Feb. 9, 1971 R. L. AYRES 3,562,383

METHOD FOR PREVENTING EDGE DEFECTS IN COMPRESSION STRETCHED ACRYLIC SHEETS

Filed Sept. 9, 1968

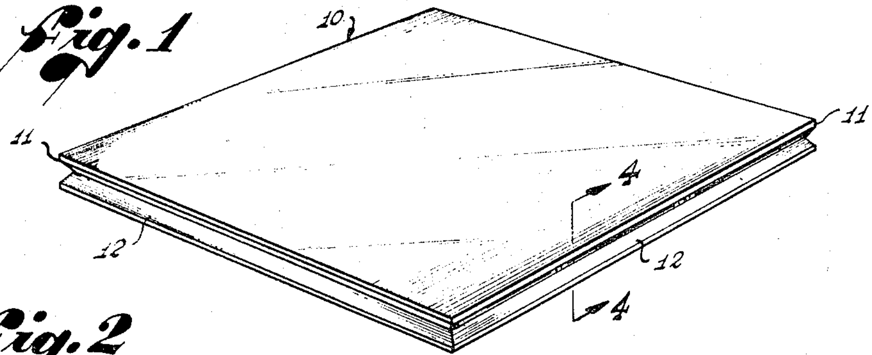

Fig. 1

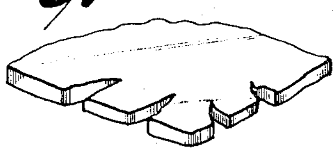

Fig. 2

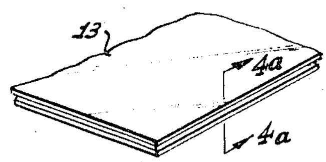

Fig. 3

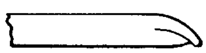

Fig. 9

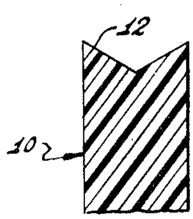

Fig. 4

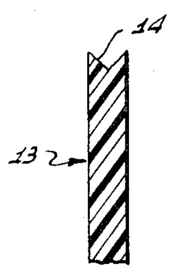

Fig. 4a

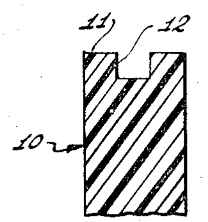

Fig. 5

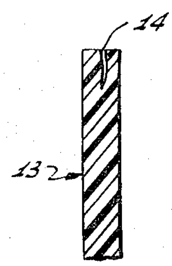

Fig. 5a

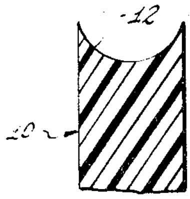

Fig. 6

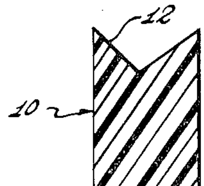

Fig. 7

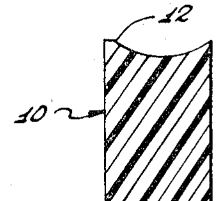

Fig. 8

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METHOD FOR PREVENTING EDGE DEFECTS IN COMPRESSION STRETCHED ACRYLIC SHEETS

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U.S. Cl. 264—296 8 Claims

ABSTRACT OF THE DISCLOSURE

A method which comprises providing an acrylic blank with a circumferential groove having a depth of at least 5% of the initial thickness of the blank and thereafter compressing the blank to cause the acrylic material to flow outwardly from the center of the blank to produce a compression-stretched sheet having less thickness than the blank. This method reduces edge defects in compression stretched acrylic sheets.

BACKGROUND OF THE INVENTION

This invention relates to stretching of acrylic sheets and, more particularly, to the prevention of edge defects in stretched acrylic sheets.

Because of its strength, formability, and light transmission characteristics, acrylic material has a variety of uses and particularly has been used to form windows and canopies for aircraft. Manufacture of the acrylic part often involves a stretching step in which the acrylic material is heated and stretched to enhance its physical characteristics and/or to provide the acrylic part with a required curvature. Heretofore, stretching of acrylic blanks has been accomplished by either pulling the edges of the acrylic blanks in opposing directions such as is described in U.S. Pat. Re. 24,978 of Bottoms et al. or of compression stretching acrylic blanks as described in U.S. patent application Ser. No. 691,294 of Terry D. Fortin, filed on Dec. 18, 1967. Regardless of the way in which the acrylic blanks are stretched, stresses are set up in the edges of the acrylic blanks which cause cracking and subsequent loss of material around the edges of the acrylic blanks. Additionally, such edge cracks can propagate throughout the stretched sheet, thereby resulting in a near total loss of the acrylic part.

To reduce losses from acrylic blanks stretched by the tension method described in the above-mentioned Bottoms patent, the edges of the acrylic blanks have been cooled relative to the remainder of the acrylic blank as the acrylic blank is stretched. This method has reduced the material lost when stretching by this method. However, other stresses are produced in the stretched acrylic sheet due to the temperature differential between the edge and interior sections of the stretched acrylic part.

To the best of the knowledge of the instant inventor, no methods have been previously used to prevent edge losses when stretching acrylic blanks by the compression method described in the aforementioned Fortin application.

SUMMARY OF THE INVENTION

The method of this invention comprises providing the circumferential end surfaces of acrylic blanks with a substantially continuous groove therein. The depth of the groove is at least about 5% and, preferably, is greater than about 10% of the initial thickness of the acrylic blank. The groove may have a variety of configurations such as, for example, V- and U-shaped configurations and the centerline of the groove may be offset from the centerline of the circumferential end surfaces. However, it is preferable to position the groove so that its center-line corresponds with the center-line of the circumferential end surfaces.

The grooving of acrylic blanks as described is relatively easy to accomplish and the machining producing the groove apparently sets up no noticeable stresses in the edges of the acrylic blanks. In spite of its simplicity and ease of accomplishment, the method of this invention has been extremely successful in substantially eliminating losses from the edges of compression stretched acrylic sheets.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a perspective view of an unstretched acrylic blank showing one form of circumferential end groove of this invention formed therein;

FIG. 2 is a partial perspective view of a compression-stretched acrylic sheet which was stretched from an acrylic blank having no circumferential end groove therein (i.e., prior art);

FIG. 3 is a partial perspective view of a compression-stretched acrylic sheet stretched from the acrylic blank of FIG. 1;

FIG. 4 is a partial sectional view of the unstretched acrylic blank of FIG. 1 taken along the lines **4—4** of FIG. 1;

FIG. 4*a* is a sectional view of the stretched acrylic blank of FIG. 3 taken along the lines **4*a*—4*a*** of FIG. 3;

FIG. 5 is a sectional view of an acrylic blank provided with another form of circumferential groove of this invention but different in shape from the groove of FIG. 4;

FIG. 5*a* is a sectional view of that portion of the acrylic blank shown in FIG. 5 after being compression-stretched;

FIGS. 6, 7 and 8 are sectional views of unstretched acrylic blanks having variously shaped and positioned circumferential end grooves of this invention; and

FIG. 9 is a partial elevational view of a stretched acrylic sheet showing "edge roll' produced from compression stretching.

DESCRIPTION OF THE PREFERRED EMBODIMENT

The method of this invention comprises providing the circumferential end surfaces of acrylic blanks with a groove which is substantially continuous therewith. The depth of the groove is at least about 5% and, preferably is at least about 10% of the initial thickness of the acrylic blank. Various configurations, e.g., V- and U-shaped and rectangular configurations, may be used. Preferably, the center line of the groove lies along the center line of the acrylic blank taken in the thickness direction.

Acrylic blanks having the aforedescribed groove may be heated and compression stretched as described in the U.S. application Ser. No. 691,294 of Terry D. Fortin, filed Dec. 18, 1967 (hereafter referred to as "said Fortin application"). When acrylic blanks are grooved and stretched in this manner, the resultant stretched acrylic sheets exhibit substantially no edge defects. Therefore, the loss of acrylic material is substantially eliminated. In acrylic blanks which are not provided with the groove of this invention, the edges of the acrylic blanks, after being stretched by the method described in said Fortin application, often are highly stressed resulting in weekened or cracked edges (FIG. 2).

Acrylic blanks stretched according to said Fortin application are heated to their softening temperature range and, thereafter, compressed to cause the acrylic material to flow or squeeze radially outwardly to form a stretched acrylic sheet of reduced thickness. It is believed that the undesirable edge defects result from the partially molten edges of the acrylic blanks "rolling" non-uniformly outwardly from the central portion of the acrylic blanks. This "rolling" of the outer edges apparently takes place at a rate faster than the radially outward movement of the remainder of the acrylic blank. This differential rate of movement is believed to be the cause of the stresses and cracks which are introduced into the edges of the stretched acrylic sheet. The success of the groove of this invention in preventing fracturing of the edges of compression stretched acrylic sheet is believed due to the restraining of this "edge roll" due to a change in edge forces which is, in some manner, derived from the aforedescribed circumferential grooving. That is, it is hypothesized that the initial compression forces exerted on the grove exceed the non-uniform outward forces which tend to create edge roll, thereby restraining outward flow of the edge material so that its outward flow is substantially equal to the outward flow of the remainder of the acrylic blank as the blank is stretched.

The method of this invention will now be more particularly described with reference to the figures. In FIG. 1, the numeral **10** designates an as-cast acrylic blank which has a circumferential end surface **11**. The term "acrylic blank" will be employed herein, and in the claims, to denote unstretched acrylic material. The end surface **11** of the blank **10** is provided with a continuous groove **12**. Some improvement in the edges of compression-stretched acrylic sheet may be produced regardless of the shape and size of the groove **12** in the acrylic blank **10**. However, it has been found that if the depth of the groove is less than about 5% of the initial thickness of the acrylic blank to be stretched some cracking and splitting of the edges always occurs. Above about 5% but below about 10% of the original thickness, some edge roll is still present and the latter is sometimes accompanied by limited cracking of the acrylic material. However, there is significant improvement as compared with stretched acrylic in which no circumferential grooves were formed. By comparison, acrylic sheets stretched from blanks having circumferential end grooves of depth greater than about 10% of the blank thickness, substantially always exhibit no edge defects.

As used herein, the term "edge defects" refers to a random, uneven stressing, cracking and/or breaking of the edges of stretched sheets as shown, by way of example, in FIG. 2. Such edge defects can result in substantial loss of acrylic material. While the shallow circumferential grooves which may be present around the edges of acrylic material after it has been stretched by the herein-described method, such as shown in FIG. 3, and constitutes a loss of material, such loss is only a minor fraction of that due to uneven stresses and other edge cracking. This loss is minimal because the shallow grooves extend a uniform distance into the material and are not accompanied by cracking, stressing, etc., which would necessitate the removal of good material in order to remove stressed or cracked as in the case with stretched sheets exhibiting "edge defects."

A section **13** of an acrylic sheet originally having a shape and edge groove **12** such as is shown in FIG. 1, is shown in FIG. 3 after being compression-stretched. In addition to having a reduced thickness as compared with the blank **10** of FIG. 1, the stretched sheet **13** has a much smaller edge groove **14**. The smaller groove **14** is produced by the filling in of the original groove **12** as the acrylic blank **10** is compression-stretched. The latter is further shown by comparing the grooves **12** of FIGS. 4 and 5 with the grooves **14** of FIGS. *4a* and *5a*, respectively. As will be seen from this comparison, the stretched sheets **13** of FIGS. *4a* and *5a* have substantially smaller grooves **14** than the acrylic blanks **10** of FIGS. 4 and 5.

It has also been found that the most advantageous results are obtained when the grooves in the circumferential end surfaces of the blanks are symmetrical about the plane passing through the center-line of such surfaces as shown in FIGS. 4, 5 and 6. That is, optimum results are produced when the maximum depth of the grooves is located at the center-line of the circumferential surfaces and the center-line of the groove corresponds to the center-line of the circumferential surfaces. With this optimum positioning of the grooves in the blanks, the material which has to be removed from the edge of the stretched sheet to remove any shallow grooves remaining after compression is minimized, as compared with an asymmetrical groove as shown in FIGS. 7 and 8.

The shape of the groove does not appear to be critical. Grooves of various cross-sectional shapes, e.g., V-shaped, U-shaped, circular and rectangular (FIGS. 4, 5 and 6) have been successfully employed. Additionally, the mouth of the groove may be as wide as, or narrower than, the width of the circumferential end surfaces, as shown in FIGS. 5 and 8. The groove is substantially coextensive with the length of the circumferential end surface (FIG. 1) since edge defects may be introduced into the stretched sheet at any point along the end surface if there is no grooving at that point.

In actual stretching operations, it is preferable to provide a test blank with a groove having a particular depth (greater than 10% of the thickness of the blank) and, thereafter, to compression stretch the test blank to the desired stretched size. By examining the depth of the groove in the stretched part, it can be determined whether to use shallower or deeper grooves in the production blanks. For example, if a relatively deep groove remains in the stretched sheet, a shallower groove than initially present in the test blank can be formed or cut in the production blanks so that edge losses from the stretched part will be further minimized.

Cracking and stressing of the edges is generally preceded by "edge roll" as shown in FIG. 9. Thus, if edge roll is present along the edges of a stretched acrylic sheet, a border-line condition is indicated and the groove placed in the acrylic blank should be deepened.

Optimally, the acrylic blank is provided with a groove having a depth of at least about 5% and preferably greater than 10% of the original blank thickness and, further, which will be substantially eliminated in the stretched acrylic sheet. That is, optimally the depth of the acrylic blank groove is selected so that the flow of material during compression stretching substantially fills the groove. Such groove selection, of course, minimizes or eliminates any losses of material from the stretched sheet.

Following the choice of a satisfactory groove depth, the production acrylic blanks are provided with edge groove by any method, e.g., sawing, which will not critically stress the blank. The blanks are then ready to be compression stretched. Compression stretching of the grooved blanks may be performed by any desired technique. However, it is presently preferable to employ the compression stretching method described in said Fortin application, the description of which is incorporated herein by reference to said Fortin application.

Examples of the article and process of this invention follow:

EXAMPLE 1

An as-cast Plexiglas 55 blank (manufactured by Rohm & Haas) having initial dimensions of 6 in. x 6 in. x 0.751 in. thick was provided with a circumferential groove having a configuration substantially as shown in FIG. 8. The maximum depth of the groove was 0.125 inch, or about 16% of the initial acrylic blank thickness. This blank was coated with Mold-Wiz F-57 lubricant (Teflon colloidal dispersion manufactured by Axel Plastics Research Lab., Inc.) and placed between a pair of polished glass plates, and isothermally heated to a temperature of 295° F.

The blank was thereafter compressed at a thickness reduction rate of about 0.10 inch per minute to produce a stretched acrylic sheet measuring 9.5 in. x 9.5 in. x 0.270 in. thick. Thereafter, the temperature of the acrylic sheet was reduced at a rate of 13° F. per minute to a temperature below about 110° F.

No cracks developed in the stretched acrylic sheet and no edge roll was observed. Additionally, the size of the groove in the blank was substantially reduced.

EXAMPLE 2

A blank of the same material and of the same size as used in Example 1 was provided with a V-shaped circumferential groove similar to that shown in FIG. 4 and having a maximum depth of 0.1 inch or about 13% of the acrylic blank thickness. This blank was stretched under substantially the same conditions as described in Example 1 to a stretched acrylic sheet having dimensions of 9 in. x 9 in. x 0.350 in. thick.

No cracks or edge roll were observed in the stretched acrylic sheet and the depth of the original groove in the acrylic blank was substantially eliminated in the stretched sheet.

EXAMPLE 3

An acrylic blank formed from the same material and having the same dimensions as that described in Example 2 was provided with a V-shaped groove similar to that used in Example 2 except that the maximum depth of the groove was 0.046 inch or about 6% of the acrylic blank thickness. This blank was stretched under the same conditions as employed in Example 2 to a stretched acrylic sheet having dimensions of 9.5 in. x 9.5 in. x 0.300 in. thick.

No cracks were observed in the edges of the stretched acrylic sheet. However, some edge roll was noticed along the edges of the sheet and, from experience, this indicated a borderline condition.

EXAMPLE 4

An as-cast acrylic blank of Plexiglas 55 having dimensions of 12.5 in. x 12.5 in. x 0.732 in. was provided with a circumferential groove of square cross-section measuring 0.187 inch in depth (about 25% of the original blank thickness) and positioned substantially as shown in FIG. 5. This acrylic blank was compression stretched employing the method of Example 1 to a stretched acrylic sheet having dimensions of 21.6 in. x 21.6 in. x 0.245 in.

No cracks or edge roll were observed along the edges of the stretched acrylic sheet.

EXAMPLE 5

An acrylic blank of Plexiglas 55 having dimensions of 12.5 in. x 12.5 in. x 0.740 in. was provided with a continuous circumferential groove similar to that shown in FIG. 7 and having a maximum depth of about 0.375 inch (about 50% of the initial blank thickness). This blank was compression stretched by the method of Example 1 to a stretched acrylic sheet having dimensions of 22.2 in. x 22.2 in. x 0.233 in.

No cracks or edge roll were observed along the edges of the stretched acrylic sheet.

EXAMPLE 6

An as-cast acrylic blank of Plexiglas 55 having dimensions of 12.5 in. x 12.5 in. x 0.735 in. was provided with a continuous circumferential V-shaped groove as shown in FIG. 4 and having a maximum depth of about 0.312 inch (about 40% of the initial blank thickness). This acrylic blank was stretched by the method of Example 1 to a stretched acrylic sheet having dimensions of 21 in. x 22 in. x 0.235 in.

No cracks or edge roll were observed along the edges of the stretched acrylic sheet.

As will be apparent from the foregoing, modifications in the present invention may be made by those skilled in the art without departing from the spirit of the invention. Therefore, this invention is to be limited only by the scope of the claims which follow.

I claim:

1. A method for compression stretching an acrylic blank having a top and a bottom surface and circumferential end surfaces extending therebetween, comprising the steps of:

providing said circumferential edge surfaces of said acrylic blank with a groove having a depth of at least about 5% of the initial thickness of said blank;

and compressing said top and said bottom surfaces of said blank to cause said blank to stretch radially outwardly from the center of said blank to produce a compression-stretched sheet having less thickness than said blank.

2. The method of claim 1 wherein the depth of said groove is greater than about 10% of said initial thickness of said blank.

3. The method of claim 1 wherein said groove is substantially coextensive with said circumferential end surfaces.

4. The method of claim 1 wherein said groove is symmetrical about a plane through the center-line of said circumferential end surfaces.

5. The method of claim 1 wherein said acrylic blank is selected from the group consisting of methyl methacrylate and modified methyl methacrylate.

6. The method of claim 1 wherein, in addition, said depth of said groove in said blank is selected so that said groove is substantially filled in said compression-stretched sheet.

7. A method of compression stretching an acrylic blank having a top and a bottom surface and a circumferential end surface therebetween comprising the steps of:

providing said circumferential end surfaces with a groove substantially coextensive therewith, said groove having a depth greater than about 5% of the initial thickness of said blank and positioned symmetrically about a plane passing through the centerline of said groove;

heating said acrylic blank to a temperature within the softening temperature range of said acrylic material;

compressing said heated acrylic material between a pair of polished elements, having a thin film of lubricant coated thereon, to reduce the thickness of said acrylic material at a rate which produces substantially uniform flow, without cracking, of said acrylic material;

cooling the resulting stretched acrylic material at a predetermined rate to prevent cracking of said stretched acrylic material to a temperature below the minimum softening temperature of said acrylic material; and

releasing said pressure after said stretched acrylic material has attained a temperature below said minimum softening temperature, whereby stretched acrylic material is produced which has improved optical and physical properties.

8. The method of claim 7 wherein said depth of said groove is at least about 10% of said initial thickness of said blank.

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U.S. Cl. X.R.

161—149; 264—291, 293, 294, 320, 322