N. Sesha Prakash* outlines the processes involved in hollow glass making.

**Parts of a glass container**

**Finish** - This is the top of the container above the neck ring parting line. It includes the sealing surface, bore and bead or collar. The sealing device (closure) can be in the finish or in the bore or mouth. The finish also serves for filling and emptying. The bead or collar of the finish is also used to assist in transferring the parison into the blow mould.

**Neck** - The part that extends from the parting line to the curve at the base of the neck.

**Shoulder** - This extends from the base of the neck to the straight part of the body.

**Body** - The main part of the container that holds the product.

**Base** - The part of the container that supports it when kept upright.

**Container types**

Containers in common use can be broadly classified as bottles and jars. While bottles are narrow necked containers, jars are containers with a neck diameter of more than 40mm. Bottles are formed by the blow-blow process or the narrow neck press and blow (NNPB) process, while jars are made by the press-blow process on IS forming machines.

Bottle finishes or ‘lips’ are almost as varied as the bottle shapes themselves.

The term ‘finish’ originates with the mouth-blown bottle production process where the last step in completing a finished bottle was to ‘finish the lip’. Other alternative names for the finish besides lip is ‘top,’ ‘mouth,’ or ‘corkage’.

With semi-automatic and fully automatic bottle machines, the lip or finish is the first forming step in the bottle making process. The finish is fully formed in the first ‘blank’ or parison mould, which only pre-forms the remainder of the bottle body.

**Finish types**

The most widely used finish designs are the crown finish, threaded finish and the lug finish. In a crown finish, the seal is formed by bending the edge of the closure over the edge bead of the finish of a narrow-neck bottle using a pressure die. This type of finish is closed using a crown cap.

In jars, the lug finish is used for thick products like jams, pickles and spreads. Wide mouth external thread finishes are most commonly found on canning jars and other food storage jars. Jars have a smooth, non-ground/ground top rim.

**Special finishes**

Mention must be made here of some special finishes, such as:

- Cork finish - Popular with wine bottles with a cork sealing on the inner bore.
- Codd soda finish - Soda bottle finish with a sealing marble. The codd –soda bottle is a special bottle sealing design which is still popular in many cases, where the bore is sealed with a glass marble.
- Vial finish - Used mainly for packing injectibles or the like in the pharmaceutical industry. The sealing surface is the bore, sealing is by means of a rubber bung held in place by a...
Finish dimensions (threaded finish)

- **“T” Dimension** - The outside diameter of the thread. The tolerance range of the “T” dimension will determine the mate between bottle and closure.
- **“E” Dimension** - The outside diameter of the neck. The difference between the “E” and “T” dimensions divided by two determines the thread depth.
- **“I” Dimension** - The inner diameter of the bottle neck. Specifications require a minimum “I” to allow sufficient clearance for filling tubes. Liner less closures, with a plug or land seal, and dispensing plugs and fittings require a controlled “I” dimension for a proper fit.
- **“S” Dimension** - Measured from the top of the finish to the top edge of the first thread. The “S” dimension is the key factor that determines the orientation of the closure to the bottle and the amount of thread engagement between the bottle and cap.
- **“H” Dimension** - The height of the neck finish. Measured from the top of the neck to the point where the diameter “T”, extended down, intersects the shoulder.

Finish area wall thickness can be classified into three ranges: <= 1.5mm; 1.5 to 2.5mm; and >= 2.5mm. In the finish of a bottle the wall thickness is generally uniformly distributed since it is formed by pressing and is determined by the forming forces.

The finish dimensions are important because they have a direct impact on the performance of the finish closure system. Dimensional consistency is quite important in finish to assure containment capability, to ensure that the cap/closure fits properly and offers correct opening strength. It is important that the finishes on the bottle meet the specifications.

The centre of the finish should always be aligned with the centre of the base. Locating the bottle in a self-centring chuck and then rotating the bottle can make this measurement. The centre of the bottle will move in a circle of radius equal to the eccentricity or non-verticality.

The dimensions of the finish and the dimensions of the closure should match for a good fit. Any deviation beyond a tolerance level will lead to a loose fit and the closure will fail in its performance. Defects can be viewed by the naked eye or by sing automated optical comparator systems.

A larger neck finish diameter means larger closures are required, which will then require a greater twisting torque to open a closure. Simple finishes such as the vial finish; cork finish or milk bottle finish do not require close tolerances since the closure can adjust to the finish dimensions.

Verticality is a measure of the horizontal deviation of the bottle finish from its intended position in relation to the base of the bottle. Lack of verticality can cause difficulty on filling lines, more so in present day automatic fast lines, the bottle will not position correctly below the filling nozzle or can pose capping problems.

### Finish and bottle closures

Finish is the part of a bottle for holding the cap or closure, which seals the contents of the bottle. A closure is the device that in conjunction with the finish, is used to seal the contents inside the bottle. The finish and closure are interrelated entities of any bottle. The closure must conform to the finish in order to function, and vice versa. The finish and closure design of a container is dependent on the type of sealing and the internal pressure of the contents of the container:

- **Crown cap sealing** – The sealing surface is on top of the finish and is used for narrow-neck containers being filled under pressure.
- **Thread or lug sealing** – A screw type cap closes the sealing surface on the top of the finish. This type is used for narrow neck bottles and wide mouth jars.
Density – 7.61 kg/m³
Coefficient of thermal expansion – 16 x 10⁻⁶/°C
High heat transfer coefficients indicate good thermal contact at the glass-to-mould interface indicating that perfect contact between the glass and the mould would assist in the most rapid heat transfer and therefore increase potential production speeds. Perfect contact, however, would imply that the glass would need to adhere to the mould. Such intimate contact would be excellent for heat transfer, but would prevent the removal of the article from the mould or increase the possibility of damage to the glass surface.

Aluminium bronzes are commonly used in areas where thermal conductivity is of primary importance such as neckrings and bottom plates. The advantage of this type of material over cast irons is that they exhibit approximately three times the thermal conductivity. Cost permitting, Minox can be used for the moulds in other areas of the bottle. The glass industry is moving towards the increased usage of these materials in other areas, but at present they cost approximately 2.5 times more than cast iron.

Neck ring lubrication and cooling
The amount of cooling used in each production cycle is critical. Improper annealing of the neck ring leads to defects in the finish of the bottles like a rippled wavy surface which is known as ‘orange peel’, i.e. a chilled surface appearance or small cracks or checks at the glass surface. Conversely, if the temperature at the mould surface is allowed to get too high, the glass may stick to the mould.

Coating on the finish
The finish part of a container is provided with very minimum hot end coating or no coating at all. A low level of

Main types of sealing systems
- Top sealing crown cork – The sealing surface is on the top of the finish and used for narrow neck containers being filled under pressure.
- Thread or Lug – The sealing surface on the top of the finish is closed by a screw type cap. Used for wide mouth jars and narrow neck bottles.
- Side Sealing - The sealing surface is on the side of the finish and the cap is pressed on to seal the contents. It is used for wide mouth jars in the food industry.

It is advisable to provide liners inside the caps to ensure a good seal with the rim of the finish.

The finish mould
The finish mould makes the finish part and connects the finish of the bottle to the neck of the bottle. The complete finish mould consists of the neck ring and the guide ring. The guide ring fits into a slot cut in the neck ring. The guide ring is the part that makes the top of the bottle. The neck ring makes the threaded part.

On container forming machines, separate smaller moulds called neck ring moulds (finish mould) are used to form the ring or finish of the bottle. The neck rings moulds are in two halves but with no pivot arrangement. They are held in ring mould holders, which open and close them. The mating faces of the two halves use some form of location, such as a dovetail.

The finish part of a bottle is formed at a much higher temperature than the body. Consequently, the finish mould or neck ring is subjected to a higher temperature. The higher the thermal conductivity of the mould material, lower will be the mould temperature. Neck ring moulds have a higher thermal conductivity. Neck ring materials should possess: High thermal conductivity, high-temperature corrosion resistance and high temperature scaling resistance. Neck rings moulds are finned externally to facilitate higher heat transfer rates.

Finish mould materials
The finish mould is generally manufactured from an aluminium bronze material called Minox:
Chemical composition of Minox bronze material – Al-9.5 -10.5%; Fe -1.0%; Pb -0.15%; Mn- 0.25%; Zn-7.5 – 8.5 %; balance – Cu.
Physical properties of Minox
Thermal conductivity – 37 Kcal/m.hr OK
treatment on the finish is necessary since interaction/contact between the coated finish and the coated closure can result in an increased twist force; especially in pilfer proof closures. Therefore when the ware is coated online, the finish is protected or covered, this being easier in bottles with long necks.

**Neck ring coating**

Thermal surfacing is a method to improve the surface properties of base metals. The process improves the surface properties and extends the operative life of the mould. The process can also be used to repair worn surfaces. Sulphur containing lubricants can deteriorate the mould surface, hence permanent coating or surfacing is preferred. The very good wear resistance of Ni-Cr-Si-B-alloys to hot glass is explained by the formation of a chromium oxide layer on the coating surface. This layer is not miscible with the silicon oxide in the glass, which enhances its wear properties. The effect is especially important when the surface layer is heated to a temperature above 600°C. Nickel based coatings also increase the sticking temperature.

The amount of cooling used in each production cycle is critical. Improper cooling of the neck ring during finish forming leads to defects in the finish of the bottles like a rippled wavy surface which is known as ‘orange peel’, i.e. a chilled surface appearance or small cracks or checks at the glass surface. Conversely, if the temperature at the mould surface is allowed to get too high, the glass may stick to the mould.

**Finish moulds**

Commonly used hard-facing coating material for the neck ring is Colmonoy (from Wallcolmonoy of UK; Hoganas is another supplier of such materials), a specially formulated range of nickel-based surfacing alloy. The alloy can be applied to the mould surface by various means such as fuse welding, plasma spray etc.

**Finish inspection**

The finish is one of the most vital parts of the container. It must be free of all serious defects to guarantee complete sealing on the filling line. Some defects, such as crizzles on the top sealing surface may cause a container to leak slowly which will only be discovered when opened and the contents found to be stale or to have spoiled.

The inspection of the finish of a container can be automatic or visual inspection. In automatic inspection, the bottles are subjected to scanning by mechanical, optical or electronic means in order to detect and then reject bottles with defects.

Nikon optical comparator with 10:1 or 20:1 capability is used to check the finish on the bottle. Optical comparator is a non-contact inspection instrument that applies the principle of optics to magnify and project the image of an inspected part. Optical inspection instruments can also be used to inspect while the part is actually moving on a conveyor. A light source emits a light beam that travels through a prism and projects the shadow of an object onto a screen a few feet away so it can be compared with a chart showing tolerance levels for the part. Tracings can be made using a combination of the maximum and the minimum tolerances band used as overlays on the comparator screen by the finish profile between the maximum and the minimum lines; the finish can be judged as in-specification.

Thread finishes require measurements of the thread pitch, thread profile, and band flatness of the sealing surface.

Crown finishes require measurements of the flatness of the sealing surface. In jars, the flatness of the top sealing surface is important. A flatness is measured by placing the jar on a surface plate and measuring the gap with a feeler gauge. A typical tolerance of 0.38mm max (for 180°) is set for the out-of-flat value. Sometimes, the top of the jar is bent or crooked finish.
Jar may be ground to achieve flatness.
Vertical load may be introduced or applied during filling/capping process or during the stacking storage, when bottles are stored on top of each other. So, the load bearing capability is tested to BS EN ISO 7113-2204 using a universal testing machine.

**Online inspection of the finish**

Bore gauge – the internal and external diameter at the finish of the bottle is inspected. Bottles out of specification are automatically rejected by means of a pusher positioned downstream from the gauge.

**Finish defects**

**Table 2**
- Dirty or rough finish – a finish which has a rough or scaly appearance with or without spots.
- Line over finish – A fine groove across the rim of the finish which can cause a leakage of the contents.
- Neck ring seam – a fin or seam of glass across the top or side of the finish.

**100ml Dettol bottle analysis**

A defect analysis conducted by a typical customer of the supplied bottles showed the following data:

- Dirty finish - critical defect
- Bird swing - critical defect
- Check - check under finish/finish check - critical defect
- Stuck bottle

By Pareto analysis:
- Dirty finish
- Bird swing
- Check
- Unfilled finish

The analysis shows that finish defects – dirty finish and checks in the finish are the major customer complaints.

**Analysis of the critical defects**

Split finish – A vertical crack that runs from the top of the finish downward towards the neck. It can be seen by observing the reflection of light when the bottle is turned. The split finish is a critical defect and the ware gets rejected. Split finish defect can lead to spoilage in vacuum packed or processed foods or can cause leakage of the contents. The major cause for split finish is the plunger in the blank mould too cold or plunger dwell time being too long. Worn plungers or neck rings can also attribute to the defect. A small variation in the gob temperature can influence the quality of the finish particularly the sealing surface or the split finish defect.

**Split finish causes**

**Table 3**

**Checked finish**

A checked finish is a closed crack in the finish of the bottle. Probably the most common finish defect. Swabbing can temporarily stop the checks.

**Checked finish causes**

**Table 4**

continued »
Hollow glass finishing

Over press – a glass protrusion which occurs on the inner edge of the sealing surface of the finish and which protrudes above the sealing surface to the extent that it may be broken or chipped in normal use. Fire polishing the finish area can prevent sharp angles and smoothen irregularities such as over press.

**Over press causes**

*Table 5*

**Choked neck causes**

*Table 6*

**Strength of the finish**

Containers are subjected to vertical loading during, filling, stacking and transport. The finish and the neck part of a container experience greater stress than the rest of the container. The compressive strength of a glass bottle is necessary to permit load support in stacking, storage and transport.

Load limits for vertical load are stated at 6000 N for refillable bottles and 4000 N for non-refillable bottles.

Glass bottles are superior packing materials and are preferred over plastic bottles. When a carbonated beverage is packed in a PET bottle, the filling pressure is lowered and therefore we experience a deterioration in the taste quality than when the beverage is packed in a glass bottle which can tolerate much higher filling pressures. PET bottles also have a lower oxygen permeability resistance and chemical resistance. Beer is very sensitive to oxygen. Moreover, Glass is environment friendly.

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