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Fatigue of Paper
—Sample Preparation and the Evaluation —

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1. Introduction

Paper, which is used most often as a base material for packaging, gradually fatigues or degrades during long-term preservation with or without mechanical loading[1,2]. As a preliminary of study on fatigue of paper [3], paper specimens were periodically extended up to various tensile load using a standard tensile tester and was also continuously folded under various tensile load using a MIT folding endurance tester, and some mechanical properties of these fatigued papers were examined in this study.

2. Experimental

2.1 Paper sample and the preparation of fatigued paper

Commercially available copy paper (basis weight: 60 g/m^2, tensile index: 29 Nm/g) was used as a base paper sample. The paper specimens were cut to 15 mm wide and 120 mm long and subjected to two types of fatigue loading under the standard atmosphere: 23℃, 50%RH.

One group of paper specimens were cyclically extended at a strain rate of 100 %/min under various tensile load using a standard tensile tester (Shimadzu Autograph AGS-100). Another group of paper specimens were continuously folded under various tensile load and number of folding times using a MIT folding endurance tester (dead-weight type: Kumagai-Riki).

2.2 Measurement

After all fatigued paper specimens were thoroughly conditioned at 23℃, 50%RH, the tensile strength and Young's modulus (static modulus) were measured using the tensile tester above-mentioned, with a pair of line type PAPRICAN clamp to secure a measurement under in-plane stress loading [4]. Sonic pulse propagation-related to dynamic modulus [5] was also measured as the sonic velocity using a fiber orientation tester (Nomura-Shoji SST-200).

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3. Results & Discussion

As a general law of various materials including paper, the logarithm of the time or cyclic number leading to their mechanical failure is inversely proportional to the applied mechanical load [2,6]. Thus, the product of logarithm of the time or cyclic number and applied mechanical load, presented as a ratio to original strength before fatigue, could be considered as a universal index of fatigue load applied to the material in fatigue evaluation testing. The change of mechanical properties, as shown as the ratio to the original figure before fatigue loading, with an increase of the applied fatigue load, as shown by the product of the logarithm of the cyclic loading number and relative load (ratio to the original tensile strength: 29 Nm/g) is shown in Fig.1 for cyclic tensile loading and in Fig. 2 for MIT-type folding. Although the cyclic number and applied load were varied, the changes in mechanical properties with an increase in the applied load for both MIT folding and cyclic tensile loading showed a clear trend. Regarding the former: both Young's modulus and the sonic velocity gradually and linearly decreased with increasing the applied load, while tensile strength did not decrease, probably because the overall specimen was fatigued. On the other hand, regarding the latter: both Young's modulus and the sonic velocity slightly and linearly decreased with increasing the applied load, while the tensile strength clearly decreased and the decreasing rate increased with an increase in the applied load, probably because a part of the specimen was intensively fatigued. Thus, it was revealed that the mechanical deterioration of paper varies, when the mechanical loading system differs. Further studies on different papers and loading systems and the related changes in paper structure are expected.

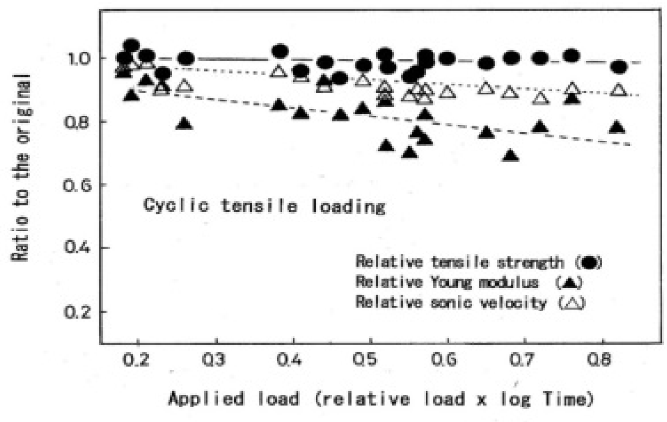

Fig.1 Effect of fatigue by cyclic tensile loading on the tensile strength, Young's modulus and the sonic velocity of copy paper.

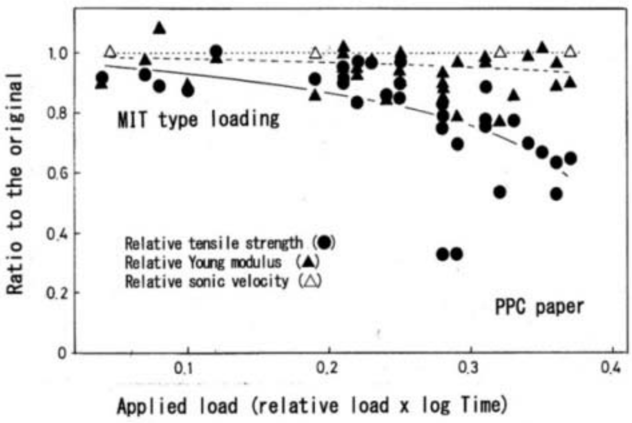

Fig.2　Effect of fatigue by MIT-type folding on the tensile strength, Young's modulus, and the sonic velocity of copy paper.

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