MACROBENDING LOSS MEASUREMENTS IN TWO-POINT BENDING

M. John Matthewson
Gregory J. Nelson

Fiber Optic Materials Research Program
Department of Ceramic Science and Engineering
Rutgers University
PO Box 909
Piscataway, NJ 08855-0909
Tel: 908-932-5933
Fax: 908-932-4545

James E. Kuder

Hoechst Celanese Corporation
Fiberoptic Products
86 Morris Avenue
Summit, NJ 07901
Tel: 908-522-7504
Fax: 908-522-7206

An automated two-point bending technique for macrobending loss measurements is described. The technique allows measurements to be made more rapidly and with greater flexibility than the common mandrel-wrap technique.

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Macrobending loss measurements are usually made by determining the optical loss while the fiber is wrapped around mandrels of various sizes. This technique is labor intensive and time consuming. This paper describes using the two-point bending technique to deform the fiber while making loss measurements. This technique, already widely used for making static[1] and dynamic[2] strength and fatigue measurements, involves constraining a loop of fiber between two faceplates, as shown in Fig. 1. The fiber is located in grooves in the faceplates. The faceplates are brought together under computer control so that loss measurements can be made as a function of the faceplate separation in an automated fashion. The technique therefore allows one to obtain large quantities of data rapidly. The technique can also be used to measure hysteresis in the loss since measurements can be made while both closing and opening the faceplates - such measurements are not possible with the standard mandrel-wrap technique. For example, Fig. 2 shows the results of repeated closings and openings for a 250 μm diameter polymer fiber where each closing had progressively smaller distances of closest approach of the faceplates (ranging from 28 down to 3 mm in six steps - the end points are marked by the arrows). The optical loss becomes significant at faceplate separations of less than approximately 13 mm but hysteresis in the loss is only observed for the final sweep. In this case the hysteresis is caused by a kink in the fiber caused by nonlinear (both plastic and viscoelastic) deformation of the polymer. While nonlinear deformations of the fiber mean that its shape is not known, this technique does better model the practical application of the fiber where, unlike in the mandrel-wrap technique, the fiber is not conformed to bend in a circle.

The shape of the fiber in two-point bending is not circular[2] and so the results of the two-point bending measurements cannot be directly compared to those of mandrel bending. However, if it is assumed that the loss in mandrel bending for a given mode of propagation can be expressed as a power series in the curvature:

$$\text{Circular Bend Loss} = \sum_{n=0}^{\infty} a_n\, R^{-n} \tag{1}$$

where R is the radius of curvature, then the loss in two-point bending can also be expressed as a power series in the reciprocal of the faceplate separation, d:

$$\text{Two - Point Bend Loss} = \sum_{n=0}^{\infty} b_n\, d^{-n} \tag{2}$$

and the coefficients, a_n and b_n, are related by:

$$\frac{b_n}{a_n} = \frac{2}{\pi}\, \Im^n\left(\tfrac{1}{2}\right) \Im\left(\tfrac{n}{2}\right) \tag{3}$$

where $$\Im(x) = \int_0^{\pi/2} \sin^x \theta = \int_0^{\pi/2} \cos^x \theta = \frac{\sqrt{\pi}}{2} \frac{\Gamma\left(\frac{x+1}{2}\right)}{\Gamma\left(\frac{x+2}{2}\right)}. \tag{4}$$

This result may be used to predict the loss in mandrel bending from the loss measured in two-point bending. However, the ratio of the coefficients given in Eq. 3 is close to unity for lower order terms (Fig. 3) showing that two-point bending and mandrel bending will generally give similar results for the loss.

REFERENCES

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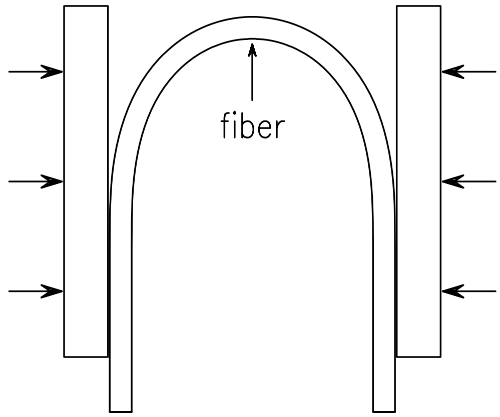

Figure 1. Schematic of the two-point bend technique for fiber optical loss, strength and fatigue measurement.

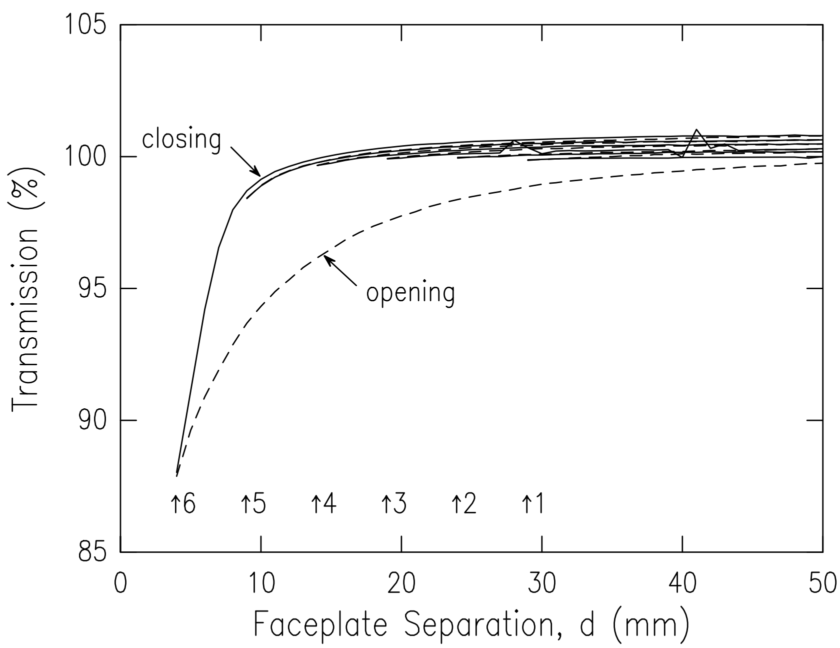

Figure 2. Optical transmission as a function of faceplate separation for a 250 μm plastic fiber in two-point bending. Results are shown for six successive closings and openings.

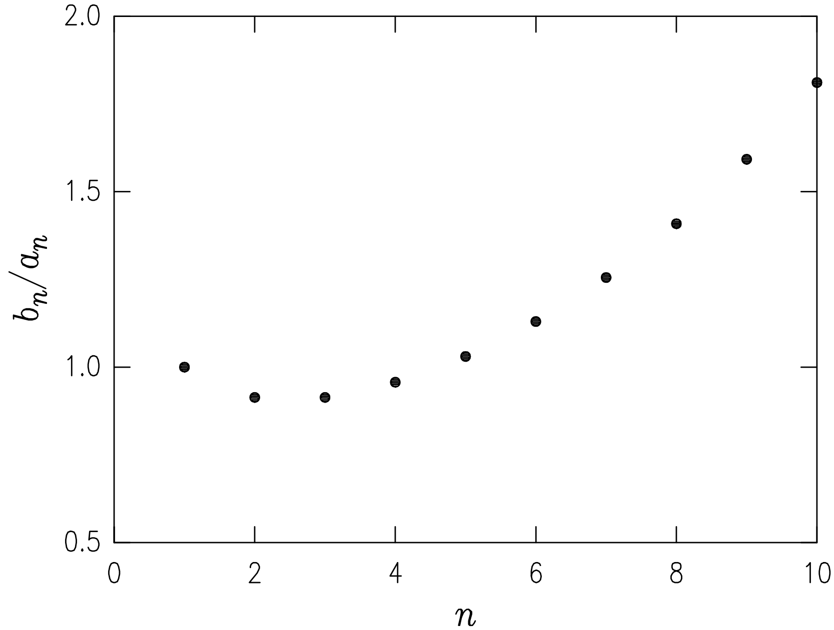

Figure 3. Ratio of the power series coefficients in two-point bending and mandrel bending as a function of coefficient order, *n*.