TECHNICAL BULLETIN 186

Stress Crazing On Acrylic Surfaces And Its Causes

Stress crazing, which appears as an area of tiny micro-cracks, occasionally shows up in areas on the surface of most thermoplastic sheets. This phenomena, although rare and preventable, is known to occur in many types of plastic sheet materials and occasionally shows up on the surface of thermoformed acrylic hot tubs.

A study of stress crazing on acrylic surfaces and its potential causes was performed by Aristech Surfaces. The purpose of this study was to become more knowledgeable of the phenomena and to generate useful information for our customers to assist them in producing high quality finished parts.

There is much printed information available regarding stress crazing in thermoplastic sheet products. A comprehensive review can be found in "Environmental Stress Cracking of Plastics" by D.C. Wright, published by Rapra Technology.

The type of stress involved with surface crazing is most usually a tensile stress. The following is one explanation of this cause and effect. The stress tends to pull apart the tightly coiled polymer chains forming the plastic sheet material. This condition makes it easier for solvent molecules to penetrate the surface of the plastic and diffuse throughout the polymer chains. The tightly wound polymer chains then begin to slip apart from one another and result in the appearance of very small cracks on the surface of the plastic sheet. Depending upon the amount of stress and the aggressiveness of the environment (i.e. chemical solvent), the small cracks grow in size and may even cause breakage of the plastic sheet.

Many studies have demonstrated that <u>two conditions must be present for stress crazing to develop on the surface of an acrylic sheet:</u> stress within the acrylic sheet and the presence of an aggressive liquid or solvent. The presence of only one of these conditions does not cause crazing. Both must be present.

Typical Causes Of Stress

- "Cold forming" acrylic sheet builds stress into the finished part. This can be demonstrated when "cold formed" clear sheets are examined using a polarized light source. Therefore, cold forming must always be avoided when thermoforming acrylic sheet. Refer to Technical Bulletin # 137 for more information on thermoforming procedures.

- After a formed acrylic shell is reinforced with fiberglass reinforced polyester (FRP) and the composite shape cools down to room temperature, some degree of stress is generated in the acrylic surface. This stress is due to the different shrinkage rates of the acrylic surface and the FRP reinforcing material. In general, an FRP material with a higher peak exotherm will result in a higher degree of stress being generated on the acrylic surface.

- The structure of a finished part may not be properly or evenly supported leading to certain areas that flex more than other areas. This can lead to additional stress in those areas.

Aggressive Liquids And Solvents

- Liquids or solvents are often used in the final steps of the hot tub manufacturing process for cleaning FRP overspray, glue, dirt, etc. from the surface.

- If a cleaning liquid or organic solvent is used, it should be dried as soon as possible to avoid chemical attack on the acrylic surface.

- Depending upon the stress level in the acrylic surface, the time required for chemical attack can be very short.

- Crazing can be minimized and/or eliminated if no aggressive liquids or solvents are used.

It should also be noted that:

— Crazing is most readily visible in clear, metalescent, and pearlescent colors where the edges of the micro cracks diffuse the incoming light rays .*

* The same effect does not occur if the crazed material is an opaque white or beige colored surface. In them, crazing may be present but our eyes do not see it. If metallic or other light reflecting particles are near the crazed surface, the light rays are diffused and scattered around, making the crazing quite noticeable. If the crazing is not severe and the area is wiped with an oily substance or paste, the micro cracks are "filled-up" and the crazing may even disappear. In some cases, heating and possibly bending the crazed area "to close the cracks" may reduce the overall intensity of the crazed surface. These corrective actions are generally not permanent and are of limited success. The real solution is preventing and avoiding the two conditions, stress and solvents, that lead to surface crazing.

How Is Stress Measured And How Much Is Required To Generate The Potential For Crazing

The stress causing the crazing is typically a tensile stress. However, for the purposes of conducting crazing experiments, stress is generated on the surface of samples by flexing the acrylic surface. This allows the stress to be measured as flexural stress (psi) or flexural strain (%).

Flexural stress or "outer fiber stress" is tensile stress at the outer surface of a bent sample. Depending on the radius of the curvature, the force needed and the dimensions of the sample, the amount of flexural stress can be calculated in psi (kg/cm^2).

When a sample is bent, the outer surface stretches and becomes longer than it was originally. We can calculate how much longer the stressed surface has become and express the result in % flexural strain.

We can compute the amount of stress both ways, so that the reader can use the type of stress with which he is more familiar. It is important to have an understanding of the amount of stress used in any given test to better evaluate liquids or cleaners that may cause crazing. For example, the test method ASTM F484-02 "Stress Crazing Of Acrylic Plastics In Contact With Liquid Or Semi-Liquid Compounds" uses flexural stress levels of 3,000, 3,500, and 4,500 psi (211, 246, and 316 kg/cm^2). In an acrylic sample 0.125" (3.2 mm) thick, the corresponding flexural strains are about 0.50, 0.59, and 0.76%.

The data points shown in Table 1 on the following page were generated in our lab. They should be used as approximate values, unless the thickness of a sample is exactly measured. A few mils above or below the nominal thickness of a sample are not very significant; but if a sample is thicker or thinner by more than a few mils the slope of the line will change.

Table 1 shows that:

— 4,500 psi (316 kg/cm^2) of flexural stress corresponds to about 0.76% of flexural strain.

— 3,500 psi (246 kg/cm^2) of flexural stress corresponds to about 0.59% of flexural strain.

— 3,000 psi (211 kg/cm^2) of flexural stress corresponds to about 0.50% of flexural strain.

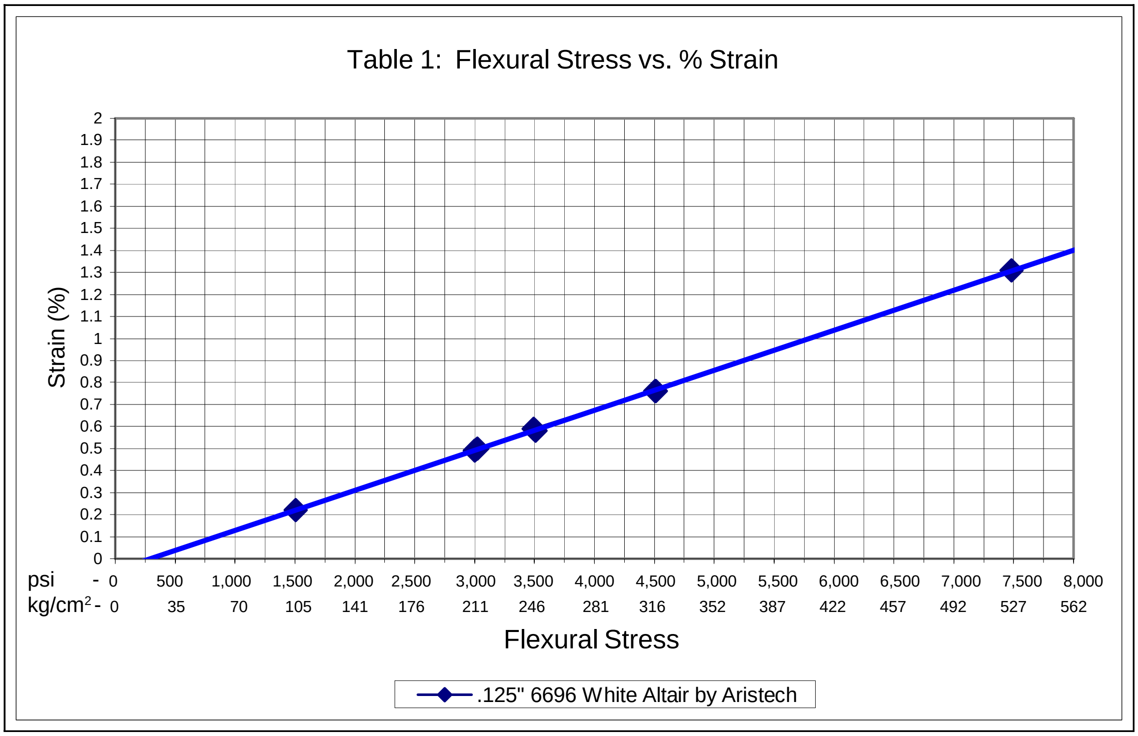
— 1,750 psi (123 kg/cm^2) of flexural stress corresponds to about 0.29% of flexural strain.

— 580 psi (41 kg/cm^2) of flexural stress corresponds to about 0.09% of flexural strain.

One of our initial experiments utilized samples with strain levels of 1.0% and 1.6%. These high levels of strain, combined with isopropyl alcohol (IPA) resulted in heavy crazing on the samples examined.

To help in preventing and/or minimizing crazing, design engineers recommend that, in general, parts should exhibit no greater than 0.5% or 3,000 psi (211 kg/cm^2). Ideally the stress in a finished part should be less than 600 psi (42 kg/cm^2) or 0.07%. However, the aggressiveness of the liquid or solvent must also be considered. A more aggressive solvent will generate crazing at lower levels of stress.

For additional information regarding stress crazing in acrylic sheet surfaces and its potential causes, contact the Arcylic Technology Department of Aristech Surfaces at 1-800-354-9858.



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