Thermoforming Meets Thermoset Adhesive

An Intriguing Potential Solution for Semi-Structural Adhesives in Heavy Gauge Thermoforming

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INTRODUCTION

For over 40 years, Alamotape™, formerly FLEXcon Industrial has pioneered high-performing adhesive tapes and laminates for use in durable goods applications. Now they have developed a new cutting-edge adhesive technology, which is a breakthrough for use with heavy gauge thermoforming plastics. This development addresses many common challenges in thermoforming by adhering similar and dissimilar substrates in-house. The new adhesive technology is an economical alternative to prototype capped parts and costly custom set-up costs.

PRESSURE SENSITIVE ADHESIVE VS. THERMOSET ADHESIVE

Pressure Sensitive Adhesives (PSA) are self-stick and form a bond when light pressure is applied to attach the adhesive with the adherend. No solvent, water or heat is needed to activate the adhesive. As the name “pressure sensitive” indicates, the degree of bond is influenced by the amount of pressure used. While PSAs are designed to form a bond and hold properly at room temperature, they typically reduce or lose their tack at low temperatures, and reduce their shear holding ability at high temperatures.

Thermoset adhesives are cured with a combination of heat, pressure, and time, resulting in crosslinking between polymer chains to produce a polymer network. The curing process creates an irreversible chemical bond that, unlike PSAs, prevents the material from being removed or repositioned. The bonded structure has superior strength and environmental resistance, which makes the use of thermosets optimal for structural and/or load-bearing applications.

LIQUID vs. TAPE

Liquid adhesive differs from adhesive tape and the name speaks for itself—liquid. The actual strength of liquid adhesives is only achieved when they have become hard because the actual adhesive is mixed with a solvent (curative) so as not to bond immediately. Liquid adhesives come in a tube or similar container that prevents the solvent from evaporating while allowing the adhesive to remain liquid. Only when the liquid is applied to the surface and exposed to the air does the solvent evaporate. The adhesive becomes hard and a solid bond is achieved. This process can take two seconds or several hours, depending on the chemistry of the adhesive, the nature of the bonding surfaces, and the evaporation rate of the solvents.

PSA tapes, on the other hand, are coated from a liquid base onto a substrate and dried during the coating process. Solvents are already evaporated, and the adhesive is ready for use, which brings new meaning to the concept of “holding fast.” The protective and separating layer, or release liner, is removed and the adhesive tape is pressed to the surface and bonding occurs. No chemical reaction or drying time is needed.

Compared to liquid adhesives, thermoset adhesive tapes are far cleaner and simpler to use. The tape is simply cut to shape and placed between the materials to be bonded. The adhesive does not fully cure with chemical crosslinking until heat and pressure are applied. Therefore, the adhesive can be pre-applied to one substrate and then stored or even shipped, thus greatly reducing processing time when bonding materials together. No messy clean-up is required, and components can be handled immediately upon cooling. The thermoset adhesive tape cures during the heat and pressure process and develops full strength quickly as it cools. These tapes are ideally suited for bonding dissimilar sheets during the thermoforming process.

Using adhesive tapes in place of liquid adhesives has distinct advantages in industry. Simple, flexible handling, and quick adhesion accelerate the processes and even optimize the end-use products. Uneven surfaces may be evened out with adhesive tape. The entire process goes
very quickly, since drying time is irrelevant as opposed to liquid adhesives. In addition, adhesive tape is clean. Follow-up work in order to remove the remains of the adhesive is not necessary.

**TACKY THERMOSET**

A thermosetting, or B-stage, adhesive tape fully cures (chemically crosslinks) under heat and pressure. When the tape is delivered to the end user, the reaction between resin and crosslinker is not complete. In a liquid adhesive, that usually indicates that the resin and crosslinker have not been physically mixed. In an adhesive tape, that usually means the resin and crosslinker have been mixed, but something is blocking the chemical reaction from taking place. When this system is heated above an activation temperature, the crosslinking is complete, and the system fully cures.

Most thermosetting adhesive tapes are tack free at room temperature, meaning they have no bonding ability until they are heated, and crosslinking occurs. Tacky thermosetting adhesive tapes provide an initial bond like a PSA tape. They bond to much higher strength, however, once crosslinking occurs from heat activation. This novel semi-structural tape might be useful for various projects and applications.

Alamotape currently provides two distinct types of thermosetting adhesive tapes:

- **Non-Tacky Thermosetting Adhesive Tapes**
  - Completely non-sticky at room temperature
  - Requires heat and pressure to achieve full cure

- **Tacky Thermosetting Adhesive Tapes**
  - Tacky at room temperature, providing initial bond without heat or pressure
  - Requires heat and pressure to achieve full cure and high bond strength

The tacky thermosetting tapes can be divided into different versions of adhesive chemistry exhibiting various properties, including:

- Medium and high surface energy substrates (e.g. Kydex, PET, Metal, ABS, Acrylic, HIPS)
- Lowest tack adhesive for bonding dissimilar surfaces
- Higher tack for improved quick stick
- Paste-like adhesive film designed for flow/saturation during curing

- High tack adhesive for bonding high-energy substrates, such as metals
- Lower temperature curable
- Low to medium surface energy substrates (e.g. TPO, BOPP, PE)
  - Adhesive for bonding dissimilar surfaces (High/low energy surfaces)
  - Adhesive for bonding dissimilar surfaces—lower temperature activation

Thermosetting tape is designed to cure or bond under high heat and pressure. This tape can be used to bond similar and dissimilar heavy gauge plastic sheets with vacuum and/or compression form processes. Prior to forming, the materials are coated with the adhesive at full web (up to 60 inches wide) by laminating the tape onto one plastic sheet and then sandwich between the second sheet layer. While machine lamination is preferred over manual methods to marry the adhesive to a specific substrate, hand lamination is relatively straightforward and can be rolled, squeegeed and then trimmed by scissors or knife, if needed.

**TACKY THERMOSET IN THERMOFORMING**

The tacky thermoset adhesive film is supplied in roll form with a release liner. Pre-attaching is done at room temperature. The protective release liner is removed immediately prior to adding a secondary substrate to ensure a clean defect-free part. The process flow for adhering two substrates is illustrated below:
Alamotape’s thermoset adhesive tapes cure with heat and pressure under the same conditions typically used during the thermoforming process. The adhesive stretches with great elasticity and welds layers of plastic film together when the activation temperature is reached. Full strength typically develops after the piece has been allowed to cool. Testing has shown that maximum strength develops approximately 60 minutes after forming and is not affected by ambient conditions.

Sheets of varying thickness can be bonded. During testing, a tacky thermoset tape with .002-inch adhesive coating thickness was applied between .080-inch and .125-inch plastic sheets with the intention of draping or “capping” a few .050-inch materials on a core product. Some applications require increasing the adhesive thickness, for example when using sheets with thickness of .125-inch or higher. Up to .004-inch of adhesive can be coated in one pass. However, because these thermosetting adhesive tapes have initial tack, they can be layered together to increase coating thickness to .004, .008 or .012 inches prior to forming.

Plastics successfully welded to date:

- ABS and ABS
- Kydex and Kydex
- Kydex and ABS
- Kydex and HIPS
- HIPS and ABS
- TPO and ABS
- Kydex and Naugahyde (Synthetic Leather)
- Acrylic and ABS

**SOLUTION TO COMMON PROBLEMS**

The process of welding two plastics together is similar to twin-sheet thermoforming in that both processes heat adjacent plastic sheets simultaneously, then form and fuse the two sheets together in order to create the finished product. However, twin-sheeting only fuses at specific pressed points to make hollow or double-walled three-dimensional parts. The adhesive film used in thermoforming welds the two plastics together on the same mold into one solid piece. Twin sheeting is optimal when merging two sheets of the same substrate. While marrying two differential substrates together through twin sheeting might be possible, the equipment itself is quite expensive.

Plastic sheet extruders offer a ‘cap’ layer laminated to a sheet with a ‘tie’ layer, which bonds the cap to the base sheet. Since those custom runs require a special set up, the sheet extruders require a minimum run to cover their fixed costs. Typically, these custom sheets are only available in Minimum Order Quantities (MOQ), which are typically larger than the average job shop run, resulting in excess inventory of remaining materials. To solve the problem of high MOQ, thermoformers can essentially supplant the function of a tie-layer in-house with the use of the tacky thermoset. With tacky thermosetting tapes, thermoformers’ customers could buy the separate components in smaller quantities and use the tacky thermoset adhesive as a tie layer rather than pay the extruder to do so as a custom service.

Being able to bond two substrates during the thermoforming process has huge advantages as bonding post process is time-consuming. Currently, a thermoformer must form each piece, cool them, and then apply the adhesive to marry the parts. Gaps can be an issue since the parts were not initially formed together as one solid piece.
Fusing sheets in-process forms bonds rapidly, resulting in higher assembly speeds and short fixturing time. Benefits include speed, low cost, and clean, easy handling of material. Superior strength and integrity of the product is achieved by welding two substrates together into one fused piece. Thermoformers will have more design freedom and shorter time to market, in addition to the absence of capital investment of new machinery. Minimum Order Quantities are low, enabling the ability to prototype, and to promote innovation at relatively low cost.

**CONCLUSION**

On a cost-per-square-meter basis, prices will start at US $4 with higher prices for thicker adhesive and liner systems. In considering total cost, a thermoset film adhesive has several advantages:

**Key Benefits**

- Excellent bond strength
- Resistant to moisture and chemicals
- Cleaner and simpler to use than liquid
- No high cost of twin sheet machine
- Two-color option; custom color layering
- Increased structural stability when cured
- Low MOQ reduces development costs
- Time saving to adhere during process

All these advantages make Alamotape’s adhesive technology an intriguing potential solution for common thermoforming challenges.

For more information, visit our website: www.alamotape.com.