As the molten polymer enters the cavity and comes into contact with the (relatively) cool surface of the steel mould, an instantaneous frozen skin layer is formed (blue).

Plastic adjacent to the frozen skin begins to cool rapidly, with a subsequent increase in polymer viscosity (yellow).

Highest flow is in the centre of the section where the polymer is hottest and viscosity is lowest (red).
If the surface temperature of the mould tool is heated above the $T_g$ (Glass Transition) temperature of the polymer, the frozen skin layer that normally forms is retarded.

This results in many benefits for both the process and the molded article as detailed in the following slides:
RAPID ISOLATION COOLING & HEATING - RICH

BENEFITS:

• Elimination of all visible weld / meld / flow lines……, NO PAINTING REQUIRED !!

• Very high gloss surface – even with standard resin grades…….NO PAINTING REQUIRED !!

• No surface blooming of glass fibres…….NO PAINTING REQUIRED !!

• Elimination of silver streaks and splay marks (Structural Foam)…….NO PAINTING REQUIRED !!

• Excellent replication of mold surface (transcription of surface micro / nano features)

• Improved optical properties – less birefringence and more uniform refractive index (lenses)

• *Thin wall sections with long flow lengths possible (light weighting)*

• Shorter cycle times achievable (when down sizing wall sections)
RAPID ISOLATION COOLING & HEATING

WELD LINE STUDY

(COURTSEY SWANSEA UNIVERSITY)
Weld Line Study
(Courtesy Swansea University)
Weld Line Study
(Courtesy Swansea University)
Weld Line Study

Measurement of weld lines using White Light Interferometry
ABS Dish Mould

View on sample surface
Weld Line Study

Measurement of weld line using WLI

Cross section of a sample from which the depth and the width of the Weld line can be obtained
Weld Line Study

Area Studied

MATT ABS WITH RICH
Weld Line Study

Measurement of weld lines with the WLI

Cross section of a sample produced with RICH technology
RAPID ISOLATION COOLING & HEATING

SURFACE ROUGHNESS STUDY

(COURTSEY SWANSEA UNIVERSITY)
Surface Roughness Study
(Courtesy Swansea University)

FOAMED ABS  NO RICH
Surface Roughness Study

STEREO SCAN MICROSCOPY OF FOAMED ABS SURFACE

500μm
Surface Roughness Study

CONTACTLESS SURFACE ROUGHNESS MEASUREMENT USING WHITE LIGHT INTERFEROMETRY (WLI)

FOAMED ABS NO RICH
Surface Roughness Study

FOAMED ABS WITH RICH
Surface Roughness Study

WHITE LIGHT INTERFEROMETRY SCAN OF SURFACE

FOAMED ABS WITH RICH
Surface Roughness Study

LONG GLASS FIBER PP NO RICH
Surface Roughness Study

STEREO SCAN MICROGRAPH OF SURFACE

LGF PP NO RICH
Surface Roughness Study

WHITE LIGHT INTERFEROMETRY SCAN OF SURFACE

LGF PP NO RICH
Surface Roughness Study

LONG GLASS FIBER PP WITH RICH
Surface Roughness Study
STERO SCAN MICROGRAPH OF SURFACE

LGF PP WITH RICH
Surface Roughness Study

WHITE LIGHT INTERFEROMETRY SURFACE SCAN

LGF PP WITH RICH
SURFACE ROUGHNESS COMPARISON ABS/PMMA

% IMPROVEMENTS WITH RICH

ABS / PMMA STD IM

ABS / PMMA WITH RICH

Ra/nm: 47.3%
Rq/nm: 48.7%
Rz/um: 44.1%
Rt/um: 31.1%
SURFACE ROUGHNESS COMPARISON FOAMED ABS

% IMPROVEMENTS WITH RICH

FOAMED ABS IM  |  FOAMED ABS RICH
---             |  ---

<table>
<thead>
<tr>
<th>Metric</th>
<th>FOAMED ABS IM</th>
<th>FOAMED ABS RICH</th>
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<td>Ra/nm</td>
<td>95.4%</td>
<td>95.0%</td>
</tr>
<tr>
<td>Rq/nm</td>
<td>88.9%</td>
<td>86.4%</td>
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<tr>
<td>Rz/um</td>
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<tr>
<td>Rt/um</td>
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</table>
SURFACE ROUGHNESS COMPARISON PP WITH LONG GLASS FIBER

% IMPROVEMENTS WITH RICH

PP LONG GLASS FIBRE IM

PP LONG GLASS FIBRE RICH

Ra/nm
Rq/nm
Rz/um
Rt/um
RAPID ISOLATION COOLING & HEATING

REDUCED FILLING PRESSURES

OR

LONGER FLOW LENGTHS WITH LOWER WALL SECTIONS
WITHOUT RICH

ABS
Wall section 1.0mm
Tmold 60°C
WITH RICH

- ABS
- Wall section 1.0m
- Tmold 160°C
RAPID ISOLATION COOLING & HEATING - RICH

STEAM HEATING WITH WATER COOLING
RAPID ISOLATION COOLING & HEATING WITH STEAM

The process involves the rapid heating (6 - 20 seconds) of the surface of the mold tool using saturated steam with a temperature of up to 244°C followed by “turbulent” flow of cooling water to quickly cool down the molded part.
RICH TRIAL WITH PA6 MATERIAL
WHY USE STEAM?

1 kg Water at 100\(^\circ\) Celsius = 419 kJ/kg (Sensible Heat)
Latent Heat Vaporization = 2257 kJ/kg (Latent Heat)
1 kg Steam at 100\(^\circ\) Celsius = 2676 kJ/kg (Total Heat)

i.e. steam has more than six times the heat energy of water at the same temperature - 100\(^\circ\) Celsius
WHY USE STEAM?

RICH controllers use steam at up to 35 BarG steam pressure.

At a pressure of 35 BarG the steam has a temperature of 244.26° Celsius and a total heat energy of 2803.2 kJ / kg.
RAPID ISOLATION COOLING & HEATING - RICH

THE TECHNOLOGY CONSISTS OF TWO MAIN ELEMENTS

• RICH steam heating system
• RICH mold design
RAPID ISOLATION COOLING & HEATING - RICH EQUIPMENT

WATER TREATMENT SYSTEM

RICH STEAM SYSTEM
RAPID ISOLATION COOLING & HEATING - RICH INSTALLATION
RAPID ISOLATION COOLING & HEATING – RICH INSTALLATION

INJECTION MOULDING MACHINE

COOLING TOWER

DRAIN

AIR SUPPLY

RICH STEAM GENERATOR WATER SUPPLY
RAPID ISOLATION COOLING & HEATING - RICH

1. Inject Air to evacuate cooling water
2. Inject Steam to raise mould temperature
3. Inject Plastic
4. Inject Air to evacuate steam
5. Start cooling water flow to reduce mould temperature for part cooling
RICH EQUIPMENT

NOW WITH INTEGRATED ELECTRIC STEAM BOILER

MODELS 48KW – 240KW
RICH EQUIPMENT

RICH2 STEAM CONTROLLER - GENERATOR
RAPID ISOLATION COOLING & HEATING

RICH MOLD DESIGN

- CONFORMAL CHANNEL DESIGN
- MOLD STEEL SELECTION
- ANALYSIS USING Moldex 3D TO DETERMINE:
  HEATING SPEED/COOLING SPEED
  CYCLE TIME
  HEATING UNIFORMITY
  MOLD FILLING AND PACKING
RAPID ISOLATION COOLING & HEATING

RICH MOLD DESIGN

TWO CASE STUDIES

• AUTOMOTIVE COVER (ASA RESIN)
• BATHROOM VENT COVER (PVC RESIN)
RICH ANALYSIS

Part Design Review

Conformal Channel Design

Model into Mold Blocks

Model Part into Conformal Channels
RICH ANALYSIS
RICH ANALYSIS

Heating – 13 Sec

Plastic Injection Time – 3 Sec

Plastic Packing Time – 13 Sec

Cooling Time – 13 Sec

A Side Temperature Curve

B Side Temperature Curve

Moldex3D
Filling Pressure with and without RICH

This image shows the injection pressure predicted as an injection moulding.
Filling Pressure with and without RICH

This image shows the same pressure using the RICH process. The pressure of fill is less than half that of the injection moulding.
RICH CASE STUDY

PVC VENT COVER
RICH Moldex 3d Analysis Report

Background

- Following successful validation trials using an existing production mould, it was decided that the existing mould design be modified to include additional channels and background circuits to make the mould more compatible for RICH. This would then reduce the overall cycle time.
- At the moment the existing part has a 4.5mm wall thickness with 3.3mm rib sections attached on the “B” side. Evidence from the trials indicates that RICH greatly improves plastic packing using slow injection speeds and extended packing times. Therefore we have analysed a part with a general wall thickness of 3mm. Note: It is not possible to reduce the rib thickness on the “B” side to improve the rib to wall thickness ratio.
- Therefore the customer provided CAD data for the modified mould, new channel circuit and the part with 3mm and 4.5mm respectively. This is to analyse results with and without RICH and with and without reduced wall thickness.
Moldex 3d Analysis Report

Objectives

- Based upon latest 3d Mould model (step format) create mould model within the Moldex 3D environment including mould plates and channel circuits received from the customer
- Creation and Preparation of model mesh.
- Model RICH channels into the “A” side of the mold
- Simulation of heating and cooling the internal channel circuit with steam in order to predict:
  a) Heating Uniformity
  b) Equilibrium effect of heat cycling the mould over a series of cycles.
- Plastic filling and packing analysis
- Based upon results optimisation of the mould design in order to achieve:
  a) Fastest Heating Speed
  b) Fastest Cooling speed
  c) Shortest Overall cycle time.

1. Analysis of the component with the modified internal channel design and 4.5mm wall thickness.
2. Analysis of the component with the modified internal channel design and 3mm wall thickness
3d Part Models

4.5mm Wall Thickness

3mm Wall Thickness
3d Mold Internal Channel Model

- Background Circuit cavity side set at 50°C
- RICH Circuit cavity side
- Background Circuit core side set at 50°C
Temperature Sensor Positions
Process Conditions Used For The Analysis

- Material – PVC
- Initial mold temperature first cycle = 50 °C
- Melt temperature = 180 °C
- Plastic injection time = 15 seconds
- Plastic packing time = 15 seconds
- Heating Time = 10 seconds
- Cooling time = 30 seconds
- Tool open time = 3 seconds
- Steam temperature = 180 °C
- Water temperature = 15 °C
- Target Mold Surface Temperature Heated = 85°C
- Target Mold Surface Temperature Cooled = 50°C
### Process Conditions Used For The Analysis

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<td><strong>90°C</strong></td>
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<tr>
<td>Heating Time – 10 Sec</td>
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<td>Air Purge Time – 5 Sec</td>
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<td>Delay Before Cooling Time – 15 Sec</td>
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<td>Cooling Time – 30 Sec</td>
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<td>Air Purge Time – 5 Sec</td>
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<tr>
<td><strong>50°C</strong></td>
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</table>
RICH Heating and Cooling Profile

**Heating** – 10 Sec

**Plastic Filling**
Time – 15 Sec

**Plastic Packing**
Time – 15 Sec

**Cooling Time** – 30 Sec

**Target Temperature**
– 85°C

**Cavity Side Sensor 1**

**Cavity Side Sensor 2**

**Core Side Sensor 1**

**Core Side Sensor 2**

**Core Side Sensor 3**

**Mould Open Time** – 3 Sec
RICH Heating and Cooling Profile

This sectioned view shows the steel and plastic surface temperature 1 second into plastic injection.

This sectioned view shows the temperature midway through plastic packing.
RICH Heating and Cooling Profile

This sectioned view shows the temperature close to the end of cooling.

This sectioned view shows the temperature half way through the heating cycle when the mould is opened.
Plastic Filling Pattern without RICH

This the filling pattern for the 3mm thickness without RICH.
Plastic Filling Pattern with RICH

This is the filling pattern for the 3mm thickness with RICH
Plastic Filling Pattern with RICH Comparison 3mm Wall Section

Without RICH the last points to fill are the corners of the general wall section.

With RICH the last points to fill change to the ends of the rib sections on the ‘B’ side of the part. This is because the hot cavity surface encourages the plastic to fill the general wall section before the rib sections that are in the core side of the mould.
Plastic Filling and Packing Pressure with RICH

This graph shows the pressure at the tip of the sprue during the cycle with 4.5mm wall thickness.

This graph shows the same pressure with wall 3mm thickness. As expected the pressure to fill the 3mm wall thickness is higher than the result for the 4.5mm wall thickness.
Part Temperature with RICH

Temperature at the end of cooling 4.5mm Wall Thickness

Temperature at the end of cooling 3mm Wall Thickness
Part Temperature with RICH

This shows the temperature distribution on the surface of the 3mm thick component with different packing times.

The plots show that changing packing has little effect on the plastic temperature at the end of cooling.
Sink Mark Prediction after RICH

3mm thick with shorter and longer pack but the same cycle time. The left hand image shows the plastic that is still molten at the end of 15secs pack. The right hand image shows the same plot with the extended 25 seconds pack time.
Sink Mark Prediction after RICH
4.5mm wall thickness compared to 3mm wall thickness.

This plot shows the sink mark prediction with the 4.5mm wall thickness and the original 15 Sec pack time.

This plot shows the sink for the 3mm wall thickness with the original 15 sec packing. The sink position and distribution is similar but the sink depth increases from 0.063 to 0.08mm.
Sink Mark Prediction after RICH
3mm wall thickness with 25 second packing time

This plot shows the sink for the 3mm wall thickness with extended packing time – 25 Seconds. The extended pack reduces the predicted sink from 0.08 to 0.05mm.

This plot shows the sink for the 3mm wall thickness with the original 15 sec packing.
This plot shows the warp for the 3mm wall thickness with the original 15 sec packing and the part is predicted to warp 1.7mm

This plot shows the warp for the 3mm wall thickness with extended packing time. The predicted warp is reduced from 1.7mm to 0.7mm
Conclusion

Summary and comment

- Cycle time achieved at the initial trial was 115 seconds. By modifying the mould to include conformal and background circuits we believe this could be reduced to between 75 and 85 seconds based upon the analysis results.

- The analysis predicts that we will see an increase in sink mark depth with the reduced 3mm wall thickness, this will be improved to an acceptable level by extending the packing time. This is feasible because RICH enables extended packing times at slower injection speeds due to the higher mould temperature that is above the Tg (glass transition) temperature of the material.

- We therefore believe that this part can be produced with a 3mm wall thickness at a cycle time of between 75 to 85 seconds subject to the mold being modified as the CAD data provided.

- System requirement – RICH4 with RO water purifier.
RAPID ISOLATION COOLING & HEATING

RICH MOULD DESIGN

• CONFORMAL CHANNEL DESIGN

RICH + ISO TECHNOLOGY SYNERGY
Conformal flow channel

Conformal cooling channel
ISO technology enables TRUE 3D geometric freedom of cooling channel design.
With the bonding and varied insert core, ISO technology is able to overcome the limitations of straight line cooling channel design using a typical gun drill machine.
Idealized cooling channel design using ISO technology maximizes cooling efficiency by minimizing dead spots in cooling channels and achieving optimized plastic flow in hot runner systems.

* ISO is an AutoCAD terms for a View mode inclining X, Y, Z axes at 45° respectively. It also stands for YUDO’s technical vision that views objects in three-dimensions to optimize TRUE 3D cooling channel design

/ Configure ideal fluidized layer considering shear rate
/ Eliminates hot spot

/ Uniform cooling of whole product
/ Shorten cooling & cycle time
What is **ISO Technology**?

**Hot Runner**
(2-pcs Manifold)

**Channel Design & Processing Optimization**

/ Secure Hot Runner Balance
/ Realize Edge-less Channel
/ Eliminate Dead Spots inside Resin Flow Channels
/ Control the Channel Surface Roughness and Illumination
/ Implement Smooth and efficient color changes
/ Decrease Resin Flow Shear Stresses (Sensitive Material, LGF…etc)

**Mold**
(Split Type Core & Gate Bush)

**Effective Mold Temperature Control**

/ Optimized Cooling Channel design
/ Shorten Cooling & Cycle Time
/ Reduce Deformation and Shrinkage
/ Minimize Flow marks when used with RICH
4-1. Case Study for Centre Console

**Tradition cooling channel design**

In a typical tank cooling design, circulation of the coolant is difficult to approach as the existing flow sections result in a **Hot spot**. This results in extended cooling times.
4-1. Case Study for Console

CAE Analysis

Due to non-optimal coolant circulation deep in the core, a Hot Spot occurs as predicted.
4-1. Case Study for Console

3D Cooling Structure with the ISO Tech

Machining cooling channels of core -> Bonding core plates -> Finishing core machining
ISO Technology enables cooling channels to access previously inaccessible areas of the core, to eliminate hot spots and shorten cooling times.
4-1. Case Study for **Console**

**Core CAE Analysis using ISO Tech**

Cooling efficiency is significantly improved in the deep core eliminating the hot spot and reducing cycle time.
4-1. Case Study for Console

Comparison of Conventional and ISO Cooling Channels Design

Temperature difference between conventional cooling channels design and ISO cooling channel design after 15 seconds of the cooling cycle.
BENEFITS OF RICH + ISO TECHNOLOGY

As THE Global market leader in Hot Runner Technology YUDO is IDEALLY placed to influence customers’ choice of mold design and process selection PRIOR to commencement of tooling.

RICH technology offers customers the ability to dramatically improve surface finishes, light weight parts and reduce warpage / distortion and sinkage.

Using ISO technology YUDO can now offer optimized true 3D Conformal Cooling Channel design for medium to large tools.

Note:
Currently YUDO’s competitors for RICH technology can only offer Conformal Cooling for small inserts.
RICH ELECTRONIC APPLICATIONS
RICH AUTOMOTIVE APPLICATIONS
RICH WHITE GOODS APPLICATIONS

FRONT LOADING WASHING MACHINE PANEL
RICH STATISTICS

<table>
<thead>
<tr>
<th>ATTRIBUTE</th>
<th>RICH STEAM HEATING</th>
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<tr>
<td>MAX TOOL SURFACE TEMP °C</td>
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<tr>
<td>HEATING SPEED ° K / SEC</td>
<td>8-10</td>
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<tr>
<td>MAX PART SIZE in mm</td>
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<tr>
<td>SEPARATE CORE &amp; CAVITY HEATING</td>
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<td>PART GEOMETRY</td>
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<tr>
<td>INDICATIVE CYCLE TIME INCREASE* %</td>
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<tr>
<td>INDICATIVE ENERGY CONSUMPTION kW</td>
<td>48 - 240</td>
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* COMPARED TO CONVENTIONAL INJECTION MOULING AND WITHOUT WALL SECTION REDUCTION
RICH AUTOMOTIVE MARKET INTEREST

AUTOMOTIVE OEM’S

• FORD UK
• AUDI
• PSA
• HYUNDAI
• MERCEDES BENZ
• JAGUAR LAND ROVER

AUTOMOTIVE TIER 1 SUPPLIERS

• MAGNA AUTOMOTIVE EXTERIOR AND INTERIOR
• MECAPLAST
• INTIER AUTOMOTIVE INTERIORS
• PLASTIC OMNIUM AUTO EXTERIORS
• CIE AUTOMOTIVE
RICH AUTOMOTIVE MARKET INTEREST

EXTERIOR APPLICATIONS

• LIGHT BEZELS (ABS / PC)
• HEAD LAMP REFLECTORS (ABS /PC or ABS / PMMA)
• DOOR HANDLES (GF PA)
• VERTICLE BODY PANELS (LGF PP)

INTERIOR APPLICATIONS

• CENTRE CONSULE GEAR SHIFT BEZEL (ABS / PC)
• AUDIO BEZELS (ABS / PC)
• A,B, C PILLARS (ABS / PC)
• UNDER BONNET ENGINE COVERS (GF PA / GF PP)
RAPID ISOLATION COOLING & HEATING - RICH

A PANACEA FOR INJECTION MOLDED PARTS

High gloss surface finish…………………………………………………………………………………RICH
Weld line / flow line visibility…………………………………………………………………………………RICH
Fiber visibility on surface…………………………………………………………………………………………RICH
Silver streaks and splay marks………………………………………………………………………………………RICH
Replication of surface micro features…………………………………………………………………………………RICH
Warp age and distortion……………………………………………………………………………………………………RICH
Sink marks…………………………………………………………………………………………………………………………RICH
Longer flow paths with thinner wall sections…………………………………………………………………………………RICH
Light weighting…………………………………………………………………………………………………………………………RICH
Cycle time reductions………………………………………………………………………………………………………RICH
WHY CHOOSE YUDO SUNS?

- HIGH PRESSURE (35 BARG) INTEGRATED ELECTRIC BOILER SYSTEM
- WORLD CLASS DESIGN ENGINEERING SUPPORT
- POSSIBILITY TO COMBINE TECHNOLOGIES (RICH + ISO) (RICH + MUCELL) (RICH + GAM)
OVER 4800 SYSTEMS RUNNING WORLDWIDE