ICE FLOWER lamination process defects; how to prevent and control them

With this first article, we are starting our collaboration with one of the flat glass sector's experts on laminating – especially with regards to large-sized auto glass – Mika Eronen. In this article, Mika gives our readers some expert advice on 'ice flower' defects during lamination and how to prevent and control these same defects.

Ice flower defects on laminated glass

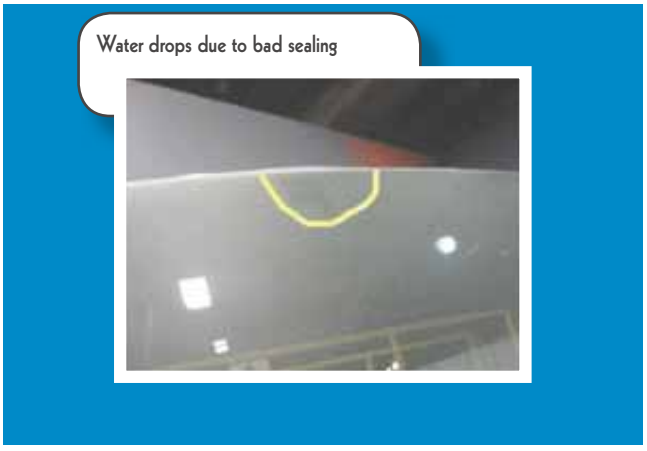
MIKA ERONEN

The introduction of acoustic PVB products brought along manufacturing challenges as these new products require more attention to process quality than traditional PVB products. With the new acoustic PVB consisting of a tri-layer structure, glass manufacturers started to suffer from a new kind of lamination defect, today known as 'ice flower' or 'snowflakes'. This is a rather fascinating defect, most likely named this way because of its nature and appearance, but it is especially difficult for

manufacturers experiencing it. It still is a popular topic of discussion internally and between glassmakers and their customers. It is also complicated, because it is a delayed defect that will appear typically after exposure to changing climate conditions and usually no earlier than in field, therefore creating huge external waste costs. In this article, I will review the appearance of this quality defect and show how to control the lamination process to prevent it.

THE DEFECT

The development of what is known as 'advanced laminated glazing' introduced a sound insulating PVB interlayer that allows reduction of glass thickness without increased noise penetrating the vehicle interior. With its tri-layer structure this new PVB product allows weight savings without compromising passenger comfort. The acoustic PVB interlayer applied in the laminated glass formulation does not differ from the traditional PVB interlayer in make-up, and, furthermore, does not have special requirements with regards to the manufacturing process. This being said, with lamination of acoustic PVB, the likelihood of any manufacturing process deficiency in lamination work resulting in defects will be significantly increased. It is simply a less forgiving material when it comes to lamination process quality.



Water drops due to bad sealing

Typically, 'ice-flowering' would first start from a small normal looking bubble that then gradually transforms to blossom as a full scale 'ice-flower'. To me this development from a normal tiny bubble to an 'ice-flower' would indicate that a certain type of 'super-saturating'-phenomenon takes place. In this super-saturation, small amounts of trapped air will, under changing climate conditions (ambient temperature changing the windshield temperature), start to penetrate through the tri-layer and accumulate into one region causing first, a small normal looking bubble and, as the amount of trapped air penetrating the tri-layer increases, it blossoms finally as a form of 'ice-flower' or 'snow flake', such as Figure 1 shows. The individual shape of this defect is related to tri-layer acoustic PVB and penetrations through the tri-layer. The super-saturation term is adopted from Dr. Bert C. Wong who, in his paper 'Shattering Old Myths about Defect Formation in Laminated Glass. Part II'[1] uses it perfectly to describe defect formation in laminated glass.

Another example of bad drops due to bad sealing

Another theory is that there is a relationship to tiny amounts of residual moisture left behind from washing process for example and is trapped between the laminate. Later under changing climate conditions, it would again activate, penetrate through the tri-layer, and form 'ice-flowering', arising due to high moisture. However PVB must have great moisture content to form a defect like this – that's why it is fair to presume that small water drop presence typically is not the root by itself of ice flowers, however water drops potentially complicate the extraction of air during de-airing, and air can remain trapped. See Figures 7 and 8 for examples. Again, in the case of the water drops, the air would be the root cause of the defect.

SO HOW TO PREVENT AND CONTROL IT?

The manufacturers of acoustic PVB products are correct when they say that this material does not require special attention during the manufacturing process. However, as said earlier, any deficiency in the process – especially in de-airing – is more probable to cause complications in forming ice flowers or snowflakes. This being said, it is obvious that the bending and lamination process as a whole must

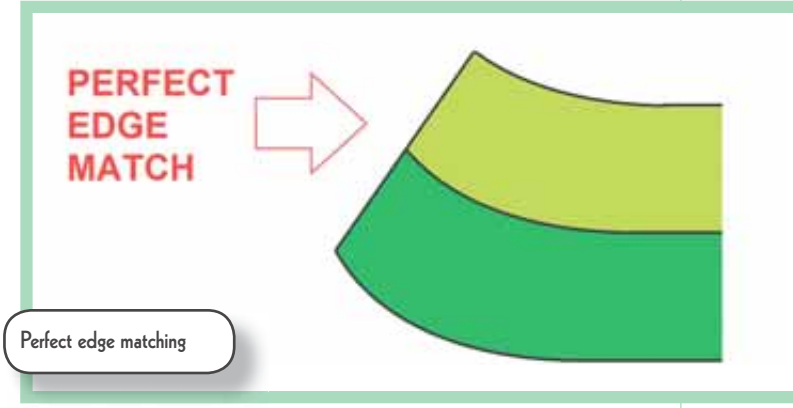
be performed to excellence, thus I would say that having a demanding material such as this in your product catalogue can be considered as a benefit, a favour, because it really requires focus into perfecting lamination process quality. I am listing here the key conditions to be controlled to prevent issues with acoustic PVB, under main topics: Glass pair gapping, Assembly work stage 1, and De-airing process.

Glass pair gapping

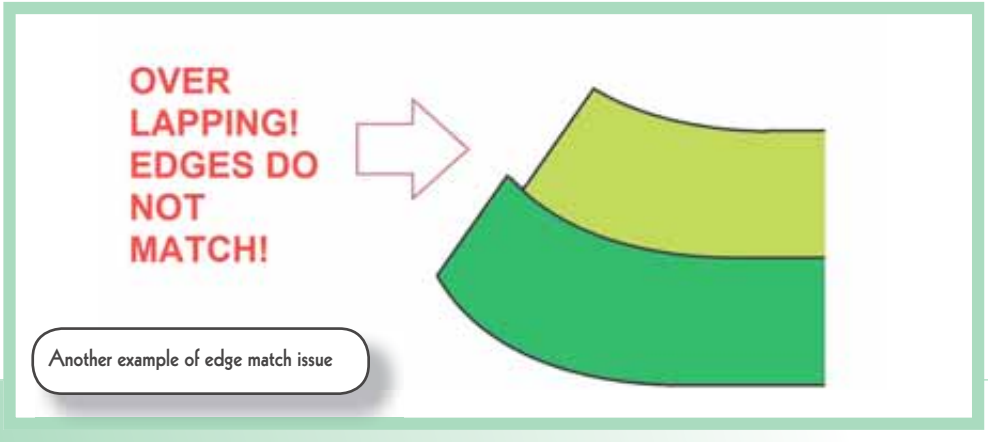
As we know, glass pair gapping is related to defects caused by residual air in the interlayer, bubbles, worms, teardrops and in the case of acoustic PVB: ice-flowers. Glass pair gapping is a characteristic that is mainly controlled in the bending process by ensuring that both glass sheets bend uniformly, but gapping can also be created at lamination works. Gapping will occur with the wrong set-up of the glass pairs. Figures ... show conditions in lamination assembly works that can create gapping between the glass pairs.

Edge match issue

Sometimes the acoustic windshields for replacement markets are produced with a decreased amount of sagging (cross curvature), means that the bending is more flat than with the normal PVB version of the product. This alteration in product dimension is carried out to reduce the gapping that can occur due to the sag bending process.
There are various recommendations about the allowed upper limit of glass pair gapping. Some claim 0.1 mm maximum, where as some allow 0.5 mm. However, it must be recognized here that gapping as a single variable is not a result of residual air causing a lamination defect. The rate of change at the occurring gapping is the key variable in this. This being said it must be recognized that any existing gapping, cured with lamination, adds to the natural manufacturing stresses of the windshield and over-the-limit manufacturing stresses at the worst conditions can cause spontaneous breakage of the windshield.



Perfect edge matching



Another example of edge match issue

Assembly work stage 1: cleaning

Ensure that the glass is cleaned properly. Note that any residual moisture water drops in the glass can difficult the air removal at de-airing. The Figures below show how the water drop(s) left on a glass edge look like, and also demonstrate that they can pass detection by disguising and then re-appearing as ice-flowers.

De-airing process

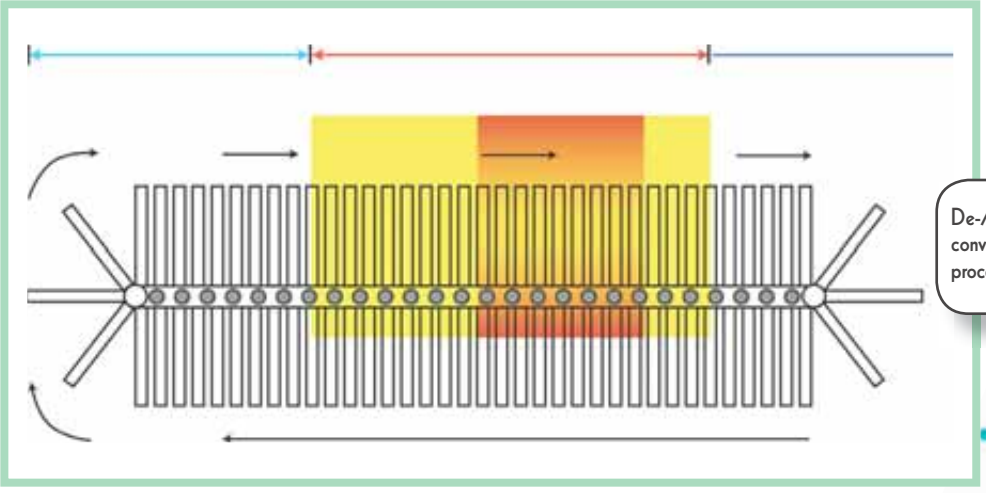
As explained earlier, the root-cause of the ice-flower defect is residual air in the laminate and that is naturally in relation to insufficient air removal and premature edge seal during processing, therefore de-airing is a paramount step when processing acoustic PVB interlayers.

Make sure that the correct vacuum ring vacuum level is reached, typically at -08 to -0.9 bar. After the vacuum is started the sandwich should be subjected to sufficient cold vacuum time to prevent premature edge seal. See the above Figure for the illustration of de-airing process stages. Cold vacuum should be maintained for a minimum of >10 minutes. Larger windshields require even longer cold vacuum time. Cold vacuum removes the major part of the trapped air.

After the sufficient cold vacuum period has been passed the laminate will be subjected to heating. Usually most common reason for the appearance of ice flowers/snowflakes is processing default at the very beginning of the heat treatment (hot-vacuum) allowing the glass edge to seal too early. Therefore to ensure that no premature edge sealing takes place, the hot de-airing heating phase should be conducted gradually and uniformly to relieve all excess air from the sandwich. Vacuum must be maintained through the entire heating period. The glass is heated to approximately 90-110°C and to do this, the de-airing conveyors' heating settings are approximately at 120-130°C depending on the equipment used. Heating time depends on the equipment, but is typically around 20 minutes in total. At this temperature, the PVB interlayer will soften, edges are sealed and a preliminary adhesion of the glass and PVB is created.

After the glass has passed the heating section it should be cooled down before the removal of the vacuum rings; note the cooling stage at the conveyor. The vacuum rings can be removed when the glass temperature is <80°C. Removing the vacuum rings from cooled glass prevents edge seal from opening. Therefore recommended cooling time is at >5 minutes depending on the used equipment and factory ambient conditions.

At this stage ensure that after the de-airing conveyor process, good opacity has been reached = glasses are almost transparent. 'Cloudiness' at the edges is an indication of issues in edge sealing.



De-Airing conveyor heating process

CONCLUSIONS

As demonstrated here the manufacturer's stipulation of no special manufacturing requirements are real, however the importance of lamination process excellence is evident. Lamination experts have agreed that de-airing step is the most important one in determining yield[2] and we have concluded here that this applies also in the case of acoustic PVB interlayers. Since air is a key-factor in defect formation, all processing parameters and conditions should aim to minimize the amount of residual air in the laminate. Naturally we must not neglect contributing factors: gapping and water drops, both of which can complicate or prevent efficient air removal.

References

1. Bert C. Wong: Shattering Old Myths about Defect Formation in Laminated Glass. Part II
2. A. Moeyersons: Edge-performance testing of automotive laminated glass

Acknowledgements

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