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A Study on the Characteristics at Low Temperature of Welded Polycarbonate

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In this study we investigated the tensile characteristics of welded polycarbonate at low temperature. This study intends to clarify the low temperature characteristics of welded part comparing with those of base material. The results of some measurements on the tensile properties from 20°C down to -70°C are reported and the changes in tensile properties under low temperature atmosphere are discussed. Furthermore, notch and load velocity effects on the brittle fracture tendency are also discussed.

Conclusions obtained in this study are summarized as follows; 1) Both welded part and base material of polycarbonate are strengthened at low temperature. 2) Welding joint efficiency of polycarbonate is very good even at low temperature. 3) Notch and load velocity effects are observed both on the base and the welded materials. 4) Correlations are observed between fracture surfaces and mechanical testing results.

1. INTRODUCTION

Polycarbonate(PC) is a relatively new polymer having the chemical structure of ester carbonate ($-\overset{\text{O}}{\overset{\|}{\text{C}}}-\text{O}$). This material excels in impact strength, heat resistance, electrical insulation, transparency and dimensional stability. In the future it is expected to find applications as a high strength material by taking advantages of outstanding impact strength. However, there seems to be little reference materials regarding the welding of PC, particularly the data on the low temperature properties of welded sections of PC are seldom found.

In this paper, it is intended to clarify the strength properties of

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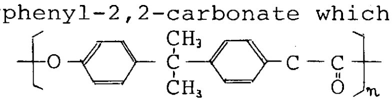
the welded section in a low temperature atmosphere in connection with the study on weldability of PC in severe conditions. That is, for both the base material and welded material, changes of tensile properties are made clear in low temperature methyl alcohol atmospheres with the temperature from the room temperature to -70°C and then microscopic reviews are made based on observations of the surfaces of test specimens and tensile fractures. Studies are also made with regard to the notch effects and effects of load velocity which influence the low temperature properties.

2. EXPERIMENTAL MATERIALS AND EXPERIMENTAL METHOD

The test material used is a polycarbonate found on the market, which is a 2mm plate of Teijin Panlite (polyester carbonate, poly-4,4'-dioxyphenyl-2,2-carbonate which can be shown by the structural formula of;



Tests are conducted for plain base material, plain welded material, notched base material and notched welded material. Both the plain base and welded materials are of dumb-bell type, 10mm wide and 40mm wide at the parallel section, while the notched materials are made by notching 2mm deep at 60° at center of both sides of the parallel section of the dumb-bell type specimen. Meanwhile, for the welded materials, the welded section is situated at center of the parallel section. The welding is done by the self-made semi-automatic hot plate welder[1] and after preliminary tests the optimum welding conditions as shown in Table 1 are obtained.*** For the tensile tests, Autograph IS-2000 is used and for the low temperature tests, methyl alcohol and dry ice are put into the low temperature vessel as in the case of previous reports.[2~6]

Table 1 Welding condition.

Cross sectional area	30 mm^2
Preheating temperature	300 °C
Preheating pressure	20 g/mm^2
Preheating time	15 sec
Welding pressure	30 g/mm^2
Welding time	60 sec

3. EXPERIMENTAL RESULTS AND CONSIDERATION

In Figs.1 and 2 are shown stress-strain curves of the plain base material and plain welded material in atmospheres of different temperatures. In Fig.3 is shown the tensile strength. The load velocity is 5mm/min in all cases. The base material has the yield point at each

***Note: Since polycarbonate is foamed if welded without predrying and has its weld strength decreased, it is predried in vacuum at 120°C for 5 hrs before welding.

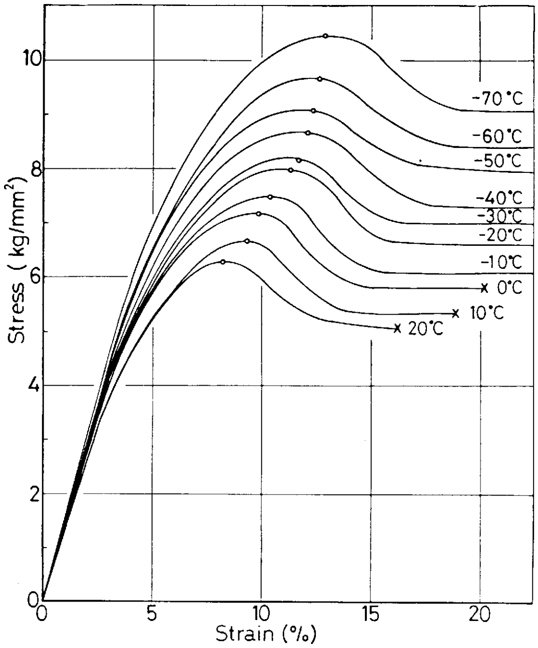


Fig.1 Stress-strain diagrams of the polycarbonate in methyl alcohol at each low temperature.

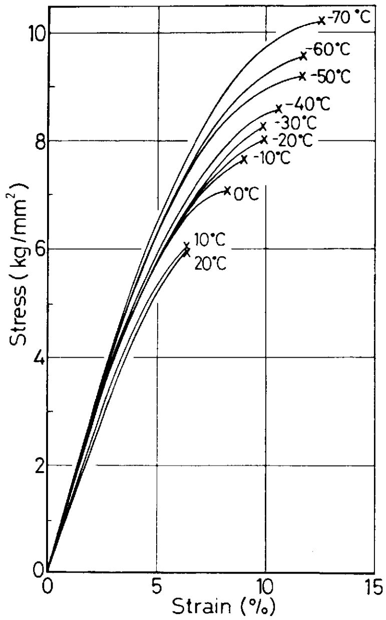


Fig.2 Stress-strain diagrams of the welded polycarbonate in methyl alcohol at each low temperature.

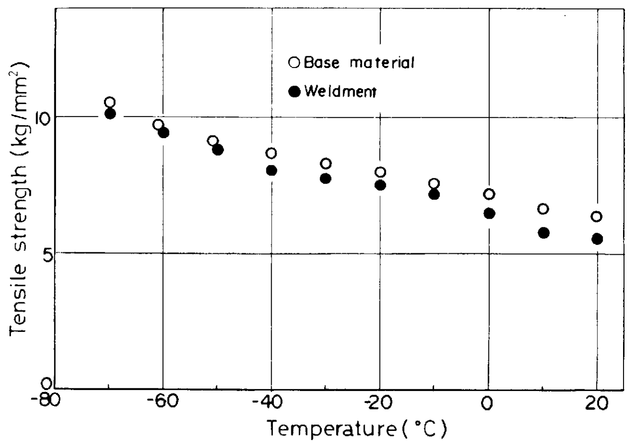
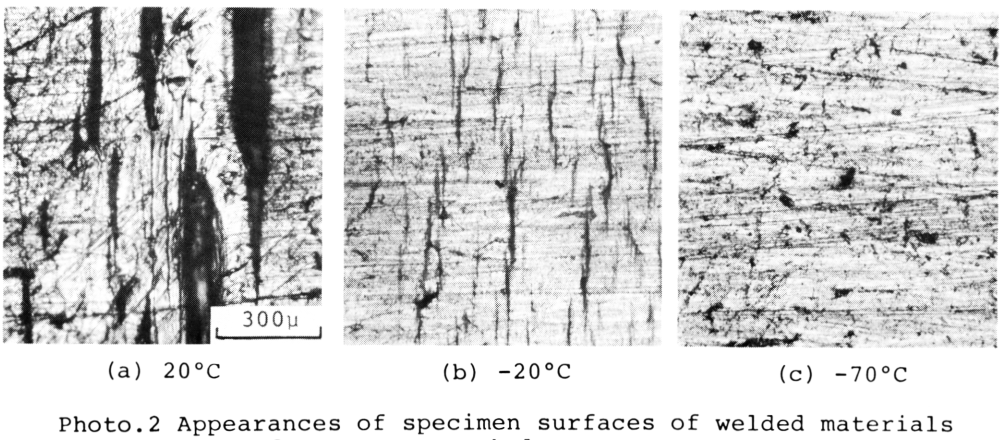


Fig.3 Tensile strength of the base material and the welded material at each low temperature.

temperature, however, the welded material fractured before the yield point in all cases. For both materials, it is noticed that the tensile strength rises as the temperature drops. Then, the weld joint efficiency at each temperature is obtained and it is noticed that the efficiency of over 90% is always maintained. In view of the fact that the value is much higher than the allowable value specified by JIS,[7] the weldability of this material is found to be very good even in low temperature atmospheres. Furthermore, for both materials, the Young's modulus of elasticity rose as the temperature dropped. Such tendencies of tensile strength and Young's modulus of elasticity are the same as those of some engineering plastics[2~6] which have already been made clear by the author and his colleagues. However, the elongation before the yield point and elongation at break have increased as the atmospheric temperature dropped thus indicating a contrary tendency to that of conventional materials. From the concept of low temperature brittleness, it seems like an unexpected result, but it may be understood well if effects of crazing as described below are taken into consideration. It is known that polycarbonate, when placed under loaded conditions in methyl alcohol, will have craze (microfine cracks)[8] and in this test it was thought that the start and propagation of crazes

(a) 20°C (b) -20°C (c) -70°C

Photo.1 Appearances of specimen surfaces of base materials after fracture at each low temperature.



(a) 20°C (b) -20°C (c) -70°C

Photo.2 Appearances of specimen surfaces of welded materials after fracture at each low temperature.

would affect greatly the low temperature properties. Then, surfaces of specimens of the base and welded materials after fracture were observed at 20°C, -20°C and -70°C. In Photos.1 and 2 are shown results of observation, where it is noticed that in each case the start and propagation of crazes are decreased as the temperature becomes lower. This is assumed that since the crazing is a chemical reaction, therefore, it is much affected by the temperature and as the temperature is lowered, the crazing and its propagation are much decreased. It is then thought that at room temperature, much crazes are started and propagated and the materials fractured with less elongation, however, as the temperature is lowered, the starts and propagation of crazes are decreased and as a result the elongation is increased gradually.

As aforementioned, polycarbonate, in both the base material and welded material, will have the tensile strength and Young's modulus of elasticity increased as the atmospheric temperature is dropped and it is now obvious that the weldability is quite excellent even in low temperature atmospheres. The elongation before the yield point and

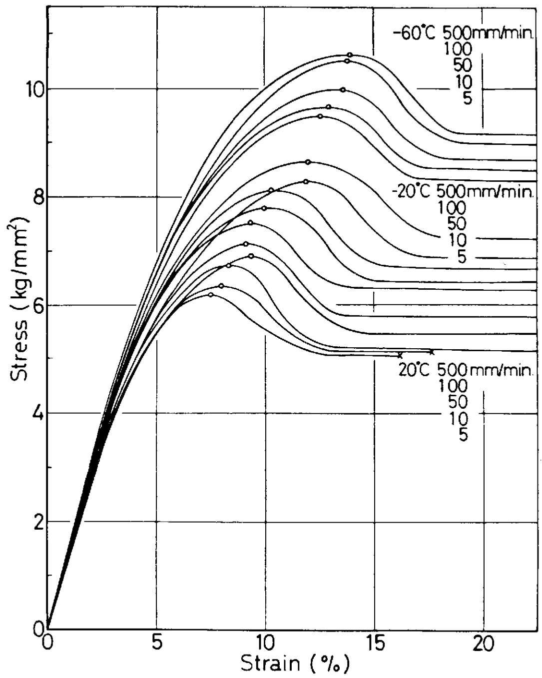


Fig.4 Effect of load velocity on the stress-strain diagram of the base material at each low temperature.

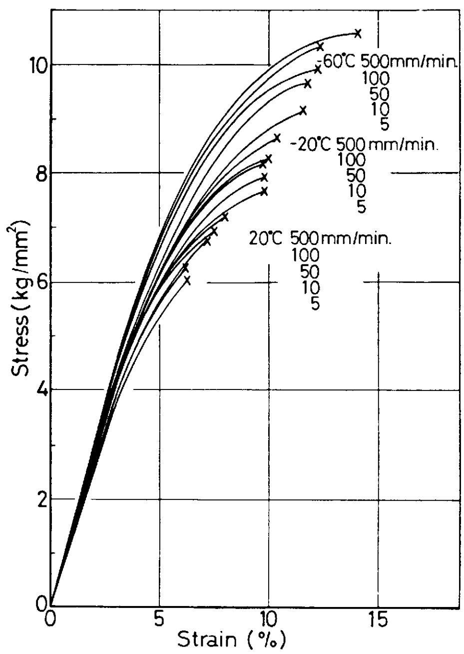
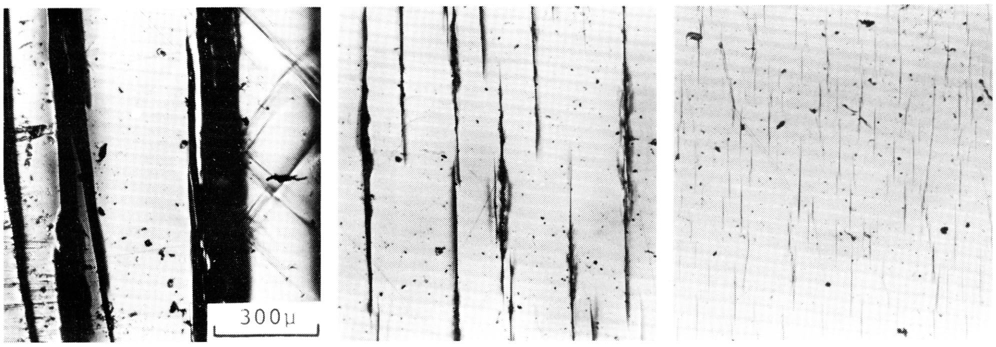


Fig.5 Effect of load velocity on the stress-strain diagram of the welded material at each low temperature.

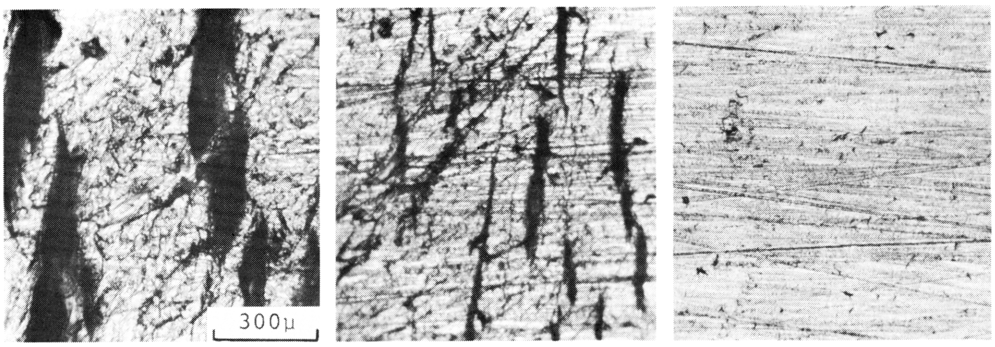
elongation at break increase as the temperature is dropped, but this is assumed to be because of crazes that are started and propagated during the tensile process.

In order to investigate effects of load velocity on the low temperature properties, load velocity change tests were conducted for both the plain base material and plain welded material. The atmospheric temperatures were 20°C, -20°C and -60°C and the load velocities were 5, 10, 50, 100 and 500mm/min. In Figs.4 and 5 are shown the results. In each case, the base material has the yield point and as the load velocity is increased, the tensile strength and Young's modulus of elasticity are also increased. The welded materials have no yield point, but the tensile strength and Young's modulus of elasticity



(a) 5mm/min (b) 50mm/min (c) 500mm/min

Photo.3 Effect of load velocity on the specimen surface of the base material after fracture at 20°C.



(a) 5mm/min (b) 50mm/min (c) 500mm/min

Photo.4 Effect of load velocity on the specimen surface of the welded material after fracture at 20°C.

indicate a tendency similar to that of the base material and these aspects are quite similar to those shown by the results obtained previously. However, the elongation before the yield point and the elongation at break are different from the results obtained previously, that is, as the load velocity is increased, the elongation is also increased. This is assumed to be because of the effects of crazing as described in the previous section. In Photos.3 and 4 are shown results of observations to investigate the effects of load velocity on the start and propagation of crazes. Photo.3 is for the base material and Photo.4 the welded material with the atmospheric temperature at 20°C. Both the base material and welded material indicate that the start and propagation of crazes are decreased as the load velocity is increased. From this, the cause of the increase of elongation caused by the increase of load velocity may be assumed as below. That is, when the load velocity is low, the start and propagation of crazes are faster than the strain speed caused by the load and consequently the fracture with less elongation will occur. On the contrary, as the load velocity is increased, the strain speed becomes faster and strain increases before the crazes start and propagate well, therefore, the fracture occurs accompanying much elongation.

In Figs.6 and 7 are shown stress-strain curves obtained for the notched base material and notched welded material, respectively. In Fig.8 is shown the relationship between the atmospheric temperature and tensile strength. In each case of the notched material, the elongation at break is greatly decreased and fractures much like brittle fractures are noticed. Effects of atmospheric temperature on tensile proper-

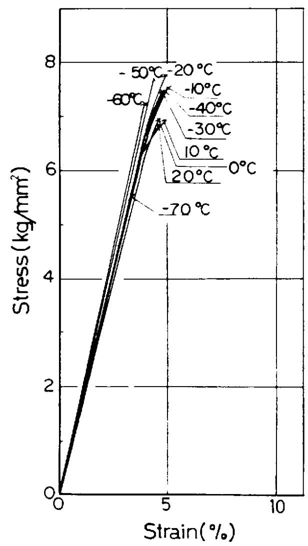


Fig.6 Notch effect on the stress-strain diagram of the base material at each low temperature.

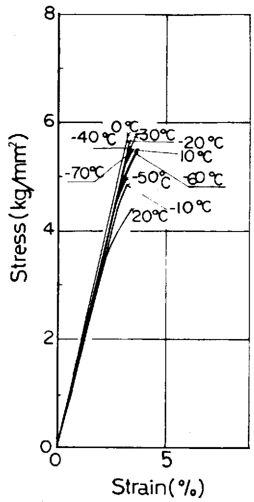


Fig.7 Notch effect on the stress-strain diagram of the welded material at each low temperature.

ties indicate that for both the base and welded materials the changes of tensile strength, elongation at break and Young's modulus of elasticity are not so great and they show nearly the same values even in low temperature atmospheres. Accordingly, the weld joint efficiency is nearly no changed at each temperature and it

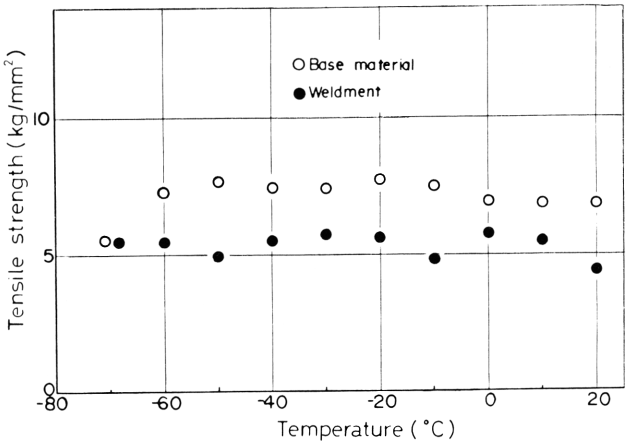
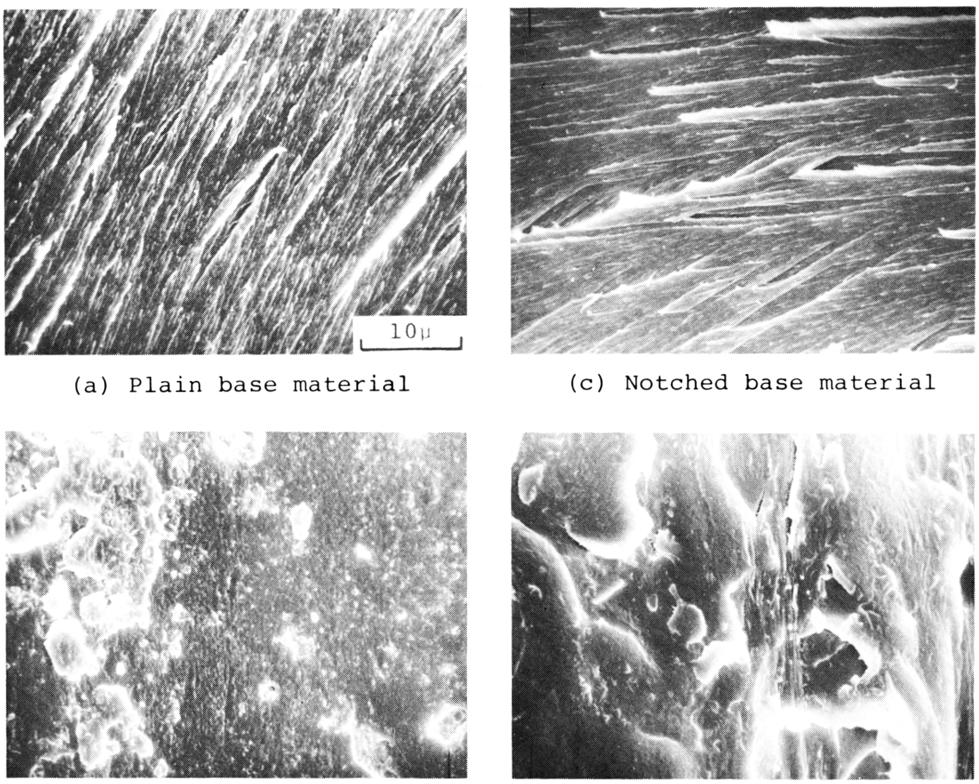


Fig.8 Tensile strength of the notched base material and the notched welded material at each low temperature.



(a) Plain base material

(c) Notched base material

(b) Plain welded material

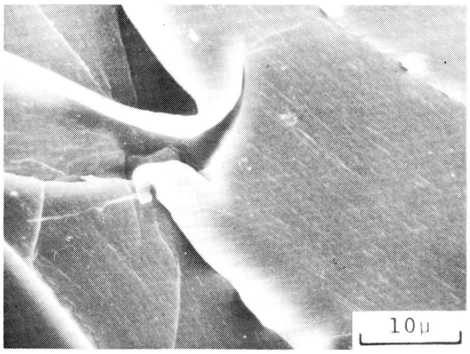
(d) Notched welded material

Photo.5 Appearances of fracture surfaces at 20°C.

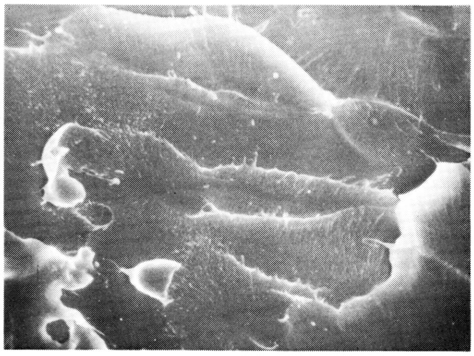
has been made clear that outstanding weldability is indicated even in low temperature atmospheres.

In Photo.5 are shown surfaces of tensile fracture of each specimen in methyl alcohol at 20°C. The plain base material and notched base material show similar fractures and the fracture is assumed to have accompanied some slip deformations. On the other hand, the welded materials, plain and notched, do not show much traces of plastic deformation and it seems that considerable brittle fractures have taken places at the welded areas.

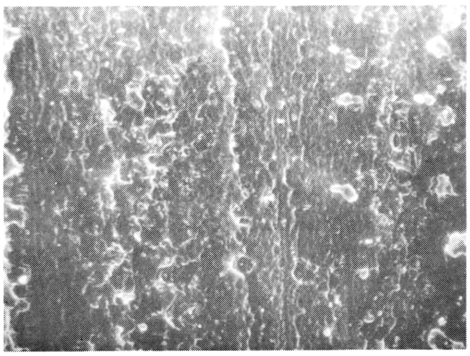
In Photo.6 are shown fractured surfaces of each specimen at -70°C. The base materials show great differences as compared with the case of 20°C. Particularly, the plain base material indicates a trace of great plastic deformation at the fractured area and, therefore, a considerable brittle fracture is assumed to have taken place there. This correspond well to the results of stress-strain curves described



(a) Plain base material



(c) Notched base material



(b) Plain welded material

(d) Notched welded material

Photo.6 Appearances of fracture surfaces at -70°C.

before. On the other hand, in case of the welded material, both the plain and notched materials do not show much differences as compared with the case of 20°C. It is assumed that considerable brittle fractures have taken places at the welded areas.

4. CONCLUSION

In the foregoing, the low temperature properties of welded polycarbonate in methyl alcohol were investigated. The results thus obtained may be summarized as follows.

1) Polycarbonate has outstanding weldability even in low temperature atmospheres.

2) Polycarbonate, both the base and welded materials, has its elongation at break increased in low temperature methyl alcohol. This is assumed to be because of the fact that the formation and propagation of crazes during the tensile process are decreased by the dropping temperature of atmosphere.

3) Polycarbonate, both the base and welded materials, has its elongation at break increased as the load velocity is increased. This is assumed to be because of the fact that the strain speed resulting from load application becomes faster than the propagation speed of crazes.

4) Polycarbonate, both the base and welded materials, has severe brittleness caused by notching. The notched specimens are not much affected by the atmospheric temperature.

5) Through observation of fractured surfaces by a scanning type electron microscope, it has been made clear the differences of fractured surfaces at the room temperature and -70°C and the differences of fractured surfaces between the base material and welded material.

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