Moldex3D
MOLDING INNOVATION

2015 Molding Innovation Day

Development and Performance Analysis of Injection Moulding Tools Fabricated Using Additive Manufacturing

Robert Zammit, Arif Rochman

Department of Industrial and Manufacturing Engineering - University of Malta

10 Luglio 2015
POINT Polo per Innovazione Tecnologica
Dalmine Bergamo

Moldex3D Italia srl
Corso Promessi Sposi 23/D -
23900 Lecco (LC)
www.moldex3d.com

Overview

- Introduction
  - Case Study
  - Objectives
- Project Methodology
  - Rapid Tooling Process
  - Mould Material
  - Designing the Cooling Channel
  - Injection Moulding Simulation
  - Fabrication
  - Injection Moulding Trial
- Conclusion

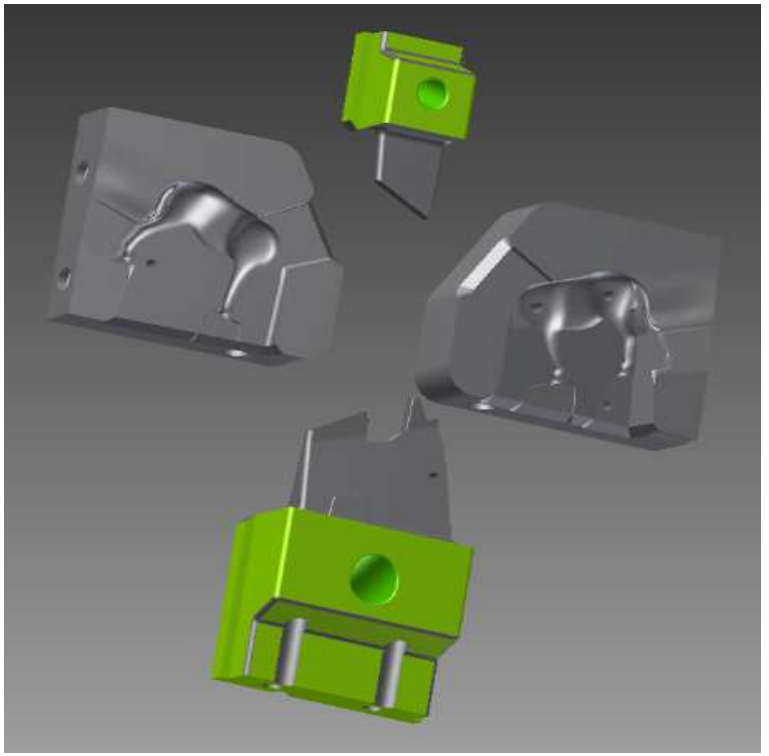
Introduction

- Importance of additive manufacturing and rapid tooling [1]
  - Higher productivity
  - Customization
  - Decrease in development time
- Injection Moulding [2]
  - Product development time
  - Conformal cooling channels

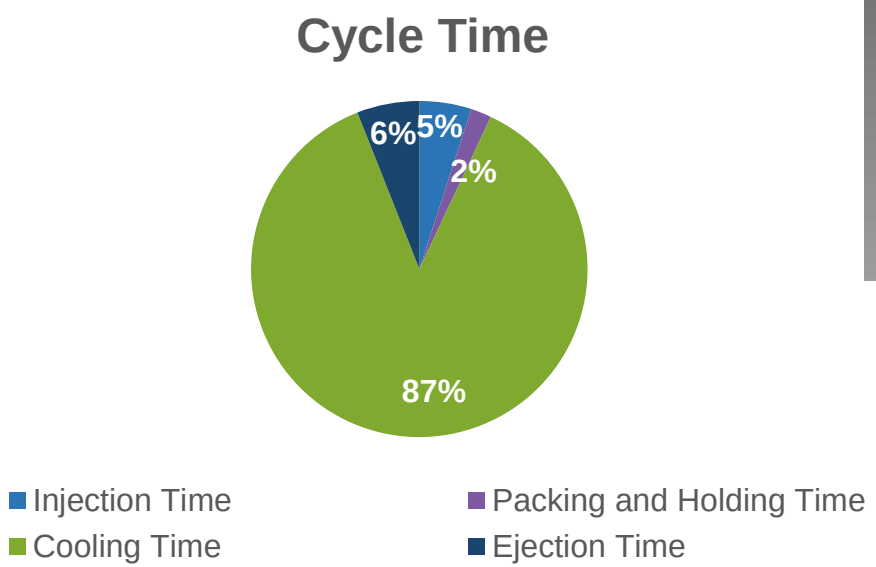
[1] C. Chua, K. Leong and C. Lim, *Rapid prototyping*. Singapore: World Scientific, 2003
[2] M. M. Farag, Materials Selection for Engineering Design, Prentice-Hall, London, 1997

Case Study

- High cooling time
  - Complexity of the produced part
  - Expanding agent
- Reduction in cooling time
  - Conformal cooling channels
  - Choosing the correct tool material



The Injection Moulding Setup



Moldex3D

Main Objective

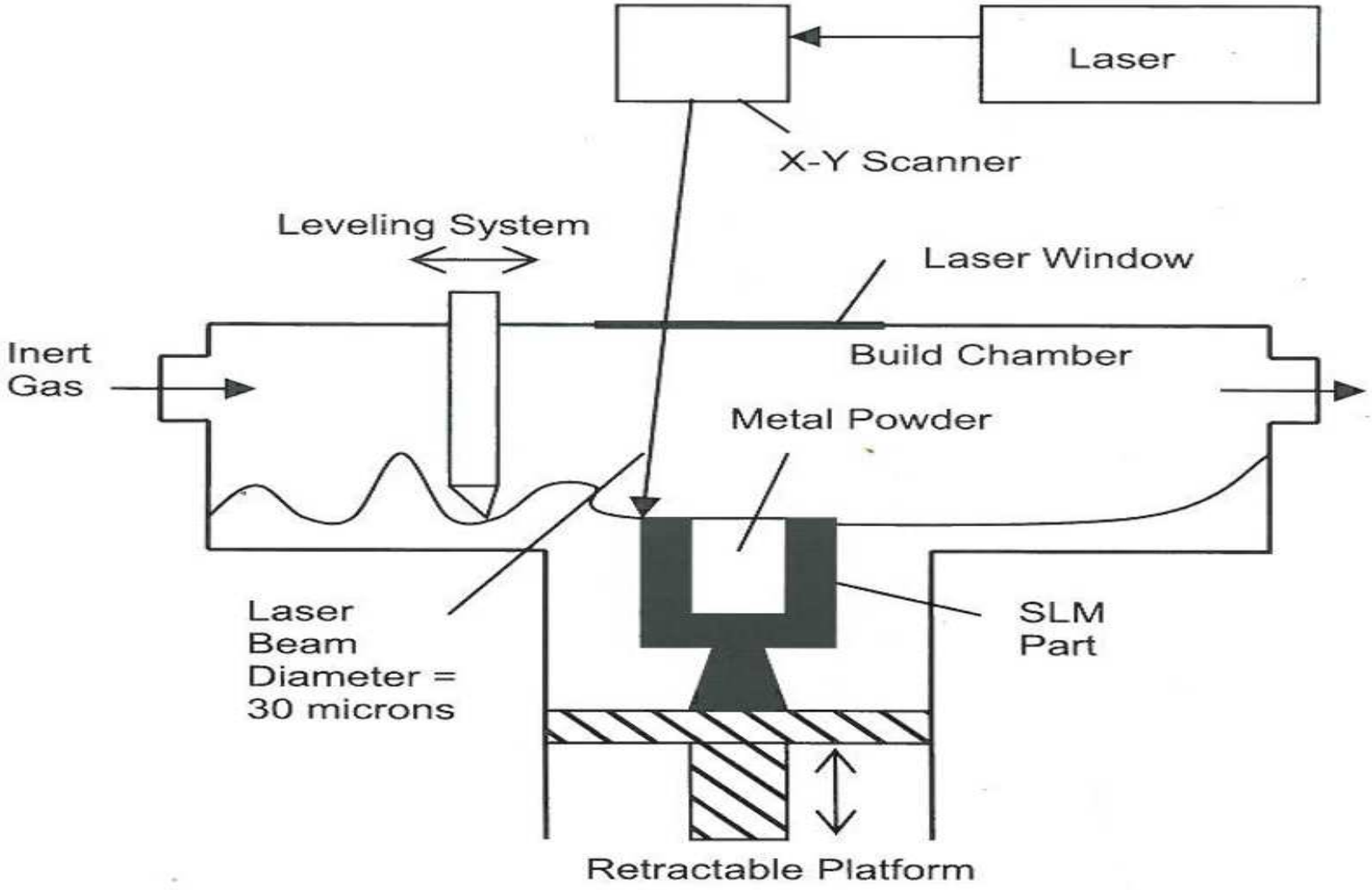
- Reduce the cycle time for the production of the horse figure
  - Choosing an additive manufacturing technique
  - Choosing the mould material
  - Designing conformal cooling channels
  - Manufacturing of the tool
  - Testing on an injection moulding machine

Additive Manufacturing

Criteria	Rapid Tooling Processes [1], [2]			
	Selective Laser Sintering	Direct Metal Laser Sintering	Selective Laser Melting	Electron Beam Melting
Density of Part	Can vary but generally low	Can be as high as 95%	Approximately 100%	100%
Material Removal from CCC	Quite difficult	Similar to SLS	Easier than in EBM	Difficult due to powder being sintered to the part
Surface Finish	Poor surface finish	Poor surface finish	Good surface finish	Excellent surface finish
Metallic Materials	Very Limited	Limited	Large range	Limited

[1] D. Kazmer, Injection mold design engineering. Munich: Hanser, 2007.
[2] N. Karapatis, J. van Griethuysen and R. Glardon, 'Direct rapid tooling: a review of current research', Rapid Prototyping Journal, vol. 4, no. 2, pp. 77-89, 1998.

Selective Laser Melting



Selective Laser Melting Process [1]

[1] C. Chua, K. Leong and C. Lim, *Rapid prototyping*. Singapore: World Scientific, 2003

Mould Material

- Raw material requirements
  - Similar to that for tool requirements
  - Powder based

Material [1], [2]	Thermal Conductivity (W/m.K) [1], [3]	Chromium Content (%) [1], [3]
Steel - DIN 1.2311	33.00	1.80-2.10
Steel - DIN 1.2738	33.00	1.80-2.00
Steel - DIN 1.2312	33.00	1.80-2.10
Steel - DIN 1.4404	**16.30**	**16.00-18.00**
Steel - DIN 1.2316	15.00	15.50-17.50

Table to choose Mould Material

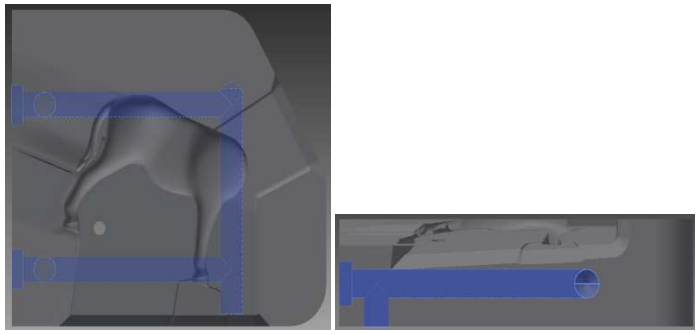
[1] http://www.ozct.com.tr/en/
[2] http://www.plasticstoday.com/articles/aluminum-vs-steel-tooling-which-material-right-how-design-how-maintain-082920122
[3] http://www.toolcraft.co.uk/tools-aluminium-alloy-steel-mould-comparison.htm

Designing the Cooling Channels

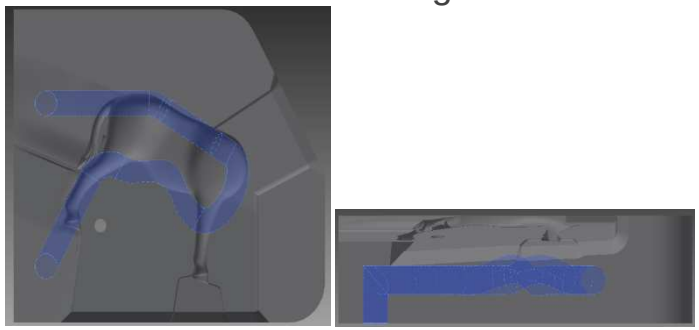
- Design Criteria
  - Only the cooling system can be modified
  - Keep certain distance away from any other feature
  - Keep cooling channels at a uniform distance from the cavity
  - Reducing the level of post-processing

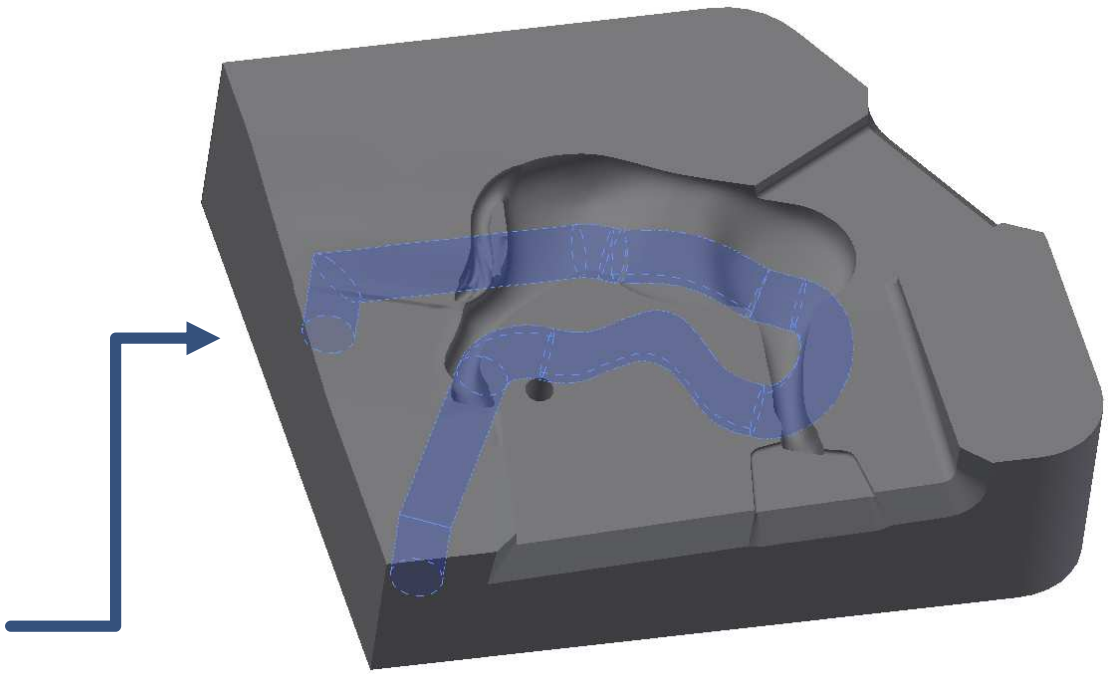
Conformal Cooling Channels

> Injection Side



Conventional Cooling Channel



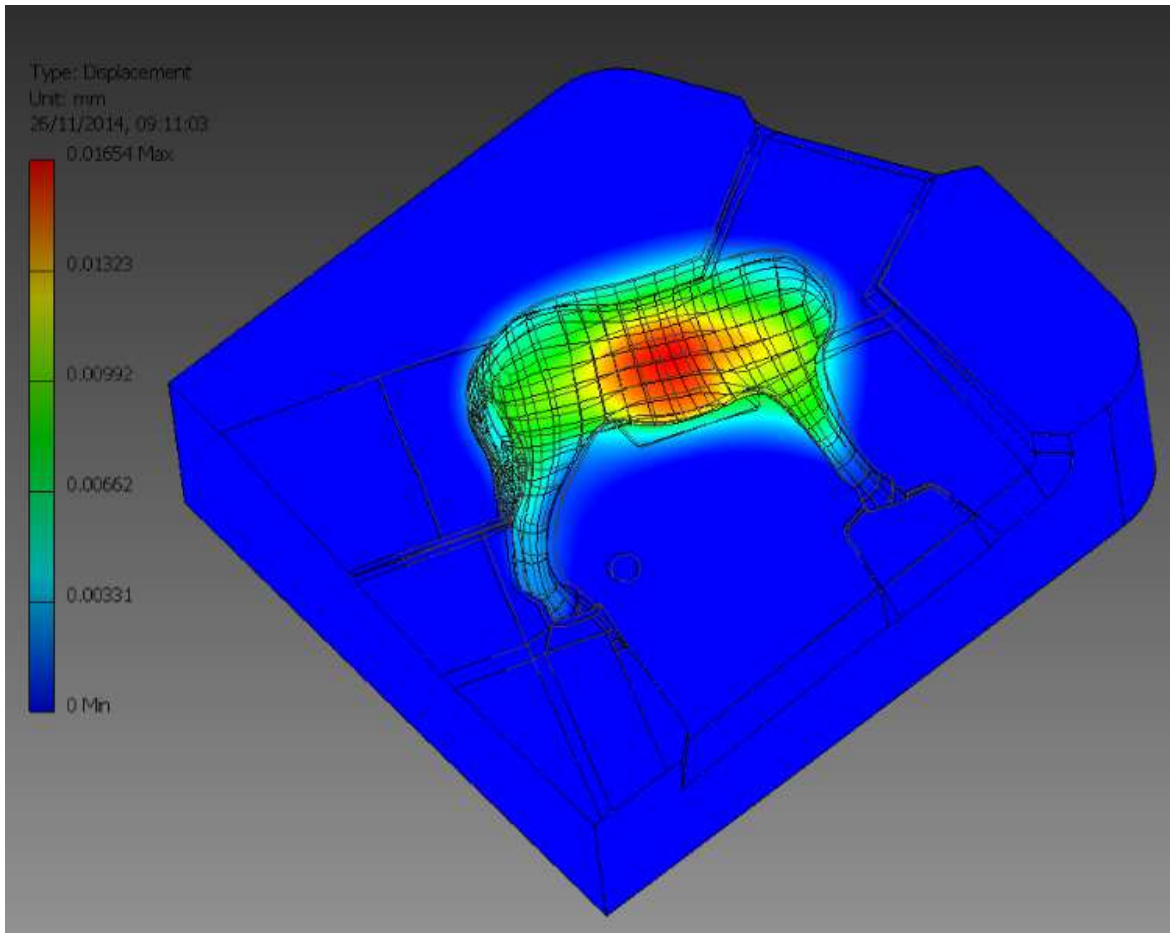


Conformal Cooling Channel

Moldex3D

Conformal Cooling Channels

> Injection Side



Deflection from Injection Pressure

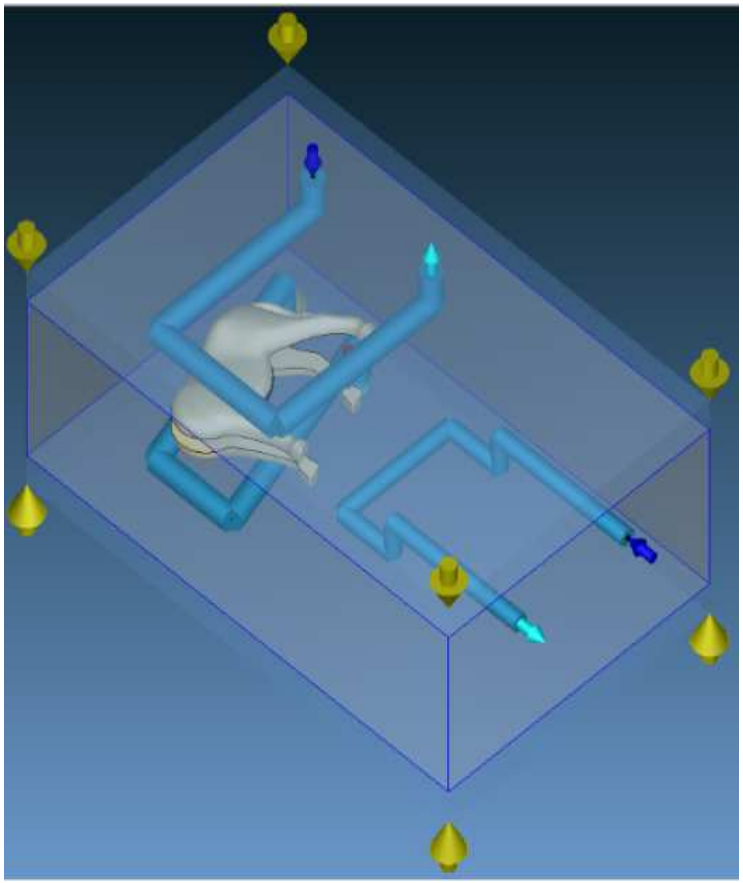
Moldex3D

Injection Moulding Simulation

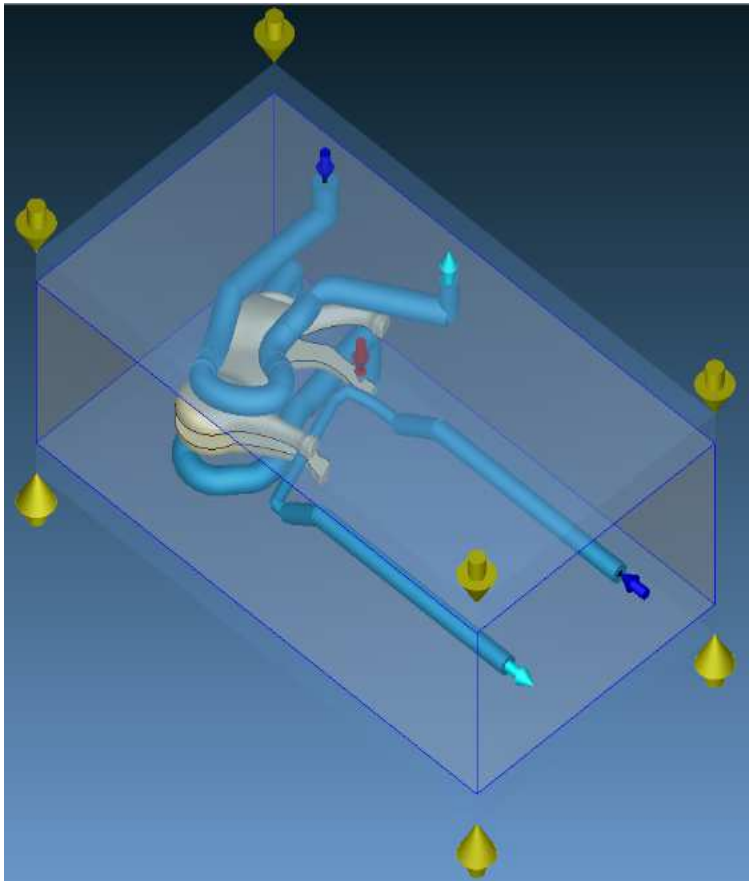
- Pre-Processing
  - Modelling
  - Material Data
  - Processing Parameters
- Simulation Stage
- Post-Processing/Analysis Stage
  - Cooling Channel Results
  - Temperature Results
  - Ejection Time Results

Injection Moulding Simulation

> Modelling the Moulds



Simulation Model of Conventional Mould



Simulation Model of Conformal Mould

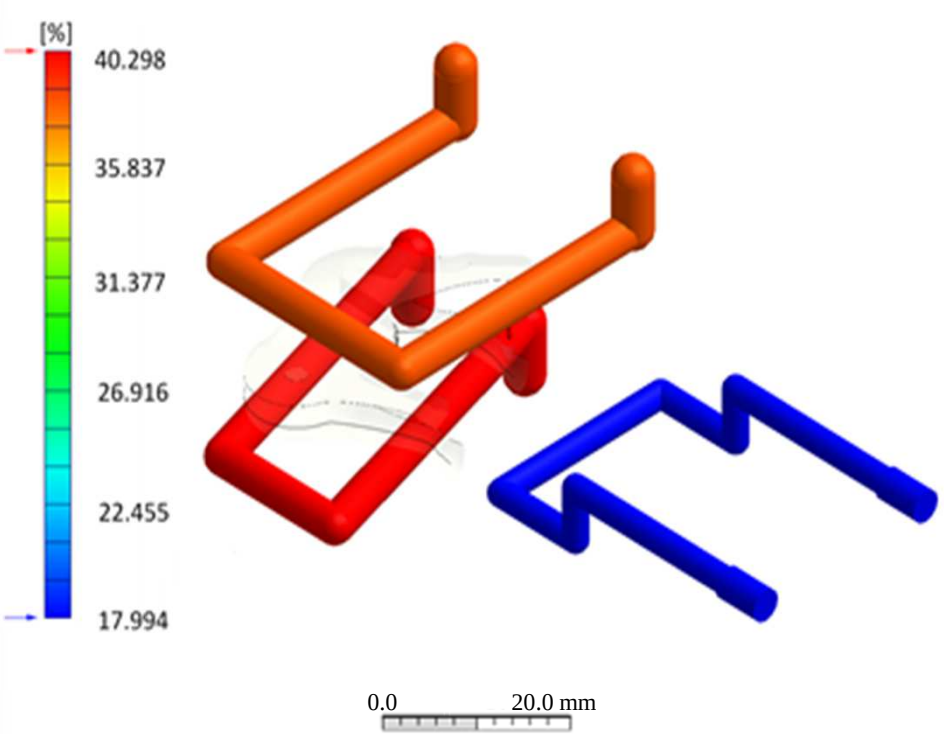
Injection Moulding Simulation

- Pre-Processing
  - Material Data
  - Process Parameters

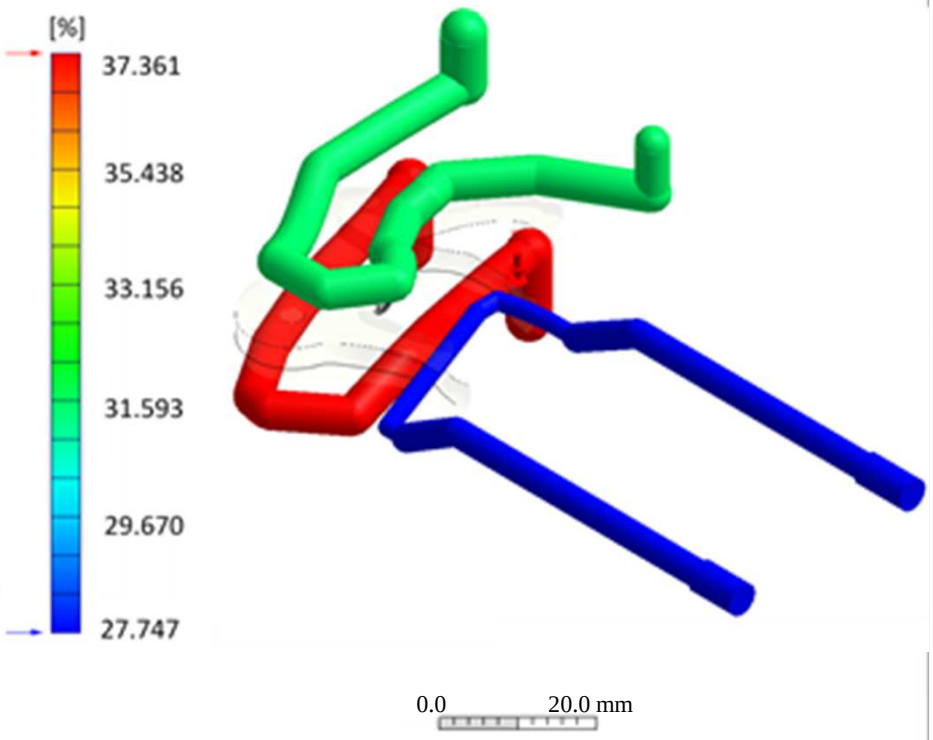
- Simulation Run
  - Full Transient Analysis (Ct F P Ct W)

Injection Moulding Simulation

> Cooling Channel Results



Cooling Efficiency of the Conventional Channels



Cooling Efficiency of the Conformal Channels

Moldex3D

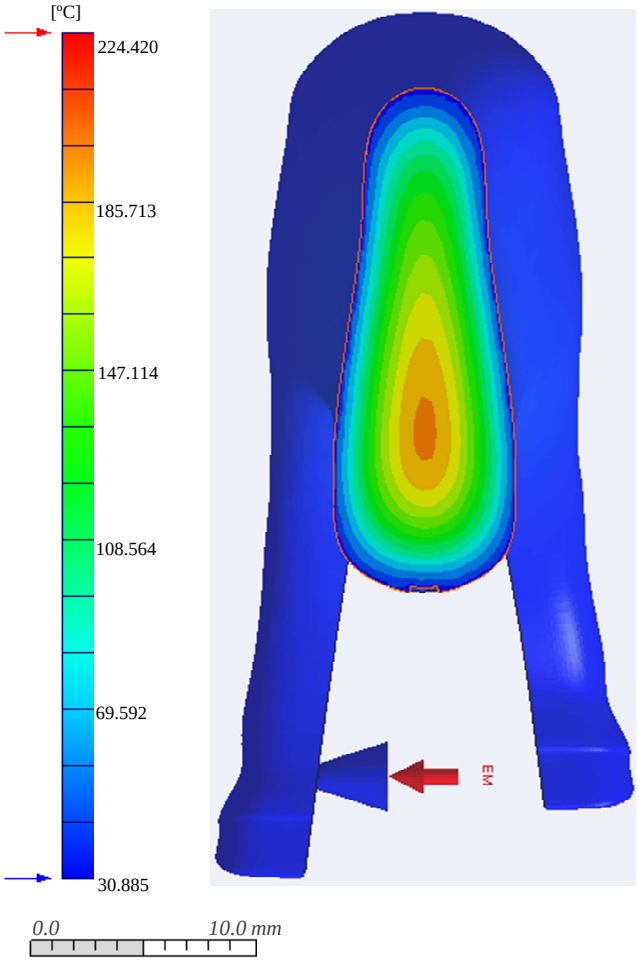
Injection Moulding Simulation

> Cooling Channel Results

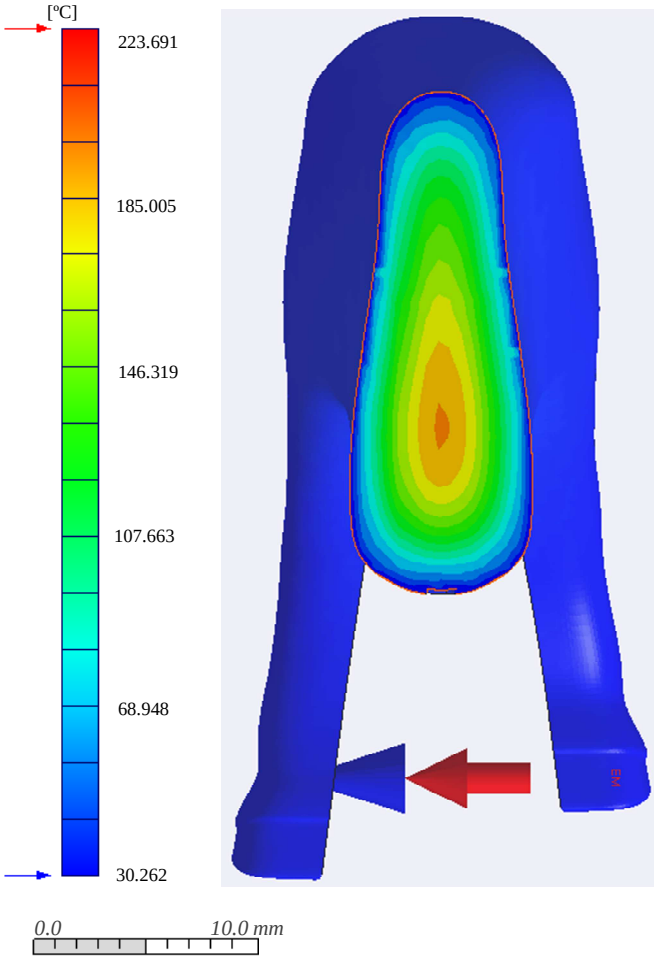
Data		Conventional Cooling Channels			Conformal Cooling Channels		
		Injection	Ejection	Slider	Injection	Ejection	Slider
Reynolds number	Max	33,191	33,200	44,135	37,541	33,126	66,264
	Min	33,097	33,097	44,135	33,097	33,097	44,207
Temperature (ºC)	Max	30.034	30.027	30.011	30.074	30.044	30.120
	Min	30.000	30.000	30.000	30.000	30.000	30.000
Pressure (kPa)	Max	21.470	39.380	53.690	20.160	14.790	55.910
	Min	3.580	3.580	3.580	1.340	1.340	1.340

Injection Moulding Simulation

> Temperature Results



Temperature of Moulded Part
Produced in the Conventional Inserts



Temperature of Moulded Part
Produced in the Conformal Inserts

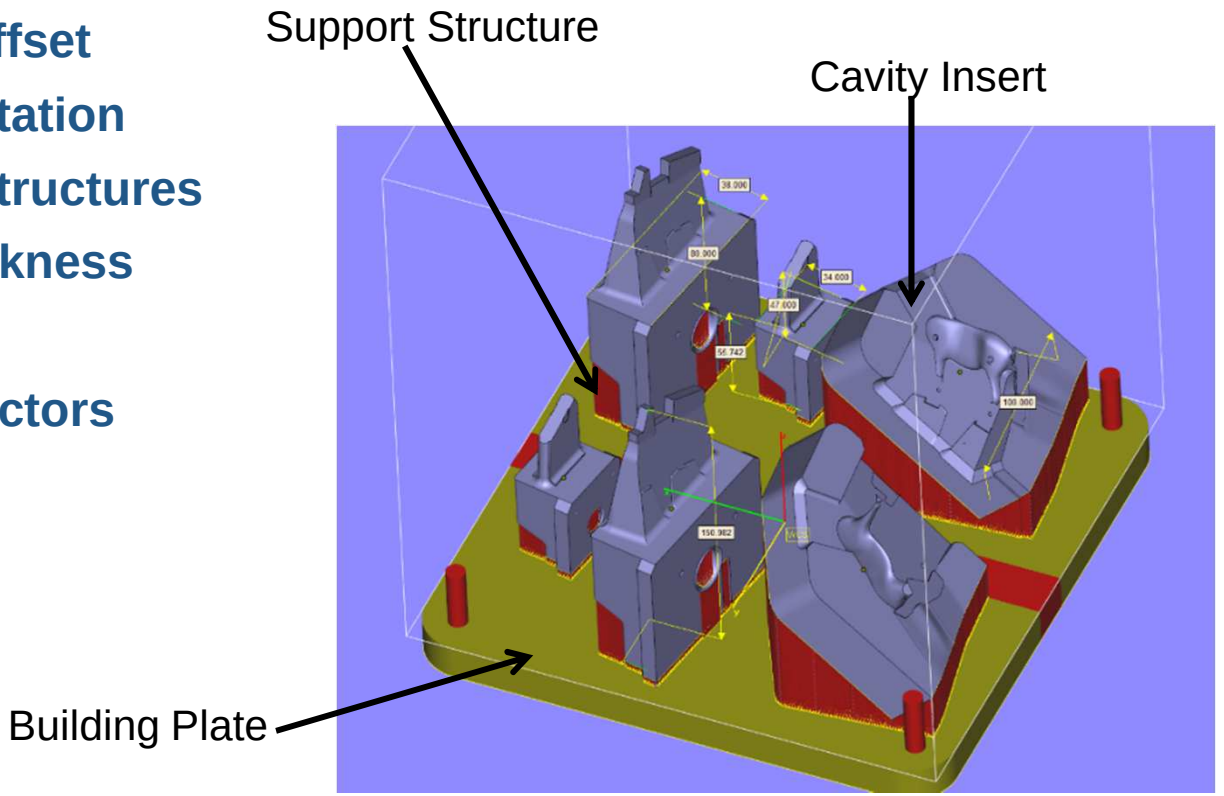
Moldex3D

Injection Moulding Simulation

- Cooling Time Results
  - Cooling time set to automatic
  - Reduction in conformal mould of approximately 2.3s

Tool Production

- Pre-Processing
  - Surface offset
  - Part orientation
  - Support structures
  - Layer thickness
  - Tool path
  - Scaling factors



Parts Placed on the Building Plate

Moldex3D

Tool Production

- > Fabrication Stage
- > Post-Processing
  - – Process Oriented Final Processing

Parts as Removed from Machine

Removing the Support Structures

Parts Without the Support Structures

Tool Production

- Post-Processing
  - Parts Inspection and Measurement
    - Really high quality parts
    - Similar surface roughness in different direction
    - Similar shrinkage in different direction
  - Machining and Finishing
    - 3-Axis CNC Milling Machine
    - 5-Axis CNC Milling Machine and EDM

Injection Moulding Trial

- Two cavity mould
- Processing parameters
- Cooling time

Injection Side of the Two Cavity Mould

Injection Moulding Trial

- Results – Part Inspection
  - Swelling was first noticed at 40 s
  - Reduction in cooling time
    - From 60 s to 45 s

Part with no Swelling

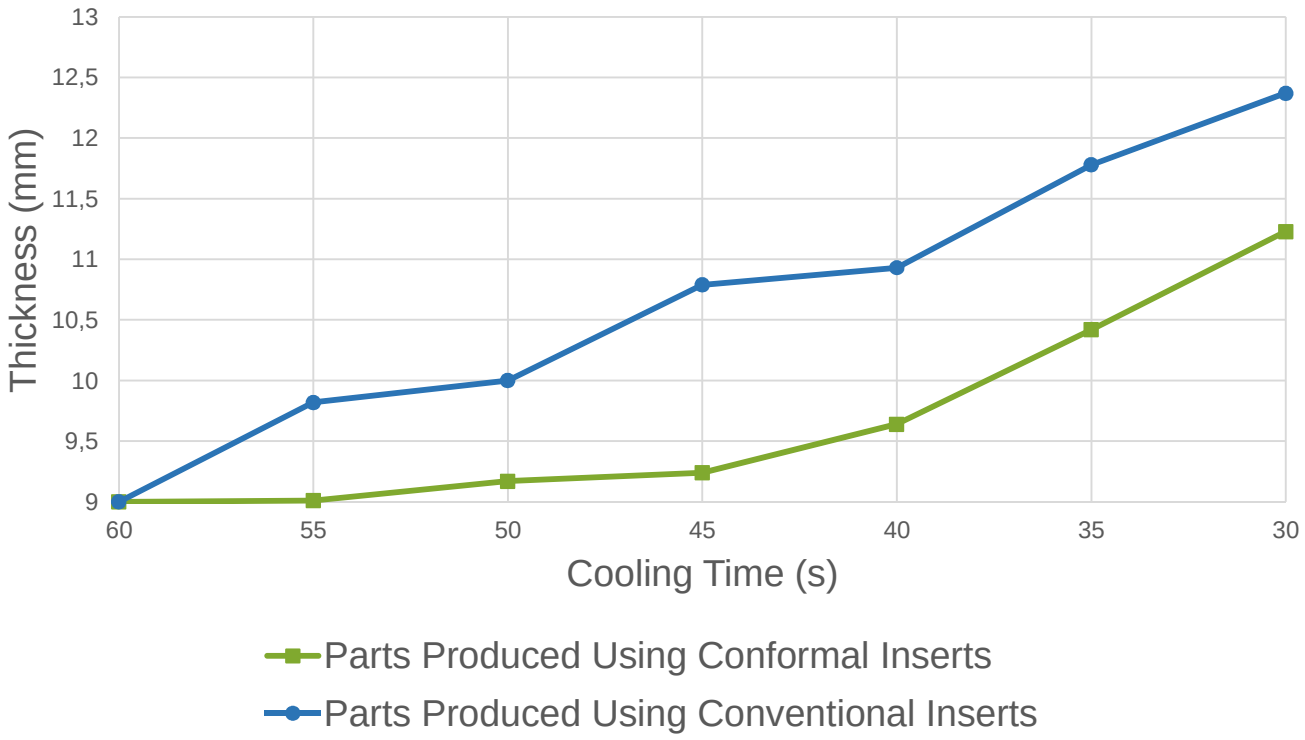
Part with Swelling

Moldex3D

Injection Moulding Trial

> Results – Part Measurement at Belly Region

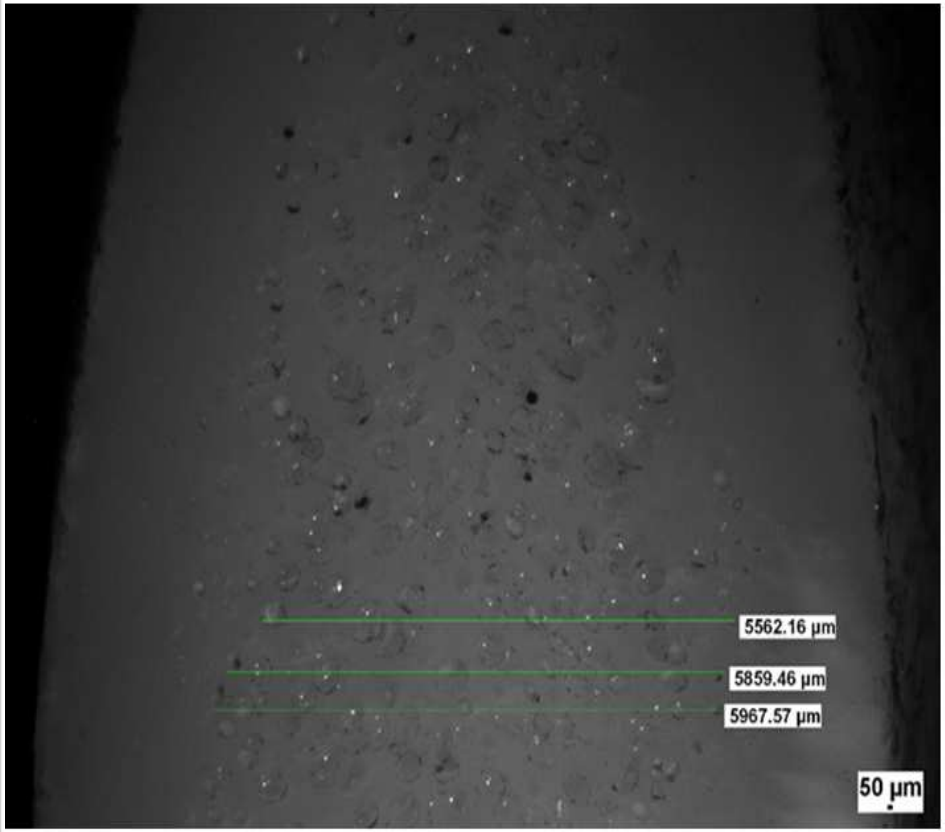
- **Part with new cooling time had just 0.24 mm increase in thickness**



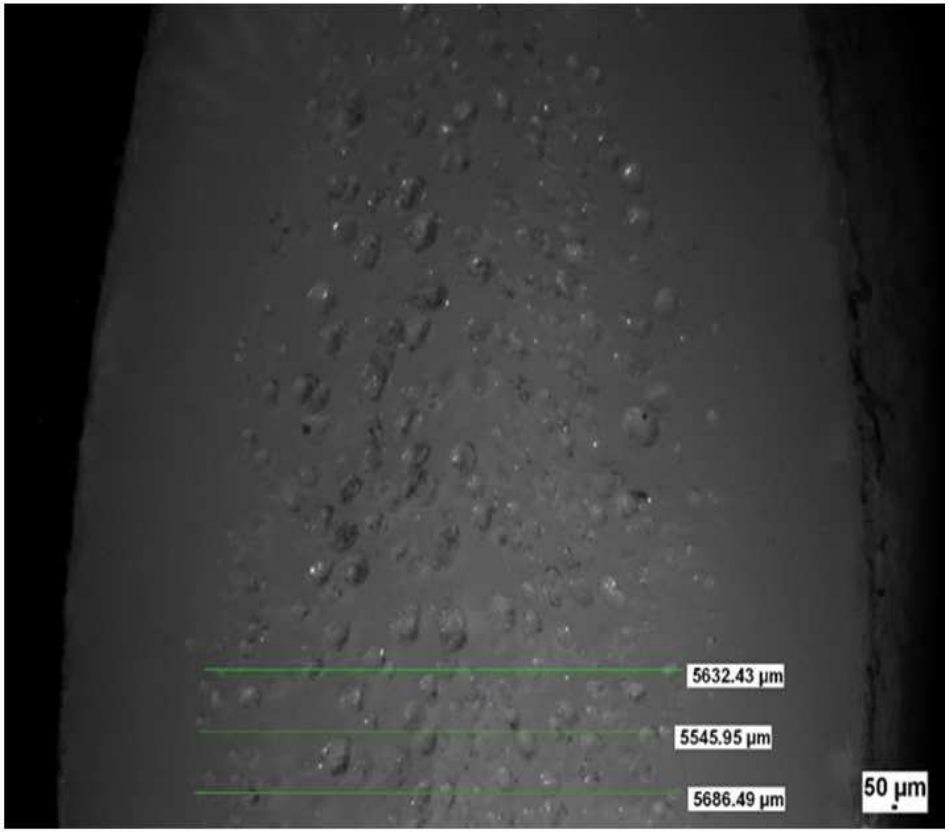
Moldex3D

Injection Moulding Trial

> Results – Cross-Sectional Inspection in the Belly Region



Micrograph of the Cross-Section of the Part Produced in the Conventional Mould



Micrograph of the Cross-Section of the Part Produced in the Conformal Mould

Moldex3D

Conclusion

- Research objective was completed
  - Importance of choosing the additive manufacturing technique and tool material
  - Importance of designing an optimal cooling system
  - Reduction in cooling time

Moldex3D

MOLDING INNOVATION

University of Malta

Playmobil Malta Ltd

SLM Solutions GmbH

Moldex3D Italia srl
Corso Promessi Sposi 23/D
23900 Lecco (LC)
www.moldex3d.it

CoreTech System Co., Ltd.
www.moldex3d.com