KAYSUN
INJECTION MOLDING & ENGINEERING SOLUTIONS

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

AUTOMOTIVE MANUFACTURERS CAPITALIZE ON METAL-TO-PLASTIC CONVERSION

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

Automotive manufacturers were very early adopters of metal-to-plastic conversion, using nylon valve stems, wiring clips, gears, bearings, bushings, switch housings, and windshield wiper systems. Today, due to federal regulations surrounding the Corporate Average Fuel Economy (CAFE) mandate and low-carbon emissions, automotive manufacturers substitute plastic parts for metal ones to reduce weight without compromising overall strength or performance.

This guide better defines the role of plastics in the automotive industry, and how injection-molded plastic parts impact:

- Applications
- Tooling
- Design
- Costs

How Plastic Parts Improve Automotive Applications

Current metal-to-plastic trends focus on:

- Reducing weight
- Increasing strength
- Improving corrosion resistance
- Consolidating multiple metal parts into one plastic part

These goals squarely align with the needs and progress of the automotive industry, where federal fuel economy and emissions directives are forcing engineers to rethink manufacturability.

It’s estimated that a 10% reduction in vehicle weight can improve fuel economy by as much as 8%.[1] Transitioning from metal to plastic, though, can seem daunting. Vehicle engines produce high temperatures, constant vibration, and chemical exposure that can punish parts.

The traditional thinking was that only metal could withstand such a harsh environment. However, the evolution of application-specific resins such as nylon, polyphenylene sulfide (PPS), and polypropylene (PP) quickly changed minds.

Lighter weight, durability, design flexibility, and uniform surfaces make plastic ideal for use in many 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
- Lighter part weight
- Highly repeatable process
- Less scrap
- Lower manufacturing costs
- Enhanced regulatory compliance
- Greater design flexibility
- Increased market stability for materials cost
- Lower packaging and shipping costs
- Up to 6x longer tool life

Plastic Streamlines Processes

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

TOOLING:

With injection molding, tools last from 500,000 to in excess of 1 million cycles. They also require less maintenance and downtime compared to metal die casting, provided the molding system is optimized for part quality and tool life, as follows:

- Proper tool steel and screw style are compatible with the selected resin
- Tools are vented to minimize erosion
- Flash is eliminated from processing, which can otherwise damage parting lines
- Hot runner systems work with the selected resin

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 (e.g., stationary transmission parts) can be designed into one injection-molded part. 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 plastic eliminates expensive secondary operations. Specific colors and graphics can be easily incorporated 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 secondary operations

Comparative Cost & Quality

Generally speaking, companies can anticipate saving 25 to 50% by converting to plastic parts without compromising quality or performance.[2] In fact, injection- or insert-molded plastic decreases costs and improve part quality in several important ways:

LOWER PIECE PRICES:

After initial tooling costs are paid, piece pricing is usually much lower 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 consistent repeatability.

NO TIME-CONSUMING AND COSTLY SECONDARY OPERATIONS:

Plastic offers 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 fasteners.

REDUCED PRODUCT WEIGHT AND IMPROVED EASE OF USE:

Weight reduction is likely the biggest advantage plastic offers automotive manufacturers, followed closely by 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 plastic reveals dramatic weight disparity:

METAL:

- Aluminum 2.5-2.8
- Brass 8.4-8.7
- Copper 8.8
- Zinc 6.9-7.2
- Steels 7.7-7.83

PLASTIC:

- Polycarbonate 1.2-1.4
- Nylon (most types) 1.2-1.7
- Polyethylene 0.92-0.95
- Polypropylene 0.90-1.04 ABS 1.02-1.4

GREATER PRODUCT STRUCTURAL STRENGTH:

Automotive parts made from engineering-grade resins can actually be stronger than their metal counterparts. In addition to material strength, structural strength is improved because ribs, bosses, and gussets can be molded in when the part is originally produced instead of added through post-mold fastening, welding, and gluing.

MORE PRODUCT DESIGN OPTIONS:

Plastic offers greater dimensional stability than metal. As a result, tight tolerances and complex shapes can be molded simultaneously using advanced tooling. 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.

Plastic also has 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. Adding up to 30% of compatible regrind with virgin material reduces costs by up to 15%.[3]

INCREASED PRODUCT LIFE:

The environmental vulnerability of metal can be replaced with the durability and longevity of plastic. Most resins have greater chemical resistance compared to most metals. Plastic does not rust or oxidize as metals do, and most are not affected by the acids or base compounds that corrode metal.

Design Process

Replacing metal parts with plastic ones sounds relatively simple, but it's actually 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:

Determining if your automotive project is suitable for metal-to-plastic conversion requires deliberate, methodical analysis. 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 part, including chemical exposure or contact solutions, temperature ranges, shielding, and forces (including worst-case scenarios). Never make assumptions during feasibility analysis; to do so could result in selecting the wrong material and setbacks in – or possible failure of – the development process.

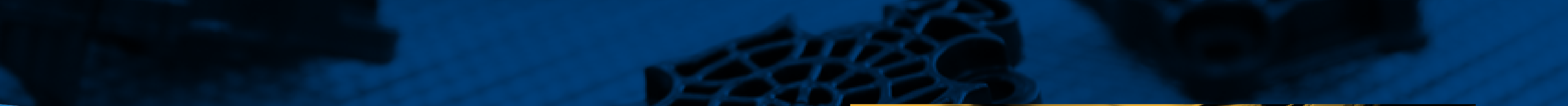
2. MATERIALS SELECTION:

The availability of 25,000 engineered resins makes for nearly limitless design flexibility and customization, but selection cannot be arbitrary.

To match resins and automotive applications, prototyping and deep resins knowledge is required. Understanding how resins perform in the real world is paramount, especially since the mechanical properties of most thermoplastics are far below those of aluminum and steel. Accounting for how the properties change with temperature fluctuations, for example, is a critical insight for automotive applications since engine compartments can generate a lot of heat.

Higher-performance blends and hybrid resins can be custom-formulated to meet very specific performance requirements. Key selection considerations 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 provide better aesthetics than long glass, as glass content of 30% or less resemble unreinforced plastic
- **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 specific gravity
- **Impact modifiers** improve toughness
- **Flame retardants** increase resistance to burning



3. MATERIALS TESTING:

Resins respond to injection molding based on their specific physical and chemical characteristics such as 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 resin 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 accounts for how design, assembly, process, and environment can reduce chemical resistance
- **Environmental:** resistance to weather, humidity, and ultraviolet light that can combine to affect color shift, gloss retention, and loss of material properties
- **Electrical:** conductivity, shielding, dielectric strength, dielectric constant loss factor, and electrostatic requirements

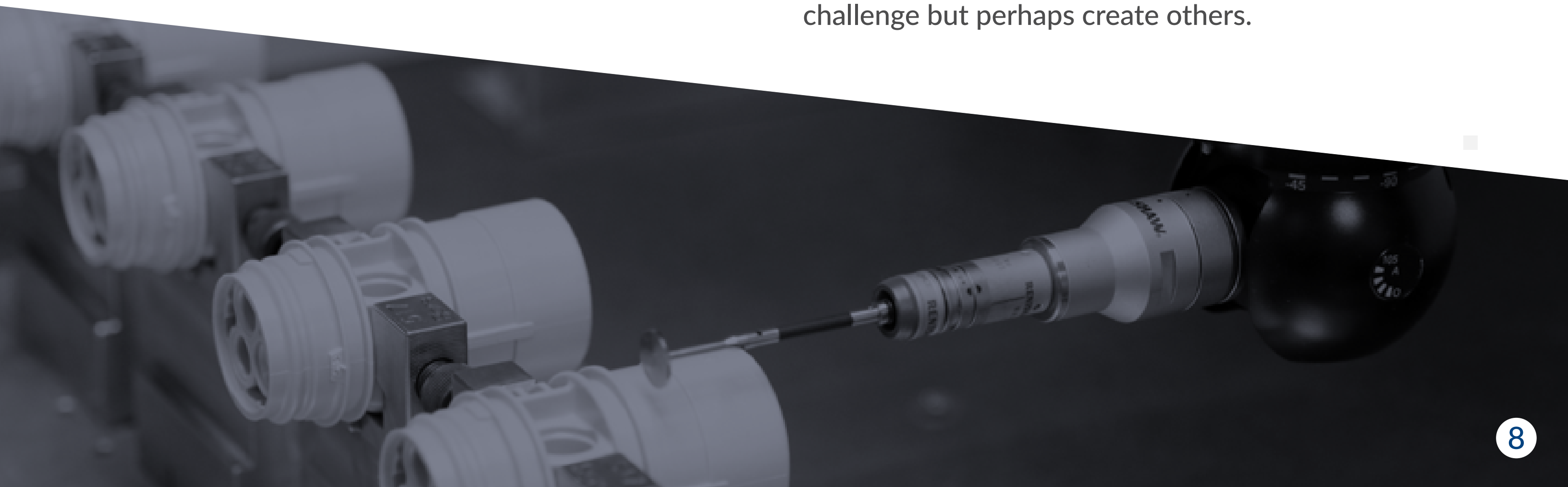
4. ADDITIONAL DESIGN CONSIDERATIONS:

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 different resins 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 resins using the same tooling to compare strength, hardness, flexibility, corrosion resistance, fatigue, and long-term creep. Further, automotive manufacturers benefit from prototyping because the lightest weight part can be used as a starting point, and features added as needed for performance.

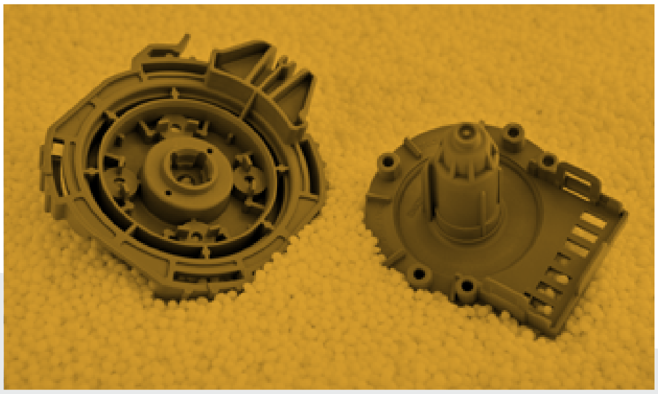
Plastic automotive parts can stress/relax – and ultimately fail – if not designed correctly using proper materials. Take time to assess design features and prototypes to determine if plastic will solve one challenge but perhaps create others.



5. SCIENTIFIC INJECTION MOLDING:

Standard molding procedures are simply not accurate enough for metal-to-plastic conversion of automotive parts containing tight tolerances. Scientific molding combines detailed materials science and precise measurement to evaluate each stage of the injection molding process, down to the molecular level.

Sophisticated software and sensors monitor the plastic inside the tool at all times and report even the smallest changes in pressure, temperature, viscosity, flow rate, material moisture rate, fill time, and cooling rate. Specialized scientific molding engineers then use that data to quickly correct any variations and consistently maintain part 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
- Tooling design
- Process and material variations
- Specifications conformance
- Re-validation
- Regulatory requirements compliance

As the automotive industry continues to embrace metal-to-plastic conversion, partnering with an experienced injection molder takes on added importance.

Kaysun design engineers are plastic specialists, and can develop the solutions you need for automotive applications both now and in the future.

Connect with the Kaysun team to discuss your next metal-to-plastic conversion project.

SOURCES

[1]MarketsandMarkets, Automotive Plastics Market Global Forecast to 2026, Undated
[2]Plastic Components, Metal to Plastic Conversion - A Comprehensive Guide, Undated
[3]Kaysun, Plastic Regrind Saves on Money and Materials, May 6, 2020

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