Materials for Reaction Injection Molding (RIM) Processing

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Abstract

Reaction injection molding (RIM) is a relatively new manufacturing technology to produce high-quality parts that can be either reinforced or unreinforced. The composites industry is very interested in RIM because:

- RIM materials don't contain styrene;
- RIM parts are generally lighter than polyester composites; and,
- RIM parts are often lower in cost than polyester composites.

This paper will help fabricators in the composites industry understand how the RIM process works, the advantages of the RIM process and the key materials used with the RIM process, as well as new developments taking place in processing and materials.

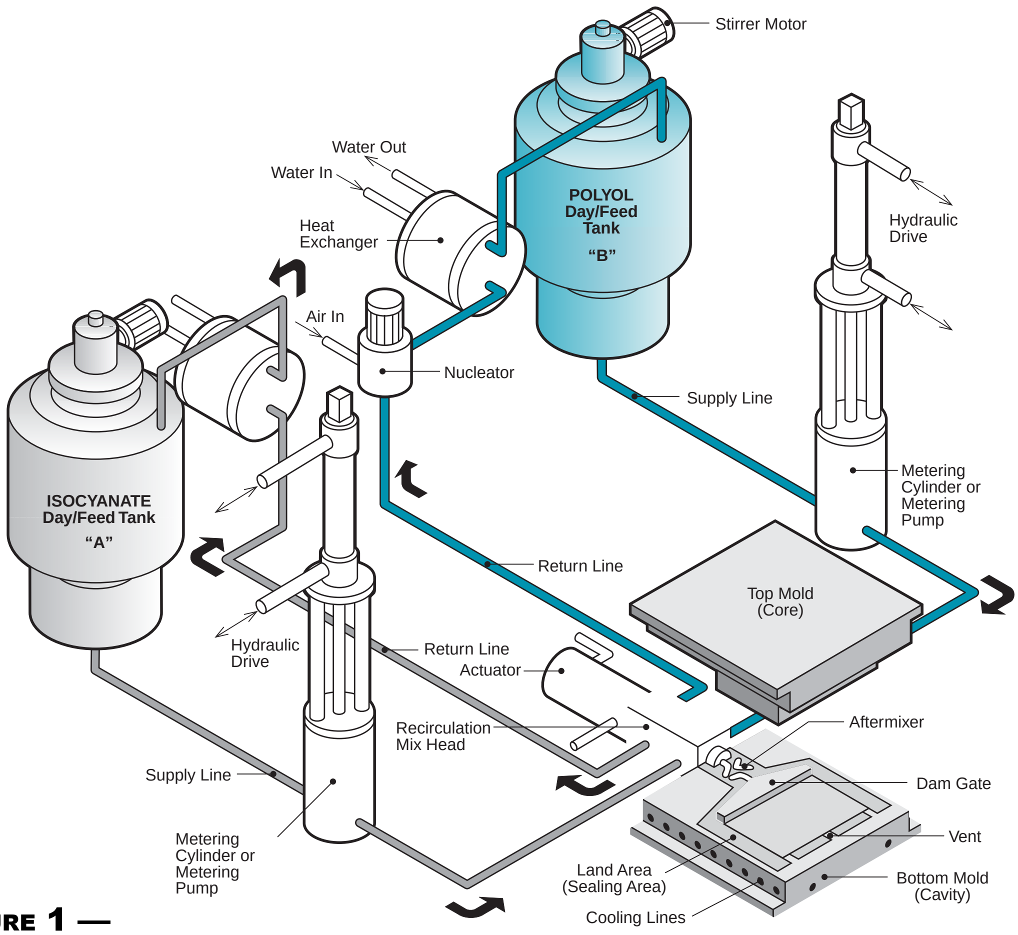
The Process – How RIM Works

At the heart of the RIM process is a chemical reaction. Two liquid reactants – the A-side component and the B-side component – are held in separate, temperature-controlled feed tanks equipped with agitators. From these tanks, the two liquid reactants are fed through supply lines to metering units that precisely meter each reactant, at high pressure, to the self-cleaning mixhead *(see Figure 1)*.

When injection begins, the liquid reactants enter a chamber in the mixhead at pressures between 1,500 and 3,000 psi through two very small orifices, where they are intensely mixed by high-pressure impingement. From the mix chamber, the mixed liquid flows into the mold at approximately atmospheric pressure and undergoes an exothermic chemical reaction, forming the polymer in the mold.

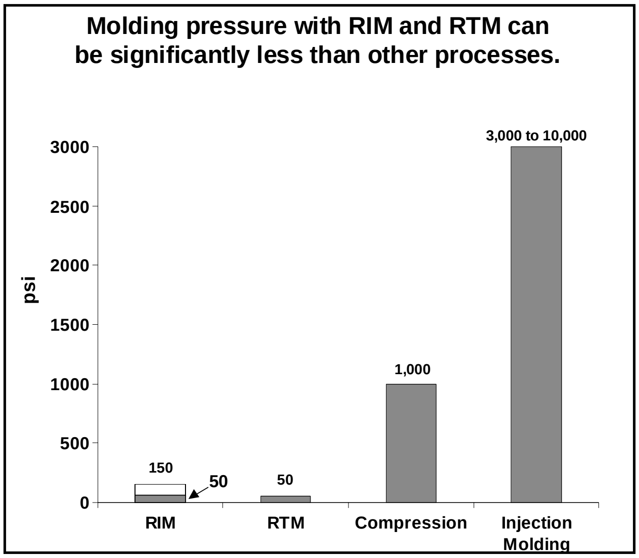
The RIM process is similar to resin transfer molding (RTM) in that both processes meter and mix two-component liquid materials that react to form a polymer. However, there are significant differences in the throughput of the metering pumps and how the components are mixed. First, the throughput of the metering pumps for RIM can range from 0.25 to 30 pounds/second versus 0.1 to 0.25 pounds/second for RTM. Second, the mixing of the materials in RIM is based on impingement mixing that occurs in a specially designed, self-cleaning mixhead. Mixing of the materials in RTM is based on a static mixer that needs to be disposed of in a landfill. An additional difference with RIM is that either reinforced or unreinforced parts can be produced. RTM parts are always reinforced.

Both RIM and RTM are low pressure molding processes *(see Figure 2)*. Pressures inside the mold for RIM range from 50 to 150 psi. With RTM, the pressure inside the mold is 50 psi. Molding pressures are significantly higher for compression molding and injection molding.



— FIGURE 1 —

Diagram of Typical RIM process



— **Figure 2** —

Advantages of RIM

The RIM process utilizes very low viscosity liquids ranging from 300 to 1,500 cps, low process temperatures of 90 to 105°F and low internal molding pressures between 50 and 150 psi. The low viscosity, low temperatures and low pressures provide some very distinct benefits or advantages for the RIM process compared with other plastic process methods.

1. Very Large Parts

The excellent flowability of RIM material systems make them ideal for large parts. The rigid, polyurethane structural foam rear shield for a John Deere combine *(see Figure 3)* measures approximately 6 feet by 6 feet and weighs 75 pounds. The size of the part that can be molded depends on the speed of the reactivity profile of the material system and the throughput of the metering pumps.

2. Encapsulation of Inserts

Inserts of many types can be placed into a mold prior to injection of the RIM material. The low viscosity liquid materials then flow around the insert. In a snowshoe example *(see Figure 4)*, an aluminum frame is placed into the mold and an elastomeric polyurethane RIM system is injected and encapsulates nearly all of the frame. Steel, aluminum shapes and frames, window glass, glass preforms, electronic connectors, PC boards, and wiring harnesses are some examples of materials that successfully have been encapsulated using the RIM process.

3. Thick and thin Walls

Variable wall sections within the same molded part are a definite problem with many plastic processing methods and materials, such as thermoplastic injection molding, blow molding, sheet molding compound (SMC) and other polymers. But thickness variations are common with many types of RIM parts. Wall thickness ranges between .25 inches and 1.125 inches are possible cross sections in the same molded part with minimal to no sink marks.

— **Figure 3** —

Large-part capability: Reaction injection molded rear wall for Deere & Company combine

4. Class-A Surfaces

The surface finish of parts molded with the RIM process allows manufacturers to produce Class A painted parts. For example, automotive manufacturers are able to produce fenders, spoilers and fascia parts that can match the high-gloss painted metal parts they are mounted next to in the final assembly.

5. Low Cost Tooling Options

The low injection pressures of the RIM process allow mold builders to use a variety of less expensive mold materials other than P-20 or hardened steel. Alternate materials range from machined or cast aluminum to cast kirksite, nickel shell, and even some plastic composite materials.

6. In-Mold Coating and Decorating

Polyurethane in-mold paints, polyester gel coats and pre-decorated films can be used with polyurethane RIM materials to produce a finished part right out of the mold. The steps are to first apply the paint or film to the cavity. Then, close the mold and inject the polyurethane RIM material. In-mold coating and decorating can greatly reduce the secondary costs for painting, which can often be a significant portion of the total part cost. In-mold coating is a unique advantage for polyurethane RIM materials and is based on achieving a urethane chemical bond between the polyurethane paint and the polyurethane RIM substrate.

These six process advantages give engineers and designers tremendous freedom to develop solutions to their design challenges not available with other manufacturing methods. The most successful end-use applications utilizing the RIM process incorporate one or more of these six advantages.

The Materials

Polyurethane, dicyclopentadiene (DCPD), epoxy and nylon have been processed via the RIM process. Polyurethanes are by far the most commonly used materials for RIM, representing over 90% of total RIM volume.

Polyurethane RIM can produce a part that can be foamed or solid and flexible or rigid. The RIM process can use numerous formulations to produce parts in one of six categories *(see Figure 5)*. Virtually anything from a flexible foam-core part to an extremely rigid, solid part is possible with the RIM process, making it desirable for a wide range of end-use applications. For example, rigid structural foam polyurethane RIM systems can produce parts with molded specific gravities ranging from 0.2 to 0.9. Solid systems can produce parts with specific gravities ranging from 1.0 to 1.2.

— Figure 4 —

Encapsulation of Inserts: aluminum frame molded into snowshoes

— **Figure 5** —

Rigid Polyurethane Structural Foams

An OEM's desire to utilize renewable resources in the production of body panels was made possible with a polyurethane structural foam. The polyurethane is made with a polyol produced partly from soybeans rather than entirely from oil and natural gas. John Deere is using the soybean-based polyurethane RIM material to mold the roof, rear shield and door of its STS harvester combines. Expanded use of soybean-based polyurethanes is expected in other applications.

Moreover, short glass or mineral fibers can be added to the polyol blend to produce reinforced RIM (RRIM) parts with enhanced stiffness and heat performance. Low viscosity RIM systems can be injected into a mold through glass mats or preforms to produce very stiff, high-strength composite structural RIM (SRIM) parts.

DCPD, epoxy and nylon materials are typically used only to produce an unreinforced, solid polymer. *Figure 6* shows a comparison of the way the materials are commonly used.

Innovations in Materials and Processing

The demands of the marketplace to meet ever-higher end-use application requirements are driving the development of new material formulations and process technologies. The remainder of this paper will focus on recent innovations that have positioned RIM technology for rapid growth in this decade.

Solid Elastomer Systems

High-heat polyurea systems have been developed that offer typical performance characteristics of polyurethane but with the added capability to handle higher-heat requirements. These new polyurea systems can easily withstand 400°F. These new high-heat systems have been used with short mineral fillers to make large automotive body panels that are assembled to the metal chassis of vehicles and go through the E-coat painting lines.

High-heat polyurea systems have also been used to produce engine enclosures and hoods for non-automotive vehicles.

	Rigid Foams	Solid Elastomer	Reinforced RIM	Structural RIM
Polyurethane	✓	✓	✓	✓
DCPD		✓		
Epoxy		✓		
Nylon		✓		

— **Figure 6** —
RIM Materials Comparison

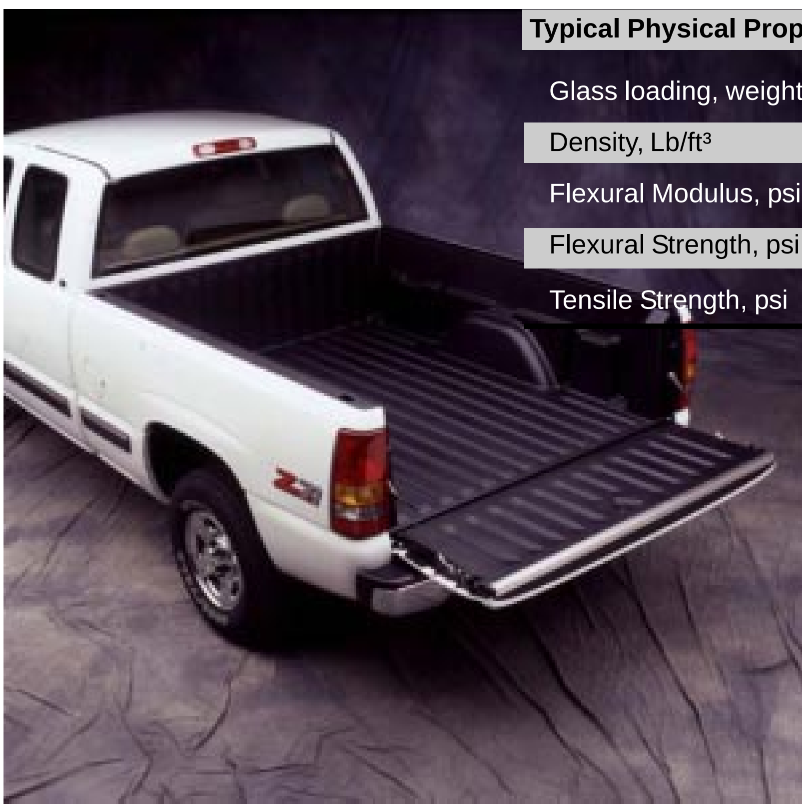
Composite SRIM Systems

The demand for lighter, tougher, more cost-effective components has driven the development of polyurethane SRIM materials and equipment. This area of RIM processing will experience the fastest growth in this decade, and it will include both solid and foamed polyurethane SRIM.

The traditional SRIM process uses either fiberglass preforms or directional or non-directional mats as inserts in the mold cavity through which the polyurethane is injected. The specially developed polyurethane system and preform produce very high physical properties for the pickup truck cargo box and tailgate for General Motors *(see Figure 7)*. The SRIM cargo box not only meets the stringent OEM performance requirements and cuts weight from the vehicle, but also provides long-term durability, low maintenance costs and freedom from rust and dents. The cargo box offers excellent high-heat and cold-temperature stability.

Foamed polyurethane SRIM is also moving into new applications based on the development of new, longer gel time and better flowing polyurethanes. The HVAC enclosure for a Caterpillar front loader *(see Figure 8)* uses a vinyl outer skin that is vacuum-formed in the mold cavity prior to inserting the glass mat and injecting the polyurethane SRIM system. The final part is 50% lighter than an RTM part and provides significant cost savings.

Foamed polyurethane SRIM opens up new possibilities for engineers and designers. *Figure 9* shows a plot of flexural modulus versus density for polyurethane SRIM and traditional plastics and composites. The foamed SRIM composites offer the same stiffness with a 20-40% lower density. Foamed polyurethane SRIM is being used for applications such as automotive door liners, furniture and marine plywood replacement.



Typical Physical Properties[1] for SRIM Cargo Box	
Glass loading, weight	50
Density, Lb/ft^3	99
Flexural Modulus, psi	1,900,000
Flexural Strength, psi	50,800
Tensile Strength, psi	30,300

[1]These items are provied as general information only. They are approximate values and are not part of the product specifications.

— Figure 7 —

SRIM cargo box and properties

— **Figure 8** —

Foamed SRIM HVAC cover

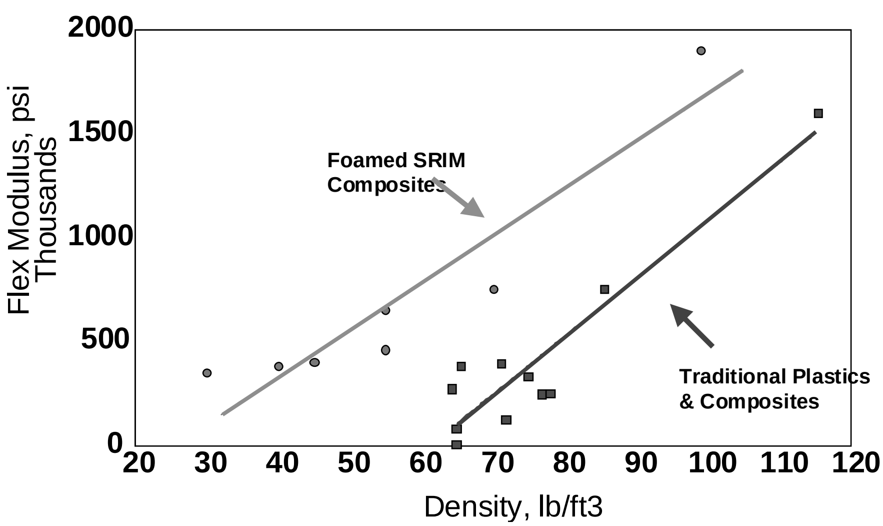
Additionally, new technologies developed by RIM processing equipment suppliers are opening up significant new opportunities. Each of the major processing machine manufacturers has developed competing technologies to inject long glass fibers along with the polyurethane system as a one-step process, rather than the traditional two-step process of inserting preforms and/or mats into the mold. In these new technologies, a glass chopper is attached to the mixhead, which is mounted to a robot. The robot is programmed to move over the open cavity while dispensing both the long glass fibers and the polyurethane SRIM formulation in an open-pour method. At the end of the pour, the mold is closed to form the part. These developments are helping to automate the SRIM process, making parts more economical to produce. This processing technology can utilize either a foamed or solid SRIM formulation.

Benefits of this automated technology include:

- Ability to utilize lower cost fiberglass rovings rather than mats;
- Ability to vary the amount of glass reinforcement in the part;
- Ability to utilize either a foamed or solid polyurethane formulation; and,
- Ability to produce polyurethane SRIM parts with polyurethane in-mold coating, thus eliminating secondary painting operations.

Interior cab components being made for a heavy-duty truck manufacturer are the first parts to be made in the United States with the one-step process. In Europe, the process is being used to produce numerous components. Examples are dashboards and parcel shelves for automobiles. The roof for the SMART Car is based on the one-step process. In this application, a sheet of thermoplastic film that becomes the exterior surface of the part and a headliner material that becomes the interior of the part are placed into the mold prior to the SRIM processing.

Development efforts are underway to develop Class A polyurethane SRIM parts based on in-mold coating and thermoplastic film technologies.



— **Figure 9** —

Baydur Composites offer stiffness at lower density

Conclusion

Recent developments in RIM processing and materials offer the composites industry new options and alternatives that can help continue the impressive growth of the industry.

RIM parts are generally lighter than polyester composites. The combination of lighter weight and in-mold coating often result in unreinforced polyurethane RIM parts that are less expensive than polyester composites. New SRIM technologies are opening up significant new opportunities for composites.

An additional advantage is that RIM materials are styrene-free.

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