

Canopy Woes

by David Koelzer

As many of you may know, when I am not composing a fascinating, insightful and Pulitzer Prize quality newsletter for our chapter, you will most likely find me pounding on something in my garage. For the past three years that something has been a Sonex or at least I hope it will be soon. My latest task has been constructing the rather unique canopy of the Sonex. Those that remember the Moni will recognize the long sloping windscreen of a Monnett design. Unlike the Moni, the glass on a Sonex is in two parts; the windscreen and the canopy bubble. The windscreen starts right at the top of the firewall and comes back to a hoop just ahead of the pilot. This part is fairly easy to make since it is simply a flat sheet of Lexan wrapped around the hoop formers. I figured I would start with this so I could develop the skills I would use on the bubble canopy. The bubble, however, is blown from Plexiglas, which I will later find behaves very differently than Lexan. However, since ignorance is bliss, I merrily went on my way using my band saw to cut the windscreen to shape, smoothing the edges with a belt sander and easing the corners with a deburr tool.



Photo by David Koelzer

Everything is going well and I begin to wonder why I had heard so many horror stories about cracked canopies. Obviously those people just did not know how to work with this stuff. Being quite full of myself, I figured I was ready to go onto the Plexiglas bubble. I had picked up the bubble last year at Oshkosh and stored it in my basement ever since. The Sonex factory recommends storing the canopy in a warm place to help cure the Plexiglas. I figured if the Plexiglas had not cured itself after 18 months then I should consult Dr. Kevorkian for one of his patented “cures”. While the factory recommends using a bandsaw to trim the canopy, I did not think I could handle the canopy well enough by myself to run it through my bandsaw. So rather than asking for help, I decided to leave the canopy stationary and cut it with my Dremel tool and a cut-off wheel. This seemed to work well but rather than cutting the Plexiglas the cut-

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off wheel was more melting its way through the bubble. I was not concerned though, figuring the extra heat was just helping to “sear” the edge. Later I would realize that the rapid and localized heating and then rapid cooling was setting up tremendous stresses right along the edges of the Plexiglas. Much like taking a hot jar out of the oven and running cold water over it. (Oh, so I suppose YOU never did that to your mother’s prize canning jars?)

For now though everything was just fine. After the cut I would move the canopy back onto my plane to check the fit. I did not take the time to sand the edge smooth, removing any stress risers before I tried to move the large unwieldy canopy, again by myself. However, I was getting away with it and the canopy showed no signs of being worse for the wear. Soon I had it trimmed to shape and I started to drill the necessary holes for the rivets. I was prepared for this though. Rather than using regular drill that can some-



time dig in too hard and crack out the opposite side, I had purchased special drills just for the Plexiglas. These drills have a special 0° rake that is easier on the plastic. Some builders say you can just take regular bit and just drill into concrete to dull the bit just enough so that it will work well on Plexiglas. Others recommend heating up a bolt and just burning a hole through the material, “searing” the edge in the process. I think this practice is too much like the “hot jar and the cold water” accident just waiting to happen.

Heat can be useful, but too much heat can also cause problems. Fellow Sonex builder David S. Petri CDR NAVSPACE/OOD put it this way: *Honestly, warm plexi is the easiest to work with... not hot, just warm. Since the canopy is toast, try to experiment. Put a chunk in the freezer and then drill/cut it and then warm a chunk to varying temps and drill/cut. That'll do two things... 1) Show you where you need to be working in the temp regime and 2) Give you more practice (and confidence) drilling and cutting plexi. Working with plexi you are concerned with viscoelastic modulus, which is simply the shear stress divided by the sum of the elastic shear deformation and the displacement by viscous flow. There are four major categories of Mve... Rigid, Leathery (yes, leathery), Rubbery and Viscous. Increase the temp and Mve transitions through these phases. If I apply stress to a plexi coupon it will eventually flow and relieve the stress. If applied too quickly in the rigid phase, it will exceed the Mve and fail... this is what's*

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*going on with your canopy! Here's the problem with cutting/drilling plexi. You are putting stress within the matrix that the plexi must relieve. If the stress exceeds M_{ve} of the material at that temperature it will fail (read crack), if below M_{ve} it will eventually flow out. The warmer the plexi, the lower the M_{ve} , the faster the stress loading rate can be applied... ie. drill/cut. This is because the structure is allowed to flow to correct for the stress. Plexi has only two choices... above the M_{ve} curve it cracks, below the M_{ve} curve it flows (the rate depends on the temp). Dig this... when you orbital sand the edge of plexi, you're not really removing stress risers (like everyone thinks) as much as you are **LOCALLY WARMING THE PLEXI** and allowing it to flow and relieve the stress!*

So what I gather is, that at certain temperatures and given time, Plexiglas will easily flow to relieve high stress areas. However, high localized heating and rapid cooling will lock in the stresses because the material will not have enough time to flow naturally to a low stress state. Of course, I knew none of this while I was doing this work (at least the first time) But back to the story:

I used my special bit to drill my holes and I even took the time to deburred the holes but again rather than asking for help, I moved the canopy by myself. The Sonex canopy bubble is also unique in that it is not blown to its final shape. It is more like a flat bubble that is just slightly bulged. Then that is wrapped over the canopy frame to give the canopy its final shape. The sides also tend to bulge out slightly and as I pressed these sides flat, things started catching up with me. As I was inserting the clecoes to hold the canopy side flat, I heard a sickening sound. With a snap, a 3" crack popped up the side of my canopy. My immediate reaction was to scream out some things similar to "darn", "shucks", "son of a gun" and "fiddle de de". After I calmed down, I continued clecoeing and then another small crack ran up the side prompting me to start another round of even more "colorful" phrases and metaphors. Including, among other things, calling the canopy's lineage into question, comparing its characteristics to type of fertilizer and suggested where it might go when I am done with it, but of course, not quite in those exact words. After exhausting my entire repertoire of profanity, I set about deciding my next move. Most of the options I thought of involved a large axe or a chainsaw but I finally settled on stop drilling the cracks and see if I could salvage this canopy.

Stop drilling turned out to be trickier than I thought. As I pressed the drill to the Plexiglas the crack would spread even farther. Finally I found that if I backed up the opposite side of the material and drilled just slightly ahead of the crack, I could catch the crack and keep it from spreading. With the cracks stop drilled I went to remove the canopy once again and as I lifted a huge crack raced right down the middle nearly splitting the entire canopy in two. To my surprise, I found myself inventing new profanity which was hither to unknown by civilized society and which I cannot include here without violating a large number of City Decency Ordinances and U.S. Postal Codes.

After briefly entertaining the idea of flying the first open-air Sonex, I finally gave up and ordered a brand new canopy and vowed to do everything the right way this time. To my delight the protective plastic covering on the Plexiglas was left on when new canopy was blown. Previously the Monnetts were removing this covering before the blowing process but one day when they forgot to remove the covering they found the Plexiglas blew into shape just fine. I, in turn, have left this covering on through out the construction process to protect against scratches. When the new canopy arrived, I brought every heater I could find into my garage and turned them on full blast raising the temperature to a toasty 85°. Previously I was working at a room temperature of 60°, which may have been part of my problem. I also asked a fellow

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Sonex builder over to help me with moving the canopy lessening the chance of applied point loads that could start a crack. Rather than a Dremel and a cut-off wheel, I cut this new canopy with my band saw with a 14 TPI blade. While I thought this would be unwieldy, it turned out to be quite easy with partner cradling the canopy as I guided it through the saw. This time after cutting I immediately sanded the edge before I move the canopy and risked starting a crack. Again I used my belt sander with a fine grit paper to even out the edges, remove the saw marks and bring the edge right down to the mark. I was careful with the belt sander though. As the Plexiglas heats up from the friction of sanding the belt will really begin to dig in and remove a lot of material.

After the belt sander, I sanded the edge by hand with very fine sandpaper to ensure that all stress risers were removed. And I again used my special bits to drill the Plexiglas. I also drilled the holes over size so that there would be room for expansion and contraction with changes in temperature. Rather than rivets I tapped the holes and used screws so I could more precisely adjust the pressure I applied to the Plexiglas. Once I had the canopy in place I put a heater inside the cockpit, set the temperature to 100° and let the canopy cook for a couple of days. This temperature is well below the melting point of Plexiglas but it is warm enough to help the material flow and relieve the internal stresses. All these techniques and practices seem to have worked because my new canopy is finished and shows no signs of cracks but then again I still, to this day, have not uncrossed my fingers.

