LIGHTENING THE LOAD

How Plastics Improve the Safety & Effectiveness of Military and Public Safety Personnel

KAYSUN CORPORATION
INJECTION MOLDING & ENGINEERING SOLUTIONS

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U.S. soldiers, fire fighters, police men and women, and other public service officers carry loads of equipment and protective gear that can weigh anywhere from 45 to 130 pounds. This is more than enough to quickly tire even the best-conditioned personnel and contribute to reduced mobility and impaired decision making that could result in casualties.

To meet the challenges of evolving – often dangerous – circumstances and to leverage advancing technologies that help make military and public safety personnel work smarter and safer, manufacturers need to deliver products that are lighter, stronger and highly functional. At the same time, companies designing and manufacturing the equipment need to reduce the total cost of ownership (TCO) associated with their products, including design, production, delivery and maintenance.

Injection-molded plastic parts are increasingly being used instead of metal in a variety of military and public safety applications, providing a practical solution that accommodates manufacturer, contractor and user needs.

This white paper:

- Examines the key benefits provided by today's advanced plastics
- Explains the best practices in material selection, part design and mold making required to deliver plastic components that can improve safety and efficiency in the field

Materials Comparison: Metals vs. Plastics

Metals have long been the material of choice for many important defense and public safety applications. Generally speaking, metals offer low thermal expansion and high strength. Many metals also offer high electrical conductivity, making them ideal for shielding electronic equipment; others offer high thermal conductivity, so they are well suited to applications requiring the rapid dissipation of heat, such as engine cooling. Finally, metal parts can be produced to very tight tolerances, though the secondary machining operations required in achieving that precision can be costly.

The prevalent trend, however, is for plastics to replace metals in these applications based on a growing number of advantages, including:

- Lower weight
- Freedom of design and assembly
- Superior durability
- Ease of finish
- Lower total cost of ownership (TCO)

Lower Weight

Plastics are much lighter than metals, making them a better choice for a wide variety of uses, from armor to clothing to equipment and protective gear.

Not only does plastic significantly reduce gear and equipment carry weights – by as much as 20 pounds in some military situations – it increases user agility (both vertical and horizontal) and safety in accord with the U.S. Department of Defense Joint Warfighting Science and Technology Plan.[1]

Freedom of Design and Assembly

Plastics offer increased freedom in design and are subject to fewer assembly constraints, enabling manufacturers to consolidate multiple parts into a single, injection-molded plastic part. The ability to design plastic parts with complex geometries (shapes) also means multiple parts can be assembled using the method best suited to a particular application – such as welding, heat staking or mechanical snap-fit.

Superior Durability

Today's sophisticated plastics are extremely durable and outperform comparable metals in resistance to heat, chemicals, moisture and impact. See "Choosing the Best Plastic" and "Additives for Options" sections, below, for discussion about the characteristics of the major plastics families and how complementary materials can be added to further improve strength and durability.

Ease of Finish

The color of equipment used on the battlefield or on the street can be an important element of its utility – from a matte finish that decreases glare to a camouflage pattern that enables stealth. With plastics, manufacturers and molders can create virtually any color or finish during the production process, and eliminate the need for expensive secondary painting or coating operations otherwise required by metal parts.

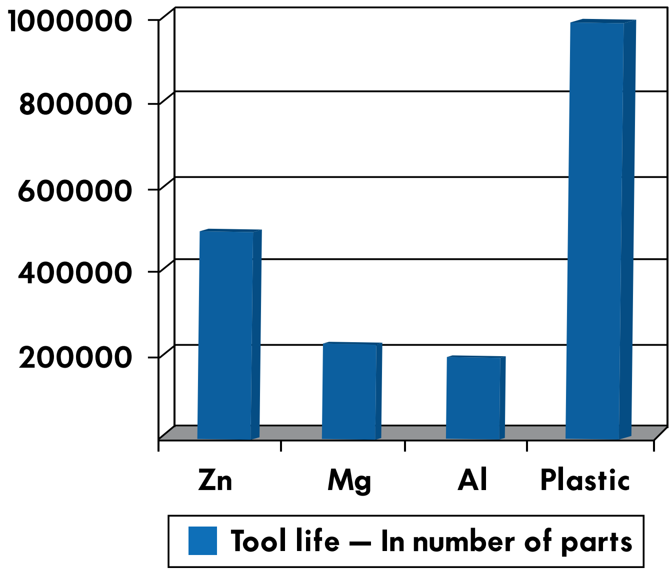
Lower Total Cost of Ownership

Taken together, the lower weight, design, assembly, durability and finishing advantages of injection-molded plastic parts result in dramatically lower total costs. Compared with metal, plastic parts do not require expensive secondary operations, such as machining or painting. In addition, because plastic parts can be designed in much more complex shapes, the manufacturer can reduce the total number of parts produced by as much as 70%.

Similarly, the weight savings created by transitioning to plastic reduces overall fuel and transportation costs. In the case of the military, this is essential since it is the world's single largest consumer of oil at more than 340,000 barrels per day, and the U.S. Department of Defense is requiring its contractors to help improve fuel efficiency.[2]

From a production standpoint, plastic injection mold tooling is extremely robust and has a much longer life than the die-cast molds used to produce metal parts. Figure 1 compares the typical useful life of die-cast molds used for popular metals such as zinc, magnesium and aluminum versus injection molds used for plastics.

Figure 1: Comparison of tool life for die-cast and injection molds



Keys to Conversion

There are several considerations that impact successful metal-to-plastic conversion:

Application Requirements

The part design process starts with identifying application requirements in three dimensions: mechanical, thermal and environmental. Will the part or product be dropped? Will it be used in an extremely hot or cold environment? Will it be exposed to harsh chemicals? How long does it have to last? The answers to these and other related questions provide a focal point for the next steps in part development and meeting functional and cost requirements.

Choosing the Best Plastic

Choosing the best plastic for your application requires deep knowledge of the wide range of possible materials. In addition to relying upon an experienced injection molding partner, possessing a basic understanding of the types of plastics, their properties and typical applications is to your benefit in projects featuring metal to plastic conversion. Here's an overview:

Plastics are made up of polymers, meaning long chains of repeated molecule units. The ways in which the chains intertwine determine the plastic's macroscopic properties.

Typically, the polymer chain orientations are random and give the plastic a random, or amorphous, structure. Amorphous plastics have good impact strength and toughness. Examples include acrylonitrile-butadiene-styrene (ABS), styrene-acrylonitrile copolymer (SAN), polyvinyl chloride (PVC), polycarbonate (PC) and polystyrene (PS).[3]

If instead the polymer chains arrange themselves in an orderly, densely packed way, the plastic is said to be crystalline. Crystalline plastics share many properties with crystals, and typically will have lower elongation and flexibility than amorphous plastics, but better chemical resistance. Examples of crystalline plastics include acetal, polyamide (PA; nylon), polyethylene (PE), polypropylene (PP), polyester (PET, PBT) and polyphenylene sulfide (PPS).

Figure 2 provides an overview of several popular plastics and includes details on their properties as well as typical applications.

Figure 2: Characteristics and Applications for Popular Amorphous and Crystalline Plastics[3]

Material Name	Material Type	Abbrev.	Trade Names	Description	Applications
Acetal	Crystalline	POM	Celcon, Delrin, Hostaform, Lucel	Strong, rigid, excellent resistance to fatigue, chemicals, moisture, naturally opaque, low/medium cost	Bearings, cams, gears, handles, plumbing components, rollers, rotors, slide guides, valves
Polyamide 6 (Nylon)	Crystalline	PA6	Akulon, Ultramid, Grilon	High strength, fatigue and chemical resistance, low friction, almost opaque, medium/high cost	Bearings, bushings, gears, rollers, wheels
Polycarbonate	Amorphous	PC	Calibre, Lexan, Makrolon	Very tough, temperature resistance, dimensional stability, transparent, high cost	Automotive (panels, lenses, consoles), housings, light covers, reflectors, safety helmets and shields
Polyester	Crystalline	PBT, PET	Celanex, Crastin, Lupox, Rynite, Valox	Rigid, heat resistance, chemical resistance, medium/high cost	Filters, pumps, bearings, cams, electrical components, gears, housings, switches, valves
Polyetherether-ketone	Crystalline	PEEK		Strong, thermal stability, chemical and abrasion resistance, low moisture absorption	Aircraft components, electrical connectors, pump impellers, seals
Polyphenylene Sulphide	Crystalline	PPS	Ryton, Fortron	Very high strength, heat resistance, very high cost	Bearings, covers, fuel system components, guides, switches, and shields
Polypropylene	Crystalline	PP	Novolen, Appryl, Escorene	Lightweight, heat resistance, high chemical resistance, scratch resistance, tough and stiff, low cost	Automotive (bumpers, covers, trim), bottles, caps, crates, handles, housings
Polyvinyl Chloride	Amorphous	PVC	Welvic, Varlan	Tough, flexible, flame resistance, transparent or opaque, low cost	Electrical insulation, medical tubing, shoe soles

Additives for Options

Plastics' characteristics can be changed by mixing in different types of polymers and/or by adding non-plastic materials.

Particulate fillers such as mineral, silica, ceramic, carbon fiber, glass fiber and powdered metal are added to increase modulus and electrical conductivity, to improve resistance to heat or ultraviolet light and to reduce cost. Plasticizers are added to decrease modulus and increase flexibility. Other additives may be used to increase resistance to ultraviolet light and heat or to prevent oxidation.[4]

Glass fibers, carbon, stainless steel and various coated fibers or Kevlar all have high reinforcing properties of tensile strength, increased tensile and flexural modulus, good toughness and stress-strain behavior similar to that of metals. They can be added to improve mechanical properties as long as careful part and tool design is used to position the fibers so they provide the required strength where it is needed.

A short list of popular additive categories and their properties includes:

- **Glass fibers** improve stiffness and increase heat resistance
- **Stainless steel fillers** improve conductivity and shielding
- **Lubricant fillers** reduce wear and friction
- **Mineral fillers** improve electrical performance and sound dampening, reduce cost, and improve dimensional stability
- **Impact modifiers** improve toughness
- **Flame retardants** increase resistance to burning

Part Design and Analysis

Part design and analysis is a critical aspect of any metal to plastic conversion. Experienced complex injection molders can identify any potential issues early, modify the design to resolve them, then re-evaluate and validate through a process of continuous improvement and tight quality control.

The tools available for part analysis include mold-filling simulation, cooling simulation, predictive shrinkage and warping, and finite element analysis. All provide assurance that the part will perform as intended, lower failure risk, and safeguard large investments in equipment and tooling.

The Injection Mold

The mold is the heart of the plastic injection molding process — and the most important investment manufacturers can make in the quality of injection-molded plastic components for their products — so special consideration must be given to the material from which the mold is made.

For relatively small runs a soft metal such as aluminum can be used. Aluminum molds can be relatively inexpensive to create, given its superior machinability, so they are well suited to producing molds for prototype parts. But, this characteristic also makes aluminum a poor choice for longer production runs since the mold will wear and result in parts with dimensions out of specification.

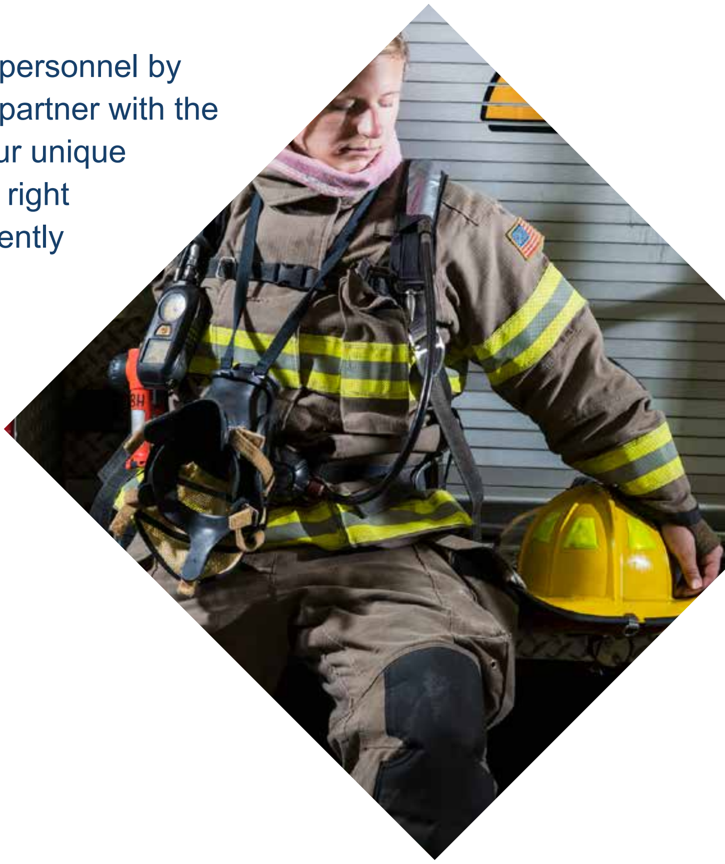
Parts with larger runs are typically produced with molds made from steel, ranging from carbon steels, such as P20 for mid-level production runs, to hardened steels, such as H13 for large volume production.

The type of raw plastic material being used can also influence the choice of mold material. Some plastics are fairly corrosive, with degassing properties that can prematurely wear softer mold metals. Some of the fillers frequently added to the plastics, such as long glass fibers, can also contribute to mold wear and thus require harder mold materials.

For applications that require low production runs, such as a handheld device with numerous optional accessories that require small modifications to a base design, molding partners can provide an economical solution through the use of hand-loaded mold inserts and other innovative production processes.

Kaysun — Your Key for Success

Lightening the physical load for military and public safety personnel by replacing metal with plastic requires an injection-molding partner with the knowledge, capabilities and experience to understand your unique application requirements. Kaysun can help you select the right material, then design and produce a robust part – consistently on spec, on budget and on schedule.



Notes:

[1] *Joint Warfighting Science and Technology Plan, U.S. Department of Defense*, May 1996

[2] *"U.S. Military Hopes to Be Energized by Alternative Fuels: High Costs, Supply Risks Send DOD Searching for Ways to Save Energy," Wharton Aerospace and Defense Report*, January 30, 2009

[3] Plastics, Custompart.net

[4] Plastic Dictionary, Electronic Development Labs, Inc.

To learn more about how Kaysun can help improve the safety and effectiveness of military and public safety personnel components, call us at **920-686-5800**. Our engineering and design teams will work closely with you to deliver a final product that meets all your design, quality and production goals.

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