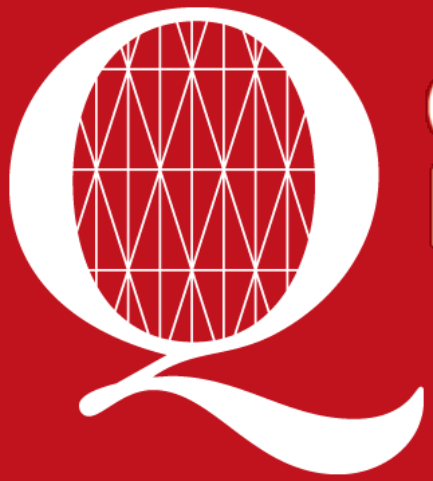
ARM Conference 2014

Advanced Rotational Moulding Technology

Rotomoulding Innovation: Internal Mould Water Spray Cooling



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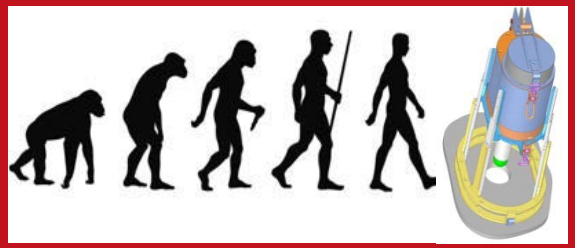
Mark P Kearns
Moulding Research Manager
Mechanical & Aerospace Engineering
Polymer Processing Research Centre

Internal Mould Water Spray Cooling: A Rotomo(u)lding (R)evolution

1. Introduction
2. Background: Innovation in Rotomoulding
3. Internal Cooling Theory: why it works
4. Operation
5. Industrial Trials
6. The Future



Evolution – continuous / incremental change

Revolution – radical / novel change

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Future Proofing the Rotomoulding Industry – Innovation

- Innovation is the life-blood of any company.
- Fresh ideas and innovative products / processes help create a competitive advantage and ultimately promote company growth.
- Evolutionary innovation optimizes and exploits existing businesses and prolongs their trajectories.
- Revolutionary innovation explores new-to-the-world opportunities and creates new business potential.

Future Proofing the Rotomoulding Industry – Innovation

'Any industry that does not regularly seek ways to evolve or improve will quickly be left behind'. ***RJ Crawford, Rotomoulding – Where to Next? Rotoworld Vol.X Issue 4 2014***

How Innovative are we?

How do we compare with competing technologies?

What is the Current Technical Status of our Industry ?

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Rotomoulding: Comparison with other Polymer Processes

Summary:

1. Rotomoulding competes well in design and overall dimensional versatility

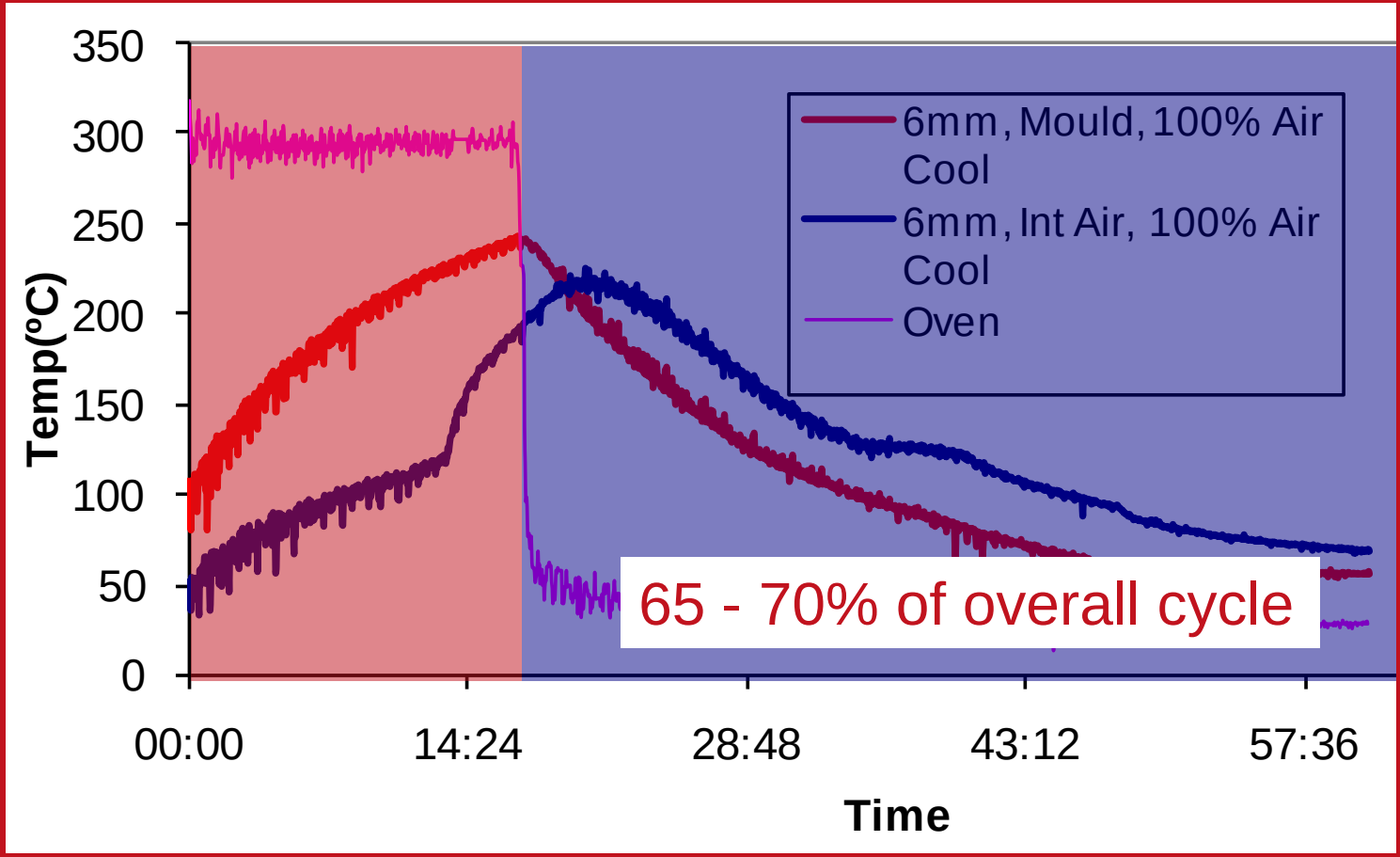
2. Rotomoulding lags in production, equipment and tooling

3. Rotomoulding lags in dimensional stability, material selection, ease of material/part handling

4. Rotomoulding lags in energy efficiency, cycle time, process monitoring/control

Reducing the Cooling Rate

One of the drawbacks of the process has been the relatively long cycle times required to produce a part.



Internal Mould Cooling is the Limiting factor

- Rotational moulding utilises unsymmetrical cooling (from the outside only), which leads to distortion (warpage) of the moulded part

- It is very important therefore that moulders exercise control over the shape of the end product. For this reason, the moulder is usually obliged to employ relatively slow cooling of the outer surface of the mould until the point when the plastic has solidified.

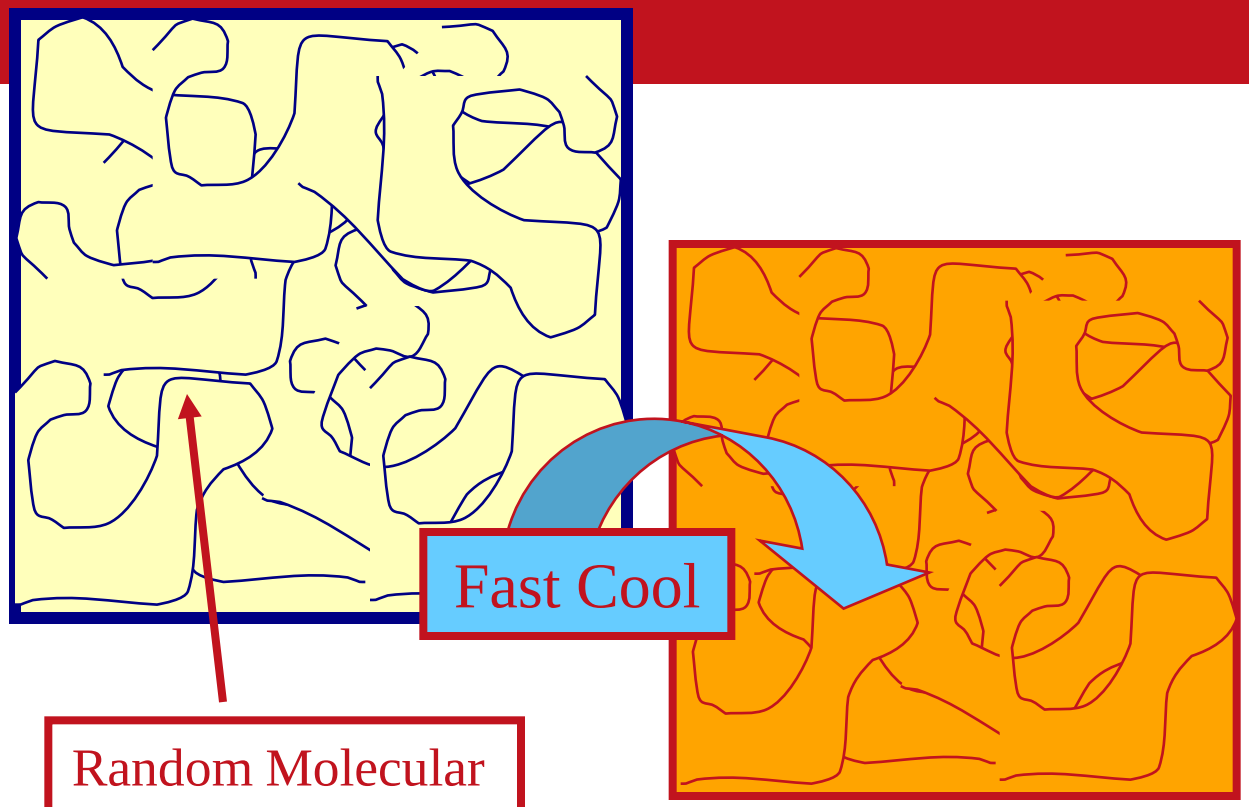
- If a molten plastic is subjected to fast cooling on one side and slow cooling on the other side, there will be a difference in the structure across the thickness of the plastic when it becomes solid.

Fast, Uncontrolled Cooling = Warpage

- The side that cools slowly will have a tendency to be more crystalline. This means that the molecular chains pack together more closely and the plastic will have a higher density in this region.

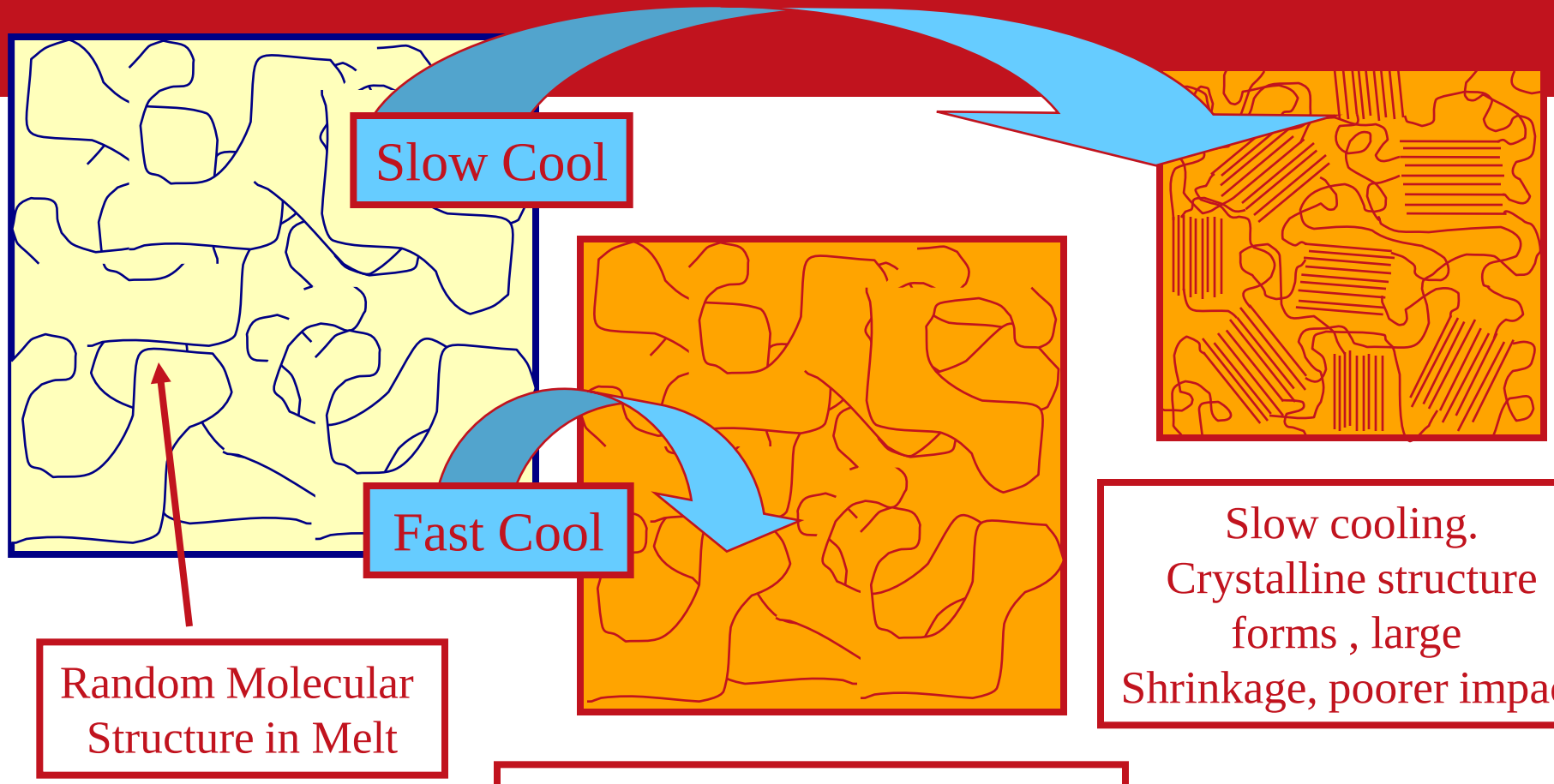
- The side that cooled more quickly will be less crystalline because the material did not have time for the molecular chains to align themselves into a crystalline structure and so will have a lower density

Structure Formation in Plastics

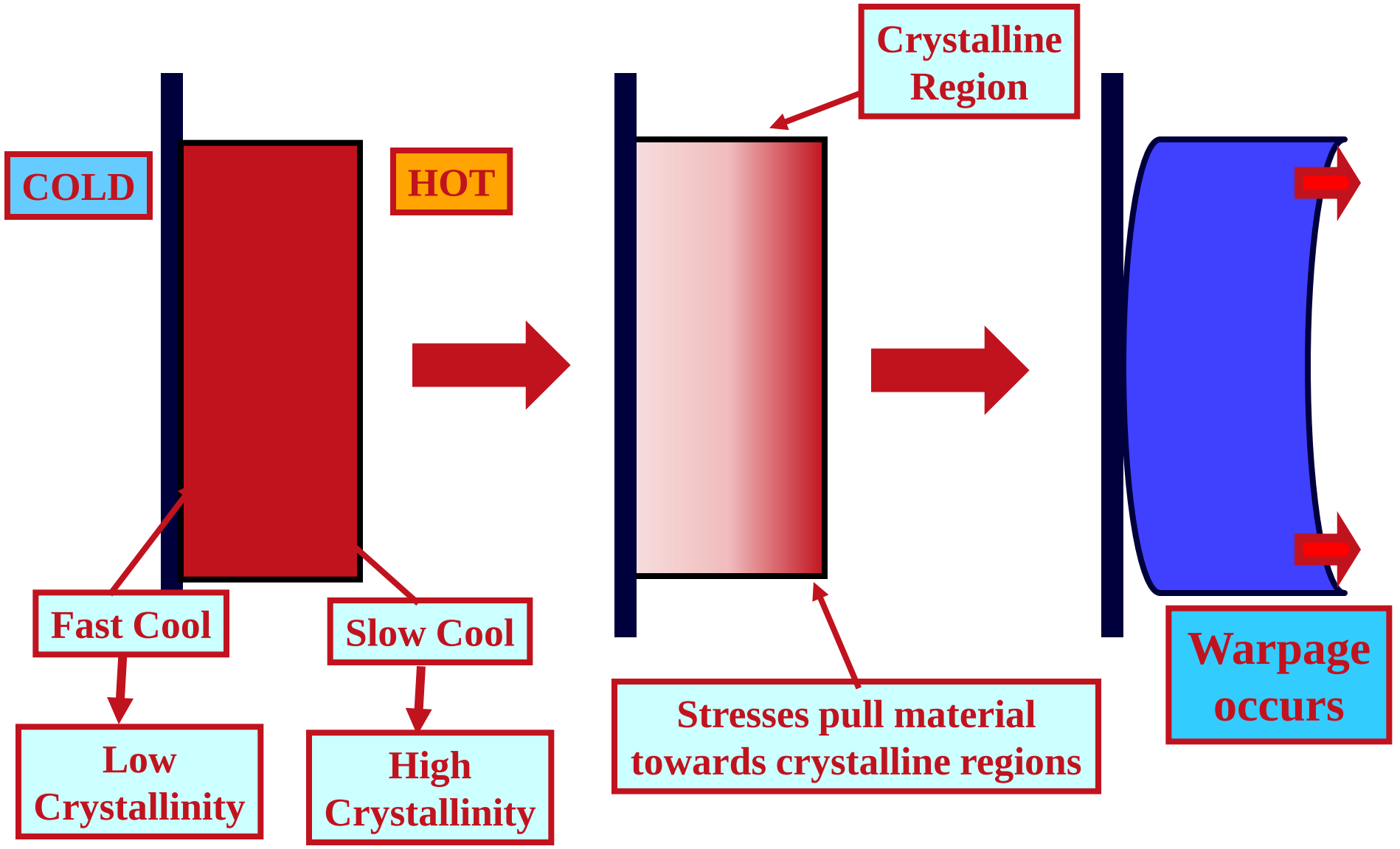


Fast cooling.
Random / Amorphous structure retained, small shrinkage, better impact.

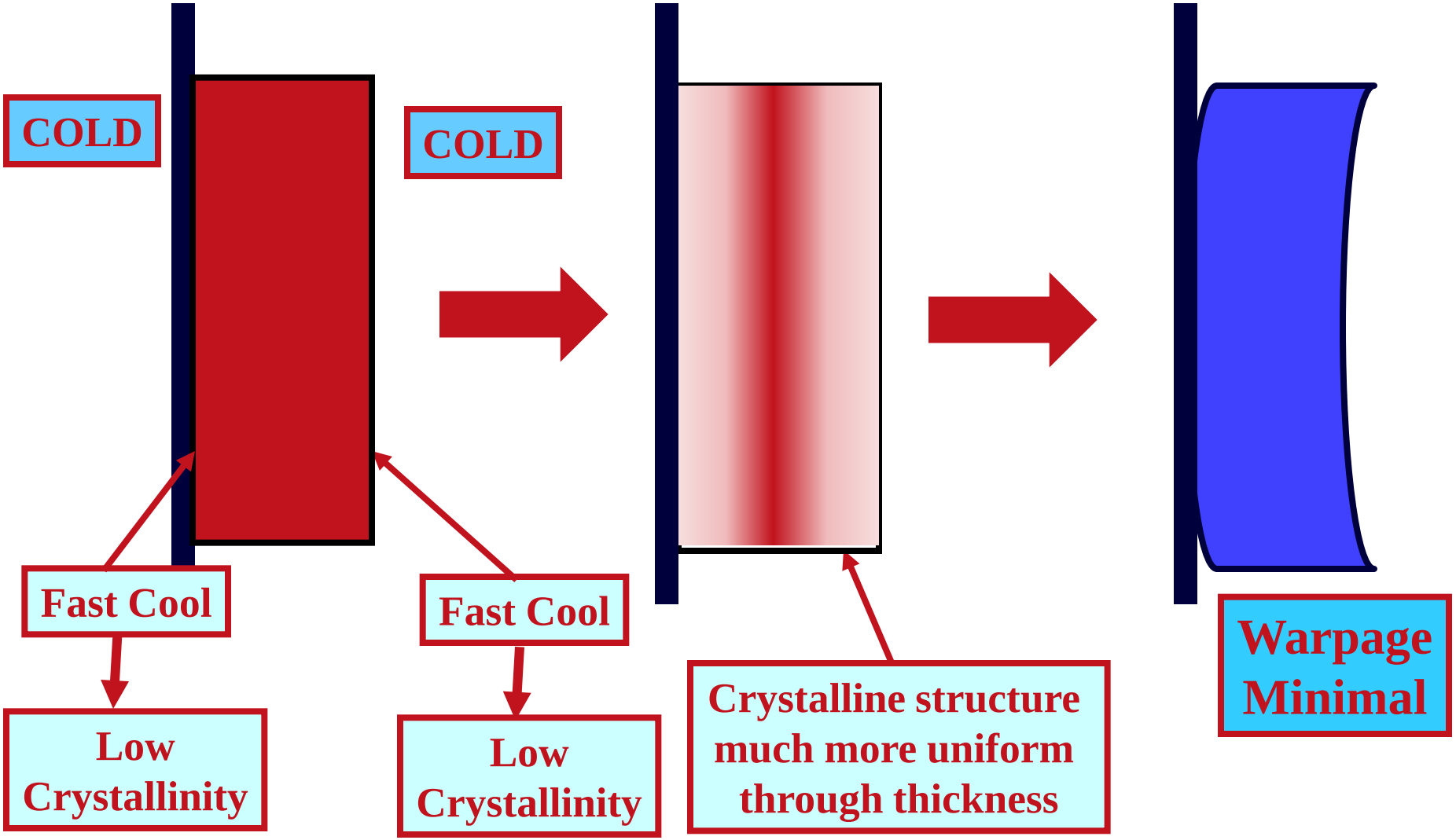
Structure Formation in Plastics



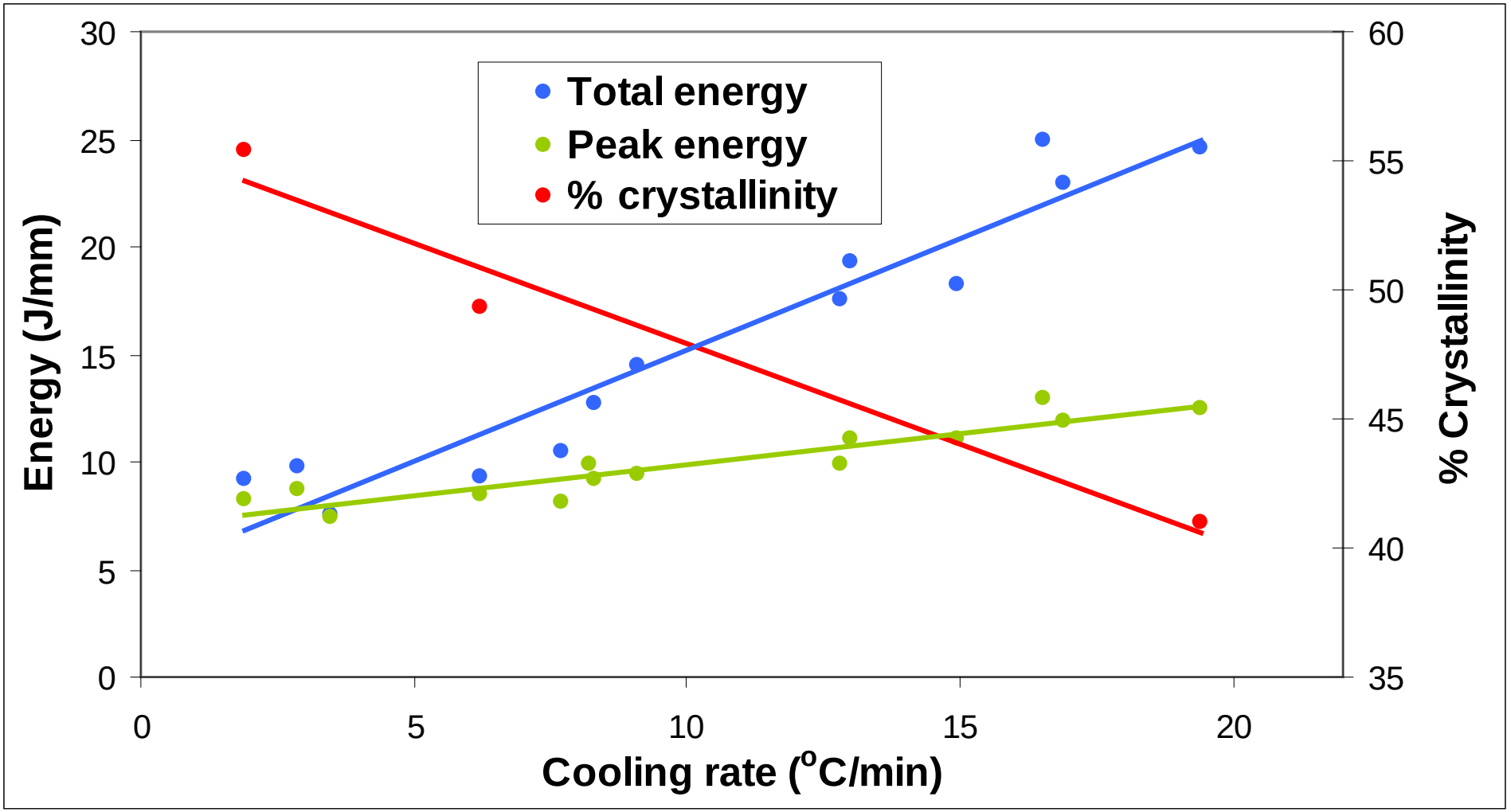
External Forced Air Cooling



External and Internal Water Cooling



Effect of Cooling rate on 3mm cube mouldings



Innovation in Rotational Moulding

The Evolution of Internal Mould Water Spray Cooling For the Rotational Moulding Process

•M.P. Kearns and M.P. McCourt: "A Rotomoulding Revolution: Rotocooler Internal Mould Water Spray Cooling", Rotoworld Vol X (2) pp.38-42 (2014)

•S.B. Tan, M.P. McCourt and M.P. Kearns, "Internal cooling in rotational molding--a review." Polymer Engineering and Science; 51(9):pp.1683 - 1692. (04/2011)

•S.B. Tan, "Accelerated Cooling of Thermoplastics in Rotational Moulding," Ph.D. Thesis in Mechanical and Aerospace Engineering, Queen's University Belfast, UK (2010).

•M.P. McCourt and M.P. Kearns, "The Development of Internal Water Cooling Techniques for the Rotational Moulding Process" ANTEC 2009 pp.1961-1965, (2009).

•S.B. Tan, M.P. McCourt and M.P. Kearns, "The Effects of Water Droplet Size and Velocity on Spray Cooling of Polymers during Rotational Moulding" ANTEC 2009 pp.1951 – 1955, (2009).

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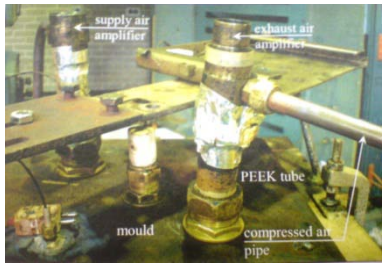
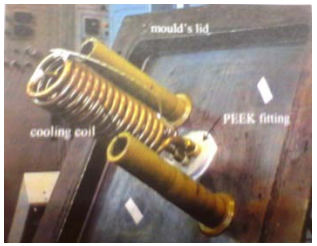
Internal Mould Cooling: Research to date - Evolution

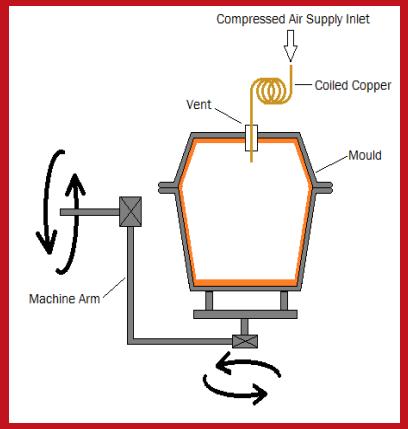
Internal cooling in Rotational Moulding

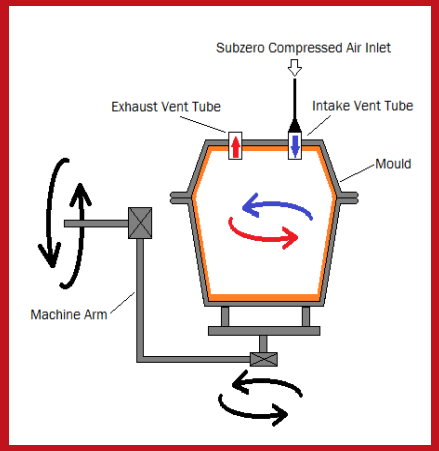
1. Use a pair of air movers, one for conveying air into the mould and one for exhaust.
2. Use a vent of 2 concentric pipes (central pipe for air into the mould and outer pipe for exhaust)
   - 2A. Use coiled copper pipe to bring in Pressurised air.
   - 2B. Use an air mover to force air into the mould.
3. Apply forced air convection with one end of the mould open.
4. Pump liquid N_2 into the cooling bay while installing air amplifier.
5. Supply the Induction air amplifier with liquid N2 and compressed air to supply exhaust air amplifier, mould not rotated.
6. Use chilled water cooling coil inside the mould for internal cooling
7. Inject liquid carbon dioxide into the mould
8. Supply of extremely dry compressed air at very low temperatures Constantly down to below -45°C into the mould. (CRAFT project)

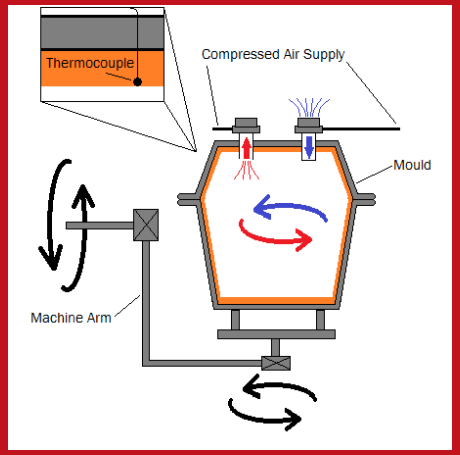


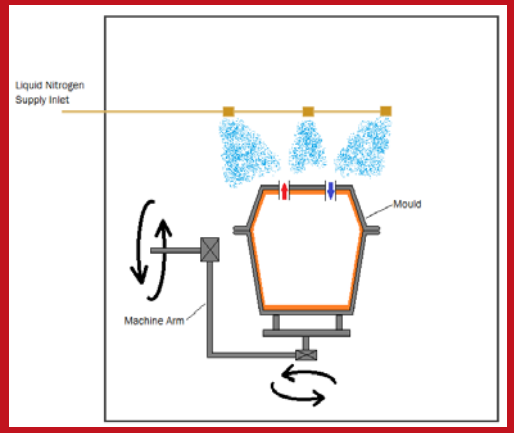


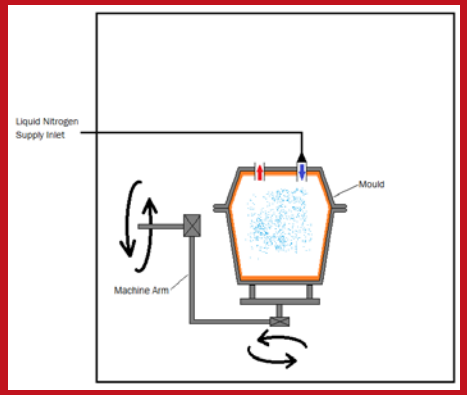
Internal Mould Cooling: Previous Research - Evolution

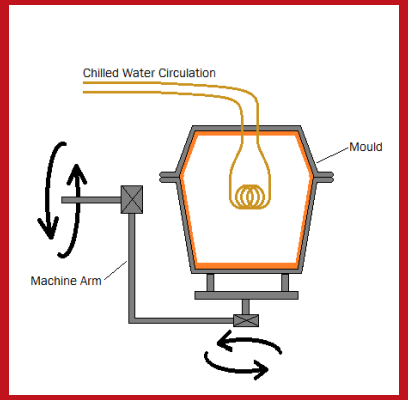












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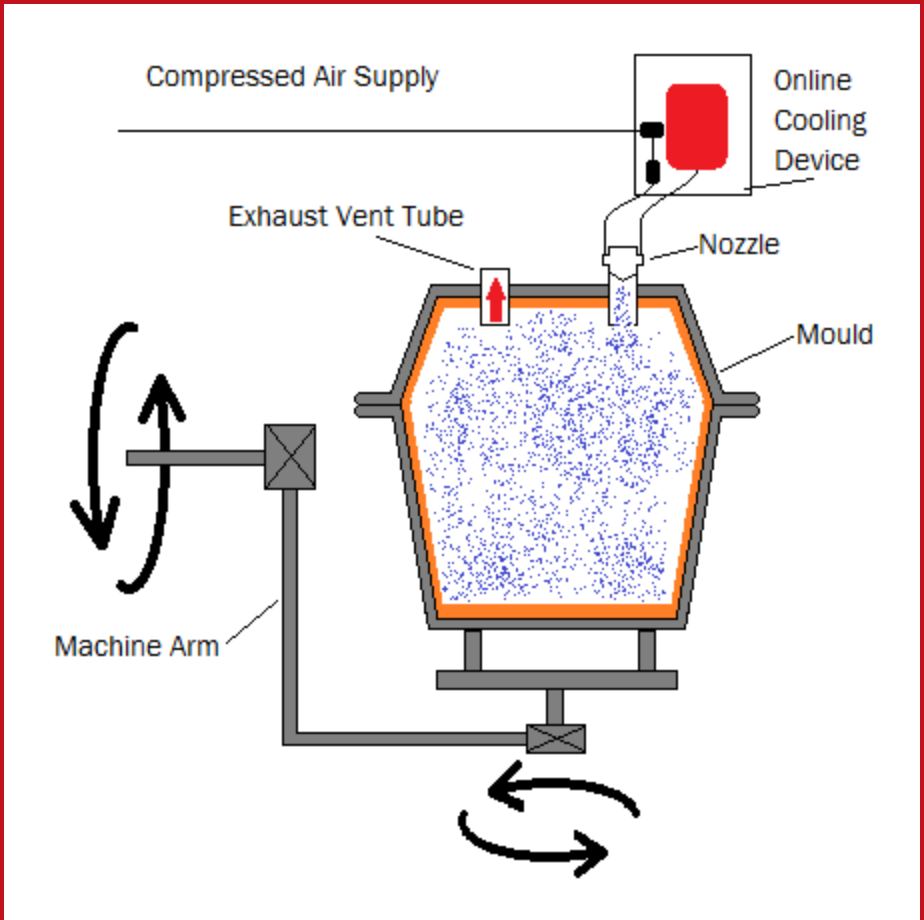
Future Proofing the Rotomoulding Industry



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Innovation in Rotational Moulding

Internal Mould Water Spray Cooling

Why it works.

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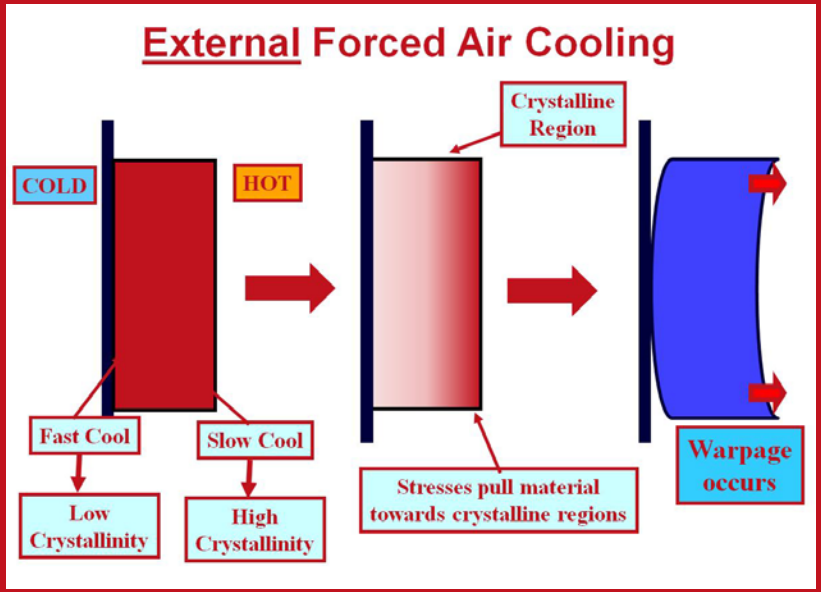
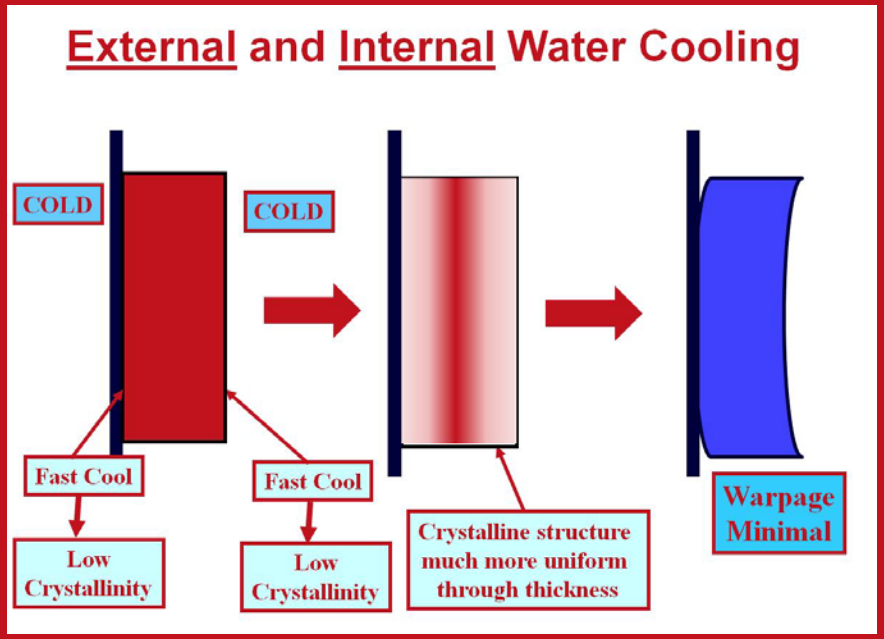
Innovation in Rotational Moulding



	Relative Convective H.T.C.
Still air	1
Forced air	5
Still water	50
Flowing water	200
Evaporating water	1000

- By accurately controlling cooling both internally and externally, very high rates of cooling can be achieved without warpage.



The Advantage of Internal Cooling

- Symmetrical, uniform cooling from both the inside and outside of the moulding produces a much more homogeneous crystalline structure across the thickness of the part.

- By spraying water into the centre of the moulding to internally cool the internal air / molten plastic during the cooling phase, permits water cooling to be used on the outside of the mould early in the cooling cycle.

- If performed incorrectly, there is the potential for minor surface imperfections on the inner surface of the moulding, there are no detrimental effects on mechanical properties.

Internal Mould Water Spray Cooling

- Fundamental understanding of the effect of water spray to cool molten polyethylene – spray nozzles, water characteristics, etc

- Experimental
  - Nozzle Type
  - DOE Study
  - Test mould analysis
  - Mechanical and Shrinkage Testing

- Industrial Water Cooling Trials

Phase Doppler Particle Analyzer (PDPA)

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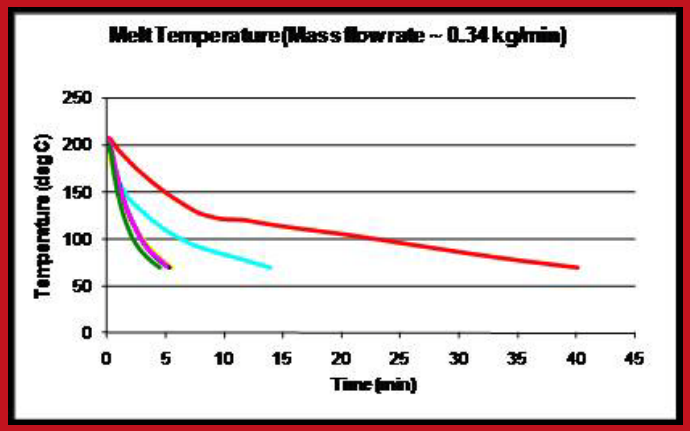
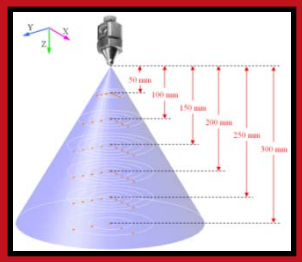
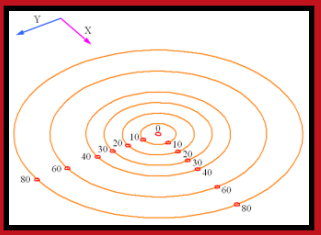
Factors Effecting Internal Water Cooling

- Water volume
- Size of droplets
- Velocity of droplets
- Mass flow rate
- Water / Air pressure
- Spray distance
- Duration of internal water cooling
- Internal water initiation temperature

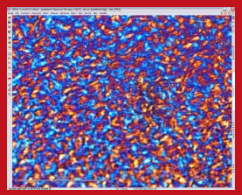




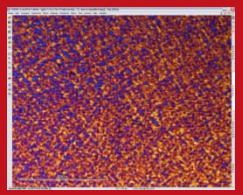


Outcomes

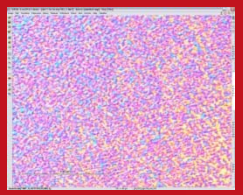
- Cooling rate
- Part quality
- Shrinkage / Warpage



Ambient



Nozzle A



Nozzle B

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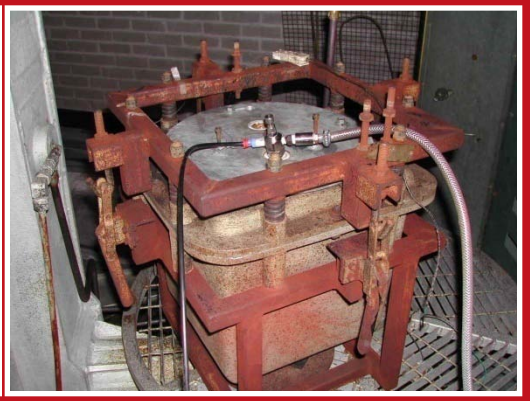
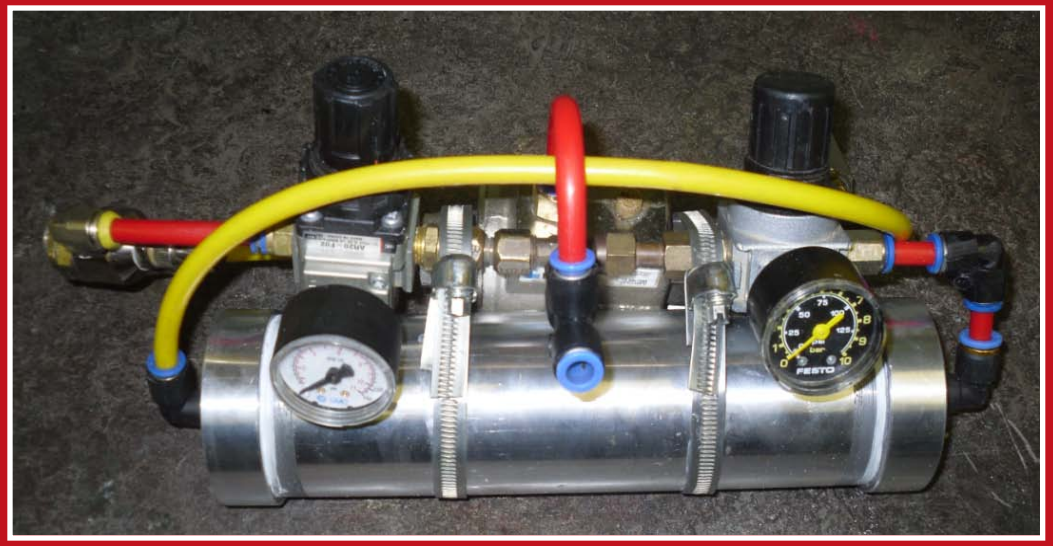
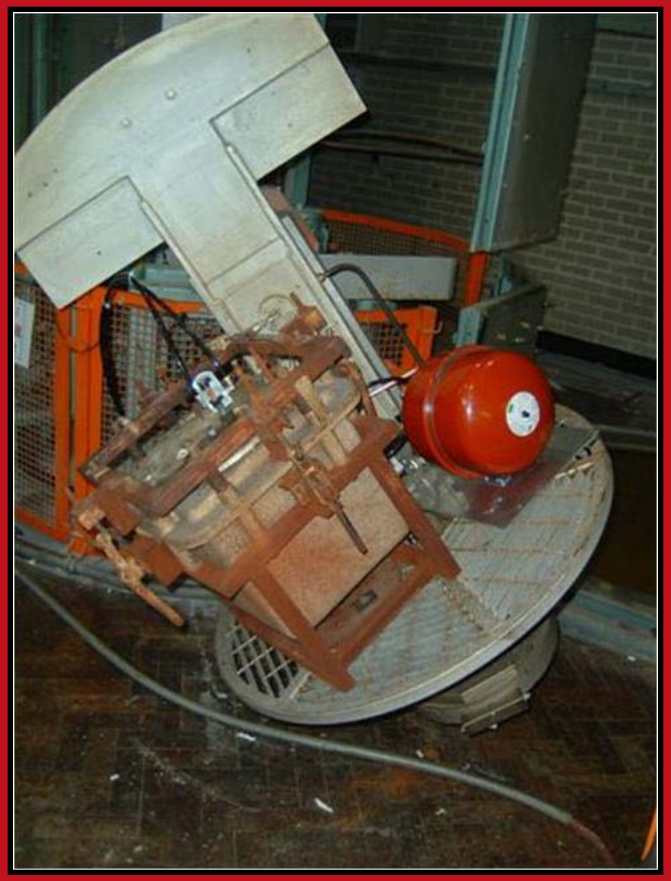
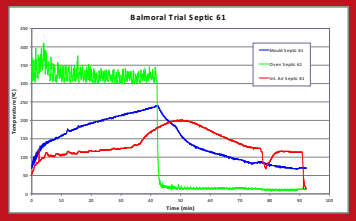
Future Proofing the Rotomoulding Industry

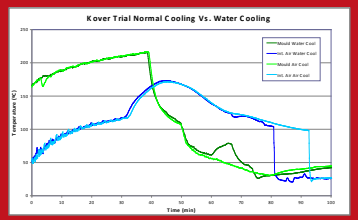




Future Proofing the Rotomoulding Industry







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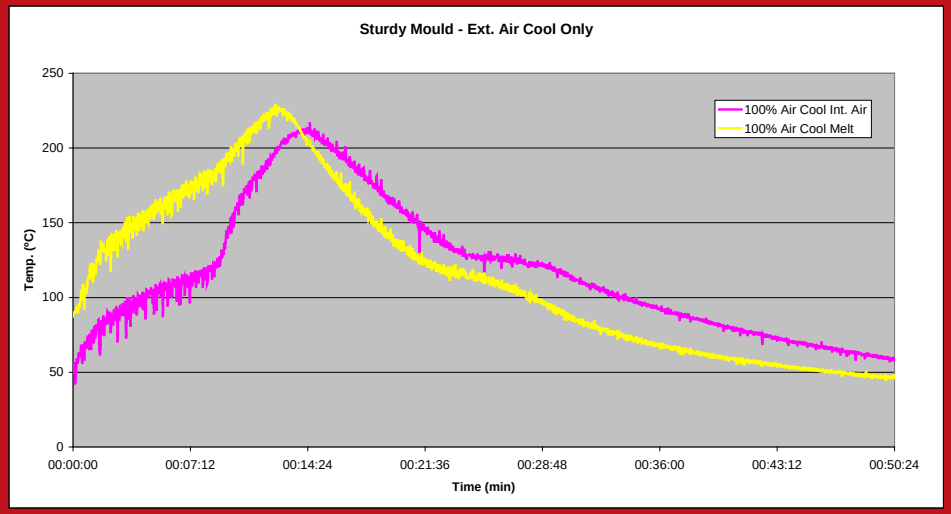
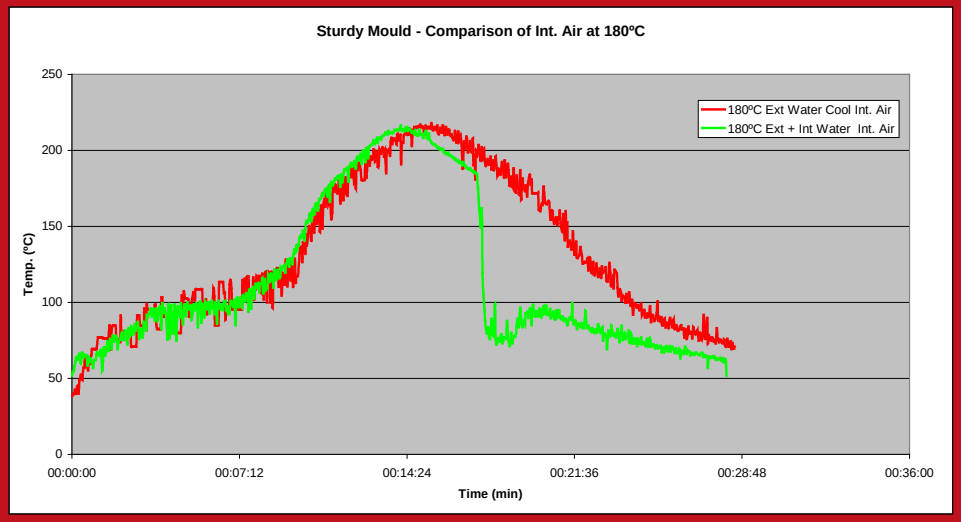
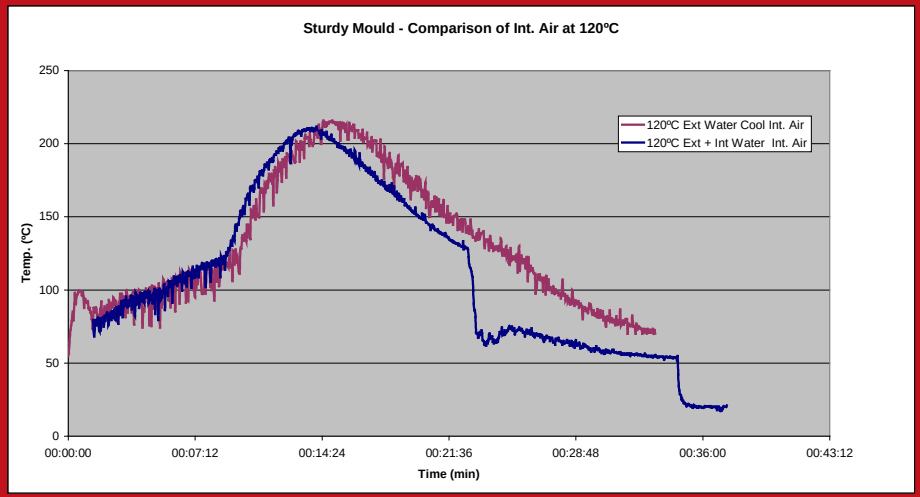
Steel Test Mould – Internal Air

Ext. Water Cooling Vs. Ext. Water + Int. Water Cooling



- Steel Mould
- Shot weight = 8.4kg
- Wall thickness ~ 6mm
- Dim: 500 x 500 x 520mm



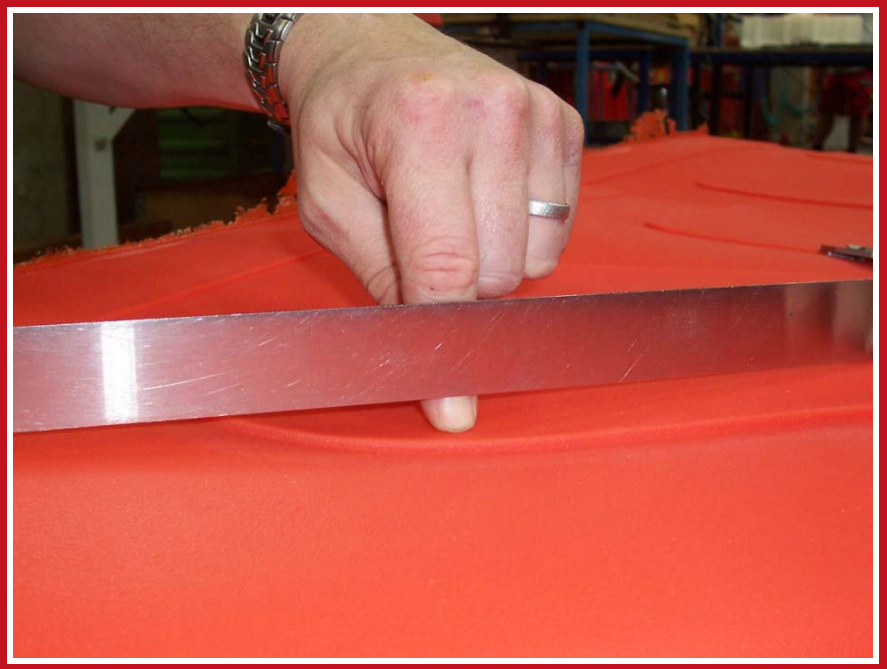


External and Internal Water Cooling

Ext. Water Cooling Only

Ext.+ Int. Water Cooling

Internal Water Cooling
Industrial Trials - floor cleaning product



External Air Cool

Int. + Ext. Water Cool

Internal Mould Water Spray Cooling Rotocooler® Development

How it works.

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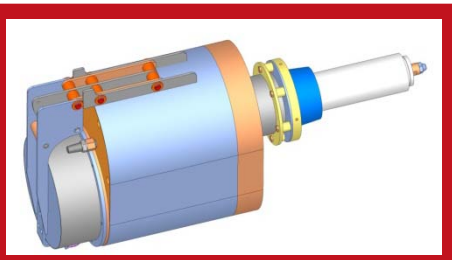
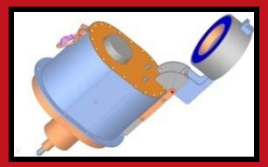
Rotocooler® Development

- The Rotocooler® has been further developed through working in partnership with rotomoulding tool manufacturer Maus GmbH.



- Various parameters have been taken into account with regards to the commercial development such as mechanics, safety, ease of use, etc.

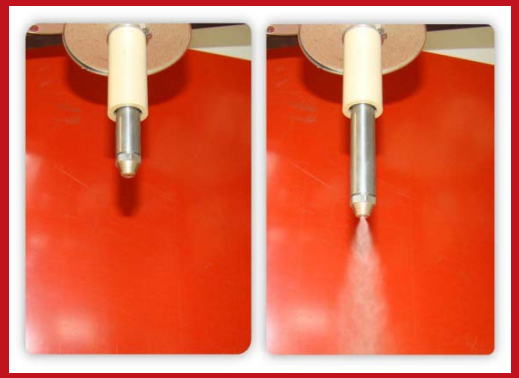
- Rotocooler® system consists of an insulated, double walled stainless steel housing with interior mechanics and a pressure-free replaceable water cartridge

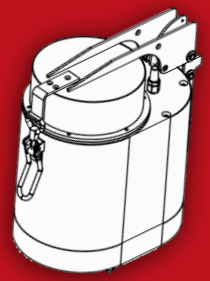


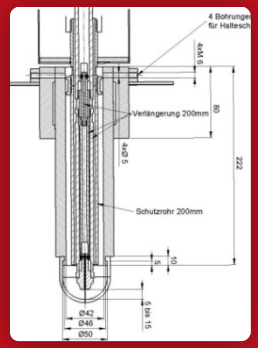
Rotocooler® Development

- The Rotocooler® is mounted to the mould frame and activated by compressed air, which introduces the spray nozzle into the mould and producing a fine water mist which rapidly evaporates, cooling the internal air

- The system requires an airline of 3 bar (min) pressure for activation of the cylinder. The possibility to turn the air on/off during the cooling stage is desirable.

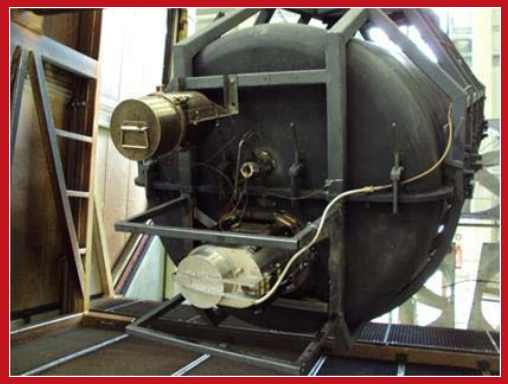




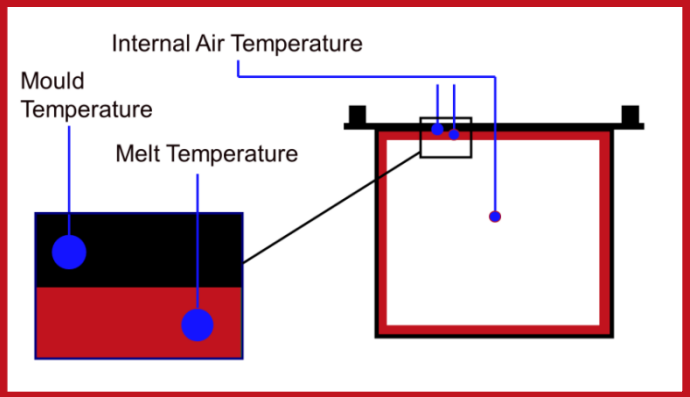


Rotocooler® Development

- It is recommended to use a temperature monitoring device to identify and eventually optimise the specific internal air temperature at which to introduce the water spray.

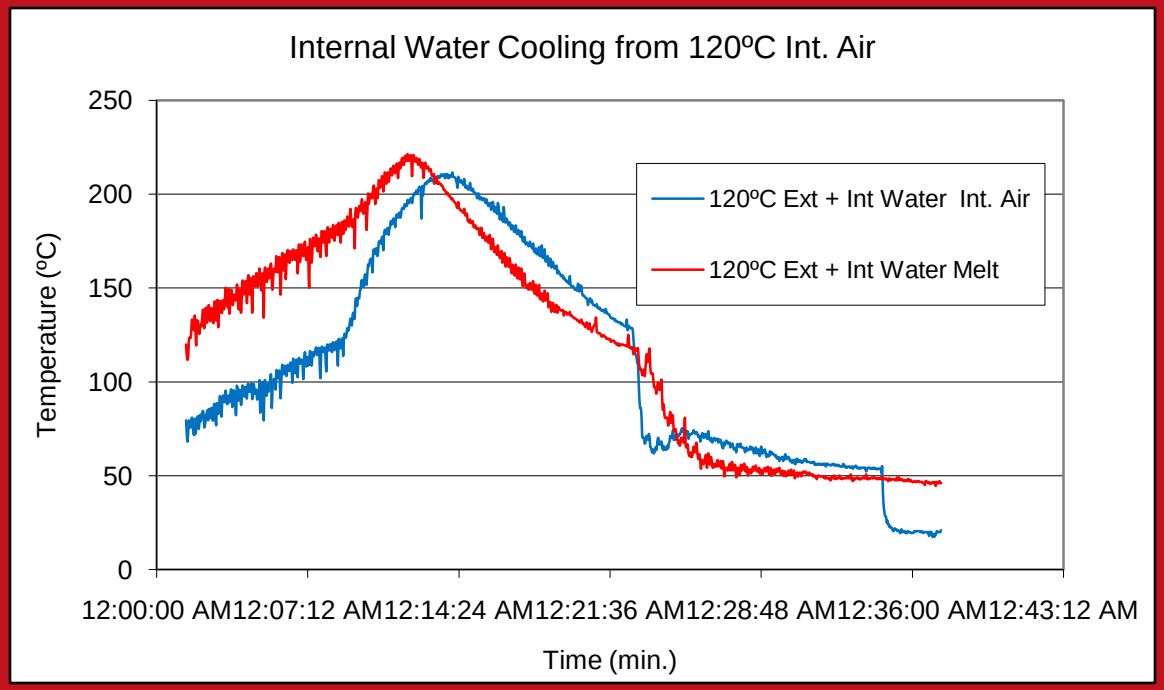


- Since the internal air temperature decreases rapidly with the application of internal water cooling, it may be necessary to add additional thermocouples to measure ‘melt’ temperature and / or mould temperature



Rotocooler® Development

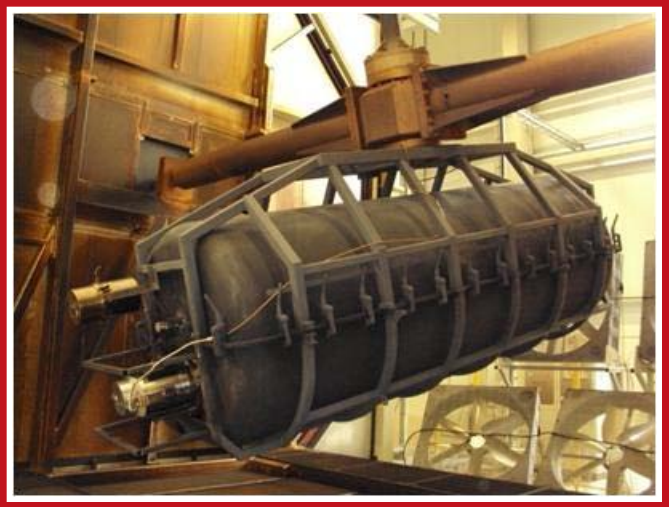
- The advantage of monitoring the melt temperature can be observed in the Figure below which shows the internal air and mould temperature with the onset of internal cooling at 120ºC.



Rotocooler® Development

- Internal Cooling optimisation enables the use of more ‘heavy’ external water cooling further balancing cooling rates and significantly reducing cycletimes.

- Faster, controlled cooling can improve mechanical properties, it is always recommended to check properties after any modification or deviation from the conventional heating / cooling cycle.

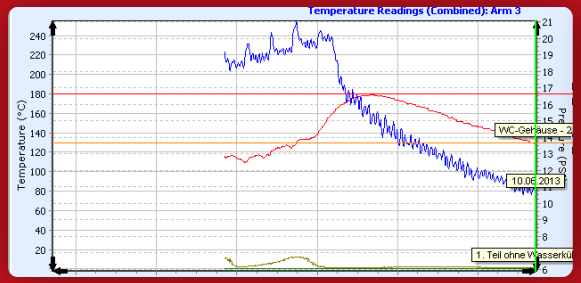


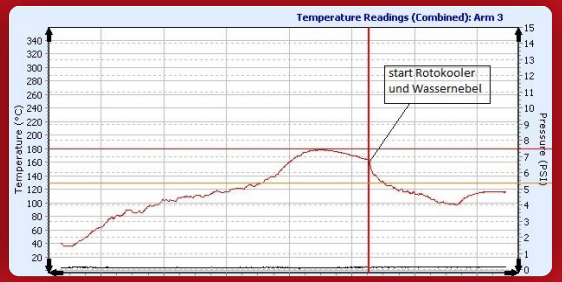
Rotocooler® Development

- Care should also always be taken to ensure proper venting of the mould.
- Depending on the shape and design of the mould Rotocooler® should ideally be positioned in the line/direction of de-moulding.

Rotocooler®

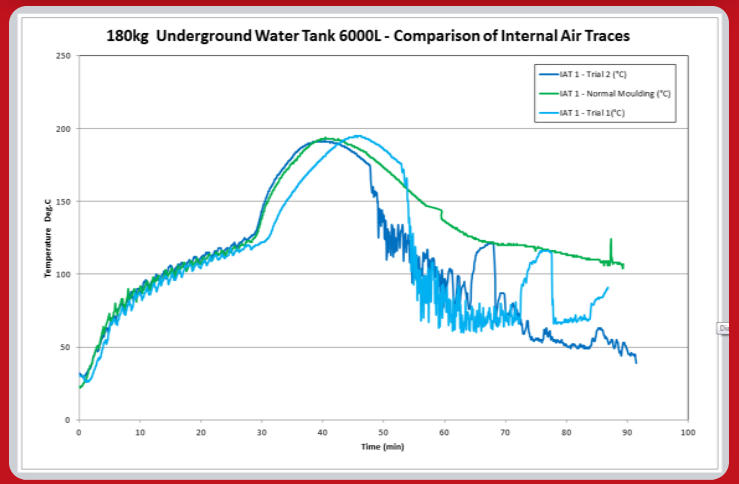
- Trial with toilet cabinet
- Shot weight 106 lb.
- Wall thickness 1/5“
- Very straight walls
- Reduced cooling by 28 %
- Straight walls stay flat
- Jigging NOT necessary (normal 90min jigging + handling – zero with Rotocooler)





Rotocooler®

- Steel mould for 6200L (1637Gal) water tank
- Shot weight 400lb
- Wall thickness ½“
- Straight walls + ribs
- Reduced cooling by 35% (normal 52min / with Rotocooler 33min)
- Straight walls and ribs greatly improved



Rotocooler®

Total Material Trials -
Rokuplast, Germany, August 2014

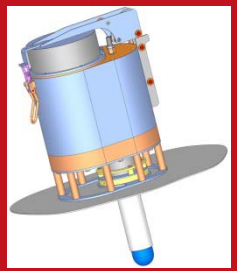
Materials tested:

High Density PE
Medium Density PE
Polypropylene

Rotocooler®

- Bottle Mould
- Sheet Steel tool
- Material Shot Weight – 140kg
- 6-8mm thickness
- 5300 litre capacity

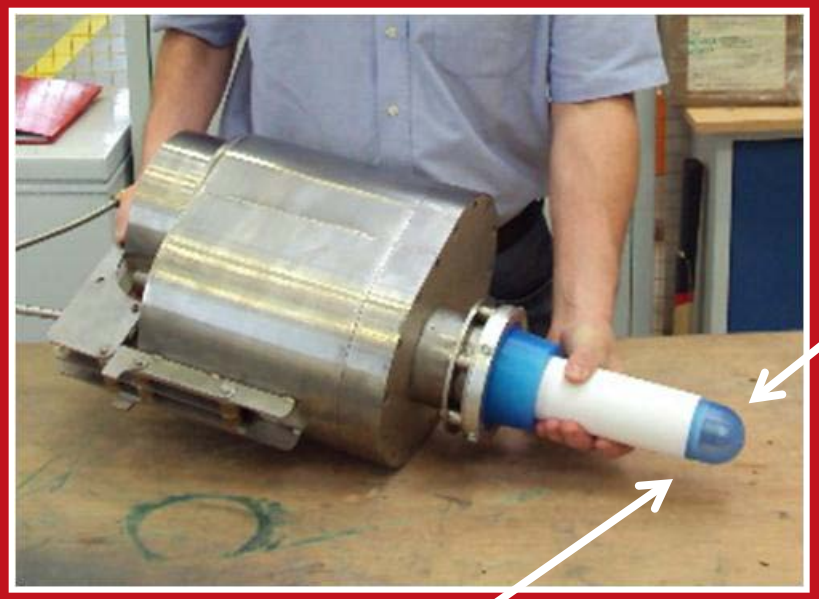
- Rotomachinery SRM 3 Sided / 3 arm Shuttle Machine
- Spherical diameter 6500 mm
- Largest machine in Europe



Rotocooler®

- Dedicated framework on mould to allow for easier mounting of Rotocooler on mould

Rotocooler®



Smaller opening for spray nozzle to prevent contamination

Spray nozzle modified to suit long mould i.e. long cylindrical spray pattern

Rotocooler®

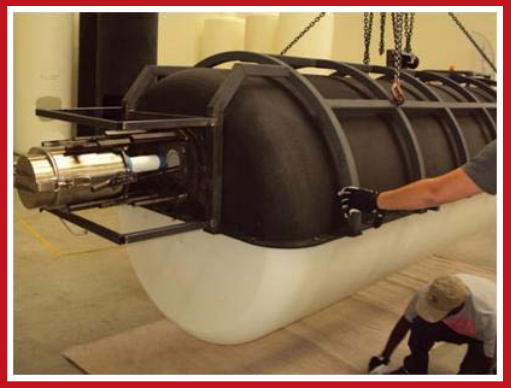
PTFE collar to prevent heat build-up on spray nozzle tube

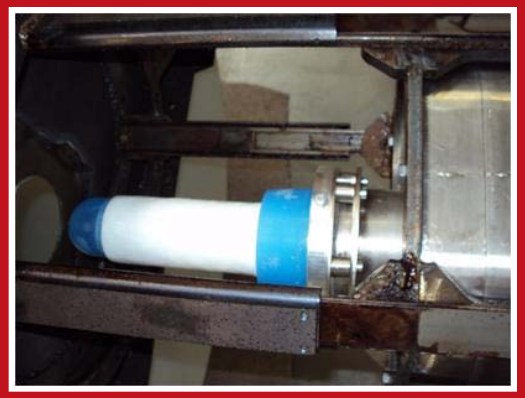
Silicone Collar to prevent powder / polymer contamination on unit

Queen's University Belfast

Rotocooler® Setup

TOTAL
COMMITTED TO BETTER ENERGY






Queen's University Belfast

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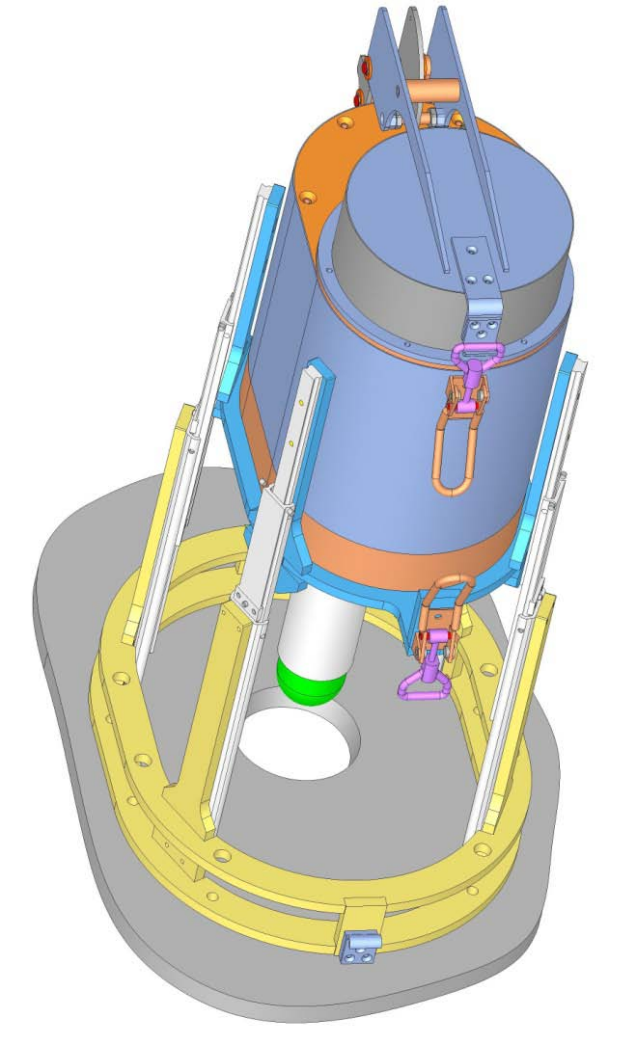
Rotocooler® Frame

Maus ROTATIONAL MOULDS



Queen's University Belfast

Rotocooler®

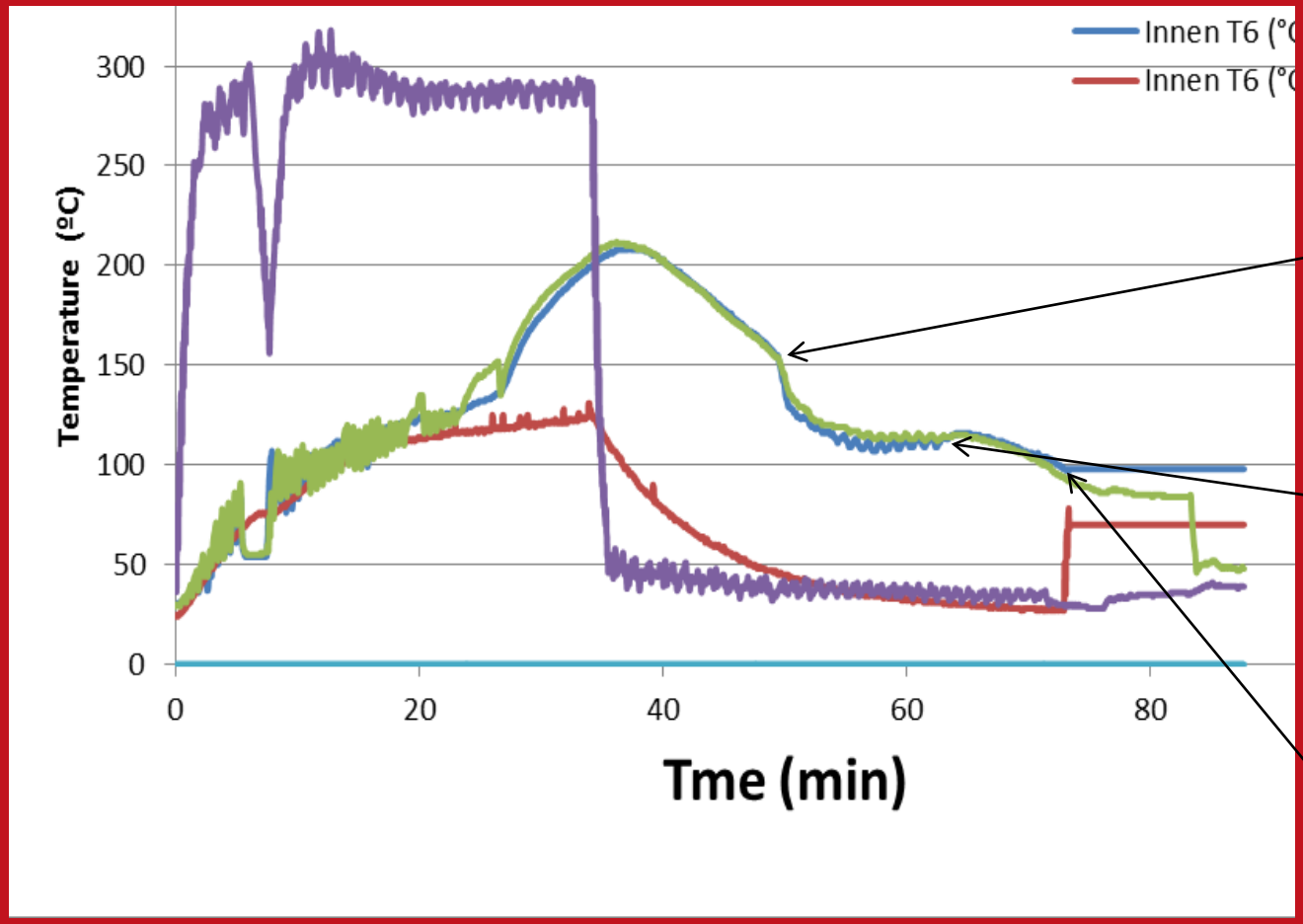
Maximum **charge** with demineralized water:	2.5 US Pt. (1.2 L)
Pressure in **water cartridge**:	zero pressure
Spraying time [2,5 US Pt., Z30 nozzle, 58Psi]	approx. 18 min
(extends by weaker nozzle and/or lower pressure - shortens by stronger nozzle and/or higher pressure)	
Minimum air line pressure to activate Rotocooler Recommended air pressure:	43 Psi (3Bar) 58 Psi (4Bar)
Compressed air consumption with Z30 nozzle: (weaker nozzles consume less air, the consumption depends on the pressure)	approx. 26 Gal/min (100 Liter/min) = 212 ft^3/h (6m^3/h)

Rotocooler®

Without Rotocooler

With Rotocooler

Rotocooler®

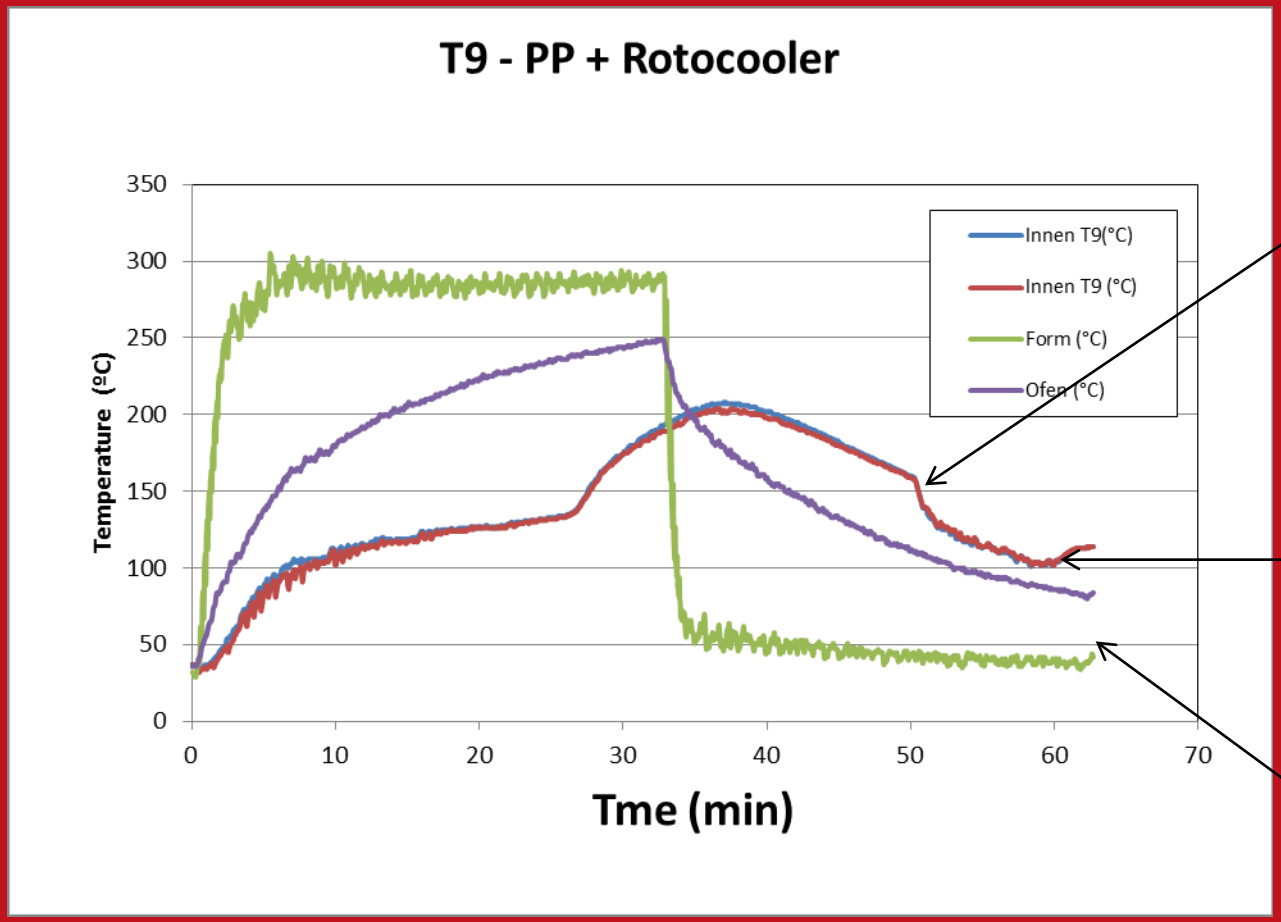


Rotocooler switched on at 160ºC

Compressed Air Stopped

Moulding Stopped

Rotocooler®

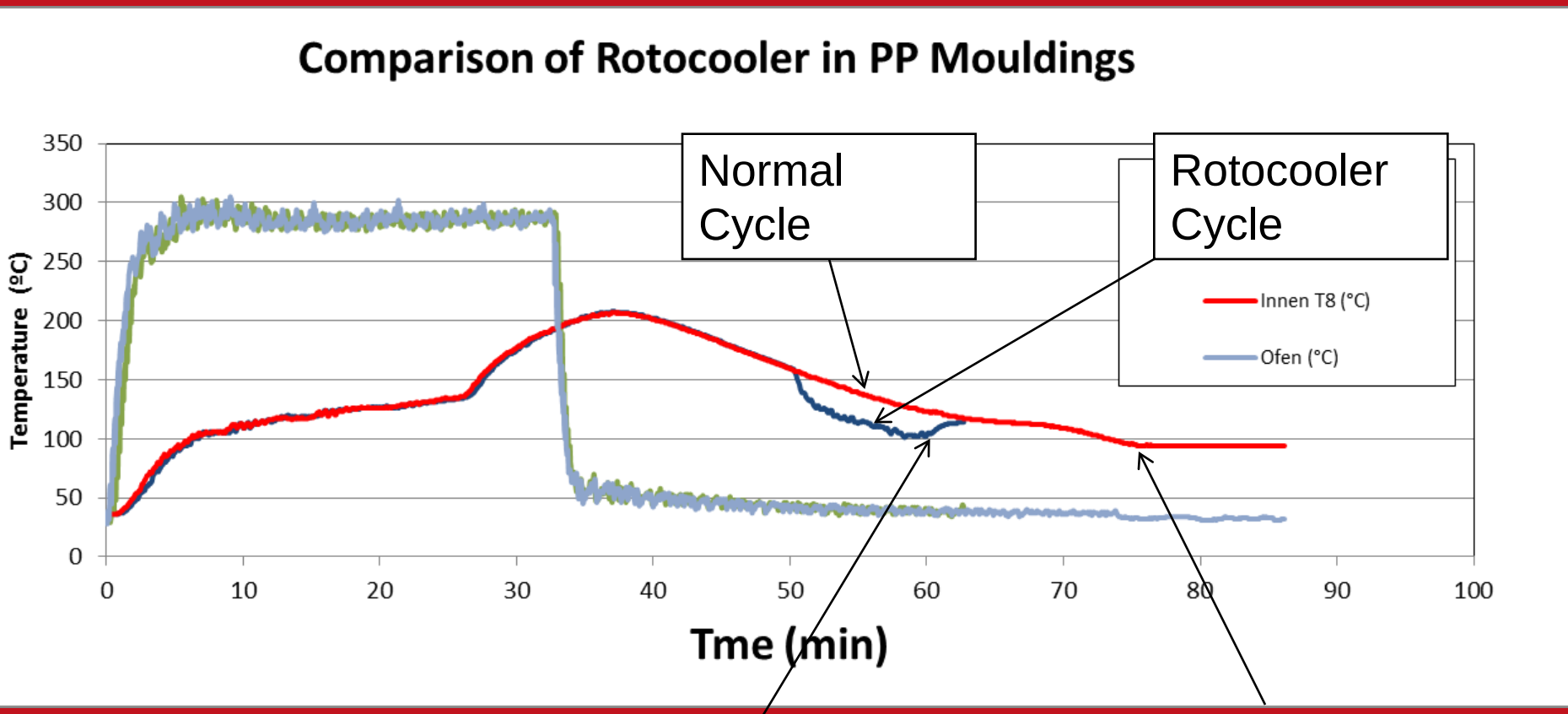


Rotocooler switched on at 160ºC

Rotocooler empty

Moulding Stopped

Rotocooler®


Comparison of Rotocooler in PP Mouldings
Temperature (ºC)
350
300
250
200
150
100
50
0
0
10
20
30
40
50
60
70
80
90
100
Tme (min)
Innen T8 (°C)
Ofen (°C)
Normal Cycle
Rotocooler Cycle
Rotocooler Moulding Stopped 61mins
Normal Moulding Stopped 75mins

Rotocooler®

- PP Normal air cooled cycle = 75 minutes
- PP Rotocooler cycle = 61 minutes

- PP moulding quality excellent in both parts, no differences in terms of shrinkage / warpage observed between Rotocooler and normal mouldings

Industrial Trials

Industrial Trials to date:

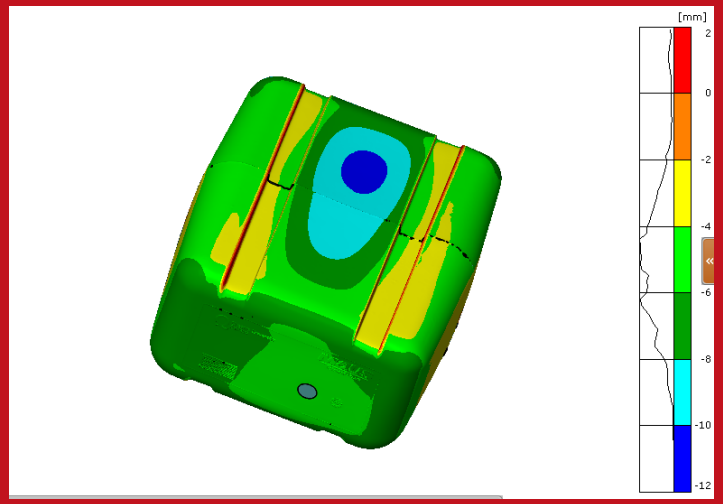
- Average cycletime savings of 15 - 20% achievable with no effect on inside surface quality – not using external water
- With further optimisation 30%+ possible combining external water cooling and applying internal water at higher internal air temperatures

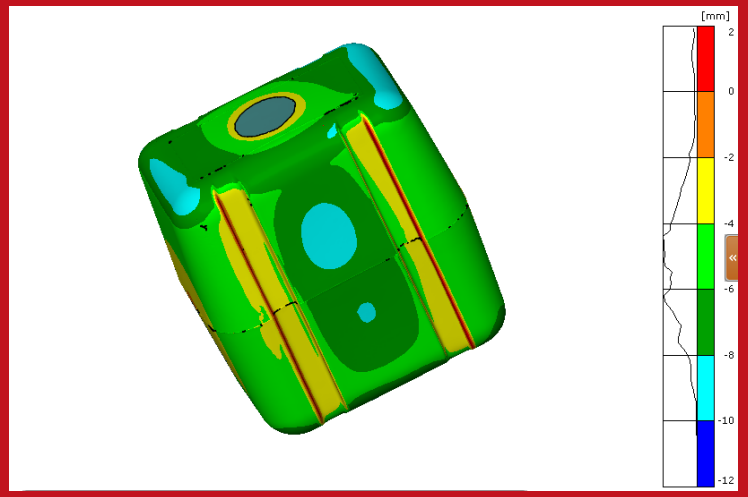
3D Analysis

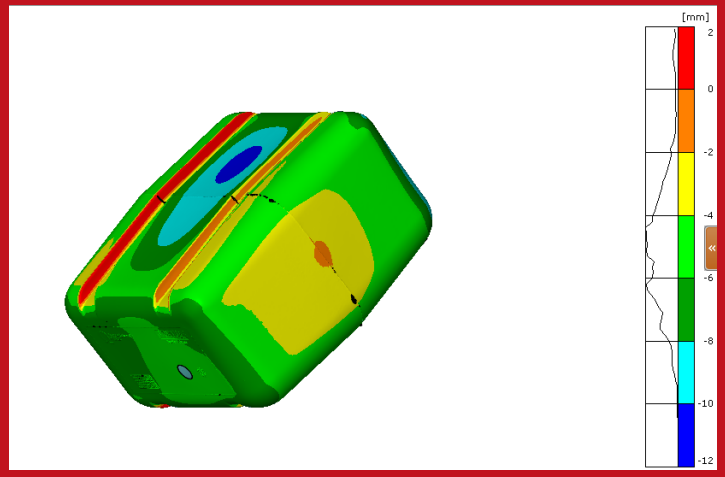
- 3D Analysis QUB mould Total M3581UV PE moulded with and without Rotocooler

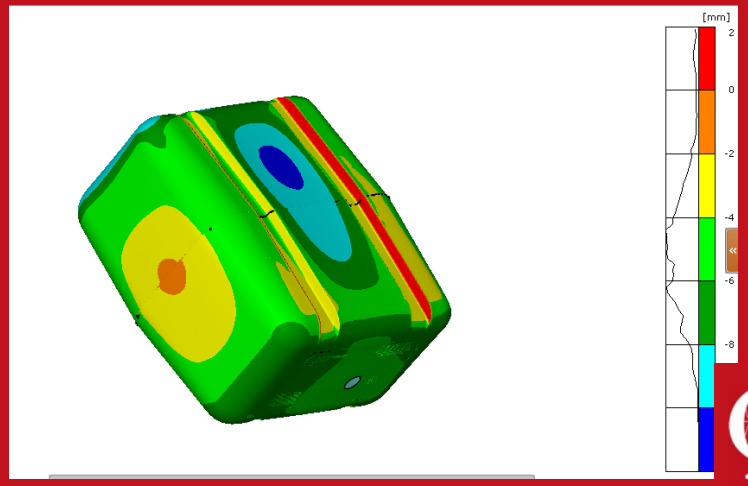
No Rotocooler®

3D Analysis QUB mould Total M3581UV PE moulded without Rotocooler



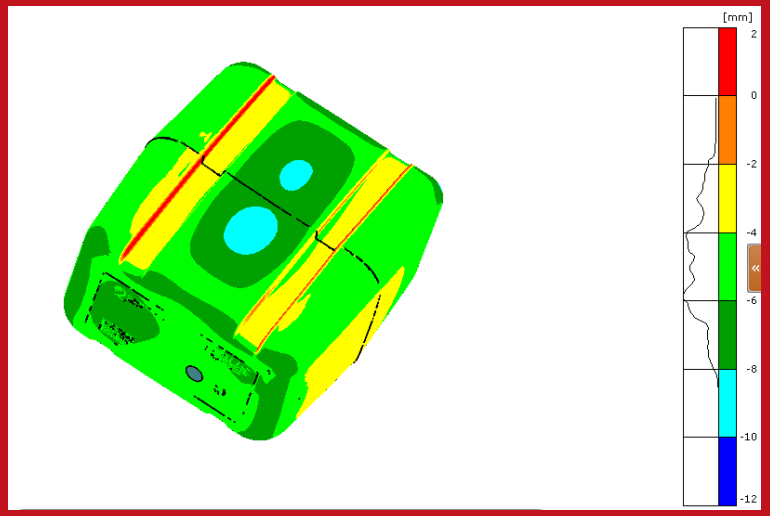


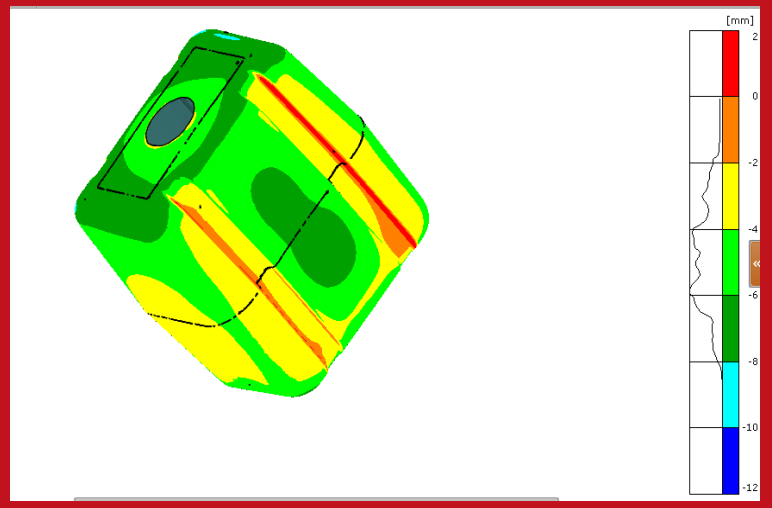


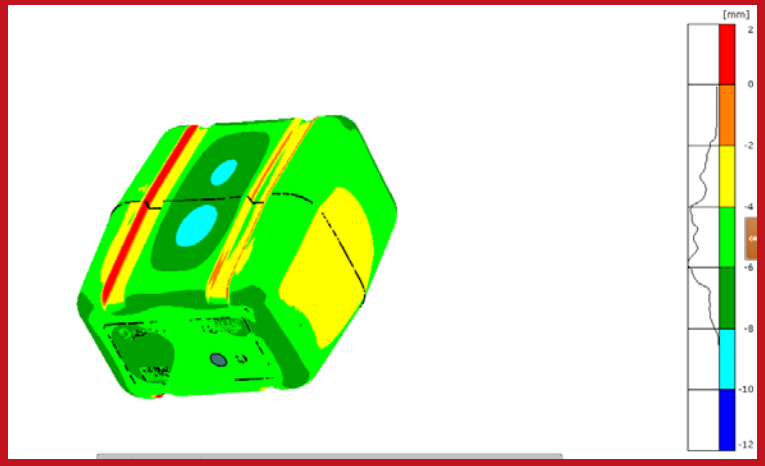


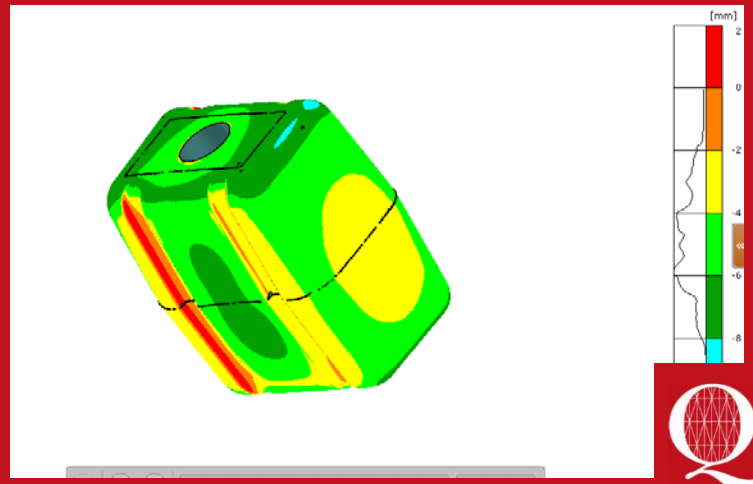
With Rotocooler®

3D Analysis QUB mould Total M3581UV PE moulded with Rotocooler









Summary

- The Rotocooler device attaches and travels with the mould.
- At the appropriate temperature / time it accurately sprays a controlled water jet into the centre of the rotating moulding.
- The effect of this is to internally cool the plastic part.
- There is no detrimental effect on part quality.
- There is no detrimental effect on mechanical properties.
- There is a reduction in cooling time.
- There is a reduction in warpage / shrinkage.
- Balanced internal / external cooling is achievable.

Summary

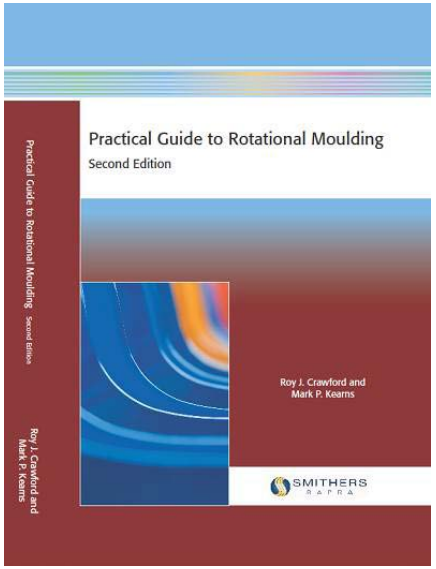
- Increased efficiency – optimising machine usage, production throughput can be maximised.
- Lower production costs -Reduced cycletime will significantly lower production costs
- Improved part quality - products with less warpage and less shrinkage
- Improved dimensional properties - Reduced warpage and shrinkage enables better dimensional properties and tolerances
- Reduced Energy Usage - production efficiencies are optimised and less energy is required to cool the products
- New High-Technology Product development – e.g. skin/foam/skin, Higher density PE, PP, engineering polymers, etc

Innovation – Evolution or Revolution?

- Innovation isn't about either evolution or revolution – it's about both.
- Evolutionary Innovation tends to optimize the world as is, whereas Revolutionary Innovation aims at creating the world as it could be.
- Evolution needs revolution in order to explore further potential to be tapped.
- Revolution needs evolution in order to survive and thrive.

Do something Revolutionary and then make Evolutionary changes

Many thanks for your attention…..



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