Capitalizing on Plastics

Engineers are using advanced plastics to make appliances more durable, less expensive, and good looking.

By: Kevin Beck (Appliance/Electrical Industry Manager) Ticona, Summit, NJ.

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Plastics might be common in small appliances, mechanisms, and electronics, but large kitchen and laundry appliances are still mostly metal. Advances in engineering resins, however, are opening new design opportunities for plastic as structural and cosmetic parts in refrigerators, washers, dishwashers, and other “white goods.” These advances promise dramatic reductions in cost, part counts, weight and noise, but they also require a new mindset in a traditionally metal-dominated industry to fully exploit plastics. Appliance designers need to understand the properties of today’s engineering resins, along with the advances in processing equipment.

Plastics are already being used in, or seriously considered for, the following key appliance areas: large appliance housings, gear and belt drives, electric motor and compressor housings, electronic enclosures, and permanently decorated or coded parts.

In each of these areas, the predictable long-term properties of modern engineering resins offer solutions to common design and manufacturing challenges.

**Integrated housings**

Video recorders, television sets and other small appliances are commonly housed in ABS, polystyrene, and polypropylene. Other major appliance housings, however, require greater impact and load-bearing strength. Currently in the U.S., enclosures for refrigerators, dishwashers and other large appliances use structural steel frames shrouded in rolled steel sheet. Prefinished skins are stamped, formed, cut, and drilled, then bolted to heavy steel bases and structural members. The high number of parts, as well as the fabricating and assembly operations associated with this process, make metal housings expensive.

Metal housings also have other drawbacks. They add weight, making appliances more difficult to assemble, ship, and install. They need thermal insulation to contain heat or cold. And without added sound insulation, the sheet-metal walls resonate and amplify noise from internal components. Mechanical fasteners also vibrate loose and let parts rattle. Over years of service, even coated metal housings corrode from contact with chlorine bleach and other household chemicals.

European appliance makers already cover structural steel bracing with polypropylene exteriors to take advantage of plastics. With a broader
systems approach to appliance housings, however, new engineering resins can provide a cost and weight-saving alternative to metal. Gas-assist molding and other production advances, for example, provide new opportunities for light, hollow plastic parts using I and C-beam construction to boost strength.

By integrating structure and skin into housing parts, engineers can reduce the total number of parts and simplify assembly. In many cases, molded-plastic housings don’t need secondary machining and can be bonded with adhesives rather than rivets or bolts. Corrosion-free plastic enclosures molded in color or made with in-mold color systems such as laminates and films, also eliminates costly painting. And they can have the various satin, textured or glossy “looks” popular on today’s appliances.

Compared with metal housings, plastic versions have low heat transfer and reduce the amount of thermal insulation required in refrigerators and freezers. Plastic housings also generate dramatic weight savings. The specific gravity of steel is about five times that of most reinforced plastics which could be used for these applications. With integral beam design, plastic structures and housings can reduce weight and still provide greater specific strength where it’s needed. Although a washing machine needs mass to keep from “walking” across the floor, the flexibility of plastic design lets designers put weight where it’s needed and still make cost savings.

Lighter freezers, refrigerators, and air-conditioners would be easier and less expensive to assemble, ship, and service. Consumers would benefit when moving or rearranging households. Also, the inherent damping properties of reinforced plastics contain, rather than amplify, the noise of washer motors and refrigerator compressors.

Recent advances with high-impact thermoplastic polyethylene terephthalate (PET) are paving the way for large, injection-molded appliance housings with built-in structural elements. A modified version of Impet Hi PET, for example, is being used to mold the large, structural body panels of Chrysler’s Composite Concept Vehicle (CCV). This new resin is now being considered by appliance makers for large housing parts. The 15% glass-filled Impet Hi 430 PET can fill large molds on common molding machines without excessive wear on injection-molding tools or equipment. The body panels of the CCV, for example, weigh up to 70 lbs a piece. Adhesively bonding the four plastic body panels together takes about one-third the assembly time of a metal shell. At less than $1.50/lb, the easy molding PET gives appliance designers an affordable material for large housings.

Long-fiber-reinforced thermoplastics (LFRT) provide another alternative to metal for large appliance enclosures and structural parts. While conventional reinforced resins have chopped fibers just 1 mm long, Celstran LFRT composites have fibers 11 mm long and provide up to 3.5 times the impact properties of conventional short-fiber-filled resins. In optimized designs, LFRT has about twice the specific flexural strength of steel, while letting designers reduce total weight, number of parts, and cost.

In one instance of part consolidation, making appliance-leveling feet out of Celstran PPG40-02-4 long-glass polypropylene eliminated...
several assemblies while providing greater impact and compressive strength than metal parts. They also eliminated corrosion concerns. Washing machine bases molded in LFRT, which are now under development, can put a host of motor mounts, braces, and other components into one molded part. A compressor base, designed for a refrigerator, eliminates several parts by incorporating a plastic spring joint for noise reduction. It also insulates the hot compressor from the refrigerator. Consolidating parts in one large piece not only cuts manufacturing cost but eliminates noise transmission points in bolted metal structures.

New grades of long-glass reinforced polyethylene concentrate, polypropylene, and other resins are now specifically formulated for blow-molding and extruding large parts, extending the benefits of LFRT materials for appliances. Blow-molded panels can include stiffeners and other features, while long extruded shapes have exceptional strength and stiffness. Long-glass-reinforced polypropylene, for example, is being used over aluminum for refrigeration supports.

**Gears and Pulleys**

Under the skin of today’s large appliances, gear and belt drives still use expensive, noisy metal parts. For appliance engineers, plastic gears, and pulleys offer powerful opportunities to cut cost, noise, weight, and wear. Today’s engineering resins can be used to mold stronger gears with greater dimensional stability, and can go into more demanding applications than previously thought possible. Plastic gears are now used in 3/4-hp laundry drives. It is expected that plastic gears will soon be able to handle applications for between 1 and 10 hp in the near-term, and up to 30 hp by the next decade.

Production plastic gears are already molded to American Gear Manufacturer Assoc. (AGMA) Q9 and Q10 quality standards. This level of power and accuracy now available with plastic gears is opening new design opportunities.

Maytag in Herrin, Ill., demonstrated the potential of plastic gears by using them in its totally new washer transmission. Gears molded in acetal copolymer effectively eliminated transmission noise. And compared with an earlier metal transmission, the split-power drive did away with 42 parts and saved 13 lbs, simplifying assembly.

Making gears using injection molding is faster and less costly than hobbing teeth in metal blanks, and molded gears can be made to handle several functions in one part. Plastic gears often require no finishing, and are ready for assembly right out of the mold. Consequently, they can cost one-half to one-tenth the price of stamped, machined, or powder-metal gears. The lower cost of plastic gears lets designers consider innovative drives with internal gears, split power paths, and other features impractical in metal.

The strength and inherent lubricity of plastic gears can make drives last longer, whether lubricated or unlubricated. To improve the reliability of its World Washer, for example, Whirlpool Corp., in St. Joseph, Mich., uses a splined clutch, or “splutch,” with a spline and gears molded in acetal copolymer. The epicyclic gear assembly lasts four times the projected life of the washing machine. It also reduces the number of moving parts by 20% compared with earlier designs using metal gears.

Plastic gears also cut drive noise. With metal gears, misalignment and small tooth errors inevitably create tiny impacts and running noise. Lower-modulus plastic gear teeth deform to absorb impact and compensate for...
inaccuracies. Thanks to this deformation, plastic gears are quieter than more costly metal gears machined one or two AGMA classes higher in quality. Special gear grades of acetal copolymer keep plastic gears from squeaking in nonlubricated environments.

The Maytag gears, injection molded from unfilled and glass-reinforced acetal copolymer, proved that they could stay strong and hold tight tolerances in an oil-bath transmission. The helical spin gear in the Whirlpool Design 2000 washer is also molded in glass-reinforced acetal copolymer and maintains tensile and impact strength in SAE60 oil. While they can work in oil, self-lubricating plastic gears naturally lend themselves to grease-free applications and less-costly drives. Without the need for a sealed gearbox, unlubricated drives are generally far less expensive than those designed to contain grease or oil.

Lower gear friction also means less energy wasted in heat. Maytag engineers estimate the cooler-running plastic transmission reduce heat rise 10 to 15% compared with previous metal drivetrains. Improved transmission efficiency can help satisfy future U.S. Energy Department standards for appliances.

Transmission housings also benefit from plastics. Long-fiber-reinforced thermoplastics make gearboxes lighter, quieter and less complicated than metal assemblies. Their low coefficient of thermal expansion also preserves critical center distances between meshing gears.

Just as plastic gears make quieter, less-costly gear drives, plastic pulleys enhance belt drives. Many of today’s horizontal washers and dryers use cast-and-machined aluminum pulleys, which cause belts to wear. Maytag engineers in Newton, Iowa, adapted an injection-molded pulley for the belt drive of their innovative Neptune washer. Detailed studies in automotive applications suggested that with the right hardness and a low coefficient of friction, a heat-stabilized Celanese nylon 6/6 would minimize pulley and belt wear. The same nylon 6/6 material provides Maytag with the temperature stability, creep resistance and low-wear properties essential to a quiet, reliable washer.

**Electric motors and compressors**

The motors that drive large appliances inevitably contain metal – no current resin can carry enough conductive fillers to make an efficient rotor or stator. Plastics, however, can reduce the cost, complexity, and noise of motor and compressor housings. Engineering plastics now have the dimensional stability essential to motor and compressor components, and offer the chance to consolidate components. For example, a developmental compressor-valve plate molded in linear polyphenylene sulfide (PPS) combines key parts and holds tight tolerances at higher operating temperatures.

Motor endshields made of aluminum typically have switches, terminal boards, and connector housings attached with screws or snap-fits. One major motor manufacturer replaced its aluminum endshields with flame-retardant polyester caps. The redesign cut the number of endshield parts in half and reduced the overall number of motor parts by two-thirds.

The cost of one widely used jetted-tub motor has been reduced 25% by incorporating the water pump into the plastic endshield. Engineers are now trying to develop motor endshields that eliminate separate center housings altogether.

While plastic motor housings make manufacturing easier, they also reduce motor and compressor noise. Metal motor housings provide little damping, and therefore generate a noticeable hum aggravated by shaking bolts and other loose components. The inherent damping properties of plastic housings and other molded parts make motors and compressors quieter. For example, one compressor manufacturer has commercialized a thermoplastic polyester muffler for the company’s refrigerator/freezer compressors. The two-part, ultrasonically welded muffler is molded in glass-reinforced PBT compatible with chemically aggressive R134A refrigerant. In place of a bonded aluminum assembly, the plastic muffler costs 15% less and eliminates noisy metal resonance. Another compressor manufacturer has adapted linear PPS for cases where a muffler needs to operate at higher service temperatures.

**Electrical housings**

Despite many drawbacks, metal enclosures are natural flame barriers. For that reason, small plastic appliance housings today often have their electrical parts in metal boxes to isolate them from nonflame-retardant housings. Makers of large appliances in Europe and Asia use a similar scheme for major appliances with plastic housings.
Additives used to give engineering resins a UL94V-0 or 5V flame rating increase the cost of these resins by a third or more. As a result, large, flame-retardant plastic enclosures that satisfy U.S. safety requirements may be too costly to compete with metal versions unless parts reduction is used. With updated safety standards, it may be possible that flame-retardant plastic enclosures within larger plastic housings will give designers fire safety, design freedom, and drastically reduced costs.

Flame-retardant plastic enclosures are already in production. Mallory Controls in Indianapolis, for example, uses flame-retardant polybutylene terephthalate (PBT) in its new washer/dishwasher timer. The 35% glass/mineral reinforced polyester provides a UL94 V-0 rating and exceptional flatness which lets the timer be positioned accurately. The snap-fit plastic housing reduces the timer’s weight by 35% and number of parts by 18% compared to metal-boxed timers. The same techniques are being applied to refrigerator defrost timers.

Long-glass-reinforced thermoplastics are available with flame-retardant nylon, polyester, polycarbonate and ABS base resins. Stainless-steel or carbon fibers offer enough conductivity to electromagnetically shield notebook computers, and have the strength and modulus to replace metal bracing. These same materials can be applied to the electronics of modern appliances.

Permanent marking

Engineering plastics chosen for appliances must resist most chemical environments. For example, the PBT used in the washer timer must stand up to spray detergents. On the other hand, acetal copolymer gears in the washer transmissions are impervious to gearbox lubricants. As a result, marking such parts with decorative logos or traceable data is difficult and expensive with traditional pad printing and hot stamping. Even when marks are printed, they are easily removed by rubbing or chemicals. However, recently commercialized laser-markable grades of acetal copolymer and PBT let appliance designers etch high-resolution graphics and alphanumerics into the plastic.

With the new resins, common Nd/YAG industrial lasers can engrave marks of contrasting color deep enough into the plastic to form indelible messages or patterns. The thermochemical reaction actually changes the color of the marks to stand out from dark background colors. The laser requires no inks, solvents or masks, and its marks can be changed on-the-fly without downtime or tooling costs. For example, keyboard keys are now being molded in acetal copolymer and laser marked in a fraction of the time required to pad print.

For highly visible pushbuttons, handles, and other controls, laser-markable plastics carry functional marks that last the life of the appliance. And colors of acetal copolymer parts and their indelible marks can be matched to designer specifications. For hidden components made under QS9000 quality control measures, laser marking is a powerful tool to trace parts back to their origin. Serial numbers and high-density 2D symbology can be etched on parts of any shape.
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