Mechanical Properties and Fracture Surfaces of Epoxide Resin / Glass Bead Composites

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Abstract

In consideration of bonding abilities of filler surfaces to the matrix, the effects of filler content and strain-rate on the mechanical properties of epoxide resin / glass bead composites were studied. The filler, i. e. the glass itself adhered to the matrix, i. e. epoxide resin. But glass bead surfaces were treated by bonding agents more adhesive to epoxide resin, for enhancement of mechanical properties of these composites. The series of epoxide resin / glass bead composites, filled with the treated glass beads by bonding agent, i. e. γ glycidoxypropyltrimethoxysilane, by non-bonding agent, i. e. silicone oil and with untreated glass beads, were tested in tension, covering the volumetric filler content-range up to 44 percent and filler size-range from 5μ to 40μ. The strain-rates ranging from 0.1mm to 30mm per minute were employed in tension.

The result obtained in this study on such a brittle type of resin containing rigid sphere-beads revealed that the fractures occurred at or near the glass bead / resin interfaces and the fracture strength were especially sensitive to the surface treatment of glass beads in the composites. By many fracture-photographs of the tests, the crack initiation and propagation were confirmed to exist at the stress concentra-

tion points or weak points on the fracture surfaces, and the relationship between the cracks and the mechanical properties of the composite was found.

Introduction

This study is performed to show how the difference of average sizes of glass beads affects mechanical properties of the composites. But the interface between filler and matrix resin in the composite has been considered important for achieving good mechanical properties. For this reason the cleaned glass beads were surface-coated with bonding or non-bonding agent. And the cleaned glass beads without surface coating and beads with surface coating were used in this experiment. To examine the effects of reinforcement by the surface treatments on interfacial failures, the fractographic observation of the composite was done by a microscope.

Experimental

The epoxide resin (Epikote 815) was cured with the curing agent (Alkyl imidazole), and with the curing cycle of 24 hours at 25°C plus 12 hours at 60°C. The glass beads having two average sizes of 35μ for large bead and 12.5μ for small bead were used in the composites. These cleaned glass beads were surface-coated with silane, i. e. γ glycidoxy-propyltrimethoxysilane or silicone oil by dipping method.

The coated beads and cleaned beads were dispersed in the epoxide resin filled with about 2% ultra-fine silica-sol (aerosol) by rapid stirring under vacuum, and then curing agent was added with mixing under vacuum for 5 minutes. After the mixing, the composite systems were cast in the mold, cured and then surface-finished for the test specimen as shown in Fig. 1. The specimens were tested at strain-rates

of 0.1, 1.0, 2.0, 30.0 mm/min.

Result and Discussion

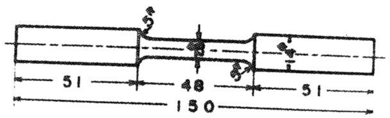


Fig. 1. Specimen for tension test

Typical stress-strain curves for specimens without filling, with filling of silane coated and uncoated small beads, and with filling of silicone coated large beads are shown in Fig. 2. This figure shows that the unfilled specimen is low in tensile modulus with relatively high tensile strength, the specimen filled with silane coated small beads is relatively high in tensile modulus with the highest tensile strength, the specimen filled with uncoated small beads is highest in tensile modulus with relatively low tensile strength and the specimen filled with silicone coated large beads is relatively low in tensile modulus with the lowest tensile strength.

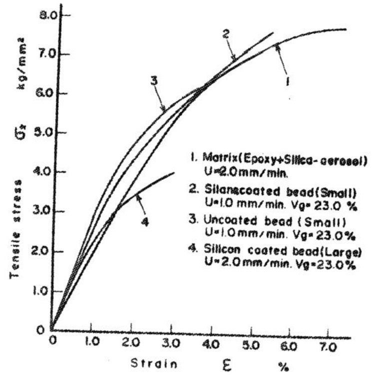


Fig. 2. Tensile stress vs. strain curves for variant beads

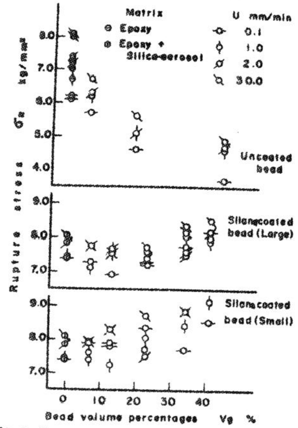


Fig. 3. Rupture vs. bead volume percentages

As shown in Fig. 3 the tensile strength of the specimen filled with uncoated beads decreases as bead-percent increases, while that of the specimen filled with silane coated beads increases as bead-percent

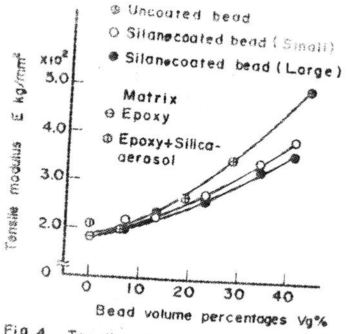


Fig. 4. Tensile modulus vs. bead volume percentages at elongation speed U=0.1 mm/min

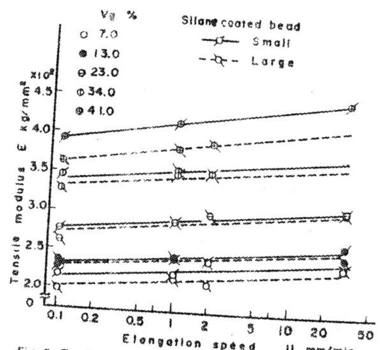


Fig. 5. Tensile modulus vs. elongation speed curves

increases; especially this specimen with small beads increases even more.

The curves of tensile modulus versus the volume percent of beads, as shown in Fig. 4, increase with increasing the bead-percent for three typical specimens. In Fig. 5 typical curves of tensile modulus versus strain-rate at various contents of glass beads are shown for the specimens filled with silane coated beads. These curves are straight and parallel with one another.

Failure of glass beads filled in epoxide resin is considered to occur in shear at or near the glass-resin boundary. It is, therefore, necessary to know how this shear stress decreases when glass beads approach with one another. If all beads are same in size and dispersed uniformly in a specimen as if they were in face-centered cubic system as shown in Fig. 6. The distances between two nearest beads are ranging from 1d to 1.8d for the specimen filled with beads of 10 volume % and from 0.2d to 0.7d in case of beads of 40 volume %, where d is a bead

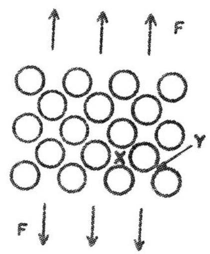


Fig.6. Model of distributed beads

diameter. Since the matrix resin is restrained by an adhesive force between glass beads-resin interfaces, then the effective tensile modulus increases with increasing of the restrained lateral force induced by the tensile force as shown in Fig. 7. Thus the effective shear force at the glass bead/resin interface decreases with increasing of the effective tensile modulus, and the fracture strength of specimen can increase with smaller size of bead and larger volume % of beads filled in the specimen.

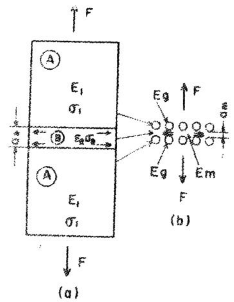
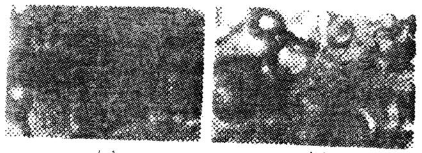


Fig.7. Schematic stress distribution at beads layer gap

If there is a strong bond between the glass bead and matrix as the case of the treating with the silane agent on the glass beads, the fractures initiated near each interface between the glass bead and matrix are observed as shown in Photo. 1 (a). If there is a weak or a nil bond between them as the case of the treating with the silicone agent on the glass beads, it is observed that the fracture travels from one bead to another in a path that minimizes the fractured area of matrix as shown in Photo. 1 (b).



(a) (b)

Photo. 1. Surface fractures of epoxy-glass beads composite
(a) Silanecoated bead
(b) Silicon coated bead

References

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