**How Materials Selection Impacts Application Cost**

Many manufacturers realize that product materials vary in cost, but they may not understand how the *process* of selecting these materials also impacts the total cost of a part. There are a variety of different factors that go into material selection to ensure the lowest cost of quality. The product itself will dictate some of the cost, as well as the environment it will work in, how long it needs to work, the instructional integrity, appearance or cosmetics, agency requirements, annual quantities and batch sizes, turnaround targets, recyclability impact, and a client's cost targets. Material selection problems are generally obvious during the manufacturing process, but they may also manifest later in the field, and experienced injection molders can help manufacturers understand these factors. There are many options and strategies for plastic material selection that can cut costs without compromising quality or manufacturing efficiency.

**Meeting the Needs of the End Environment**

To ensure low cost of quality, appropriate material selection is necessary in order to meet the needs of the end environment. If a manufacturer comes to an injection molder looking for a part, the injection molder can ask a series of questions about the application to try to obtain as much feedback as possible to plan for the necessary material selection that will ensure a quality part is made. Some of these questions might include:

1. What type of heat will the application be exposed to?
2. What temperature will the part go up to?
3. What kind of impact strength will it need to have?
4. What type of cosmetic finish does it need? Glossy? Colored?
5. Does the surface need to be abrasion or scratch-resistant?
6. Do you need to be able to see through it?
7. Will it be exposed to ultraviolet radiation?
8. Will it be exposed to chemicals or other corrosive agents?
9. Will it experience excessive vibration?
10. Will it come into contact with water?
11. Will it come into contact with water at high temperatures?
12. Will the product be exposed to long-term loading? Are there any creep characteristics that need to be accounted for?
13. Will your product be exposed to constant strain such that stress relaxation needs to be accounted for?
14. Will the application expose parts to heavy vibration or repeated deflections, thus needing good fatigue characteristics?
15. Does the application need to act as an insulator?
16. Does it need to be flame resistant?

Plastics should be tested under all manufacturing, transportation and end environment use conditions to ensure strength and optimal performance.

**Materials Compliance**

Some products will need to meet government agency or private organization specification approvals. Other companies will have their own standards that manufacturers will need to adhere to. Many resin suppliers can guarantee compliance with a variety of different common requirements. Finding a resin that already complies with these guidelines can save manufacturers time and money. Some of the more common agency standards are:

1. Underwriters' Laboratories, Inc. (UL)- This organization needs to approve most electrical devices sold in North America.
2. Food and Drug Administration (FDA)- FDA approval is needed for all plastics that come into contact with food. The FDA also evaluates medical and surgical devices for resin composition, quality and uniformity in addition to the device's structural integrity and biocompatibility.
3. Military (MIL)- The military regulates and certifies plastics for all of their applications.
4. United States Department of Agriculture (USDA)- The USDA must approve any plastics used in packaging meat and poultry that is federally inspected as well as any plastics used in meat and poultry-processing equipment.
5. National Sanitation Foundation Testing Laboratory, Inc. (NSF)- The NSF manages the use of plastics in food processing equipment and pipes and fittings for potable water, overseeing standards for taste, odor, toxicity and clean ability.

**How Fillers Impact Product Design and Cost**

Another factor impacting a part's cost of quality is how well a manufacturer can identify the best material to design more reliable or appropriate molds. The first thing a manufacturer needs to understand is how to make a mold that suits the chosen material. For example, glass is very abrasive and would not be well-suited in a steel mold because it will eat up the steel over time. But fillers and expansion agents can be used to expand mold design opportunities and make cheaper and better products.

Fillers, or extenders, are low-cost options for improving plastics processing. Examples of fillers include:

* Ash
* Calcium carbonate
* Carbon filler
* Carborundum
* Alpha cellulose
* Channel black
* Coral
* Coke dust
* Diatomaceous earth
* Ferrite
* Milled fiber
* Flint
* Fuller's earth
* Glass filler
* Glass spheres
* Hemp
* Lamp black
* Leather
* Dust
* Macerate filler
* Magnesium carbonate
* Mica
* Particulate filler
* Pumice
* Quartz
* Sawdust
* Talc
* Vermiculite
* Wood Flour

(list taken from [*Injection Molding Handbook*)](http://books.google.com/books?id=l5jqDRauKNYC&pg=PA502&lpg=PA502&dq=injection+molding+filler+cost&source=bl&ots=O_YPrGjNv3&sig=4KT_ukmseENsewBdDjarDqqafIg&hl=en&sa=X&ei=OaheUpX9A8jXyAHD-oGABA&ved=0CEsQ6AEwAA%20-%20v=onepage&q=injection%20molding%20filler%20costh)

Fillers can improve material characteristics, including hardness, thermal insulation, stiffness, and impact strength. If a manufacturer had a material that was meeting the cost targets, but not meeting physical integrity, he or she can look at fillers as a way to achieve that without spending a lot more on base materials (depending on what type of filler is used since each carry different expenses). The density and cost of the plastic and filler both determine the total savings. Fillers wouldn't make up more than 20-30% of a mold so as not to compromise the base structural integrity material. For example, suppose adding 30 wt% of talc to medium-impact polystyrene (with a specific gravity of 2.5-3.1) reduces the plastic amount by only 15%. But if a low-density filler, such as wood flour (specific gravity of 0.5) is used in the same weight percentage, the specific gravity of a part is reduced to .79. This results in a plastic content savings of 47 wt% compared to unfilled material.

**How Expansion Agents Impact Product Design and Cost**

Expansion agents can also be used to improve products and lower cost. For example, aluminum molds are used for parts requiring lower pressure, those with thicker walls or with an expansion agent. They can be put under low pressure, and, based on the sheer heat that is seen through the process once it enters the mold, it continues to expand even after it's relieved from the mold. To further illustrate this, suppose a manufacturer has a part with a plate on the underside with supporting ribs holding it up on the length of the plate every three inches across the part. Molders typically need to stay at 65%-70% of the nominal wall thickness of the top surface or they will have such a thick area that they'll see witness lines on the top surface from the ribs on the underside. One way to accommodate this if the manufacturer needs really thick walls is to add a blowing or foaming agent to the material that will take up the space without letting the post mold plastic cool after it gets out. In this way, an expansion agent can aid structural integrity and lower overall cost.

**Fillers and Expansion Agents Increase Through-Put Time**

Fillers and expansion agents can also save money by increasing through-put time. Blowing or foaming agents take up space without letting the post-mold plastic cool after it gets out. That has an impact on through-put since manufacturers wouldn't have to let the part sit in the mold to cool. Other material differences can impact final cost. For example, generally-speaking, crystalline materials have faster cycle times than amorphous resins. On the other hand, if a material exhibits corrosive or abrasive behaviors, this could lead to longer cycle times from increased mold and press maintenance costs.

**Compensating for Shrinkage and Warpage**

Manufacturers who understand appropriate material selection can maintain lower cost of quality by adequately compensating for shrinkage and warpage. Shrinkage and warpage are inherently part of the injection molding process. Shrinkage occurs when a plastic is cooled from a high temperature. Warpage describes the unintended distortion of a molded part's surface. Warpage is an effect of molded-in residual stress, which is caused by differential shrinkage. Shrinkage variations are caused by molecular and fiber orientation, temperature differences in the part and even different pressure levels applied during packing.

Shrinkage and warpage must be compensated for to avoid manufacturing defects. Uncompensated volumetric contraction can create sink marks or voids within a mold. Controlling contraction is especially important in parts needing tight tolerances. If shrinkage and warpage are not addressed in the mold design process, it could lead to high scarp costs for parts with tight tolerances.

There are published linear shrinkage rates available for a variety of different plastics, but these reports typically include ranges of data since actual shrinkage depends on a variety of complex factors including material, part geometry and processing to name a few. The most important processing factors that affect shrinkage rates are injection pressure (higher pressures force more plastic into the mold, reducing shrinkage), compaction time (more compaction time reduces shrinkage), melt temperature (higher melt temperatures reduce shrinkage) and part thickness (thicker parts increase shrinkage rates). The table below references some of the common shrink rate ranges manufacturers can use to aid mold design.

[Common Linear Shrinkage Values (*S*) for Various Thermoplastics](http://www.gepolymerland.com/research/tech/tip97dec.html)

|  |  |
| --- | --- |
| Material | Shrinkage (S) in inches/inch (per ASTM D955) |
| ABS-High-Impact | .005-.007 |
| ABS-Medium-Impact | .005-.008 |
| ABS-High Heat | .004-.006 |
| ACETAL | .020-.035 |
| ACRYLIC- General Purpose | .002-.009 |
| ACRYLIC- High Flow | .002-.007 |
| ACRYLIC- High Heat | .003-.010 |
| ACRYLIC- Impact | .004-.008 |
| NYLON- 6,6 | .010-.025 |
| NYLON- 6 | .007-.015 |
| NYLON- Glass Reinforced | .005-.010 |
| POLYCARBONATE | .005-.007 |
| POLYESTER .025-.050 thick | .006-.0012 |
| POLYESTER .050-.100 thick | .012-.017 |
| POLYESTER .100-.180 thick | .016-.022 |
| POLYETHERIMIDE | .005-.007 |
| POLYETHYLENE-LDPE | .015-.035 |
| POLYETHYLENE-HDPE | .015-.030 |
| POLYPROPYLENE | .010-.030 |
| PPO/HIPS (NORYL) | .005-.007 |
| POLYSTYRENE-Crystal | .002-.008 |
| POLYSTYRENE-Impact | .003-.006 |
| POLYURETHANE | .010-.020 |
| PVC-RIGID | .002-.004 |
| PVC-FLEXIBLE | .015-.030 |
| SAN | .002-.006 |

Source:

[http://mfg.eng.rpi.edu/aml/course/Shrinkage Rate Exercise.pdf](http://mfg.eng.rpi.edu/aml/course/Shrinkage%20Rate%20Exercise.pdf)

**Multifunctional Materials Help Manage Total Cost**

Multifunctional materials are divisions of materials that can meet multiple needs. For example, one material may be able to improve a plastic's overall strength and chemical resistance. Or another may be able to help meet the needs of an application that requires waterproofing capabilities and high-impact resistance. All plastics are multifunctional to some extent, but high-end, critical-use applications created with complex injection molds require thorough examination in order to select the optimal materials for optimal multi-functionality. These materials are a popular way to increase functionality while maintaining cost efficiency. Manufacturers with expert knowledge of plastics are able to develop efficient solutions while controlling total cost. Some broad categories of materials have equally broad characteristics:

* *Polycarbonate and polycarbonate blends/alloys* are known for their durability and impact resistance, high-temperature resistance, good aesthetics, and ability to be easily welded or bonded.
* *Nylons* have high-temperature resistance, chemical resistance, oil resistance, and toughness.
* *Polyesters* have high dielectric strength, high-temperature resistance, chemical resistance, oil resistance and UV stability.

Fillers and other reinforcements can also add functionality to different materials. For example, glass fibers increase stiffness and resistance to heat. Carbon and metal fibers can improve heat transfer capability and EMI/RFI shielding. Additionally, silicone fibers reduce friction. If aesthetics and EMI/RFI shielding are important for manufacturers, multifunctional materials can be used to more efficiently manage total cost by eliminating secondary production processes to achieve desired cosmetic effects, such as product painting.

**Using Recycled Materials Can Help Reduce Cost**

If manufacturers are open to darker colors of plastic, recycled material can be another way to reduce cost by as much as 40%. But molders must be careful when considering regrind. Scrap thermoplastic material from partially-filled or rejected parts can be saved from the molding process. These pieces can be chopped up and mixed with virgin material to produce different parts. But if regrind is continually chopped up, fed back into a press and re-melted several times, it becomes vulnerable to contamination and abusive pressing. This can damage the mechanical and cosmetic properties of the material. Anyone using regrind should strictly limit their ratios and avoid it entirely in critical applications or when resin properties demand virgin material properties.

But assuming the use of recycled plastics is carefully controlled, they offer significant cost-saving potential. [Machinedesign.com](http://machinedesign.com/news/recycled-plastics-gets-bigger-role-molding) reported in 2010 about one technology manufacturer's PC/acrylonitrile butadiene styrene job that used about 250,000 pounds of material a year. After using a blend of recycled plastics, the company saved about $0.80 per pound, which amounted to an annual savings of $200,000 per year without sacrificing any product quality.

Understanding the intricacies of how material selection affects cost can help manufacturers save money without compromising quality. On the other hand, incorrect or inexperienced material selection can lead to several manufacturing problems. For example, applications may crack under pressure, melt, or fail mechanically. Materials knowledge helps manufacturers be proactive with materials selection, which, in turn, avoids costly accommodations in mold design to enhance the properties of the material. Communication between manufacturers and injection molders is key to optimal material selection. Even if a manufacturer doesn't know everything about material selection, the right injection molder can know a lot about a product just by looking at it and ask the right questions to make sure they are making the most suitable application for the end environment.