The influence of glass and metal properties on the peculiarities of an item of art’s shaping in ethnostyle

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Abstract. Modern esthetics dictates the domination of glass and metal not only in architecture. The topicality of artistic material processing technologies’ synthesis is demanded in different spheres of interior, environmental and jeweller’s design. The objective of the work is the comparative analysis of different methods of joining glass and metal and practical recommendations on items’ production on their basis on the pattern of items of art taking into consideration these materials’ properties. The influence of technological and material conditionality on an item’s shaping is revealed in solving the problems of a design object’s visual-tactile sensing.

1. Introduction

The history of creating glass and metal items of art starts from stained-glass windows’ making. The technology of coloured pieces of glass’ joining together by means of small H-shaped leaden stripes was worked out in the VI th century. Scientists of different countries are still interested in stained-glass windows’ production technique of the medieval period [1, 2]. The possibilities of glass and metal’s joining together in the modern world are not restricted to stained-glass windows and are realized in a great variety of spheres of interior and environmental design, the design of art-objects and jeweller’s technique. The production combining a metal foundation and a glass surface (tables, decorative panel) is widely spread in interior design, and glass and metal synthesis is seen in street lamps and stained-glass window compositions in environmental design.

The peculiarities of glass and metal items of art’s shaping are described in this article. On the one hand, the topicality of the work is conditioned by the necessity of harmonious and esthetically expressive objects’ creating. On the other hand, it is conditioned by technological factors’ influence on such products’ shaping. One must take into consideration the properties of items combining glass and metal when choosing the technology of their production.

The objective of the work is the comparative analysis of different methods of combining glass and metal and practical recommendations on items’ producing on their basis on the pattern of items of art taking into consideration the properties of these materials.
Technological and material conditionality are chosen for items of art’s esthetical characteristics in the work [4]. Technological conditionality characterizes the correspondence of an item’s form to the materials and technology. Form’s plastic must correspond to materials’ properties. Thus, form’s rigid graphic is possible and justified for metal items, and soft outlines and big radiuses of details’ junction are preferable for glass items, which are shaped in a plastic state. Form’s plastic is also determined by the method of an item’s producing. Glass items produced by the method of free shaping have more soft and fluid forms than pressed. Metal items produced by casting method are characterized by contour softness as compared to items produced by cutting method.

Material conditionality characterizes the correspondence of a material to its function and displays the level of decorative qualities (colour, transparency, facture, etc.). The oxides of different metals (chromium, vanadium, copper, nickel, cobalt, iron, manganese, titanium, cerium), selenium, and sulphur as well as sulphureous chemical combinations of lead, copper, cadmium, and iron are used for coloured glass’ production. Using these combinations, one can get different tints and colours: green, violet, milky, red. The surface of an item is covered by paints, or special methods of surface treatment (chemical, electrochemical or heat treatment) are used for the diversity of colour. Facture as a property of material characterizing form exterior structure is estimated through visual-tactile perception – roughness, smoothness, relief, lustre, dullness, etc. [5]. Modern technologies allow one to produce most diverse factures on glass and metal’s surface.

2. Methods of Joining Glass and Metal together, Taking into Consideration their Properties

There are two main methods of joining glass and metal together, which may be conditionally subdivided into “cold” and “hot”. The cold method is glass processing in a solid state and joining it together with metal by special glues or pastes. A variation of this method is a mechanical joining of glass and metal with the help of screws, through resiliency of the mechanical construction as well as combined technologies. The advantage of the cold method is a relative simplicity in the technological aspect and the fact that there are practically no restrictions on the dimensions of an object. Agglutination in interior design has a great preference over other technologies of joining due to the simplicity of the equipment and the absence of restrictions on the dimensions of an object. It is also applied when glass is laid on metal and when metal is laid on glass. A glue joint is absolutely invisible, that is why it is the most preferable one for the production of objects, the main function of which is esthetic. The imperfection is the necessity of obligatory preparation of glued surfaces and the absence of distortion of the junction’s geometrical form in the process of production and exploitation of an item. Besides, a relatively low thermal capacity and small elasticity are typical of glue joints, which lowers exploitation characteristics.

The method of hot joining is devoid of these faults. When applying this method, glass is in a molten or softened state. Processes of physico-chemical nature are the basis of glass and metal’s soldering. Moistening of metal with a liquid glass is made by its spreading over the metal’s surface and also due to surface tension forces. The technological problem of items’ producing by this method is thermal stress in glass and metal soldered joints. Residual stresses resulting from the interaction of heterogeneous materials with different properties can lead to cracking of an item.

The values of thermal expansion coefficient (TEC) characteristic of some glasses and metals are given in table 1. According to the correlations of glass and metal’s TEC soldered joints are subdivided into coordinated and non-coordinated. In coordinated soldered joints the difference between glass and metal’s TEC doesn’t exceed 10 % in the whole interval of temperatures to which the joint can heat or cool in the process of production or exploitation. Non-coordinated joints are those which TEC values differ greatly. The comparative characteristics of technological and decorative properties of the values given in the table shows that such widely spread metals as aluminium, iron, copper as well as alloys on their basis differ greatly in thermal expansion coefficient from glass. Glasses of different structure also have a large dispersion of coefficients’ values. If one views the most widely spread silicic glasses, which are mostly used in glass items’ production, one can see that an average TEC value is at an
interval of $85 - 90 \times 10^{-7}$, deg$^{-1}$. In that case the choice of metals suitable for soldering with glass is very limited from the point of view of the joint’s coordination.

**Table 1.** Characteristics of glass and metals’ technological and decorative properties

| material | TEC $\times 10^{-6}$ deg$^{-1}$ | temperature of melting(softening) | colour | facture | light-reflecting capacity and transparency |
|----------|---------------------------------|----------------------------------|--------|---------|------------------------------------------|
| metal    |                                 |                                  |        |         |                                          |
| Al       | 24                              | 660                              | mono-chromaticism | depends on the value of surface microdistortions | intransparency | dull lustre |
| Cu       | 16                              | 1083                             |        |         |                                          |
| Fe       | 12                              | 1538                             |        |         |                                          |
| glass    |                                 |                                  |        |         |                                          |
| of silicate | 9                           | $\approx$600                     | diversity of colour and tints | smooth, soft | transparency of different degree |
| of quartz | 1                             | $\approx$1400                    |        |         |                                          |
| leaden   | 10                              | $\approx$565                     |        |         |                                          |

3. Results and Discussion

Two items of art made of glass and metal are chosen as the objects of investigation. The item in the form of a table is produced according to the cold method by means of gluing a metallic semi-manufacture and a tempered glass together. Metallic semi-manufacture’s producing has different levels of mechanization and automation depending upon the technologies, which may be conditionally subdivided into plane and volumetrical. Plane technologies are those where two-dimensional details are worked up; in the case of volumetrical technologies – three-dimensional details. Plane are the most productive ones, wholly automatic. The basis of volumetrical technologies are different kinds of casting. In that case a metallic half-finished product is made according to the technology of artistic forging with the use of soldering for joining the elements of the construction together.

First of all, a glass upper surface of a table is cut according to the dimensions, and then it is thermally treated by a special mode of operation to temper it. It is well-known that a tempered glass differs from untempered not only in an improved mechanical and thermic resistance, but also in its safety. The safety of such glass is determined by the fact that it breaks to pieces with blunt edges when hitting.

![Figure 1. Glass and metal items of art: (a) table (Denisov M.), (b) decorative panel (Soroka A.)](image-url)

The second item of art made by one of the authors is the most complicated one in the technological aspect of joining glass with metal. A combination of two methods is applied here. A metallic foundation is made according to the technology of casting by means of pouring of a liquid brass with
further crystallization. Casting to smelted models is a kind of artistic casting which is applied for producing thin-walled, complicated in their configuration mouldings. The background of the pendant is made by fusing technology, which foresees conglomerating of glass of one and the same composition, but of different colour in that case into one volumetrical composition. Such properties as the temperature of glass softening, the temperature of an item’s virtual deformation and thermal expansion coefficient become the most important ones in glass conglomerating. Some characteristics of the glass used in the work are given in table 2. The calculations are made with the help of SciGlass 7. Calculated values of glass thermic properties allowed us to determine the temperature conditions of its treatment. Such characteristics as glass length and crystallization index point at glass behavior in the process of heating and cooling of an item. Index 20 corresponds to glasses with low crystallization capacity and glass suitableness to mechanized moulding. Glass length of 808 °C corresponds to slowlyhardening glasses. The temperature of softening defined by Littleton’s method (thread lengthening under the influence of its own mass when heating) corresponds to glass viscosity of 10^-6 Pa.s. The values of refractive index and light scattering coefficient are characteristic of glasses of silicate composition.

| Glass composition, oxide content, mass fractions % | SiO_2 | Al_2O_3 | Fe_2O_3 | CaO | MgO | Na_2O | K_2O | SO_3 |
|--------------------------------------------------|-------|---------|---------|-----|-----|-------|------|------|
| 72.18 | 1.09 | 0.04 | 8.85 | 3.60 | 13.62 | 0.26 | 0.35 |

| Glass properties | TEC up to 400 °C, 10^-6, deg^{-1} | optical refractive index | light scattering coefficient | glass “length” of fusion | crystallization index of virtual deformation | temperature, °C | Littleton’s Littletone’s | refractive index | light scattering coefficient | glass “length” of fusion | crystallization index of virtual deformation | temperature, °C | Littleton’s Littletone’s |
|------------------|---------------------------------|------------------------|-----------------------------|-------------------------|-----------------------------|-----------------|------------------------|-----------------|-----------------------------|-------------------------|-----------------------------|-----------------|------------------------|
| 9.14             | 1.516                           | 0.00871                | 808                         | 20                      | 605                         | 634             | 726                    |

The technological process of soldering glass and metal includes the following main operations: preparation of the materials’ surface to soldering; annealing of a soldered joint; control of an item’s quality. Glass and brass used for the panel’s production have TEC values of 9.14 · 10^-6 and 18.9 · 10^-6, deg° correspondingly. This tells about a non-coordinated joint’s making and the possibility of dangerous stresses’ formation. This problem is solved by means of a differentiated annealing of an item. For this purpose the difference in temperature is supported, so that thermal pressing of metal and glass would remain approximately the same during the whole process of cooling of an item combining glass and metal.

Glass items of art’s producing by the method of conglomerating allows one to get different decorative effects. For example, one can make large stained-glass windows by means of fitting glass panels produced by agglomeration method on a metal or combined frame. Agglomeration method can be combined with glass sheet bending in fireproof ceramic moulds. An interesting decorative effect is achieved if one fills hollows in the mould by crushed glass of the same composition as a sheet which is laid upon it. Two items made by the method of fusing and conglomerating of glass on a metal foundation are represented in figure 2. The decorative panel representing a strength joint of several layers of coloured glass is produced by means of partial fusing of one piece of glass into another under a temperature of 750 °C preserving its configuration. A glass with both a reflecting facture and a smooth transparent surface is chosen for obtaining a volumetrical image. The main means of artistic expression in that case are local colour stains of glasses. The substrate of coloured glass let us to add an emotional content of colour palette consisting of turquoise, dark blue and sky blue tints to cast metal’s graphics.

According to the depth of an item’s decorating one can single out three main groups: deep, surface and intermediate (Table 3). The criterion of classification is the depth of the factor’s spreading over an item’s thickness. In deep technologies the decorative factor (colour) is spread over the whole thickness...
of an item or its element – in the case of fusing. In surface technologies colour is concentrated in a thin surface layer. Surface technologies are presented mainly by decol and paintings [7]. Intermediate technologies unite different kinds of mechanical treatment and chemical etching as well as their combinations [8]. The decorative factor in that case is the relief and facture of the surface.

![Figure 2. Glass items of art produced by: fusing – on the left, agglomeration – on the right (Soroka A.)](image)

Table 3. Comparative characteristics of a decorative effect in glass items of art

| Group        | Peculiarities of a decorative factor | Automation | Decorative effect                      | Level of effect |
|--------------|--------------------------------------|------------|----------------------------------------|-----------------|
| deep         | is spread over the whole material’s or layer’s thickness | low        | purity of colour detailed drafting of the pattern | high middle     |
| intermediate | controlled depth of a decorative factor is concentrated in a thin surface layer | middle     | relief of the surface                   | high            |
| surface      |                                      | high       | purity of colour detailed drafting of the pattern | middle high     |

Thus, different techniques of production of items of art combining glass and metal exist nowadays. One can single out three main groups of these items. The first one is glued items of sheet glass on a metal foundation. The second – items of volumetrical pieces of glass joined together by means of conglomerating and soldering. Combined techniques of joining refer to the third group. The influence of technological and material conditionality on items of art’s shaping is revealed first of all in solving the problems of a design object’s visual-tactile sensing.

4. Resume

The comparative analysis of different methods of glass and metal’s joining allows us to give the following practical recommendations on items of art’s production on their basis.

1. When producing items of art by means of hot joining of glass and metal, taking into consideration the fact that thermal expansion coefficients of glass and metal differ more than in 10 %, it is worthwhile using a differentiated annealing. This allows one to avoid residual stresses, which lead to defects in a finished item.

2. Glue joining of glass and metal is a relatively simple one in a technological aspect, it doesn't require choosing materials according to TEC values and is suitable for large objects. However, an
additional technological operation of glued surfaces’ preparation and the absence of a joint’s geometrical form’s distortion are obligatory in production and exploitation of items made by a cold method.

3. The combined method, which foresees soldering of glass and metal and agglomeration of glasses of different colour, allows us to produce different decorative effects of colour spreading over an item’s thickness and facture. The combined method can be supplemented with other different methods, mechanical and chemical decorative treatment of glass, which allows one to improve esthetic qualities of a design object’s visual-tactile sensing.

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