Analysis of defects of glass products

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Abstract. With the developing industry, the speed of technology advancement, there is a constant demand for innovation, streamlining the production process. One of the serious drawbacks and negatives affecting the input costs of the entire production process is the defectiveness of products, non-defectiveness and unforeseen, unplanned failures of elements in production. It is by unambiguous determination, definition and specification of the causes of product defects, with the use of innovative devices, that we can eliminate or eliminate these failures, defects. The article describes a case study in the glass industry and the exact definition of defects in glass products. Glass is one of the most famous technical products with exceptional properties, the development of which is linked to the development, production and service of glass in the industry, glass intended for aerospace and shipping companies, as well as for gastronomy and household. Of course, all with regard to its specific characteristic, which is certainly fragility.

1. Introduction

Glass is characterized by high light transmission in the visible part of the spectrum. At normal temperatures, this material is rigid and hard, but at the same time it is brittle. It is weather and chemical resistant, impermeable, has high compressive strength, relatively low specific thermal and electrical conductivity.

The glassy substance can be distinguished by two characteristic features:

1. The glassy substance does not have a regular arrangement over a long distance
2. A glassy substance is characterized by a characteristic transformation from a liquid to a glassy state and vice versa

The glass formation temperature T_f cannot be considered as a material constant because its magnitude depends on the cooling conditions. This temperature reaches higher values at higher rates of cooling of the substance. Hard glass changes viscosity rapidly as a function of temperature, but soft glass changes viscosity slowly, i.e. it is more ductile for longer. [1]

The melting of glass sometimes gives rise to areas of the glass phase that do not have the same properties and various defects in the glass occur. figure 1

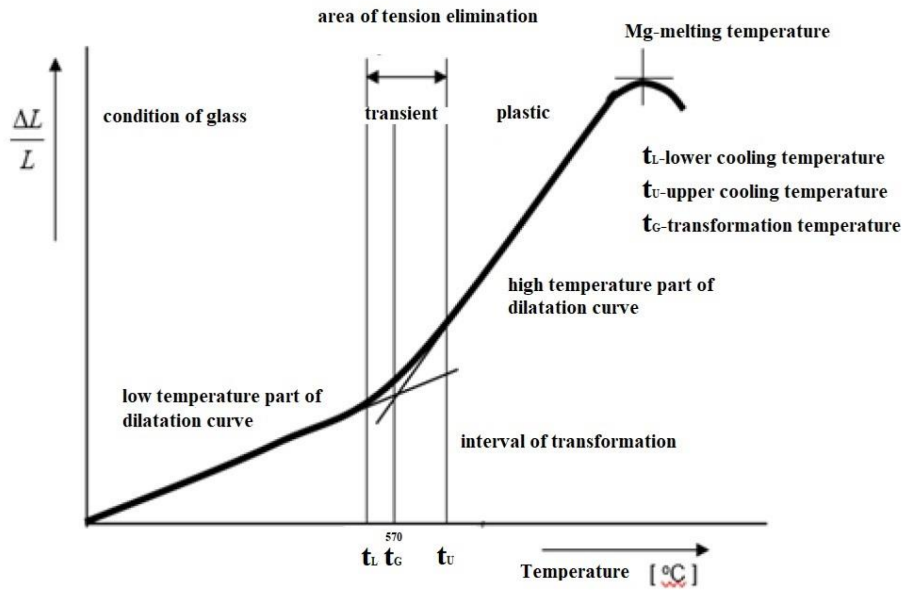

Figure 1 Dependence of the volume of a substance on its cooling temperature T_m-Temperature of crystallization, T_f - Temperature of glass formation [2]

2. Glass forming for light bulb

Shaping glass means permanently changing the shape. Forming can only be carried out after the processing temperature has been reached. If the temperature is lower, this can cause damage to the glass material or introduce strong stresses into the material, which are difficult to remove in the subsequent process. Important temperatures to consider when forming glass. figure 2

Type of Glass Glass forming temperatures [°C]	291 –Glass [°C]	360 – Glass [°C]	8487-Glass [°C]
Deformation point **The tension disappears within a few hours**	410	455	550
Cooling point **Tension disappears in 15 minutes**	445	485	580
Softening point **Glass cannot be deformed below this temperature**	460	500	600
Softening point **Glass deforms by its own weight**	635	675	775
Working point **Temperature for glass forming in the process**	1005	1020	1135
Melting point **Glass enters the liquid phase**	1510	1490	

Figure 2 Glass forming temperature [1]

In terms of the production of light bulbs, glass forming is primarily the production of glass tubes from enamel. The glass tubes are the basic semi-finished material needed to produce the glass parts of the bulb. The tubes are produced by drawing glass from the base material - enamel. The tubes are then moulded in a further process to produce the three or four basic glass components of the bulb**Figure *3***:

- banks,
- saucers,
- pumping tubes,
- beads (only in certain types of bulbs). figure 3

On the figure 3, it's just an illustration of the bulb concretely her detailed inside.

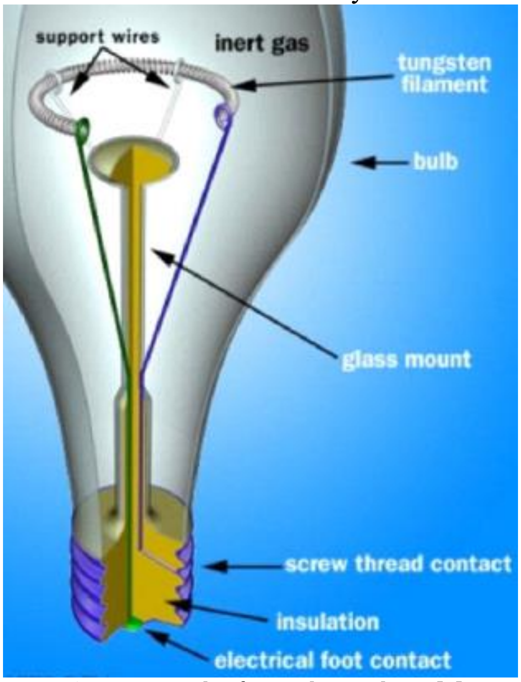

Figure 3 Details of incandescent lamp [3]

In the production of light bulbs, it is necessary to analyze the various influences on defects in the production. The input semi-finished saucer can affect the defects of the final products. figure 4 The defects can occur not only in the material used, but also in the production process.


Figure 4 Faulty input semiproduct – saucer

In the production of plates, a significant part is used for the production of car bulbs, where the demands on quality are extremely high. Defects in the final products can occur not only in the material used, but also in the manufacturing process. This leads to the search for ways to eliminate these defects, reduce economic costs and be successful on world markets. Errors arising in production can be divided into different categories. figure 5

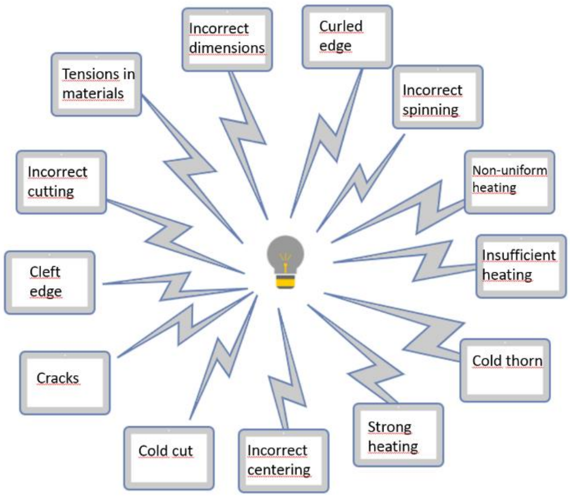

Figure 5 Defect in bulb production

3. Potential factors influencing confusion in production

The confusion in saucer production is conditioned by various causes related to the quality of input material, process setup, machine setup, human factor. The chemical composition of the glass in individual glass tube supplies can fluctuate and consequently affects the processing technology. In particular, the critical point is the plate spinning, quenching and cutting. Mechanical wear of the spinning mandrel or the cutting carbide knife causes permanent deformations in the forming process, which cannot be eliminated in the subsequent process. Improper hardening, i.e. improper cold air blowing of the platen, can cause insufficient or excessive stress in the platen. A plate without hardening becomes very fragile and, conversely, a plate that has been over-hardened tends to crack spontaneously in storage. The position and shape of the quenching head has an influence on the degree of hardening. This is given in the rebuild card, i.e. replacement of the quenching head or incorrect position is unlikely. A more likely cause of errors is an inappropriately set cooling air flow. This may be due to fluctuations in the compressed air pressure in the system.

For practice, it is advisable to address work process error rates through various analyses. One of them is to determine the cause and effect using the so-called Ishikawa diagram. It is used to show the relationship between problems (effects) and their possible causes. The main axis of the diagram represents the problem, the branches of the tree are formed by the individual effects that cause the problem. This diagram should become the first step in solving all problems that may be caused by multiple causes. The processing is simple and easy to understand, which leads to the involvement of a wider range of workers and provides ideas for new unconventional solutions. Teamwork using brainstorming is a prerequisite for effective processing of the cause and effect diagram. The involvement of lay people who are not burdened by 'operational blindness' is recommended. [4]

In the case of product quality problems, the following main categories are often used:

- material,
- equipment,
- methods,
- people,
- environment.

Decomposition of causes into "causes of causes" should be done until all root causes of the effect are revealed. Root causes can be considered as specific possible causes of a consequence that no longer need to be decomposed further and specific corrective or preventive measures can be proposed to address it.

The Ishikawa diagram procedure:

- The problem is clearly shown in the head of the fish.
- The backbone and ribs should be drawn.
- Continue to fill in the diagram by asking the question "why?" for each cause of the problem.
- Looking at the diagram and identifying the root causes.
- Suggesting actions to eliminate the root causes.

3.1 Impact on production error/confusion rates

In identifying the causes of errors in production, it is the machinery itself. In particular, the critical point is the plate spinning, hardening and cutting. Mechanical wear of the spreader mandrel or the cutting carbide knife will cause permanent deformations in the forming process, which cannot be eliminated in the subsequent process. Improper quenching, i.e. improper cold air blowing of the plate, can cause insufficient or excessive tension in the plate. A plate without quenching becomes very brittle and, conversely, an overquenched plate tends to crack spontaneously in storage. The position and shape of the quenching head affects the degree of hardening. The more likely cause of defects is an inappropriately adjusted cooling air flow. This may be due to fluctuations in compressed air pressure in the system. Here again, the human factor has a significant influence. figure 6

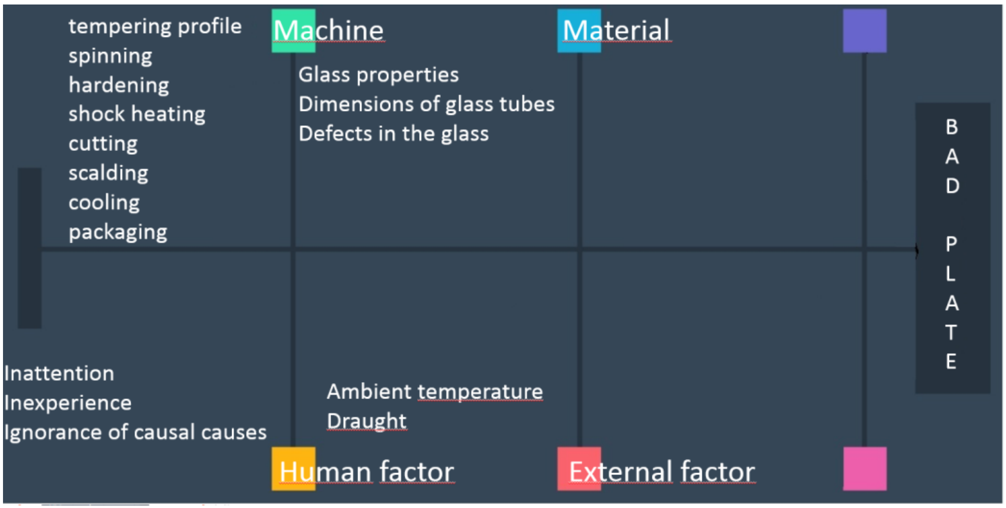

Figure 6 Factors influencing the error rate

3.2 Impact on the occurrence of cracked and broken plates

The causes are partly interacting and need to be understood holistically, as e.g. tension increases the risk of handling errors, faulty cutting can cause microcracks near the cutting edge and this in turn can cause microcracks. If the inserts are removed from the machine directly after the tempering furnace so that they do not touch each other until they have cooled completely, they show very good resistance to thermal shock. In comparison, removing the plates with metal (cold) tweezers also introduces some tension into the plate. The incidental contact of different hot plates with each other introduces a secondary point microstrain into the glass causing increased susceptibility to cracking. Figure 7

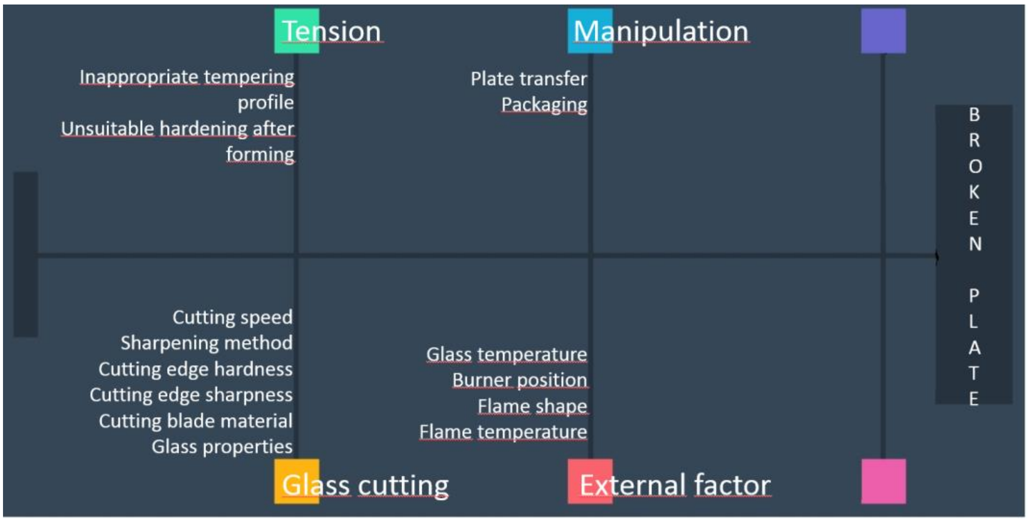

Figure 7 Factors involved in the occurrence of cracked and broken saucers

3.3 Causes of faulty cutting

Glass cutting is a specific problem. The cutting process itself consists of suddenly heating the glass locally with a hydrogen flame and then pressing a cutting knife against the glass, which with its sharp edge creates a fine indentation (tension) on the surface and the glass separates. The cut in the glass is actually made by the action of the micron errors of the knife on the surface of the glass. In doing so, a high point pressure is generated in the glass, which causes tiny chips on the surface of the glass. In the absence of these micro-porosities at the cutting edge, the knife must be pressed against the glass surface with more pressure, which can lead to macro chipping in the glass at the cutting point. figure 8

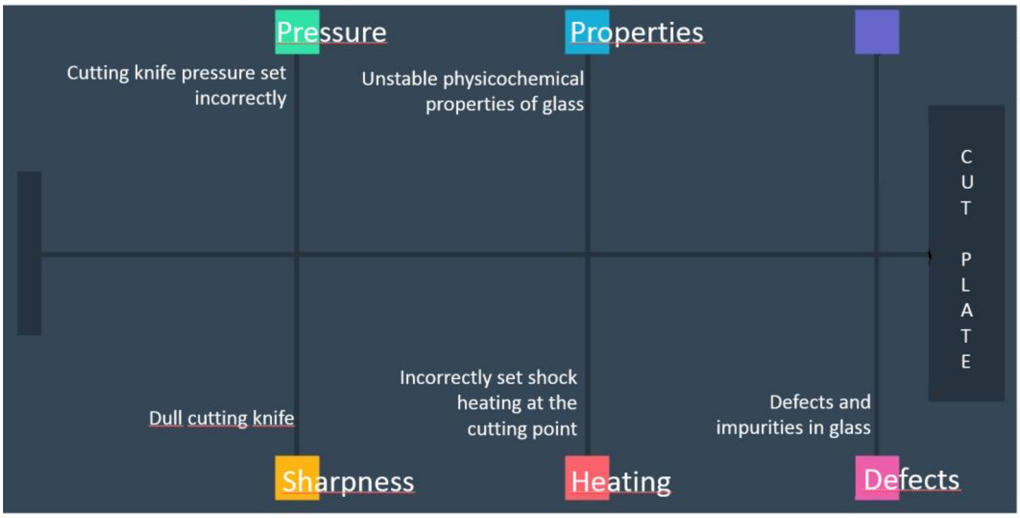

Figure 8 Causes of defective cutting

3.4 Causes of cracks in the plate spinning

The temperature at the point of glass forming is decisive for the occurrence of cracks in the plate. The temperature of the glass just prior to forming dominates the occurrence of expansion cracks. It is therefore necessary that this temperature is measurable continuously during the manufacturing process. The SO_2 flow rate in the burners also plays a role. Sulphur dioxide acts as a lubricant in glass forming. It can be shown experimentally that its effect on forming is significant. figure 9

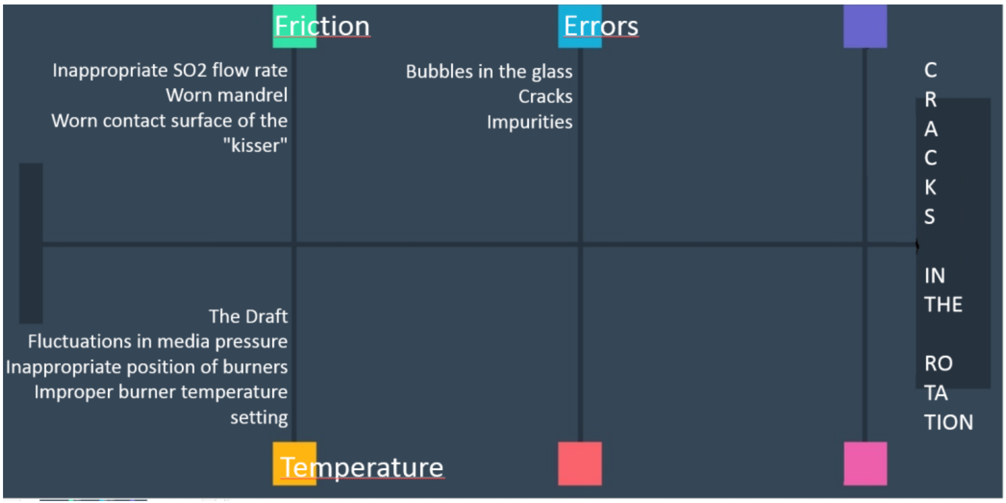

Figure 9 Causes of cracks in the spinning saucer

4. Results

When the analysis of the defective samples for the 12 months is made, it is clear that the largest share of the defective samples for the period under review is accounted for by cracked plates, accounting for up to 59% of the defective samples. During the work in the laboratory, the error rate of the glass plates was monitored and the different influences on the different error rates were evaluated through the Ishikawa diagram and then transferred to a graph. Cracks in the expansion are in second place with an error rate of 16%. Other defects in decreasing amounts are faulty cutting, broken plates, plate contamination, tension and reduced plate size. figure 10

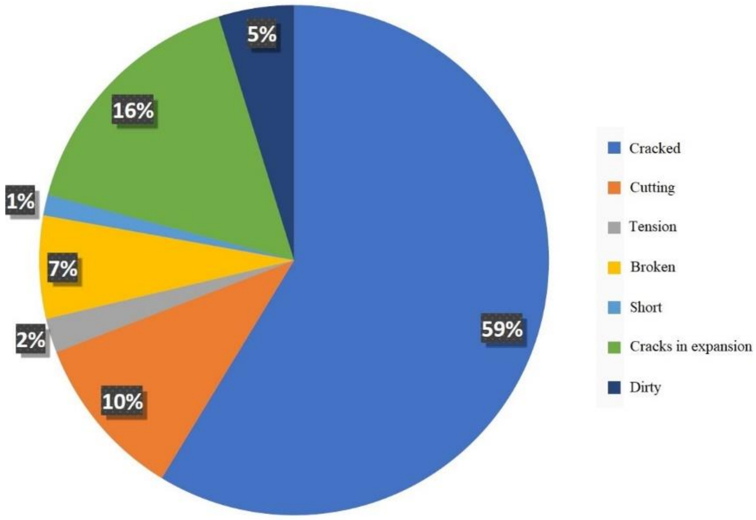

Figure 10 Percentage of individual causes of defective plate production over a 12-month period

5. Designing tools to make production more efficient

Summarizing the main errors affecting the production of glass semi-finished products affects:

- Reduction valves in the media distribution lines are unreliable.
- The handling of the plates after the tempering furnace is unsatisfactory.
- The method of adjusting the cutting knife pressure is inappropriate.
- The temperature of the glass prior to the forming of the tempering is not measured.
- There is no camera inspection of the production quality on the platemakers.

Proposals to address the elimination of the errors generated, taking into account the economic return of the measures.

5.1 Checking the heat resistance of the saucer (shock test).

During the production process it is desirable to include a shock test check in the inter-operational inspection. This test should be carried out by the set-up person operating the platemaker or by a person authorised to do so. The test should be carried out at least once a day and usually at the beginning of the shift after the machine itself has been checked and the quality of the production checked. The results of the check should be recorded on existing check cards. It is not economically advantageous to do a shock test every day on all machines, but other circumstances should also be considered. For example, loss of company reputation due to customer complaints, loss of time of other employees in quality, technology, logistics, etc. in dealing with complaints. Therefore, it is recommended to perform a shock test on the line regularly during normal production on a daily basis. For this purpose, it is necessary to allocate funds for the establishment of a permanent workplace and to designate a person to carry out this test on an ongoing basis. figure 11

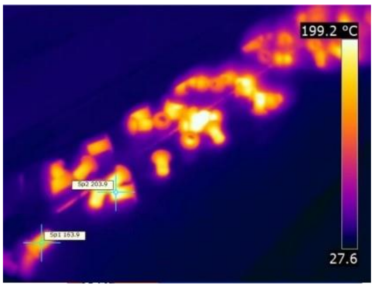

Figure 11 Shock test

5.2 Checking of pressure reducing valves in media distribution systems.

Control is carried out by mechanical diaphragm pressure reducing valves. In a check measurement of the stability of the pressures, which was carried out continuously over five consecutive working days on one machine, it was found that the stability of both compressed air and oxygen is satisfactory, but the fluctuation of the natural gas pressure is significant. The proposed corrective measure is to replace the existing pressure reducing valves with new ones, and to include a pressure stability check approximately once every 2 months in the regular maintenance schedule.

5.3 Changing the handling of plates after tempering oven.

In the production is the necessary to resolve transporting with gripping with the changed temperature. Some gripping criterions are removed but problem with higher temperature is not solved and have to be exist. For example, not to take with hand and anyone contact of human is not available. The way the plates are handled after falling out of the tempering furnace significantly influences the occurrence of cracked and broken plates in particular. Contact with differently heated plates introduces secondary stresses into the glass and this must be avoided. The smooth conveyor belt for removing the finished plates needs to be slightly redesigned. A metal baffle should be included in the drop-out path to narrow the existing width of the path from 10 cm to 4 cm. The baffle needs to be coated with Teflon film to reduce the thermal conductivity of the metal baffle. The modifications can be carried out relatively quickly and at minimal cost. The narrowing of the pathway results in less scattering of the incident plates on the pathway and ensures that hot and cool plates do not mix and touch each other. Figure 12 shows an unsuitable type of conveyor, where the glass saucers touch and on which additional thermal stresses are set when they fall out of the oven.

Figure 12 Movable plate removal belt from the tempering furnace

5.4 Cutting knife setting.

The pressure of the cutting knife on the glass surface creates a locally high pressure which causes micro-splinters on the glass surface. However, the hard surface of the glass will also cause the cutting knife edge to break off small particles. This gradually dulls. Excessively high pressure on a sharp knife at the beginning of the cutting process will cause rapid dulling of the cutting edge. Therefore, the force of the pressure should be continuously adjustable and repeatedly adjustable. In order to achieve this, a simple fixture must be made to hold the knife and adjust the pressure using an adjustable screw. A force gauge can be used as a pressure indicator. figure 13

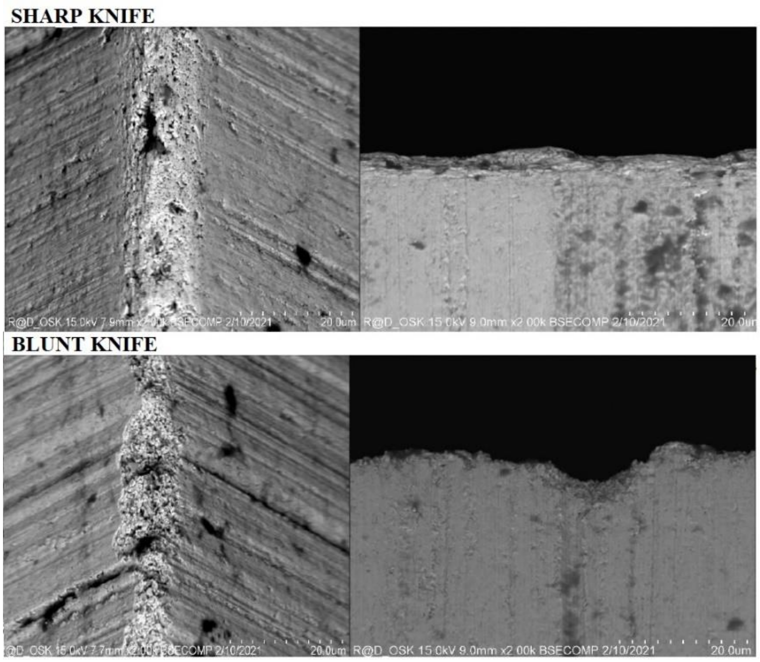

Figure 13 Comparison of dull and sharp knives

5.5 Control of the glass temperature before moulding

The glass temperature before moulding was experimentally determined to be 850 ± 10°C. It is necessary to control this temperature during the manufacturing process and to adjust it if necessary. For this purpose, it is necessary to install a suitable non-contact temperature gauge on each saucer. Of the available measurement methods, the pyrometer appears to be the most suitable. The important parameters of these instruments are the wavelengths of the radiation detected, i.e. to measure the actual temperature of the surface to be measured. The demands on the measuring instrument are high, as the instrument must be able to measure in the vicinity of intense heat sources. It must be resistant to flying fragments of hot glass. At the same time, in the vicinity of the measuring point, glass dust is produced from fine fragments which adhere to surrounding objects, i.e. also to the measuring device lens, and cause inaccuracy of the measurement over time. It is very important that the instrument is equipped with an optical system that can be focused on the surface to be sensed.

5.6 Camera quality control of production

The cameras reliably carry out inspection and subsequent sorting of non-conforming plates. When the inspection and sorting capability is measured, the sorting capability is found to be relatively high with respect to the main dimensions of the wafer, i.e. length and diameter of expansion. As for the crack detection capability, the situation is slightly worse here, the camera can only reliably detect cracks larger than 1mm. For example, it cannot detect cracks in the expansion at all. figure 14

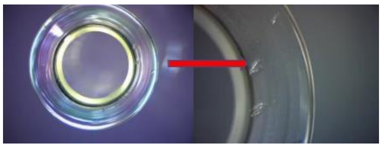

Figure 14 Cracks in the glass

6. Conclusion

The use of glass as a building material needs to be improved all the time. The development of glass technology leads to glass semi-finished products with higher mechanical strengths and in the required precision. Because of the fragility of the material, it is necessary to use knowledge of the mechanical properties of glass. In practice, innovations must be designed according to the ongoing production to ensure that the quality and quantity of the products are up to standard. Standards have to be met for different areas e.g. ISO 9001 Design, development, manufacture and sale of products for the lighting industry, IATF 16949 Design, development and manufacture of automotive lamps in accordance with customer specific requirements. Of course with consideration for occupational health and safety.

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