AEGG: glass container Fracture Analysis explained

How can we identify the cause of a glass breakage when all we have are pieces of broken glass and no idea of the manner in which the glass broke? This question is especially useful when seeking to understand fracture analysis.

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At some time in our lives we've all accidentally dropped a glass jar or bottle, only to watch it break as it hit the ground. Indeed most of us are familiar with the fact that a glass container will break if we hit it hard enough just as a bottle will burst if we over-pressurise it or a jar will crack if we pour boiling water into it.

Much as Fire Brigade investigators will trace tell-tale signs of a fire to where the original flame broke out, glass manufacturers will do likewise when determining how and why a bottle broke - only, for the latter, it's key to have enough of the container to hand so a full reconstruction of what happened can be made.

FRACTURE MARKINGS

Ripples

When a container breaks it may appear instantaneous. This is because a crack can propagate at 3 kms per second, spreading out from its origin. Much like the ripples in a pond after a stone has been cast into it, so the ripple marks on a fractured surface will show the direction in which the breakage travelled. (image 1)


(image 1) courtesy Alli Hartmann

By marking the direction of travel and piecing the fragment back together, one can study the fracture pattern to determine the cause and origin of the breakage. The origin can be a manufacturing fault, such as a split or inclusion, or else damage to the surface which has occurred elsewhere.

Stress + Origin =Fracture.

If the stress causing failure is very great then the origin could be that of micro-cracks present on the surface of the glass. Instead a large split may only need a small force to extend it.

This is one of the reasons glass containers are coated - to help prevent surface damage while allowing containers to slide against each other on a filling line.

Tin is applied to the surface at the Hot End and chemically bonds to the glass, providing a better surface for the Cold End coating to adhere to. These 2 coatings work together to provide protection from scuffing and allow the easy flow of containers along today's high speed filling lines.

MIRROR SEQUENCE

A further set of features indicates the direction of travel. Where the fracture moves from the origin, through a smooth area known as mirror, on to a rougher area known as mist or grey and finally into hackle before propagating along a fracture edge leaving ripples.

DWELL MARKS

As the name suggests, these are where the fracture has stopped momentarily. They appear as a defined line or heavy ripple and can help identify splits or checks in the glass created during the manufacturing process.

FRACTURE PATTERNS

There are four main fracture patterns, namely:

Impact

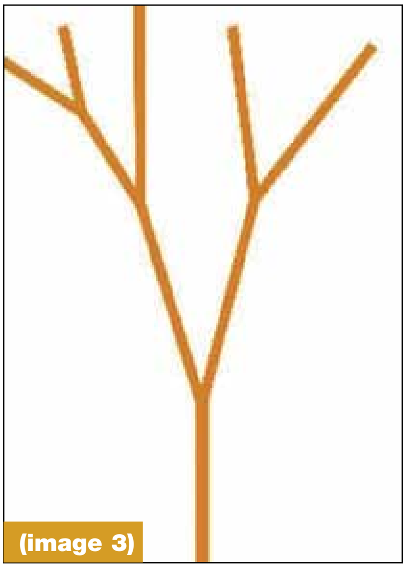
Typically this presents a radiating pattern - much like a spider's web with its origin at centre. (image 2)

(image 2)

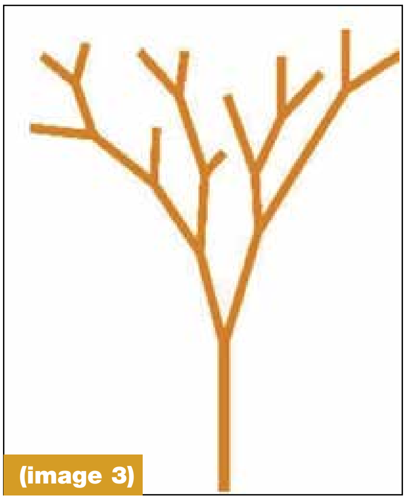
At the point of impact there may also be signs of a Hertz fracture cone, where a cone shaped piece of glass has been knocked out.

Pressure

The fracture will spread out initially as a single line which then splits in two in what is known as binary forking. The pressure when the bottle bursts will affect the degree of forking. (image 3)



(image 3)



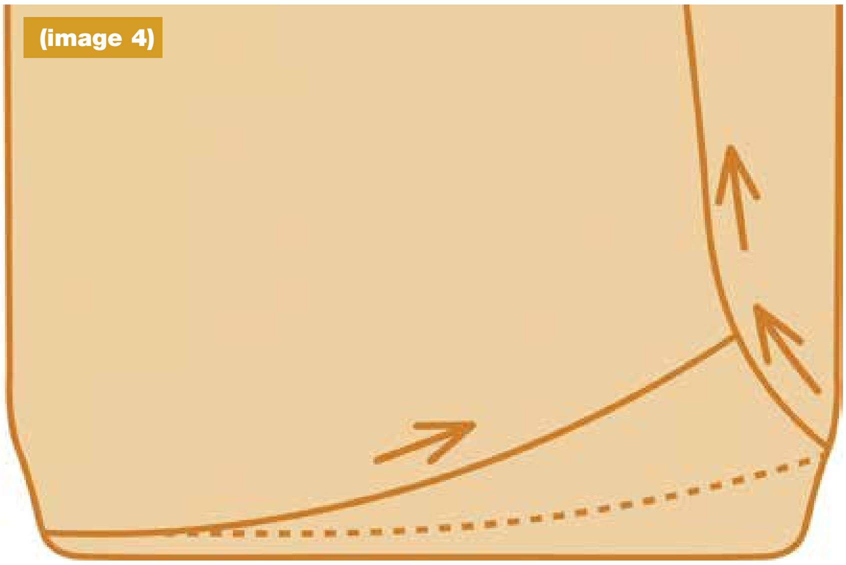
(image 3)

If the origin occurs in the heel or stippling area then the fracture pattern will appear slightly different, but the origin will still be found in the area of single straight fracture at the base.

Thermal shock

This occurs due to temperature differences between the inner and outer surfaces of the container, causing stresses which result in a simple fracture pattern - usually with a single fracture around the base and up the side of the bottle or jar. (image 4)

The breakage pattern generally comprises more rectangular, vertically-aligned fragments around the shoulder or heel, depending where failure occurs. (image 7)


(image 4)


(image 7)

Vertical load

A vertical load failure can occur when a downwards stress is applied to the finish of the container - either during capping or on the lower layers in a stack of pallets. The load produces tensile stresses in the outer surface of the shoulder which, if large enough or if a defect is present, can result in failure.

The sharper the angle of the shoulder, the less vertical load it can bear. A champagne bottle can take a load of 5000 kg, but a square shouldered bottle can only take 250 kg. (image 5-6)

IMPORTANT CONSIDERATIONS

Though this has been a very basic guide to fracture analysis there are some very important learnings nonetheless:

- When collecting samples for fracture analysis it is very important to save as much glass as possible, and to try and keep different broken containers separate.
- The more glass that is saved, the more likely it is to determine the cause of breakage.
- Since stress + origin = fracture, it is important to reduce the number of origins. These can be manufacturing defects or damage by the filling line.
- It is also important to reduce the stresses the container is subjected to. Whether it is impacts on the line or in the supply chain, over pressurisation, high temperature differentials i.e. hot filling cold glass or applying too great a top load. ■


(image 5)


(image 6)