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EFFECT OF BENDING OPTICAL FIBRE ON BEND LOSS OVER A LONG PERIOD OF TIME

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ABSTRACT

In Malaysia, fiber cable is commonly installed underground or overhead. Once optical fibre cable is installed either underground or over-head, there is no physical maintenance implemented. The only maintenance on fibre cable is the monitoring of optical fibre attenuation. Bend loss affects the attenuation and any bending cable that contributes to the bend loss remains unmaintained since there is no study on the effect of bending fibre on bend loss in a long period of time. The effect of bending optical fibre in long term is investigated in this paper. The study has been done on the existing optical fibre of OPGW that is installed on a high voltage transmission tower. The effect of bending optical fibre with bend loss is monitored in 10 months and the permanency is verified.

Keywords: bending optical fibre, bend loss, attenuation, mode field diameter.

INTRODUCTION

Bend loss is one of the losses that contribute to the lack of fibre performance (Yu Zhi and Wang Hong, 2012). Bending of optical fibre can be mostly found at termination points and joining points. Termination points will be in telecommunication room where if any loss detected due to the bending of fibre at this point, the rectification can be done immediately. Unfortunately, if the bending loss is detected due to the bending that is located inside the joint closure as shown in Figure-1, especially those installed crossing the forest or jungle, the rectification work will take some times.

Figure-1. Bending of the optical fibre in joint closure.

Since each single optical fibre in a fiber cable has business value especially to utility companies as their alternative income instead of tariff related business, the attenuation of optical fibre for long distance fibre has to be maintained within the acceptable value.

As discussed by Jenny (2000), Hakim (2010), Abramczyk (2008) and Potter (2010), the attenuation of fibre is affected by several factors. Bending of fibre is one of them. Among those type of losses, the factor that can be seen by naked eye is bend loss where it is due to the bending of optical fibre (JDSU, 2007) (Zendehnam, *et al.*, 2010) (Dutton, 1998) (Lietaert, 2009). Unfortunately, there is no study on its effect in long term. Practically, the loss will disappear when the bending was released but that experiment has been done in laboratory and the bending was released just after the experiments have completed.

In this study, the effect of bending optical fibre that is left for a long time will be presented. Since in the real situation, the bending of optical fibre is left for a long time, the effect of bending on loss that is related to that bending has to be studied. The experiments have been conducted in order to detect if permanent bending with loss associated with it will affect the performance of the optical fibre permanently. From this experiment, further steps of study can be done in order to determine the maintenance period and develop guideline in radius of bending in joint closure.

METHODOLOGY

Bending loss has a direct relationship with the radius of bending (Zendehnam, *et al.*, 2010) (Dutton, 1998). As the radius is smaller, the loss will get higher. In addition, there is a different effect of bending loss on different wavelength of light (JDSU, 2007) (Lietaert, 2009).

Mode Field Diameter (MFD)

The single most important factor that determines the susceptibility of a fibre to bending that induces loss is the Mode Field Diameter (MFD) (Corning, 2001) (JDSU,

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2007). MFD represents the area in which the light goes through and includes the core and a part of the cladding. A smaller mode field diameter indicates that light is more tightly confined to the fibre centre and, therefore is less prone to leakage when the fibre is looped (JDSU, 2007). Figure-2 shows the relationship of light power and MFD where diameter of core and the wavelengths are the important parameters in determining the sensitivity of bend loss.

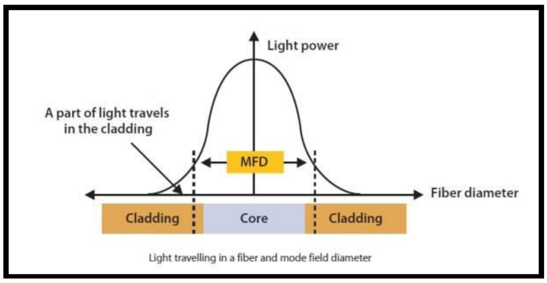

Figure-2. The relationship between light and MFD (JDSU, 2007).

The total number of modes supported in a curved, multimode fibre is therefore related to the index profile, the propagating wavelength, and the radius of curvature as shown in Equation (2).

$$N_{eff} = N_{\infty}\left\{1 - \frac{\alpha+2}{2\alpha\Delta}\left[\frac{2\alpha}{R} + \left(\frac{3}{2n_2kR}\right)^{2/3}\right]\right\} \quad (2)$$

Where N∞ is the number of modes supported in a straight fibre, α defines the index profile, Δ is the core-cladding index difference, n2 is the cladding index, k = 2π/λ and R is the radius of curvature of the bend (Potter, 2010).

However, single mode fibre has a larger mode field diameter at 1550 nm than at 1310 nm and at 1625 nm than at 1550 nm. Larger mode fields are sensitive to lateral offset during splicing, but they are more sensitive to losses incurred by bends during installation or in the cabling process (JDSU, 2007). 1550nm is more sensitive to bend in the fibre than 1310nm. This indicates that longer wavelength will encounter loss due to bending at the same radius, R.

Bending radius and bending loss

Radius of bending is the important parameter to know. The measurement of bending will be used to determine the loss that is associated with it. Figure-3 shows the illustration of bending optical fibre and its radius.

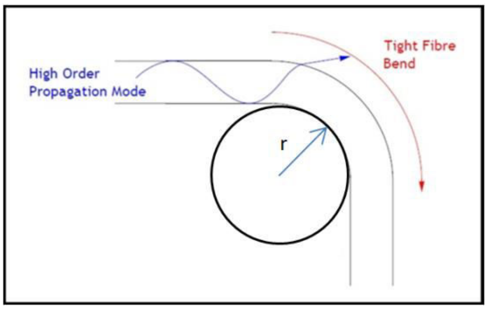

Figure-3. The illustration of bend with radius r.

Bend loss has a direct relationship with the radius of bending. The critical radius of curvature, R_c is defined by Zendehnam, *et al*. (2010) and Dutton (1998) as equation (1).

$$R_c = \frac{3n_2.\lambda}{4\pi(NA)^3} \quad (1)$$

where R_c is the critical radius of bending, n_2 is the refractive index of the clad and NA is the numerical aperture of the fibre and λ is the wavelength. Dutton (1998) conducted an experiment on the effect of bending radius where as shown in Figure-4, as R increases, the loss decreases but at some points, the reduction does not happen, but the rise of loss is obtained.

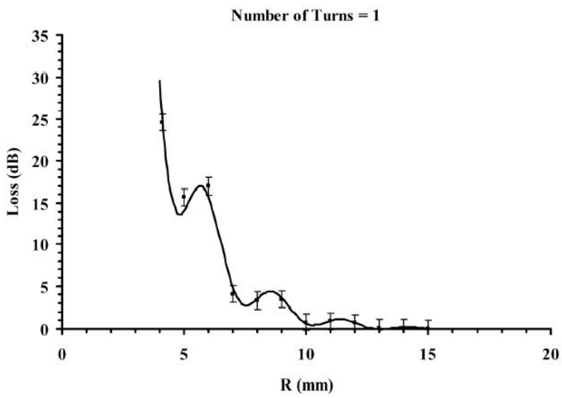

Figure-4. Variation of loss against radius of curvature, R (Dutton, 1998).

Wavelengths sensitivity on bending

By measuring the same fibre, which includes splices and connectors, using those two wavelengths, the potential bending optical fibre could be determined. For a given event (splice or connector), if there is no bend, the loss measurement shall be about the same at any wavelength. If there is a large difference more than 0.2 dB between the two wavelengths, this is due to bend (Potter, 2010). Figure-5 shows the sensitivity of different wavelengths on macro bend. The variable used is bend radius.

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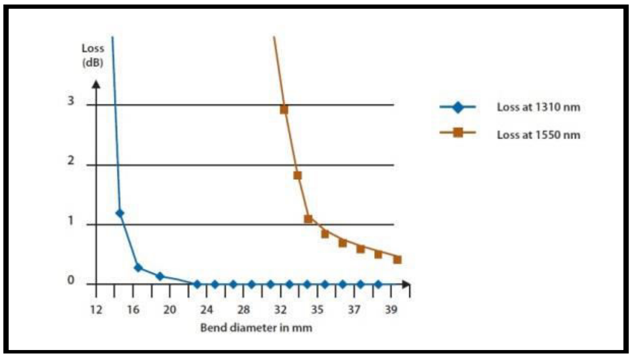

Figure-5. 1310 nm vs. 1550 nm on diameter of bend (JDSU, 2007).

OTDRs are the ideal tools for detecting and locating bends in a fibre link (JDSU, 2007). As bend is sensitive to longer wavelengths but not for shorter wavelengths, most of the operators use two wavelengths from OTDR to test the fibre links. The wavelengths that are commonly used for detecting bend loss are 1310 nm and 1550 nm. These two wavelengths will be used in this paper for that purpose. For future analysis on bending loss, the wavelengths should be taken between 1310 nm and 1625 nm, or between 1550 nm and 1625 nm, which are relevant wavelengths for DWDM testing.

EXPERIMENTS

The experiments have been done on the existing optical fibre that is installed on high voltage transmission towers. The length of fibre cable is 54.554km and has 24 joining points. The coiling of the optical fibre in joint closure will be monitored to see whether it will give loss since the joint closure will be left untouched for long time upon the installation as there is no maintenance on joint closure.

Determining bending loss

The Optical Time Domain Reflectometer (OTDR) uses the effects of Rayleigh scattering and Fresnel reflection to measure the characteristic of an optical fibre (Vita and Rossi, 1988) (Collin, 1981) (Fermann, *et al.*, 1988). By sending a pulse of light into a fibre and measuring the travel time and strength of its reflections from the points inside the fibre, it produces a characteristic trace, or profile, of the length vs. returned signal level on a display screen.

When the 1550 nm wavelength was added to the 1310 nm transmission wavelength, the bending effect was analysed. The bending of optical fibre will give optical power loss that affects longer wavelength more than shorter wavelength (Robertson, 2005) (Ryer, 1998) as shown in Figure-6.

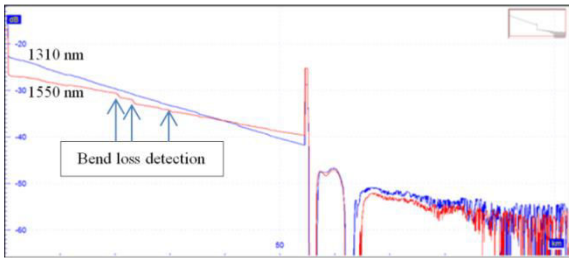

Figure-6. The 1310 nm and 1550 nm traces of Experiment I.

However, the losses that are detected by 1550 nm wavelength in optical fibre of OPGW that is already installed on high voltage transmission tower is not necessarily due to the bending of optical fibre. To decide whether losses captured by 1550 nm is the bend loss, the value of losses for 1310 nm and 1550 nm wavelength at each location is compared. As studied by JDSU (2007), the bend loss causing the loss that is captured by 1550 nm will be higher than the losses captured by 1310 nm by at least 0.2 dB. Data from event table will be used to detect the value of losses along the tested fibre. The comparison of loss value between 1310 nm and 1550 is shown in Table-1.

Table-1. Bend loss determination from Experiment 1.

Wavelength	Location		
	1	2	3
1310 nm, (dB)	0.050	0.094	0.143
1550 nm, (dB)	0.772	0.842	0.436
Differences, (dB)	0.722	0.748	0.293

Bend losses have been detected at three locations which are 20.065km, 23.170km and 34.619km from the starting point of light source. Table-1 shows the difference between loss captured by 1310nm and 1550nm and the values are satisfied with the recommendation made by Potter (2010) and JDSU (2007).

From this comparison, the focused areas are the location of detected bend losses. There are three locations of focused areas as shown in Table-1. These bending points will be left for 10 months to monitor whether those bendings will give permanent effect on the optical power attenuation.

Rectification work

The locations of bending fibre are determined by comparing the distance obtained from OTDR with the actual data on the location of joint closures. On site, the bending of optical fibers is observed. There is more than single bending found inside joint closures that produce bending loss. The bendings are shown as in Figure-7, Figure-8 and Figure-9 for Location 1, 2 and 3 respectively.

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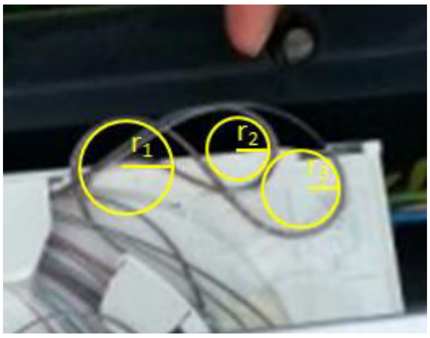

Figure-7. Three bending found at Location 1.

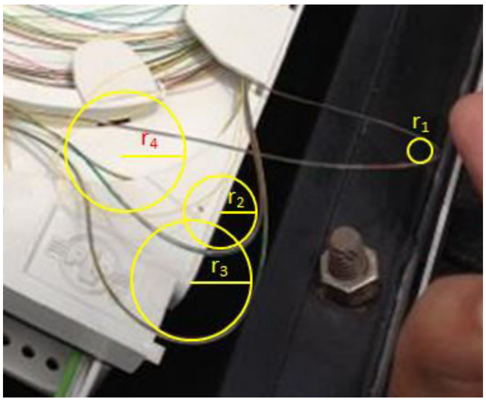

Figure-8. Four bending found at Location 2.

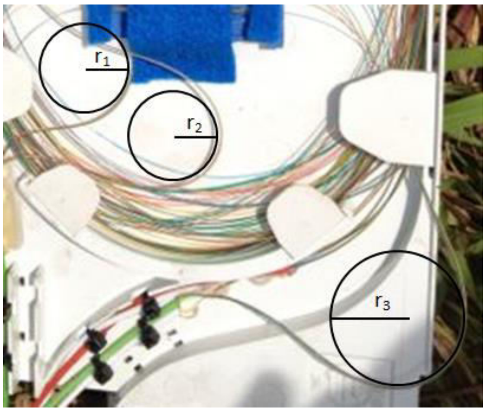

Figure-9. Three bendings found at Location 3.

The rectifications have been done where it involves the process of releasing the bending and rearranging the bending according to the appropriate radius so that no more losses occur due to bending fibre.

Verification experiment

Verification experiment (Experiment II) has been conducted to determine the effect of bending optical fiber after rectification job was done. The experiment used the same procedure as in Experiment I. There is no more loss captured by both traces, 1310 nm and 1550 nm wavelengths as shown in Figure-10.

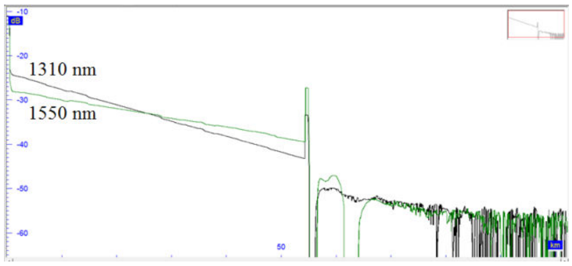

Figure-10. The 1310 nm and 1550 nm traces of Experiment II.

DISCUSSIONS

The bend loss can occur due to the bending of optical fibre inside the joint closures either caused by human error or natural activities. Further investigation has to be conducted to determine the actual cause. The bending losses on long distance optical fibres were detected by comparing the value of losses that were captured at a particular point using two different wavelengths. The minimum difference of value is set at 0.2 dB in order to decide if there is bending loss at that point. Conducted experiments have shown that the losses can be vanished by releasing the bending and rearranging the bending by considering the appropriate bending radius even after 10 months in that bending formation.

This will give an advantage to the rectification planner to organize a rectification job to overcome bending loss problem. This study also can be used to develop the existing guideline on fibre maintenance where the maintenance can be done in a tolerated duration as long as the attenuation is within the system margin.

Since the experiments have been conducted on existing long distance optical fibre, the bending radius was not taken into account in determining the permanency. For further study, the permanency effect of bending optical fibre must be related to the radius of bending. The experiment can be done in laboratory first then compared with the real situation. This will give clearer understanding on the effect of bending of optical fibre to the fibre performance.

This study is important, so that rectification job can be planned accordingly. The bending that occurs in joint closure which contributes to attenuation should be rectified but not necessarily done immediately. This will give advantage since rectification job will take a long time as the steps of dismantling joint closure from high voltage transmission has to be carried out accordingly and requires complex activities including outage of the transmission lines, outage of telecommunication services, competent climber and high order of safety procedures.

CONCLUSSIONS

The experiment has been successfully conducted in order to detect bend loss and locate the bending optical fiber. The results have shown that there is no permanent effect of bending in 10 months. In order to improve the experiment in future, the experiment might be conducted in laboratory with radius of bending is set as variable parameters. Hence, the results of test can be compared with the actual situation on site in order to determine the appropriate bending radius required during installation.

REFRENCES

Yu Zhi X. and Wang Hong X. 2012. Analysis of Theory and Experiment on Bend Loss Research by OTDR, Wuhan: Electronic College of Engineering.

Jenny R. 2000. Fundamentals of Fiber Optics: An Introduction for Beginners, Volpi Manufacturing USA Co., Inc. pp. 1-22.

Hakim S. A. 2010. Attenuation and Dispersion in Optical Communication, Dhaka: Bangladesh Communications Company Limited.

Abramczyk H. 2008. Dispersion Phenomena in Optical Fibers, Poland: Technical University of Lodz.

Potter B. G. 2010. Module 3 - Attenuation in Optical Fibers, Material Science and Engineering Dept, University of Arizona. pp. 1-16.

JDSU. 2007. White Paper: Macrobend Detection Using an OTDR, JDS Uniphase Corporation. pp. 1-4

Zendehnam A., Mirzaei M., Farashiani A. and Horabadi Farahani L. 2010. Investigation of bending loss in a single-mode optical fibre, Pramana Journal of Physics. 74(4): 591-603.

Dutton H. R. J. 1998. Understanding optical communications, IBM Corporation. International Technical Support Organization. p. 1.

Lietaert G. 2009. White Paper: Fiber Water Peak Characterization. JDS Uniphase Corporation. pp. 1-8.

Corning. 2001. OTDR Gainers. What Are They? Application Note, Corning Incorporated , USA.

Vita P. D. and Rossi U. 1988. The backscattering technique: Its field op applicability in fiber diagnostics and attenuation measurement, Opt. Quantum Electron. 12, pp. 17-22.

Collin R. E. 1981. Rayleigh scattering and Power Conservation. IEEE Transactions on Attennas and Propagation, AP. 29(5): 795-798.

Fermann M. E., Poole S. B., Payne D. N. and Martinez F. 1988. Comparative Measurement of Rayleigh Scattering in Single-Mode optical Fibers Based on an OTDR Technique, Published in Journal of Lightwave Technology. 6(4): 545-551.

Robertson B. 2005. Optical Loss Testing Concepts Application Note, Kingfisher International.

Ryer A. D. 1998. Light Measurement Handbook, International Light Inc, Newburyport, MA, 2, pp. 9-12.