

## ► A High-Performance TEEE Surround Material

By Steve Mowry

DSM Arnitel® is an Ether/ester based Thermoplastic Elastomer (TEEE) that appears to have excellent material properties for audio transducer surround/edge/suspension applications. Arnitel combines the advantages of engineering thermoplastics—being easy to process with excellent mechanical properties—and the flexibility of rubbers. Unlike rubber surrounds, Arnitel does not require vulcanization, which leads to reductions in parts costs. Arnitel can be used over a wide range of temperatures and has exceptional fatigue, creep resistance and resistance to oils, greases, and many other chemicals. Arnitel can be injection molded or extruded, has exceptional flexibility, and can perform or even outperform functions that normally require conventional rubbers. Available in a wide range of hardness, it can replace thermoplastics, cloth, and rubber, often with a reduction in finished part costs.

### CHARACTERISTICS

- Excellent strength over a wide range of temperatures
- Excellent dynamic properties, e.g., creep and fatigue
- High degree of versatility in processing
- Easy coloring using master-batches
- Surface quality from high gloss to textured
- Excellent heat resistance (long term 165° C)
- Good electrical insulation properties
- High inner loss,  $\tan \delta$
- Low moisture absorption, excellent dimensional stability
- Easy flow, fast cooling times

Arnitel is used extensively in the automotive industry for applications requiring exceptional fatigue resistance and resistance to oil and greases, such as air bags, rack and pinion bellows, constant velocity joint boots (CVJ boots), and air brake tubing. Arnitel finds enormous potential and is also widely used in the consumer electronics industry by some of the world's major companies. It is also used in the athletic shoe industry as well as in highly demanding applications such as in mobile phone antennas. However, I am not aware of any loudspeakers that utilize this material in surround or

edge applications.

Amazingly, Arnitel can even be painted; however, this is not recommended. It is a strong indication of the ease of bonding/attachment unlike the popular polypropylene-based Santoprene®, TPE. Although most rubber materials are quite attachment “friendly,” Santoprene typically requires controlled humidity and a cyanoacrylate-based adhesive with a primer for surround to basket attachment. This is due to the polypropylene-based elastomer characteristics.

The manufacturer, DSM, has indicated that suitable non-CA based adhesives are available to bond Arnitel to aluminum or steel. This reduces cost and cosmetic rejects and potentially allows reworking hard-part assemblies. As in all cases, the most effective method for determining the “best” adhesive is through a design of experiments (DOE) with subsequent testing including power and pull-apart tests.

### Materials Comparison

**Table 1** compares the typical properties of the commonly used materials that implement a “rubber” surround along with Arnitel for comparison. These include natural rubber (NR), acrylonitrile-butadiene rubber (NBR), styrene butadiene rubber (SBR), santoprene (STR), and Arnitel (TEEE). Note that some surround manufacturers also use a combination of NBR/SBR rubber materials.

**TABLE 1**

MATERIALS	NR	NBR	SBR	STR	ARNITEL
Hardness	30 Shore D	30 Shore D	70 Shore A	50 Shore D	34 Shore D
Density	0.95 g/cc	1.15 g/cc	0.94 g/cc	0.94 g/cc	1.11 g/cc
Modulus	1.5 MPa	3.0 MPa	1.7 MPa	2.0 MPa	50 MPa
Tensile Strength	28 MPa	6.9 MPa	28 MPa	4.4 MPa	25 Mpa
Poisson's Ratio*	0.3	0.3	0.3	0.3	0.3
Operating Temp.	100°C Max	135°C Max	107°C Max	135°C Max	165°C Max

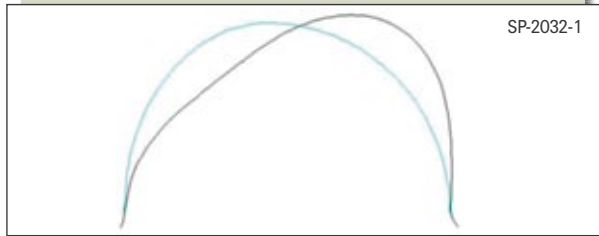
Material properties are courtesy of <http://www.matweb.com/> and/or manufacturers' data sheets. Poisson's ratio was assumed to be 0.3 for all materials. You should obtain actual material properties directly from the surround part suppliers.

These materials have similar properties with the exception

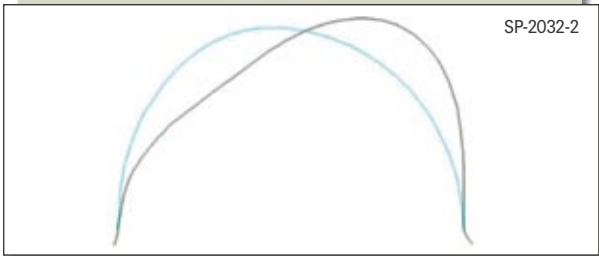
of the modulus of elasticity of Arnitel. It is quite high, indicating that Arnitel can be used much thinner than the other materials, while still maintaining good buckling resistance with low effective moving mass. I will use simplified axisymmetric nonlinear Finite Element Analysis to evaluate each of the materials listed within **Table 1** with regard to buckling resistance and force versus displacement for a given geometry and varying only the material thickness and properties.

**Figures 1 through 4** illustrate that the resultant buckling mode shapes are essentially identical at the same pressure, 1.0 PSI. Only the thickness and the material properties were varied to obtain these results. However, **Fig. 5** illustrates a desirable symmetrical buckling mode shape at 2.9 PSI, almost a 300% increase, with a thickness of only 1.0mm.

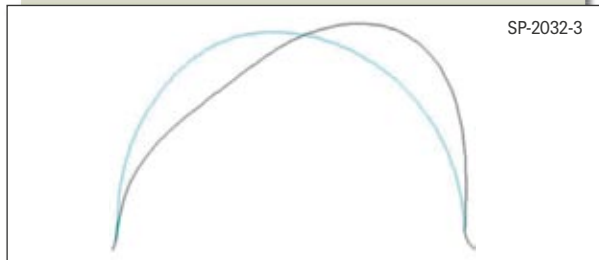
**FIGURE 1: Static and buckling mode shape at 1.0 PSI for NR at 2.6mm thick.**



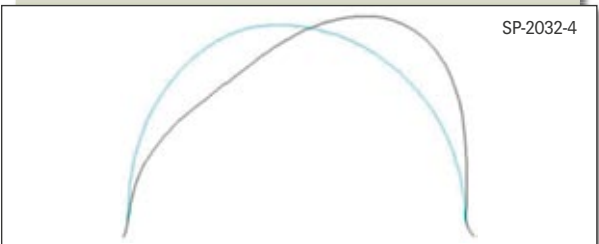
**FIGURE 2: Static and buckling mode shape at 1.0 PSI for NBR at 2.0mm thick.**



**FIGURE 3: Static and buckling mode shape at 1.0 PSI for SBR at 2.5mm thick.**



**FIGURE 4: Buckling mode shape at 1.0 PSI for STR at 2.3mm thick.**



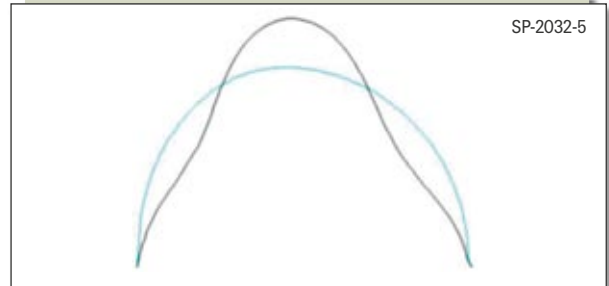
With a thickness of 0.75mm, the buckling mode shape was still symmetrical at 1.5 PSI, a 50% increase, illustrated in **Fig. 6**. This also implies a reduction in more than 50% of the surround mass over all the other models. Now I will evaluate the force versus displacement for each case and plot the results in **Figs. 7 and 10**.

Within **Fig. 7**, the NR, NBR, SBR, and STR model results are very similar and illustrated by the bunched blue, red, green, and brown curves, respectively. There were two Arnitel models, one at 0.75mm thick and one at 1.00mm thick.

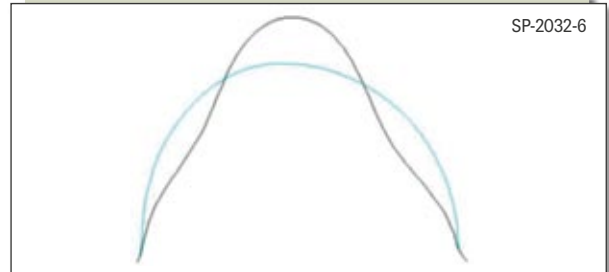
**Figures 8 and 9** illustrate the static and displaced shapes of the axisymmetric y-direction Nonlinear Finite Element Model.

**Figures 11 and 12** illustrate the static and displaced shapes of the axisymmetric x-direction Nonlinear Finite Element Model.

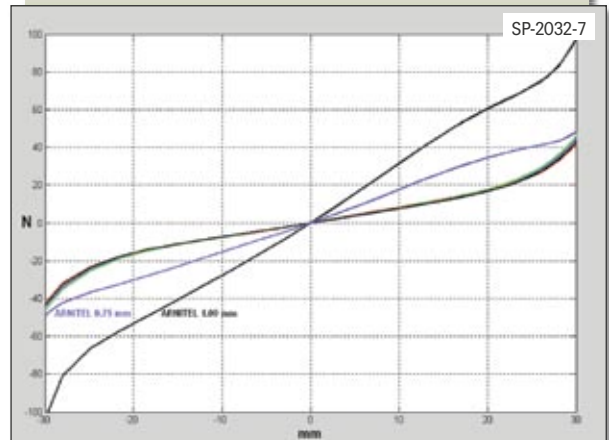
**FIGURE 5: Buckling mode shape at 2.9 PSI for Arnitel at 1.0mm thick.**



**FIGURE 6: Buckling mode shape at 1.5 PSI for Arnitel at 0.75mm thick.**



**FIGURE 7: Simulation of force versus displacement in the axial y-direction for the five surround materials.**



## FUTURE APPLICATIONS

It has been shown by means of computer models that Arnitel may be worth investigating as an alternative to the typical rubber/elastomer surround. The exact surround geometry implemented in Arnitel is inherently stiffer in both axial (y) and the radial (x) directions, the slopes of the curves in **Figs. 7** and **10**, respectively, are the stiffness,  $K_{SRY}$  and  $K_{SRX}$  (N/mm). The high modulus of elasticity and the high tensile strength make for a robust but somewhat stiff surround that should also help to control mechanical instabilities at high displacements. The surround and spider work together to provide reaction force to the system and to center the moving assembly in relation to the radial magnetic gap.

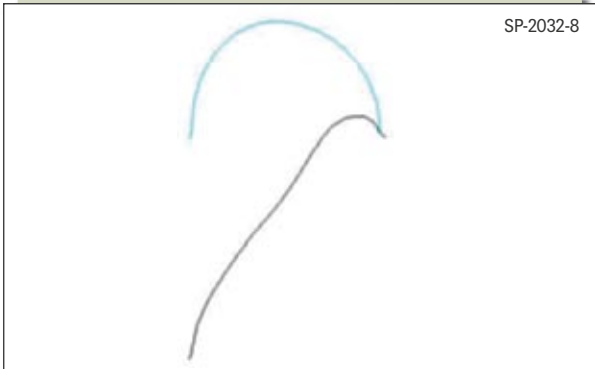
The manufacturer, DMS, indicates that this TEEE material is available within Asia and the Pacific Rim, typically in pellets. Assuming injection molding as the manufacturing process of choice and the quantity of material required for the respective part, there is a potential for cost reduction and a performance enhancement.

There are other materials within the TEEE material class that I did not investigate. These include Dupont Hytrel® and Ticona Riteflex®, which might be worth listing and appear to have similar material properties to Arnitel.

There is also potential for heavy-duty spider application for the TEEE material class; however, this has yet to be investigated. These materials are available in various moduli that should be quite stable over time. The geometry could be molded to assure consistent spider stiffness. There would inherently be added mass to the moving assembly versus a

treated cloth spider implementation. This is something to think about for a future high-performance transducer development project. **VC**

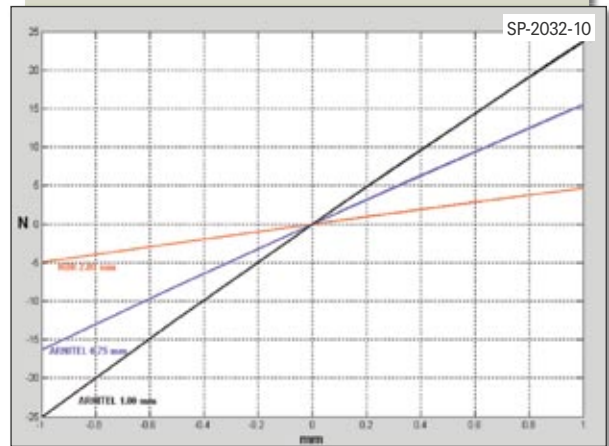
**FIGURE 8:** Static and displaced shape in the negative y-direction of the 1.0mm thick Arnitel surround.



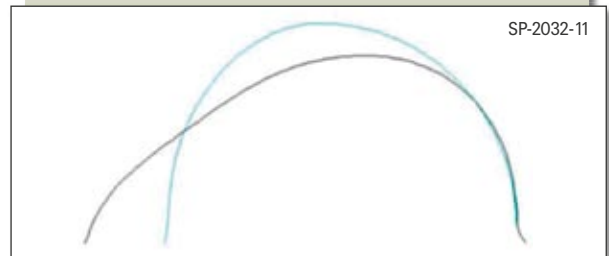
**FIGURE 9:** Static and displaced shape in the positive y-direction of the 1.0mm thick Arnitel surround.



**FIGURE 10:** Simulation of force versus displacement in the radial x-direction.



**FIGURE 11:** Static and displaced shape in the negative x-direction of the 1.0mm thick Arnitel surround.



**FIGURE 12:** Static and displaced shape in the positive x-direction of the 1.0mm thick Arnitel surround.

