NORDEL™ EPDM-based Sponge
Troubleshooting Guide

Mixing

In order to prevent quality issues downstream, maintaining a consistent quality of mix is critical. The choice of mixing equipment, design of the mixing process (i.e., one-pass, multiple passes, upside-down, right-side-up, etc.), and order of ingredient addition all have significant effects on the final quality of mix.

1.1 Mixing Equipment

A rubber internal mixer (either intermeshing or tangential rotor design) is recommended for the mixing of NORDEL™ EPDM-based sponge compounds. The intermeshing rotor mixer is recommended for use with EPDM sponge compounds that are temperature sensitive, as this design provides better heat exchange capabilities and therefore enables better compound temperature control. In addition, the intermeshing rotor mixer can provide higher mixing energy input and better mixing due to the markedly lower clearance between the two rotors in the intermeshing zone.[1] Nevertheless, other rubber mixing equipment (e.g., rubber kneader and two-roll mill) can be utilized with appropriate mixing procedures and mixing conditions.

1.2 Mixing Procedures

Careful consideration should be taken when designing the mixing procedure. NORDEL™ EPDM-based sponge compound mixing can be carried out via "one-pass mixing" or "two-pass mixing."

- The two-pass mixing process is typically preferred to achieve better mixing quality and filler dispersion which, in turn, yields extruded profiles with better surface quality.
- One-pass mixing procedures are generally adopted to increase productivity. However, the one-pass mixing procedure must be carefully evaluated to ensure consistent production of sponge compounds with good mix quality. In order to achieve good mix quality using a single-pass mixing procedure, a good balance between filler and blowing agent dispersion and compound temperature control must be reached. This balance is also necessary to avoid scorching and premature decomposition of the chemical blowing agent.
- Upside-down (polymer is added last) mixing procedures are preferred for EPDM sponge compound mixing. Upside-down mixing procedures enable fast filler/oil incorporation and fast mixing cycles as well as a higher degree of dispersion due to the higher mixing power input.
- Fill factors of approximately 73-75% work well for NORDEL™ EPDM-based sponge compound mixing. Avoid under-filling the mixer as it could yield poor mixing, poor dispersion, and long mixing cycles. Conversely, over-filling the mixer could potentially cause undispersed EPDM lumps, excessive heating, and damage to the dust stop seal.
- Compound temperature control is critical during mixing due to the incorporation of chemical blowing agents (either azodicarbonamide [ADC] or 4-4' Oxydibenzenesulfonyl hydrazide [OBSH]) and the use of fast sulfur curing systems in the compound. It is recommended that the compound drop temperature be kept below 110°C when all ingredients (blowing agents and cure package added) are incorporated. Optimum compound temperature control can be achieved without sacrificing the good mix quality and filler dispersion with the order of addition of ingredients, rotor RPM, and ram position.
- During subzero temperature storage conditions (subzero temperatures), the EPDM material will become harder and have a higher modulus. As such, conditioning the NORDEL™ EPDM bale in a hot room (~30-40°C) for at least 24 hours before compound mixing production is recommended to avoid potential undispersed EPDM lumps.[2]

[1] Limper, Andreas. *Mixing of Rubber Compounds*. Hanser Publications, 2012.
[2] Johnson, Peter. *Rubber Processing*. Hanser Publications, 2001.

Extrusion and Vulcanization

2.1 Extrusion

Standard rubber extruders can be used for profile extrusion.

- The shelf life of the final compound should be well established for the standard operation discipline. It is recommended that the final compound be consumed within two weeks for fast cure EPDM sponge formulations.
- It is highly recommended that the final compound strips be stored in an air conditioned warehouse, especially during hot weather conditions (>30°C).
- Rubber extruder temperatures should be controlled carefully. Barrel and screw temperatures should be controlled with individual temperature control units (TCUs) to remove excess heat during extrusion.
- At the feed zone, an optimum bank size/rolling ball must be carefully maintained to ensure a constant extrusion output rate and extrudate dimensional stability.
- A screen pack set is recommended for filtering out any possible contaminants and undispersed agglomerates.
- Extra care should be taken to monitor the extrudate temperature. It is recommended that the extrudate temperature not exceed 90°C for continuous extrusion runs in order to avoid scorching.

2.2 Vulcanization

The extruded profile can be continuously cured on a continuous vulcanization (CV) line, which is a combination of multiple hot air and microwave ovens.

- The oven temperature/microwave power setting should be set appropriately to allow the EPDM sponge profile to go through the pre-cure, foaming/curing, and final curing steps.
- The oven conveyer belt speeds should also be adjusted to match the sponge profile expansion in the oven.
- The microwave oven is very effective for applying heat to the sponge profile. The microwave provides quick and uniform heat throughout the profile and can cause dramatic changes in the curing and foaming process. Therefore, the microwave generator power setting should be adjusted carefully to effectively control the state of cure and foaming.

Sponge Profile Properties

3.1 Density of Sponge and Profile Dimension/Expansion Ratio

Consider adopting the following approaches to adjust the foam density in a closed cell foamed structure that has low open cell content.

- Increase the microwave power. It is the easiest way to fully utilize the entire amount of blowing agent being added to the formulation to enable foaming and therefore lower the foam density (Figure 1).
- Reduce the compound cure rate via cure package modification. This will significantly reduce foam density. When the cure rate is too fast (short ts2), the compound will vulcanize quickly before the chemical blowing agent begins to decompose. The increased compound crosslinking density will limit cell nucleation and cell growth. The optimum cure rate is needed to fully utilize chemical blowing agent decomposition and allow the cell growth to reach its full potential (Figure 2).
- Adjust the chemical blowing agent level, as this will help fine-tune the foam density.
- High open cell content and high water absorption are indications of over-foaming and under-curing. In that scenario, degassing may be causing the foam density increase. Therefore, it may be necessary to reduce foaming by lowering the oven temperature and microwave power output, which will surprisingly yield a lower foam density. In this case, the faster cure rate will also reduce the high open cell content and therefore lower the foam density.

Figure 1: Foam Density as a Function of Microwave Power

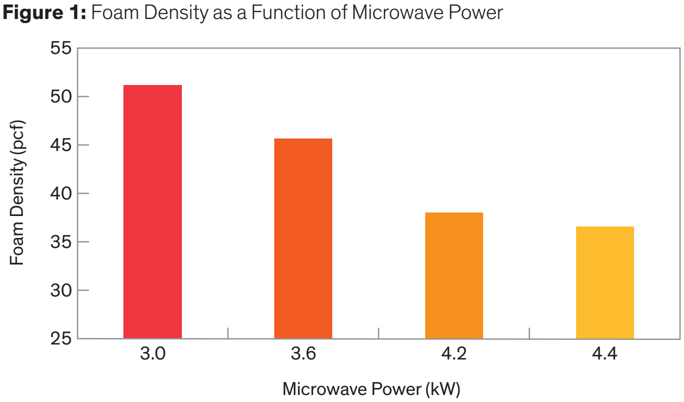
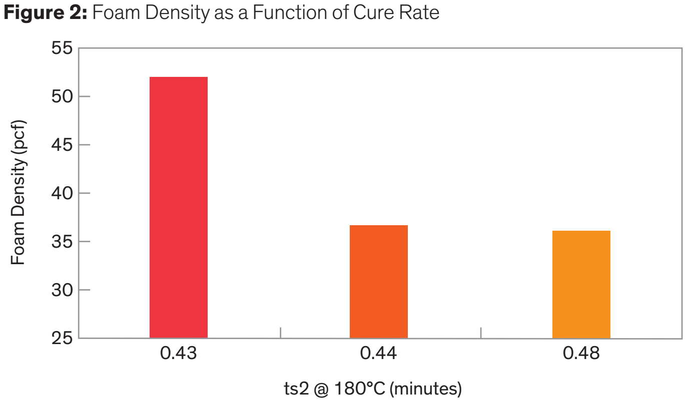


Figure 2: Foam Density as a Function of Cure Rate



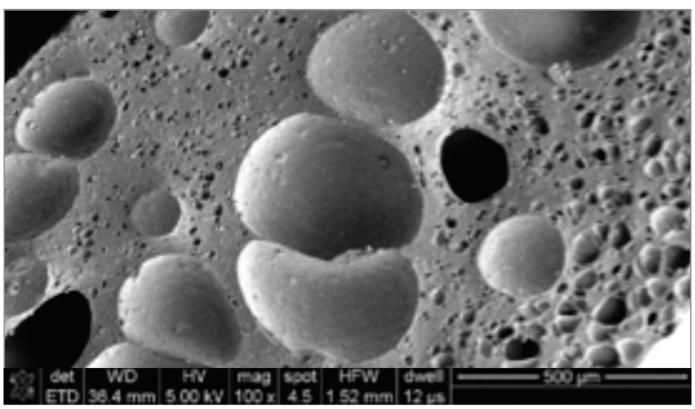
3.2 Surface Smoothness

A good mix quality (superior filler dispersion) will guarantee skin smoothness of the extrudate. If necessary, a straining process will be needed after the mixing process to produce a Class A surface compound. The vulcanization process is also very critical to the quality of the sponge profile surface. A typical cell structure of a sponge profile cross-section is shown in Figure 3. Notice that a relatively dense skin is formed on the outer surface of the sponge profile to enable a smooth surface. The pre-cure step is critical to the formation of that dense layer. Typically, increasing the cure rate (fast pre-cure) and decreasing the OBSH content (delayed foaming) are beneficial for dense layer formation close to the surface and therefore improves the skin smoothness.

3.3 Open Cell Content/Water Absorption

High open cell content is very detrimental to the sponge profile properties, as it causes increased water absorption. High water absorption in the sponge profile allows freezing during wet and cold temperature conditions, which may cause poor sealing performance and profile damage.

Figure 3: Cell Morphology of Sponge Profile Cross-section



Typically, high open cell content is a result of delayed curing relative to the foaming reaction and chemical blowing agent decomposition. When the cell growth (chemical blowing agent decomposition) begins before enough compound strength has developed (curing), the cell wall becomes stretched and thins to the point of rupture, resulting in an open cell structure. As such, both slow curing and fast chemical blowing agent decomposition can cause the open cell content to increase. Adjustments to the foaming (OBSH content) and curing (cure rate) will alter the open cell content significantly. In general, reducing the OBSH content and increasing the cure rate will lower the open cell content and therefore lower the water absorption (Figure 4).

3.4 Compression Set

Compression set is dependent on the state of cure of the compound. A higher state of cure will typically yield compounds having lower compression set values. Therefore, fast curing and a high state of cure is generally needed to reduce compression set.

However, when foaming begins, gas bubbles form inside the profile part and act as an insulating layer that slows down heat transfer. In this instance, the cure kinetics (MDR) show good and fast curing characteristics; however, the prematurely foamed compound (caused by early decomposition of the blowing agent) behaves like an under-cured compound due to the reduced heat transfer. Therefore, the prematurely foamed compound not only produces more open cells, but also reduces the state of the cure, thereby increasing the compression set.

In general, the best compression set properties can be obtained by achieving a high degree of cross-linking while balancing foaming and curing reactions. As shown in Figure 5, lower OBSH content generally yields lower compression set values.

Figure 4: Water Absorption as a Function of OBSH Content

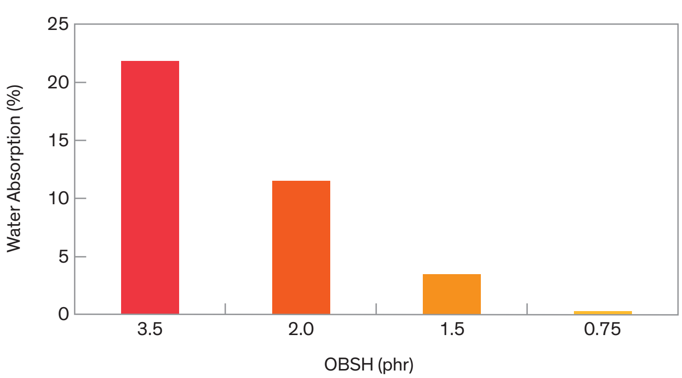
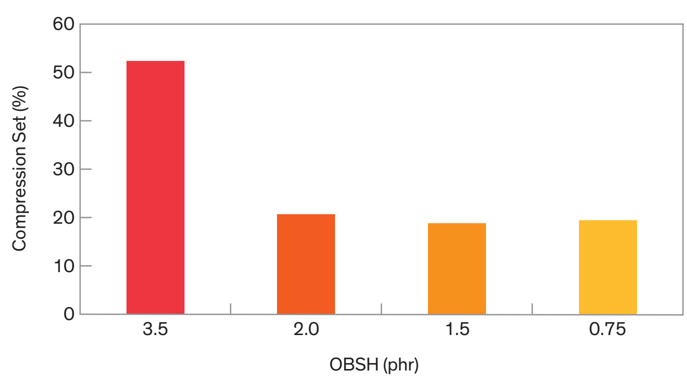


Figure 5: Compression Set as a Function of OBSH Content



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