Metal-to-Plastic Conversion: REVOLUTIONIZING THE MANUFACTURING PROCESS

KAYSUN

INJECTION MOLDING & ENGINEERING SOLUTIONS

Metal-to-Plastic Conversion:
REVOLUTIONIZING THE MANUFACTURING PROCESS

Even though it's been around since the 1950s when engineering-grade resins were first introduced, many manufacturers are still not familiar with the many benefits of metal-to-plastic conversion. As this process continues to evolve with the rapid development of new advanced plastics that can outperform metal at lower cost, an increasing number of manufacturers are taking notice.

Automotive manufacturers are especially familiar with converting existing metal products or parts to plastic. A federal mandate calling for automobiles to average 54.5 miles per gallon by 2025 has put pressure on manufacturers to look for ways to drastically improve fuel efficiency. While the mandate could potentially be repealed in the future, there's no denying the increased consumer demand for more fuel-efficient vehicles. One way to increase fuel efficiency in the automotive, aviation and aerospace industries is by reducing component weight. Metal is far heavier than plastic, but with the proper design, engineered plastics can be just as strong as metal.

Their chemical resistance and heat resistance, combined with their lighter weight and superior vibration absorption, make engineered plastics especially useful for fuel systems, fluid handling systems and other high-temperature applications. For example, heat-resistant polyether ether ketone (PEEK) thermoplastic has been used to replace piston rings in automobile automatic transmissions and wear plates in gear systems. Other plastics engineered to be thermally and electrically conductive are routinely used in electronic components as electromagnetic/radio frequency interference (EMI/RFI) shields.

In addition to its growing popularity among automotive and aerospace manufacturers, metal-to-plastic conversion plays an important role in military/defense applications, particularly those related to troops' gear and equipment. Plastic parts can be up to 50% lighter than their metal counterparts, so swapping out metal for plastics in certain components like the casings and housings of GPS and vision systems allows soldiers to carry substantially less weight in the field.

Benefits of Metal-to-Plastic Conversion

For OEMs in a wide variety of industries, the collective benefits of converting metal parts to plastic are compelling:

- Tensile strength comparable to metal
- Greater design flexibility
- Up to six times longer tool life
- Robust chemical resistance
- Wider recyclability
- Generally fewer secondary operations and less required assembly
- Lighter part weight
- Lower manufacturing costs
- Enhanced regulatory compliance
- Increased market stability for material cost
- Lower packaging and shipping costs
- Easier to prototype

Current metal-to-plastic trends focus on reducing weight, improving strength and corrosion resistance, and consolidating multiple metal parts into one plastic part with good reason. Plastic parts can be just as tough as metal parts and achieve the same tight tolerances, with fewer secondary operations. With the proper design, engineered resins with long-glass filler can actually exceed the physical properties of metal, and plastic parts can be designed to perform just as well as the metal parts that they are replacing. In fact, plastics can be engineered to have specific physical and chemical characteristics that are ***even better*** than metal.

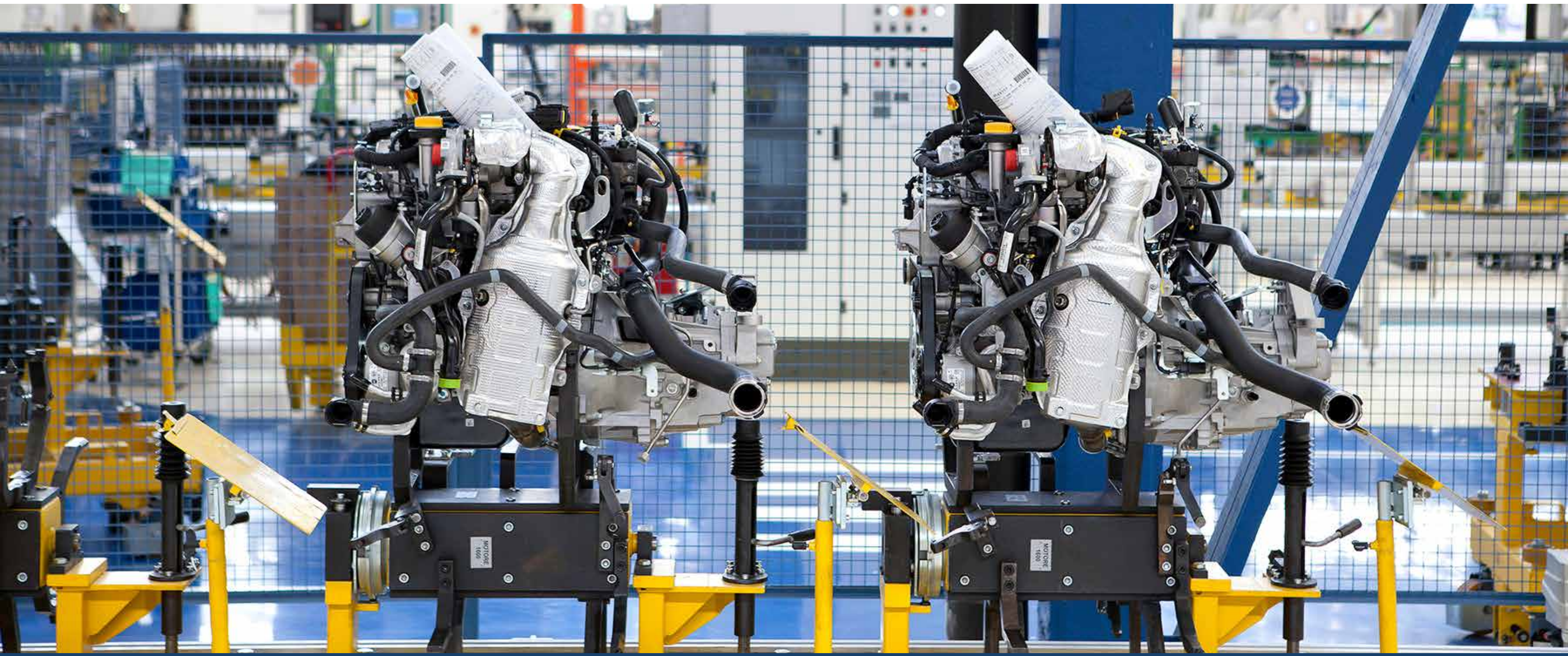
Let’s Talk About Cost

Cost containment is usually a top priority for any project, making cost reduction one of the biggest benefits of switching from metal to plastic.

In general, companies can expect to achieve an overall cost savings of **25-50%** by converting to plastic parts principally due to:

1. **Decreased piece part prices.** After initial tooling costs are paid, the piece part pricing is usually much less than the same part produced in metal, whether it is a stamping, casting or a die-cast part. This cost savings is realized because the injection molding process has faster cycle times (more parts made per machine hour) and these parts are final net shape, which eliminates secondary machining.

2. **Elimination of time-consuming and costly secondary operations.** There are many ways in which metal-to-plastic conversion reduces the need for time-consuming secondary operations. For example, plastic material can be colored with color concentrates before molding, eliminating secondary painting operations. Injection molds can be textured or polished resulting in molded parts with final surface finishes. The costly assembly of several metal stampings or castings fastened together can often be replaced by a single injection molded part, incorporating the features of the total assembly. This can eliminate the need for welded joints between metal parts, which also eliminates risks for leakage. If multiple assemblies are required, the plastic parts can be engineered to have snap-together features to eliminate any fasteners.



3. **Reduced product weight and improved ease of use.** One of the biggest advantages of using plastics instead of metals is weight reduction. Reducing product weight with plastics gives you more parts per pound of material, significantly reduces shipping costs, and improves the end-user's physical ease in using the product.

   A comparison of the specific gravity values of metals to plastics shows how dramatic the difference in weight can be:

METALS	PLASTICS
Aluminum 2.5 - 2.8	Polycarbonate 1.2 - 1.4
Brass 8.4 - 8.7	Nylon (most types) 1.2 - 1.7
Copper 8.8	Steel 7.7 - 7.83
Zinc 6.9 - 7.2	Polythylene .92 - .95
Steel 7.7 - 7.83	Polypropylene .90 - 1.04
	ABS 1.02 - 1.4

4. **Greater product structural strength.** Plastic parts can actually be stronger than metal parts when engineering-grade materials are used. In addition, the ability to mold in features such as ribs, bosses, and gussets, when the part is originally produced instead of introducing secondary operations afterwards can increase the total strength of the assembled part, as well as reduce additional costs.

5. **Increased product design options.** It is much easier to produce finished-level complex part designs out of plastic than metal simply because of plastic's dimensional stability. Tight tolerances can be achieved and molded in conjunction with complex shapes due to advanced injection mold/tool design capabilities, and uniform thin-wall dimensions can be achieved due to high injection pressure, replacing the costlier thicker-walled features of die-cast metal parts.

6. **Reusability of plastic materials.** Re-using materials by adding regrind (ground up runners and scrap parts) can generate cost savings of **up to 40%**. In fact, most injection molding plastics are thermoplastics and can easily be reprocessed (thermoset materials, however, cannot). Regrind can also be used immediately, rather than needing to be re-smelted like steel.

7. **Increased product life.** Because plastics do not rust or oxidize as metals do, and most are not affected by the acids or base compounds that corrode metal, plastics can offer significant product life and durability advantages over metal.

In-Depth Feasibility Analysis

Metal-to-plastic conversion is not suitable for every application, and determining if it's a viable option for your project isn't necessarily a quick decision. It requires considerable analysis, and a comprehensive understanding of the end-use application, environmental conditions, material evaluation and analysis, manufacturability, and the economic feasibility of the conversion.

For example, it is critical to know how the product will be used, as design engineers must be able to accurately evaluate the real-world environment that will be impacting the product, including chemical exposure or contact solutions, temperature ranges, shielding, and other influences (including worst-case scenarios). All of this information must be analyzed together to make the best material choice and ensure the chosen resin can meet its performance requirements.

Perhaps the most important rule at this stage is to never make any assumptions. The lack of a complete and thorough application review could result in selecting the wrong material, which could derail the entire development process.

SELECTING THE RIGHT PLASTIC

Polymer science has made tremendous strides over the years, advancing the ability to compound a variety of plastic materials with fillers and reinforcements that provide a tremendous amount of structural integrity. With more than 25,000 engineered materials available for manufacturing applications – including new, higher-performance blends and hybrids that can be custom-designed to meet very specific performance requirements – it's important that manufacturers choose the right resin for the job. Depending on the project, doing so can take some time and requires specific insights about:

- **Crystalline vs. Amorphous:** Evaluate requirements such as chemical resistance, impact, flow, processing, etc.
- **Additives:** How do filled and unfilled plastics compare? Additives will affect strength, rigidity, cost, and heat deflection.
  - Long-glass fiber additives improve stiffness and strength, increase temperature performance up to 150° C, and create a moderate surface appearance
  - Short-glass fiber additives improve stiffness, increase temperature performance, and improve appearance over long glass (glass content of 30% or less allows parts to look as good as unreinforced plastic parts)
  - Carbon and stainless-steel fillers improve conductive and/or shielding properties
  - Lubricant fillers improve wear and friction properties
  - Mineral fillers improve electrical performance, weighted feel, sound dampening, dimensional stability, and increase specific gravity
  - Impact modifiers improve toughness
  - Flame retardants increase resistance to burning

TESTING THE PLASTIC

Determining how a plastic performs in the end-user environment often depends on prototype testing for:

- Post-mold shrinkage and warp
- Strength
- Hardness
- Flexibility
- Corrosion resistance
- Fatigue
- Long-term creep

Often, several plastics are prototyped to identify which best performs within these parameters. This is essential because at typical, everyday usage temperatures and loads, metals can dissipate heat without undue fatigue or undesired creep. Some plastics cannot, and the resulting stress can cause bending, creep and other failure-inducing deformities.

Since it is relatively easy to sample a variety of plastics using the same mold at the prototyping stage, this testing can and should be a routine part of the process prior to final materials selection.

Likewise, plastics respond differently to injection molding depending on their physical and chemical characteristics. Strength and flexibility, melting and cooling behavior over a range of temperatures, polymer structures, and chemical bonds can be enhanced by adding filler materials or by creating hybrid plastics with superior mechanical, thermal, chemical, electrical, and environmental properties, such as:

- **Mechanical:** tensile strength, flexural modulus (stiffness), impact resistance, creep, and dimensional stability
- **Thermal:** thermal expansion, heat deflective temperature, relative thermal index, coefficient of thermal expansion, mechanical response at temperature, plastic stability
- **Chemical:** chemical resistance (semi-crystalline vs. amorphous), molecular weight, and part stress (combination of design, assembly, process and environment can reduce chemical resistance)
- **Environmental:** resistance to weather, humidity and ultraviolet light—how the combination of these factors affects color shift, gloss retention and loss of material properties
- **Electrical:** Conductivity, shielding, dielectric strength, dielectric constant loss factor and electrostatic requirements

OTHER DESIGN CONSIDERATIONS

One of the greatest benefits of metal-to-plastic conversion is the design freedom it creates. For example, multiple metal parts that need to be fastened together can be designed into one injection-molded plastic part. This also expands the geometrical possibilities for new designs.

Similarly, injection molding is a faster, more efficient process, and can achieve tighter tolerances compared to making die-cast metal parts. In addition, tools can last 500,000 to 1,000,000 cycles or more with injection molding and require less maintenance and downtime compared to metal die cast.

To optimize part quality and make the molding system last as long as possible, it's crucial that:

- Proper mold steel is selected for the plastic of choice
- Molds are properly vented to minimize erosion
- Processing is properly designed to eliminate flash, which can damage the mold parting line
- Hot runner systems are compatible with the selected material
- Screw styles and materials are well-suited for the selected plastic

However, switching processes is only part of the equation. Designers need to shift their mindset in order to understand the mechanical/structural differences between metal and plastic. Simply substituting plastic for metal in a design rarely works because plastics have different mechanical properties that affect how the product performs in the end-user environment.

These variations, however, can be corrected in plastic components prior to mold construction by adding design features such as uniform wall thickness, ribs, gussets or radii to improve strength and support. The advantage here is starting with a lightweight part and then adding features as needed, which can be done quickly and efficiently using an in-house tool shop like the one on-site at Kaysun.

Scientific Injection Molding

Metal-to-plastic conversion requires the best possible manufacturing design and controls, especially for high-performance, critical-tolerance parts. This can be delivered through the use of scientific molding, which uses detailed material science and precise measurement to completely understand – down to the molecular level – what's happening during each stage of the injection molding process. This will eliminate issues associated with:

- Resin optimization
- Evaluating and blending color concentrates
- Molding and tooling design
- Process and material variations
- Non-compliance with specs or regulatory requirements
- Re-validation

Standard molding procedures are simply not accurate enough for metal-to-plastic conversion and the tight tolerances it requires.

By fully understanding how the material and process parameters interact during all phases of production, specialized scientific molding engineers maintain high precision across multiple production runs. Sophisticated software and sensors monitor each phase of the manufacturing process, allowing the molding team to know what's happening with the material inside the mold at all times. With in-depth insight into how small changes in pressure, temperature, viscosity, flow rate, material moisture rate, fill time, and cooling rate impact the quality of the final product, molders can correct any process variations within seconds.

Because all of the scientific molding data is recorded, the manufacturing process can be easily replicated as needed—even when production is transferred from one machine to another— saving a tremendous amount of setup time. This is also essential for validating the process and meeting any regulatory requirements.

Scientific Molding in Action: A Kaysun Success Story

By understanding every phase of the metal-to-plastic conversion process and all aspects of material behavior, Kaysun's scientific molding engineers can design the most efficient process possible for your product—saving money on material costs and speeding up throughput because "peak production" is maintained through the entire process.

For example, a client approached Kaysun about manufacturing one of its air-operated double diaphragm pumps in plastic instead of metal. The goal was to increase corrosion resistance and chemical resistance to achieve a longer pump life at a lower cost.

Using a scientific molding approach, Kaysun worked closely with the client design team to select resins that possessed the specific mechanical and chemical properties that were needed to withstand the various environmental conditions that would be affecting the pumps. Several general resin families were considered, including unfilled polypropylene, PVDF (a derivative of Teflon with very high chemical resistance), and some carbon-filled static dissipative and spark resistant resins for the mining industry.

After PVDF was selected as the material, the part design was adjusted to better fit the injection molding process. Structural ribs and material core-outs were added to minimize thick sections and balance material flow. Mold cooling circuits were designed to keep the cycles as low as possible, yet still achieve dimensional repeatability. This was challenging because the pump required walls up to 1.5 inches in thickness, which is very difficult to achieve with injection molding and requires extremely precise control.

By applying scientific molding principles and processes, the final plastic product met all the performance goals set by the client, including lower production costs.

Parting Thoughts

Perhaps the most exciting advantage of metal-to-plastic conversion is the design freedom it gives engineers to think unconventionally about complex geometry, performance in harsh environments, shielding considerations, weight and structural limits, thermal management, and product differentiation—both for performance and how the product looks on the shelf.

As material suppliers continue to develop high-strength thermoplastics that are increasingly impact-resistant, corrosion-resistant, and heat-resistant, more companies are converting from metal components to plastic. Along with lighter weight, factors driving conversion decisions are the ability to consolidate parts, net shape components, aesthetic improvements, and better durability of plastics – all of which contribute to it's sustained and growing popularity.

It is highly likely that the most impressive breakthroughs with metal-to-plastic conversion have yet to come—especially with advances in engineered plastics. In fact, the process could revolutionize the way manufacturing is done across a range of industries as more R&D teams recognize the tremendous potential that metal-to-plastic conversion has for improved performance and enhanced manufacturability of complex, mission-critical parts.

***Contact us** today to request a quote for your next complex injection molding project.*

KAYSUN
INJECTION MOLDING & ENGINEERING SOLUTIONS

Follow us on: