Development of a Novel Vibration Polishing Method for Fiber Protrusion in Multi-fiber Connectors †

by Jie Xu, Akihiro Murakami* and Takashi Shigematsu**

ABSTRACT A novel ultrasonic vibration polishing method for multi-fiber connector with high precision has been developed by introducing a supplementary polishing ferrule between the fiber-ends and the ultrasonic vibrator. This method enables us to obtain effectively the desired fiber protrusion regardless of the materials used for the connector. Good and stable physical contact (PC) connection was achieved even in single-mode 12-fiber MPO connectors, and return loss and insertion loss remained stable during 500 cycles of reconnection. These results demonstrate that this polishing method is effective in achieving both sufficient fiber protrusion and good PC in multi-fiber connectors. The method can be applied in high-precision processing.

1. INTRODUCTION

Mechanically transferable (MT) and multi-fiber push-on (MPO) connectors were developed to meet the need for rapid transmission of large volumes of data [1), 2)], and both types are widely applied due to their excellent characteristics. In these connectors, index-matching material is usually employed to reduce Fresnel reflection caused by the presence of air between the fiber endfaces. However a physical contact (PC) connection without index-matching material is preferable in terms of long-term stability and good optical characteristics.

PC connection requires that all the fiber endfaces are even and protrude beyond the ferrule end, preferably, 3 μm or more. Thus, it is difficult to achieve good PC connection by the conventional polishing method, which takes advantage of the difference in hardness between the plastic ferrule and the fiber (silica) to obtain fiber protrusion. It generally takes about 5 minutes to produce 1 μm of fiber protrusion.

Unfortunately, owing to the limitation of the difference in hardness between the two materials, it is almost impossible to obtain a fiber protrusion of above 3 μm even when polishing is continued for a long time. It is also difficult to achieve both even endfaces and sufficient fiber protrusion for all the fibers, especially in connectors with fiber counts of 12 or more.

† Compiled from Trans. JSME, Category-C, Vol.67, No.662, pp3317~3322 (2001)

* Production Engineering Development Center, Plant & Facilities Div.

Here we describe a novel vibration polishing method for multi-fiber connectors by which, sufficient fiber protrusion is easily obtained in a short time regardless of the material used for ferrule and fiber. Good PC connection was also achieved. This method can be applied to angle-polished 12-fiber MPO connector and good optical characteristics are obtained.

2. NOVEL POLISHING METHOD

2.1 Fiber Endface Conditions Required for PC Connection

Figure 1 shows the structure of an 8-fiber MPO connector. To decrease reflection, fiber endfaces in this kind of connector are polished at a gradient of 8° to the fiber cross section. The connector endfaces are held together by the engagement of the guide pins in guide-pin holes. To achieve PC connection in such a connector, it is necessary that the process of polishing achieve the following three main elements:

1. sufficient fiber protrusion,
2. flat endfaces, and
3. angular precision between the fiber endface and the connection endface.

The novel polishing method enables us to achieve PC connection since all three of these conditions are achieved by polishing connector and fiber ends separately, guaranteeing the flatness of fiber endfaces.

2.2 Principle of the Novel Polishing Method

Figure 2 illustrates the novel method of fiber protrusion polishing by means of an ultrasonic vibration polishing machine. First, the MT type ferrule is lapped by a special

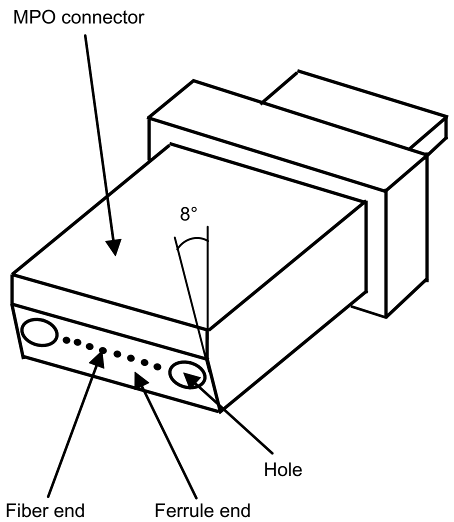

Figure 1 8°MPO optical fiber connector.

lapping wheel to align the fiber ends with a high degree of flatness. The MT ferrule with highly flat endfaces is then aligned by the guide pin with the assisting ferrule, in which there are empty fiber holes, and an abrasive is added between the ferrule ends. The assisting ferrule is then vibrated by the vibrator attached to it, and only the MT ferrule endface is polished leaving the fiber-ends untouched because they are free from contact with the assisting ferrule. This polishing method leaves the fiber endfaces unpolished without failure. The desired fiber protrusion can be obtained easily in a short time by suitably selecting the vibration frequency and the abrasive particle size.

In this method, fiber protrusion and fiber-end flatness are achieved by completely separate polishing processes. Sufficient fiber protrusion can thus be obtained while keeping the fiber endfaces precisely even, thereby realizing good PC contact.

3. EXPERIMENTAL FIBER PROTRUSION POLISHING

3.1 Apparatus and Method

Figure 3 is a photograph showing an external view of the experiment apparatus. A small commercially available ultrasonic polishing machine was used as the vibrator. The position of the connector and the assisting ferrule are settled by two guide pins set horizontally, and the two endfaces are pressed together by a compressed spring with abrasive between them.

The polishing load can be established quantitatively using a micrometer and load cell. During the polishing process, however the load is kept virtually constant, since the amplitude of vibration and real protrusion are so small that the displacement caused by the compressor spring is practically negligible.

In this experiment, a 12-fiber MPO connector with the pre-polished endfaces was used, and the effect of load on the protrusion and eccentricity of the fiber protrusion center was investigated. The load was set at 2 N, 3 N, and 4 N, and fiber protrusion was measured every 10 seconds using a two-dimensional roughness detector. The frequency of the vibrator was set at 20 kHz. To improve

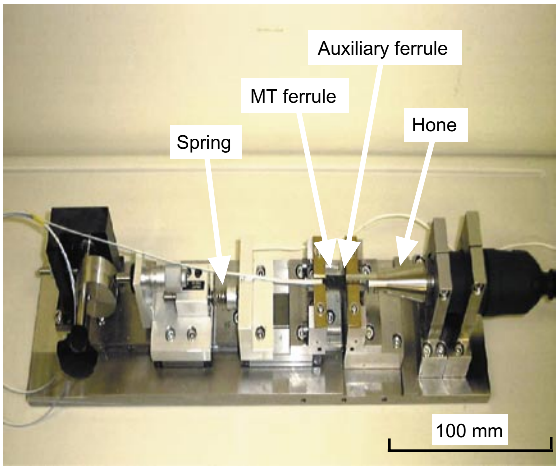

Figure 3 External view of experimental equipment.

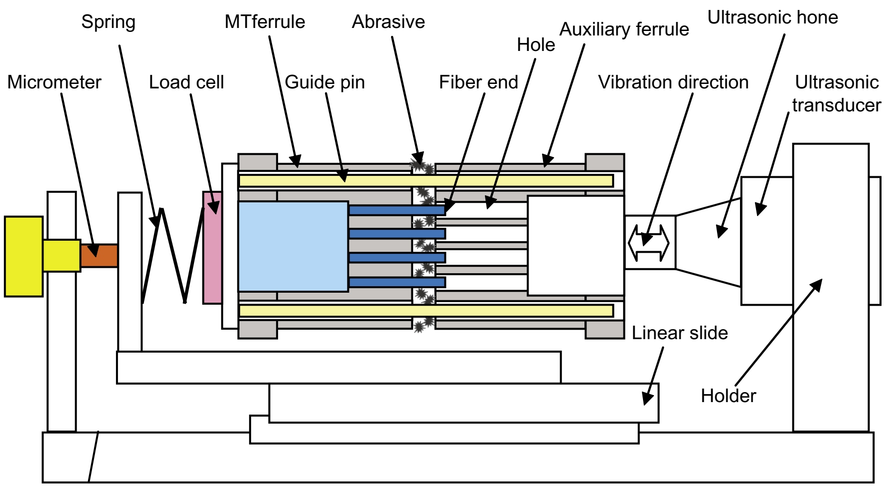

Figure 2 Principle of the novel vibration polishing method.

polishing efficiency and to decrease peripheral damage, 10 wt% diamond abrasive with a particle diameter of 3 μm was used.

3.2 Experimental Results and Discussion

By means of this novel polishing, good fiber protrusion and endfaces were obtained. The characteristics of processed fiber endfaces were investigated.

3.2.1 Relationship between Fiber Protrusion and Load

As Figure 4 shows, fiber protrusion is proportional to the polishing time at any given load, and the slope of the curve increases as load is increased. From Figure 4 it can also be demonstrated that polishing efficiency is much greater with this novel method than with the conventional method, in which as much as 5 minutes was required to produce a fiber protrusion of no more than 1 μm.

During the initial 20 seconds of polishing, the increase in protrusion was a little slow. We attribute this to the difference in the original flatness between the connector and ferrule endfaces, as well as the property of the abrasive which make it is easily ejected from the gap.

It is known that the type and grade of abrasive have an effect on the efficiency of polishing. In our experiment, polishing efficiency was found to decrease about 10 percent when alumina abrasive was used instead of diamond abrasive of the same grade.

3.2.2 Eccentricity of Fiber Protrusion Center

As shown in Figure 2, in this novel method, it is essential to accurately insert the fibers, with a diameter of 125 μm, into the corresponding holes with a diameter of 126 μm, in the assisting ferrule, because this positioning determines whether the protruded fiber end is in the center of the core (diameter 10~62.5 μm) which forms the optical pathway. Especially in the case of fibers with a diameter of 62.5 μm, if the eccentricity exceeds 20 μm, it is possible that some part of the core end will be removed by vibration polishing. In practice it is desirable that the variation in eccentricity be kept below 10 μm.

We next investigated the relationship between variation in fiber protrusion center and load. In three independent experiments, eccentricity in the fiber protrusion center, using our novel polishing method, were both below 5 μm under the loads of 2 N and 3 N (Figure 5). These results indicate that the fiber protrusion center was accurately kept unchanged by this novel method. Our experiments also showed a tendency for the eccentricity in the fiber protrusion center to increase with increasing load. The reason, we think, is that the horizontal component produced by the load exerted at the angle of inclination of 8°, caused the vibration in the horizontal plane.

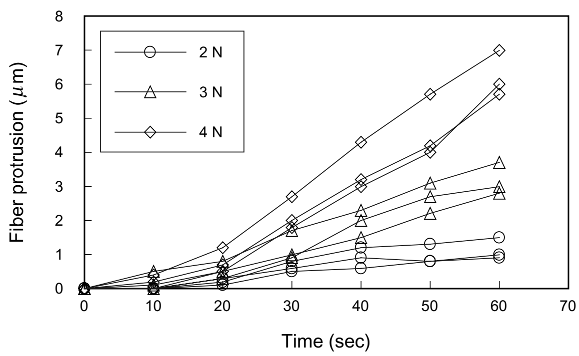

Figure 4 Relationship between fiber protrusion and load.

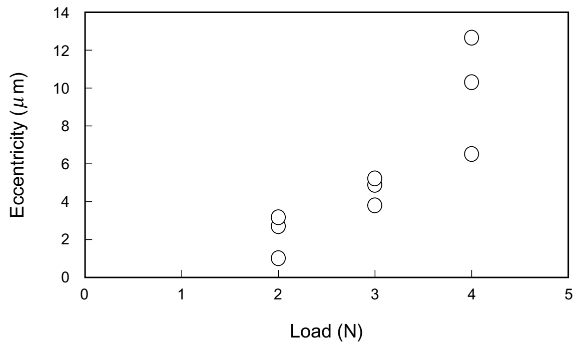

Figure 5 Relationship between fiber protrusion eccentricity and load.

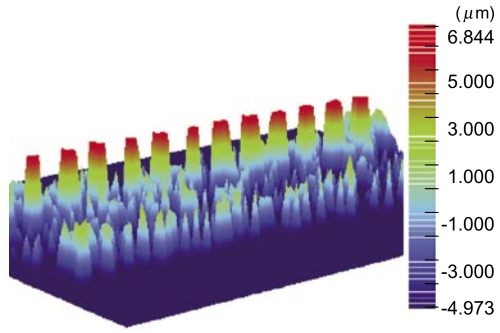

Figure 6 Fiber protrusion in 12-fiber MPO connector.

3.2.3 Status of Protruding Endface of Processed Fiber

Figure 6 is an example of the result of measuring processed fiber protrusion endfaces in a 12-fiber MPO connector examined by a surveying instrument from WKYO Co., Ltd. All the fiber endfaces are smooth with 5 μm of protrusion from the MT ferrule.

Figure 7 shows photographs of a fiber endface before and after vibration polishing. It is clear that the endface of fiber was kept untouched without damage after polishing. In addition, the breach damage on the periphery of the fiber endface was very slight so that roundness was well controlled within a few micrometers.

Also, the effect of diamond particle size on the status of the fiber endface was investigated. Although the efficiency of polishing was proportional to the size of diamond particle abrasive for 3 and 6 μm diameters, breach damage exceeded 10 μm in the case of 6 μm diameter. Thus a diamond particle diameter of about 3 μm is most suitable.

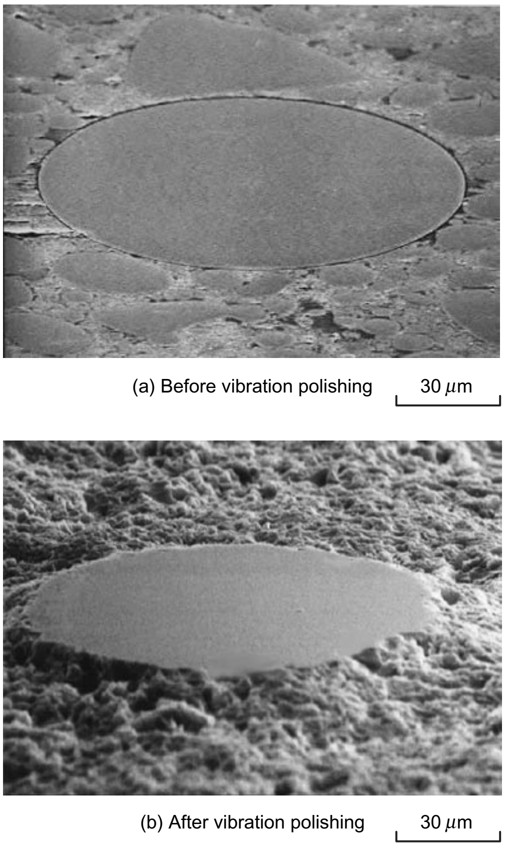

Figure 7 **Fiber and ferrule surfaces before and after vibration polishing.**

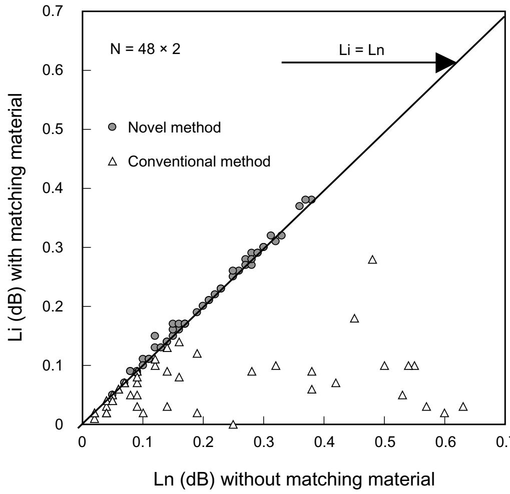

Figure 8 **Relationship between insertion losses with and without index-matching material in single-mode 12-fiber MPO connectors polished by the novel vibration and conventional polishing methods.**

4. EVALUATION OF OPTICAL CHARACTERISTICS

PC connection was evaluated in single-mode 12-fiber MPO connectors with 5 μm of fiber protrusion processed by the novel vibration polishing method. Stability test for connection-reconnection 500 cycles was also conducted to determine insertion loss and return loss in this connector.

4.1 PC Connection Test

In order to evaluate whether good PC connection is achieved, we measured insertion loss with and without index-matching material in single-mode 12-fiber MPO connectors processed by the novel vibration polishing method.

Without index-matching material, if the fiber endfaces do not achieve PC connection, a layer of air will appear between endfaces, causing a large insertion loss. It is known that with single-mode fibers, a layer of air 0.3 μm thick can cause insertion losses of above 0.6 dB. In general, if the difference in the insertion loss with and without index-matching material is above 0.05 dB, good PC connection cannot be said to be achieved.

Figure 8 shows the insertion loss with and without index-matching material detected in single-mode 12-fiber MPO connectors processed by the novel vibration polishing method. If there is no difference between insertion loss with index-matching material (Li) and without (Ln) the line will be straight, representing an ideal PC connection. In the sample polishing by the novel method, virtually no difference was found between Li and Ln. The maximum difference in Li and Ln, insertion loss was less than 0.04 dB (n=48). These results indicate that excellent PC connection was achieved by the novel polishing method.

4.2 Stability Test

The novel method presented here enables us to obtain sufficient protrusion regardless of the materials used in the connector, but doubts persist that such a long protrusion might increase the risk of fiber end damage.

To evaluate the stability of fiber protrusion in practical performance, the changes in insertion loss and return loss were evaluated in a 500 cycles connection-reconnection test of the single-mode 12-fiber MPO connectors, conducted without index-matching material. Fiber protrusion was 5 μm, and the ferrules were connected under compression force of 9.8 N. The insertion loss and return loss at 1310 nm wavelength were measured for all the fibers every 25 cycles. For the sake of simplicity, Figure 9 and Figure 10 show only the results of the first, sixth, seventh and twelfth fibers measured every 100 cycles. The results demonstrate that there is virtually no change in optical characteristics in these reconnection tests, indicating that the performance of connectors, even with a fiber protrusion of 5 μm, is very stable.

5. CONCLUSION

A novel vibration polishing method for multi-fiber connectors has been developed to achieve physical contact (PC). By polishing 12-MPO connectors by means of this method, we drew the following conclusions:

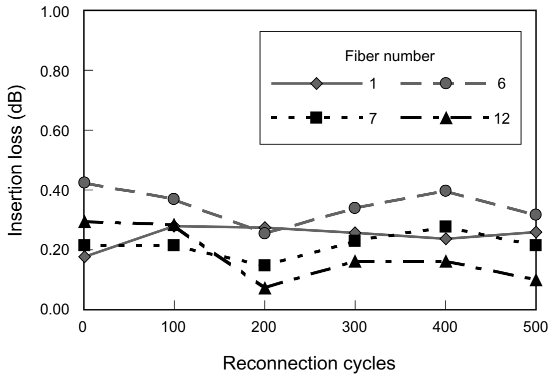

Figure 9 Change in insertion loss during 500 reconnection cycles.

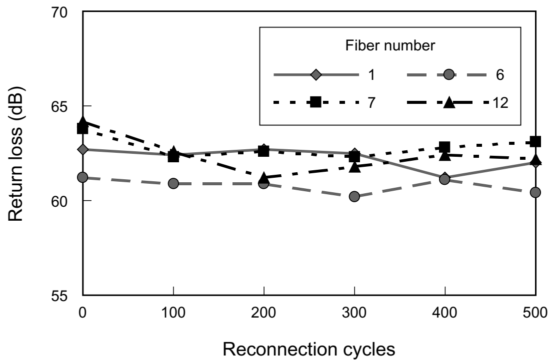

Figure 10 Change in return loss during 500 reconnection cycles.

1) Sufficient fiber protrusion with flat endface can be obtained easily without restrictions on the ferrule material as a result of using a supplementary ferrule.
2) Fiber protrusion is proportional to the load employed in polishing.
3) Eccentricity of the fiber protrusion center can be kept to less than 10 µm under the proper load.
4) Excellent PC is achieved.
5) Insertion loss and return loss remain stable during the 500 cycles of reconnection when fiber protrusion is 5 µm.
6) Process efficiency is 10 fold higher than with the conventional method.

These results demonstrate that this novel polishing method can be employed effectively even in high-precision processing.

REFERENCES

1) T. Satake, et al. J. Light. Tech., 4 (No.8), 1232 (1986)
2) S. Nagasawa, et al. Tech. Dig. IOOC'89, 21C2-1, 48 (1989)
3) S. Nagasawa, et al. Photon Tech. Lett., 3 (No.10), 937 (1991)
4) W.C. Young, et al. Photon Tech. Lett., 1 (No.12), 461 (1989)
5) K. Okude, Ultrasonic Physics, Corona Publisher (1995) (in Japanese)