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Polycarbonate as an Adhesive

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by

S. E. Newfield
E. P. Ehart

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POLYCARBONATE AS AN ADHESIVE

by

S. E. Newfield

E. P. Ehart

ABSTRACT

Injection-molding grade clear polycarbonate resin has been used as a hot-melt adhesive in several experimental bonding applications. The low creep, non-outgassing, and favorable heat-deformation properties of this resin, linked with its newly discovered adhesive properties, make polycarbonate an ideal adhesive in certain applications.

Introduction

Since its introduction in 1960, polycarbonate resin has found many applications suited to its unique properties. This clear, thermoplastic resin is made by condensation of a dihydroxy aromatic with an active carbonate such as phosgene. The common starting materials of phosgene and bisphenol-A produce a polymer with the structure:

The exceptional properties of polycarbonate listed in the literature¹ are:

1. High rigidity coupled with exceptional toughness
2. Up to 87% optical transmission
3. -60 to 250°F useful temperature range
4. Tensile strength of 9,000 psi
5. High dielectric strength, low conductivity
6. Creep resistance (design limits: 2,000 psi at 73°F, 500 psi at 212°F)
7. High deflection temperature
8. Non-outgassing property in vacuum

The previous use of polycarbonate as an adhesive has not been found in the literature, but its combination of properties has led to its experimental use in certain applications.

Construction of an accelerator tube ion-injection chamber required the use of an adhesive. The device uses large ceramic rings which must be bonded to thin titanium rings (see Fig. 1). The final assembly was to be suspended horizontally, supported only at the ends. The adhesive was required to have high shear strength, high resistance to temperature deformation, good high-vacuum properties, good dielectric strength, and exceptional creep resistance. These requirements led to the use of polycarbonate* as a hot-melt adhesive.

Experimental work has also been done with polycarbonate to determine its adhesive properties relative to materials other than titanium and ceramic.

* General Electric "Lexan" injection-molding polycarbonate, grade 114-112, was used throughout the experiment. The material was purchased in October, 1967 and the batch number is not known.

Fig. 1. Accelerator tube ion-injection chamber.

Experimental

To determine the tensile strength of ceramic-to-titanium bonds using polycarbonate as an adhesive, ceramic "dogbone" test specimens were used with a titanium washer between the pieces (Fig. 2). A TFE rod was used to align the ceramic pieces and the titanium washer. Each of the four bonding surface areas was 0.180 in.^2 .

Preparation of Samples

The resin used was an injection-molding grade of clear, heat-stabilized, low viscosity polycarbon-

ate. The injection pellets were dissolved at room temperature in chloroform to obtain a solution containing 15% by weight of the polycarbonate. This solution was brushed on all bonding surfaces of the sample and allowed to dry 1 h. The pieces were then assembled and placed in an oven at 270°C with 20 psi of force applied by means of a steel weight (3.6 lbs for the 0.180 in.^2 bonding surface). Later work showed that an external jig, in addition to the Teflon rod, helped maintain alignment of the bonding pieces during the heating cycle when the resin becomes fluid. Each assembly remains in the oven for a fusion period during which time the polycarbonate melts and flows, providing some squeeze-out. The fusion time required depends on the size, specific heat, and conduction properties of the parts being bonded.

For the dogbone samples, 30 min was found to be adequate. At the end of that time the assembly is allowed to cool under pressure, and the joint is complete. Micrometer measurements of the assembled pieces before coating and after bonding allow the determination of the glue-line thickness, although a relationship between glue-line thickness and bond strength was not established in this study.

The ceramic-titanium assemblies were then tested for tensile strength in accordance with ASTM test

Fig. 2. "Dogbone" test samples.

F-19-64. Table I shows the performance of the test pieces.

To determine the adhesive properties of polycarbonate in bonds between other materials, several additional series of tests were run. Dogbone samples without titanium washers were used to determine ceramic-to-ceramic bond strengths. To prepare tensile samples of steel, 1-in.-long 1/4-28 hex-head bolts were used. These were machined in a lathe to provide a flat bonding surface perpendicular to the bolt shaft (Fig. 3) to fit into the tensile testing machine.

Early tests indicated that a polished bonding surface produced the strongest bonds. The pieces were polished with #210 emery paper and then wiped with dry cheesecloth. The surfaces were coated with the polycarbonate-chloroform solution and allowed to dry 1 h. The pieces were then placed in an oven at 270°C for 9 min, after which they were removed and quickly pressed together by hand with careful attention to alignment. The use of weights or a press was found to be impractical for these test pieces because of the problem of proper

1-in.-long, 1/4-28 hex-head bolt,
Bonding surface area: 0.16 in.²

Fig. 3. Hex-head bolt samples.

alignment. Once cool, the test pieces were tensile tested using a pulling rate of 0.1 in. per min, and the breaking load was recorded. This value was divided by the bond area to give bond tensile strength in psi.

The hex-head pieces were also used to determine the bonding strength of polycarbonate bonds between mild steel and glass. A cover glass 0.006-in. thick was sandwiched between the test pieces. The glass had been previously coated with the polycarbonate solution, dried, and preheated with the steel pieces.

A similar procedure was followed in testing the strength of glass-to-glass bonds. Two coated cover glasses were placed between the steel pieces, and the tensile strength was recorded for pieces that failed by glass-to-glass bond separation.

Stainless steel bonds were tested by processing pairs of stainless bolts in the manner described above.

The adhesion of glass to stainless steel was tested in the same manner, using stainless bolts and a sheet of cover glass. The results of this and the other tests are in Table I.

Conclusions

The previously untried use of polycarbonate resin as an adhesive showed the potential of this material. As a hot-melt bonding resin it exhibited high tensile strengths for bonds among ceramic, steel, titanium, and glass.

Only one grade of polycarbonate resin was used in this study. Other grades may give different results, especially since injection-molding grades often contain lubricants and additives to aid in molding.

Table I
Polycarbonate Tensile Bond
Strengths for Some Materials

Bonding Materials	Maximum Strength	Average Strength	Number Tested
Ceramic to ceramic*	7,806	3,143	13
Ceramic to titanium*	7,028	4,570	10
Mild steel to mild steel**	10,000	6,915	22
Mild steel to glass**	7,000	6,178	7
Glass to glass**	5,470	4,063	7
Stainless steel to stainless steel** (unpolished)	6,250	4,958	7
Stainless steel to stainless steel** (polished)	7,345	5,730	9
Stainless steel to glass**	9,220	5,963	8
Mild steel to stainless steel**	7,188	5,408	9

* Tested in accordance with ASTM test F-19-64.

** Tested on a National Forge Universal Testing Machine, Model TMU-B, with a pulling rate of 0.1 in. per min.

The use of polycarbonate resin as a hot-melt adhesive is necessarily limited to joints which can be heated to 270°C. A further limitation is the required surface preparation; i.e., bonding surfaces should be flat and moderately polished to achieve maximum bond strength.

Despite the limitations on its use, polycarbonate resin as an adhesive seems to have potential for

future applications. Its unique combination of properties gives it special advantages for certain uses which are not found in other currently available adhesives.

Reference

1. Morgan, D. F., and Wendle, B. C., "Polycarbonates," Modern Plastics Encyclopedia, Vol. 45, McGraw-Hill, Inc., New York (1967).