Static Fatigue Characterization With Uniform and Ultra-Small Bending

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Abstract: Static fatigue characteristics with uniform and ultra-small bending are investigated using a proposed slotted bending fixture. The humidity dependence of the time to failure characteristics in HAF is confirmed experimentally for the first time.

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1. Introduction

Recently, various types of bending loss insensitive fibers (BIFs) have been proposed [1, 2] with a view to achieving ease of fiber handling and wiring on residential and business premises. These fibers can be bent with a smaller diameter than conventional single-mode fiber, and offer improved handling characteristics. One BIF consisting of hole-assisted fiber (HAF) can achieve low bending loss characteristics and good compatibility with conventional G.652 fiber as regards mode-field diameter and chromatic dispersion characteristics [3].

It is well known that the mechanical reliability of optical fiber deteriorates when it is under excessive stress induced by bending, tension or torsion [4-6]. Moreover, the failure characteristics of optical fiber have been investigated taking the complex deployment conditions of BIFs into consideration [7]. When we focus on bending stress, there are several techniques for mechanically testing optical fiber. The two-point bending technique is widely used for measuring strength and static fatigue. An improved estimation model for investigating static fatigue characteristics under two-point bending has been reported [8]. However, the bending radius of the fiber varies along the fiber axis direction with this method [9]. The simplest fiber bending model is usually realized by winding a fiber onto a mandrel [10]. However, both bending and tensile stress are loaded if we wind the optical fiber on a mandrel with a small radius. Thus, there have been few reports on the failure characteristics that occur under uniform and ultra-small bending conditions. In this paper, we experimentally investigate the static fatigue characteristics of hole-assisted type BIF taking account of the humidity dependence. We propose a slotted bending fixture for realizing uniform and ultra-small bending conditions. The validity of the proposed evaluation technique is discussed. It is also confirmed that HAF exhibits time to failure characteristics that are similar to those of conventional single-mode fiber.

2. Experiments

We proposed a slotted bending fixture to examine the time to failure induced by uniform and ultra-small bending. Figure 1 is a schematic of the slotted bending fixture used in our experiments. It is composed of a slotted plate and a shutter, and it can induce a uniform bending strain in a test fiber. By constructing several fixtures with different slot radiuses, we could vary the uniformly applied bending strain systematically. In this study, all the experiments were performed in a chamber with a temperature of 25±2°C and a relative humidity of 15~85±5%. More than 25 fiber specimens were examined under each humidity condition. Fractures in the optical fibers were detected by monitoring the transmitted optical power.

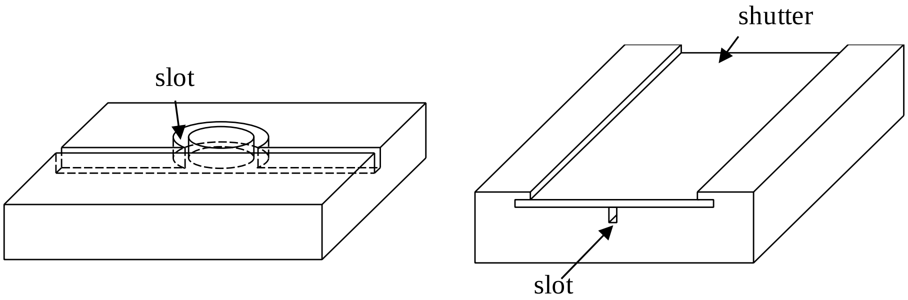

Fig. 1 Schematic of a slotted bending fixture

3. Results and discussion

3.1 Validity of measurement

First, we investigated the validity of our newly proposed measurement technique. Figure 2 shows a Weibull plot of a static fatigue test performed with an ultra small bending radius of 1.625 mm. A shape parameter m of 3.2 is obtained from Fig. 2. Generally, this indicates an increasing failure rate. The inset shows an example of a fracture surface. This confirms that the surface of the specimen exhibited fatigue fracture characteristics. Based on these results, we speculate that the failure observed with the proposed equipment was caused by fatigue.

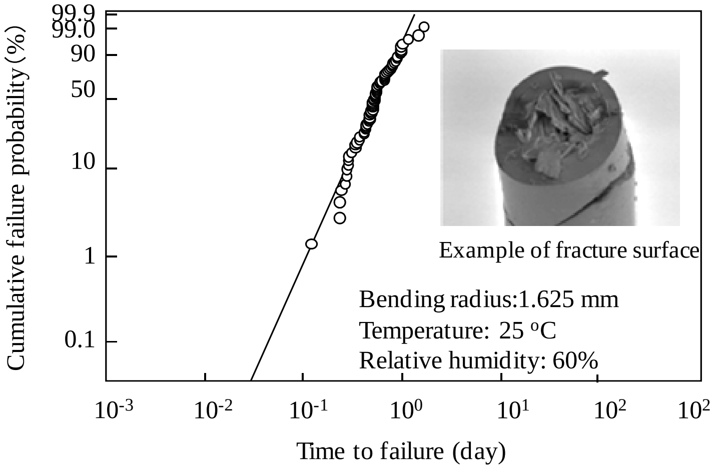

Fig. 2 Example of static fatigue test under 1.625 mm bending radius

Figure 3 shows the measured strain of the fiber in the slotted bending fixture. We measured this strain using optical frequency domain reflectometrery, and analyzed the strain-induced frequency shifts of Rayleigh backscattering [7]. We measured the fiber axial strain with and without a tensile load on the bent section of the fiber. When an optical fiber was inserted into the slotted bending fixture, an initial tensile strain of about 0.01% was observed around the bent section as shown by the blue line in Fig. 3. The figure also shows that the maximum strain increases up to 0.08% with a 75 gf tensile load. Moreover, Fig. 3 confirms that the strain returned to its initial value when the tensile load was removed. These results imply that bending stress is dominant in our proposed slotted bending fixture as we expected. When both bending and tension are applied to an optical fiber simultaneously, the combined strain causes a degradation in the time to failure characteristics [10]. Therefore, the proposed slotted bending fixture is beneficial for evaluating static fatigue under uniform and ultra-small bending conditions.

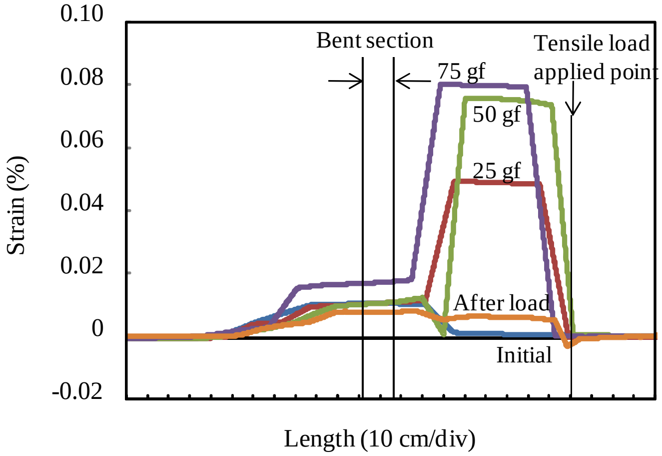

Fig. 3 Fiber strain in the slotted bent fixture

3.2 Static fatigue characteristics of HAF

Figure 4 shows the time to failure dependence on the bending radius. The open diamonds and circles show the results obtained with different HAFs. The filled circles show the results obtained with conventional single-mode fiber. Here, each plot indicates the mean time to failure (MTTF) value (i.e. 63.2%) calculated from the Weibull distribution. More than 25 specimens were used for each bending radius. The test specimens used in this study had a 125 μm diameter, and were coated with UV-curable resin with an outer diameter 250 μm. The fatigue parameter *n* derived from Fig. 4 was 22.5~23.5. We also found no significant difference between HAFs and conventional fiber. We then investigated the humidity dependence of the failure characteristics. Figure 5 shows the relationship between time to failure and relative humidity. The figure confirms that the time to failure varies depending on the humidity. These tendencies agreed well with those described in a previous report [12]. As a result, we can confirm that the proposed slotted bending fixture is beneficial for evaluating static fatigue characteristics with uniform bending. We also observed for the first time that the humidity dependence of the time to failure in hole-assisted type BIF is similar to that in conventional single-mode fiber.

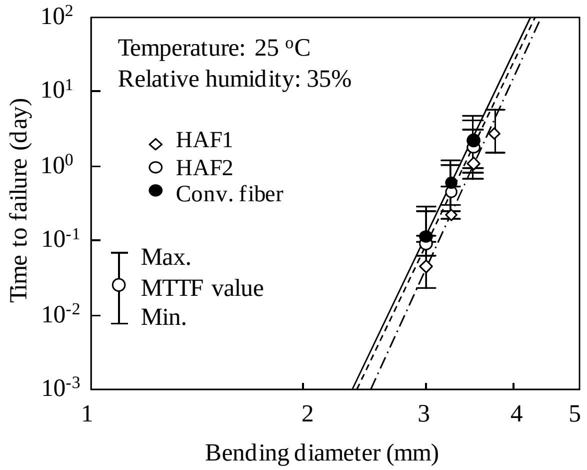

Fig. 4 Time to failure under ultra-small bending radius

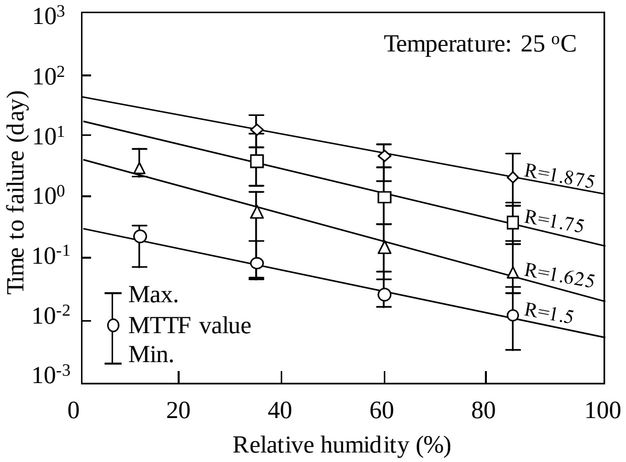

Fig. 5 Relative humidity dependence of time to failure

4. Conclusion

We investigated the static fatigue characteristics of hole-assisted type BIF under uniform and ultra-small bending conditions experimentally. We proposed a slotted bending fixture technique for evaluating the influence of strain induced solely by uniform bending. We confirmed the validity of the proposed technique, and examined the time to failure characteristics in HAF under ultra-small bending conditions. As a result, we confirmed for the first time that the humidity dependence of time to failure in hole-assisted type BIF is similar to that in conventional single-mode fiber.

Reference

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