Primeaux Associates LLC

Polyurea Technology & Application Consulting

Technical Note

My Polyurea Keeps Cracking and Tearing!

Shrinkage Characteristics of Polyurea Coating and Lining Systems

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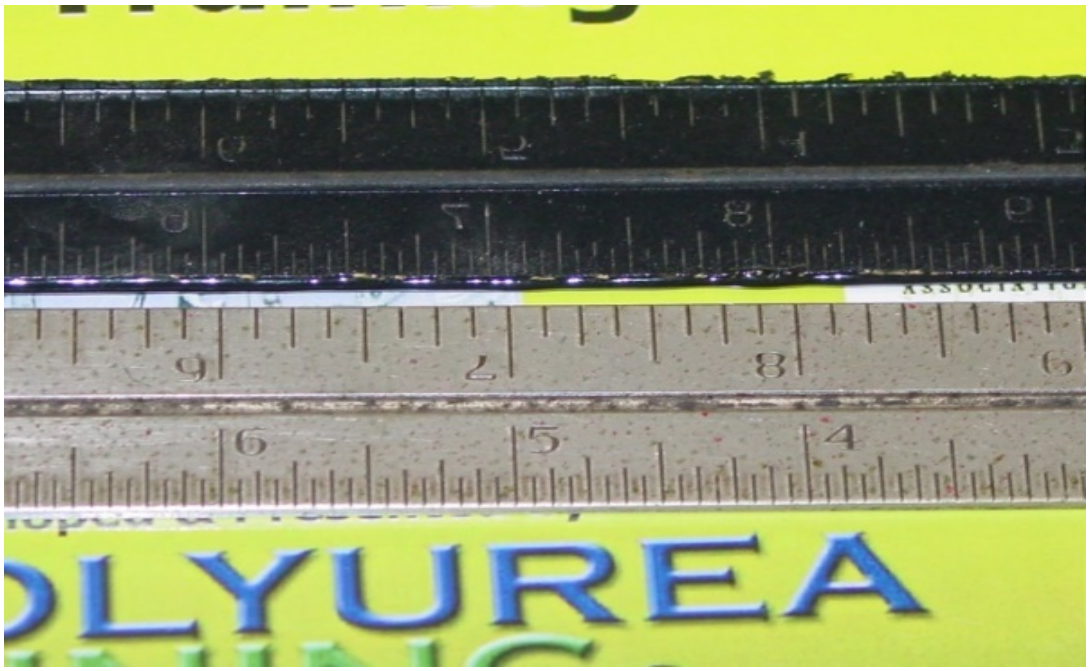
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Technical Note: Shrinkage and Polyurea Elastomers

Amazing! Polyurea spray elastomer systems are now showing ***shrinkage*** in the field???? Many are acting as if this is something new, or never before encountered. So there must be something wrong with the systems now. But wait, **ALL THERMOSET MATERIALS SHRINK!!!**

Shrinkage: slight dimensional reduction brought about by the reduction in volume of the cast or molded material as it cools, reacts and solidifies. When shrinkage of a part will present fitting problems, e.g., interchangeability, the casting pattern/mold cavity is made slightly larger.

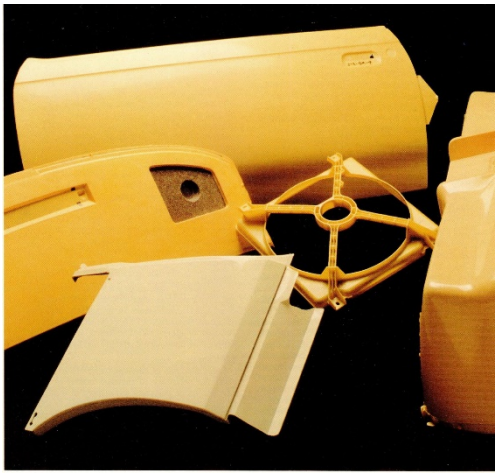
Seems to be an issue now, but this is NOT something new. Polyurea spray elastomer systems are part of the Thermoset Technology realm. This includes polyurethane, hybrids, epoxy, polyester, vinyl ester, etc. And with all thermoset's, there is shrinkage as the materials cure. Always has been, always will be. There is no "0" zero shrinkage, it's a fact as when chemicals react and bonds form, those bonds pull molecules closer together to create the characteristic we observe as 'shrinking'.[1]



If you have attended any of the PTG: Polyurea Training Group seminars, the PDA and PDA-E training schools, the PolyureaUniversity or Primeaux Associates LLC Applicator Training programs, you have seen the following picture. This is the simple example of a polyurea system applied to a metal ruler (with release agent), peeled off after set, allowed to cure and compared to the ruler marks. ***Bam***, there it is, shrinkage, about 3% linear no less.

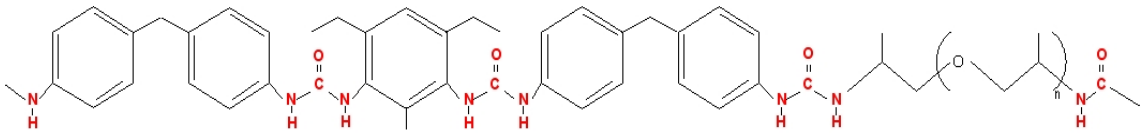
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As we all know, the polyurea spray technology developed from the polyurea RIM (Reaction Injection Molding) technology, were we learned quite a bit about characteristics. In this area, shrinkage was a known fact, and mold designers always made the molds larger to accommodate part shrinkage.[2, 3]



A little known fact by those now in the polyurea spray technology is that for the RIM systems, the resin blend portion was always nucleated with either CO_2 or Nitrogen gas to produce very fine microcellular structure that helped minimize shrinkage. In addition, various levels of flake glass or Wollastonite was added to the resin (filler) to also overcome shrinkage in the part, as well as increasing part stiffness (Flexural Modulus). Both of these factors will come into play as discussed later for spray application work.

The polyurea technology is an AB_N -block co-polymer system with phase separation of the hard and soft segments in the polymer matrix during cure. This is where the shrinkage comes, with most being noted within the first 24-hours during that initial cure period. The shrinkage is not due to solvent loss as these system are 100% solids materials.



Shrinkage of the spray system in field work can prove to be very devastating for certain projects if the applicator is not fully aware of this characteristic. This shrinkage can cause distortion of the substrate, pulling of flashing or other unsecured substrate, tearing or cracking of the applied coating, or shearing from the substrate in situations were improper or incomplete surface preparation techniques have been employed. The following examples illustrate these various conditions:



Flashing Pull Away on Roof

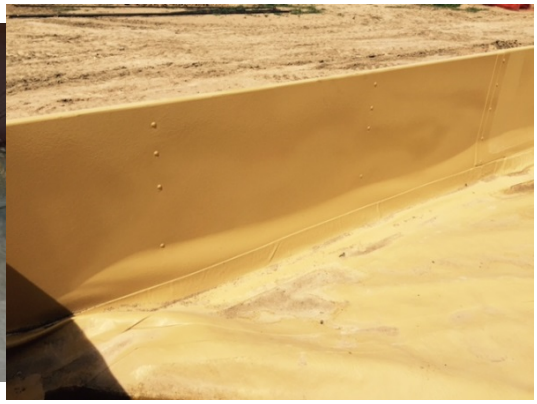


Shrinkage and Tear on Improper Seam

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Severe Shrinkage and Curling on Geotextile



Shrinkage and Pulling away in Corners



Cracks in a Secondary Coat of Polyurea
Low Temperature Processing - Shrinkage

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Shrinkage of Polyaspartic Ester Polyurea Systems



Curling of EPS, PUA Applied to One Side

So what causes the shrinkage in these systems? Many feel the sole reason is from the formulation used, but can also be affected by application techniques and spray equipment usage. But note that this shrinkage can also occur in the harder, polyurea based joint sealant systems. This is observed as pulling away from the shoulder of the concrete joint, coupled with movement of that concrete slab.

Formulation Contribution:

In general, the harder and faster the system is, the more linear shrinkage will be noted. As a guide, the general characteristics can be seen for fast set spray polyurea systems:

Shore D Hardness	Tensile strength, psi	Elongation, %	Shrinkage, %
60 – 70	2500 – 5000	< 100	3 – 5%
50 – 60	2000 – 3000	< 250	2 – 4%
40 – 50	2000 – 3000	250 – 500%	1.5 – 2.5 %
< 35	1500 – 2000	250 – 500%	0.5 – 1.0%

It is also shown that for a given fast set system, if the reaction is slowed by use of raw material selection, the overall shrinkage value will in fact be less than for the comparable faster version. The slower systems have a “softer” hard block composition.

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Some formulations may employ the use of plasticizer that help to soften the shrinkage characteristics. But use of these bring a whole new characteristic for the cured film and application work. More commonly, these are employed in the joint sealant system, to assist with shrinkage characteristics of the installed polymer.

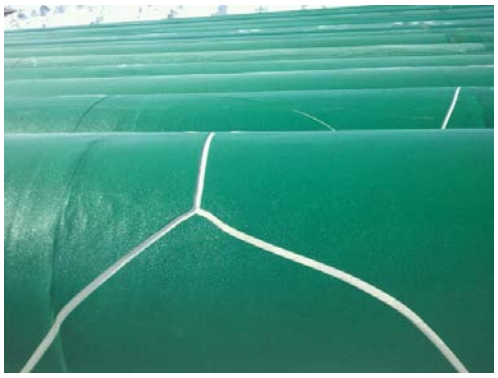
Another not to well know technique is system pigmentation. Many are using small amounts of pigment dispersion to "color" the system, but the solid pigment actually plays a key role in both performance and shrinkage reduction. Remember the use of the flake glass or Wollastonite in the polyurea RIM work noted above? Well the use of higher levels of solid pigment can help achieve similar characteristics; however, the loading of solid pigment may need to be substantial. Additionally, the inclusion of certain powders into a spray polymer material at the loading necessary to minimize shrinkage could have other detrimental influences on the system.

Spray Application Technique:

If from the application standpoint, one employs the industry standard spray technique of the criss-cross multi-pass buildup, shrinkage can be minimized.[4] For those that always spray in one direction, and continue to build material in that one direction, linear shrinkage can be different in the various layout directions. It is not that this is wrong per say, but one needs to be aware of the consequences of such spray technique. The thicker one builds on one pass, well the worse the shrinkage observed can be noted.

Application Equipment and Spray Gun:

Application process can play a very important role in the success of a polyurea coating and lining project. The material shall be processed as per the polyurea systems supplier, and NOT by suggestions from the equipment supplier! This is often the fatal blow. The material is to be processed at the pressures and temperature configurations identified, otherwise excess shrinkage and cracking can and will occur. This is mainly due to too cold of processing conditions. [5 – 8] The picture on the right is shrinkage cracking from non-bonding to substrate, and cold exposure too quick.



Many often ask: "which is the best spray gun for polyurea?" and that is often responded to as what is more comfortable for the application. There are numerous spray guns out there, and all work and provide the mix and physical properties for performance. But just like polyurea systems, there are not all created equal. Again, this relates back to the polyurea RIM work, though it was not a spray gun, but an impingement mix RIM head.

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Spray guns are either "air purge" or "mechanical purge" design. Many feel that the air purge is easier to use, has less parts, and easier to maintain. But the fact remains that mechanical purge gun always shows higher physical properties than the same system processed on an air purge gun. Ah but the mechanical purge guns provide more overspray (due to the restricting pattern tip) than an air purge (free flow) gun.

And some people have also noted that when the mechanical purge gun is used, the resulting polymer film possess a slight microcellular structure as compared to the air purge gun for a fast set system. Well guess what, there is also less shrinkage noted with the mechanical purge processed material, compared to the same with the air purge gun. This goes back to that nucleation technique employed with the polyurea RIM processes and parts made.

The following illustration provides for this comparison of spray gun used to shrinkage observed. Please don't get me wrong here, I like using a properly set-up air purge gun, they WORK!!!

Spray Gun Type*	Shore D Hardness	Tensile Strength, psi	Elongation, %	Shrinkage, % 24 hour	Shrinkage, % Full Cure
Air Purge	44	1975	200	1.25	1.50
Mechanical Purge	43	2230	245	1.11	1.20

* Both gun setup to provide for about 1 gal/min output, sample thickness of 60 mils (1.5 mm)

No need to panic here, shrinkage of the polyurea coating and lining system can easily be evaluated. As noted in SSPC-Paint 45, a modification of ASTM D6289 can be used. [9, 10] Using a solid, flat mold substrate, parallel marks can be made, and distance measured. The polyurea is then applied to the mold-released substrate, allowed to set, then peeled from the mold. Due to the characteristics of the polyurea technology, the marks will be picked up from the mold, mirrored if you will. These marks in the polyurea can then be measured over cure time, compared to initial marks in mold, and shrinkage calculated. It should be noted that most of the shrinkage occurs with the first 24 hours.

So ***Shrinkage*** happens with all thermoset based coating and lining systems. Don't let it ruin your day, be aware! Bottom line, shrinkage is a characteristic, and will only become a problem if it is not recognized, managed properly and one let's it become a problem…..

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Additional Reading / References:

[1] "Bond Breaking and Bond Making in Chemical Reactions." *Bond Breaking and Bond Making in Chemical Reactions*. N.p., n.d. Web. 16 Sept. 2015.

[2] Rubenstein, Judith E., "Polyurea RIM," Texaco Chemical Company, brochure, September 1987.

[3] Primeaux II, D. J., et.al., "Polyurea RIM in Exterior Body Panel Applications," SAE International Congress and Exposition, Detroit, MI (February, 1988).

[4] SSPC-PA 14, "Application of Thick Film Polyurea and Polyurethane Coatings to Concrete and Steel Using Plural Component Equipment," Coating Application Standard No. 14, SSPC: The Society for Protective Coatings, Pittsburgh, PA, September 25, 2012.

[5] Primeaux II, D. J. and Kenneth C. Anglin, "Processing Polyurea Elastomer Systems – A Spray Equipment Approach," UTECH '92, Den Hague, Netherlands Congress Center, March / April, 1992, pp. 173 – 176.

[6] Primeaux II, D. J. and Kenneth C. Anglin, "The Processing of Spray Polyurea Elastomer Systems," Polyurethanes '92, the 34th Technical / Marketing Conference, New Orleans, Louisiana, October, 1992, pp. 598 – 604.

[7] Torges, K-F and D. J. Primeaux II, "Cast Polyurea Elastomers: Application, Processing and Performance," UTECH '94, Den Hague, Netherlands Congress Center, March, 1994, pp. 1 – 8.

[8] Primeaux II, D. J., "Application of 100% Solids, Plural-Component Aliphatic Polyurea Spray Elastomer Systems," SSPC 2000, Nashville, Tennessee, November 2000, pp. 95 – 102.

[9] ASTM D6289, "Standard Test Method for Measuring Shrinkage from Mold Dimensions of Molded Thermosetting Plastics," ASTM International, West Conshohocken, PA.

[10] Primeaux Associates LLC, "Spray Coating Shrinkage Evaluation," Test Mold Procedure and Test Form, 2015.

Note: This is an update to the original version of this article, written by the same author and John Winfrey, and then used by PolyureaUniversity.com in March 2016.

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