Advanced chemical tempering of glass

Greater applications than those for the traditional heat process for strengthening glass have led to increased interest in chemical tempering. One company active in the field is Iontech, part of the Finind Group. In this article, the author looks at this glass-strengthening process and at the advanced technology now available. Emphasis is also placed on the possibilities of overcoming the limitations of heat tempering, and on the fact that chemically tempered glass has higher bending and impact resistance.

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Equipment capabilities

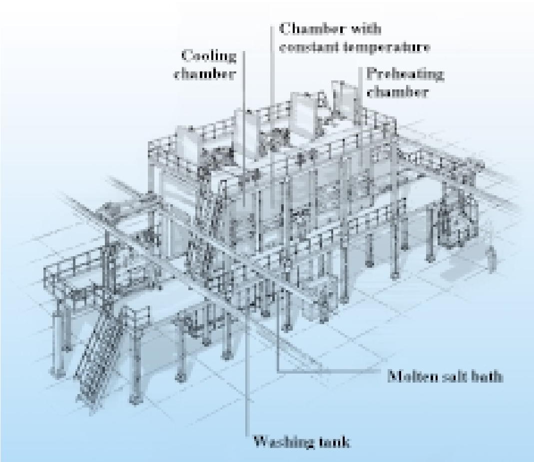
Chemical processing allows the tempering of glass as thin as 0.5 mm and makes it possible to obtain tempering specifications which are superior to those of normal annealed or heat tempered glass. Two years of research have enabled Iontech (part of Italy's Finind Group) to develop chemical tempering equipment capable of handling flat or curved glass sheets measuring up to 3,200 x 2,000 mm, and of producing bending resistance of up to 600 mPa.

Chemical versus thermal

While heat tempering processes and the characteristics of heat-tempered glass are generally familiar, chemically tempered glass and its properties are slightly less well known.

When the glass is subject to traction, stress on the ends of microscopic grooves on the

Fig. 1 Iontech's chemical tempering plant



surface can easily lead to a spreading of the grooves until the glass breaks.

Industrial methods employed to improve the mechanical characteristics of glass are based on the introduction of a system of residual forces characterised by a state of surface pre-compression which is designed to counter the weakening effects of grooves.

This state of surface compression can be achieved by a process of tempering which can be thermal or chemical.

In heat tempering, the process is limited when:

1) The glass is less than 2.5 mm in thickness;
2) The glass has very complex shapes or dimensional characteristics;
3) The glass requires particular mechanical resistance characteristics;
4) The glass needs to be resistant to impacts of a certain degree;
5) The glass, as well as having mechanical resistance, must also have particular optical characteristics or a total lack of surface defects.

Chemical tempering makes it possible to overcome the limitations of heat tempering. Thickness and shape of the glass represent no problem, the glass remains perfectly flat (the tempering process takes place at temperatures below that at which sagging occurs), and clearly superior levels of tempering can thus be achieved.

The process itself

Chemical tempering is a surface treatment which is carried out at temperatures below that of vitreous transition. The glass being treated is lowered into a tank of molten potassium salts at a temperature of around 450°C, producing an ion exchange between the sodium ions on the glass surface and the potassium ions in the salt.

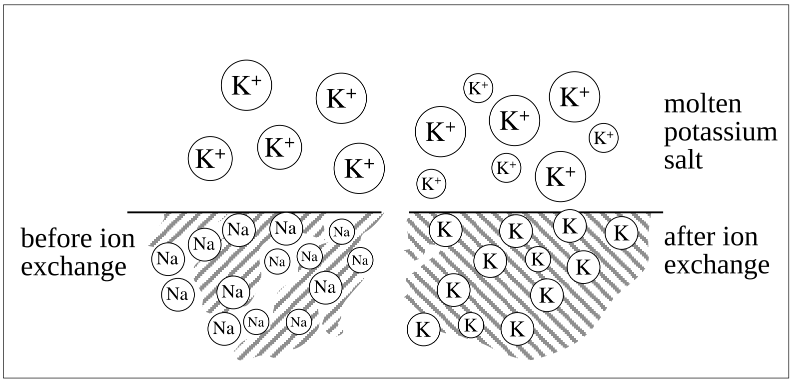


Fig. 2
Ion exchange in chemical tempering

The introduction of potassium ions which are considerably larger than the sodium ions brings about residual forces characterised by surface compression compensated for by traction inside the glass (see Figure 2).

Glass properties

The principal properties of chemically tempered glass can be examined on the basis of two parameters:

- *MOR* (modulus of rupture): this is the level of traction corresponding to the breaking load, which can be measured by means of either a bar bending test (ASTM C 158-95) or a coaxial bending test. This parameter is related to the original strength of untempered glass and to the pre-compression applied to the glass surface by ion exchange.
- *Depth of penetration* (the depth to which the glass composition has been chemically modified by the ion exchange): this parameter is to some extent related to the depth of glass subject to compression by the system of residual stresses introduced by the ion exchange (see Figure 3).

In Iontech's chemical tempering equipment, where the ion exchange process takes place, there is constant monitoring of the levels of tempering reached (in terms of both MOR and depth of penetration). The efficiency and the effectiveness of the chemical process of ion exchange are constantly checked to ensure that

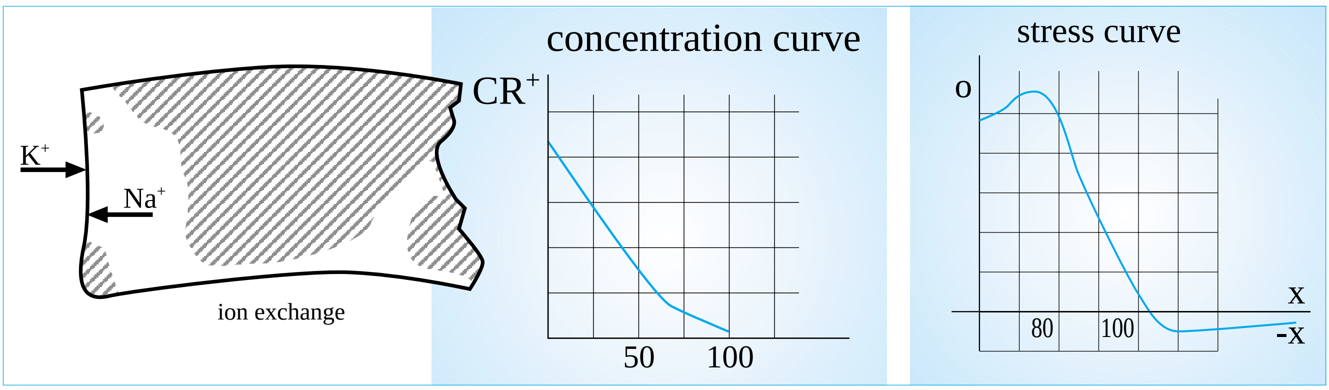


Fig. 3
Typical stress concentrations and formation

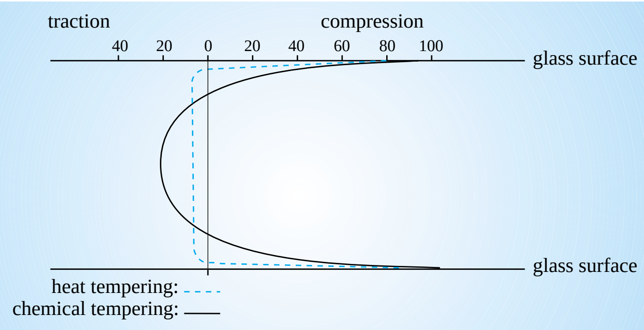


Fig. 4 Residual stress configuration

the final degree of tempering is the desired one.

Process parameters can be modified according to the type of glass to be treated and the tempering specifications required, thus guaranteeing optimal processing cycles.

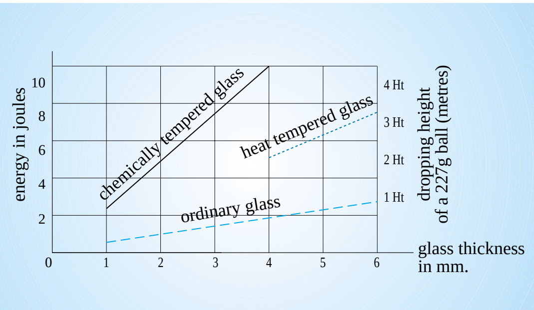


Fig. 5 Comparative impact resistance

Stress configuration

The configuration of stresses brought about in the chemical and thermal tempering processes differs (see Figure 4). In chemically tempered glass, surface tension is greater and depth less compared to heat tempered glass, while the traction inside the glass is lower.

Mechanical properties

The physical properties of chemically tempered glass can be summed up as follows:

Depth of penetration: *20-100 microns

Bending resistance

(MOR ASTM C 158-95): *300-600 mPa

[* The differences in penetration and resistance levels are related to the length of the heat cycle. Cycle programming is therefore determined on the basis of the particular requirements specified].

In simpler terms, if heat tempered glass withstands approximately five times the stress of normal glass before it breaks, chemically tempered glass withstands as much as 10-15 times the stress. As well as its resistance to bending, the other important characteristic of chemically tempered glass is its resistance to impacts. If a heat tempered sheet of glass has a steel ball impact resistance which is two and a half times that of ordinary glass, a chemically tempered sheet of glass can be up to five times as resistant (see Figure 5).

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GLASS STRENGTH: UNITS OF MEASUREMENT

To better understand and correctly interpret the figures indicated, the following are the international units of measurement for the stresses, pressures/tensions mentioned in the text.

Newton (N)*: This indicates the force necessary to give a mass of one kilogram (kg), an acceleration of one metre per second for each second.*

f *= m x a (force = mass times acceleration); in other words:*

1 kgf = 1 kg x 9.81 m/S^2 = 9.81 kg x m/S^2 = 9.81 N

for simplicity of calculation:

1 kgf = 10 N

with the multiples:

1 kN (kilonewton) = 10^3 N

1 mN (meganewton) = 10^6 N

Pascal (Pa)*: This indicates the relationship between a force and a surface:*

1 Pa = 1 N/m^2

In the definition of a material's resistance characteristics, the ***megapascal (mPa)*** *is used:*

1 mPa = 1 N/mm^2

The relationship between the international measurement system and the technical one can be expressed in the following equivalence factors:

1 kg/cm^2 = 0.1 N/mm^2 (mPa) = 10^5 N/m^2 (Pa)

1 N/mm^2 (mPa) = 10 kg/cm^2 = 10^6 N/m^2 (Pa)

psi *(pounds per square inch): The unit of measurement used to indicate the degree of surface compression of glass after the tempering cycle.*

1 mPa = 145 psi

1 psi = 0.07031 kg/cm^2