

Metal-to-Plastic Conversion Parts Help Drive Heavy Industry

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While metal-to-plastic parts conversion actually began way back in the Fabulous Fifties, think toys, household products, etc., it is only in more recent years that plastic conversion has gained a firm foothold in the more strength- and lifetime-demanding applications such as aerospace, under-the-hood automotive, motors, valves, bearings and, as they say, much more. This was made possible by ongoing technical advances in both highly engineered polymers and injection molding machinery.

Some history, from Mark Fiorina, technical director of International Plastics LLC. “At the end of World War II there were a handful of commercially available plastics. By 1980 that number had grown to 4,500, and by 2000 there were more than 50,000 commercially available formulations.”

What about gears? Plastic, in some cases highly complex, gears are everywhere (see above)—just don’t expect to see them supplanting, for example, AGMA 12 gears any time soon. It is not until you get down to commercial AGMA 8 or less that plastic conversion can be considered. For more detail on this subject, Fiorina says “The best reference manual I have found for qualifying a plastic gear design was published by Plastic Gear Technology Inc., titled ‘Plastics Gearing.’”

Ron Brookhart, program manager/project engineer, Engineered Plastic Components, Inc. (EPC), suggests “contacting a custom-compounder for suggestions on a specific application. Custom-compounders are capable of engineering a plastic to work for a specific application and may have already done something similar.”

As reported in the opening, the takeaway here is that there still exists an almost limitless array of heavy industry-type applications in which plastic is reliably used. You may be interested (as were we) in knowing what determines whether an existing metal part can be plastic-converted. Fiorina walks us through a typical scenario.

“OK, I have a metal part and I think it can be plastic (what it is and the metal are irrelevant at this point). The first question



Figure 1 Zinc gear International Plastics prototyped, followed by first production gear (All photos courtesy International Plastics LLC).



Figure 2 A family of three plastic-to-steel thermostat covers.

you need to ask yourself is why do I want to change material? What are the problems the metal part is having and how would a plastic part solve those problems? Metal parts often have corrosion issues that require plating and/or painting, which is environmentally unfriendly; and sometimes there is a lot of machining of the metal, which is slow and costly. Many times multiple setups and multiple machines are required. Sometimes there are lubrication problems with a metal part, which results in premature failure of the product. Metals are conductive and you need insulating properties. This list can go on and on, and is different for every industry and every application. Then, you really have to look hard at the application and determine if plastics can handle the temperatures and mechanical loads that will be applied. This is the step that gets people into trouble.”

Trouble? What trouble?

Fiorina explains: “While you will usually find a range of materials that can solve the types of problems mentioned above, it is the temperatures and loads that often limit your material selection or prove to be outside of the capability of plastics—even with clever redesigning. This is when reality steps in and either tells you that you had a good idea or a bad one.”

Leaving that aside, there is another critical component to consider when looking to convert a metal part to what is known as engineering (higher-end) grade polymer, i.e. — the required injection molding.

Fiorina says that, “When moving to plastic from metal, especially if the metal part is a machined part, the 800-pound gorilla in the room is the plastic injection mold. This is an expensive piece of capital equipment (half-million dollars-plus) that the end user frequently never sees or touches.” Why so expensive? “Unless you are talking about an inexpensive, aluminum prototype mold, they are typically made from hardened tool steel. Even though a mold builder has made hundreds or thousands of them, each one is a unique, one-off mechanical device. A mold has a highly engineered filling system to get the plastic into the cavity which will produce the part; a complex three-dimensional cooling system that must remove the heat from the cavity uniformly to control shrinkage and warping; an ejection system to push the part out of the mold without damaging it; a

structural housing to support all of this that is capable of taking very high compressive loads for millions of cycles without mechanical failure; an alignment system that will keep both halves of the mold in proper location when the mold is closed and plastic is injected at 300° F to 720° F under pressures of 5,000 psi to 40,000 psi. Lastly, it has to hold the precision cavity(s) that will actually produce the part. Frequently parts require undercuts, or threads or windows in the side of the part, (adding) substantial cost to the mold. The ins-and-outs of mold construction is a topic that could take up a couple of semesters, in senior level engineering.” Also required is expertise in grinding, EDM, wire EDM, CNC programming in 3,4 and sometimes 5 axes, CAD/CAM, solid modeling, CNC machining, heat treating, CNC Turning, and mechanical assembly.

Aside from the complexity and cost, what eases the pain according to Brookhart is that “The higher the volume, the more cost effective injection molding is.”

Indeed, what makes the above investment work is that the payback for metal-to-plastic can be considerable. For Fiorina, injection molding is a beautiful thing.

“The beauty of injection molding is that the process is fast relative to machining,” he enthuses. “Small, thin wall parts can cycle in 5 or 10 seconds; medium-sized parts can be molded in 20 to 40 seconds; big parts might take a minute or two. Also, one machine running a multi-cavity mold can produce several parts at one time.” Continuing, “The economic power of injection molding is unbelievable. Molding a part with it’s finished color in the material and eliminating 2,3,4,5 machining steps or assembly operations gives this process a unique advantage over machining.”

And what is the strongest poly-based (often with additives) material available? According to Brookhart, “The strongest materials are long-glass materials; polypropylene and nylon are the most common.” Combinations of the above are considered custom compounds. Explaining further, Brookhart says, “A custom compound is a plastic that has specific additives (glass fiber, UV, minerals, lubricants, etc.) to give it the properties required for a specific application. A custom compound is needed when off-the-shelf commodity plastics do not meet the requirements for the application.”

For functioning in harsh environments, and at elevated temperatures (300° F to 400° F), sophisticated polymers such as PPS, PPSU and PEEK are state-of-the-art. Example: Fiorina says that PEEK, capable of operating at temperatures as high as 500° F; it is used, for example, in oil and gas down-hole applications; electronics; pumps; insulators; etc. “But,” says Fiorina, “PEEK comes with a hefty price tag of \$50-to-\$70/pound,” adding, “As you go up the food chain, the materials get progressively more difficult (to work with).”

Considering other definitive attributes of plastics over metals, Fiorina says “Plastics are often an upgrade from a metal in applications where lubricity is the primary property required. While there are lots of additives that can make a material slippery (reducing the static and dynamic

Table 1 Materials comparison chart.

	lb/ft ³	Tensile strength (psi)	Modulus (psi × 1,000,000)	Coefficient of friction
Steel	490	100,000	30.0	0.65
Aluminum	165	56,000	14.0	1.20
Bronze	510	33,000	12.0	0.22
Nylon (40%carbon fiber)	82	40,500	4.0	0.34
Nylon (30% Glass fiber)	86	29,500	1.5	0.27
Nylon (Neat)	71	12,500	0.5	0.11
Nylon (Lubricated)	73	10,500	0.3	0.06

coefficient of friction), several engineering-grade materials are naturally slippery without any additives (acetals and nylons). If you can eliminate lubrication you can eliminate one more point of failure.”

And did you know that, according to Fiorina, we can be thankful for the fact that “The introduction of PAI (torlon) washers and spacers into automotive transmissions (is what) got manufacturers to the 100,000-mile warranty.”(And) “The introduction of acetal piston rings in pneumatic cylinders got us to the longer-life, no-maintenance cylinder. Longer life and reduced or no maintenance, (are) primary benefits of lubricated plastic parts.”

As demonstrated, components/parts used in heavy industry are proliferating. But as for the day when outside plastic parts become reality, Fiorina points to two applications: gears in an automotive transmission (high power, high torque), and large ring gears that are several feet across and carry large loads in compressors, or big machinery. “I do not see either of these applications going to plastic any time soon; the latter application is just too big, volumes are low, the molding machine required and mold itself would be huge and a very large investment. And, the physical loading is outside the envelope that plastics can handle.”

He boldly predicts, however, that “If you want to know if automotive transmission gears can be made of plastic, keep an eye on Formula One. They are definitely the tip of the spear when it comes to applications like that. When you see that first plastic gear show up in F1, you will see it on the street in 5 years.”

Tying things up in a neat, if complex, package, Fiorina says that, “The only thing that is constant in this process is that it is one full of compromises. The part geometry, material, mold, molding machine, and process all interact with each other simultaneously. It is a process that sounds simple in concept but in practice is one of the most complex. Add in client expectations, misconceptions, and snake oil sold by some molders, I am amazed we have come as far as we have.”

For more information

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