Converting Metal Automotive Components to Plastic: A MANUFACTURER'S GUIDE

KAYSUN
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INJECTION MOLDING & ENGINEERING SOLUTIONS

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Even though engineering-grade resins were introduced in the 1950s, the many benefits of metal-to-plastic conversion are still being realized.

Automotive manufacturers were very early adopters of metal-to-plastic conversion, using nylon parts for non-critical components like valve stems, wiring clips, gears, bearings, bushings, switch housings and windshield wiper systems. Today, due to pressure from the federal government's **Corporate Average Fuel Economy** (CAFE) mandate and low-carbon emission regulations, ***the automotive industry continues to shift to complex, critical-use plastic components for reducing weight without compromising strength or performance.***

This guide will help to better define the role of plastics in the automotive industry, and how injection-molded plastic components impact:

- Automotive applications
- Tooling
- Design
- Costs

Automotive Applications for Complex Plastic Components

Current metal-to-plastic trends focus on reducing weight, improving strength and corrosion resistance, and consolidating multiple metal parts into one plastic part. These goals squarely align with the needs and progress of the automotive industry, where federal directives regarding fuel economy and carbon emission reductions are forcing engineers to rethink manufacturability.

Transitioning from metal to plastic, though, can be daunting. Automobile engines produce high temperatures, constant vibration and chemical exposure that can punish components.

The traditional thinking was that only metal could withstand such a harsh environment. However, the evolution of nylon, polyphenylene sulfide and polypropylene, among other application-specific plastics, quickly changed minds.

The light weight, durability, design flexibility and uniform surfaces of such plastics make them ideal for use in a wide range of automotive applications, including:

- Powertrains
- Air-intake manifolds
- Valve covers
- Fuel rails
- Water pump housings
- HVAC systems
- Brake fluid reservoirs
- Electronic throttle controls
- Engine covers
- Filtration systems
- Clutch assemblies
- Transmissions
- Oil distribution systems

Metal-to-plastic conversion is paying measurable dividends in the automotive industry. For example, Nissan engineers reduced average weight by 40% through using plastic rocker covers and front covers on the diesel engines within its Pathfinder models. Nearly equivalent reductions were achieved in converting electric water valve assemblies from steel to plastic in Armada, Quest and Titan vehicles.

10 Benefits of Metal-to-Plastic Conversion

- Metal-comparable tensile strength
- Reduced part weight
- Highly repeatable process
- Less scrap
- Lower manufacturing costs
- Enhanced regulatory compliance
- Greater design flexibility
- Increased market stability for material cost
- Lower packaging and shipping costs
- Up to 6x longer tool life

Advantages of Plastics

Injection molding is faster, more efficient and can achieve higher tolerances as compared to die-cast metal parts. In fact, ***it requires fewer steps to produce complex, high performance parts with the highly controlled injection molding process.*** This is a boon for automotive manufacturers because of the wide variety and volume of plastic components required, and quick turns mean faster time to market.

TOOLING: Tooling is also more efficient with injection molding. ***Tools last 500,000 to in excess of 1 million cycles, and require less maintenance and downtime compared to metal die casting,*** provided the molding system is optimized for part quality and molding system lifetime.
The following are required to optimize tool life:

- Proper mold steel and screw style are compatible with the selected plastic
- Molds are vented to minimize erosion
- Flash is eliminated from processing, which can otherwise damage the mold parting line
- Hot runner systems work with the selected plastic

DESIGN: ***One of the greatest benefits of metal-to-plastic conversion is the design freedom it creates.*** For example, multiple metal components that need to be fastened together, like stationary transmission parts, can be designed into one part that can be injection-molded. This design efficiency substantially reduces assembly time and part count, meaning lower labor investment on the line and in inventory management, resulting in greater productivity.

Designing with injection-molded plastics eliminates expensive secondary operations. Plastics can incorporate specific colors and graphics so no painting is necessary; and, molding in features like snap-fits, bosses, ribs brackets and attachment points streamlines fabrication.

Metal v. Plastic: Comparing the Benefits

METAL:
- Thermal conductivity
- Electrical conductivity
- High stiffness
- Low tendency to creep
- Low coefficient of thermal expansion
- High strength
- Minimal warping

PLASTIC:
- No corrosion
- Low density
- Design freedom
- Extended tool life
- Chemical resistance
- Recyclability
- Fewer required parts/less assembly

Comparative Cost and Quality

Generally speaking, ***companies can anticipate saving 25 to 50% by converting to plastic parts without comprising component quality or performance.*** In fact, injection- or insert-molded plastics decrease costs and actually improve part quality in several important ways:

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, regardless of whether it is stamped, cast or die-cast. The injection molding process has faster cycle times (more parts are made per machine hour) and the parts are identical, which eliminates secondary machining.

NO TIME-CONSUMING AND COSTLY SECONDARY OPERATIONS: Plastics offer versatility. They can be colored, textured or polished before or within the first steps of molding; configured to replace multi-part, welded-joint assemblies that are expensive to construct and can introduce leakage; and engineered to have snap-together features to eliminate any fasteners.

REDUCED PRODUCT WEIGHT AND IMPROVED EASE OF USE: Weight reduction is plastics' biggest advantage to automotive manufacturers, but there are secondary benefits including more parts per pound of material, reduced shipping costs and improved ease of use.

Weighing the Difference

Comparing the specific gravity values of metals to plastics reveals dramatic weigh disparity:

METALS:		PLASTIC:	
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	Polyethylene	0.92-0.95
Zinc	6.9-7.2	Polypropylene	0.90-1.04
Steels	7.7-7.83	ABS	1.02-1.4

GREATER PRODUCT STRUCTURAL STRENGTH: ***Plastic automotive parts made from engineering-grade resins can actually be stronger than their metal counterparts.*** In addition to material strength, plastic components improve structural strength because ribs, bosses and gussets can be molded in when the part is originally produced instead of performing expensive post-mold fastening, welding and gluing operations.

MORE PRODUCT DESIGN OPTIONS: Plastic offers greater dimensional stability than metal that, when coupled with advanced injection mold/tool design capabilities, provides finished level complex part designs. Tight tolerances and complex shapes can be molded simultaneously due to advanced injection mold and tool design capabilities, plus plastic can accommodate uniform wall dimensions in thin-walled parts because of high injection pressure, replacing the more costly thicker-walled features of die-cast metal parts.

Plastics also have advantages over metals in the prototype stage. ***Inexpensive, soft tools can be used to try out different materials and finalize design, with prototype parts easily machined out of plastic slabs, sheets or rods.***

MATERIALS REUSABILITY: Most injection-molded parts are constructed from thermoplastics, which are easily reprocessed as regrind. Runners and scrap parts, for example, can be ground up and immediately added to virgin materials – a distinct advantage over re-smelting steel. ***Regrind also generates up to 40% in cost savings.***

INCREASED PRODUCT LIFE: The environmental vulnerability of metals can be replaced with the durability and longevity of plastics. Most plastic materials have greater chemical resistance compared to most metals. Plastics do not rust or oxidize as metals do, and most are not affected by the acids or base compounds that corrode metal.

Design Process

While exchanging metal automotive parts for injection molded plastic components may sound relatively simple, in reality it's a complex engineering process. Designers need to understand the mechanical and structural differences between metal and plastic to determine how the materials will perform in end-user environments, and in which ways metal-to-plastic conversion will impact outcomes.

To do so, there are five critical phases:

1. **FEASIBILITY ANALYSIS:** ***The first step is finding out if your automotive project is suitable for metal-to-plastic conversion, which requires considerable analysis and often is not a quick determination.*** It is essential to fully understand the end-use application, environmental conditions, material evaluations, manufacturability and economic feasibility.

   Further, design engineers must be able to accurately evaluate the real-world environment that will impact the product, including chemical exposure or contact solutions, temperature ranges, shielding and forces (including worst-case scenarios). The most important rule at this stage is to never make assumptions. To do so could result in selecting the wrong material and setbacks in – or possible failure of – the development process.

2. **MATERIALS SELECTION:** ***The availability of 25,000 engineered plastic materials makes for nearly limitless design flexibility and customization, but selection cannot be arbitrary.***

   Matching the appropriate material to the automotive application takes prototyping and deep plastics knowledge to understand how the plastic will perform in the real world, especially since the mechanical properties of most thermoplastics are far below those of aluminum and steel, and the properties change with temperature fluctuations typically found within automobile engine compartments.

   Luckily, new higher-performance blends and hybrid materials can be custom designed to meet very specific performance requirements. Key considerations for selecting the correct type of plastics include:

   - **Crystalline v. amorphous** – evaluate requirements such as chemical resistance, impact, flow and processing.

   - **Additives** will affect strength, rigidity, FR package requirements, heat and cost.

     - 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, as 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

3. **MATERIALS TESTING:** Plastics respond differently to injection molding depending on their physical and chemical characteristics like strength and flexibility, melting and cooling behaviors over a range of temperatures, polymer structures and chemical bonds.

   These characteristics can be enhanced by adding filler materials or by creating hybrid plastic blends with very specific properties:

   - **Mechanical:** tensile strength, stiffness, impact resistance, creep and dimensional stability
   - **Thermal:** thermal expansion, heat deflective temperature, relative thermal index, coefficient of thermal expansion, mechanical response at temperature and plastic stability
   - **Chemical:** semi-crystalline v. amorphous chemical resistance, molecular weight and part stress; also account for how the combination of design, assembly, process and environment can reduce chemical resistance
   - **Environmental:** resistance to weather, humidity and ultraviolet light can combine to affect color shift, gloss retention and cause loss of material properties
   - **Electrical:** conductivity, shielding, dielectric strength, dielectric constant loss factor and electrostatic requirements

4. **ADDITIONAL DESIGN CONSIDERATIONS:** Even if the feasibility analysis and materials selection point to successful metal-to-plastic conversion, jumping into the project could prove counterproductive without accounting for every aspect of the design. ***Simply substituting plastic for metal in a design rarely works because plastics have different mechanical properties that affect product performance in the end-user environment.*** These variations, however, can be corrected by adding design features such as greater wall thickness or ribs for strength. Similarly, prototyping allows for testing several plastics using the same mold to compare strength,

hardness flexibility, corrosion resistance, fatigue and long-term creep. An advantage to automotive manufacturers is that you can start prototyping with the lightest weight part possible and then add features as needed for performance.

Evaluating the need for design features and prototyping are critical because plastic automotive components can stress/relax – and ultimately fail – if not designed correctly using proper materials. Take time to assess if plastic will solve one challenge but perhaps create others.

5. **SCIENTIFIC INJECTION MOLDING:** ***Standard molding procedures are simply not accurate enough for metal-to-plastic conversion of critical automotive components and the required tolerances.*** Scientific molding delivers high-performance, critical-tolerance automotive components by combining detailed materials science and precise measurement to completely understand what's happening during each stage of the injection molding process, down to the molecular level.

   Sophisticated software and sensors monitor the material inside the mold at all times and report even the smallest changes in pressure, temperature, viscosity, flow rate, material moisture rate, fill time and cooling rate. Specialized molding engineers then use that data to quickly correct any variations and consistently maintain product integrity.

7 Ways Scientific Molding Streamlines Manufacturing

Since all data is recorded, the scientific molding process is easily replicated and virtually eliminates issues that can arise in seven key areas impacting manufacturability:

- Resin optimization
- Color concentrate evaluation and blending
- Molding and tooling design
- Process and material variations
- Not meeting specifications
- Re-validation
- Regulatory requirements compliance

As the automotive industry continues to progress, especially as it relates to using new advanced plastics that can outperform metal, partnering with an experienced injection molder is more critical than ever. ***Kaysun design engineers are plastics specialists, and can develop the solutions you need for automotive applications both now and in the future.*** Call us at **1-800-852-9768** today to discuss your next metal-to-plastic conversion project.