MACHINABLE COMPOSITES FOR E-MOBILITY

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Abstract

Fiber reinforced epoxy mold compounds (EMC) have many favorable characteristics that make them potential candidates for a variety of automotive applications. They have an exceptionally high HDT (Heat Distortion Temperature) for a non-metallic material, 320-340°C or higher, and this is with only 5% fiber reinforcement. Epoxies are known for their electrically insulating properties, and developmental materials are pushing the limits of thermally conductive polymers. These composites can be molded to net shape or near-net shape, and recent experiments have demonstrated that they have very good machinability properties as well. Several one inch thick plates of 5% fiber-reinforced epoxy were subjected a variety of milling and turning experiments. References will be made to how this data compares with metal machining and tool wear. In cutting experiments on the EMC, sharp edges were achieved without chipping or unintended material loss. We were also able to take a block and turn it down into uniform cylinders of varying diameters, again with no chipping or unintended material loss. With composite molding costs being a fraction of metal molding costs, what metal parts will you convert to epoxy composite first?

Background

The transportation industry has always driven innovation toward low weight, high performance materials. As this industry moves toward electrification, fine moldable and machinable epoxy compounds could excel in both energy conversion devices such as motors and generators, and in the electricity distribution grids within vehicles. New technologies will require new materials to achieve optimum performance. However, what appeals to car buyers is often maximum performance. These epoxy composites will help with that appeal.

Mass production processes require interchangeable, precision parts. Metal became the material of choice because it was easy to mold or cast, and then machine to close tolerance. Reinforced thermoplastics tempted the industry with weight savings but their processing times, running from hours to weeks, made them a poor fit for this industry that runs at the pace of an assembly line. Reinforced epoxy composites do not have the same process times or economics. These reinforced epoxies also out-perform the reinforced thermoplastics in some significant properties.

SolEpoxy's roots are deep in the electronics industry where our predecessor company developed the first semiconductor molding compounds. These epoxy composites support mass production processes at the scale of billions of devices per year. SolEpoxy's current customers utilize our reinforced epoxies for both electrical insulation and mechanical strength in applications that include transportation equipment components, many of which operate at high temperatures, under-hood. These observations caused us to consider fine molded epoxy composite in applications where metals are currently assumed.

The molding process would be similar to that for metal but the molds would not need to be as large or expensive, and would not need to tolerate the high temperatures required for metal forming. Just like with metals, the molding process for fiber-reinforced epoxy is very repeatable and very fast. Molding cycles run for minutes. Final cure is achieved in the mold or with a post-bake of just one or two hours. Dimensional precision and stability is equivalent to metal molding and better than sand casting. Epoxy composites offer can offer a significant weight reduction versus metal parts, and this reduced weight has benefits that begin with part production and continue all the way to the end product or vehicle.

Material

For this study, we chose SolEpoxy MH20-2000. This product is about 75% (wt) silica and 5% (wt) fiberglass. We had this material compression molded into panels one inch thick and 20” x 30” in size.

Cutting. We reduced the size of these large panels for the machinability study, and even here, we learned how best to deep-cut reinforced epoxy moldings with a saw. In our laboratory, we commonly cut and cross section cast parts. We typically use a high speed precision saw with a diamond cutting blade.

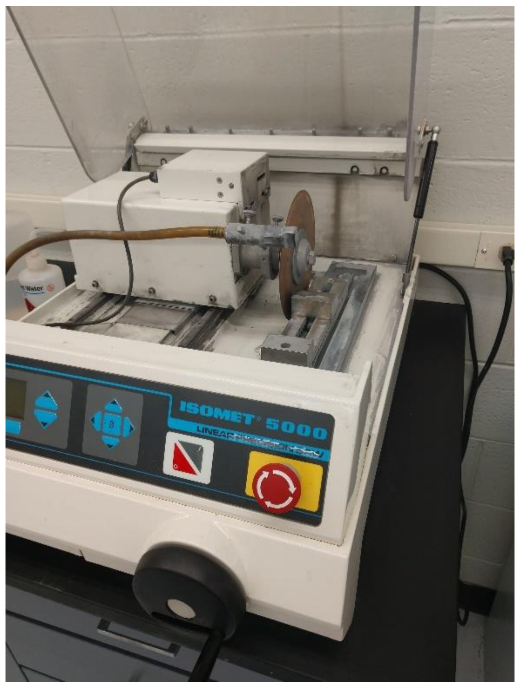

Image 1. Linear saw with diamond cutting blade

This saw has size limitations of about five inches of length and 2 inches of width and depth. The cutting process is slow, on the order of 0.002-0.004” (0.05-0.10 mm) per minute, but the cut is smooth and exact. In order to get pieces that would fit this machine, we first had to section our molded panels with a circular saw fitted with a diamond cutting edge.

This cutting speed of the precision saw is not sufficient for large volume production and the circular saw is not practical, so Solepoxy commissioned a tooling study by Bray Development of Portville, NY.

Bray Development started their study by trying to section the panel with a carbide tip circular saw. The saw was able to cut about ½” into the panel before being dulled down. Next, an abrasive cut-off wheel was used, trying to cut the panel at full thickness. After cutting in about 2”, the wheel heated up, the resin core melted and separated from the arbor. After multiple failures with the cut-off wheel, cutting the panel in 1/4" depth passes allowed for sectioning. The final recommendations for cutting were a band saw with a carbide tip blade or a waterjet 175-225 rpm with a material feed rate of 0.025"/minute would be potential starting points. This was the best setup determined for chip free cutting.

Milling. Milling the panel, it was determined that 0.050" was the most that could be removed in one pass without chipping. An H.S.S. 1" mill was used. Solid carbide with a tin coating on an oxide coated bits held up the best but still wore quickly.

Image 2. Surface milling of composite panel

Image 3. Side milling of composite panel

Image 4. Routing in the composite panel

Image 5. Composite panel after all milling

Drilling and tapping. When drilling was tested, it was found that a standard cobalt tip drill with a 135 degree cutting angle was sufficient to drill holes. Some chip-out did occur when the drill broke through the back wall of the panel. This could possibly be mitigated by a backing plate of some sort. Tapping the panel was very difficult and required excessive pressure.

Image 6. Drilling of epoxy composite panel

The screws ended up being loose in the tap. A special, large chip tap might be more effective.

Image 7. Composite panel after all machining

Turning. Lathing the material was very straight forward. A rectangular, saw cut piece was chucked up in the lathe. It was center drilled and turned with a 1/16” tool nose indexable carbide bit. It was turned at 200 rpm with a 0.026 feed. It held tolerance very well.

Image 8. Turning a block of composite

Image 9. Machined cylindrical, multi-diameter part

Summary

Epoxy composites are proving to be a very interesting material the replacement of metals in many potential applications including the automotive industry.   Epoxy composites are lighter than metal. They can be molded and machined in a similar manner as metals, but at a lower processing and tooling cost. Epoxy composites also have properties beyond metals that could become very important as the automotive industry transitions from a combustion engine format to an electric generator format. SolEpoxy aims to be at the forefront of that transition.