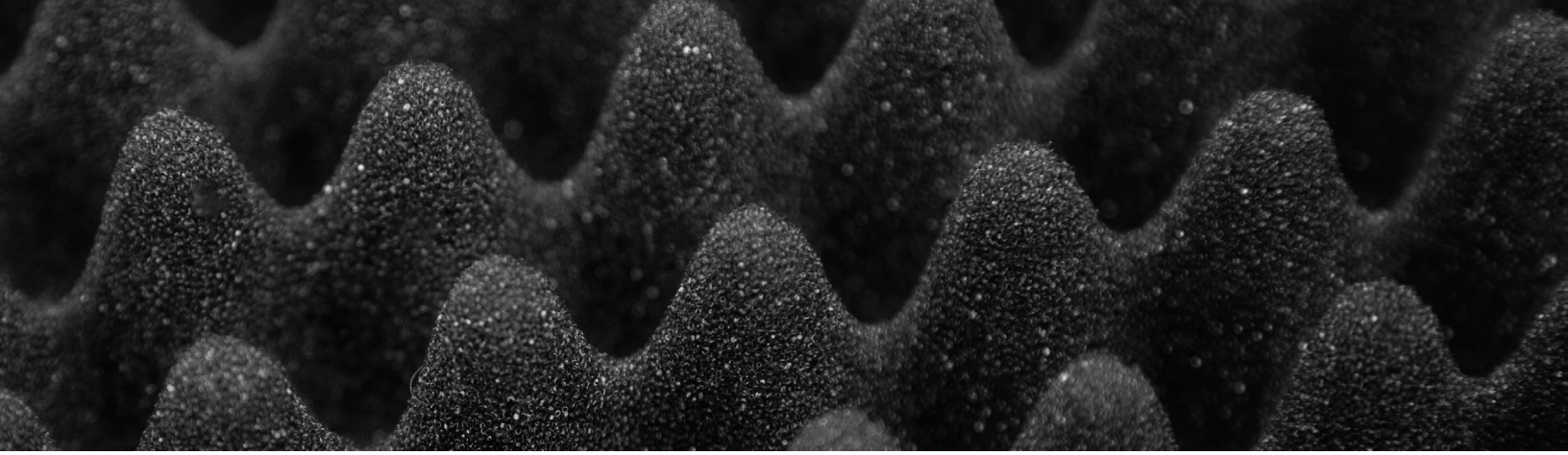

Foam Adhesion: Identifying the Challenges & Solutions

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Abstract

For most foam applications, adhesion to the substrate is a top priority. However, it is also an area where many foam systems may fail. This is generally caused by the multitude of applications, environmental conditions, and lifecycle requirements that stress adhesive systems, sometimes leading to failure. This raises two questions: 1) how do we identify and address or avoid potentially damaging conditions, and 2) how do we create more robust solutions that can better withstand these adverse conditions? This paper will explore both questions, concluding with key steps manufacturers and end-users can take to help address and avoid system failure as a result of lifecycle challenges.

NOTE: For the purposes of this paper, we will specifically be discussing solid foam materials that are made from rubber and plastics. Liquid foams do not apply to this discussion.

Identifying the Challenges of Adhesives and Foam Substrates

There are a number of variables that can impact the efficacy of the adhesive system, and they are often seen in conjunction. This creates a situation where a foam adhesive system may encounter different challenges at different points during its lifecycle. By identifying these variables, we can develop processes and technologies that will allow us to address them for the entire lifecycle.

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Foam Substrates:

One of the primary aspects of foam is that it can take many different forms and consistencies. The versatility of foam that makes it so widely applicable is also what causes foam adhesion to be so difficult. Foam can vary by weight, rigidity, porousness, and, perhaps most importantly, application. Each of these variables requires unique characteristics and functions out of the foam and the adhesive system, and each one presents its own challenges.

- Surface Texture: Foam surface textures range from smooth to rough, and each texture requires special adhesives for bonding. Smooth surfaces, in particular, often require specific surface treatments, such as abrading or corona treating, to ensure an effective bond.
- Skived/Skin: Sometimes converters want to bond to “skived” foam where the cellular structure of the foam is exposed, and other times they want to bond to the “skin” of the foam. The challenge with skived foam is that there is less surface area for the adhesive to contact, and this causes the adhesive to tend to “bridge” over the open cell structure.

  Alternatively, foam with the skin intact presents its own set of issues. The skin may contain release agents or other surface contaminants that can interfere with the ability of the adhesive to bond effectively. The skin will also have the highest concentration of ingredients that could migrate to the skin surface and cause bonding problems.
- Adhesive-Foam Compatibility: Some adhesive materials contain solvents and monomers that can swell and collapse particular types of foam. Destructive chemical reactions can also occur in the opposite direction because polymeric materials contain additives that can migrate to the surface and destroy the adhesive bond. Adhesives must be formulated to resist chemical interaction with surfactants, plasticizers, waxes, oils, and other substances. This can be particularly complicated as foam manufacturers continually evolve and improve their formulas, altering the chemical composition of their products and potentially impacting the efficacy of the adhesive.
- Foam Compression: A foam’s compressibility dictates and limits how much pressure can be applied by the converter when the pressure sensitive adhesive (PSA) is applied to the foam and the material travels through the laminating equipment. In general, stiff foam materials hold up to considerable pressure. Alternatively, some highly compressive foams cannot recover from applied pressure while others have good memory characteristics and can withstand significant pressure.

Manufacturing:

Foam manufacturers and adhesive manufacturers are typically not the same company. As a result, production engineers and product designers will generally select a foam material(s) and then subsequently identify an adhesive system that works with that material, applying it universally to that type of foam. Unfortunately, in practice, there are no “one size fits all” adhesive solutions that will work for all applications of a particular foam material. This can lead to using the wrong adhesive for the given application.

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Release Liners:

Most foams have to be adhered to two separate substrates: first, the release liner and second, the final substrate. The release liner must remain securely attached throughout the early lifecycle stages (transportation, fabrication, etc), but they must also be easy to remove during application. In other words, the system must have a so-called “tight release” during laminating, cutting operations, storage, etc, and it must also have an “easy release” to enable automated or manual removal during the application process.

Bear in mind, that the adhesive requirements for the temporary function of the release liner and the adhesive requirements for the permanent function of the final substrate are in direct opposition to each other.

Fabrication:

Generally, foam is not market-ready as soon as it leaves the manufacturing line. It often needs to undergo some form of fabrication to fit the use(s) of the application. When adhesive impedes or fails during the fabrication process, it can lead to product damage, waste, and disruptions to manufacturing.

Environment:

As with many materials, foams and adhesives can be highly susceptible to changes in their environments - hot/cold, humid/dry, exposed/enclosed, chemical exposure (grease, for example), etc. These varying environmental conditions can change the consistency and rigidity of both the foam and the adhesive.

As these materials undergo physical changes caused by their environments, it creates the potential for a different interaction between the foam substrate and the adhesive or the adhesive and the final substrate. Moreover, the environment can change at any point during transportation, storage, or application. Thus, the adhesive must be able to remain intact and effective in a myriad of different environments and applications.

Example of a Practical Application

To better understand these challenges, consider this example: imagine a foam component with adhesive on it that has been die-cut from a sheet. Part of the requirements for this component to function properly is that it must lay flat and remain in place while being transported a thousand miles. Moreover, during transportation and handling, the release liner on the foam component must remain entirely intact, even if it’s in a hot, humid truck in Florida or in a below-freezing truck in Alaska.

Once the component arrives, the installer needs to be able to remove the release liner from the foam, and then affix the foam to a car door. Once applied, the adhesive will need to be able to withstand grease, solvents, UV light, the stress of the door being slammed hundreds of times, and temperatures that reach 40°F below zero.

It is clear that there are many challenging variables that the foam adhesive system will encounter throughout its entire lifecycle, and each of these variables must be addressed while designing an effective foam adhesive system.

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Addressing the Challenges of Adhesives

Identifying the challenges an adhesive will face is simply the first step in addressing adhesive failures. The next step is to put practices in place and create technologies that will effectively address and mitigate these challenges.

Environment:

For the first half of the foam lifecycle, it is possible to control the environment by taking appropriate measures during manufacturing, transportation, storage, etc. These measures are typically recommended by the adhesive and foam manufacturers. In general, they include relatively simple requirements: store flat, in a cool dry area. That said, once the foam has been applied and the final product is in the hands of the end user, it is impossible to control the environmental conditions. There are two solutions to this – first, the system should be designed to withstand outliers of the application (extreme temperatures, excessive force, weather exposure, etc), and second, the end user should be made aware of the system's capabilities and parameters to prolong the life of their overall system.

Manufacturing:

During manufacturing, it is best practice to specify an adhesive that accounts for both the characteristics of the foam and the specific application of that foam; however, this practice can be difficult. In order for the engineer to identify which adhesive is best for the foam and the application, they must understand both the requirements of the application and the unique capabilities of the adhesive. Coupling these two variables together during the design phase can help ensure optimal success for the adhesive system once adhered to the final substrate. In many cases, engineers or foam manufacturers can work directly with adhesive manufacturers to identify the best adhesive system for the application.

Chemistry:

Adhesive manufacturers can alter the adhesive chemistry to better address the application requirements and challenges. While this may seem like a simple solution, creating an effective foam adhesive is a careful balancing act. An adhesive's chemistry must address the significant variability of the foam, the environments, and the applications it may encounter throughout its lifecycle. As already established, these aspects are tremendously diverse and often require one-off considerations. This makes it difficult to engineer adhesive systems that are reliably functional throughout their lifecycle and that can be broadly applied for many different applications.

As an example, certain applications require the adhesive to have a 100% foam tearing bond. In this case, the strength of the adhesive is greater than the internal strength of the foam, leading to the destruction of the foam itself. In other applications, the adhesive is expected to remove cleanly from the foam to prevent the foam from tearing at all.

There is no silver bullet adhesive that will work for all applications and also address every potential challenge. In many cases, an adhesive will have to be adapted to support the unique requirements of a specific application.

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How to Create Solutions that Address Adhesive Challenges

There are many factors to consider when engineering adhesive systems, and perhaps the topmost is the chemical composition and mechanical properties of the foam(s) and the substrates. Substrates can be highly variable and include things like glass, plastic, metal, painted surfaces, and even human skin. Additionally, an adhesive system must be designed to meet the particular performance requirements and environmental conditions of the end-use application. With these design requirements in mind, there are specific steps adhesive manufacturers can take to preemptively address challenges that may impact the performance of the adhesive system.

Foam Bonding Studies:

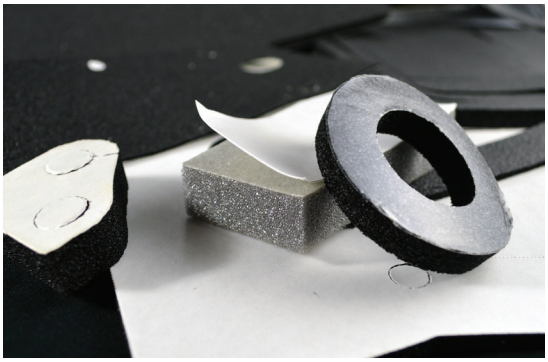
An adhesive manufacturer should be conducting general foam bonding studies. These are studies that explore how well the adhesive bonds to both the foam and the substrate. They evaluate various types of foam, substrates, and adhesives to ensure the chemical bond is sufficient to withstand the rigors of applications where they may be applied. These types of studies are crucial to evaluating whether or not the adhesive will be efficacious in a real-world application.

Publish Foam Bonding Studies:

The results from these studies should not be buried in an archive. The bonding reports are critical for engineers to make informed decisions regarding which adhesive is right for their foam as well as their applications. When selecting an adhesive identify manufacturers that have published their foam bonding reports to ensure there is science supporting the requirements of the application. Prior to engineering a foam adhesive system, engineers should carefully evaluate the bonding reports to ensure that the materials they select will be appropriate for the application.

Innovate:

Foams are constantly changing, and adhesives need to both keep pace with these changes and allow for new foam innovation. Consistently developing and testing new adhesive solutions that can evolve with foam manufacturers or even lead the changes in the foam industry are critical to overcoming the many challenges listed in this paper.



Collaborate with Foam Manufacturers:

Foams and adhesives work in conjunction, and so should adhesive and foam manufacturers. By sharing chemistry and research both manufacturers will be able to provide better and more effective solutions for their customers.

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Technical Support:

Many applications are unique and can face any (or all) of the challenges outlined in this paper. Optimal success can often come down to a personalized consultation with a technical expert. This is someone who can make recommendations on the bonding conditions (pressure/temp/time) to achieve specified performance. Don't hesitate to use these resources, they can make a significant difference in the overall efficacy of the foam system.

Utilize a Broad Portfolio:

Given that there is no one-size-fits-all tape for every application, one of the best solutions to many of these problems is having access to a broad portfolio of adhesive solutions. This will offer the diversity needed to engineer the optimal solution for a given application without sacrificing performance.

Testing:

There is no way to confirm that an adhesive can withstand the required conditions without running it through specification testing. In many industries, this is required; however, to overcome these challenges sufficiently, materials must be tested against the barriers of the challenge itself. Identifying those that cannot meet the specific needs of the application can help engineers create longer-lasting foam adhesive solutions.

Conclusion

Applications for foams and adhesives are tremendously varied, and they play an important role in many industries. For this reason, ensuring foam adhesion is a critical aspect for many foam specifiers, manufacturers, and end-users. Ultimately, the foam cannot perform its intended function if it does not stay where it is placed.

Identifying the challenges that can be disruptive to foam adhesion is crucial to creating practices, methods, and technologies to help combat them. Many of these can be addressed by the adhesive manufacturer if the manufacturer takes specific steps to mitigate the challenges through collaboration and innovation. This approach not only helps preclude the challenges outlined in this paper, but it also helps evolve the industry as a whole.

Engineers can play their own part by vetting the adhesive manufacturer and their research, reports, and products, preemptively forestalling these challenges before they become a problem.

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