Customer Design Guide

[Basic principles and guidelines for the design and manufacture of Rotationally Molded and Laser Sintered products.]

Rotational Molding and Laser Sintering

Contents

1. About Us

RMB Products was founded in 1963. Since 1978, we have specialized in rotational molding, laser sintering, and engineered polymers for the aerospace, chemical processing, semiconductor and biopharmaceutical industries.

Over 35 years after pioneering our industry, we have built a solid reputation for solving challenges that require innovation, broad experience and a commitment to meeting exacting standards.

Our manufacturing capabilities are geared for custom, low-volume products for critical applications and those requiring tight specifications. Our rotational molding and laser sintering (additive manufacturing) capabilities offer optimal flexibility in complex part geometries and compatibility with a wide array of highly engineered polymers.

We offer turnkey services including design and engineering, mold fabrication, material compounding, fabrication of metal substrates, production, custom finishing and assembly. We adhere to a robust quality management program and offer extensive testing capabilities.

2. Aerospace Division Capabilities

RMB Products' in-house manufacturing capabilities, robust technologies and comprehensive processes let us provide a turnkey solution for your most challenging application. Our ability to control all aspects of design, inspection, production and finishing enables us to meet or exceed your highest quality standards.

RMB Products specializes in:

- Rotational molding
- Additive manufacturing (laser sintering), sometimes referred to as 3D printing

Our full-service manufacturing capabilities include:

- Custom finishing, assembly, and trimming
- Design and engineering
- Technical welding
- Tooling creation
- Polymer formulation, compounding, and cryogenic pulverization

3. Processes

3.1. Rotational Molding

Rotational molding applies a thin layer of thermoplastic material onto the interior surface of a mold. This process creates hollow, one-piece, free-standing thermoplastic products and is ideal for manufacturing seamless components with complex geometries.

In the rotational molding process, rotational-grade polymer in granular form is placed inside the metal mold and heated while being rotated simultaneously about two perpendicular axes. During the heating cycle, the polymer particles melt and adhere to the metal mold, forming a thin, uniform layer of thermoplastic.

After a predetermined time at a specific temperature, all plastic is distributed over the interior surface of the part; the mold is then cooled. Finally, the part is removed from the mold. The resulting seamless, freestanding thermoplastic piece can be trimmed, routed, or 5-axis machined to tight tolerances, or otherwise finished and assembled with other details to create a finished part.

If you require components such as mounting nuts, brackets, nut plates, bellows or insulation, RMB Products can help determine whether to mold them in or assemble them after molding using adhesives or mechanical fasteners such as rivets.

Advantages

- Possible Cost Reduction - Cost effective alternative to expensive composite layup or metallic solutions
- Robust Properties - Increased durability compared to composite which results in decreased operating costs over the entire life cycle of the product
- Long term solution - Compared to alternatives rotationally molded ECS ducting has been in continuous service in commercial and military related aircraft for over 20 years
- Quality and Consistency - Extremely high quality and dimensionally consistent products resulting from RMB Products' extensive expertise in rotational molding
- Low Non-recurring - Tools that are significantly lower in cost than blow and injection-molded tools—making short and medium product runs affordable
- Seamless Design - Ability to create complex geometries in a single seamless part
- Short lead times - From product conception through manufacture
- Proven Materials - The most commonly used molding materials are polyamide based (nylon 12 primarily) and are used extensively throughout the aerospace industry. RMB offers a fire retardant (RMB 437) and a non-fire retardant (RMB 421C) nylon 12, both of which are impact modified.
- Fire Retardant Grades - Meet or exceed the 12 and 60 second burn requirements:
    - FAR 25.853 Transport Aircraft Fire Protection of Compartment Interiors (fixed wing)
    - FAR 29.853 Transport Rotorcraft Fire Protection of Compartment Interiors (helicopter)
- Chemical Resistance - Materials offer excellent chemical resistance and can be used in environments that include fuel, oil, and many of the aggressive cleaning chemicals.
- Low moisture absorption - <2%

Disadvantages

- Requires an initial investment in non-recurring for a mold and in most cases a trim fixture.
- Changes to geometry that affect “as-molded” characteristics of the product will require tooling modifications or perhaps new tooling.
- Lends itself well to hollow shape geometries. While internal features such as flow straighteners and stiffeners are producible, you should consider laser sintering as well in your decision process.

3.2. Laser Sintering

Laser Sintering is a form of Additive Manufacturing. The term additive manufacturing is the broader name adopted by the ASTM F42 committee to describe this type of manufacturing. More recently, the term “3D Printing” has become the generic term used for all additive manufacturing processes. Our focus herein will be related to the laser sintering process.

Additive manufacturing differs in that it adds material to create the final part as opposed to traditional subtractive techniques such as milling and lathe operations that subtract material from the part. Many aircraft OEM’s (original equipment manufacturers) have written their own proprietary laser sintering specifications. RMB performs to and produces additive manufactured parts for most of the domestic OEM’s. ASTM F42 committee exists to produce a standard that any industry can use for design assistance/guidance.

Other common additive manufacturing terms and technologies are 3D Printing, rapid prototyping, Stereolithography (SLA), Fused Deposition Modeling (FDM), etc. Laser Sintering at RMB is unique in that the use of stringent process controls allows the manufacture of flight-ready parts for production applications.

Laser sintering is a process in which complex plastic parts and assemblies are fabricated in a single process, one layer at a time. Parts are fabricated directly from a computer-aided design (CAD) file, allowing the manufacture of products to meet the exact design specifications created by engineers.

Fine plastic powder is loaded into containers in a heated chamber and rolled across a platform that incrementally lowers as each layer is processed. The laser sintering system slices the solid CAD model into thousands of horizontal layers, each of which is selectively melted by a CO2 laser. Each cross-sectional layer is successively melted on top of the previous layer to create a fully dense, solid part. The build envelope is approximately 13 x 11 x 17 inches. All parts need to be “nested” in such a way as to optimize the build space for yield and part quality purposes. Full height production builds can be completed in as little as 3-4 days after completion of the qualification process.

Each run can yield multiple parts, all nested together within the build volume. Test coupons and/or tensile bars can be built alongside each part to nondestructively validate the parts’ mechanical or chemical integrity.

The sintered parts are now service-ready. Alternatively, as necessary, the parts may be post-machined, painted, bonded together and assembled with other hardware, resulting in a fully finished assembly. It is common to rivet nut plates, or bond silicone sleeves, bellows, and insulation to the sintered details.

Advantages

- No Tooling—Eliminates costly production tooling and die castings.
- Direct CAD Model Manufacturing—Manufactures complex parts with internal geometry directly from electronic data.
- Design Flexibility—Integrates key features and eliminates costly secondary operations.
- Revision Changes—Assimilates design changes quickly, without the need to retool.
- Robust materials – mechanical toughness that rivals rotational and injection molding tensile strength.
- Proven Materials - The most commonly used sintering materials are polyamide based (nylon 11 and 12) and are used extensively throughout the aerospace industry. Fire retardant and non-fire retardant materials are available as well as many filled materials including glass & carbon.
- Chemical Resistance - Materials offer excellent chemical resistance and can be used in many environments.
- Low Moisture Absorption - <2%.
- Environmentally Friendly - Nylon 11 (PA11) is an agricultural based (castor bean), renewable resource material. Nylon 11 is a recyclable material, and RMB has put processes in place to fully optimize this attribute.
- Part Count Reduction—Incorporates multiple, individual components into a single component; less inventory to manage, less procurement and contract management costs.
- Cost Reduction—Optimized designs and reduced part count provides attractive savings opportunities compared with traditional manufacturing methods.
- Weight Reduction—With the ability to optimize design features, products may weigh less while maintaining design intent for strength, flow and other characteristics.
- Product Design Optimization—Design a product with optimal features without traditional manufacturing constraints (allows for variable wall thickness, internal features, mounting brackets, etc.).
- Short Lead-times—Quick-turn, low-volume alternative to tooled, multistep processed parts.
- Eliminates Obsolescence Issues—Addresses the growing industry problem of obsolescence for out-of-production spares in which tooling and/or materials are no longer available.

Disadvantages

- May not be as cost effective as rotational molding in higher quantities – this is part size dependent. Larger sizes will favor rotational molding whereas smaller, more complex details favor laser sintering.
- The “as-sintered” finish is rough – equivalent in finish to an aluminum sand casted part (800 RA). Typically not used on cosmetic parts or in visible areas of the aircraft unless the part has been finished with sanding, machining and painting. The surfaces are easily machined or sanded smooth to your requirements as a secondary operation and are often top coated.

- Extremely tight GD & T tolerances for bolt-hole configurations may be too tight for the "as-sintered" product. RMB recommends that any tight tolerance features be discussed before locking in the engineering design. Again, the material drills and machines very easily and a secondary -operation and fixture may be required to accommodate. One benefit to this "disadvantage" is that these fixtures can be CMM inspected and calibrated and added into our recurring calibration system for use in the final buy-off of this feature of the part.

4. Which process should I choose?

RMB looks forward to discussing specific projects with our customers. We will take the time to evaluate each part, with the help of the customer, and determine which process is best suited for your needs. The goal is to match the right process to your specific part, not force a process on a part.

Below is a list of questions that will aide in determining which process is best for you particular application. Please note this list is not all encompassing and there may be some exceptions.

What is the expected production volume/rate for the life of the product?

Laser Sintering Typical Volumes: 1 to 200 parts/year

Rotational Molding Volumes: 100 to 5000 parts/year

Can additional features be designed into the product?

Laser Sintering: "If you can model it, we can grow it!" Obviously there are certain restrictions to this statement, however Laser Sintering allows for many features that are just not possible using conventional methods. Internal flow straighteners and stiffeners, undercut geometry, integrated mounting tabs are all possible using Laser Sintering. Since the parts are "self-supported" by the powder during the sintering process the part has to be designed in such a way as to accommodate powder removal and post-sinter cleaning of the internal surfaces of the part. Keep this in mind when designing your parts.

Rotational Molding: It is possible to incorporate integrated aluminum stiffeners and molded in inserts into the design. Please consult with RMB as to the correct application of these features.

What are the initial lead-time requirements?

Laser Sintering: As short as 3 weeks from design completion to first article part.

Rotational Molding: As short as 8 weeks from design completion to first article part.

Is there a budget for non-recurring costs such as tooling?

Laser Sintering: Zero non-recurring costs.

Rotational Molding: Typical non-recurring costs include rotational mold and trim fixture tooling.

How mature is the overall design of the part and system?

Laser Sintering: Ability to accommodate an iterative design process similar to Agile Development. The absence of tooling creates the ability to build a part, evaluate its effectiveness and make changes without costly tool modifications.

Rotational Molding: Due to the requirement of mold and fixture tools you want to make sure that the design is not subject to change so that tooling can be manufactured.

Does the material need to meet flammability requirements?

Laser Sintering & Rotational Molding: RMB Products offers materials that are compliant to the 12- and 60-second vertical burn requirements of Federal Aviation Regulation (FAR) 25.853 and FAR 29.853 (RMB 437). Material datasheets are available for all grades of our materials.

What are the overall dimensions of the product?

Laser Sintering: Parts made using the Laser Sintering process, must be capable of fitting into a 13”x 11”x 17” cube. Larger parts can be accommodated by splitting the parts into sections and creating bond joints. Clocking features can be designed into the split to insure the correct orientation. It is common to bond multiple details together to accommodate larger geometries. Additionally, laser sintered details can be bonded to rotationally molded or injection molded details if needed.

Rotational Molding: Seamless parts can be made up to 12” in diameter and up to 8 feet long.

What are the cost advantages of each process?

Laser Sintering: In most cases laser sintering will be much less expensive than traditional processes such as composite layups or metallic weldments. When compared to rotational molding, the recurring laser sintered part price is typically 1.5X more expensive, but does not have the non-recurring tooling expense.

Rotational Molding: The least expensive option for manufacturing parts that meet the criteria noted in this guide.

What about adoption in a company where the standard is composite?

Laser Sintering: Most of the large US aircraft OEM’s have already adopted the use of laser sintered parts in production aircraft for non-structural applications. ECS ducting for cold and hot air is a common application along with shrouds, & wire management/conduits to name a few products. RMB estimates that well over 100,000 sintered details are flying on aircraft with no known failures and have been in service for over 10 years.

Rotational Molding: Again, most of the large US aircraft OEM’s are already taking advantage of the cost and weight savings of rotationally molded ECS ducts, spuds, fluid containment tanks, conduits, covers, etc. RMB’s fire retardant nylon 12 (RMB 437) is used extensively on commercial aircraft. RMB estimates that millions of rotationally molded ducts are flying on commercial and defense related aircraft and have been in service for well over 20 years.

The application of these two technologies is thoroughly embedded in the aerospace industry on both fixed and rotary wing aircraft. In addition, there is a significant level of specification compliance for RMB’s fire retardant and non-fire retardant rotational molding materials throughout the aerospace industry. With this level of usage and success, adoption for new applications is very low risk.

5. Tolerance Capability and Dimension Schemes

Rotation Molding:

It is advisable to use tooled surfaces (OML – Outside Mold Line) for dimensioning features. Where non-tooled surfaces (IML – Inside Mold Line) must be dimensioned, special consideration for the wall thickness variation that can occur in rotationally molded parts must be taken to ensure part-to-part consistency.

As-molded tolerances are recommended at +/- .004” per inch depending on geometry. For example a 10 inch dimension should carry with it a +/- .040” tolerance. Tighter part tolerances can be obtained

with some part geometries or by tool and process modifications. In general it is recommended to stay within recommended tolerances. Tighter tolerances can also be achieved using post molding processes such as trimming and routing.
Laser Sintering:

Standard aerospace tolerance schemes apply. Specific recommendations regarding holes and other features can be found in the Advantages/Disadvantages section 3.2 above.

GD & T tolerances for bolt-hole configurations may be accommodated using secondary operations for both rotational molding and laser sintering.

6. Applications

Aircraft Ducting, Fluid Containment Tanks and More

RMB Products manufactures a variety of aircraft ducting and other components that reduce cost, weight and time for our customers. In-house polymer expertise and a vertically integrated manufacturing facility offers customers a cost- and performance-effective aircraft ducting solution for environmental control system (ECS); heating, ventilation and air conditioning (HVAC); auxiliary power unit (APU) and air handling unit (AHU) ducts and wire management conduits, as well as fluid containment tanks.

Applications include

- Providing drop-in replacement solutions for existing ducting processes plagued by material obsolescence issues or missing tooling.
- Working with customer engineering to manufacture a rotationally molded or laser-sintered alternative to expensive, long-lead-time composite and aluminum aircraft ducts, providing cost reduction and, in many cases, weight reduction.

7. Value Engineering Opportunities

7.1. Convertible Technologies

RMB is able to convert existing aluminum and composite ducting and fluid tanks to utilize the rotational molding or laser sintering process. In most cases RMB is able to provide a drop-in replacement with no effect to the surrounding system. Examples of convertible technologies include, but are not limited to: fiberglass/Kevlar®/carbon fiber composite layup, bonded thermoforming, aluminum weldment, and blow molding.

7.2. Complimentary Technologies

Rotational molding and Laser Sintering can be combined with other plastic molding technology to give the customer the best solution for their application. Examples of this are bonding injection molded, thermoformed, compression molded, or laser sintered pieces to a base rotationally molded duct or fluid container. This allows you to utilize the advantages of each technology within one product.

8. How to Design for Rotational Molding and Laser Sintering

8.1. Rotational Molding

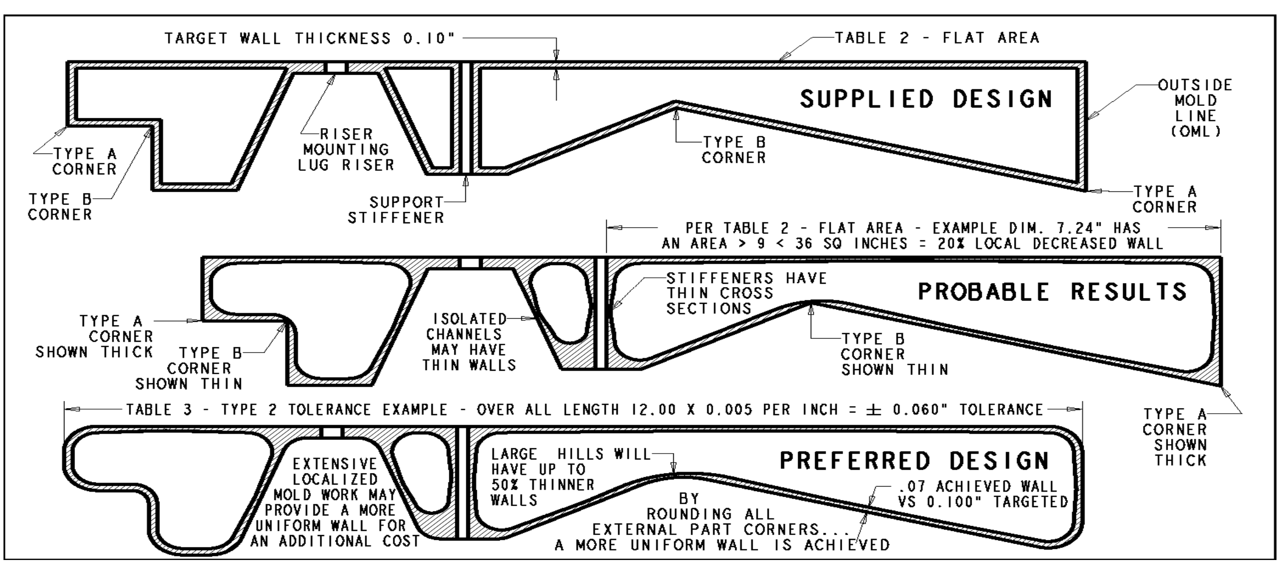
Rotational molding has significant advantages in making hollow parts over other molding processes. Rotational molding, like all processes, does have special considerations that must be incorporated into part designs.

8.1.1. Part Geometry (Radii)

As thermoplastic materials melt inside the rotational mold they never become a free flowing liquid. Rather these materials are distributed in powder form and adhere to the inside mold surface during oven processing. The material remains in place on the mold surface after melting. This makes rotational molding highly sensitive to the dry flow of the material. Areas of the mold that have more resident time during the molding process have more material accumulation resulting in increased wall thickness. The antithesis of this is also true less material resident time will result in decreased wall thickness.

Areas that tend to see the most effect from these conditions are radii. An inside radius on a part tends to be thicker than an inside radius. As a general rule of thumb an outside part radius equal to the wall thickness of the part will result in a 2x increases in wall thickness. A radii twice the wall thickness will see a wall thickness increase of 50%. Inside part radii will see similar increases and decreases in wall thickness. All of this is affected by tool geometry, resin characteristics and molding conditions. It is generally recommended at some point in the design the rotational mold supplier is involved to help predict what potential effects on wall thickness the part geometry in introducing. In general using as large of radii as possible can help reduce wall thickness deviations.

MODELED RADII	TYPE **A** CORNER		TYPE **B** CORNER	
Outside Mold Line (OML) corner "R" (radii) size	INSIDE mold corners may have an INCREASE of wall thickness at its cross-section.	EXAMPLE: Value of .100" wall thickness INCREASE defined on an inside corner	OUTSIDE mold corners may have a REDUCTION of wall thickness at its cross section.	EXAMPLE: Value of .100" wall thickness REDUCTION defined on an outside corner
R < 1x Target Wall	+ 5x	.50" probable wall	- 80%	.02" probable wall
R = 1x Target Wall	+ 4x	.40" probable wall	- 60%	.04" probable wall
R = 2x Target Wall	+ 3x	.30" probable wall	- 40%	.06" probable wall
R = 3x Target Wall	+ 2x	.20" probable wall	- 20%	.08" probable wall
Radii that are modeled 3x or less than the target wall may have a cross-section variation as listed above.				



8.1.2. Part Geometry (Large Flat Panels)

Large flat panels have a similar issue with material residence time as to outside part radii. The residence time of material as it flows across large flat panels becomes less and rotationally molded parts tend to get thinner in the center sections of these panels. This can eliminated or reduced by mold trials and mold modifications.

If a flat panel can be re-designed with a slight curvature, the chances of a more uniform part increases.

8.1.3. Twist and Bends

With the advent of solid modeling practices and CNC tooling, complex parts and tooling are now possible. The simplest and least expensive rotational mold is a two piece, flat parting plane tool with no undercuts. As part complexity increases the respective tooling costs will also increase. Involving the rotational molder in the part design process can help to control production related costs.

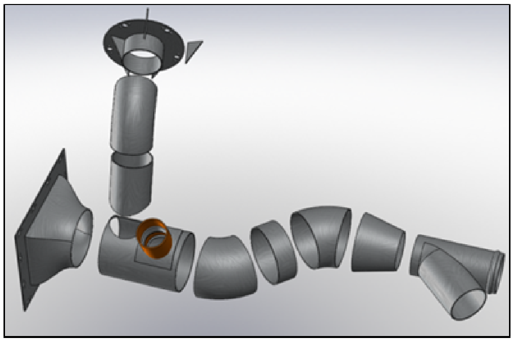
8.1.4. Factors Affecting Mechanical Properties

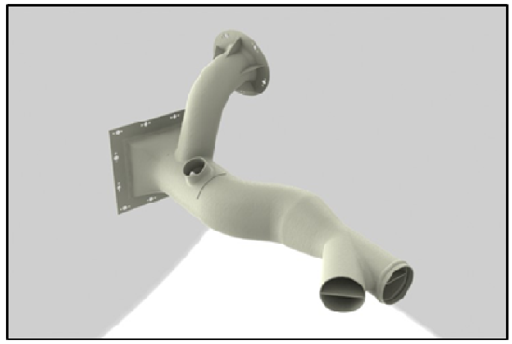
Design for elevated temperatures must address two issues. One is the performance of the material at the temperature. The second is long term degradation of material properties over time. The continuous operating temperature (COT) for Nylon12 is 180 degrees F. When considering process and materials, thought should be given to the COT of the part/system. The maximum recommended intermittent operating temperature for nylon 12 is 1000 hours at 250F at which time you reach 50% of the expected elongation.

8.2. Laser Sintering

When designing for Laser Sintering it is almost as simple as saying if you can design it, it can be built. Typical designs make provision for removal of the un-sintered powder from the part after the build is complete. In the extreme sense, imagine designing an enclosed cube within the part geometry. Un-sintered powder would remain in the cube with no way of removing it, essentially creating a solid mass. RMB machines are capable of fitting parts into an 11” x 13” x 17” cube. Larger parts can be broken up into multiple pieces and then bonded together if desired. This is quite common for many assemblies that RMB produces. Designing for Additive Manufacturing is unique in that you have almost unlimited design latitude. Design, consideration should be given to sub-component details on your legacy parts such as brackets, internal flow straighteners, internal stiffeners, mounting bosses, and even neighboring parts to take advantage of part count reduction opportunities. In legacy assembly, all of these sub-component details would have to be attached using rivets or adhesive. Using laser sintering, details can be incorporated in a one-piece design. These are all opportunities for part count reduction, cost, weight, and inventory savings.

For example, the 2.5” diameter ECS duct below was originally manufactured out of aluminum and welded together in sections. It was then converted to Laser Sintering and made in 1 piece. The resultant cost and time savings were dramatic. The customer went from 19 different aluminum details and 8 manufacturing process, down to 1 Laser Sintering detail and 2 processes.





(Aluminum Weldment) (Laser Sintered Detail)

Another significant consideration is the opportunities for impact (OFI). For the traditional welding process there are potential impacts on raw material lead-time for sub components, 19 sub component drawings, C of C's, testing & finish processes, & shop load schedules for each of the 8 above referenced processes. In comparison, the OFI for the laser sintered product is limited to raw material lead-time, 1 drawing, 1 C of C, & 1 primer process. Impact items will affect lead-time, quality and cost - less OFI equals less cost.

Additive manufacturing provides a value engineered solution to address cost, lead-time, material obsolescence, lost legacy tooling and previous design constraint issues.

9. Material Data

Nylon 11 (PA 11) and 12 (PA 12) compounds have been the materials of choice in the Aerospace industry and other high tech vehicle applications for the laser sintering and rotational molding processes. Nylon is a low-density, semi-crystalline material with excellent mechanical properties throughout its recommended temperature range (-40 degrees C to 82 degrees C). Its outstanding abrasion and frictional characteristics make Nylon an excellent choice in demanding applications. This combined with its excellent solvent resistance and wide processing window make Nylon a superior candidate for Aerospace and high tech vehicle applications.

Nylon 11 & 12 stand out compared to the more common Nylon 6 compounds. The distinct advantages over Nylon 6 these are:

- Lower Molecular Weight
- Lower specific gravity
- Better Thermal Stability
- Excellent UV stability
- Dimensionally stable in wet environments due to low water absorption
- Superior Impact Strength at low temperature and in dry conditions
- Lower processing temperatures reduces risk of resin degradation during processing
- Excellent chemical resistance in solvents, fuel, oil, greases, & salt solutions to name a few
- Stress crack resistant
- Exceptional abrasion and fatigue resistance
- Material modification possibilities:
    - Impact resistance
    - UV stabilization
    - Fire retardant to FAR 25.853, FAR 29.853 (12 & 60 sec vert)
    - Conductivity
    - Reinforcement/fillers

For full material specifications for these and other materials, please visit our website at www.rmbproducts.com.