

Process Research

Process Summary

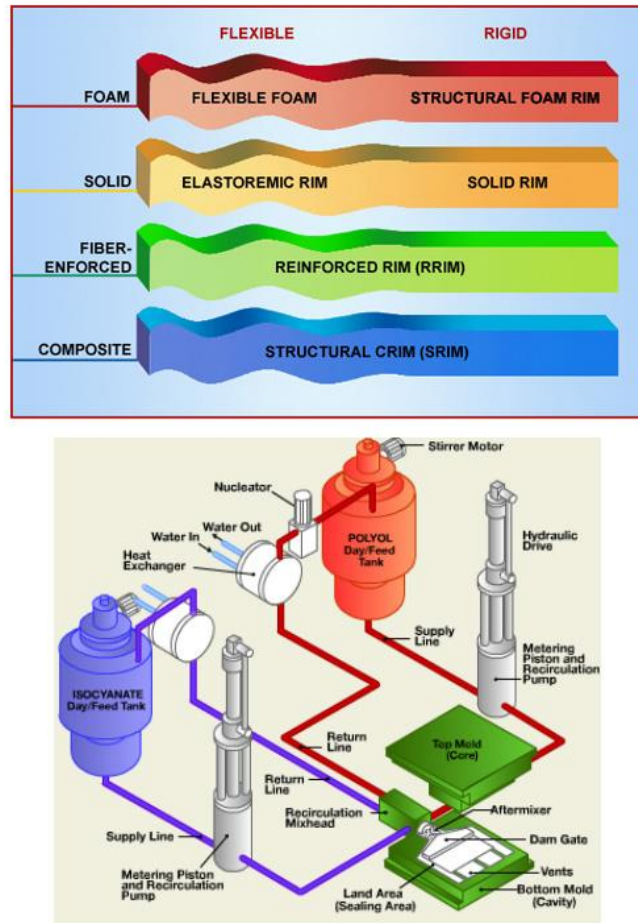


Figure 1 (RIM MFG, 2013)

Reaction Injection Moulding (RIM) (figure 1) is a manufacturing process quite similar to traditional injection moulding, in the sense that a liquid is injected into the cavity of a mould, allowed time to cure, and then is ejected ready for post processing (Purmold, *Polyurethanes*, p. 2, 2018). However, rather than using a single polymer in pellet form, that is heated to a liquid state (Ibid. p. 2), RIM manufacturing uses two liquid products, Polyol (part A, which determines the parts physical characteristics (Essential Chemistry Industry, 2018)), and an Isocyanate (part B, which is a hardener (Ibid, 2018)) that are each contained in their own temperature-controlled feed tanks, with agitators to keep the liquid fluid (Creative Urethanes, *Our Services*, Pt. 2, 2018).

Within each of these tanks additives such as catalysts, reinforcing agents, surfactants and fillers etc. can be added to obtain certain process or product qualities e.g. increased curing time or expansion and foaming (Frazee, 2017).

When the process is ready to begin the products are separately fed into a metering piston unit, that precisely measures the right quantity of liquid required for correct curing to occur, and the size of the part being produced (calculated prior to processing). From there, the two reactants continue under high pressure (1,500 to 3,000 psi) to a single container with a mix-head, that is opened through valves. Within this chamber the two liquid parts are rapidly mixed, and combine to produce a single curing polymer; because of the relatively quick exothermic reaction that is occurring, and the small curing time, the injection moulding must begin post-haste. The polymer then leaves the mixing chamber and flows into the part specific mould at a pressure of between 30 and 100 psi, before fully curing, during this stage the resin reaches a momentary temperature of 177 degrees, before being ejected by pins, air, or by hand.

(Creative Urethanes, 2018; Frazee, 2017; YouTube, *Reaction Injection Molding*, 2016; YouTube, *Process Overview*, 2016; RIM MFG, 2013; Hollcraft, 2016).

Suppliers

Email template sent to the below companies:

Dear Sir or Madam,

I am currently trying to design a product and I am wondering whether the Reaction Injection Moulding process would be suitable for it.

Would it be possible for your company to send me a sample of a RIM moulded part and maybe some information on your company such as an informative pamphlet?

If it so happens that the process is right for me I would be sure to prioritise your company for prototyping and manufacturing needs.

Yours Sincerely,

Keri Shaw

(Shaw, 2017)



(Rapitypes, 2018)

Robert Wingrave <robert.wingrave@rapitypes.com>
to me, Debbie ▾

Nov 27 ★ ↩ ▾

Good Morning Keri,

To send you a sample part would not really help as it would not necessarily be a representative sample on the type of part you are intending to have manufactured. There are a range of considerations to consider which a sample may not cover.

We would need additional information to help you with your enquiry such as size, complexity surface finish, colour, in mould coatings etc. as these are all considerations in the design of a product.

I have attached an outline brochure on the services and products we can offer, so if you could let me know a little more we will be better able to help you.

Best regards,

Robert Wingrave

Robert Wingrave
Business Development Manager

(Wingrave, 2017)

Company: Rapitypes

Tel: +44 (0) 116 253 6591

Mobile: U/A

Email: sales@rapitypes.com

Location: Leicester

Website: <http://www.rapitypes.com/>



(Midas, 2018)

Rachel Sparkhall (Nee Collier) (Midas Pattern Company Ltd) <r.sparkhall@midas-pattern.co.uk>
to me ▾

Nov 27 ★ ↩ ▾

Hi Keri

Many thanks for getting in touch with Midas regarding your potential RIM moulding enquiry.

I would certainly be more than happy to send you through a copy of our brochure for you to read through if you can let me know your address. There is probably as much, if not more info on the website nowadays but I appreciate it is sometimes nicer to read a hardcopy.

With regards sending you through a sample, we do not tend to just have sample parts as it makes much more sense to have a chat about the project and see some CAD first to understand if the project is going to be suitable first. If you have some initial concepts and info, perhaps you could send it through and then we could have a chat?

As an overview RIM is ideal if you are looking for a fascia or an enclosure part that is typically larger than A4 in size and is enshrouding high value parts that are going to be produced in low volumes. This can be anything for a handful of parts right up to 2000 per year. We finish paint all our mouldings so you have the flexibility to have a fantastic range of colours/textures/durability to chemicals and UV stability. If that all sounds of interest that RIM could certainly be the right process for you.

Look forward to hearing from you.

With kind regards

Rachel

(Sparkhal, 2017)

Company: Midas

Tel: +44 (0) 1234 358394

Mobile: +44 (0) 7791 161542

Email: enquiries@midas-patter.co.uk

Location: Bedford

Website: <https://www.midaspattern.co.uk/>

RIMPLAS TECHNOLOGIES

(Rimplas Technologies, 2018)

James <james@rimplas.co.uk>
to me ▾

Nov 28 ★ ↶ ▾

Hello Keri,
Thanks for contacting us.
For more info on RIM please see our website its very informative and user friendly.

Once you have some CAD data available (STEP and STL is best for us to view) please send through and we can look at tooling cost and piece part prices.

Please note though we use aluminium temperature controlled tools and often if the quantities per year are below the 50 – 100 mark its difficult to justify the investment in the tooling.

If you are going beyond these figures then def worth looking into RIM

Many Thanks

James Whyte

(Whyte, 2017)

Company: Rimplas

Tel: +44 (0) 1268 729679

Mobile: U/A

Email: sales@rimplas.co.uk

Location: Essex

Website: <http://www.rimplas.co.uk/>



(Techni-form, 2018)

NO EMAIL RESPONSE

Company: Tecni-Form

Tel: +44 (0) 1785 286476

Mobile: +44 (0) 7764 9323035

Email: sharon.tinsley@tecni-form.com

Location: East Sussex

Website: <http://www.tecni-form.com/>



(Cellular Mouldings, 2018)

NO EMAIL RESPONSE

Company: Cellular Mouldings Ltd.

Tel: +44 (0) 1536 275000

Mobile: U/A

Email: enquiries@cellularmouldings.co.uk

Location: Corby

Website: <http://www.cellularmouldings.co.uk/>

Materials and Datasheets

A large range of materials are used within reaction injection moulding, such as: epoxy resins, vinyl esters, amide ester resins, unsaturated resins, and some traditional composite materials (Industri-man, 2017; Thomasnet, 2018). However, the most useful and vastly utilised material, based on my exploration into a number of websites and companies concerning the process, is a Polyurethane resin and its variants (Thieme, 2018), which have been placed in a table below to display: an overview of the materials, their areas of application, and their technical parameters.

Materials	Properties																											
Polyurethane Integral Hard Foam	<u>Overview</u> This variant has a sandwich-style design that allows for good design flexibility, through the fact that it can have variable wall thicknesses without sink marks, whilst having a high rigidity and good thermal and acoustic insulation properties.																											
	<u>Areas of Application</u> ▪ Consumer Electronics ▪ Medical Technology ▪ Bank Payment Stations, and Access Systems ▪ Workplace Carriers and Handling Units																											
	<u>Technical Parameters</u>																											
	<table><tr><th>Properties</th><th>Value</th><th>Unit</th></tr><tr><td>Density</td><td>600</td><td>kg/m³</td></tr><tr><td>Pulling strength</td><td>19</td><td>MPa</td></tr><tr><td>Ultimate elongation</td><td>6</td><td>%</td></tr><tr><td>Bending strength (max.)</td><td>38</td><td>MPa</td></tr><tr><td>Bending E-module</td><td>900</td><td>MPa</td></tr><tr><td>Impact strength at 23 °C</td><td>14</td><td>KJ/m²</td></tr><tr><td>Surface hardness</td><td>67</td><td>Shore D</td></tr><tr><td>Dimensional stability (HDT)</td><td>97</td><td>°C</td></tr></table>	Properties	Value	Unit	Density	600	kg/m ³	Pulling strength	19	MPa	Ultimate elongation	6	%	Bending strength (max.)	38	MPa	Bending E-module	900	MPa	Impact strength at 23 °C	14	KJ/m ²	Surface hardness	67	Shore D	Dimensional stability (HDT)	97	°C
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Density	600	kg/m ³																										
Pulling strength	19	MPa																										
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Bending strength (max.)	38	MPa																										
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Impact strength at 23 °C	14	KJ/m ²																										
Surface hardness	67	Shore D																										
Dimensional stability (HDT)	97	°C																										
	(Thieme, PUR Integral Hard Foam, 2018)																											



(Alibaba, 2018)

Polyurethane Compact Foam

Overview

This product is an alternative material to thermoplastics used in traditional injection moulding, and has a tight structure with a high impact strength, and can be used to manufacture large parts of around 6m², as well as thin wall sections.

Areas of Application

- Medical Devices
- Consumer Electronics
- Containers, Trays, Machine and Device Enclosures
- The Railway Industry

Technical Parameters

Properties	Value	Unit
Density	1050	kg/m ³
Pulling strength	50	MPa
Ultimate elongation	14	%
Bending stress at 3.5 % outer fiber strain	58	MPa
Bending E-module	1900	MPa
Impact strength at 23 °C	57	kJ/m ²
Surface hardness	75-77	Shore D
Dimensional stability (HDT)	92	°C

(Thieme, PUR Compact Foam, 2018)



(Indiamart, 2018)

Polyurethane Casting System

Overview

This PUR system is a high strength to weight ratio alternative to steel or grey cast iron, and is specialised for functioning parts that undergo particular mechanical or chemical stress, it also withstands abrasion well.

Areas of Application

- Agricultural, Pump, and Waste Water Technology
- Applications within Sewage Purification Plants
- Grounding Cable Connection Systems
- The Construction Industry

Technical Parameters

Properties	Value	Unit
Density	1180	kg/m ³
Pulling strength	47	MPa
Ultimate elongation	21	%
Bending strength (max.)	72	MPa
Bending E-module	1500	MPa
Impact strength at 23 °C	60	kJ/m ²
Surface hardness	74	Shore D
Dimensional stability (HDT)	95	°C

(Thieme, PUR Casting System, 2018)



(Waterpoolpump, 2018)

Polyurethane Flex Foam

Overview

PUR Flex Foam offers high impact strength along with durability at extreme temperatures, and very good abrasion resistance. It can also be made aesthetically pleasing through structured tool surfaces.

Areas of Application

- Industrial Trucks and Driver Cabins
- The Construction Industry
- Agricultural Technology
- Logistics and Access Systems

Technical Parameters

Properties	Value	Unit
Density	1050	kg/m ³
Pulling strength	34	MPa
Ultimate elongation	90	%
Tear resistance (max.)	59	kN/m
Bending E-module	1020	MPa
Impact strength at 23 °C	Not Broken	kJ/m ²
Surface hardness	69	Shore D
Dimensional stability (HDT)	77	°C

(Thieme, PUR Flex Foam, 2018)



(Crown, 2018)

Polyurethane Energy Absorption Foam

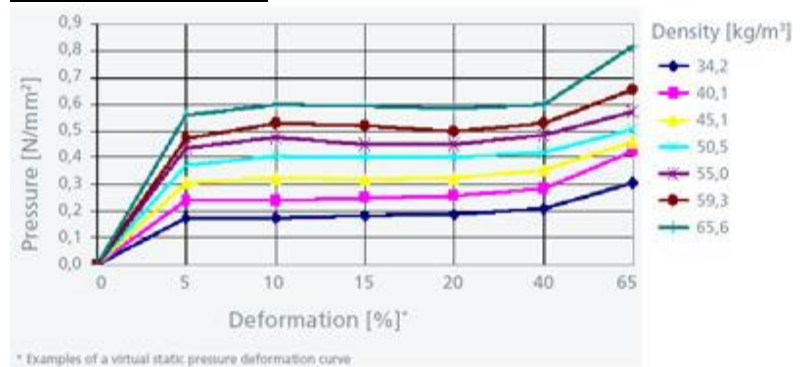
Overview

This material has very diverse uses, and can be used for passenger protection on vehicles due to its ability to be deformed under kinetic energy, rather than breaking.

Areas of Application

- Body Protection e.g. Head, Knee and Elbow Pads
- Vehicle Exteriors e.g. Grit Guards and Bumpers

Technical Parameters



(Thieme, PUR Energy Absorption Foam, 2018)



(Alibaba, 2018)

Polyurethane Semi-hard Integral Foam

Overview

This product can be used for a range of lightweight comfort components of different softness's due to its variable densities.

Areas of Application

- Door Panelling
- Seat Components e.g. Arms, Backs and Filling

Technical Parameters

Properties	Value	Unit
<i>Density / core</i>	138,0	kg/m ³
<i>Pulling strength</i>	207,0	Pa
<i>Ultimate elongation</i>	53,0	%
<i>Compression hardness at 40 %</i>	45,1	kPa
<i>BenCompression set (50 %, 70 °C, 22 h)</i>	9,3	%

(Thieme, PUR Semi-hard Integral Foam, 2018)

	 (Carid, 2018)
Isocyanates	<u>Overview</u> Combined, both of the following isocyanates help to form around 95% of polyurethanes produced industrially. <u>Toluene Diisocyanate or Methylbenzene Diisocyanate (TDI)</u> TDI is utilised as a hardener when producing low density flexible foams. <u>Methylene Diphenyl Diisocyanate or Diphenylmethane Diisocyanate (MDI)</u> A more complex isocyanate than TDI, MDI allows more process and product versatility, and is commonly used when producing rigid foams. (Essential Chemical Industry, Production of Isocyanates, 2018)

Process Design Applications

Reaction Injection Moulding can produce a range of parts, such as: large and very large parts (Thomasnet, *Advantages*, 2018; Covestro, *Advantages*, 2018), parts with variable wall thicknesses (Covestro, 2018), parts with particularly thick or thin walls (Premold Corp, *Design Guide*, 2017), extremely lightweight parts (Covestro, *Advantages*, 2018), and parts with smooth surface finishes (Thomasnet, *Advantages*, 2018). The process also offers value for money, in the sense that the parts produced through this method have brilliant material properties e.g. a high tensile strength, corrosion, heat resistance etc., which means that the customers benefit from a high turnover rate especially when concerning products for technical industries (Ibid, 2018; Covestro, *Advantages*, 2018). Because of the great deal of benefits that the process can offer, reaction injection moulding is used by a vast range of sectors, such as:

Aerospace: The casings for in-plane entertainment systems, plane interior surfaces, and helicopter turbines are commonly produced using reaction injection moulding (Midas, *Aerospace*, 2018).

Automotive: This industry usually produces side panels, dashboards, steering wheels, armrests, bumpers and body frames etc. using this process (Midas, *Automotive*, 2018; Rutland, *Applications*, 2018; Thomasnet, *Applications*, 2018).

Beauty: Many large industrial beauty product exteriors are produced using this process e.g. the shell of a spray tan machine (Midas, *Beauty*, 2018; Rutland, 2018).

Broadcasting: Some audio mixing console and control panel exteriors are produced using this process (Midas, *Broadcasting*, 2018).

Consumer: The consumer industry generally benefits from the elastomeric properties that reaction injection moulding has to offer, in order to manufacture: household appliances, internal heating and cooling systems etc. (Midas, *Consumer*, 2018; Rutland, *Applications*, 2018, Thomasnet, *Applications*, 2018).

Environmental: Within the environmental trade, solar powered bus stops, public litter bins, and water recycling unit exteriors are a few examples of what the RIM process can produce (Midas, *Environmental*, 2018).

Lifestyle: The leisure and lifestyle industry has use for RIM processing within kayaks, canoes, body boards, skis, children's apparatus, thermal compression technology etc. (Midas, *Lifestyle*, 2018; Rutland, *Applications*, 2018; Thomasnet, *Applications*, 2018).

Marine and Transportation: A variety of products such as: offshore crew transportation, fuel tanks, precision foundry patternmaking, and low-cost tooling for polypropylene diesel fuel tanks, are produced for this industry using reaction injection moulding (Midas, *Marine and Transportation*, 2018).

Science and Medical: RIM offers a lot of possibilities in this sector, from mobile machine casings, such as those for liver transplants and electron microscopes, to breathe ventilators. Additionally, the RIM process has been seen to produce measurement and inspection equipment such as the body of FARO arms (Midas, *Medical/MEDTEC Devices/Metrology*, 2018).

Prototyping: The production of low volume, high quality foam parts to benefit the designer. (Pro2Pro Ltd., *Typical Applications*, 2018).

Speed (Shot, Cycle and Lead Times)

From the point that the two parts (polyol and isocyanate) have been thoroughly mixed into a single liquid polymer, the curing begins. This leaves between approximately five and thirty-five seconds time (depending on the material being used) for the liquid to be injected into the mould (Premold Corp, *Time to Inject*, 2018). After the mould has been filled, the time before releasing the product is entirely dependent on the size of the product being produced, and the composition of the material. The time range for this to occur can be anywhere between a few seconds and several minutes (Premold Corp, *Shrink Factor*, 2018). An example of the RIM processing speed for an elastomeric product in an average sized mould, would be one second or less for the mould to be filled, and between thirty and sixty

seconds for demoulding to occur (Covestro, 2018). Archetypical lead times that can be expected from this process, and can be anywhere around 10 to 20 working days, but these values are dependent on the company and the component size and design (Protobroker, 2018). Finally, this relatively quick process for the parts that it turns out, is complimented by a fast tool manufacturing rate (Rutland Plastics, *Advantages*, 2018).

Volume

Due to factors such as weaker moulds compared to that of those used in traditional injection moulding, e.g. aluminium compared to steel (Purmold, 2018; Paragon, 2018), and the fact that RIM processing is favoured for the production of typically large products (Design Octaves, *Advantages of the RIM Process*, 2018). Reaction Injection moulding is suitable for low to medium volume production, which can vary anywhere between 50 parts per year, to 50,000 parts per year (Osborne Industries, 2018). It is to be noted though that although reaction injection moulding can produce around a thousand products from a single RIM specific tool, the process is only really cost effective in quantities up to 300 units, before injection moulding tools such as those made from machined steel should be considered (Paragon, 2018). Furthermore, according to James from Rimplas (2017) a minimum volume of 50 or more parts is recommended to produce in order to justify the cost of tooling.

james <james@rimplas.co.uk> Nov 28 ★ ↶ ↷
to me ▾

Hello Keri,
Thanks for contacting us.
For more info on RIM please see our website its very informative and user friendly.

Once you have some CAD data available (STEP and STL is best for us to view) please send through and we can look at tooling cost and piece part prices.

Please note though we use aluminium temperature controlled tools and often if the quantities per year are below the 50 – 100 mark its difficult to justify the investment in the tooling.

If you are going beyond these figures then def worth looking into RIM

Many Thanks

James Whyte

(Ibid, 2017)

Cost

The cost to produce parts through reaction injection moulding, from a customer perspective, would be relatively low, due to the fact that the process involves both a low pressure and temperature environment (Premold Corp, *Numerous Advantages to RIM*, Pt. 4, 2018), meaning that energy costs are lower, and moulds such as those made from aluminum, nickel, epoxy resin, model board, or silicon rubber can be used over costly machined steel moulds, which are typically 80 to 90% more expensive (Covestro, Pt. 6, 2018; Purmold, 2018; Hepworth, 2018). Also, maintenance costs are comparatively low, as there is less to be maintained during the process, because the mix-head self-cleans, and less clamping force is required due to the low pressure involved in moulding, which means a reduced amount of equipment (Hollcraft, *Slide 3*, 2016; Ashida, 2006). However, because reaction injection moulding is often a human driven process, labour costs can be high, which will push up the customer costs as well (RIM MFG, *RIM Overview Video*, 2017). In addition to this, the raw materials are expensive (Rutland, *Disadvantages*, 2018).

Post Processing

Once the part(s) have cured, they are ejected from the mould by hand, air, or pins (Hollcraft, *Slide 4*, 2016). After this, the excess material that overflows in the mould, commonly known as flash, is removed using automated grinding machines, or by hand in the case of parts with an intricate perimeter (YouTube, *Thieme*, 2008). Due to the fact that the RIM process offers many finishing options whilst still inside the mould, such as Class-A Surfaces and In-mould Decorating through hydrographic/thermoplastic films*, in addition to high quality texture being relayed onto the product through intricate milled or cast moulds, means that when ejected, the product already processes the desired colours and textures that many other processes would have to be complimented by sand blasting, painting etc. to achieve (which also significantly lowers production costs if chosen) (Covestro, Pt. 4, 5, 2018; Hollcraft, *Slide 8*, 2016).

These techniques for in-mould finishing are why the process is so favoured by the automotive industry, as they can produce large, light weight pieces made from a rigid foam, that have the same finish as the metal car components, or different textures that improve the aesthetics of the vehicles interior (Covestro, Pt. 4, 2018; YouTube, *Air Design USA*, 2017).

If these in-mould finishes are not chosen for the product, then some typical post processes that may apply: are surface filling, sanding (automated or by hand), drilling holes, painting using an RFI/ EMC shielding paint, to protect current or future internal electronic components, textured paints, soft-touch paints, anti-microbial paints, pad printing or silk screen printing for product graphics, or simply paint to change the products final colour or finish, which will gain the highest cosmetic finish (Rimplas, *Painting and Finishing*, 2018; Premold Corp, *Design Guide, Painting and Decorating*, 2017; Rutland, *Disadvantages*, 2018).

Many RIM companies also offer partial, or full assembly as a post processing possibility for the parts that they produce, whereby they utilise fixings to connect either premanufactured or other RIM processed parts together, to aid the customers production line (Rimplas, *Assembly*, 2018).

*Colour pigments are not usually used with RIM processing, as they depreciate the final finish of the product (Hollcraft, *Slide 8*, 2016).

Design Considerations

(All values converted from Imperial to Metric, and rounded for viewer convenience)

Parting Lines: Edges on the parting lines should be sharp if possible, and then they can be rounded off to a radius later on during the finishing process. This will be more economical for the mould: design, construction and maintenance. If a radius is required at the parting line then it should be larger than smaller, as this will lead to a better overall part. Furthermore, it is good practice to design all of the parting lines on one plane, rather than having it contoured or changing from one side of the part to another, this improves the parts economy (Premold Corp, *Design Guide*, P. 8, 2017)

Undercuts: Undercuts are not ideal, but are sometimes economically viable options to include in a design as they are easier to tool and mould. For when an undercut is required, by-pass cores can be used, or alternatively, loose piece cores can be set into the mould and then ejected with the part (Premold Corp, *Design Guide*, P. 17, 2017).

Draft Angle: Draft angles are required for the vertical surfaces of products produced using the RIM process, in order for the part to not create a vacuum during demoulding. A good draft angle would be around 3 degrees, and these are particularly relevant on the interior walls of parts, as RIM components shrink within the mould. Low draft angles of between 0.25 and 1 degrees can be used, but this should be consulted with the manufacturer before applying to the mould (Premold Corp, *Design Guide*, P. 9, 2017).

Wall Thickness: The parameters for the thickness of RIM parts are comparable to that of traditionally injection moulded parts, whereby, a working thickness of between 1.5mm and 6mm is sufficient. However, the RIM process can produce parts with wall thicknesses as large as 38mm. In addition, the resins used within the RIM process are much more accepting of variations in wall thickness (although a consistent thickness is recommended from a design perspective). When thicker walls are required for insulation purposes, insert-moulding can become an option, over a dramatic wall thickness increase. Moreover, utilising ribs and bosses can improve a parts strength without the need for thick walls (Premold Corp, *Design Guide*, P. 8, 2017).

Ribs: The total thickness of a rib should be more than 1.5mm (ribs of this thickness should be no more than 3mm high), and less than 75% of the adjoining walls thickness, in order to avoid sink marks on the reverse side of the part. In addition, the height of a rib can be more than 100mm on large components, however, it must be accompanied by a minimum base thickness of around 4.7mm and top thickness of 1.5mm. Also, draft is required to make demoulding of ribbed parts easier. Likewise, it is better to include unidirectional or diagonal ribs in a part, over bidirectional, as they cause less reduction in resin flow and decrease the likelihood of air pockets (Premold Corp, *Design Guide*, P. 9, 2017).

Bosses: Bosses can be designed and moulded into a part to minimise the number of components in an assembly, and it reduces costs on mating surfaces as there is usually less of a requirement for threaded inserts etc. Bosses can be located on, or next to the walls of a product, but it should be ensured that the boss doesn't make the wall too thick, and that if it is positioned next to a wall, ribbing should connect the boss and wall together. Bosses should be designed with a fillet at their base for strength, if the boss is to be cored out then it should be done for the boss's entire height to prevent sink marks on the reverse side. Furthermore, vent ribs positioned at a forty-five-degree angle from the top of the boss down, should be placed around a boss to enable the resin to fill the entire structure and cure correctly (these can be machined off after, if required). The bosses wall thickness should be great enough to hold a screws thread, but no larger than 75% of the overall parts wall thickness. Exceptions can be made with thin walled parts, or certain types of self-tapping screws and threaded inserts. Finally, it is more accustomed to core the holes during the parts production, rather than drilling them post-process, as it is easier, and the self-skinning properties of some RIM materials enables a better grip of a screws thread (Premold Corp, *Design Guide*, P. 11, 2017).

Radii and Fillets: Radii should be implemented whenever the products surface transitions. For the exterior edges 0.7mm radii is suitable, in order to prolong tool life and improve the parts economy for the designer. It is suggested that interior corners have a radius of 3mm, as it is good for the products moulding and strength. Bosses should be accompanied by a 1.5mm radius to reduce their wall thickness (Premold Corp, *Design Guide*, P. 12, 2017).

Holes, Grooves and Slots: Holes can be implemented into the part in either the direction of the draw, or in the areas where the hydraulically retractable pins are. By-pass coring can be utilised where there is enough draft angle in the mould. As an alternative to moulding the holes, holes can be easily drilled post-

process for little extra cost. Furthermore, slots and grooves that are designed so that they extend around the products corners, or ones that are set on sloping walls, reduce tooling costs. Subsequently, to promote good resin flow and prevent air pockets; slots, grooves and ribs should be positioned in the direction of resin flow, and consist of fillets or chamfers. This can also prevent stress on the cured product (Premold Corp, *Design Guide*, P. 12, 2017).

Joints Between Parts: When designing RIM components that mate together it is good practice to make at least one component align via a joint. When creating this joint, however, certain relief must be created for an easy and stress-free connection. Other considerations for joints would be a draft angle, and large radii on the corners of either component. The best joints for allowing clearance for tolerances and paint thickness, are tongue and groove joints. If this feature extends around most of the parts perimeter then an increased clearance must be allowed. Although joints allow parts to locate on an X and Y axis, fasteners are required to take care of the Z axis. Tall and deep mated components require less fasteners than that of shallow parts (Premold Corp, *Design Guide*, P. 14, 2017).

Moulding Small Details: Although small and complex features can be moulded into RIM produced parts, it is easier for them to be cut out of the product during post-processing. If it is preferred for them to be moulded in, then it should be ensured that good resin flow can get to the detail, so that air pockets are not formed. This is particularly important with small bosses (Premold Corp, *Design Guide*, P. 15, 2017).

Letters and Logos: Protruding and indented letters and logos are compatible with the RIM process. However, they must be oriented in the direction of resin flow (like any details), so that they gain full resolution, and so that no air pockets are formed. Moreover, there are variable factors which will have to be discussed with the moulding company to produce the best possible characters or logos, with minimal costs and lead times. These factors are: the feature height/depth, feature width, radii around the feature, and space between the features. Both the inside and outside of the letters or logo should consist of radii between transitioning surfaces, this will minimise machining and the overall part costs (Premold Corp, *Design Guide*, P. 16, 2017).

Snap Fits and Moulded-In Hooks: Snap fits and moulded in hooks can be used to speed up and improve the economy of the products assembly, as they can enable numerous components such as electrical wires and PC boards etc. to be attached without additional hardware. The same design protocol that is used for snap fits with thermoplastic resins should apply to RIM processing. Moulded in hooks can be implemented through by-pass cores (Premold Corp, *Design Guide*, P. 17, 2017).

Threaded Inserts and Self Tapping Screws: Yardley Trisert thread locking inserts are recommended for optimal fastening of polyurethane parts. In contrast, Loctite branded or nylon inserts are not suitable for RIM parts as they will turn out with the screw. The part being fastened should not be allowed to rotate against the threaded insert, as this will turn it loose, or further into the component. The parameters for self-tapping screws are: that they can only be used with rigid polyurethane parts, and those for thread-cutting screws are: that they should be used if the screw is to be removed and replaced over five times. Sufficient radial clearance around the screw heads and shanks of either types of screws is required to compensate for both manufacturing and hole-to-hole tolerances. The parameters of the hole on the component are, that it is recommended to be a median between the smallest and largest diameters of the screw, and it should have a draft angle of 0.25 degrees on all edges. Additionally, the thread should be double the screws diameter. If two components are being mated with a machine screw then

sufficient clearance within the adjoining part must be made, if not, the screw will not pull into the material, and instead push the fastener out (Premold Corp, *Design Guide*, P. 18, 2017).

Insert Moulding: Inserts are usually quite feasible within RIM processing. However, the inserts must have certain criteria in order to be moulded into the parts. These are: that they must be able to undergo pressures of between 25 and 50 psi, be able to withstand temperatures of around 122 degrees Celsius for a limited period of time, whilst the exothermic reaction occurs, and will not be damaged by the liquid material flowing around it. Finally, as a designer the stress that inserts can cause on the product during material shrinkage, must be taken into consideration (Premold Corp, *Design Guide*, P. 20, 2017).

Additional Information

Alternative RIM processes: Reaction Injection Moulding stems off into three primary sectors which are Reinforced Reaction Injection Moulding (RRIM), whereby reinforcement agents such as mica and glass fibres are added to the storage tanks prior to impingement and make the product to be produced stronger in multi-directional ways (Ashida, P. 79-81, 2006; Composites Lab, 2018). Additionally, there is Structural Reaction Injection Moulding (SRIM), in which a fibrous material such as a vinyl mesh is set in the mould, and submerged into the product during the process (Bridgewood, 2018). Finally, there is Polyurethane Reaction Injection Moulding (PU-RIM), which is the most common form of RIM processing and utilises an isocyanate and polyol combination to produce parts. Also, this is the most common material for this process, it however, (as discussed previously) is not the only material that can be utilised (Hutchinson, 1987).

Gating: An edge gate is usually appropriate for RIM moulds, and a common example of this type of gate is a dam gate. Dam gates are useful in this scenario as they slow down the resin and allow it to spread out in a laminar fashion, in order to fill the mould quickly and accurately, ensuring that all of the fine details are covered (Premold Corp, *Design Guide*, P. 4, 2017; Hollcraft, *Slide 3*, 2016).

Removing Air from the Mould: Venting around the mould and its details (as previously discussed in the design considerations section) is utilised to remove air from the mould. Additional means of removing air from the mould are: injecting the resin in from the base, and tilting the mould press to spread the resin, and depress air pockets (Ibid, 2017).

Shrinkage: Although shrinkage is a characteristic of the RIM processed materials, it is usually dealt with effectively during mould production, due to the materials predictable and uniform shrink properties. Because of this, it does not need to be considered by the designer (Premold Corp, *Design Guide*, P. 24, 2017).

Recycling: Currently polyurethane is the most vastly recycled RIM material, and it can be recycled in the four following ways: grinding, compression moulding, glycolysis, and energy recovery (Purmold, *Recycling*, 2018).

Reaction Injection Moulding Compared to Other Processes

The RIM process offers substantial benefits compared to that of several other manufacturing processes, which might have been considered to manufacture a product, where reaction injection moulding is superior. Shown through the following screen-shots:

Injection Molding

RIM Advantages

- Approximately 70% less expensive
 - Molds thick, lightweight structural parts without sink
 - Varying wall thicknesses on same part
 - Similar tolerances to injection molding
 - Molds over metal, glass, wood, wiring, circuit boards, hardware, etc.
 - Much better economies for lower volume parts
 - Shorter tooling lead times
- Injection Molding Advantages

- Lower high-volume per-part cost
- Colored plastic parts don't need paint
- Finer part detail
- Greater range of material choices

Thermoforming

RIM Advantages

- Much greater design freedom
 - Lower costs for complex parts
 - Higher part tolerances
 - Combination of multiple parts
 - Molded-in bosses, ribs and other 3D features
 - Thicker, stronger parts
- Thermoforming Advantages
- Less expensive simple parts
 - No paint needed for single-color parts
 - Generally less expensive tooling

Rotational Molding

RIM Advantages

- More sophisticated design
 - Higher tolerances
 - Increased strength and durability
- Rotational Molding Advantages

- Hollow part molding

Sheet Metal

RIM Advantages

- Much greater freedom to design attractive, sculpted parts
 - Less expensive complex or curved parts
 - Generally lighter-weight parts
 - Enhanced sound and vibration insulation
 - In-mold painting
 - Soft-touch or flexible parts possible
 - Encapsulation of parts – glass, metal, wood, wiring, circuit boards, etc
 - High corrosion- and rust-resistance
 - Non-conductive
- Sheet Metal Advantages

- Parts sometimes structurally stronger
- No additional EMI/RFI Shielding needed
- Less expensive tooling
- Lower expense for simple parts

Die Casting

RIM Advantages

- Lower weight
 - Higher tolerances
 - Greater design freedom
 - No brittle parts
 - Net shape with no machining
 - Corrosion-resistance
- Die Casting Advantages

- Low tooling cost
- Shorter lead-time

(RIM MFG, *Reaction Injection Molding Vs. Others*, 2013)

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Reaction Injection Moulding (RIM)

Process Description

RIM manufacturing uses two liquid products, Polyol, which determines the parts physical characteristics, and an Isocyanate, which is a hardener. They are each contained in their own temperature-controlled feed tanks, with agitators to keep the liquid fluid. Within each of these tanks additives such as catalysts, reinforcing agents, surfactants and fillers etc. can be added to obtain certain process or product qualities e.g. increased curing time or expansion and foaming. When the process is ready to begin, the products are separately fed into a metering piston unit that precisely measures the right quantity of liquid required for correct curing to occur, and the size of the part being produced (calculated prior to processing). From there, the two reactants continue under high pressure (1,500 to 3,000 psi) to a single container with a mix-head, that is opened through valves. Within this chamber the two liquid parts are rapidly mixed, and combine to produce a single curing polymer; because of the relatively quick exothermic reaction that is occurring, and the small curing time, the injection moulding must begin post-haste. The polymer then leaves the mixing chamber and flows into the part specific mould at a pressure of between 30 and 100 psi, before fully curing. During this stage the resin reaches a momentary temperature of 177 degrees, before being ejected by pins, air, or by hand.

Polyurethane Integral Hard Foam

Overview: Sandwich-style design, that allows for good design flexibility, through the fact that it can have variable wall thicknesses without sink marks or part distortion, whilst having high rigidity and good thermal and acoustic insulation properties.

Areas of Application: consumer electronics; medical technology; bank payment stations and access systems; workplace carriers and handling units.

Polyurethane Compact Foam

Overview: This product is an alternative material to thermoplastics used in traditional injection moulding and has a tight structure with a high impact strength, and can be used to manufacture large parts of around 6m², as well as thin wall sections.

Areas of Application: medical devices; consumer electronics; containers, trays, machine and device enclosures; the railway industry.

Polyurethane Casting System

Overview: This PUR system is a high strength to weight ratio alternative to steel or grey cast iron, and is specialised for functioning parts that undergo particular mechanical or chemical stress, it also withstands abrasion well.

Areas of Application: agricultural, pump and waste water technology; applications within sewage purification plants; grounding cable connection systems; the construction industry.

Polyurethane Flex Foam

Overview: PUR Flex Foam offers high impact strength along with durability at extreme temperatures, and very good abrasion resistance. It can also be made aesthetically pleasing through structured tool surfaces.

Areas of Application: industrial trucks and driver cabins; the construction industry; agricultural technology; logistics; access systems.

Polyurethane Energy Absorption Foam

Overview: This material has very diverse uses, and can be used for passenger protection on vehicles due to its ability to be deformed under kinetic energy, rather than breaking.

Areas of Application: body protection e.g. head, knee and elbow pads; vehicle exteriors e.g. grit guards and bumpers.

Polyurethane Semi-Hard Integral Foam

Overview: This product can be used for a range of lightweight comfort components of different softness's due to its variable densities.

Areas of Application: door panelling; seat components e.g. arms, backs and filling.

Compatible Materials



Considerations

Design considerations that should be looked into are:

Ribs; Bosses; Undercuts; Draft Angles; Parting Lines; Radii and Fillets; Wall Thickness; Holes, Grooves and Slots; Joints Between Parts; Moulding Small Details; Letters and Logos; Snap Fits and Moulded-In Hooks; Threaded Inserts and Self; Tapping Screws; Insert Moulding.

<http://www.premoldcorp.com/wp-content/uploads/2017/08/Design-Guide-8th-Edition-2017-151990-Premold-final-1r.pdf>

Suppliers



A temperature controlled and agitated storage tank that holds Polyol.

01

02

Another identical storage tank that holds Isocyanate.

03

Pipe lines that transfer the liquid components at high pressure.

04

Measuring pistons that process precise amounts of the components.

05

A mix head that rapidly mixes the two components to the stage of reaction.

06

A weakly clamped mould of aluminium, nickel, epoxy resin, model board, or silicon rubber.

Volume

Low to medium volumes anywhere from 50 to 50,000 parts per year can be produced.

Factors such as lower volumes per mould, longer processing, and larger part production depreciates the volume that this process can produce.

A maximum of around 300 parts can be produced before stronger traditional injection moulds should be considered.

The process should be utilised to produce more than 50 parts per year in order to gain back your investment.

Post Processing

Regardless of the route chosen (below) once ejected, the parts requires the small amount of flash to be removed by hand or automated machines.

Route 1 - Class A surfaces, In-mould decorating through hydrographic or thermoplastic films, and intricate mould textures can give the desired finish with no post-processing.

Route 2 - Filling, Sanding, drilling, painting for the best finish with RFI/EMC shielding, textured, soft-touch, anti-microbial paints, pad printing, or silk screen printing for product graphics, and finally subassembly of components.

The RIM process does not take to colour additives well as they depreciate the parts finish.

Speed

It takes between 5 and 35 seconds for a mould to be filled by the material after mixing.

Depending on the size of the part being produced and the material composition being used, it can take anywhere between a few seconds and several minutes.

A product can be demoulded in a matter of seconds, but it can sometimes be longer, if the the component has multiple mould parts, or is delicate and requires removal by hand.

Example: An elastomeric part of average size would fill the mould in less than a second, and be demoulded in between 30 and 60 seconds.

Typical lead times vary between companies but parts are usually ready for shipping in a matter of days.

Cost

Mould costs are often 10 to 20% of traditional injection moulds.

Low pressures and temperatures mean lower energy cost.

A self-cleaning mix-head and less clamping force means less equipment costs.

Expensive Raw Materials.

Because this process is human driven, larger parts in smaller quantities could be competitively high due to labour costs.