Construction and Safety Aspects of Glass Used in Aviation Transport

Konstrukcija i sigurnosni aspekti stakla koje se koristi u zračnom prijevozu

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Summary

Glass is an essential component of several sectors which significantly form our present-day economy. These include machining, the chemical industry, the electrotechnology industry, construction, the automobile industry, the aviation industry and many others. The aim of this article is to provide some detail about and explain the technology used for manufacturing glass which is subsequently used in the automobile and aviation industries and the specific adaptations which help to improve its characteristics. A general trend is increasing the share of final products having high added value, which is done by finishing glass with special processes of surface modifications, mechanical treatment and thermodynamic processes with targeted special traits, including a wide scale of functional coatings.

KEY WORDS
windshield glass
aviation industry
glass manufacturing

Sažetak

Staklo je osnovna komponenta u nekoliko sektora koji imaju značajnu ulogu u suvremenoj privredi. Ovo uključuje strojarstvo, kemijsku industriju, elektrotehniku, građevinu, automobilsku industriju, avioindustriju i mnoge druge. Cilj ovog rada je opisati i objasniti tehnologiju koja se koristi u proizvodnji stakla koje se zatim koristi u automobilskoj i avioindustriji, te specifične prilagodbe kojima se poboljšavaju osobine stakla. Postoji opći trend povećanja udjela konačnog proizvoda s visokom dodanom vrijednošću, što se postiže konačnom obradom stakla kroz specijalne procese modifikacije površine, mehaničkim tretmanom i termodinamičkim procesima kojima je cilj dobiti posebne karakteristike, uključujući široki spektar funkcionalnih premaza.

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INTRODUCTION

A good view in a straight direction is a basic demand with the development of glass design. But the designer must during its development also take its functional requirements into consideration, which include safety, a favourable weight, resistance, permanence and aerodynamic suitability.

Because of its difficulties in manufacturing, fragility and weight it is primarily used in places where a true and non-deformed optical perception of the surroundings is critically important for the driver or pilot. For other transparent surfaces polycarbonated material, so-called plexiglass, is used in certain cases, from which extremely resistant covers of jet airplanes are also made.

Float glass is a sodium-calcareous-silicate compound made from oxides of silicate, calcium, sodium and other metals. It is characterized by relatively high mechanical firmness, hardness and high light permeability. It has both surfaces parallel, with minimum curvature with a high reflective and glossy surface. It is resistant to water and other atmospheric influences. It does not contain a crystal structure and does not have a defined melting point. In general, it is made for more demanding glazing work, for the manufacture of mirrors, insulated double glass and mainly for the production of safety hardened and layered glass for buildings, automobiles and the aviation industry.

THE TECHNOLOGY OF SAFETY GLASS MANUFACTURING

Safety glass is understood to be glass that is able to maintain its integrity even under extreme physical and climatic conditions. The mechanical resistance of the glass can be increased up to a ratio of 3:4. The rupture of the glass in the case of breakage is many times less dangerous, because the shards that originate are small and their edges are not sharp enough to cut. But after hardening it is no long possible to cut a sheet of glass or to alter its shape. At present two methods of its manufacture exist; these are thermal and chemical tempering.[1]

HARDENED (TEMPRED) GLASS

The manufacture of hardened glass is seemingly very similar to the production of hardened steel, during which the steel, after heating to a critical temperature, is quickly cooled. The physical changes when tempering glass are diametrically different.The oldest, but still the most widespread method of mollifying the fragility of glass is tempering. During this process part of the energy from the atomic bonds in central (the highest quality) part of the glass are removed and led to marginal areas, where internal stress is concentrated during previous treatment. This transfer of energy, which prevents the spreading of surface cracks, can be carried out either by a thermal or chemical process.[1][7]

MECHANICAL CHARACTERISTICS OF TEMPERED GLASS

For achieving the desired quality and type of glass, which we label as hardened, tempered or safety glass, the creation of a value of permanent internal tension in the exterior or in the interior layers of a glass sheet is used. It still applies that the maximum value in extension is half the maximum value of compression. The relatively high value of a layer which is located in compression explains the strong increasing of the resistance of hardened glass in the curve. For example, with 5 mm thick automobile glass a mere 1 mm deep disruption of the surface is sufficient to lead to its complete destruction.[6]

This phenomenon explains why the use of tempered glass in the windshield glass of automobiles and airplanes has begun to decline. A sudden and unexpected change in visibility, the reason for which could be the instant destructive fragmentation with fissures of windshield glass from possible collision of gravel, a small stone, a flying object or only the curve of the frame of the glass with a sudden change of direction of a flight meant fatal consequences for the crew.

LAYERED LAMINATED GLASS

Due to the safety risks and growth of injuries from broken glass during accidents from the 1920s experimentation began with the joining of two or several sheets of glass using a flexible interlayer. The aim was to ensure safe and predictable behaviour after breakage, but also the reinforcing of the glass itself when stressed during a drive or a flight. Folios from polyvinyl butyral (PVB), ethyl vinyl acetate (EVA) and ionoplast (SGP) are typically used as the interlayer.[9]

For composing an individual set, which in transport aircraft consists of up to three sheets of glass, sheets must always be used which were bent to the required shape in a bending oven at temperatures near their melting point, which is about 600-620°C and subsequent rapid cooling in the same (unique) shape.

Therefore, it can be stated that each set is unique, although probably only with minimal deviations, and the use of external glass from one and the internal (which must be legitimately smaller) from another form could cause problems with the joints.

The application of a folio itself must run under laboratory conditions with consistent humidity and a dust-free environment, because any impurity is able to impair the entire set.

OPTICAL AND ENERGETIC TRAITS OF TEMPERED GLASS

Among the most important optical characteristics of glass is its solar permeability. According to the purity of the raw materials used, but mainly the influence of the presence of oxides causing the colouration of clear glass, the solar permeability of different colour shades can differ. As an example we present the

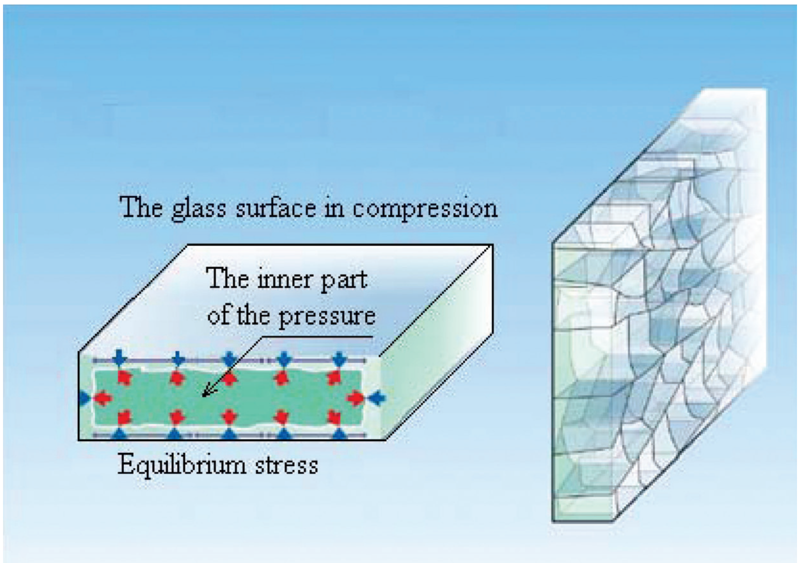

Figure 1 The glass surface in compression

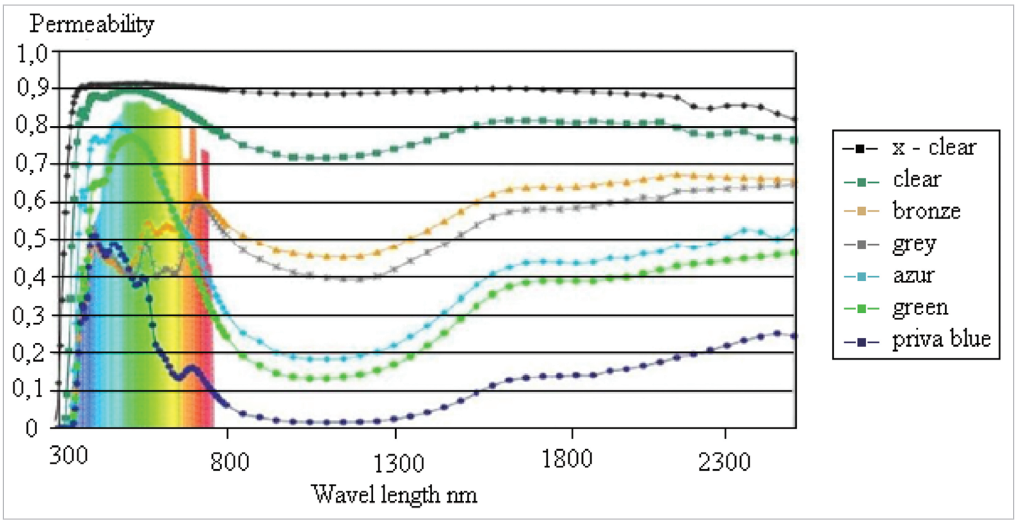

Figure 2 Chart light transmittance of each colored glass version

courses of solar permeability of the basic shades made for the European market by roughly 6 mm thickness.[6]

With respect to the different requirements for using the given glass (increased absorption or radiation, reflectivity, resistance against abrasion etc.) the resultant characteristics change depending on the surface modification of the glass used with application of thin layers of different chemical coatings. With their function of reflectivity they are able to absorb visible light, which is defined between wavelengths of length 380 to 780 nm. But they also influence the transitivity of the electromagnetic spectrum in the infrared area, when they protect a crew from dangerous infrared radiation, which is defined by wavelengths shorter than those in the visible range, but smaller than 1 mm. At high altitudes during a flight they thus also lower the unwanted warming of the pilot's cabin or the space for travellers. This radiation is able to activate secondary radiation matter located in the interior. Therefore, the higher reflectivity the glass has, the more its characteristic approaches the ideal state of maximum penetrability of visible elements of sunlight and minimization of the unwanted thermal amplification (from reflection or absorption) from this radiation. But it is not possible to achieve absolute elimination of thermal effects of light rays with full penetrability of visible elements. Therefore, a compromise between the transfer of the visible element of the sun's rays and its thermal effects must always be negotiated.[6]

It is possible to generally define radiation as the expanding of energy by space. According to electromagnetic theory we can label radiation by its wavelength λ (Lambda), or by the number of vibrations per time unit v (frequency). The speed of radiation spreading in a vacuum is about 2998.108 m/s.

These optical, in essence transparent, layers can be created by the metals gold, silver, copper, aluminium or alloys of metals and other inorganic substances creating dielectric layers. These coatings are applied to the interior parts of the glass before assembly and subsequent lamination, so that this coating is not destroyed by the working of atmospheric or other mechanical phenomena. This layer is applied by vacuum powdering using the magnetotronic method, when under high pressure the given material is deposited in a growing thin layer and a so-called sandwich structure is created. But in this way the created layers are extremely susceptible to mechanical damage and are labelled as "soft" layers.

In a graphical animation the visible functionality of the plated layer on penetrability of solar radiation through sheet of glass is clear.

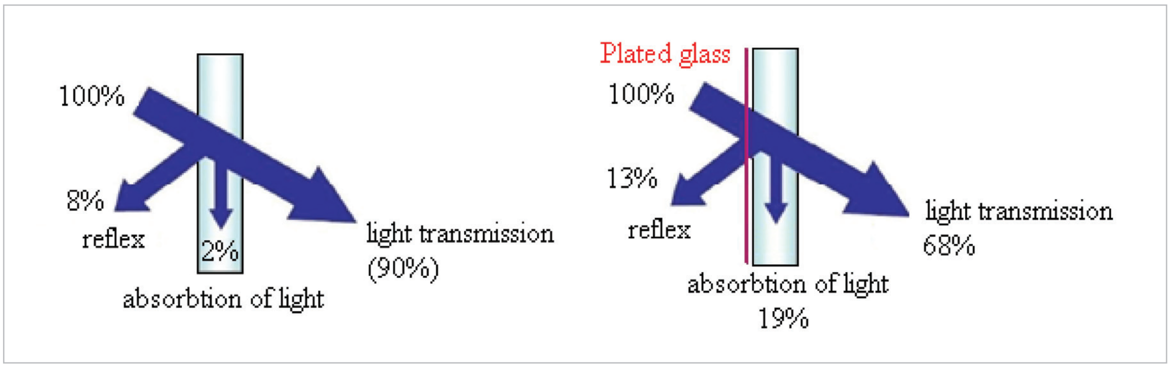

Figure 3 Comparison of light absorption on plated and non plated glass

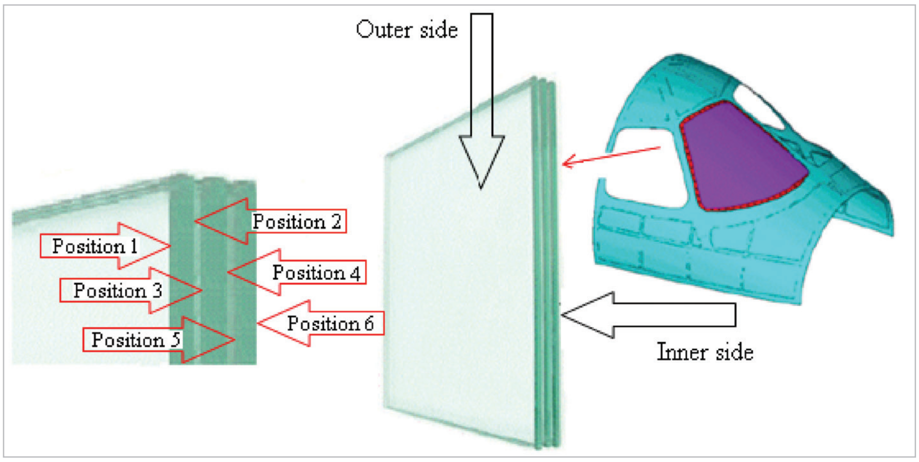

Figure 4 The numbering of the individual positions of the glass sheets

But a method still exists which is able to create a significantly more resistant surface layer. It runs in the phase of passage of the shaped glass strip from the tin bath at the beginning of the annealing oven, where hot air comes into contact with an environment which is enriched by gas, the organic-metal element of which at temperatures of about 600°C decays and creates a thin coating of the given oxide on the surface of the glass strip. But it is always necessary to note that such a modified layer is located in positions 2, 3, 4 or 5 (but this is most often in position 3 or 4 in windshield glass of airplanes).

An independent category comprises coatings with hydrophobic, hydrophilic and photocatalytic characteristics which mainly have the role in aviation of repelling smears and water, protecting the surface of glass, which is exposed to extreme climate changes, against corrosion. Polymers (silane or fluoropolymers) are used as materials. Although this coated layer is applied on the external layer of glass by the most modern method, the so-called CVD (chemical vapour deposition) method, with subsequent chemical hardening its resistance to mechanical damage is always notably limited. Therefore, a water-repellent solution is applied as a supporting system as needed for the flight.[5][8]

STANDARDS OF QUALITY FOR USE IN THE AVIATION INDUSTRY

Before the acceptance of the generally respected standard of quality in the aviation industry private corporations predominately used standard ISO 9000 together with corporations orientated on the automobile industry supplemented by its own specific requirements and documents, such as, for example, Boeing with its D1-9000 or the automobile industry with its individual Q standards (TQS, VDA). But this created a non-transparent mosaic of competing requirements, which were not generally comprehensible and mainly enforced with difficulty. Therefore, at the start, mainly large American companies specializing in the aviation industry, united in order to try to create a single unified standard of quality, which was labelled as AS 9000. The exactly same situation occurred in the automobile industry, where the international labour group IATF (International Automotive Task Force) was set up. This now came out of the updated standards required by ISO 9001 and created a completely specific standard under the label of ISO/TS 16949.[8]

In the year 2000 revision of aviation standard AS 9000, which is based on important organizational and philosophical changes of managing enterprises, was done at the same time as ISO 9000 (renamed to ISO 9100), from which it emerged and so revision C from January 2009 is at present valid as AS 9100.

The basic advantages of fulfilling the requirement of this standard are:

- Reducing the risk that a given service or component which causes an error or fatal failure is made.
- Improving the system of management of quality so that the requirements following from a contract are met.
- The company acquires access to the online supplier information system (OASIS)
- It gains the trust and credit of customers, which helps them during negotiation of new projects.

Certification according to these standards is a basic requirement for any company which wants to supply its service and products for the aviation industry. Other specialized standards come out of this basic standard.[8]

TESTING METHODS OF GLASSED-IN PARTS USED IN TRANSPORT AIRCRAFT

Each individual work must be subject to strict validation tests which simulate the most extreme loading and conditions during its life cycle. These tests are divided into the so-called optical tests, which have the role of confirming the required optical quality, and the functional tests, which simulate endurance and the required functions under all conditions. The execution and evaluation of tests comes from the requirements of the standard EN/AS/SJAC 9102x, which clearly defines the legal requirements of the individual regions.

But specific standards for individual regions, such as, for example, homologization for the US military, are devoted to individual circles of tests:

- MIL-W-81752 General standard for required specifications of windshield glass
- MIL-I-18259 Aircraft glass requirements
- MIL-STD-210 Climatic resistance
- MIL-STD-850 Aircraft vision requirements

- MIL-R-81367 Water-repelling systems requirements
- MIL-T-5842 De-icing requirements for windshield glass
- MIL-G-5485 Requirements for special bullet-proof glass
- etc.

We divide the stages of testing of an individual component into:

- development tests
- homologization tests
- validation tests on releasing to serial manufacture
- daily tests in serial production
- requalification tests

Basic types of tests:

- bird-strike simulation test, which represents striking by a metal ball weighing 1814 g. with a firing speed of 400 knots (740 km/h) at an altitude range for most birds (5000 feet / 1524 m)
- striking by crash-test dummy's head
- test of resistance to high temperature
- measuring of optical deformation
- test of separation of a secondary image
- light permeability
- resistance to abrasion
- resistance to radiation
- etc.

These tests are supplemented by others, depending on the nature of the product and its functions, such as electrical circuitry, built-in antennae, de-icing elements and the like. The results of tests are archived for a period of at least 15 years.[7]

CONCLUSION

Safety in aviation transport is one of the basic factors for its proper functioning. However, this isn't related only to safety with safety checks of travellers but also many other factors, and one of them is the safety aspects of the glass parts of an airplane.

The article explains and clarifies the basic facts about production, treatment, testing and building of the glassed-in parts of an airplane, which like all components are continually improved and made of higher quality.

All of the glass used today in the aviation industry is without exception laminated for its increased safety and endurance, which is guaranteed by legislative requirements of the individual countries with the help of homologization procedures, which have undergone several years of development.

The present trend for the future is the lowering the weight of glass while simultaneously increasing crews from the viewpoint of safety, temperature and acoustic comfort of travellers. Glass itself is continually in a greater measure supplemented with now standard accessories, such as heating elements, alarms, antennae as well as cameras, or so-called head-up displays. Thanks to the continual improvements builders are able to increase the share of glass surfaces while preserving sufficient toughness and strength of the airframe itself.

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