Plastic Speaker Cone History

September 17, 2015 by Mike Klasco

Paper is by far the dominant component in speaker cones. It is hard to beat cellulose paper for its mix of strength, lightness, stiffness, damping, and sound quality. Yet its strength drops off when it gets wet. The characteristics of paper cones shift due to humidity and tearing results from stress and punctures. I think almost everything has been used for speaker diaphragms, including acetic acid bacteria (Acetobacter) material, which is also used in flan recipes, and metals (e.g., magnesium, aluminum, and beryllium), but the most common alternative to paper cones are plastics.

In the mid-1960s, the British Broadcasting Corp. (BBC) did work on monitor speakers provided much of the early impetus for the study of plastics for speaker cones. Thermoformed plastic cones created quite a stir when the famous British speaker company Bowers & Wilkins (B&W) introduced speaker systems with Bextrene woofers more than 45 years ago. KEF’s B110 bass-midrange, which was introduced in the mid to late 1960s, also boasted a Bextrene cone. And by the early 1970s, the French OEM Audax was also offering Bextrene cone speakers.
The B139 was probably the most famous of the KEF drive units.

The speakers were innovative at the time, but some of their characteristics (e.g., too low a Young’s modulus) resulted in serious mid-band breakup—typically just around 1.5 kHz. Throwing damping layers and complex cross networks at the shortcomings were just band-aids for this flawed alternative to paper cones. The Bextrene-extruded sheet was thermoformed into a cone. While it provided less distortion compared to paper pulp cones, this polymer was intended for consumer packaging material and was too inconsistent for the precision thickness required from thermoformed speaker cones.

While the formulation was potentially more consistent than paper pulp, the extrusion of the Bextrene sheet was not consistent. Expanded polystyrene foam cones (e.g., the huge EV 30W
30” woofer) were also introduced in the 1960s and 1970s. Other companies using expanded polystyrene foam cones included KEF with its first speaker system (the K1 slimline) and its polystyrene racetrack-shaped KEF B139 (see Photo 1). Long before NXT, poly-planar rectangular flat speakers with form polystyrene were popular for outdoor use and marine applications. It was even used in the factory OEM speakers for Jeeps (see Photo 2). Later, the Bertagni Electroacoustic Systems (BES) flat panel speakers used various forms in the polystyrene family. You may also remember Yamaha’s efforts with a giant ear-shaped speaker that used expanded foam.

The poly-planar flat speakers were popular for outdoor use and marine applications.
Polystyrene, while light and rigid, is also noisy (creaky) when flexed, and this limits its appeal for most speaker applications. Polypropylene (PP) became the preferred resin sheet material for thermoformed speaker cones. Polypropylene cones are popular for home theater audio, whole-house audio (e.g., in walls, on walls, ceiling speakers, and bathroom speakers) because PP cones do not absorb moisture and can have low distortion. Avoiding moisture absorption is important because the cone mass and other critical parameters can significantly shift with humidity.

PP has some appealing attributes, including consistency, stability, strength (regardless of humidity) and a smooth and well-damped sound quality. PP is a terrific value, with price varying due to quantities and reinforcing fibers. However, PP has remained on the edge of mainstream audio but never achieved the success paper has in the cone business.

For 30 years, my company Menlo Scientific has worked with clients who use PP for speaker cones. In the early 1980s, we supported our Korean clients in sourcing extruded PP sheet materials from Transilwrap. In the 1990s, we consulted for Transilwrap, which for years was the key converter for extruded PP sheets worldwide. Later, at various time, we worked with Nike, RTP, and Fabex on their extruded PP sheet material speaker cone applications.

Today, most US poly extruders have left the PP sheet business. Running soft PP resin through an extrusion machine seems sensible. Yet, product consistency has been elusive for all these quality extruders, eventually causing them each to drop extruded PP sheet material for the speaker industry from their product lines. Since the 1990s, Japan and Taiwan have filled the supply chain void, and now even local Chinese extruders can provide at least marginally adequate product.

Regardless of the vendor, PP sheet customers have found the following product deficiencies:
• Inconsistent gauge thickness (±5% is desired for consistent thermoforming, but ±10% is typical)
• Pits, gels, and poorly distributed carbon black filler
• Poor surface finish and inconsistent finish
• Regrind issues—there are real performance benefits in taking a bit of post-extruded polypropylene sheet, grinding it, and tossing it into the virgin material being extruded. The problems are the volume consistency and regrind content.
• Inconsistent resin vendors

The material’s ideal target characteristics should be lightweight and stiff with a scuff-resistant surface. It should also have a consistent thickness.

PP makes an outstanding outdoor speaker, due to its low-moisture absorption and loading with carbon black, the ultimate UV block. PP is available in a clear finish, as well as in some colors, but the black PP (carbon black as a UV stabilizer) will weather the sun the best. On the downside, polypropylene is soft, and while it is quite light (e.g., its specific gravity is 0.92, but most PP is mineral loaded and closer to 1), the typical PP cone replaces paper cones with a weight and sensitivity penalty.

Midrange speakers use much thinner PP sheet stock, as narrow as 0.20.” High-power
subwoofers, whether for home theater or autosound, often use PP cones if they are to fit into tight enclosures because PP resists creasing and tearing. Often heavy-gauge, as thick as 0.04 to 0.05,” PP is used.

PP is a soft well-damped material. For speaker cones, higher Young’s modules would enhance performance and fillers can be used (e.g., talc, mica, graphite, and glass). Any of these improve stiffness, but they also increase specific gravity. Yet, there are other ways to increase stiffness without weight (e.g., “self-reinforced” woven polypropylene).

In 2007, I introduced CURV woven polypropylene cones to the speaker industry (Voice Coil, February 2007). CURV, a woven self-reinforced polypropylene material, promised an innovative and superior cone with performance comparable to woven composites. The material is light and stiff. It contains a high Young’s modulus and high damping. CURV is not hydroscopic and it provides a high temperature tolerance. CURV is relatively inexpensive, at least when compared to carbon fiber or Kevlar.

To make it, pure PP is extruded, drawn into tapes, woven, and heat-treated to produce a self-reinforced PP composite. In this unique patented process, the surface of the tapes is selectively melted to bond the fabric together, providing a single-polymer composite. The drawing process provides higher stiffness by orienting the polymer and, as the surface facings are melted and re-crystallized to form the matrix, an ultra-stiff and smooth skin sheet is produced. The resulting sheet material properties are enhanced through this molecular orientation rather than mineral loading. Typical PPs for speaker cones have talc, mica, or glass compounded into them, which increases the material density by about 10%. CURV contains pure PP without mineral loading. While the stiffness is 30% higher than conventional glass-filled PP, CURV’s density is 0.92, about 10% lower than glassloaded PP.

The CURV product generated a lot of interest. The problem was the forming process, which required precise time, pressure, and temperature. Most cone formers never mastered the process. The temperature required to heat the cone so it was ductile enough to form was almost the same temperature that would also reverse the benefits of the crystallization process. This was definitely a potential outcome if conventional thermoforming was attempted. To preserve the crystallization treatment, manufacturers needed to use a hydraulic forming process with a positive and negative mold. While not complex, this was not the process used by the supply chain that provided PP cones. Instead, it used a process comparable to making Rohacell foam. By the time the CURV cone was thermoformed, the benefits of the weaving and crystallization treatment were lost and the cone performance was less than spectacular.
SEAS Prestige U18RNX/P is a high-fidelity woofer with an injection-molded metal chassis, intended for bass reflex and transmission line designs.

I should mention a few high-end speaker vendors used formed CURV competently and they do achieve what was promised. A few examples include most of the cone speakers in the Wilson Benesch product line and some new SEAS drivers (see Photo 3). Many speaker companies have also been using injection-molded PP cones for years. Injection molding has some benefits, but it requires a large investment in tooling. Material flow and “grain” are different than thermoforming. This is where the higher polymer’s orientation (i.e., crystallization) is achieved so injection-molded PP has a slightly higher Young’s modulus than most extruded PP. While injection-molded PP cones were considered the future a few years back, their market share has slowed due to the speed of thermoforming multiple PP cones. Cycle time of injection-molding and cost of multicavity tools in injection-molding have made cupcake trays of thermoformed cones look attractive.

**Woven Composites — Glass, Aramids, and Carbon Fiber**

There are many techniques for woven composite cone fabrication. Most woven cones are not axisymmetric in characteristic due to the weave’s 90° orientation. Tri-axial weaves are rare but have superior audio characteristics. The weaving process actually results in some loss of strength (about 5%) compared to non-woven constructions. Some cone vendors buy resin-treated woven sheets of glass, carbon fiber, or aramids (e.g., Kevlar, Technora, etc.), which is a technique used on the cone shown in Photo 4.
This cone was formed using woven composite fabrication.

Woven sheets containing no resin are commonly available, and a few coats of epoxy seal lock in the shape. Other proprietary processes can bind the woven fibers, lock in the shape, and seal the cone. While the fibers can be light and stiff, the thermoset epoxy binder coatings are heavy and the resulting cones tend to weigh more than paper cones. Polypropylene binders have also been used, including powered coating the PP before weaving and using thin PP tissue between layers of fine woven fibers and heating them under pressure. Consolidation is a significant issue in the process. There is no point in using expensive fibers if the binder slips between the stiff fibers.

Yet in testing many woven cones, poor consolidation is a common shortcoming. Sound qualities of cones comprised of woven fiber with the epoxy coating are highly influenced by the resin binder’s acoustic characteristics. For some applications multilayer cones using a core of Rohacell or honeycomb are popular with woven fiber skins. In this case, the skins are of the thinnest weave possible, as the weight of the skins and core add up!

Availability and price of the woven fibers are an issue, especially carbon fiber pricing, which often fluctuates. Aramids include meta aramids (e.g., Nomex and Conex) and para aramids (e.g., Kevlar, Twaron, and Technora). The para aramids provide higher performance with higher Young’s modules, which is an important parameter for speaker cone performance. Recently several Chinese vendors have launched meta aramids for applications (e.g., dampers and fabric surrounds). These vendors will probably also release products using para aramids. When determining what’s next for speaker cones, speaker engineers watch for breakthrough speaker
cone materials like Endumax. VC

For more on Endumax, read another article by Mike Klasco here.