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Investigating novel elastomer blend foams for shoe soles

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Ethylene-vinyl acetate/polyurethane foams containing calcium carbonate fillers are produced via a batch foaming process, with the use of supercritical nitrogen.

Foamed polymer materials (i.e., polymer materials containing many very small voids that are filled with air or other gases) are commonly used in a number of applications because of their favorable characteristics, e.g., good cushioning, sealing, and thermal insulation properties. For example, ethylene–vinyl acetate (EVA) is a widely used thermoplastic elastomer in the production of films, wires, cables, and toys.[1,2] Although EVA is most commonly used as the material for the soles of shoes, virgin EVA foams exhibit poor compression set, wear, and tear properties. EVA is therefore normally blended with natural rubber (NR) in shoe-sole applications, but these blends are still subject to some limitations (e.g., coloring problems).

The development of new EVA-based blends is thus an ongoing quest in the footwear industry. For instance, in previous work,[3] butadiene rubber has been blended with EVA to produce microcellular shoe-sole foams. It was found that the overall performance of these foams was comparable to commercial EVA/NR foams, but compatibility between the EVA and rubber was problematic. Moreover, most elastomer (e.g., EVA) foams are currently produced with the use of chemical blowing agents,[3–7] which can cause harmful environmental and health effects. In addition, batch foaming processes—involving the use of more environmentally friendly supercritical gases, such as carbon dioxide (CO_2) and nitrogen (N_2)—are relatively unexplored for elastomers compared with thermoplastic foams.

The main aim of our study[8] was therefore to produce—in an efficient and environmentally friendly manner—improved EVA-based foams that can be used as soles in the footwear industry. We used a batch foaming process to produce blends of EVA and polyurethane (PU) rubber in a variety of ratios. We chose PU for this purpose because of the polar groups on its polymer chain that provide excellent compatibility with EVA. For our batch foaming process we used supercritical N_2 as the blowing agent. We also included calcium carbonate ($CaCO_3$) fillers in a range of concentrations.

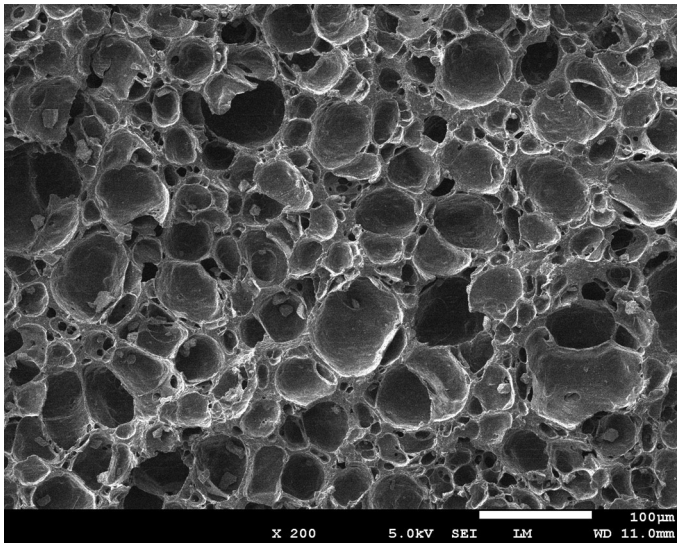

Figure 1. *Scanning electron microscope image of the ethylene–vinyl acetate/polyurethane (EVA/PU) blend (in an 80/20 weight ratio) foam containing 30 parts per hundred rubber calcium carbonate fillers.*

We subjected our EVA/PU samples to a variety of tests so that we could investigate their physicomechanical, friction, and wear properties. For example, we obtained scanning electron microscope (SEM) images and found that all the compounds contained spherical cells with a closed-cell morphology. As an example, the SEM image for the EVA/PU blend (in an 80/20 weight ratio) foam containing 30 parts per hundred rubber (phr) of $CaCO_3$ is shown in Figure 1. Overall, the SEM images illustrate that the blend foams had lower average cell sizes than the neat EVA foam and that the cell sizes of the foams decreased with increased PU content.

The measured physicomechanical characteristics of our EVA/PU foams are given in Table 1. Our results show that the density, hardness, and resilience of the blend foams lie between those of the neat EVA and neat PU foams. In addition, the values of these parameters increase with increasing PU content of the blends. However, despite the good compatability of the EVA and PU phases, we did not

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Table 1. *Measured physicomechanical properties of the EVA/PU blend foams. The EVA/PU blend ratio is provided for each foam.*

Foam (blend ratio)	Density (g/cm^3)	Hardness (Shore C)	Resilience (%)	Compression set (%)	Tensile strength (MPa)	Tear strength (kN/m)
EVA/PU (100/0)	0.30	62	48	15.6	3.7	21.3
EVA/PU (90/10)	0.36	63	49	17.3	2.8	10.0
EVA/PU (80/20)	0.37	64	50	24.4	3.2	11.7
EVA/PU (70/30)	0.41	66	51	24.6	3.5	12.6
EVA/PU (60/40)	0.46	68	53	24.8	3.6	15.5
EVA/PU (0/100)	0.56	72	58	25.0	5.0	18.9

measure any improvement in the tensile strength and tear strength of the blend foams compared with the EVA foam. This is probably because of a decrease in the effectiveness of the bis(t-butyl peroxy isopropyl) benzene that we used as a crosslinking agent in the blends. Our tests also revealed that the friction coefficient and abrasion resistance of the EVA/PU blend foams were significantly better than for the neat EVA foam, which is an important result for shoe-sole applications.

We found that incorporating $CaCO_3$ up to a concentration of 40phr in the blends had a number of effects. First, it caused a decrease in the cell sizes, as well as increase in the density and hardness, of the foams. This increase in the density and hardness did not appear to be significant, because the foam expansion was not adversely affected by the dispersion of $CaCO_3$ in the matrix of the blends. In addition, we found that the tensile strength and tear strength of the foams improved with increased $CaCO_3$ content (i.e., up to 40phr).

In summary, we have investigated the morphological, physicomechanical, friction, and abrasion properties of EVA/PU blend foams—produced via batch foaming with supercritical N_2—that contain $CaCO_3$ fillers. Overall, our aim was to determine a compound formulation that provides improved friction and wear characteristics compared with current EVA-based foams, i.e., for shoe-sole applications. Our tests indicate that the hardness, resilience, friction coefficients, and abrasion resistance of the EVA/PU foams were better than the neat EVA foam, whereas their compression set, tensile strength, and tear strength were inferior. Furthermore, the incorporation of the $CaCO_3$ fillers causes an increase in the density, hardness, tensile strength, and tear strength of the blend foams, but decreased their resilience, compression set, friction coefficients, and abrasion resistance. In our future studies we plan to explore the role of crosslink density in elastomer vulcanizates. We will also examine how foaming of vulcanizates is affected by the incorporation of a variety of platy fillers.

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References

1. A. M. Henderson, *Ethylene-vinyl acetate (EVA) copolymers: a general review*, **IEEE Electr. Insul. Mag. 9**, pp. 30–38, 1993.
2. H. Ashrafizadeh, P. Mertiny, and A. McDonald, *Evaluation of the effect of temperature on mechanical properties and wear resistance of polyurethane elastomers*, **Wear 368-369**, pp. 26–38, 2016.
3. M. Maiti, R. V. Jasra, S. K. Kusum, and T. K. Chaki, *Microcellular foam from ethylene vinyl acetate/polybutadiene rubber (EVA/BR) based thermoplastic elastomers for footwear applications*, **Indust. Eng. Chem. Res. 51**, pp. 10607–10612, 2012.
4. R. Roslim, M. Y. A. Hashim, and P. T. Augurio, *Natural latex foam*, **J. Eng. Sci. 8**, pp. 15–27, 2012.
5. M.-S. Kim, C.-C. Park, S. R. Chowdhury, and G.-H. Kim, *Physical properties of ethylene vinyl acetate copolymer (EVA)/natural rubber (NR) blend based foam*, **J. Appl. Polym. Sci. 94**, pp. 2212–2216, 2004.
6. B. S. Zhang, X. F. Lv, Z. X. Zhang, Y. Liu, J. K. Kim, and Z. X. Xin, *Effect of carbon black content on microcellular structure and physical properties of chlorinated polyethylene rubber foams*, **Mater. Design 31**, pp. 3106–3110, 2010.
7. N. N. Najib, Z. M. Ariff, A. A. Bakar, and C. S. Sipaut, *Correlation between the acoustic and dynamic mechanical properties of natural rubber foam: effect of foaming temperature*, **Mater. Design 32**, pp. 505–511, 2011.
8. Z. X. Zhang, T. Zhang, D. Wang, X. Zhang, Z. Xin, and K. Prakashan, *Physicomechanical, friction, and abrasion properties of EVA/PU blend foams foamed by supercritical nitrogen*, **Polym. Eng. Sci.** doi:10.1002/pen.24598