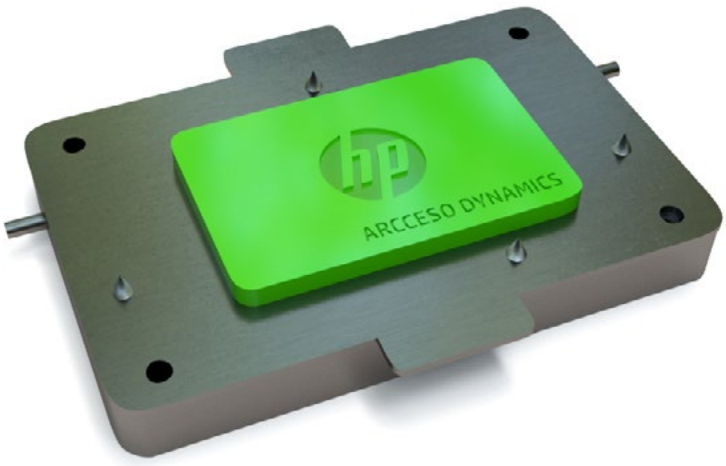
White paper

Reaction Injection Molding (RIM) Molds with HP Multi Jet Fusion Technology



Executive summary

Reaction Injection Molding (RIM) technology is widely used in the manufacturing of low-volume, large plastic parts (machinery covers, medical devices covers, etc.) in a variety of formulations and densities, using polyurethane as the material.

The process involves the injection of two compounds—polyol and isocyanate—that react with each other to form polyurethane. Polyurethane-curing chemical reactions that occur inside a RIM mold normally take place at low temperatures and pressures, comparable with the conditions of plastic Injection Molding. These low-pressure and -temperature working parameters make HP Multi Jet Fusion (MJF) materials very suitable for RIM mold manufacturing.

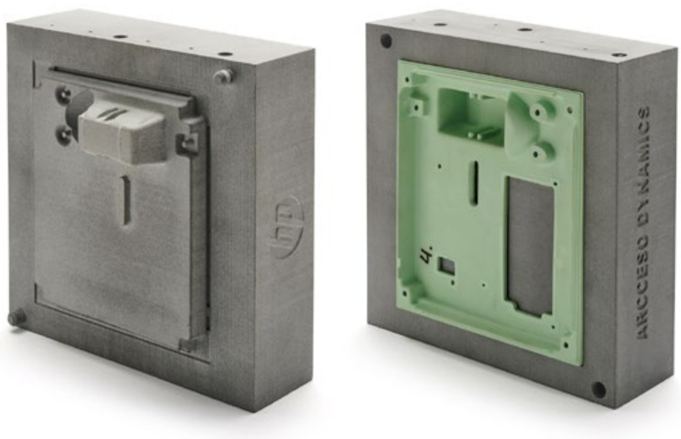


Figure 1: Reaction Injection Mold printed with HP Jet Fusion 3D 4200 and HP 3D HR PA 12
Data courtesy of Arcesso Dynamics.

Currently, RIM technology is the optimal technology for producing short runs of large plastic parts, such as machinery equipment covers or medical device housings, but also of automotive foam components within other families of parts. This competitiveness is lost against plastic Injection Molding when it comes to small or even medium-sized parts due to individual part manufacturing costs at similar mold prices.

By using HP Multi Jet Fusion molds, fabrication fixed costs will be reduced to a fraction of the original values, allowing the technology to address a much wider market of small- and medium-sized plastic parts.

The main advantages of making RIM molds with HP MJF technology are as follows:

- **Chemical compatibility:** The chemistry behind polyurethane is complex, and many materials (e.g., silicones, moisture in materials, etc.) are not compatible with the technology as they affect the curing reaction process. HP 3D High Reusability (HR) PA 12 has proven to be compatible with polyurethane molding.
- **Cost:** HP MJF allows for the possibility of creating the molds from a CAD file, which eliminates the intermediate steps in the process compared with CNC (CAM, pre-setting machining tools, etc.). Typically, the price of a medium-sized part mold decreases to 10% to 20% of the original cost with HP MJF.
- **Weight:** Usually 3D printing materials are lighter than aluminum or steel. Furthermore, 3D printing allows for the creation of high-rigidity, lightweight lattice structures that reduce mold mass and maintain mechanical properties.
- **Freedom of design:** Mold tempering and heat removal homogeneity are key in Reaction Injection Molding. HP MJF allows for the creation of complex, close-to-surface cooling conduits, thus increasing process performance.
- **Mold texturizing:** Using HP MJF technology will allow textures (e.g., wood, leather) to be printed directly into the mold, preventing high costs and long lead times on manual mold texturizing processes.

Figure 2: Reaction Injection Mold printed with HP Jet Fusion 3D 4200 and HP 3D HR PA 12
Data courtesy of Arcesso Dynamics.

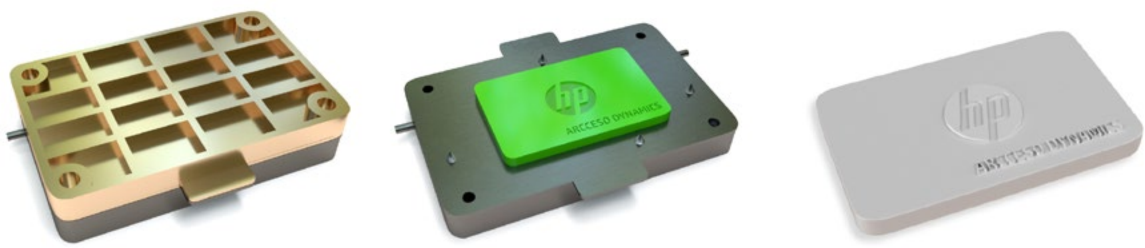


Figure 3: HP MJF–printed mold and part.

Current RIM applications

Advantages such as lower equipment costs for big, solid, or foam parts make RIM a widely used technology for parts such as covers and enclosures.

Figure 4: Medical device, a drink dispenser, and a steering wheel.

Requirements for HP MJF RIM molds

- **Surface roughness – Demolding:** Although HP MJF molds will be suitable for some of the parts, lower surface roughness will translate into easier demolding processes thanks to the fact that curing polyurethane will wet less the inner faces of the mold. It will also prevent the need to use a demolding component, which adds additional process times and risks that will affect the final part.
- **Surface roughness – Final part cosmetics:** Any surface imperfection (e.g., stair stepping, surface roughness) will be precisely reproduced and made even more visible in the final polyurethane part.
  - For both reasons, **mold polishing** is the recommended post-process for the mold in order to avoid surface defects on final parts as well as easy demolding processes. Having a well-finished mold will require time, but it will represent huge savings on final part post-processing. This polishing, which will be a manual operation, will involve orbital polishers, Dremel®, or sandpaper.
  - **Tumbling** prior to polishing will reduce the amount of manual work required.
- **Mold hardness:** Increased hardness leads to more durable molds. HP 3D HR PA 12 is strong enough to make durable molds, although characterization on mold lifetime is ongoing.
- **Accuracy:** Accuracy that is not as tight as with Injection Molding (such as +/- 0.2 mm) is required.
- **Possibility of making puzzle molds:** Addressing bigger parts with HP MJF puzzle molds is an option to consider.

Traditional technologies and materials for RIM molds

Machined clay

Traditionally RIM molds were fabricated over machined clay. The cost of these molds is less than the machined aluminum ones, as well as the overall machining costs (due to less material hardness). These molds are machined on a clay base and then coated with a resin coating (gel coat or similar).

Clay molds are used less with time: Lower aluminum machining costs make mold cost differences less pronounced, and problems associated with clay molds push RIM manufacturers to purchase machined aluminum assets, which results in the following problems:

- Reduced lifetime: Clay is eroded with time, forcing the RIM manufacturer to re-purchase the mold to continue fabricating parts, while machined aluminum is almost perpetual.
- Fragility: Clay is fragile by nature, so an accidental impact against the mold could partially destroy it.
- Gel coating reduces mold accuracy since its thickness cannot be perfectly controlled.

Machined aluminum

With the development of computer-aided milling machines, a machined aluminum plate has become the standard way of manufacturing multiple cavity molds for the RIM industry. Al 6061-T6 is the workhorse of this mold-making industry. It is easily machined and dimensionally stable. Cooling channels are gun-bore drilled for deep-draw molds. For shallow molds, a cooling plate is mounted to the mold base. Because the mold is made directly from the dimensions on the product design, the mold dimensions are quite accurate.

Advantages of machined aluminum molds in RIM technology are:

- Long-lasting molds (almost perpetual, according to RIM normal production volumes).
- Excellent heat transmission rate: This helps reduce times in mold tempering and improves heat extraction from the RIM reaction process.

Why use HP Multi Jet Fusion–printed molds?

Economical advantage

Traditional RIM molds are fabricated in machined aluminum or clay (the latter of which is no longer widely used). Given the setup costs of RIM production (mold cost is relatively high) and the low process speed (approximately 20 minutes per part), the economics of this technology for medium-sized parts normally fall out of range.

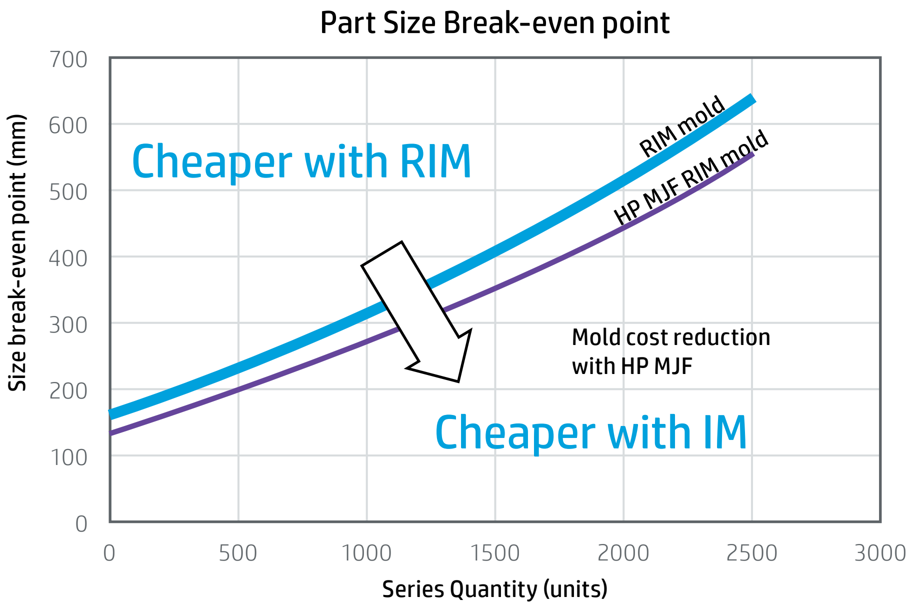
Using HP Multi Jet Fusion RIM molds offers some advantages to RIM technology, mainly:

- Lowering cost of mold manufacturing to a small fraction of the traditional cost.
- Much lower mold costs will allow for the use of multiple molds at the same time for the same given price, thus increasing production speeds.

The scenario described herein shows how HP Multi Jet Fusion technology will help RIM technology increase its market size by allowing it to address the small- and medium-sized parts applications. Key points to consider are:

- Costs of Injection Moulding (IM) molds soar with parts dimension, but for small- and medium-sized parts, they are very similar to RIM molds.
- Variable costs of RIM are much higher than IM: The RIM production rate is much slower than IM and the process is highly manual.
- RIM variable costs do not escalate with part size, but they do with IM.
  - Bigger IM parts require bigger injection presses that have much higher operating costs.
  - While small parts in IM have almost no manipulation procedures, bigger parts do, which significantly increases part cost.

In the following graph, the displacement of the break-even point when using HP Multi Jet Fusion molds is evaluated regarding fabrication lot size and part size.



Technical advantages

- **Weight:** 3D printing materials are lighter than aluminum. Furthermore, 3D printing will allow for the creation of lattice structures that reduce weight, nearly maintaining the desired mechanical properties.
- **Improved tempering and cooling circuits:** Tempering (before injection) and cooling (during curing reactions) is crucial in Reaction Injection Molding. Although the heat transfer rate of HP 3D Printing materials is much lower than the aluminum heat transfer coefficient, the possibility of creating complex cooling circuits that are closer to the molding surfaces facilitates this heat transfer and maximizes thermal homogeneity in the inner faces of the mold. Cooling circuits of a machined aluminum mold are extremely complex to manufacture; this process is normally achieved by drilling through holes across a mold's block and then plugging the adequate ends, or by machining serpentines on a block and then assembling it against a lid plate.
- **Material hardness:** Although not comparable with aluminum, HP Multi Jet Fusion materials have high hardness values, which lead to a longer life for the molds.
- **Immediacy:** Manufacturing times of aluminum molds would normally take weeks once the design is closed. With HP Multi Jet Fusion, molds are ready to inject in a matter of hours. Lower lead times and costs will prevent the bottlenecking of the mold manufacturing, allowing for more trials, riskier (but more innovative) solutions in part design, and other innovations.
- **Texturizing:** Texturizing an aluminum mold is a handmade operation that must be performed by a mold expert, who can be considered an artist in this case. It is a critical procedure as there is no way to reverse it. With HP Multi Jet Fusion molds, textures can be applied in the CAD, so no extra operation will be required once the mold is printed.

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