MEMOIRS OF THE FACULTY OF ENGINEERING
FUKUI UNIVERSITY
VOL.28 NO.2 1980

A Study on the Fatigue Characteristics of Polymethylmetacrylate Adherends

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(Received Jul. 24, 1980)

In this paper we describe an experimental study. Reported in this article are tensile fatigue characteristics of polymethylmetacrylate and its bonded material in relation to wave form of load, loading velocity and notch effect. In experiments, heat cured acrylic resin was used for base material, while heat cured and self-cured polymethylmetacrylate (Denture Acrylic SHOFU "Bio" Resin) were used as Adhesives.

As a result of the research of test and experiments, it is found that;

1) Fatigue limits of the bonded materials using heat cured and self-cured P.M.M.A. are approximately 2/3 and 1/3 of that of the base material.

2) Two-fold property of S-N curve can be seen with dental P.M.M.A., and such property is partly attributable to temperature rise of the test piece. Fatigue limit drops as test velocity increases, and such drop is again partly attributably to temperature rise of the material.

3) Effect of notch is observed and it is noted that the notch causes deterioration in endurance limit by about 1/4.

1. INTRODUCTION

Any material may fail even with small load, when subjected to such load repeatedly, no matter how it has excellent values in terms of static strength, bending strength, etc. Fatigue character has to be taken into consideration as important dynamic characteristics when we use polymer materials for dental purposes. Especially, since applica-

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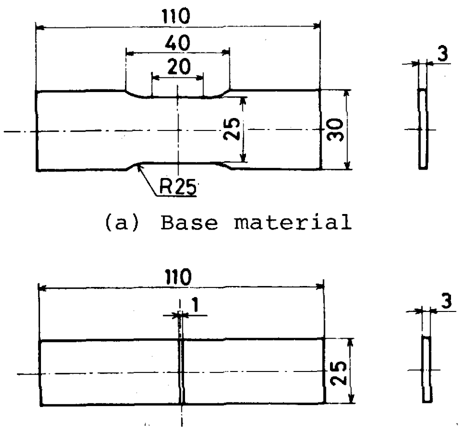
tion of polymer materials for dentistry always comes together with bonding, fatigue characteristics of polymer materials under bonded condition are important.[1)~6)] Reported in this article are tensile fatigue characteristics of dental P.M.M.A. and its bonded material in relation to wave form of load, loading velocity and notch effect. Heat cured acrylic resin and self-cured acrylic resin P.M.M.A. were used for bonding.

2. EXPERIMENTAL MATERIAL AND EXPERIMENTAL METHOD

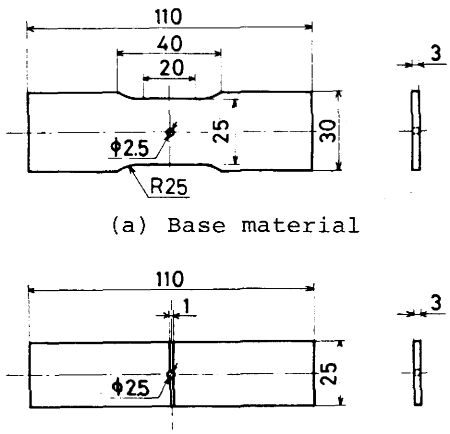
In experiments, heat cured acrylic resin was used for base material, while heat cured and self-cured P.M.M.A. (Denture Acrylic SHOFU "Bio" Resin) were used as adhesives. Scheme of manufacture of fatigue test pieces was that material was hot-press molded in metal mold for 45 minutes in 100°C under 100kg/cm^2, thence processed into base material fatigue test pieces for Baldwin SF-01 having profile and size as shown in Fig.1(a). Heat cured and self-cured P.M.M.A. were applied to bonding beveling of the test piece materials so processed, and made into the profile and size of the bonded materials as shown in Fig.1(b) after bonding through curing and reaction. For fatigue testing, electro-hydraulic servo-type fatigue tester, Shimadzu Servopulser Lab-5P, was used, with which repeated tensile load of 1, 10 and 20Hz. in Sine and triangular waves were applied to the test pieces. In order to observe two-fold property of S-N curve and influence of test



(a) Base material

(b) Adhered material

Fig.1 Plain specimens for fatigue test.



(a) Base material

(b) Adhered material

Fig.2 Notched specimens for fatigue test.

velocity, surface temperature of test pieces was measured by thermo-electric couple. For observation of notch effect, holed test pieces as shown in Fig.2 (2.6 in stress concentration modulus) were used. Scanning type electron microscope, HSM-ZA made by Hitachi, was used for microscopic observation of fatigue fracture.[7)~11)]

3. EXPERIMENTAL RESULTS AND CONSIDERATION

Fig.3 shows result of fatigue test by Sine and triangular waves applied to the base material. Two-fold property of S-N curve, which cannot be seen with metal material, can be observed here. Although endurance limit is not as distinctive as with metal, it can be assumed with 10^6N. Some difference in influence by different wave forms of repeated load can be observed; viz. triangular wave is slightly

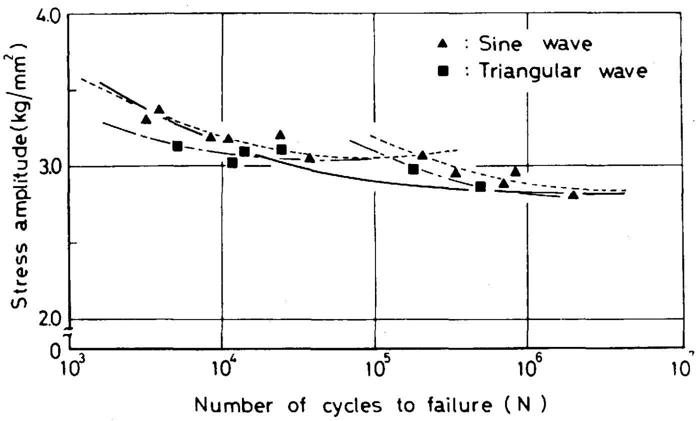


Fig.3 Effect of repeated stress mode on the S-N curve of dental P.M.M.A.. (Frequency:10Hz.)

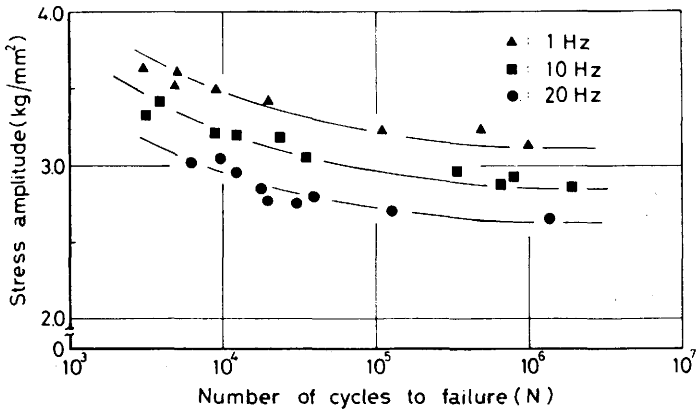


Fig.4 Effect of frequency on the S-N curve of dental P.M.M.A..

severer than Sine wave. Fatigue limit was 2.8kg/mm^2. Effect of repetition velocity is shown in Fig.4, from which it is found that, to the contrary to the case of metal, strength drops remarkably as velocity increases, and fatigue limits were 3.1, 2.8 and 2.6kg/mm^2 at 1, 10 and 20Hz. respectively. Result of fatigue test in which the effect of repetition velocity was looked for with the bonded material adhered by heat cured P.M.M.A. is shown in Fig.5, from which the same tendency as in the case of the base material is observed. However, the fatigue limits were lessened uniformly; viz. 2.4, 2.2 and 2.1kg/mm^2 at 1, 10 and 20Hz. respectively, which were 77-80% of the base material. The case of self-cured P.M.M.A. as adhesive is presented in Fig.6, from which the same tendency as in the case of the base material is also observed. Fatigue limits in this instance were deteriorated to more degree, as 1.5, 1.2 and 1.0kg/mm^2 at 1, 10 and 20Hz. respectively, which corresponded to 38-48% of the base material. Since two-fold

Fig.5 Effect of frequency on the S-N curve of adhered dental P.M.M.A. by heat-cured acrylic resin.

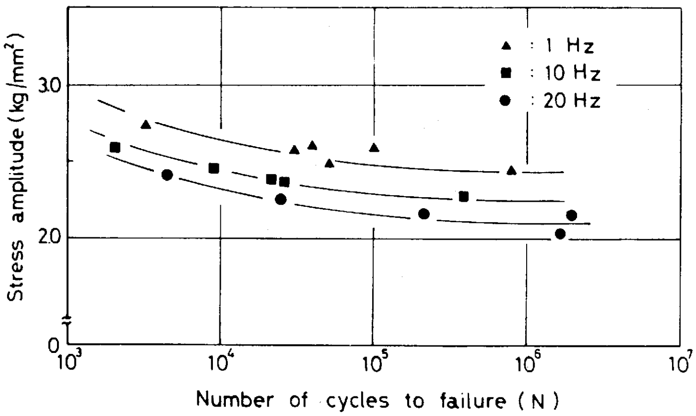
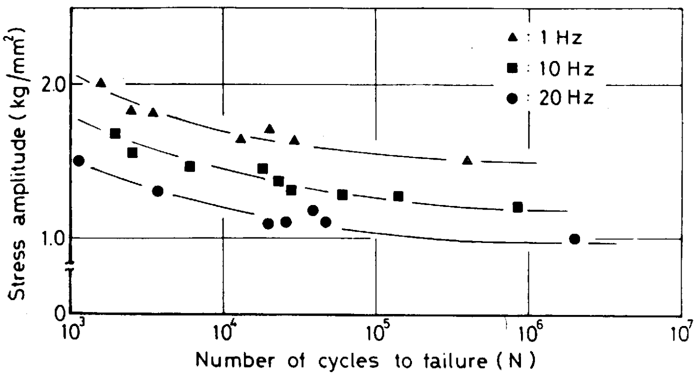


Fig.6 Effect of frequency on the S-N curve of adhered dental P.M.M.A. by self-cured acrylic resin.



property of S-N curve as shown in Fig.3 and effect of test velocity as presented in Figs.4-6 are thought to be partly attributable to

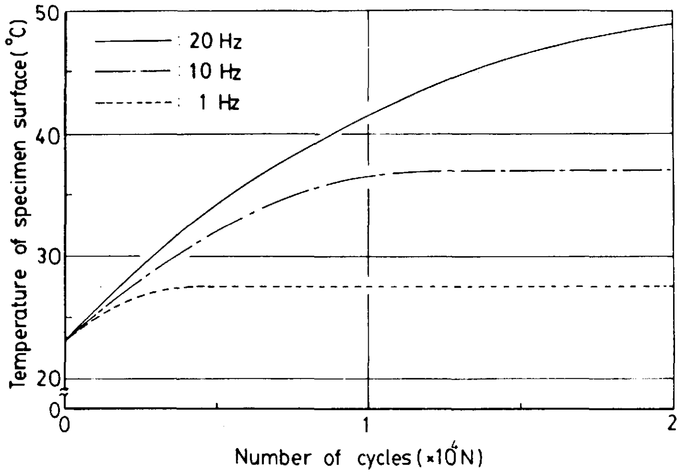


Fig.7 Relation between temperature of specimen surface and number of cycles for dental P.M.M.A.. (Stress amplitude: 2.87kg/mm^2)

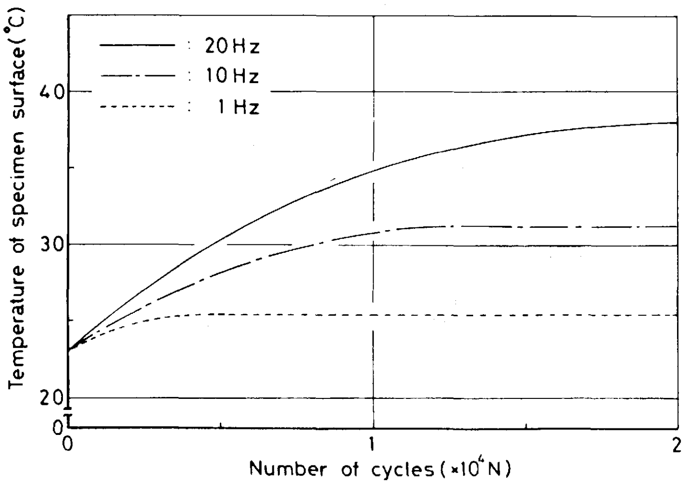


Fig.8 Relation between temperature of specimen surface and number of cycles for adhered dental P.M.M.A. by heat-cured acrylic resin. (Stress amplitude: 2.19kg/mm^2)

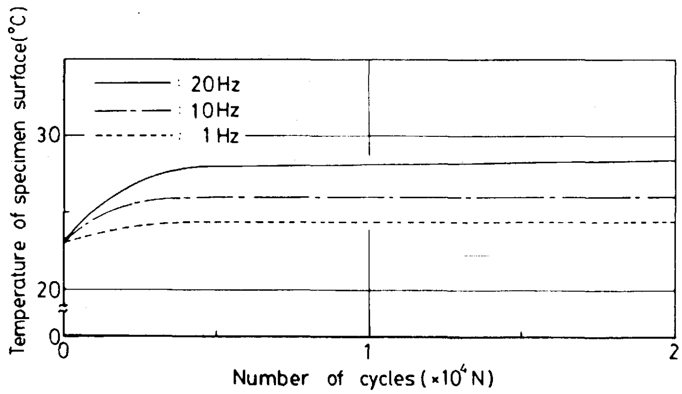


Fig.9 Relation between temperature of specimen surface and number of cycles for adhered dental P.M.M.A. by self-cured acrylic resin. (Stress amplitude: 1.20kg/mm^2)

temperature rise of test pieces, relation between surface temperature of test pieces and number of repetition was looked for, and results as shown in Figs.7-9 were obtained. In every case, temperature rose as test velocity increased, and rate of temperature rise was biggest with the base material, thence heat cured P.M.M.A., and the self-cured

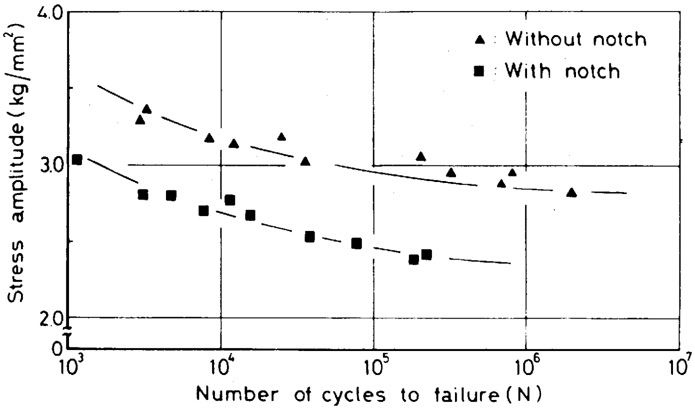


Fig.10 Notch effect on the S-N curve of dental P.M.M.A.. (Frequency:10Hz.)

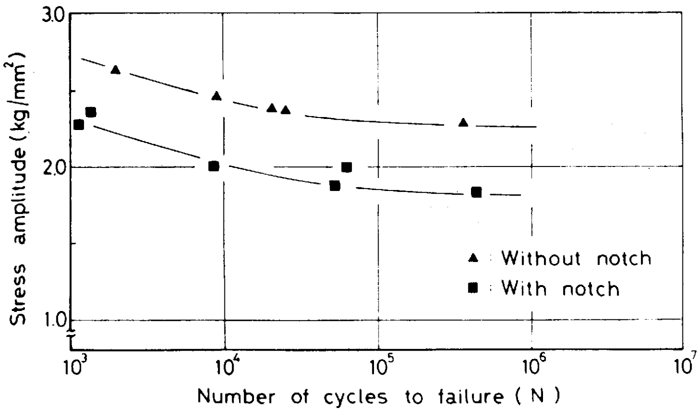


Fig.11 Notch effect on the S-N curve of adhered dental P.M.M.A. by heat-cured acrylic resin. (Frequency:10Hz.)

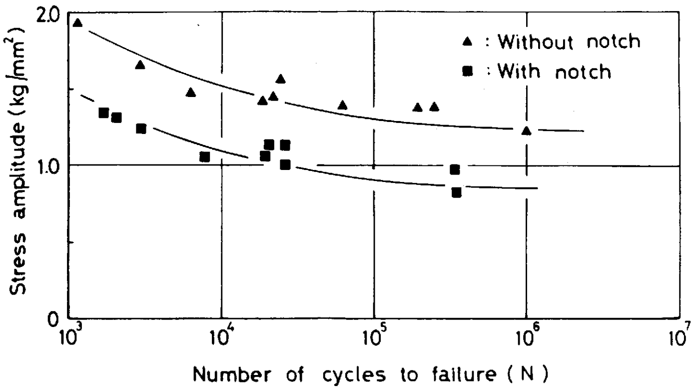
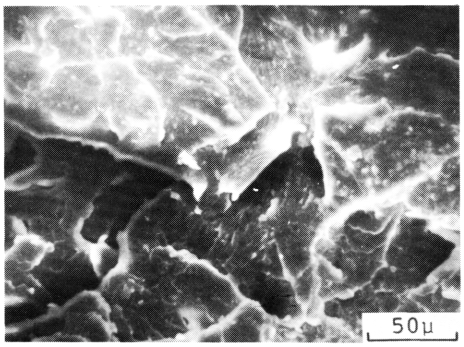
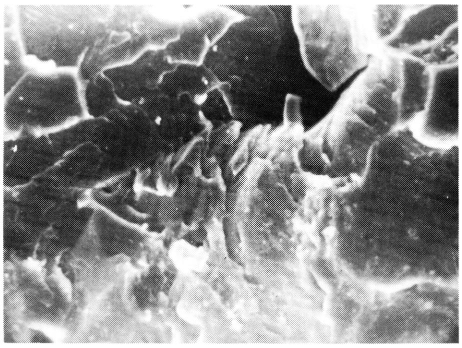


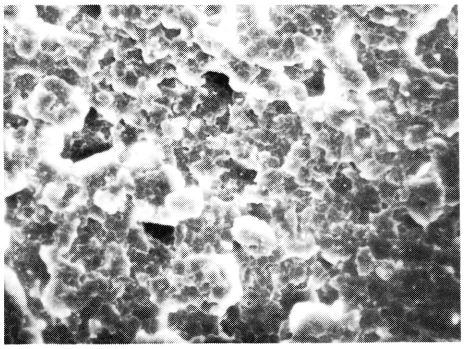
Fig.12 Notch effect on the S-N curve of adhered dental P.M.M.A. by self-cured acrylic resin. (Frequency:10Hz.)



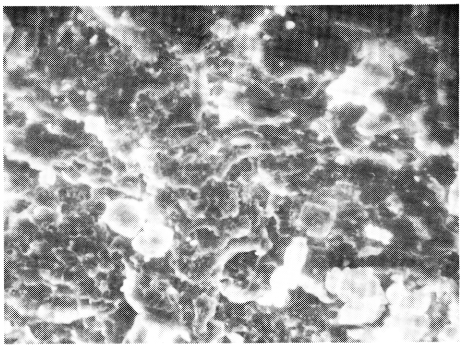
(a) Base material, f=1Hz, $\sigma=3.5kg/mm^2$



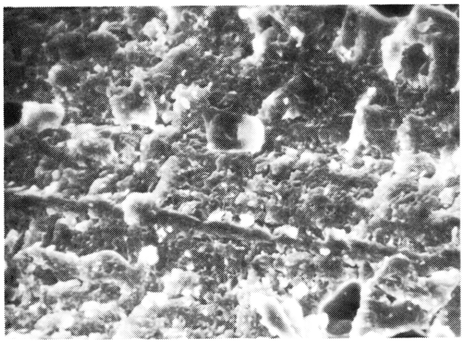
(b) Base material, f=20Hz, $\sigma=2.72kg/mm^2$



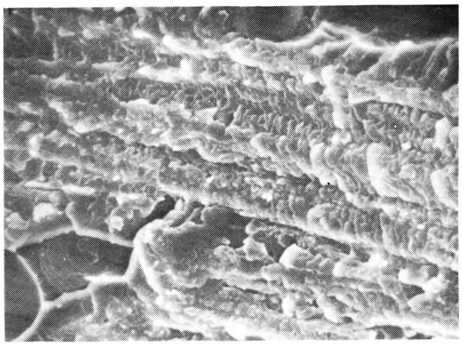
(c) Adhesion by heat-cured acrylic resin, f=1Hz, $\sigma=2.62kg/mm^2$



(d) Adhesion by heat-cured acrylic resin, f=20Hz, $\sigma=2.27kg/mm^2$



(e) Adhesion by self-cured acrylic resin, f=1Hz, $\sigma=1.7kg/mm^2$



(f) Adhesion by self-cured acrylic resin, f=20Hz, $\sigma=1.15kg/mm^2$

Photo.1 The appearances of fatigue fracture of dental P.M.M.A. and adhered dental P.M.M.A. by heat and self cured acrylic resin.

P.M.M.A. was smallest (Table 1 and 2). Results of experiments looking for the notch effect are shown in Figs.10-12, from which the effect of notch is clearly observed. Fatigue limits were lessened to 86, 78 and 72% respectively, and it has to be understood that the fatigue limit drops in average by about 1/4 because of a notch. Photo.1 shows fracture in which effect of test velocity can be seen. It is noted that plastic flow in the fracture caused by high frequency is slightly bigger.

Table 1 The fatigue characteristics of metal, dental P.M.M.A. and it's adherends.

Fatigue characteristics	Metal	Dental P.M.M.A. and it's adherends
Endurance limit	Clear	Loose
Twofold property	Non-existent	Existence
Effect of the test velocity	Non-existent	Existence
Effect of the loading shape	Non-existent	Existence
Temperature up	Non-existent	Existence

Table 2 Relation between maximum temperature of specimen surface and number of cycles for each materials.

	Frequency 1 Hz	Frequency 10 Hz	Frequency 20 Hz
Parent material	3000 N 27°C	10000 N 37°C	20000 N 49°C
Bonding material (Heat-cured acrylic resin)	3000 N 25°C	10000 N 29°C	20000 N 38°C
Bonding material (Self-cured acrylic resin)	3000 N 25°C	4000 N 26°C	5000 N 28°C

Where, room temperature ; 23°C

4. CONCLUSION

The following summary can be made from the results of the present research. In the practical use, fatigue limits of the bonded materials using heat cured and self-cured P.M.M.A. are approximately 2/3 and 1/3 of that of the base material. Two-fold property of S-N curve can be seen with dental P.M.M.A., and such property is partly attributable to temperature rise of the test piece. Fatigue limit drops as test velocity increases, and such drop is again partly attributable to temperature rise of the material. Effect of notch is observed and it is noted that the notch causes deterioration in endurance limit by about 1/4.

ACKNOWLEDGMENTS

The authors wish to express sincere thanks to Shofu Tooshi Manufacture Co. Ltd. for preparing to experimental materials.

This work is supported by the Grant-in-Aid from the Ministry of Education of Japan.

The main results of this research were published at the lecture meeting of the 40th general meeting of the Japan Research Society of Dental Materials and Appliances on May 9, 1980.

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