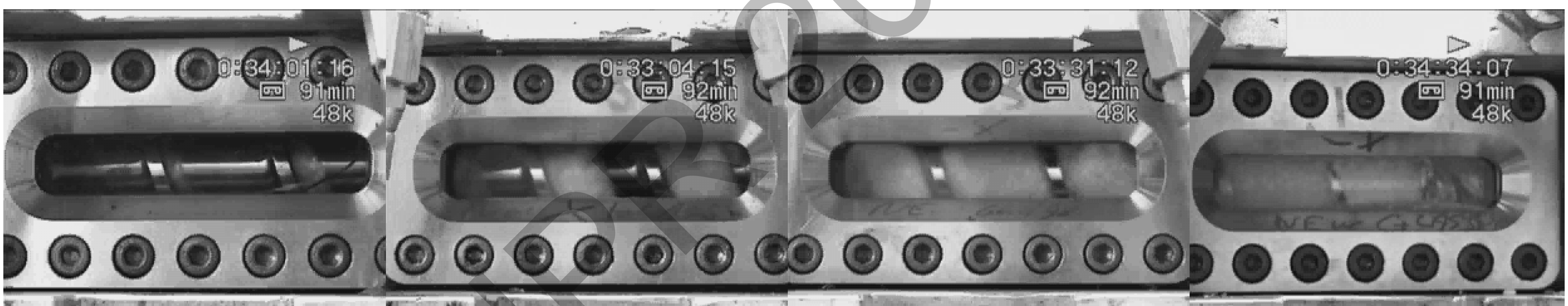


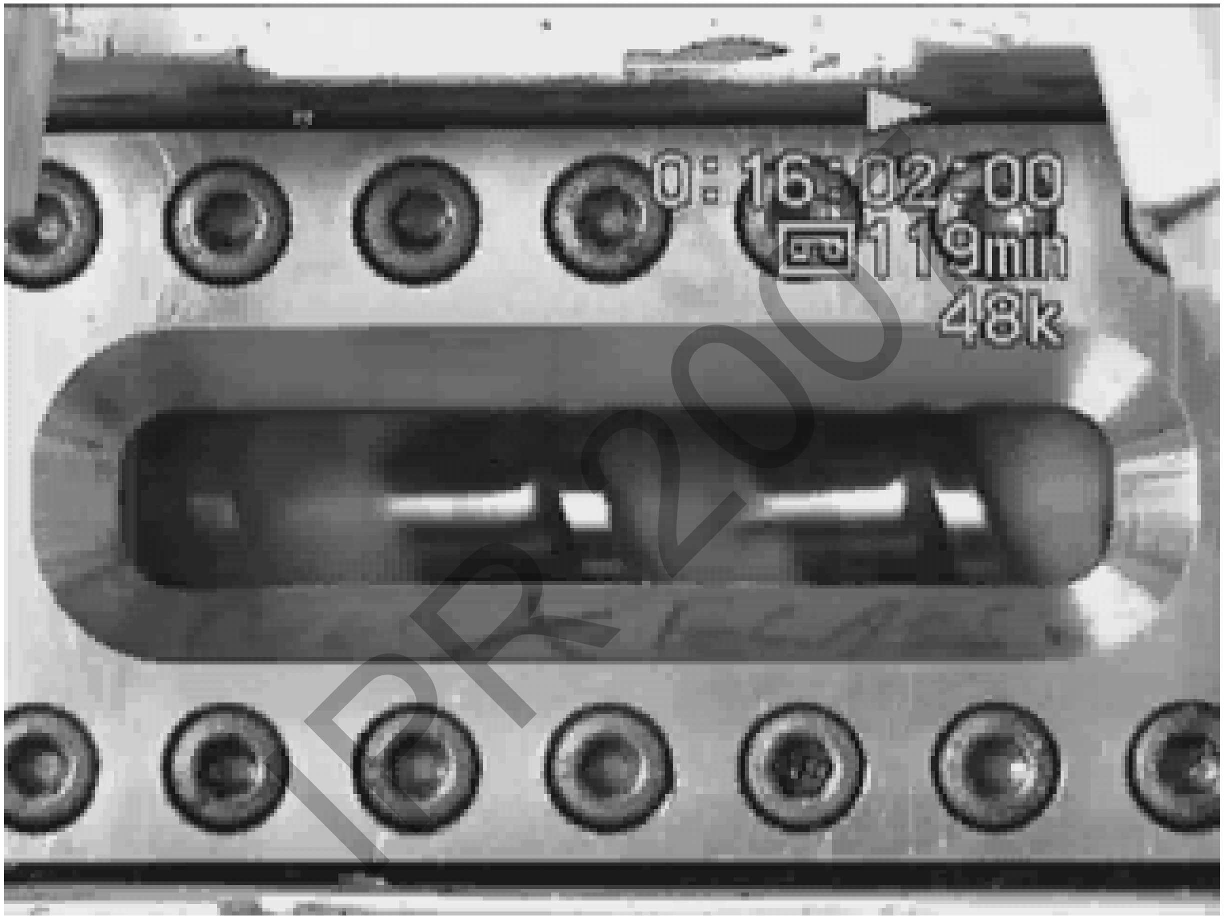
Photo of Extruder Screw

- **The screw used to produce the film had a noticeable discoloration in the feed and compression region.**

Comprehensive Tests with the Glass Window Extruder

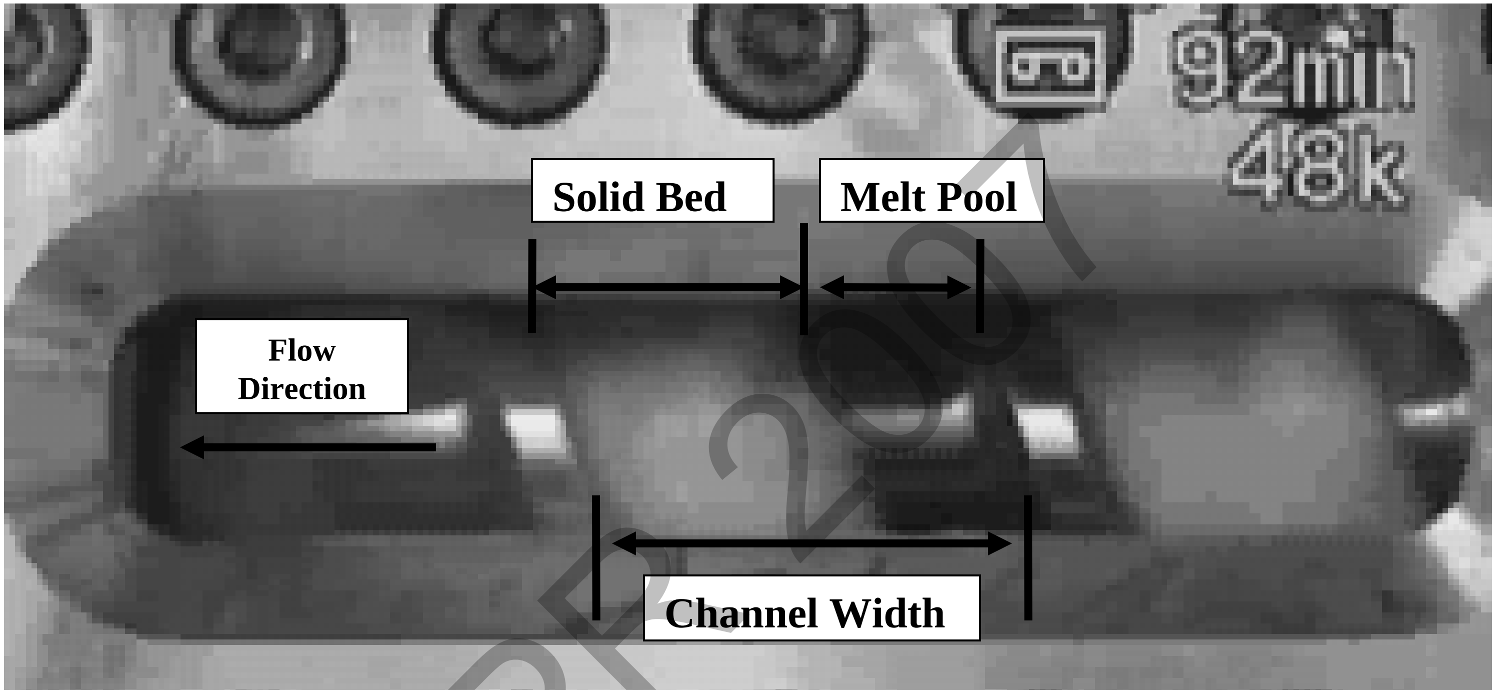
LDPE 50 RPM @ W2 & W3, melt @ ~ 17D

Solid Bed Break-Up



- **Improper screw design results in solid bed break-up and there is no mixer to compensate**

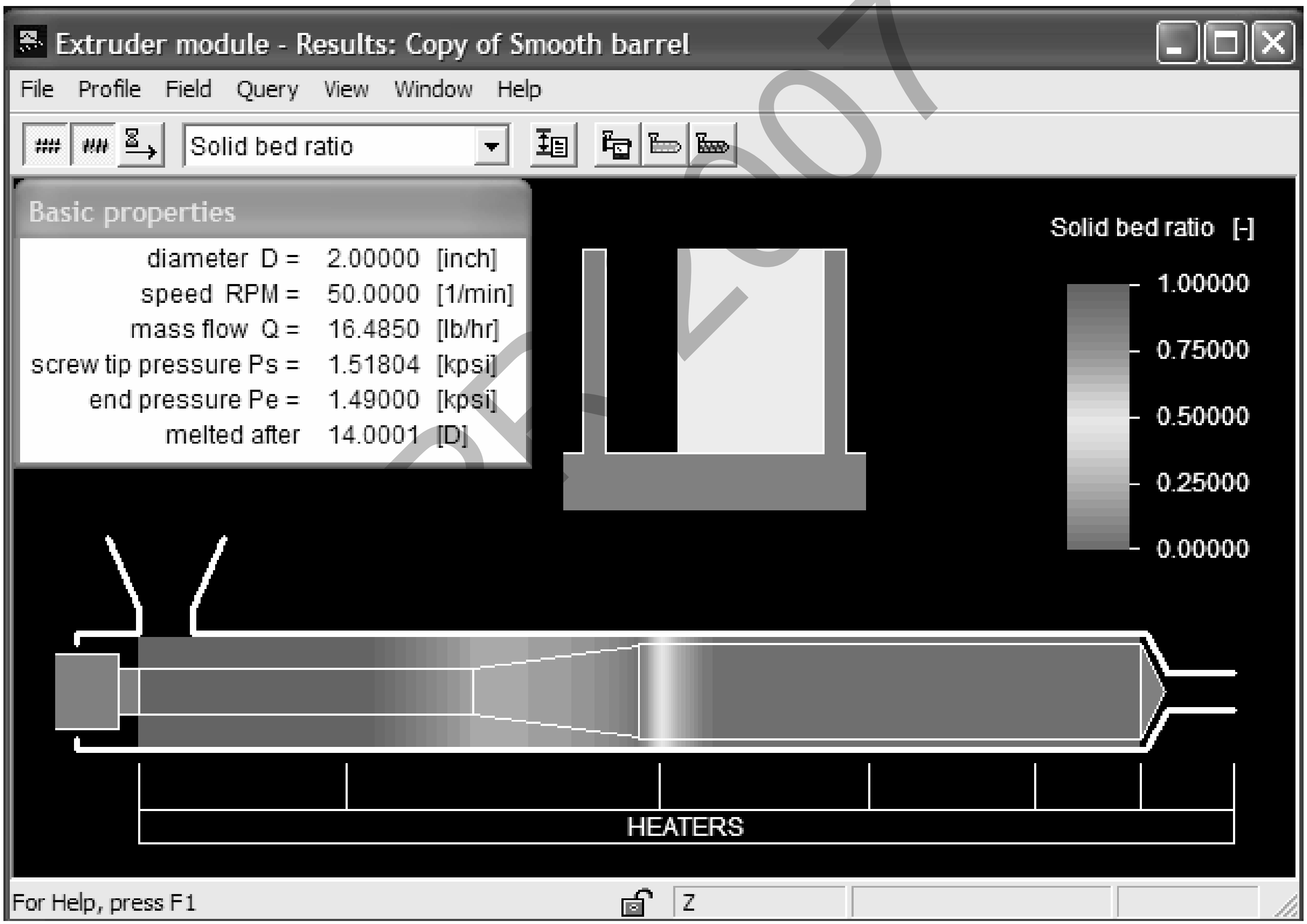
Define: Solid Bed Ratio



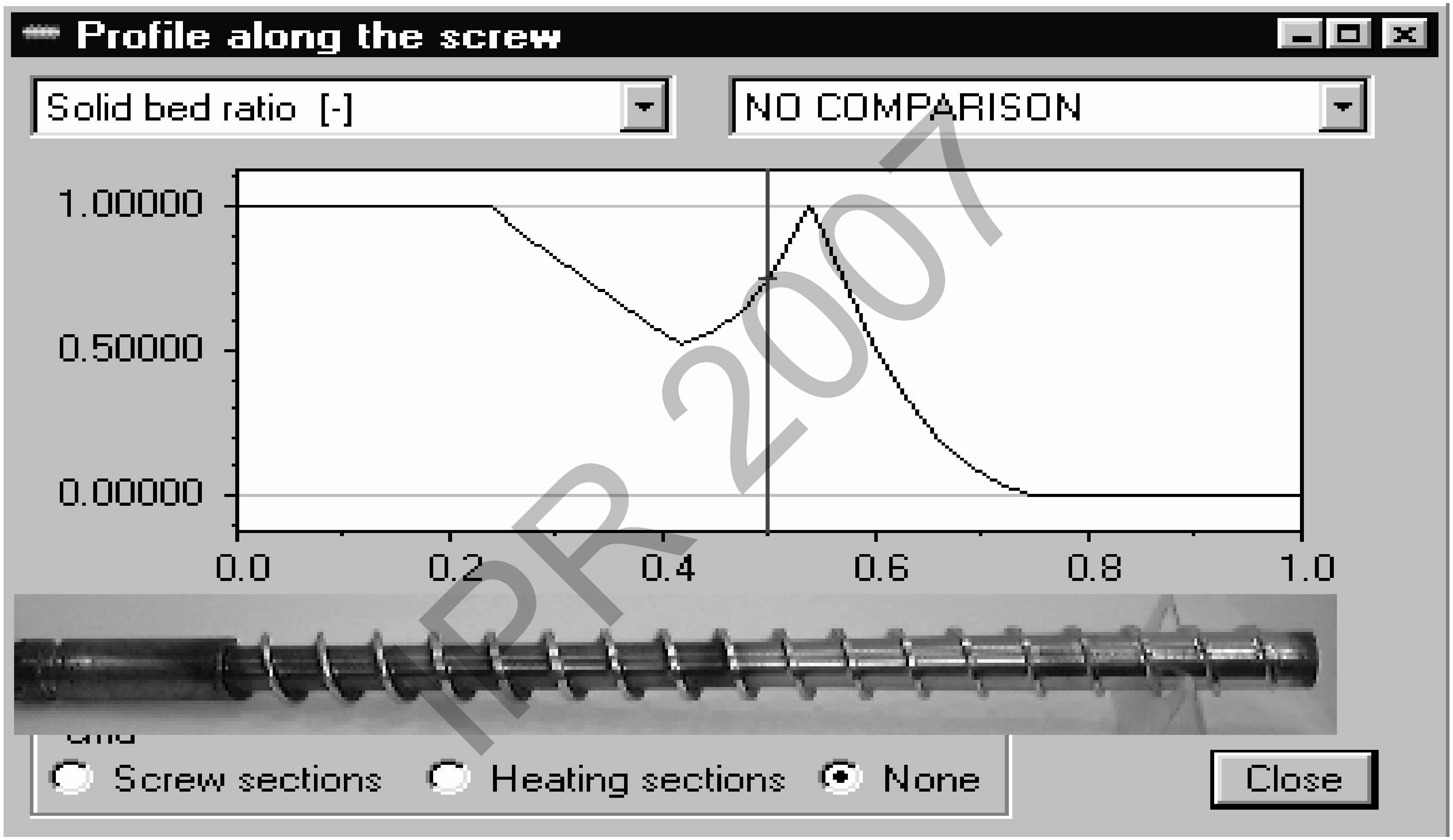
- **Ratio of Solid bed width to Channel Width**
- **Indication of melting capability of the screw**

$$\text{Solid Bed Ratio} = \frac{\text{SB Width}}{\text{Channel Width}}$$

Compuplast®
Virtual Extrusion Laboratory™
Extruder Simulation

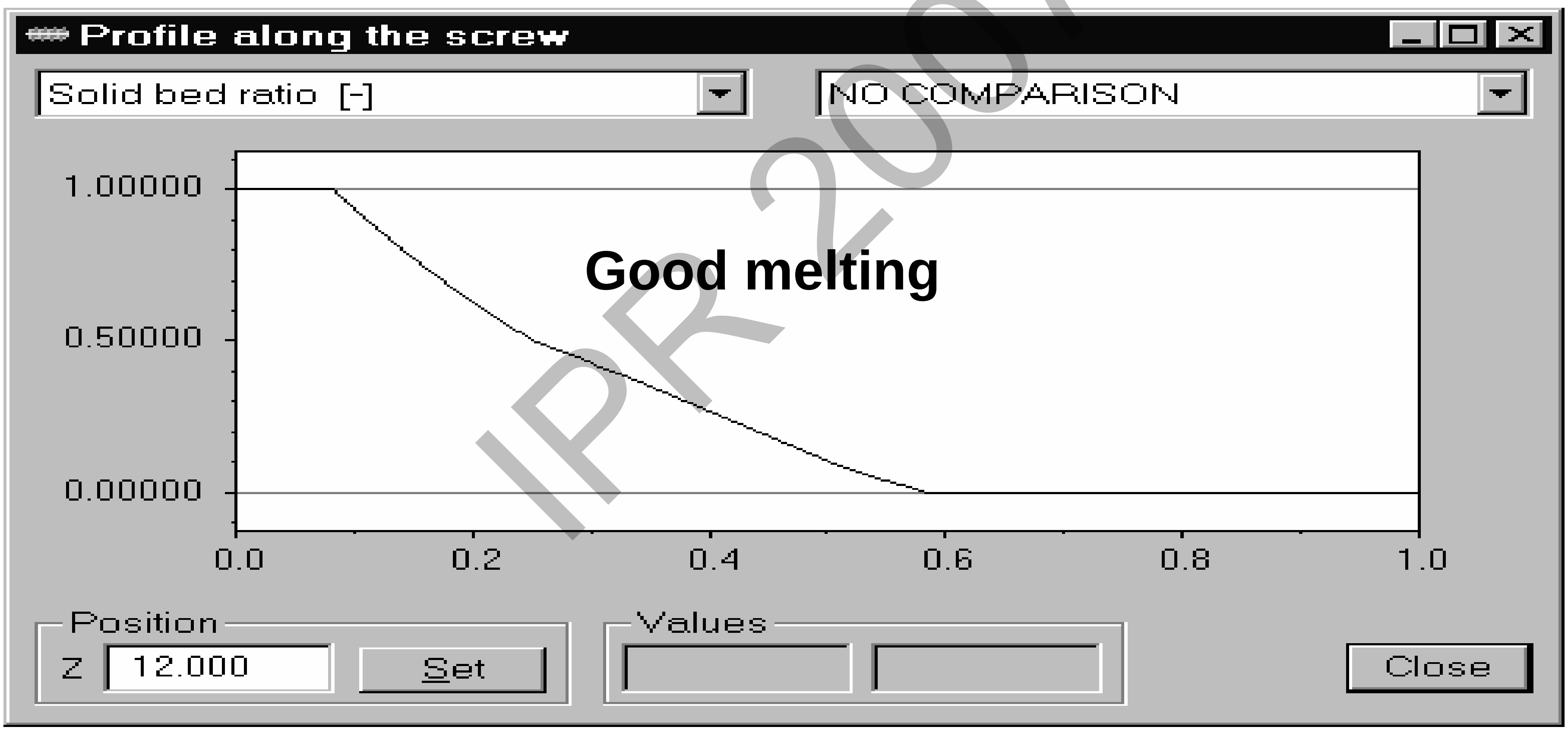


Analysis of Solid Bed Ratio



Simulation indicates that the Solid bed ratio does not reduce gradually as preferred but actually increases near center of screw.

Solution: Modify Process Conditions, Change Material or Screw Design to achieve better melting performance

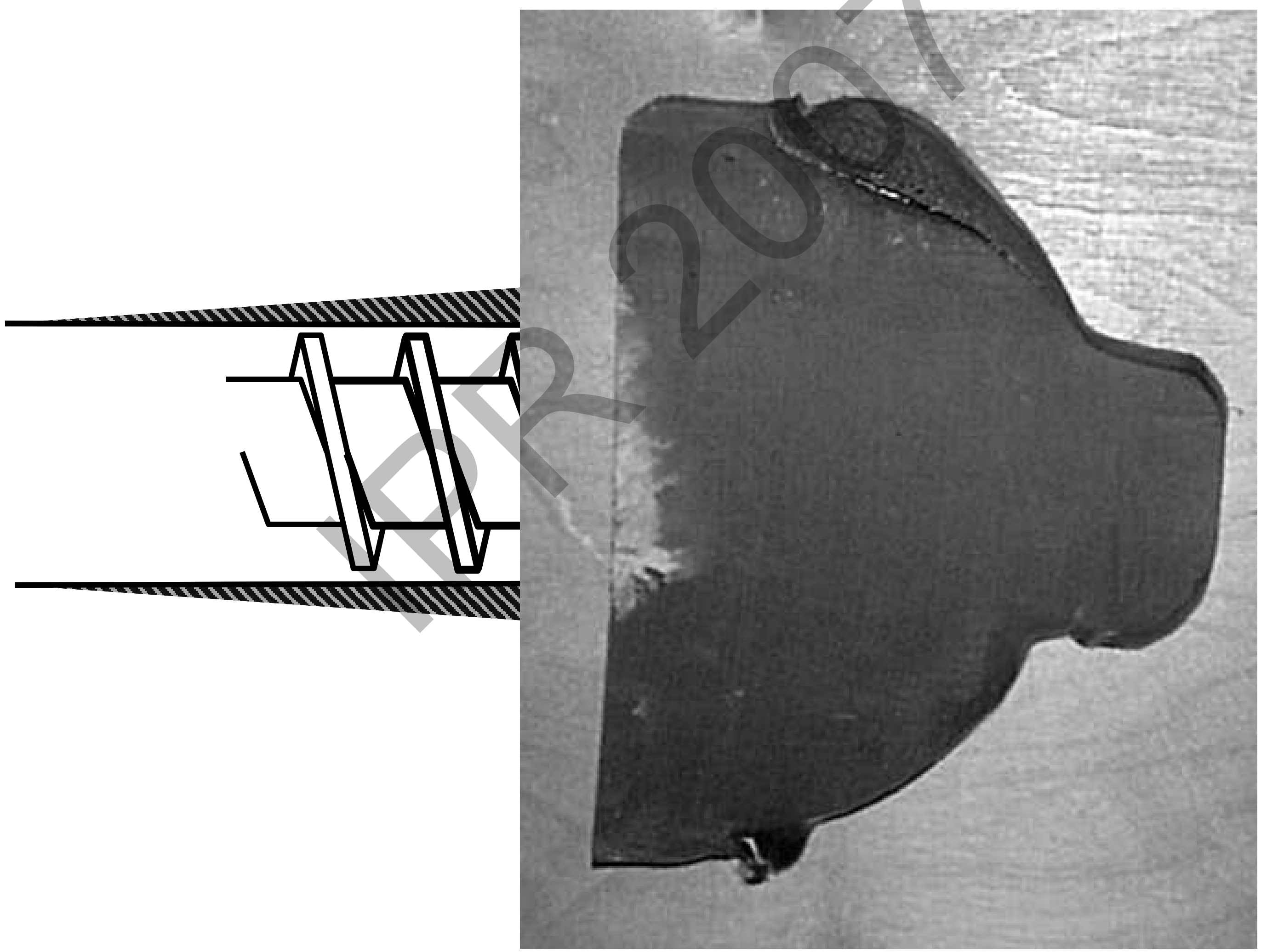


Problem: Polymer Degradation

- **Screen Changer**

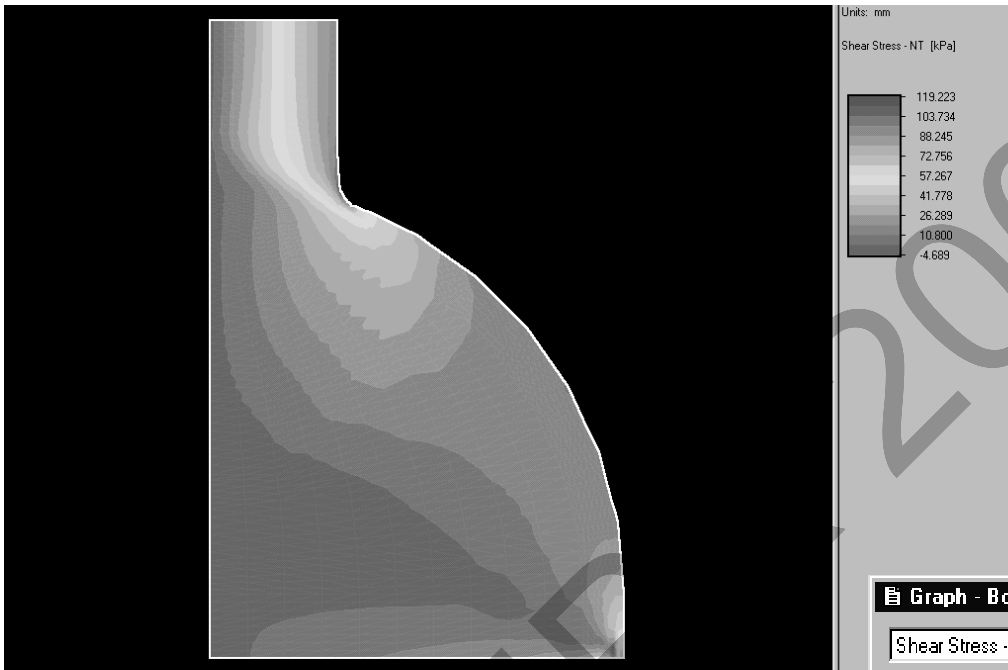
Degradation

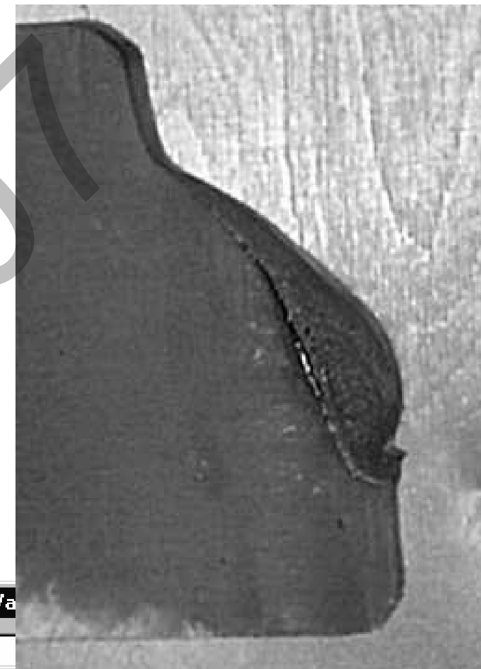
SCREW / BARREL / SCREENCHANGER

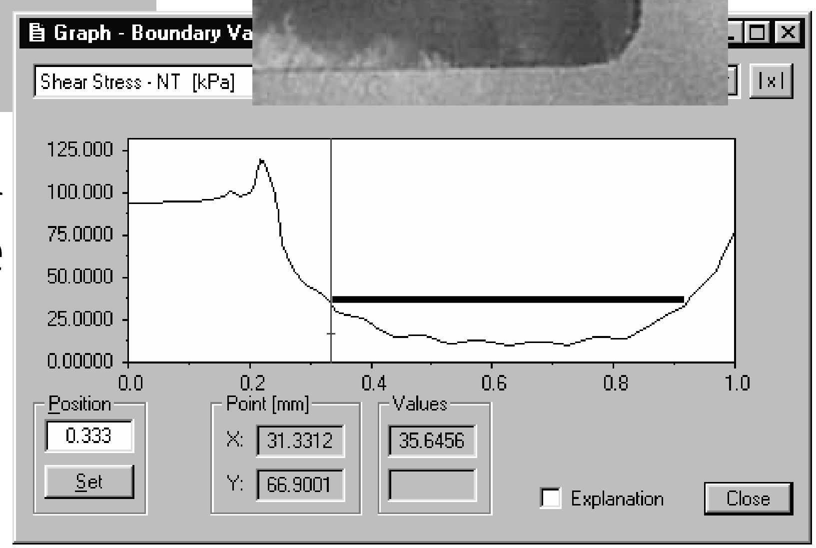


Original Shape

Shear stresses inside the flow domain



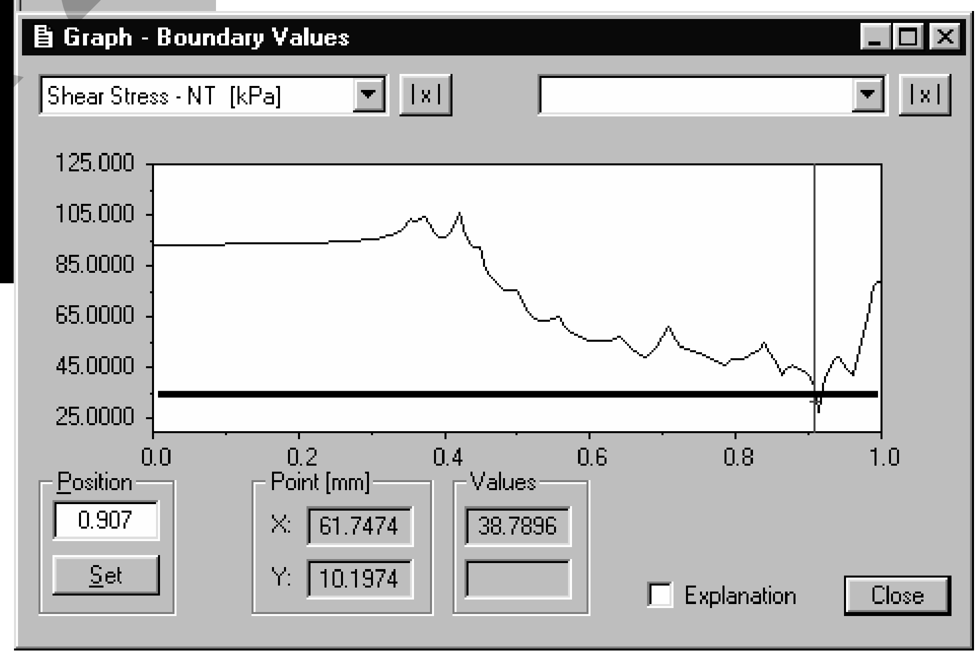




Compuplast® Virtual Extrusion Laboratory™, 2D FEM module

New Shape

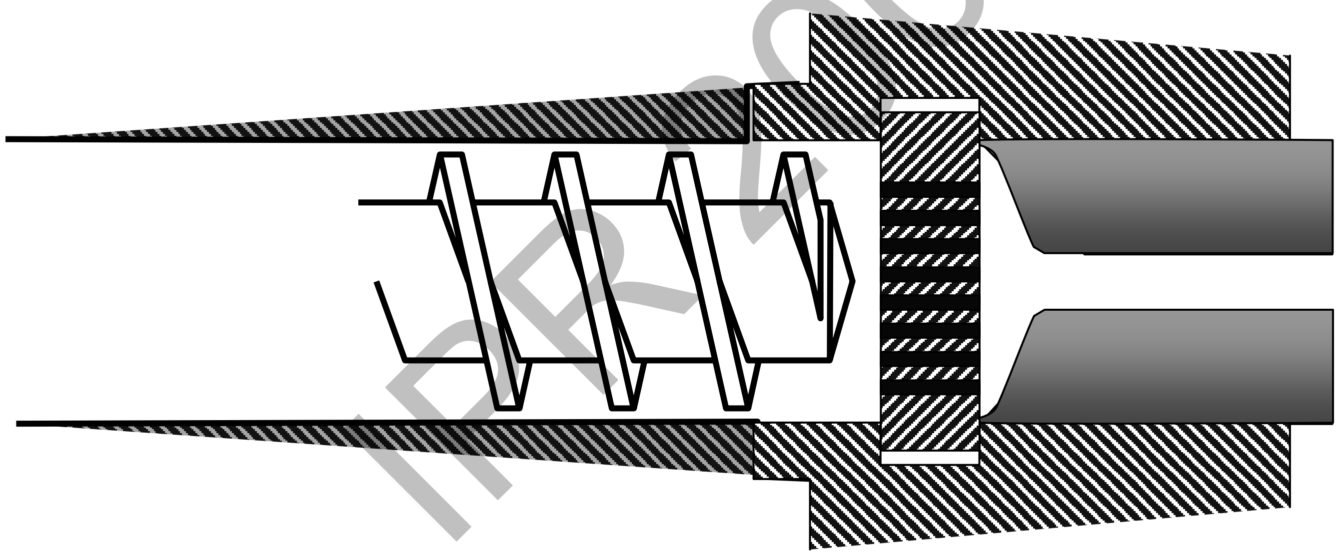
Shear stresses inside the flow domain



Compuplast® Virtual Extrusion Laboratory™, 2D FEM module

Degradation on

SCREW / BARREL / SCREENCHANGER
(Improved design)



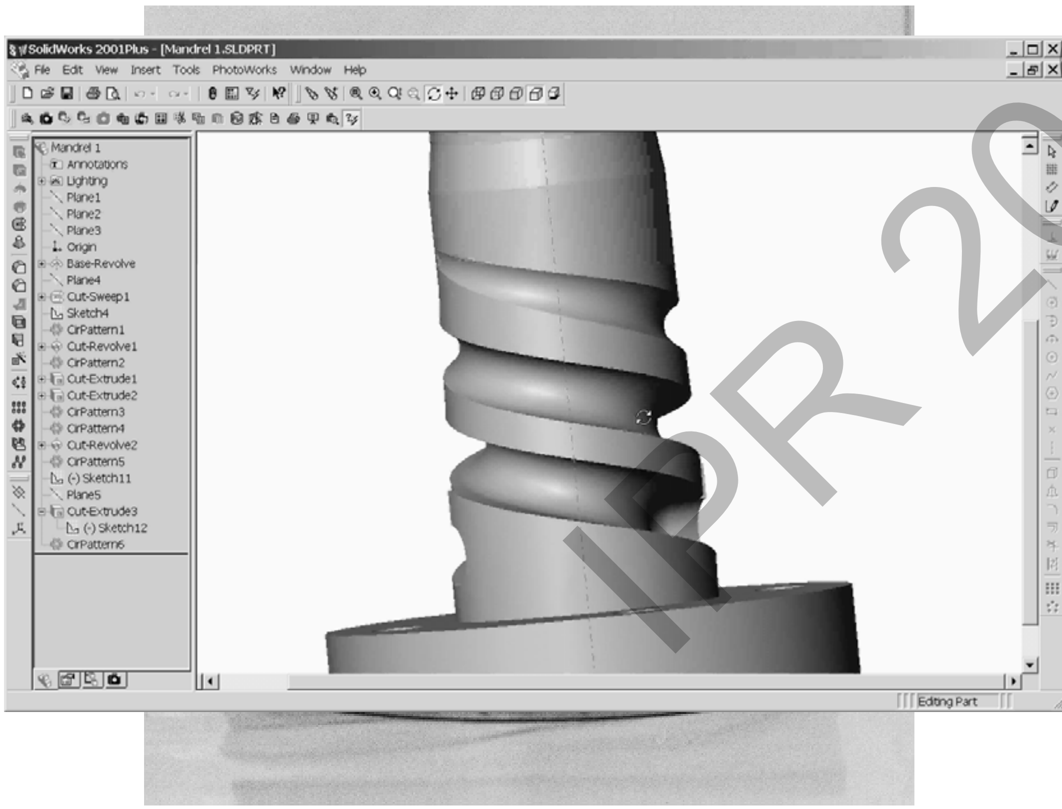
Polymer Degradation Solution

- Ensure adequate shear stress in all flow channels.
  - Proper Channel Design
  - Proper Operation Conditions

Problem: Periodic Lines in Tubular Film Bubble

- **Lines appear as a visual defect in film produced on a spiral mandrel type die.**

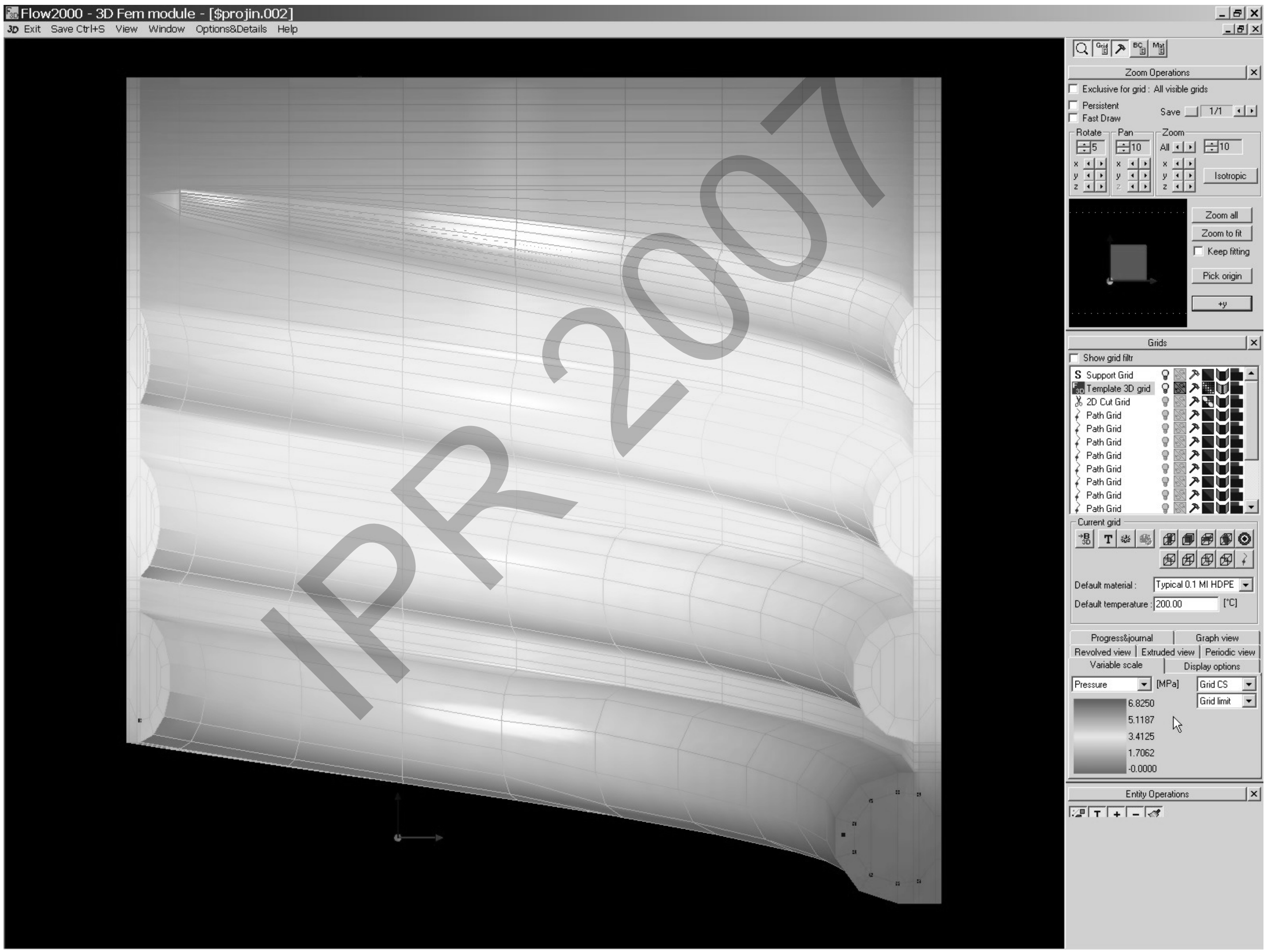
Spiral Mandrel Dies



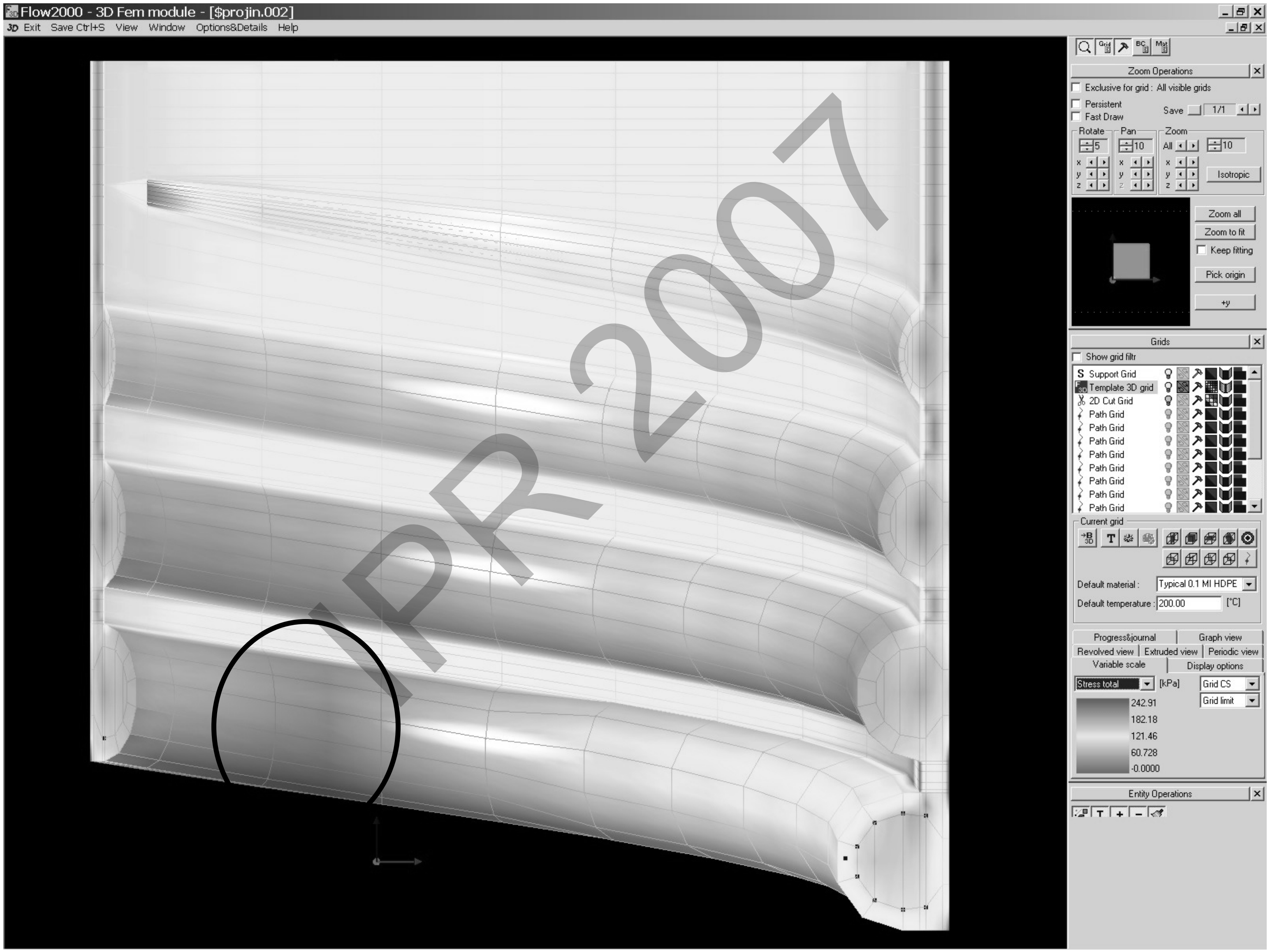
- **Commonly used for tubular (blown) film production since 1950's.**
- **In more recent years applied to pipe and blow molding dies**

Spiral Mandrel Flow Video

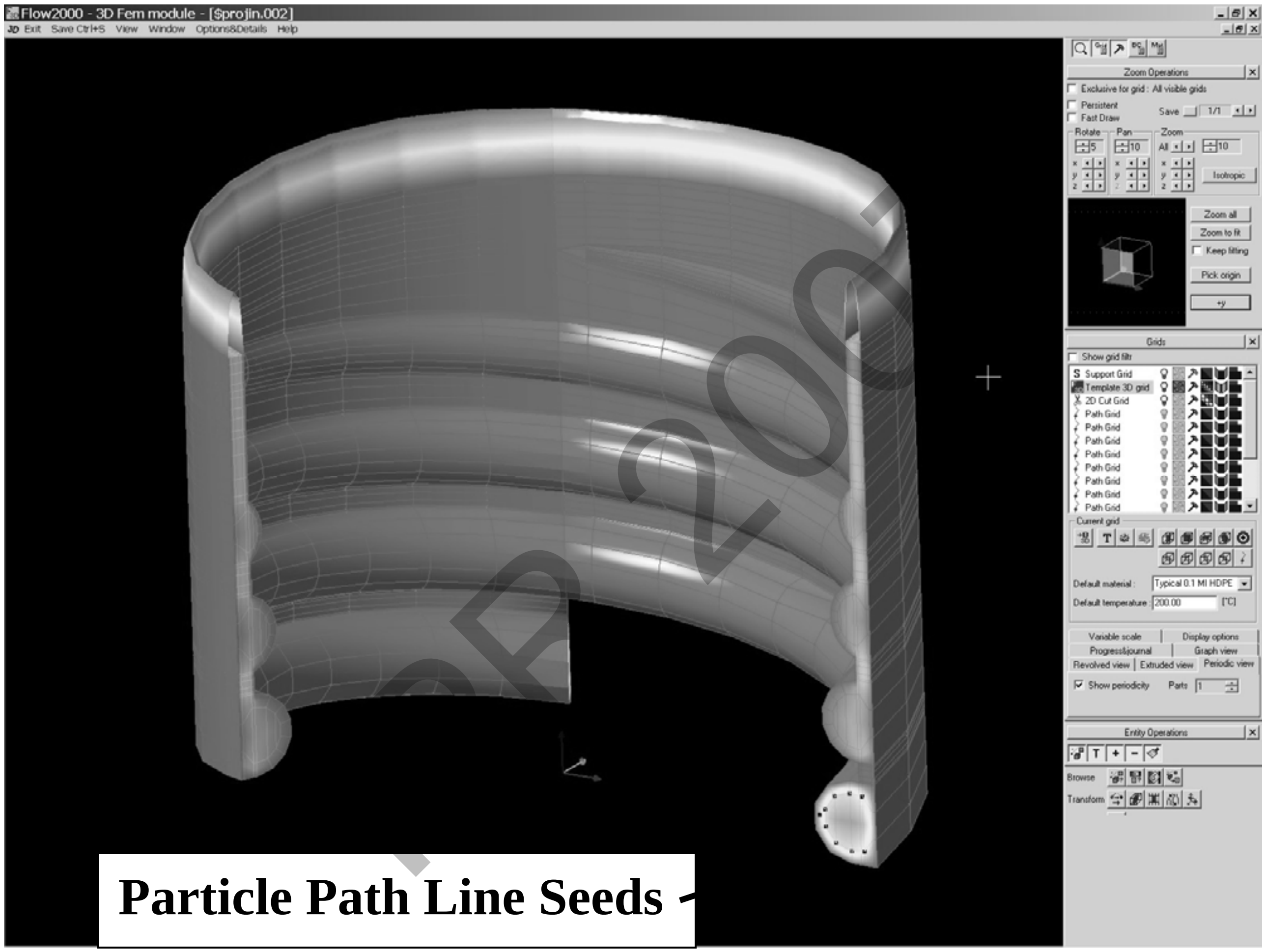
3D FEM - Pressure Drop



3D FEM - Shear Stress

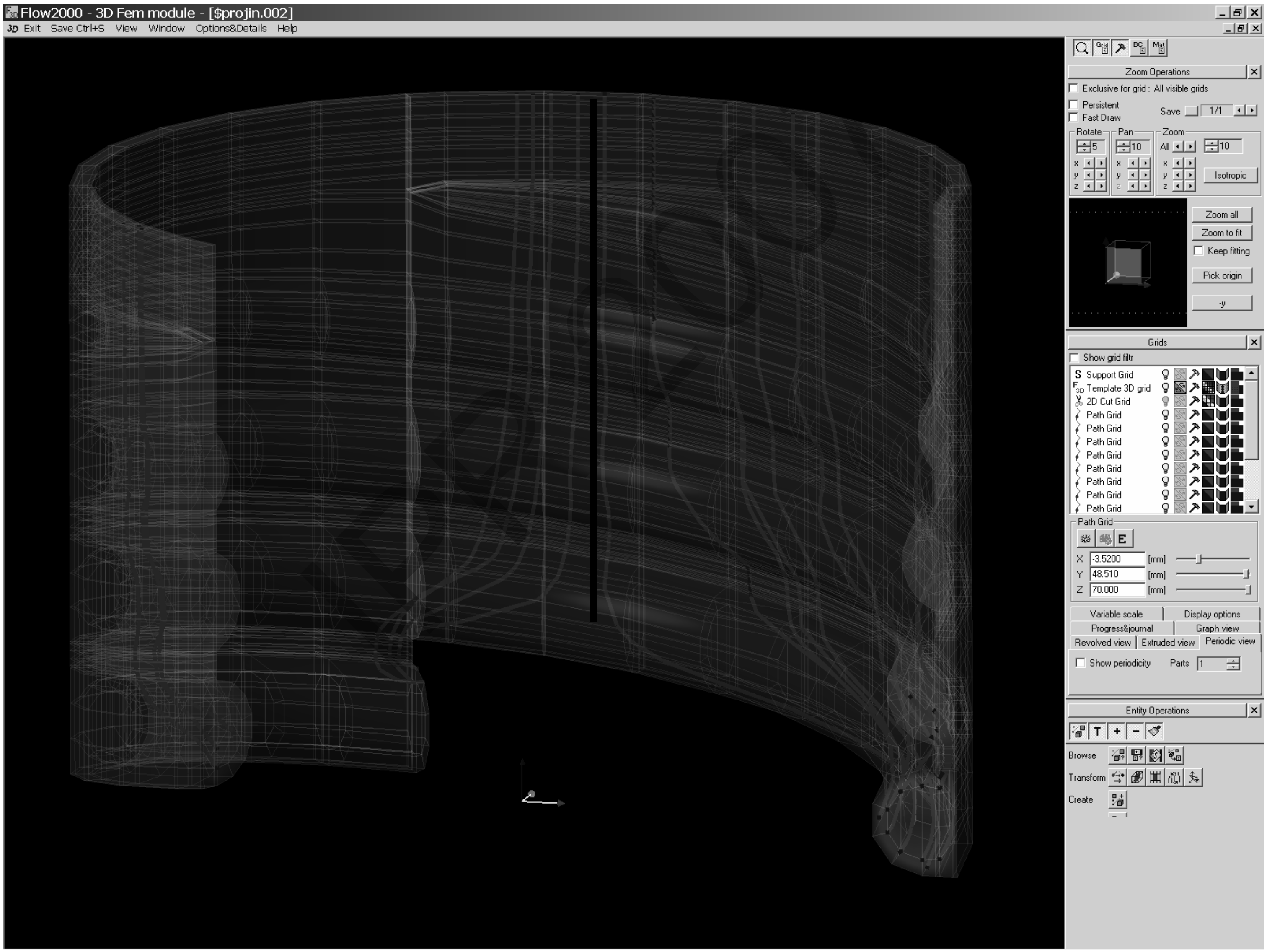


3D Flow Analysis



- **Velocity contours for 2/3 of the die and path line seed locations**

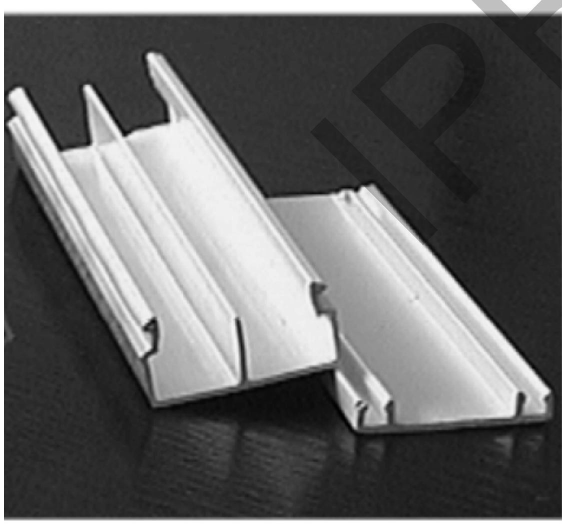
3D FEM Spiral Die Simulation



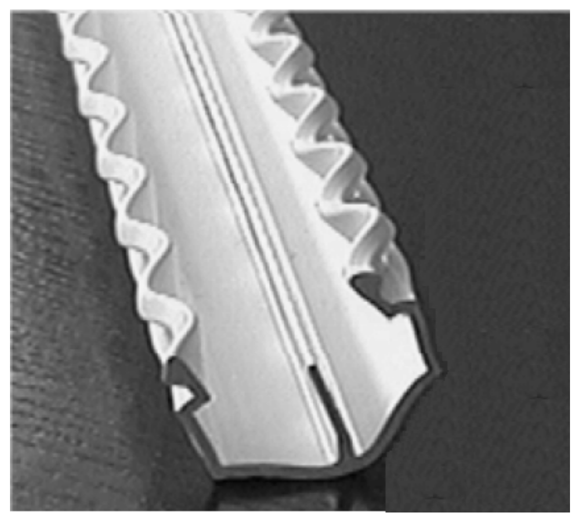
Objective of Profile Extrusion

- **Maximize Profits**
- **Maximize Production Rate**
- **Minimize Design Time**
- **Minimize Development Time**

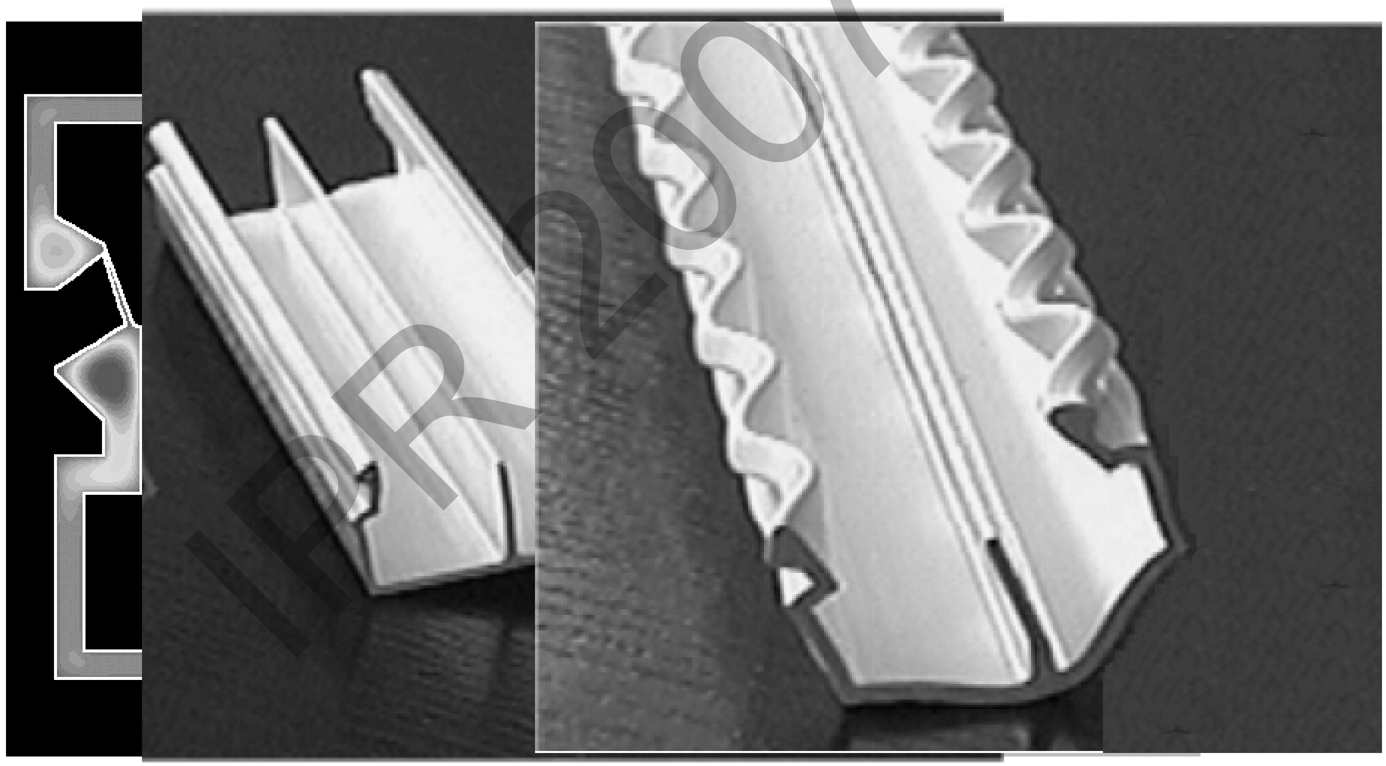
Make This



Not This



Example



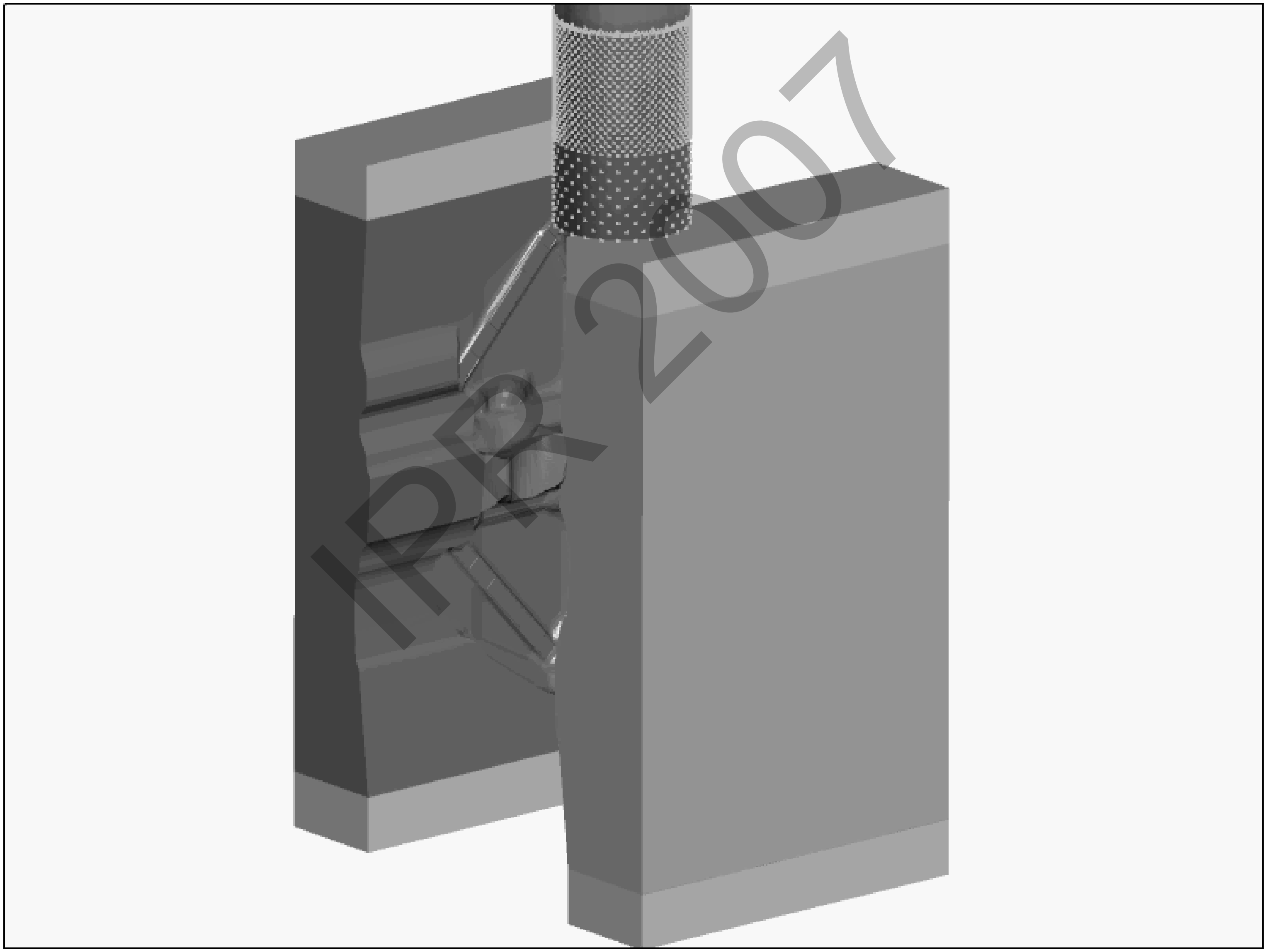
B-SIM,

Blow Molding Simulation Software

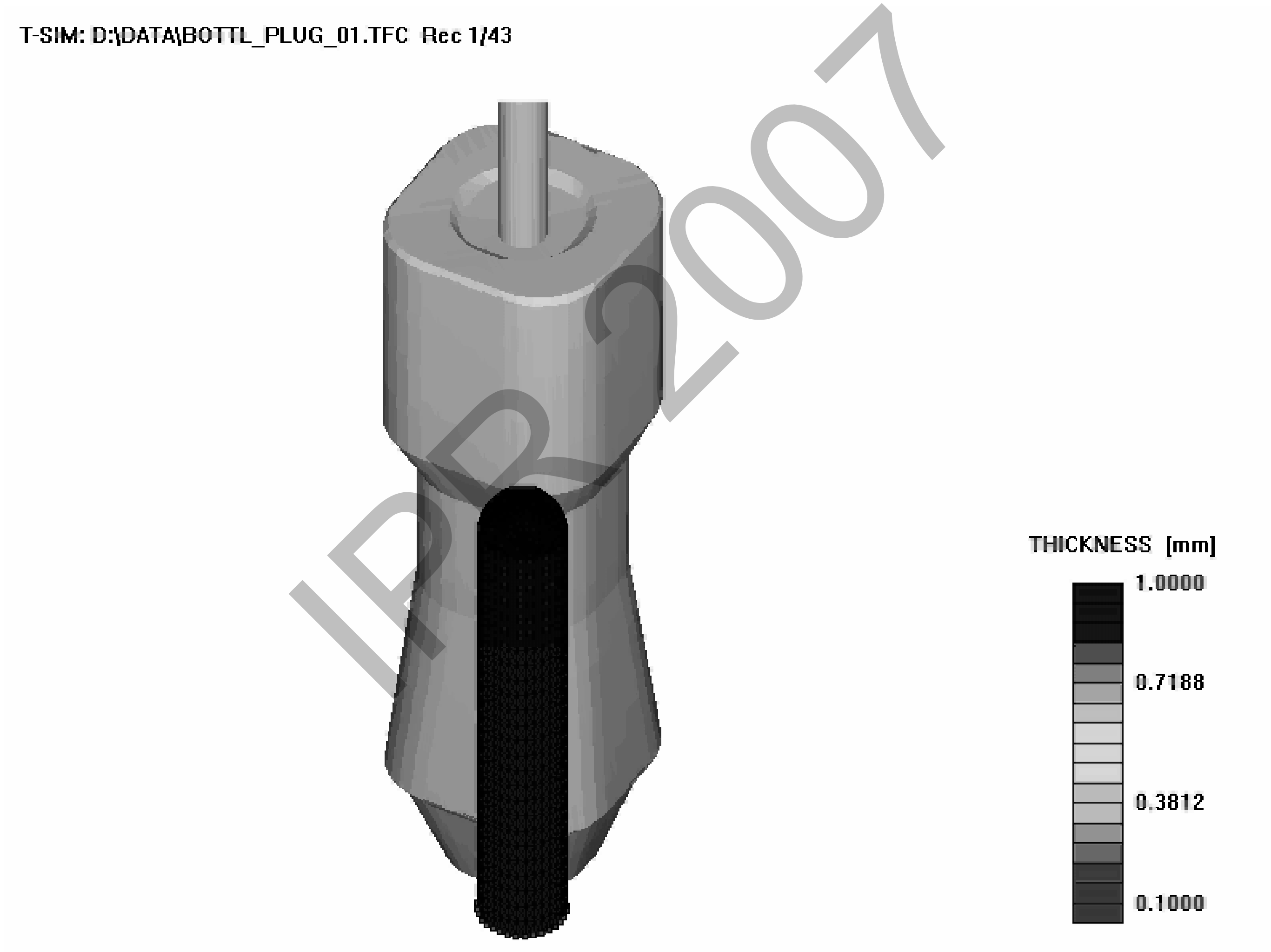
Accuform, Czech Republic

Extrusion Blow Molding

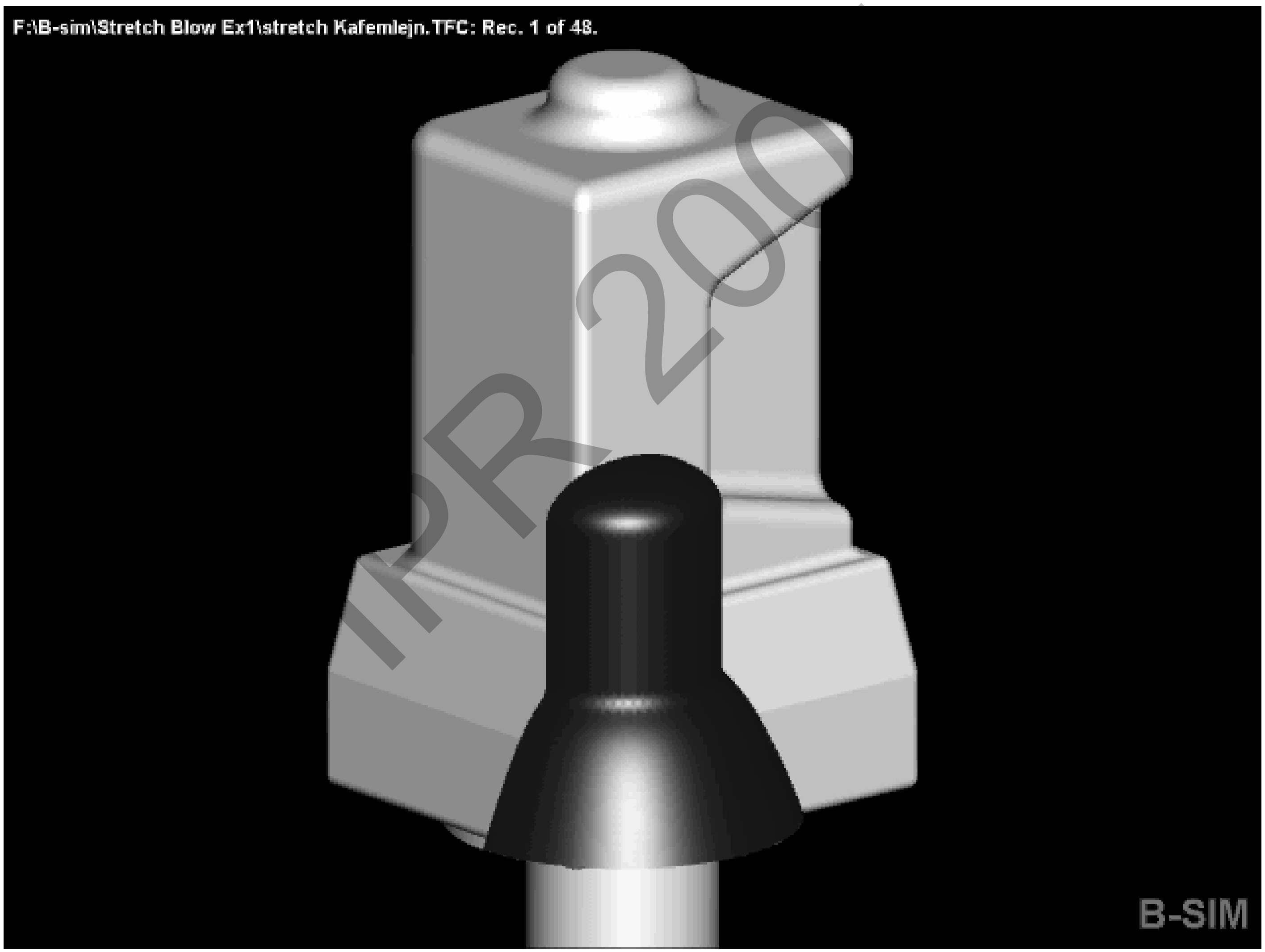
Fuel Tank



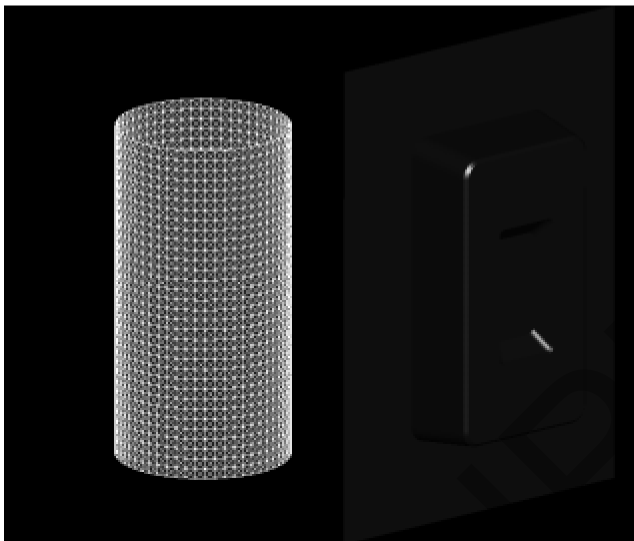
Stretch Blow Molding
(Bottle)

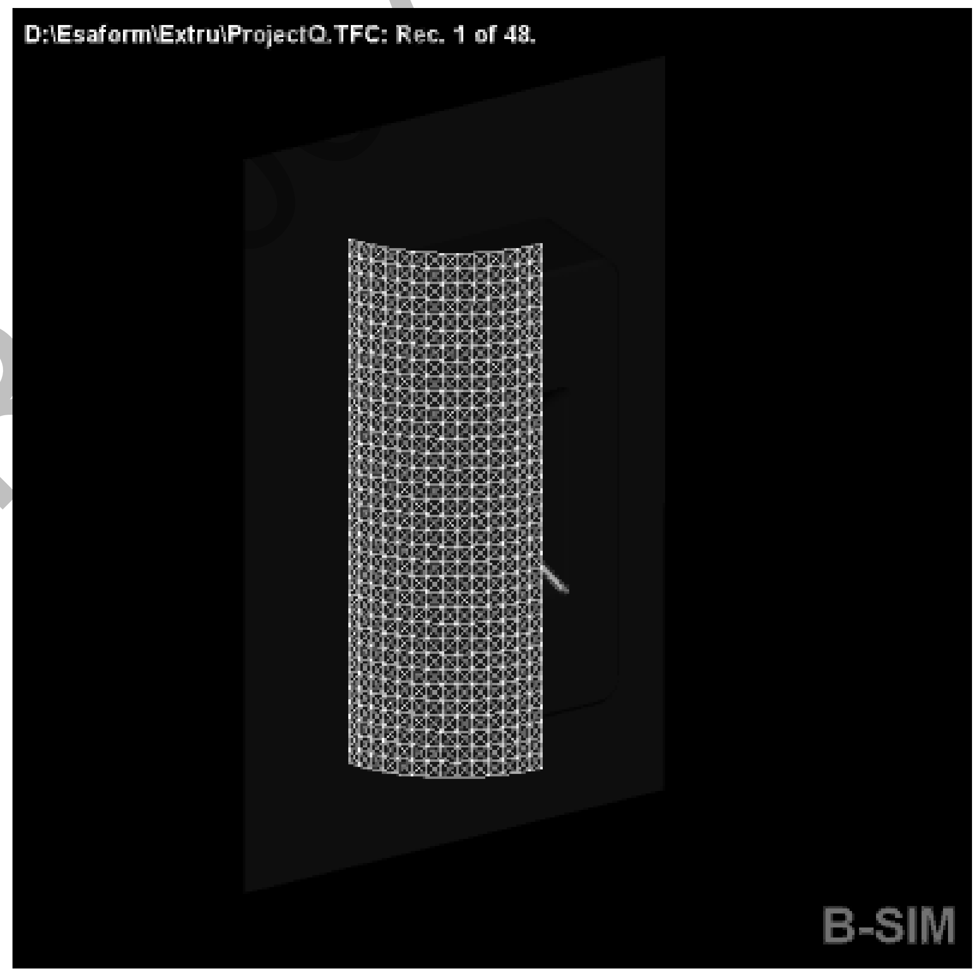


Stretch Blow Molding



Extrusion Blow Molding Optimization - Example 1





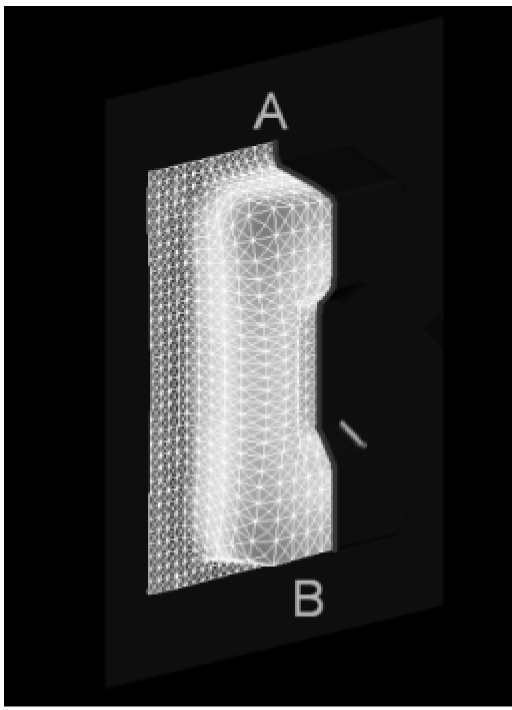
Extrusion Blow Molding Optimization - Example 1

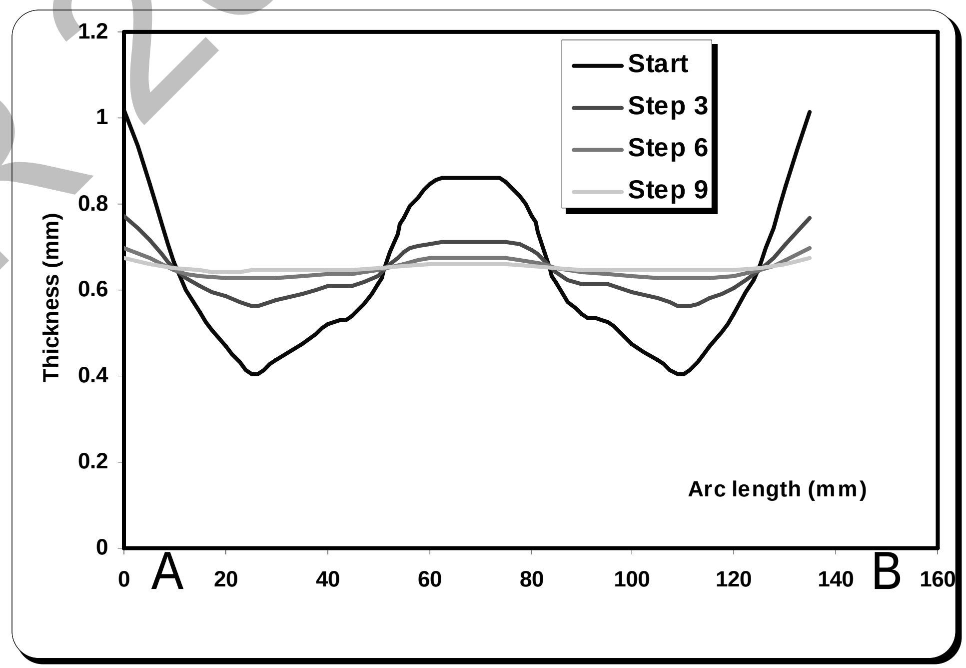
- **Automatic optimization of the parison thickness profile:**

$$t_{i+1}^{e\,init} = t_{i}^{e\,init}\left[1 - C\left(t^{e\,final} - \bar{t}^{\,final}\right) / \bar{t}^{\,final}\right]$$

Extrusion Blow Molding Optimization - Example 1

- **Automatic optimization results - the final thickness distributions:**





Extrusion Blow Molding Optimization - Example 1

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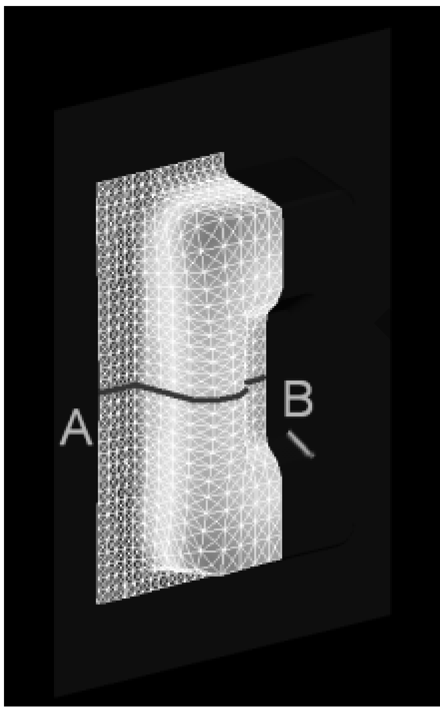
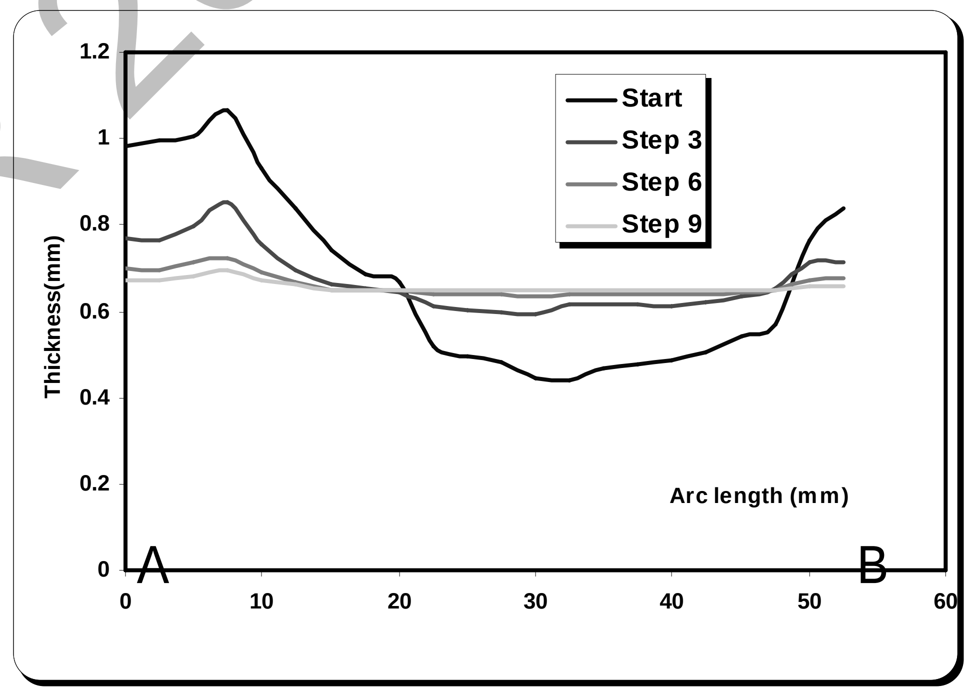
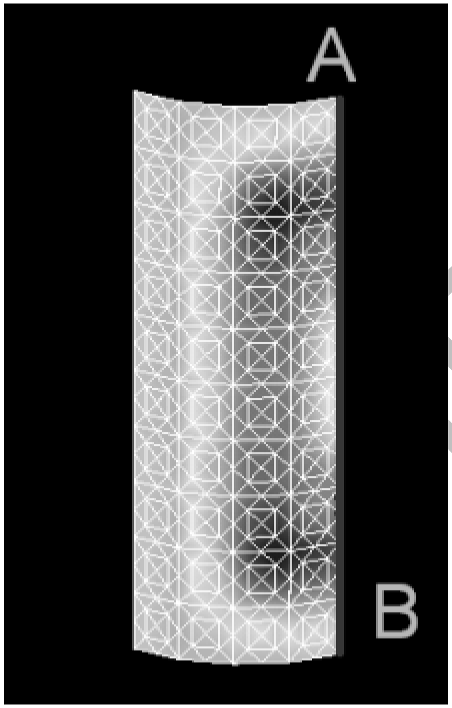
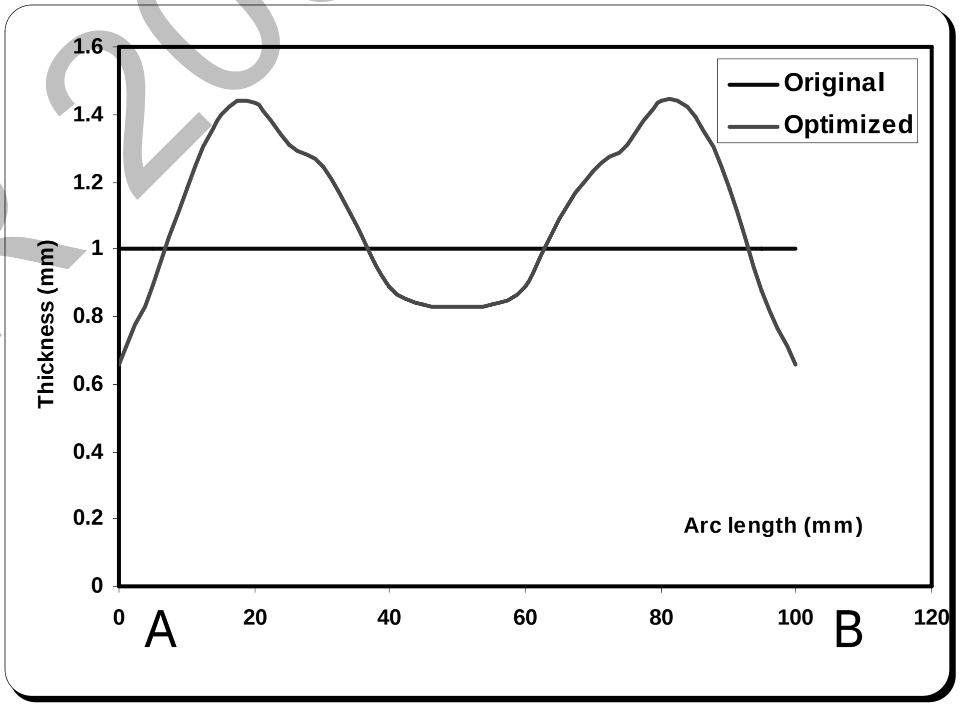




Extrusion Blow Molding Optimization - Example 1

- **Original and optimized initial thickness profile of the parison:**





Extrusion Blow Molding Optimization - Example 1

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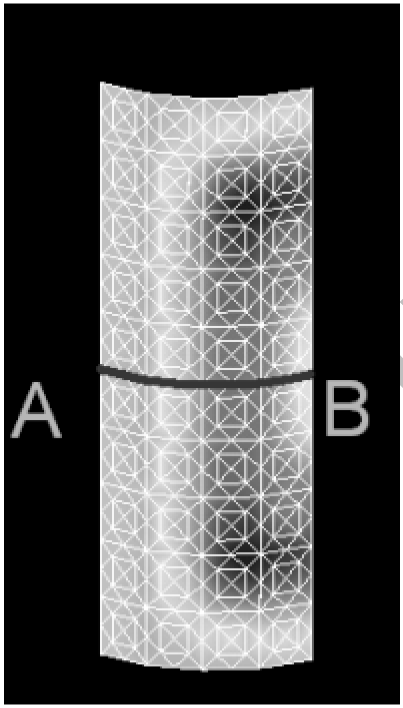
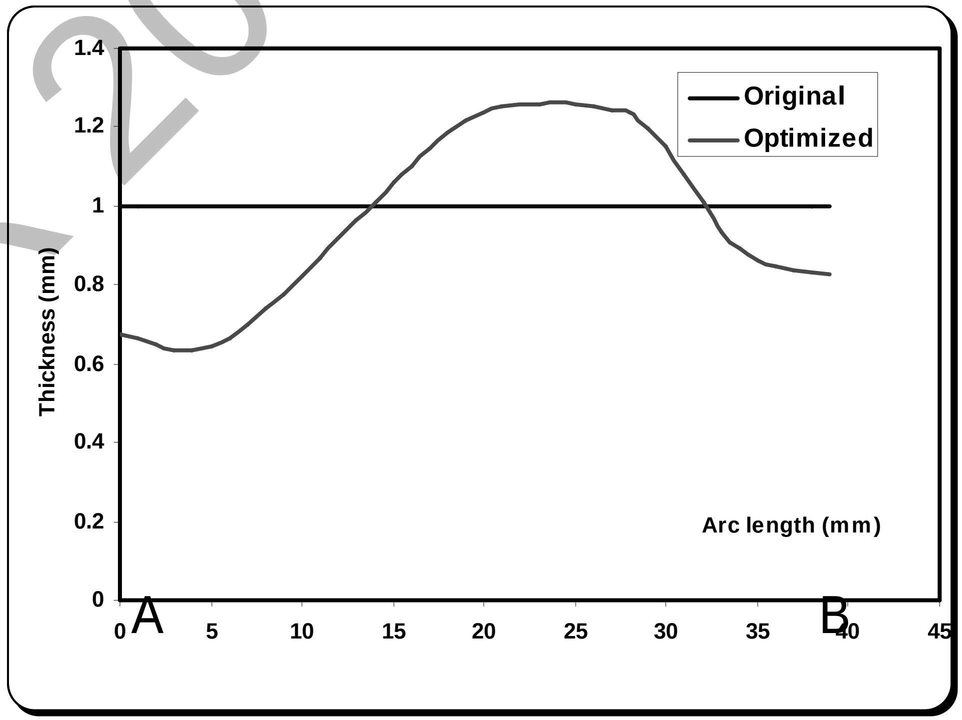
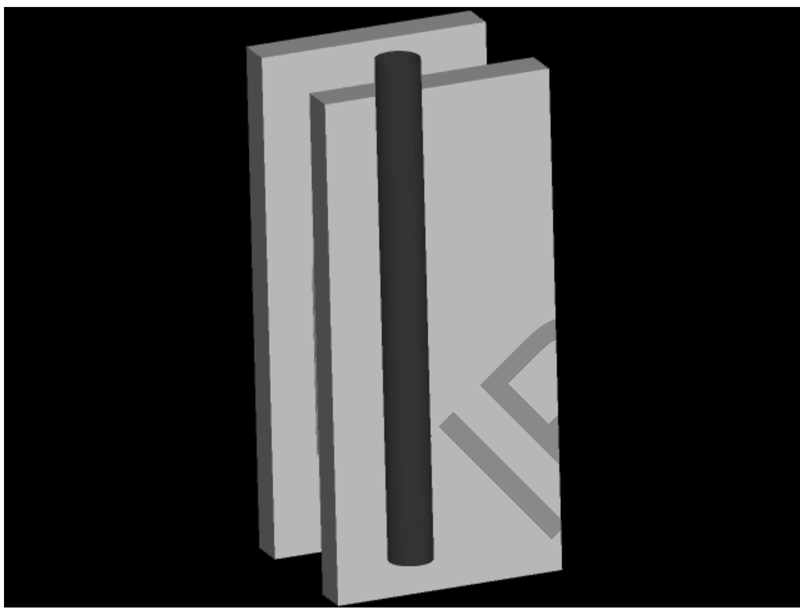


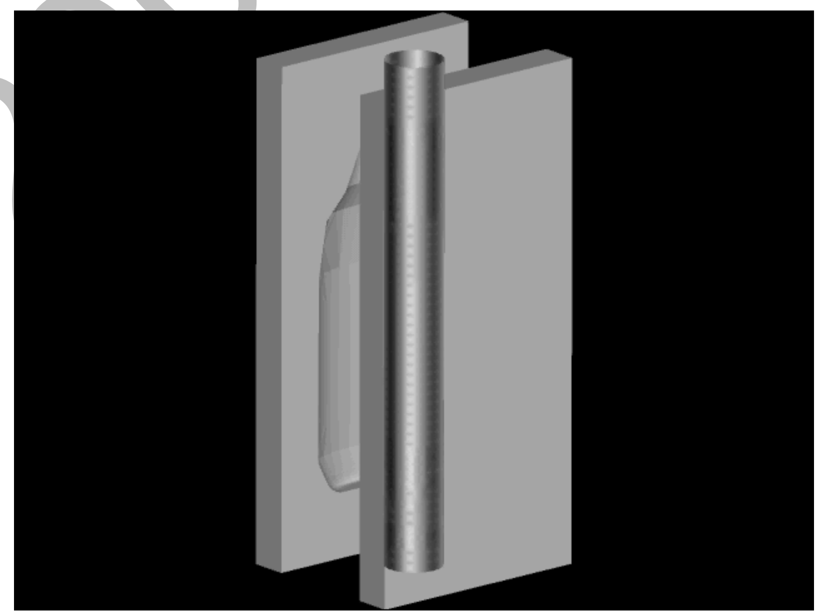


Parison Design Comparison

38 mm Not-profiled



50 mm Profiled



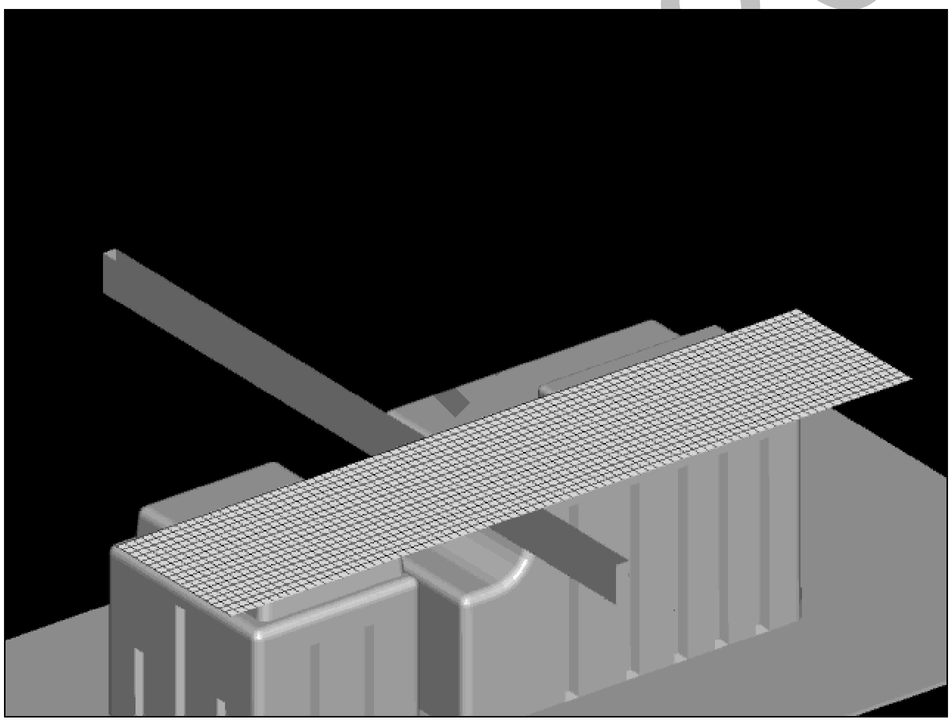
T-SIM,

Thermoforming Simulation Software

Accuform, Czech Republic

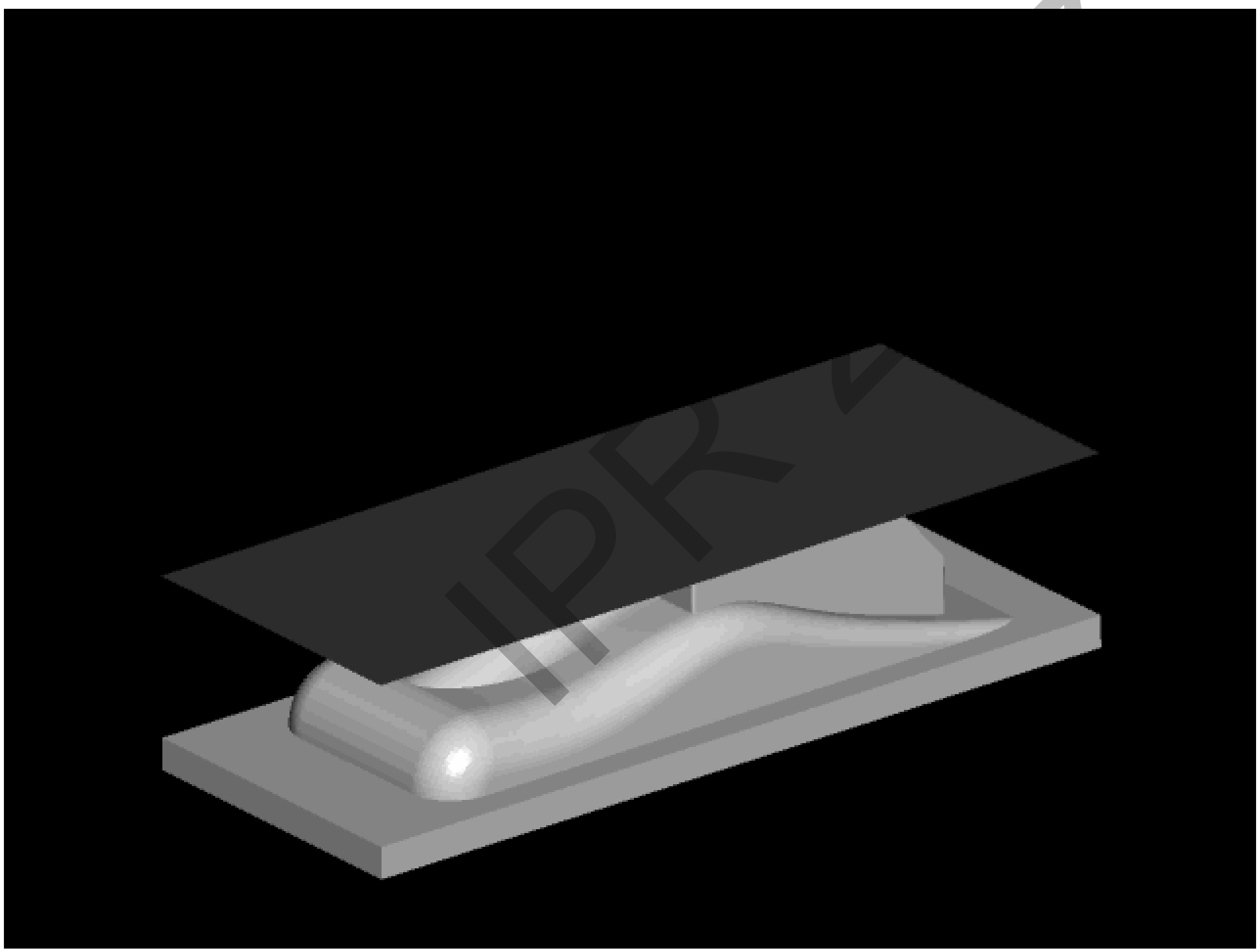
Thermoforming Process

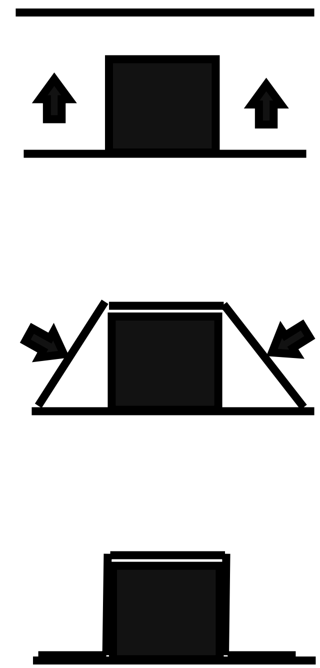
- **Characterized by large deformations of polymeric materials**



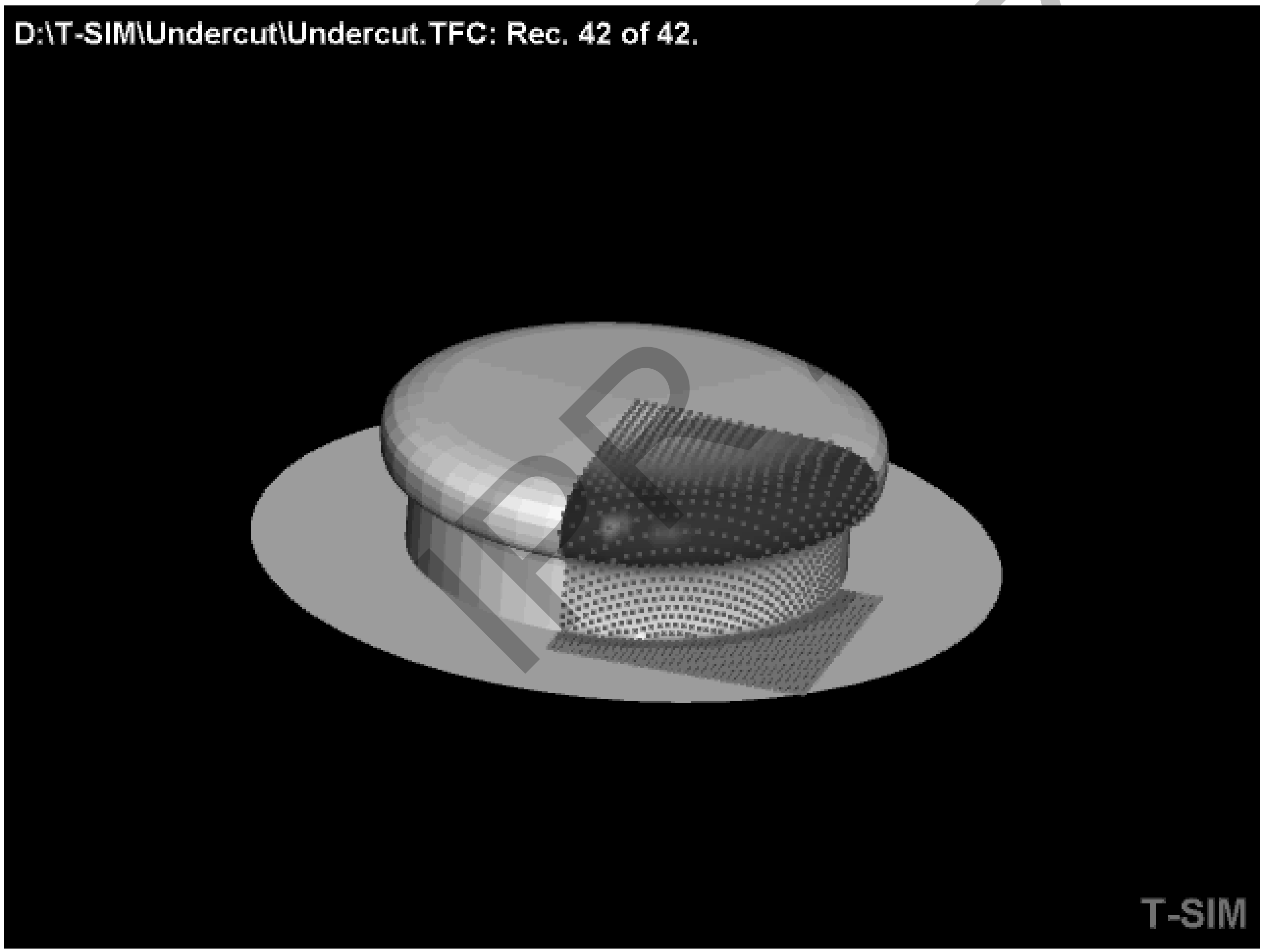
Deformation field visualized by an initially square grid

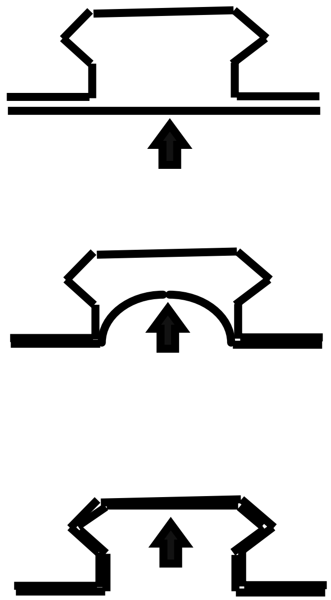
Positive forming



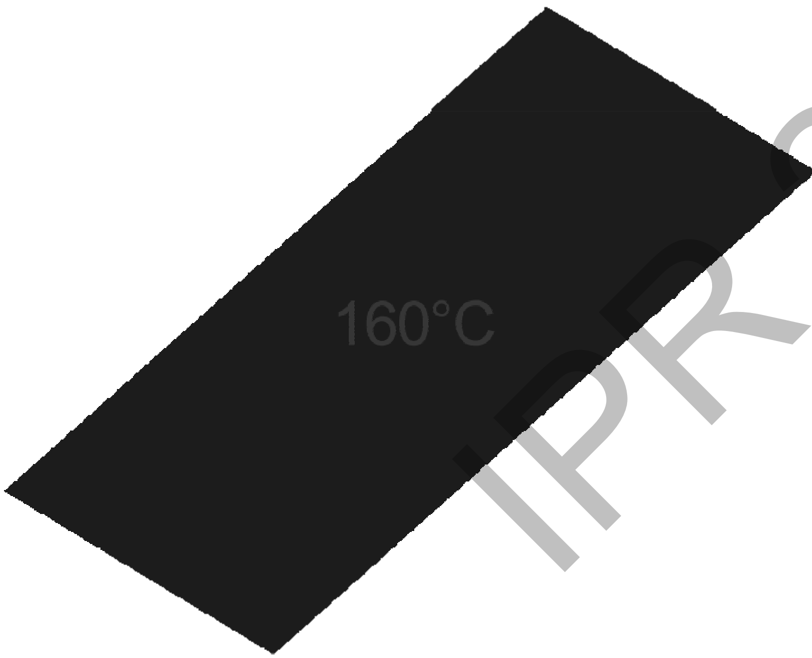


Negative forming with undercuts

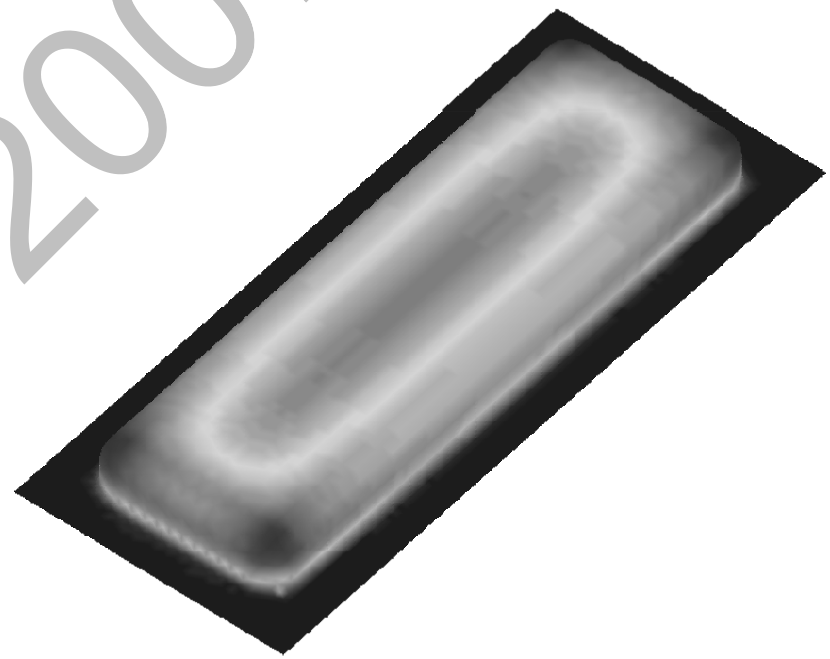




Effect of temperature distribution

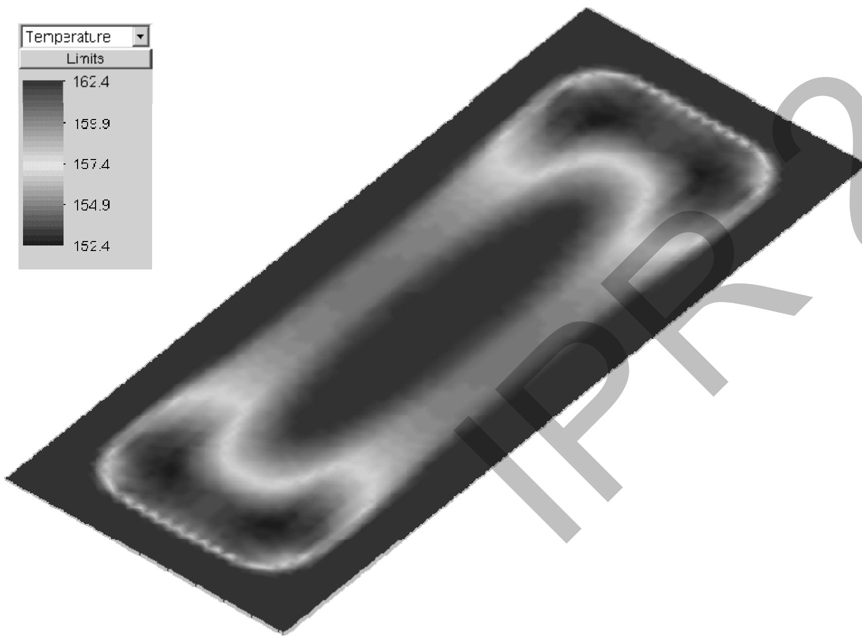


Uniform initial temperature (160°C)



Final thickness profile

Effect of temperature distribution

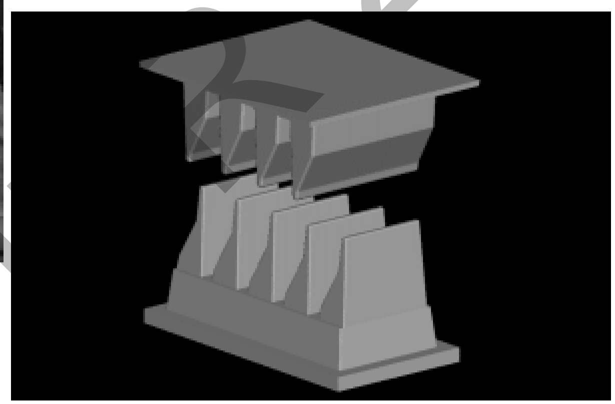


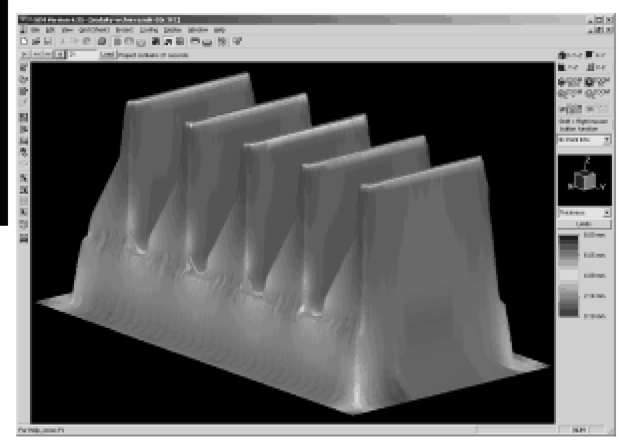
Optimized initial temperature profile (152 - 162°C)

Final thickness profile

Webs or Wrinkles

- **T-SIM used as a web prediction tool**

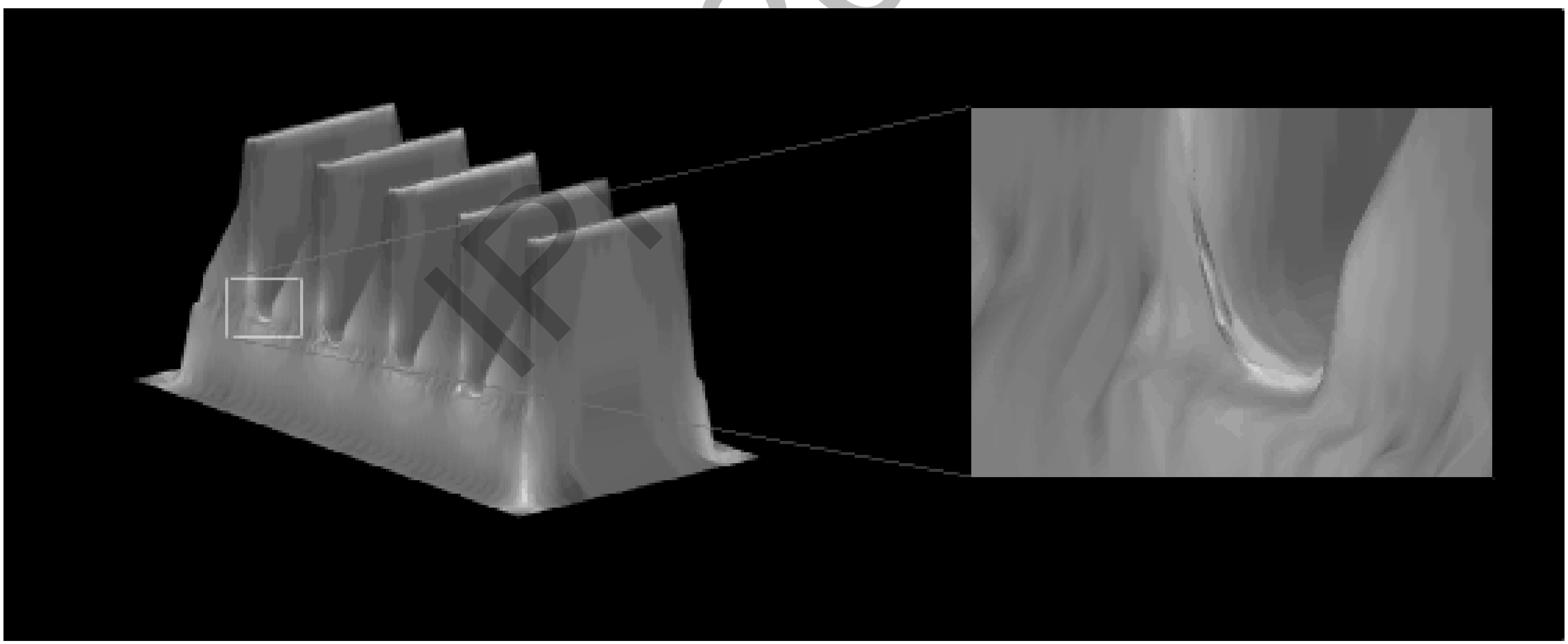




Courtesy of Vyvaplast s.r.o, Czech Republic

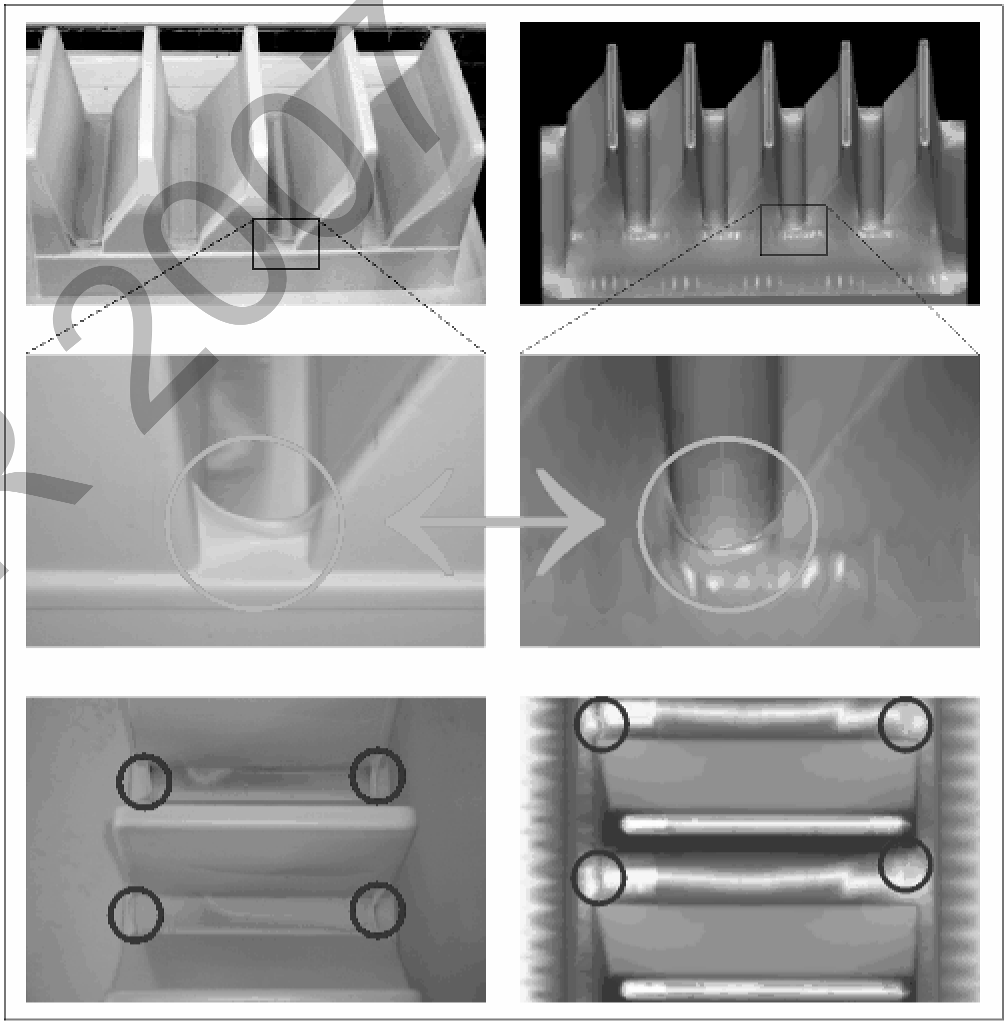
Case study II

- **Simulation in T-SIM predicts several webs (wrinkles)**

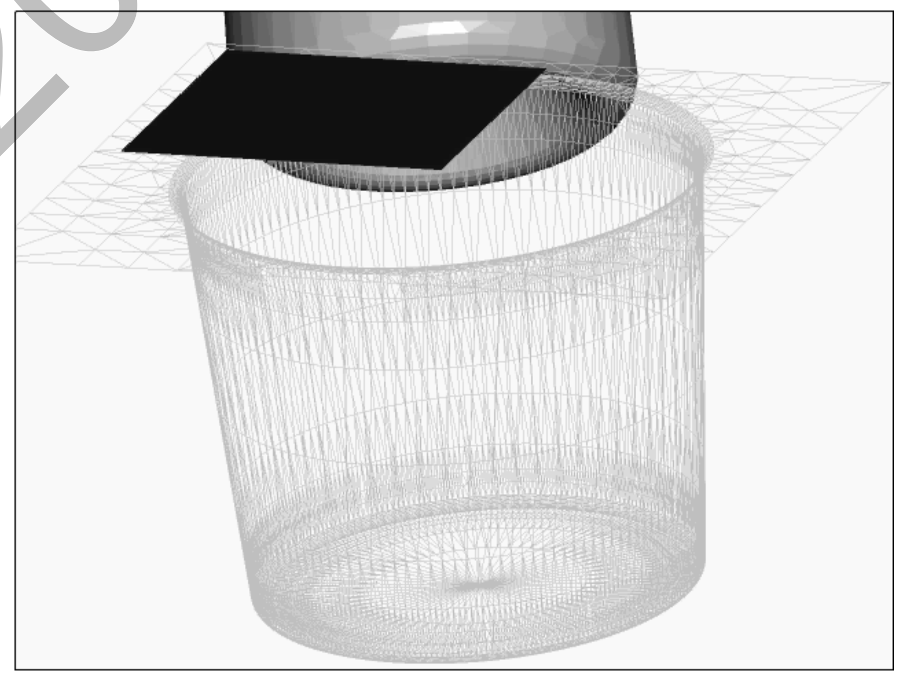


Comparison

- **Comparison with a real product shows a very good agreement**



Comparison of thickness distribution for two different plugs



Comparison of thickness distribution for two different plugs

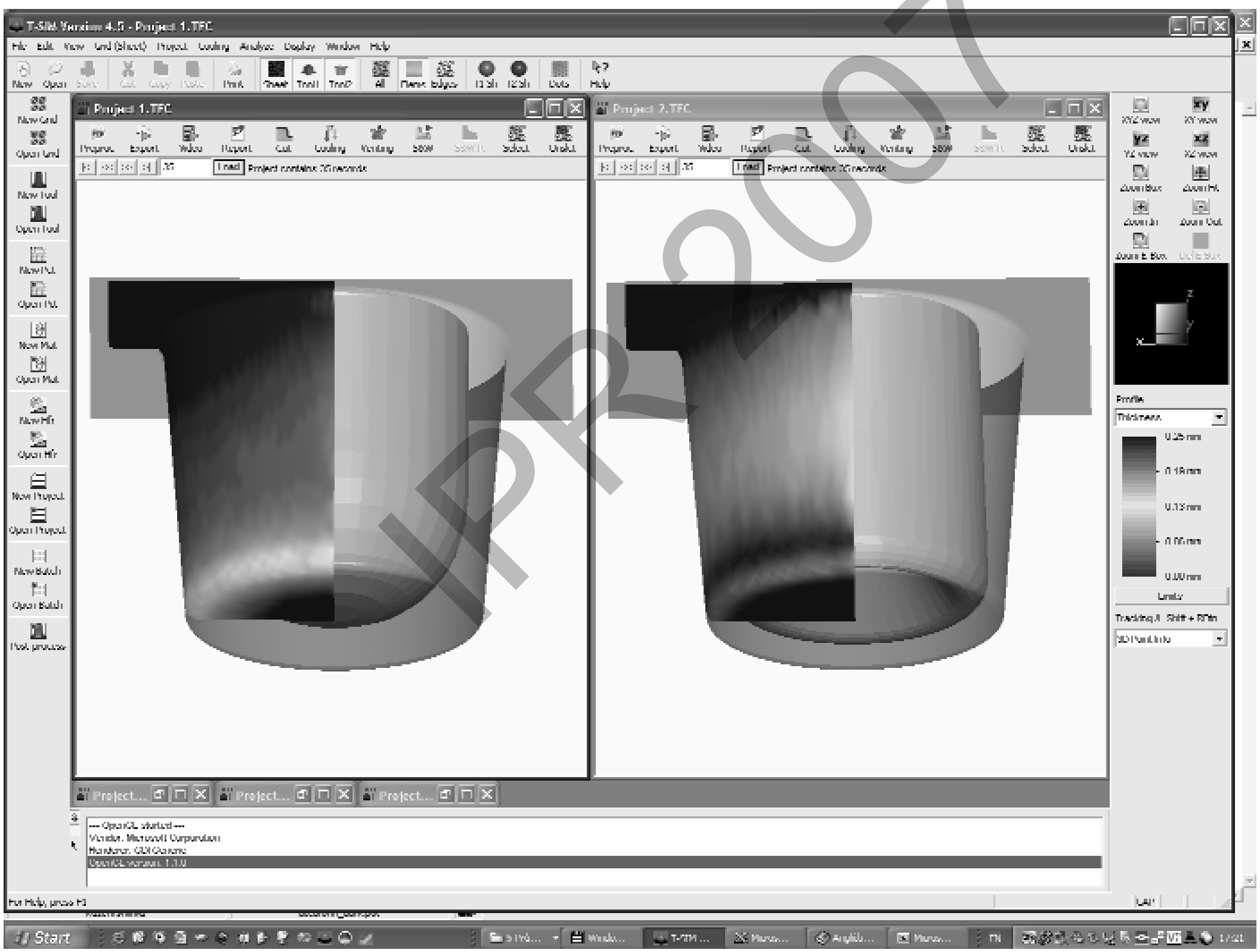
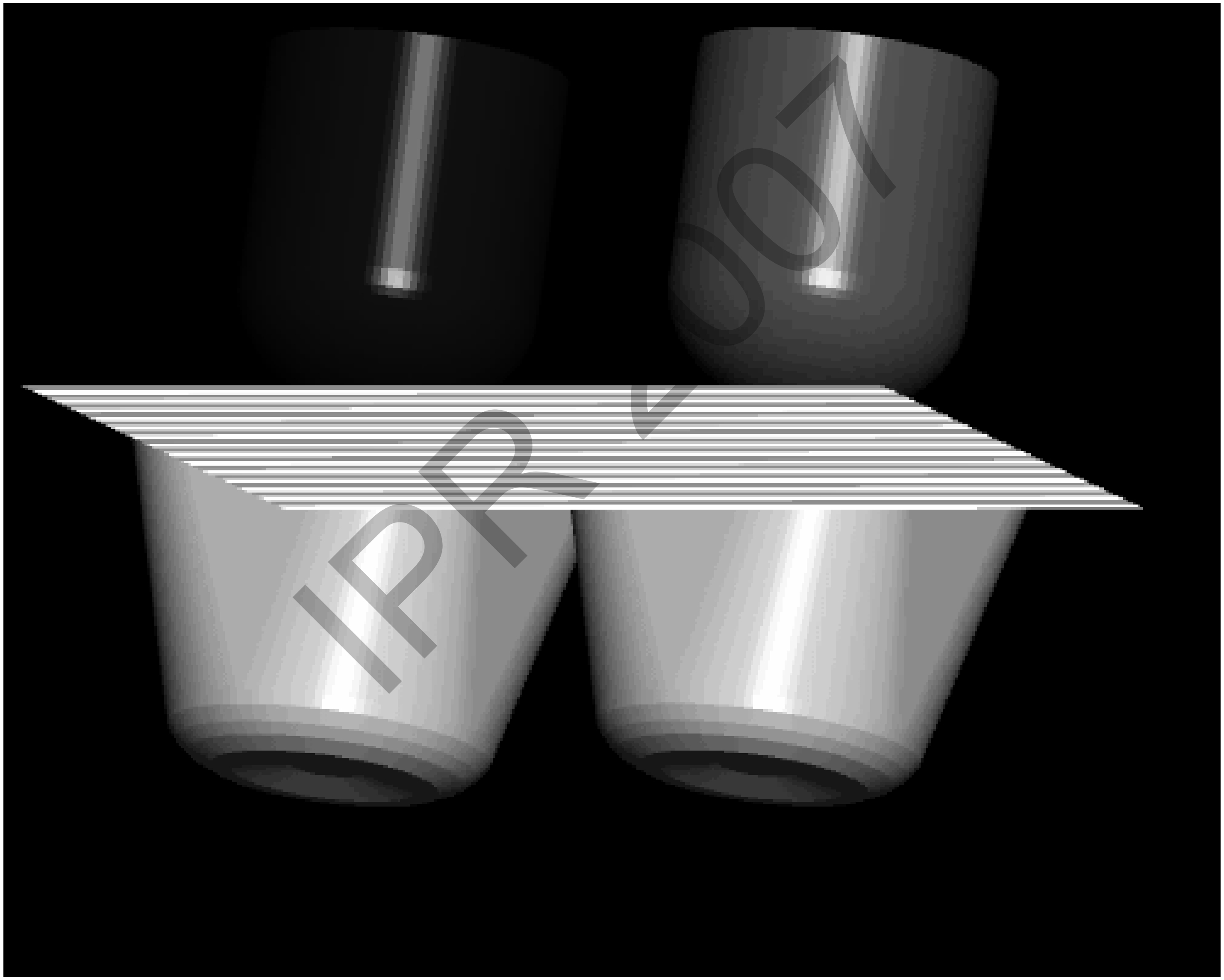


Image Distortion



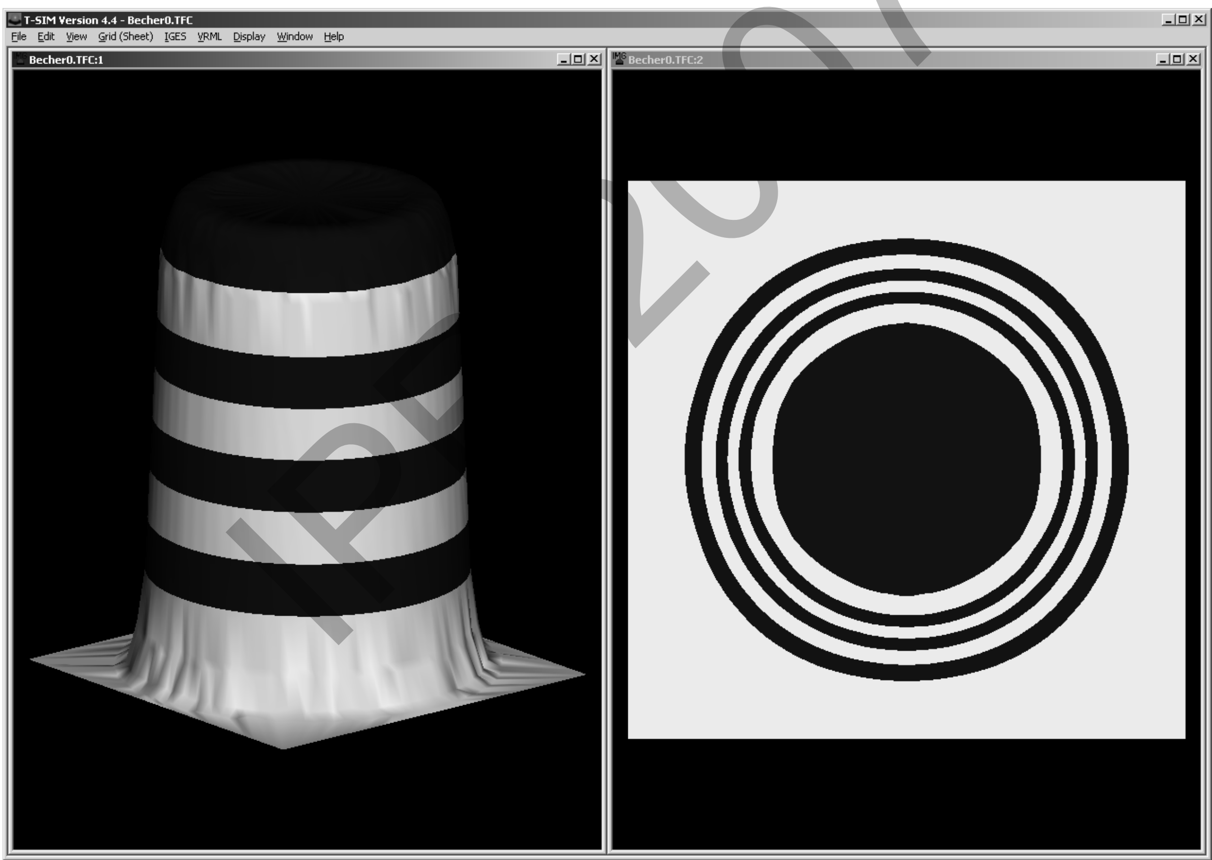
Prediction of image deformation

Preprinted flat sheet

Deformed sheet with image

Reverse engineering of image deformation

Image on
final product



Pre-distorted
image,
predicted
by T-SIM

Moldex3D/Solid

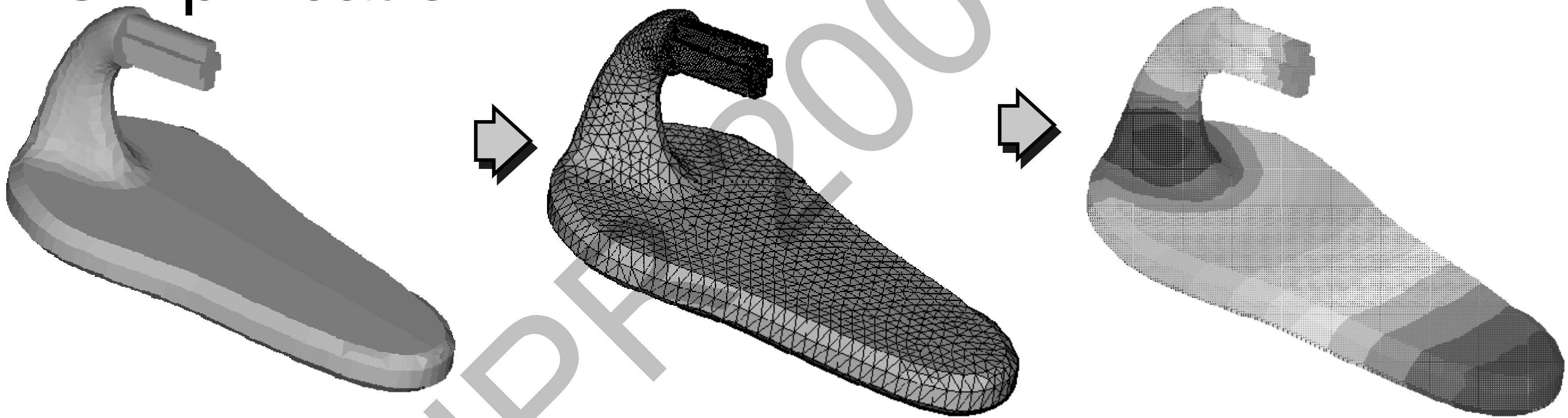
Innovative True 3D Simulation for Plastics Injection Molding

CoreTech System Co., Ltd.

http://www.Moldex3D.com

Why 3D Analysis ?

- Realistic simulation with minimum model simplification.

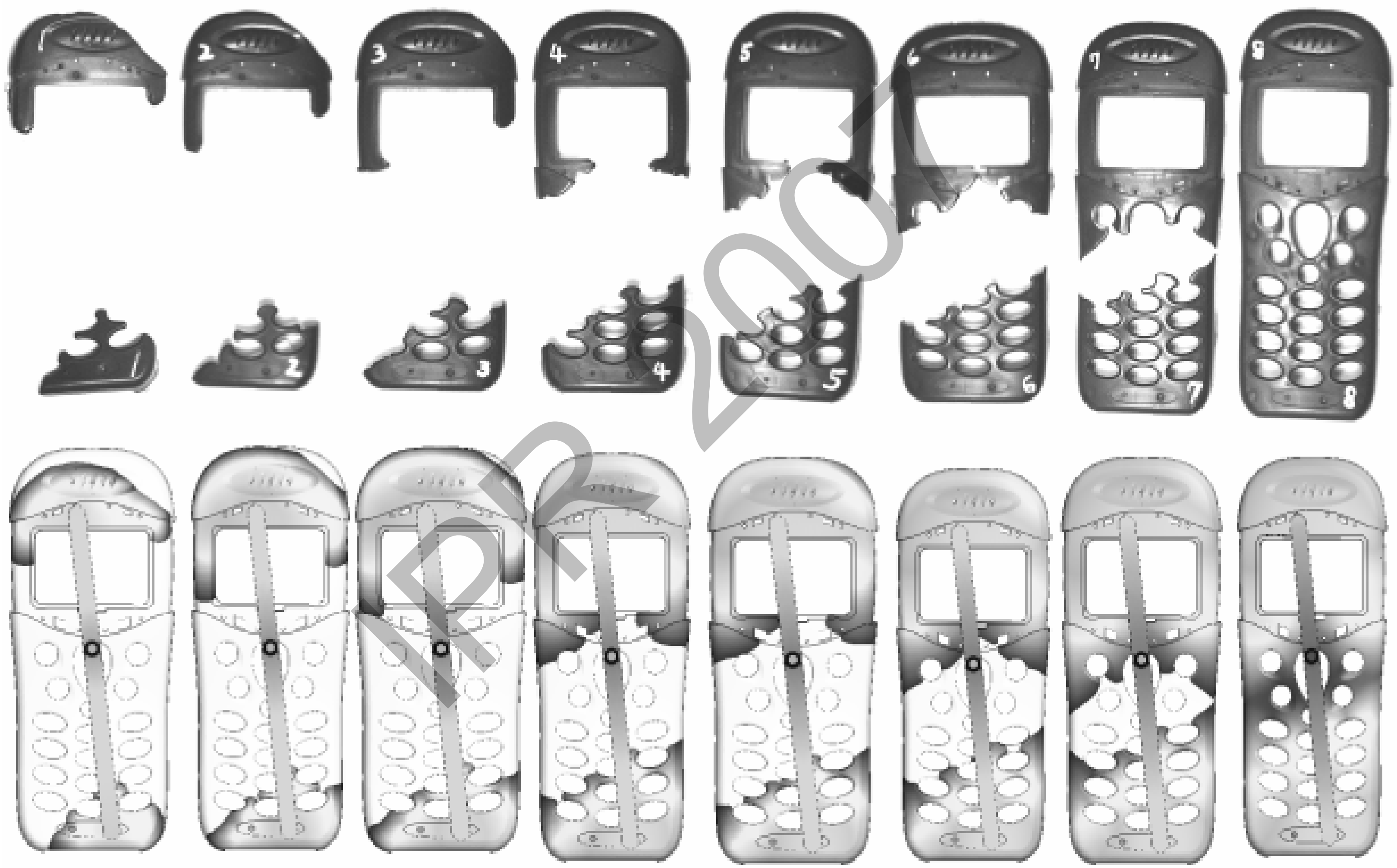


3D Solid model

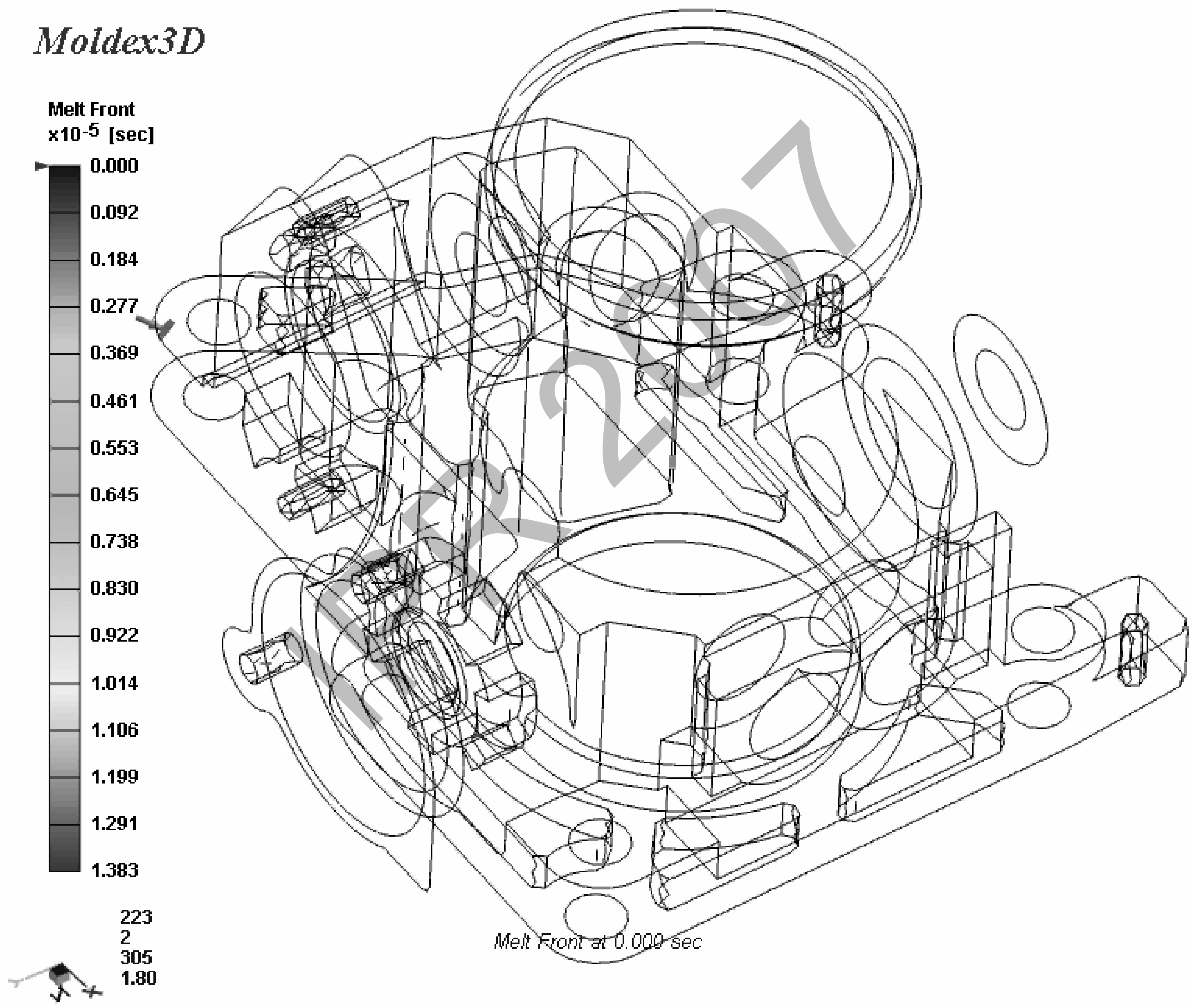
Automatic solid mesh

Analysis

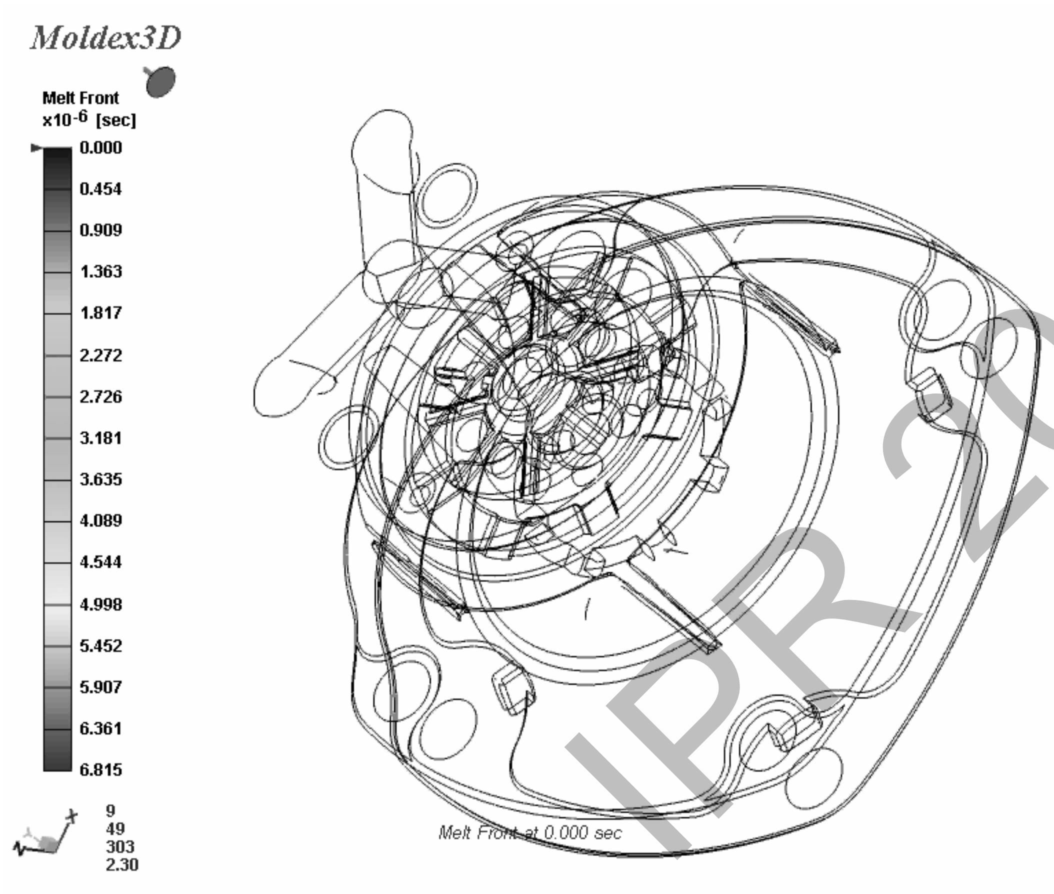
Upper Phone Cover

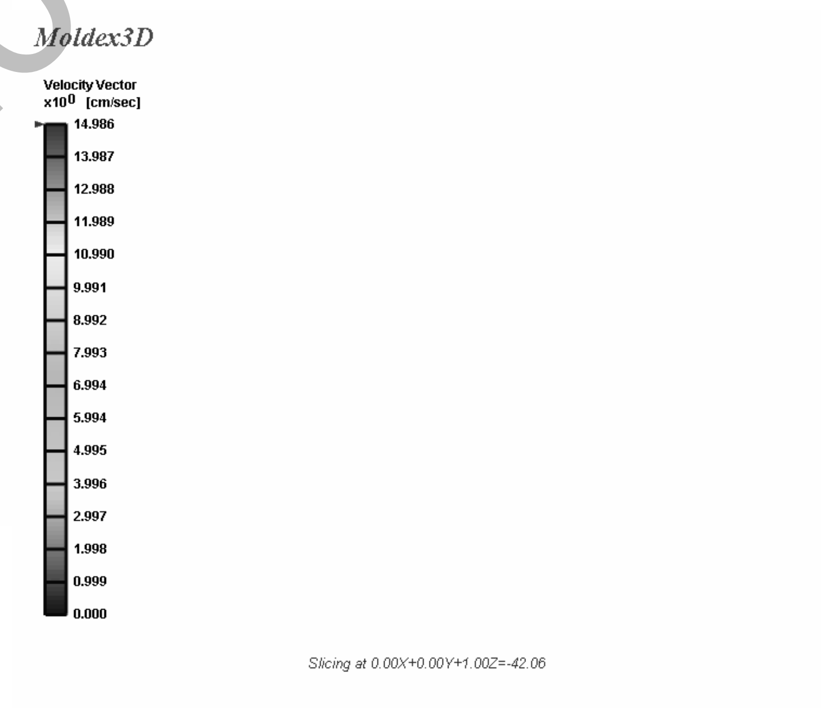


Moldex3D Flow/Filling

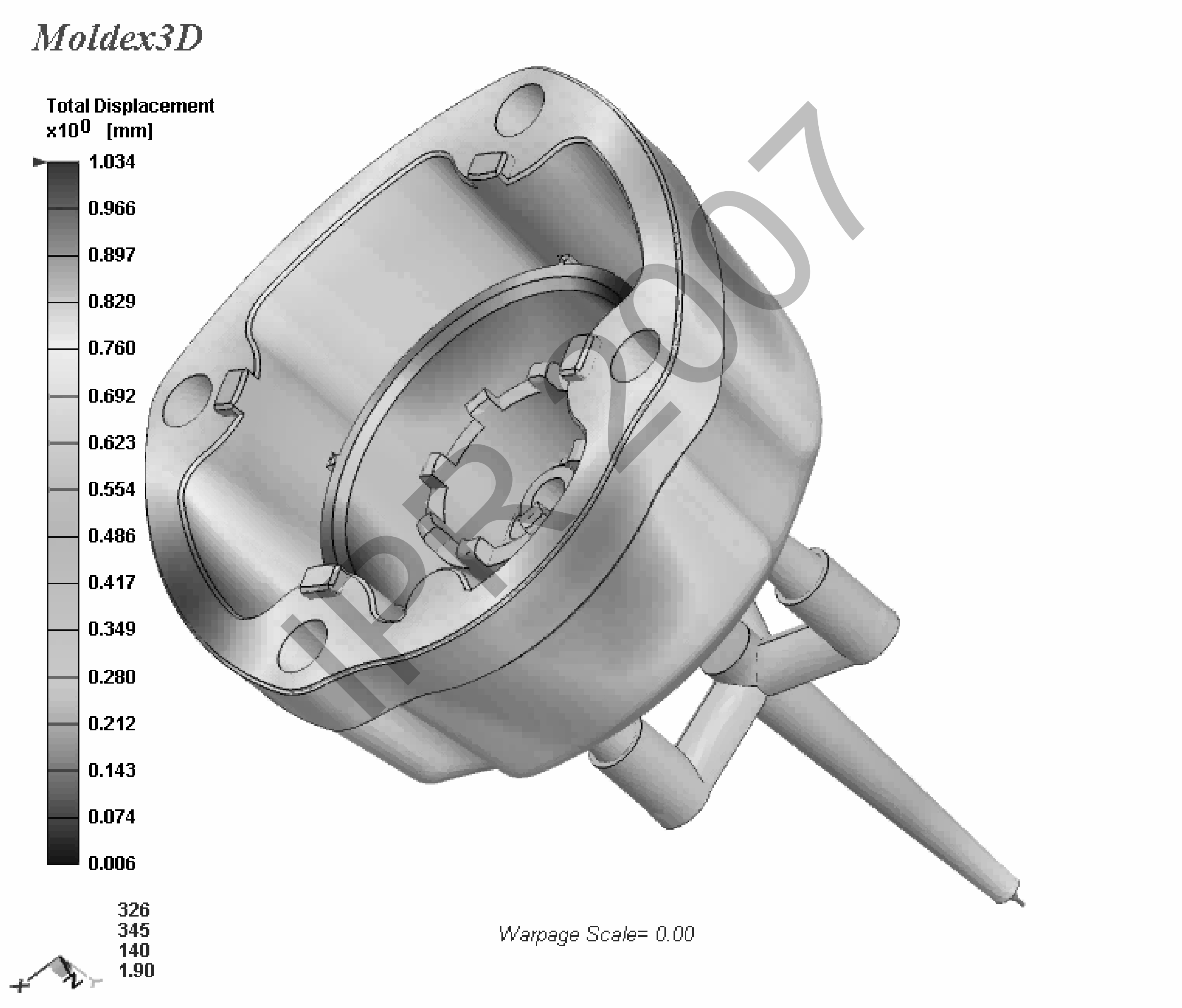


Moldex3D-Flow: Cover Part



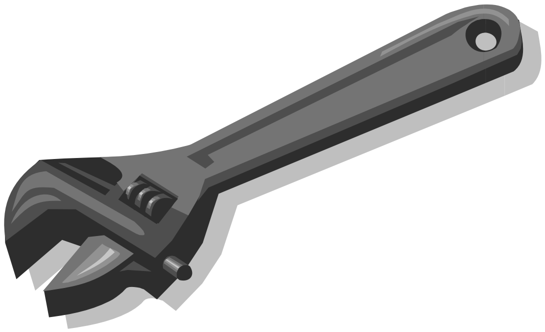


Moldex3D-Warp:Cover Part



Application: Wrench

Moldex3D/Solid-I2ABAQUS

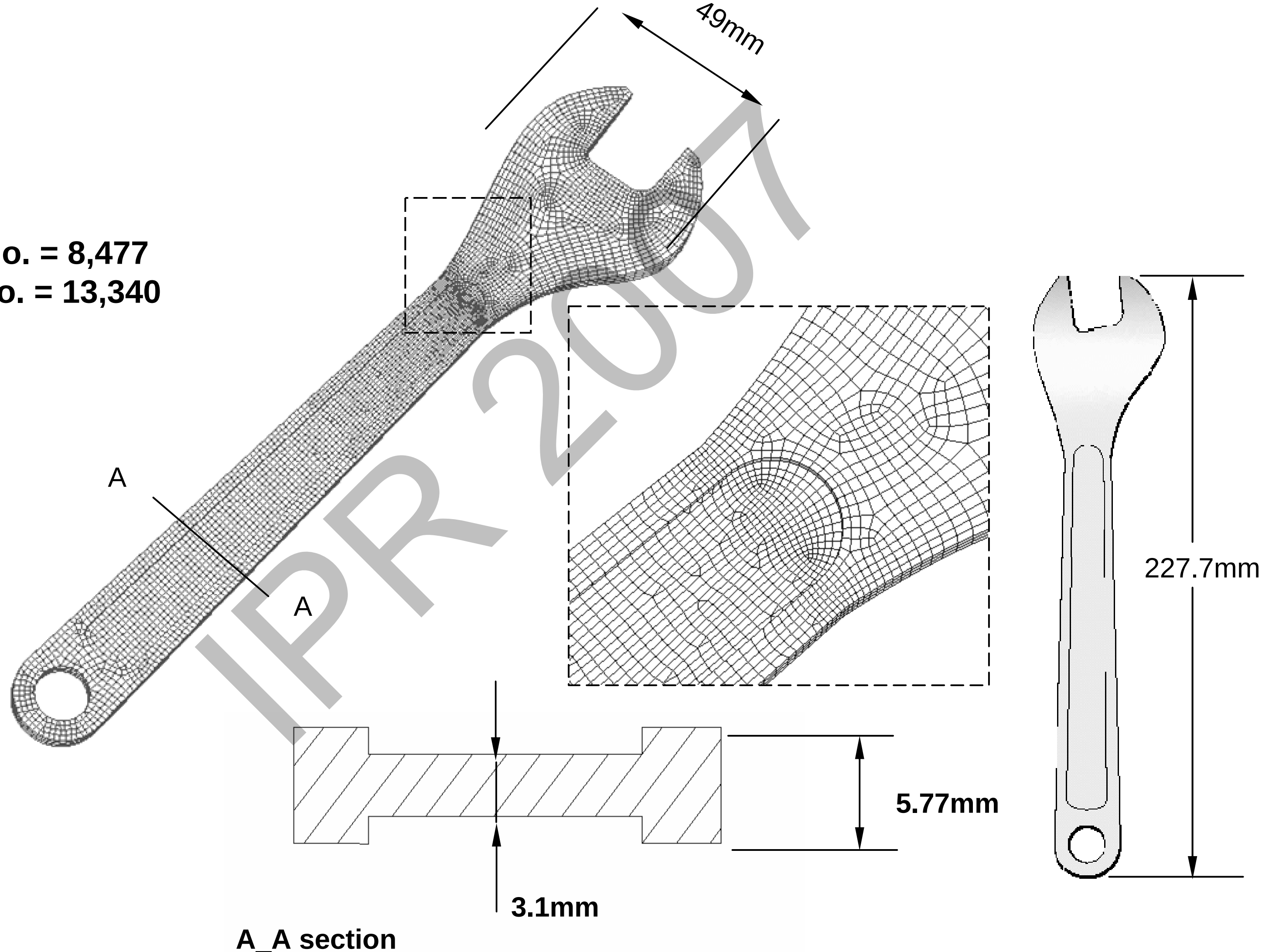


Model Summary

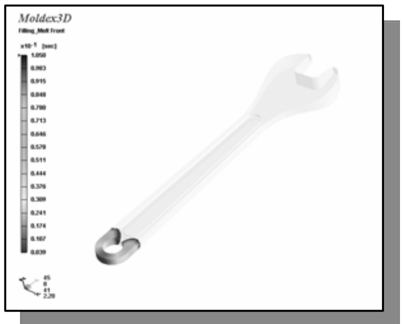
- Introduction
  - Thickness 3.1 ~ 12.3 mm
  - Length 227.7 mm
  - Width 49 mm
- Material
  - PA66 \ ORGALLOY RS6630 \ ATO (30%GF)
- Process Condition
  - Filling Time 1.5 Sec
  - Melt Temperature 300
  - Mold Temperature 70
- Injection Analysis Results
  - Filling
    - Melt Front
    - Temperature Distribution
  - Warpage
    - X-Displacement
    - Y-Displacement
    - Z-Displacement
- Structure Analysis results
  - Stress
  - Strain
  - Displacement

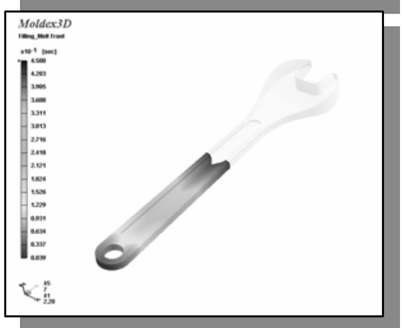
Injection Simulation: Mesh Model

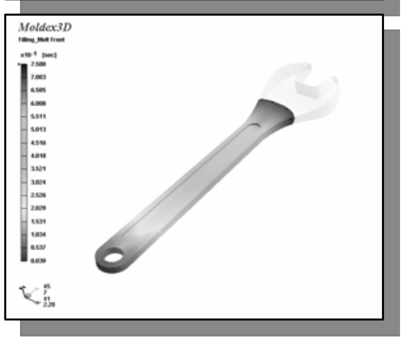
Elem. No. = 8,477
Node No. = 13,340

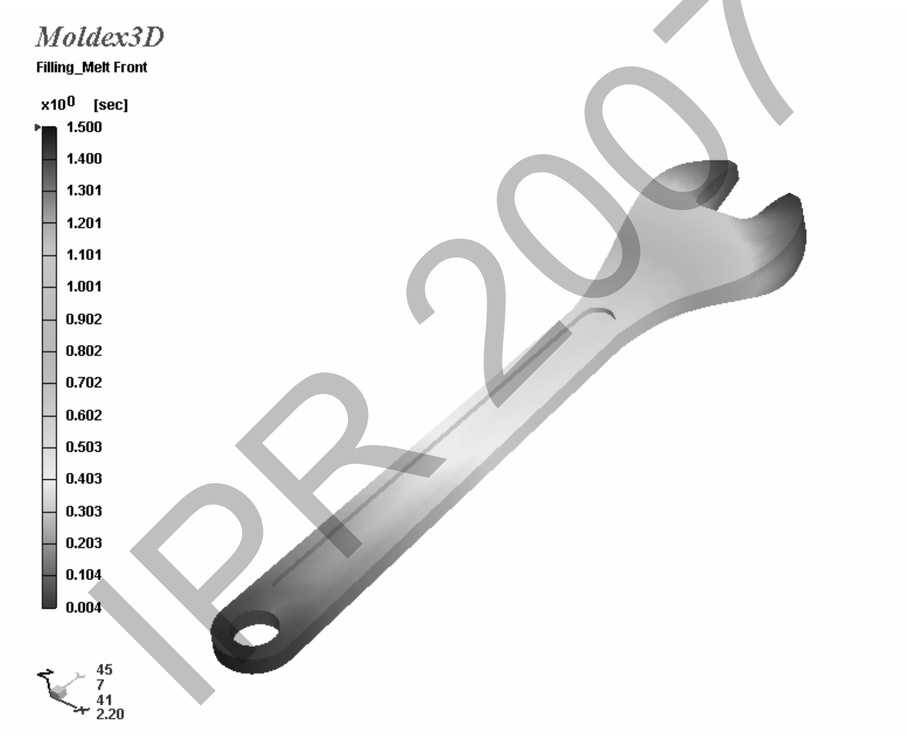


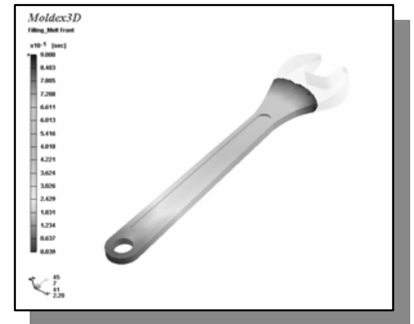
Injection Simulation: Melt Front

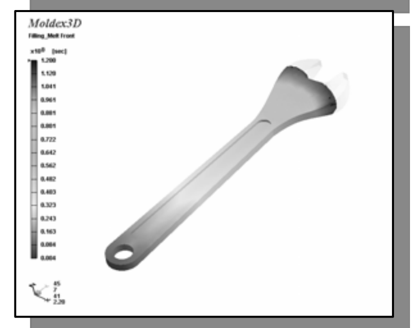


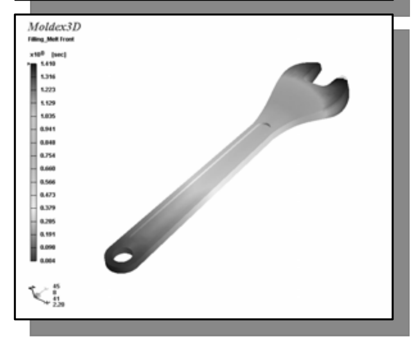




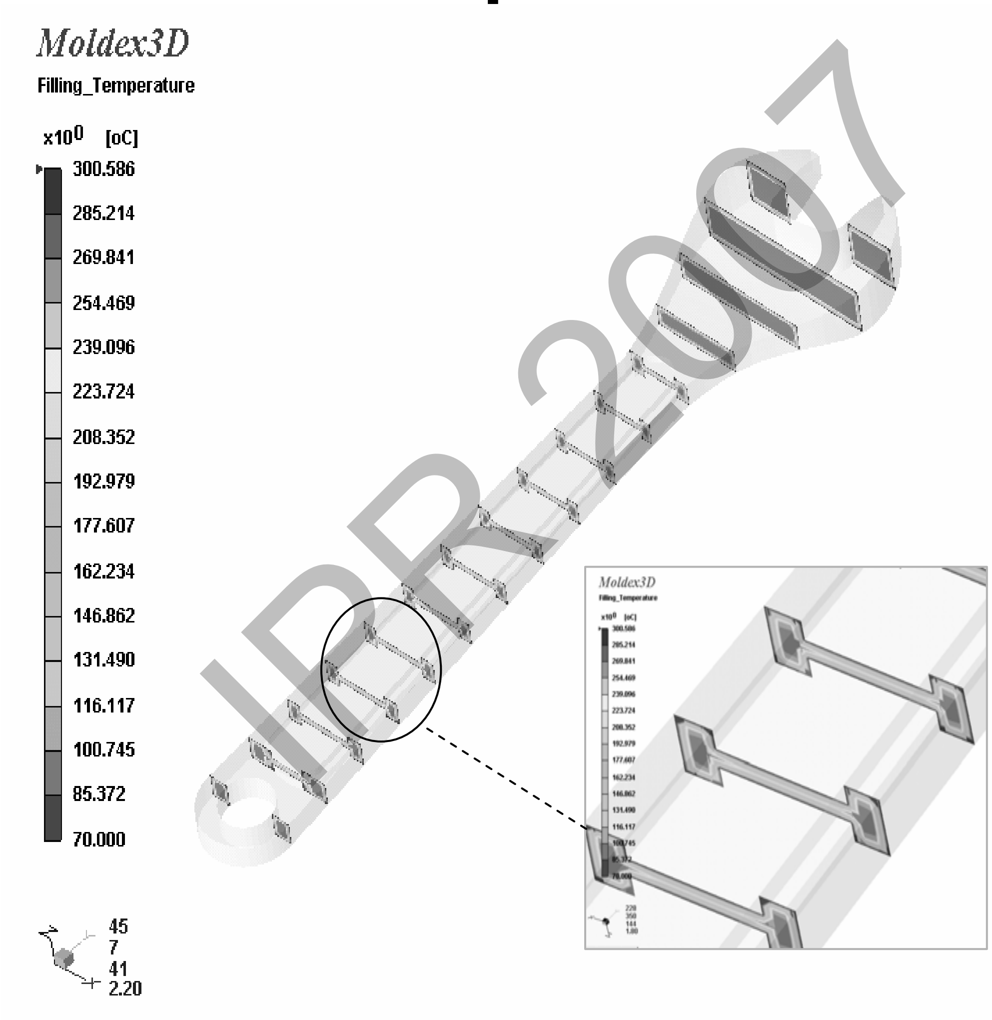




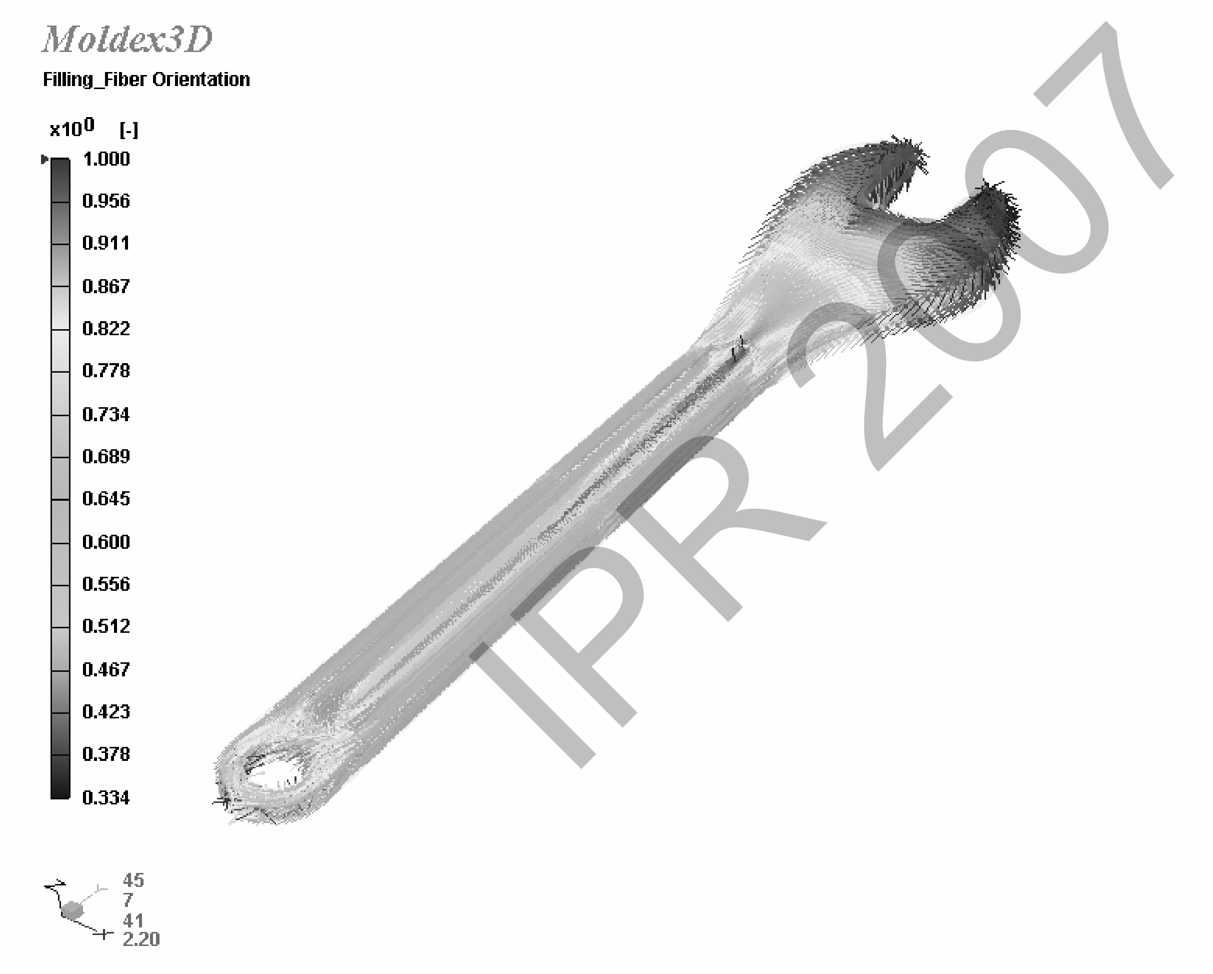




Injection Simulation: Temperature

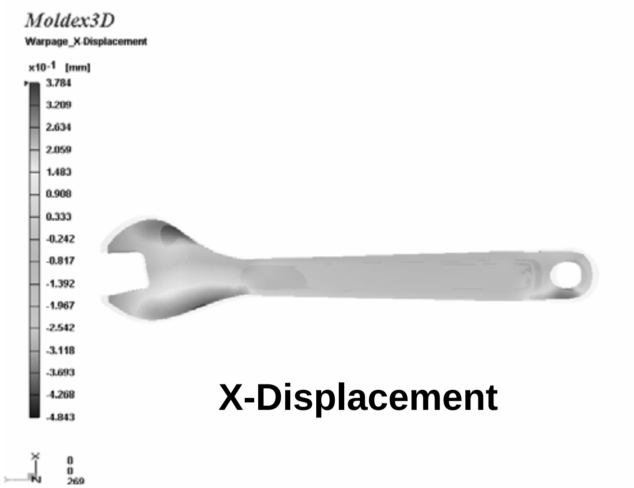


Injection Simulation: Fiber Orientation

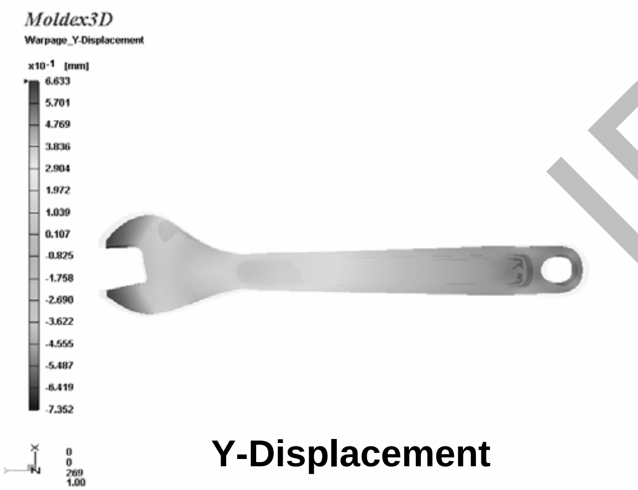


- **Fiber Orientation is the fiber orientation vector distribution of plastic melt at EOF.**
- **1/3 means the fibers exhibit an random orientation; 1 means the fibers are 100% oriented. The higher value means the fiber is highly oriented over the region by the flow field.**
- **Fiber orientation effects not only the shrinkage rate but also the strength of the part.**

Injection Simulation: Warpage



X-Displacement

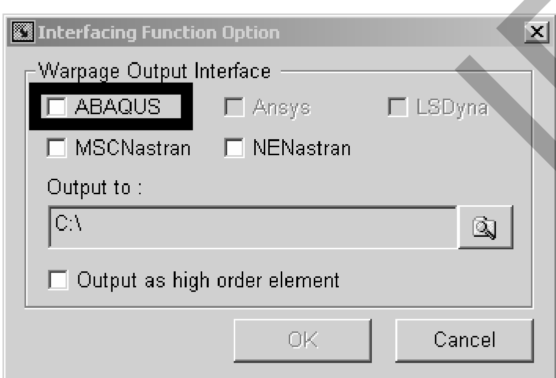


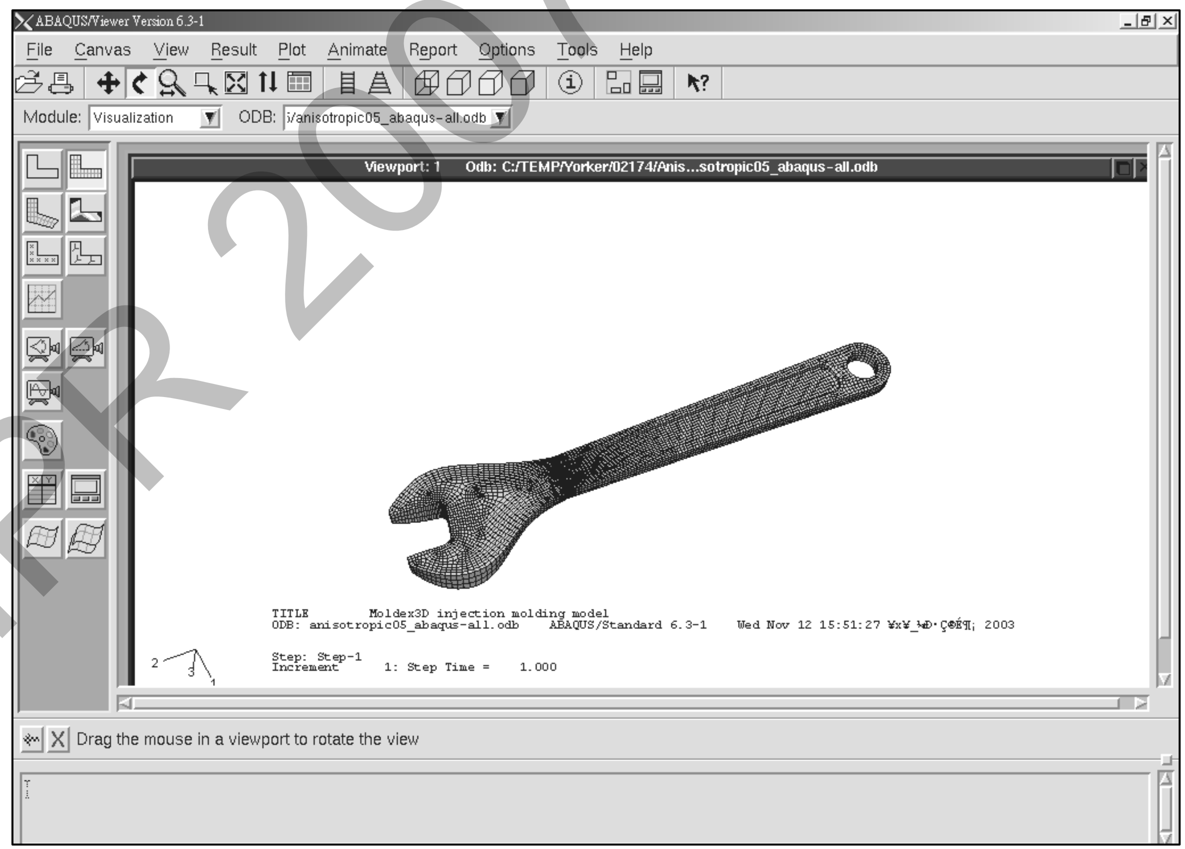
Y-Displacement

Total Displacement

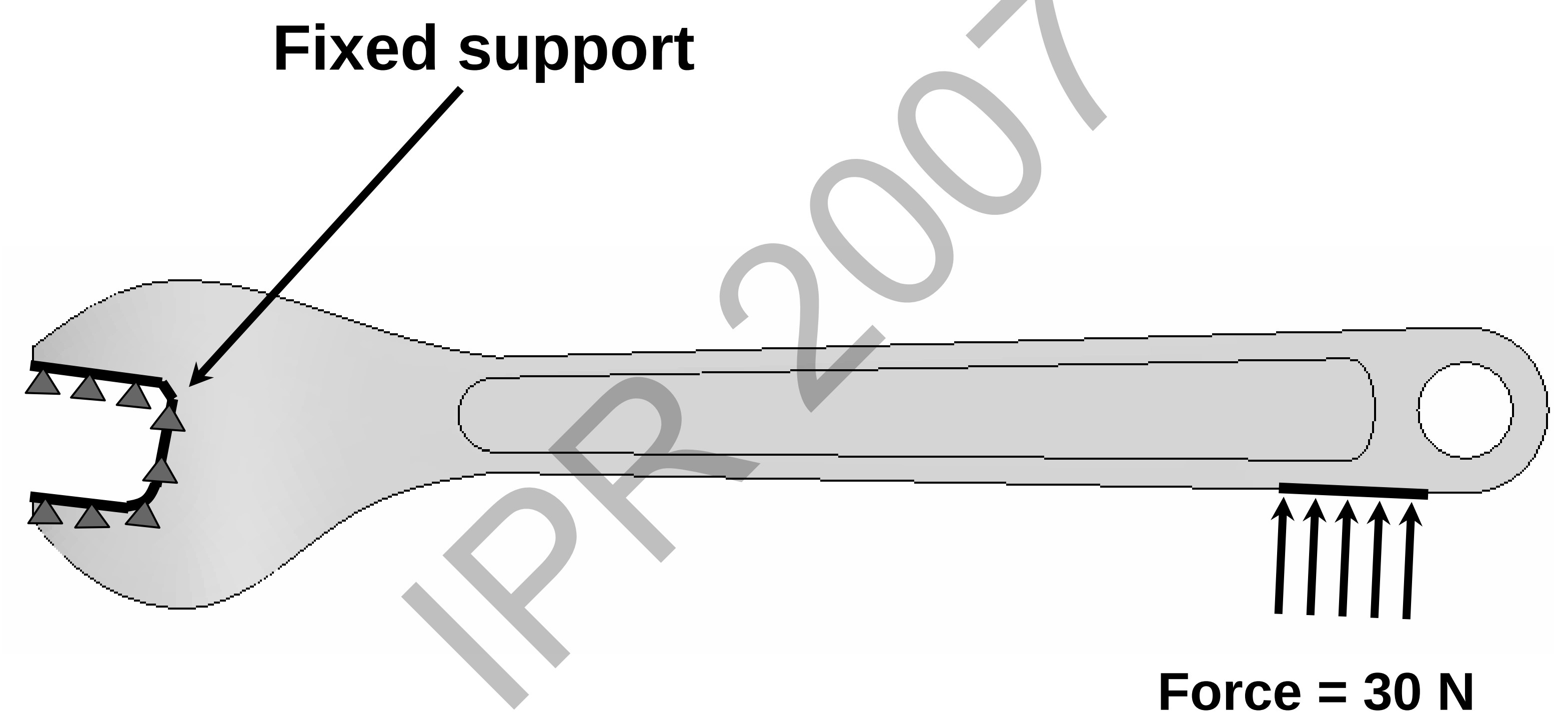
Structure analysis: Link to Abaqus

- Model preview
- Pre-process
  - Load
  - Constraint
  - Others

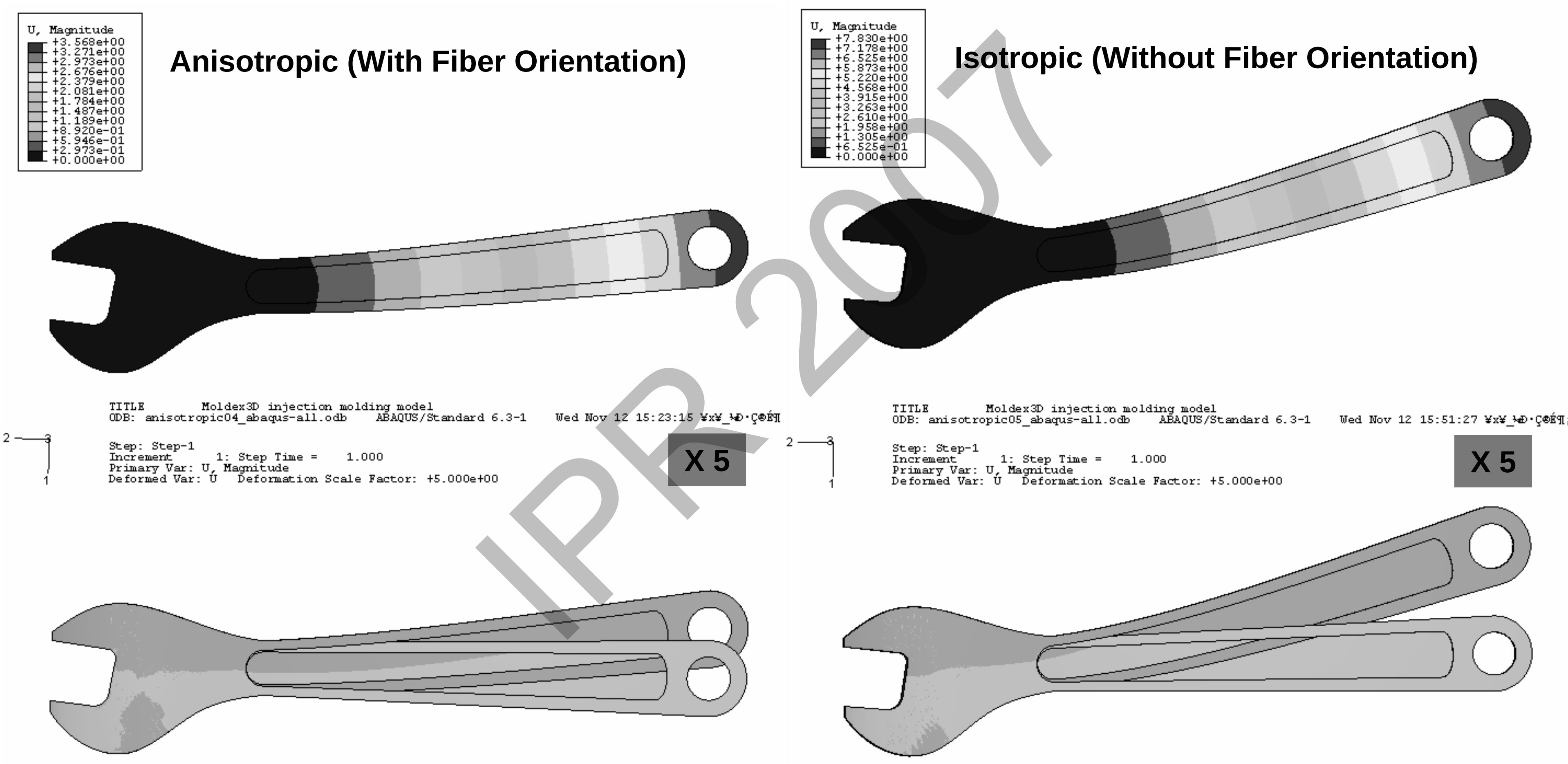




Structure analysis: Boundary Condition



Structure analysis: Deformation



Fiber-filled molded part has small deformation

Concluding Remarks

- **Process simulation provides more information for correlation between process conditions and production problems**
- **Simulation gives new insight into problems, which can lead to faster and more precise solutions**
- **Simulation offers the possibility for precise process/design optimization**

Stop Guessing...Start Simulating!

THANK YOU!!!

Questions?

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