

Recycling and Recovery of Polyurethanes

REUSE AND REPROCESSING

There are different reuse options for used PU foam articles. In this factsheet only proper reuse or physical reprocessing without additional PU raw materials are described. PU polymers are thermo set type polymer structures, which can be recycled as materials also without addition of isocyanate type chemicals. Particles from rigid PU foam are widely used as an oil binder or in combination with cement as insulating mortar. Flexible PU foam from production scrap is widely used in North America as undercover flooring together with virgin foam.

Technology

There are two types of End of Life (EoL) PU foam reprocessing: densification via baling, briquetting and extrusion or size reduction via grinding (standard or cryogenic), precision knife cutting and milling with roll mill, impact disc mill or pellet mill.

Description

Densification:

PU flexible foam can be densified resulting in low to medium apparent densities of 100-400 kg/m³ by a baling press. Rigid foam can also be pressed into briquettes of 400 to 800 kg/m³ densities. Powder pressing after the milling of EoL foam results mostly in a lower density of about 300 kg/m³.

Size Reduction:

A range of grinding techniques have been developed for various polyurethane materials: rigid, flexible and Reinforced Reaction Injection Moulding Materials (RRIM). The required particle size may vary from particles less than 200 micron,

for reuse as filler, to larger pieces for feeding into a chemolysis or an energy recovery unit.

Precision knife cutting: For powdering flexible or rigid foams to particle sizes less than 0.25 mm, special types of knife cutters can be used. These so-called precision knife cutters are characterised by a large number of static and rotating knives. The special sieves used in this type of equipment are designed in such a way that additional powdering is achieved.

Two-roll mill: The two-roll mill consists of at least one pair of rollers, rotating in opposite directions and at different velocities. The resulting forces in the very narrow gap between the two rolls convert the polyurethane foam into a fine powder with a typical particle size of less than 0.1 mm.

Pellet-Mill: The pellet-mill consists of two or more metal rollers, which press the polyurethane foam through a metal plate with small holes (die). Depending on the type of foam and processing conditions, the output of the mill consists of either fine polyurethane powder or compacted pellets.

Impact disc mill: Grinding of RIM or RRIM materials is done typically in a two step process. Materials are first granulated in a knife mill to a particle size of ca. 3 mm and then in a second step, where PU is powdered in an impact disc mill. This typically gives a powder containing a fraction of ca. 40% with a particle size of less than 200 micron. This fine material can be separated by sieving.

Cryogenic grinding: Because of the resilient/elastic nature of flexible polyurethane foams, the grinding of flexible PU materials into small particle size is difficult, particularly when the material is heated during the grinding operation. By cooling these



materials to well below the embrittlement temperature, the grinding process can be made much more efficient but it is also costly.

Extruder: A process for grinding various polyurethane foams (from rigid to flexibles) to fine powders was developed using solid state shear extrusion. The method operates at moderate temperatures (20 - 100°C). Particle sizes that can be obtained depend on the type of polyurethane foam: for rigid foam, particle sizes less than 0.032 mm were reported.

Technology Status

Significant equipment and process development was done on size reduction and compacting during the time of feedstock recycling development in the form of chemolysis. Small particles have been used as feed material, which could be continuously pneumatically conveyed.

PU Specifics

A significant share of polyurethane materials are used in low density foams (typically 20 to 60 kg/m³). These low densities offer many advantages during the useful lifetime of these products (weight/energy/material savings, cost effectiveness). In those cases, however, where transport of waste polyurethane materials from a collection point to a recycling plant is required, the foams need to be compacted in order to make transportation both energy and cost-efficient.

Market & Cost

The market size for reuse applications in the form of boards or powder is limited. They have been marketed for years as “oil binders” mostly as loose powder and/or small particles in sacks for the treatment of spillages on land. Loose powder and/or small particles in hoses for the containment of spillages on water surfaces (note: PU rigid foam floats on water). The specific advantages are higher absorption capacity than sawdust and sand and a much lower weight / lower disposal cost than sand.

The market size for insulating mortar with light weight, thermal and acoustic insulation and easy handling also has limits and still needs further technical development and building code recognition as it competes with traditional insulation materials.

Ecology

The direct reuse application always competes with virgin foam and recycled material. Due to unknown material properties, old EoL foam carries the risk of the unknown property. Specific types of polyurethane foams may contain flammable blowing agents and/or flame retardants.

Application of heat ensures that the gases are also removed from the polymer which forms the cellular matrix. In this case the entire system should be encapsulated and operated under negative pressure to prevent leakage. Where there is the possibility of flammable gases or fine particles being released, the equipment and process conditions should be designed to eliminate the risk of fire or explosion.

Limits

As with any organic powder, precautions must be taken to prevent powder explosions. Flexible foam powder has been found to promote flame propagation at more than 100 g/m³. A way to avoid powder explosion occurring is inertisation using nitrogen. The suitability of materials for the envisaged recycling process and necessary precautions required to prevent work-place exposure and emissions should at all times be checked. PU size reduction and compacting are rather energy intensive steps with significant cost associated.

Products

Oil binders: PU powder and larger particles obtained from the cutting and shaping of rigid foam for building & construction applications are long known to be excellent absorbers of oil and, more generally, many kinds of liquids that have



been accidentally spilled.

Insulating mortars: A combination of rigid foam particles (up to about 1 cm diameter) – generally production scrap from building and construction applications – and powder – often from post-consumer refrigerators and freezers – is suitable as the main raw material (more than 90%) for insulating “mortar”.

Conclusions

The correct choice of equipment may depend on many factors and should be performed in close consultation with manufacturers and existing

operators using these machines. Depending on the article to be ground, precautions might be required to prevent damage to the equipment by, for example, steel inserts. National and local regulations which may govern the recovery and disposal of materials should be consulted. Observation of such regulations includes the recovery and disposal of CFC's, if and when contained in these materials.

References

See Fact Sheet List of References and suggested Reading Material

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