Mattress Recycling Council®

Converting Post-Consumer Recycled Polyurethane Mattress Foam into Surface-Engineered Powders

Executive Summary

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Background

Over 2 billion pounds of flexible polyurethane (PU) foam is used annually in the United States, about half of it in furniture and bedding [1]. Nearly 2 billion pounds of flexible foam are discarded annually. Contributing to that total are more than 18 million mattresses, most of which go to landfills or incinerators [2].

Waste foams have traditionally been a challenge to recycle due to their toughness, elasticity, cross-linked structure and thermal resistance. The primary outlet for recycled PU flexible foam is rebond carpet pad. However, as the volume of recycled foam increases, and demand for carpet pad declines, new markets for recycled flexible foam at end of life are desired.

Chemical recycling methods, such as hydrolysis and glycolysis, are inherently inefficient, as they require significant energy to break the urethane bond and they convert the PU to a complex mixture of amines and polyols, often requiring separation before use in new PU products.

We believe flexible foam offers potential for mechanical recycling into high surface area, potentially high-value materials, if the challenges of grinding and control of surface properties can be met. While technologies exist for pulverizing rigid foams, we are unaware of existing cost-effective technology for grinding flexible foams into fine powders with good control of particle size and surface functionality.

Through an iterative process, we designed and fabricated equipment for a non-cryogenic process capable of converting flexible foam waste into sub-200-micron particles, with different degrees of surface modification. The surface modification allows tuning of the surface to tailor the particles for use in various applications (e.g. cement, paints, polymer composites, adhesives & sealants), while unmodified powders may be reincorporated into new PU flexible foams, improving circularity of these products.

Key Accomplishments

Effect of Process Parameters on Powered Foam Particle Size & Surface Functionalization

All foam powder samples were produced using shredded post-consumer mattress foam provided to RoCo® by the Mattress Recycling Council (MRC). The effect of three processing parameters (grinding time,

process temperature and type of gas infused) on particle size and surface functionality was evaluated. We found noticeable differences in PU foam powders produced, depending on the processing conditions, with higher temperatures and reactive gas perfusion leading to a higher degree of surface functionalization.

Two representative powders were evaluated as additives in selected applications. The bulk densities of these powders were 0.175 and 0.140 g/cc for powder processed under N_2 and CO_2, respectively. This represents about a 10x increase in density compared to the starting foam. The average particle sizes for the two samples, processed under N_2 or CO_2, were determined to be 167 and 176 microns, respectively.

Evaluating the PU Powders in Potential Applications

The two powders described above were tested as a functional additive in cement and rigid foam. The impact of the foam additive on multiple material characteristics in these applications was assessed.

- Cement

Not surprisingly, the introduction of the powdered foam reduced the density of the cement. The effect of the ground foam on the thermal diffusivity of the cement was dependent on the volume percentage of foam powder added. Changes in the surface of the cement following exposure to salt fog testing were observed to differ, depending on which foam powder variant was used.

- Rigid Foam

In rigid foam, we explored the potential of the additives for lightweighting and noise dampening. Samples prepared using a commercial 2-part rigid foam system, containing up to 20 percent foam powder by volume, showed reduced density compared to the control. Although the additive did not reduce sound transmission significantly, it did provide frequency modulation (reduction). Current efforts are underway to better characterize this performance metric in rigid foams.

Conclusions

We designed and demonstrated proprietary grinding equipment to produce fine, surface functionalized powders from recycled PU mattress foam. We were able to control the foam powder's particle size to produce sub-200-micron foam particles with a 10x increase in bulk density compared to the original mattress foam. While further characterization is still needed to fully understand the surface functionalization chemistry, we have found evidence that surface functionalization of foam powder occurs during our grinding process.

Current efforts are ongoing to validate these products for selected target markets in collaboration with potential customers, brand owners, and manufacturers.

References

[1] C. Liang *et al.*, "Material Flows of Polyurethane in the United States," *Environ. Sci. Technol.*, vol. 55, no. 20, pp. 14215–14224, Oct. 2021, doi: 10.1021/acs.est.1c03654.

[2] "Why Recycle," Mattress Recycling Council | Recycling Programs in California, Connecticut & Rhode Island. Accessed: Feb. 25, 2025. [Online]. Available: https://mattressrecyclingcouncil.org/why-recycle/