RESEARCHES AND EXPERIMENTS ON TELECOMMUNICATIONS OPTICAL FIBER WELDING

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Abstract*: This paper presents the welding phases of optical fibers and welding technology of five types of optical fiber in following combinations: unimodal, multimodal and with modified dispersion.It is presented welding equipment and working parameters for each execution phase. The welding joining presents properties and qualities that are superior to mechanical joining.*

Keywords*: optical fiber, welding of optical fiber, welding quality, optical fiber welding phase*

1. INTRODUCTION

Optical fiber communication systems are the most effective signal transmission cables, occupying a higher frequency band used for different purposes: telephony, data, video telephony with high frequency and security.

Through optical fiber we understand a optically transparent medium, very long, with circular cross section and refractive index and symmetric radial steady or variable, separately by another material with constant refractive index lower, because the dividing surface to produce total reflection of light radiation without loss. An optical fiber may be associated with a dielectric waveguide used for the propagation of electromagnetic energy at optical frequencies.[1]

2. OPTICAL FIBERS WELDING PHASES

In the technology of welding optical fiber these steps are necessary[2]:

- Fiber preparation for welding- FS-FO-1;
- Implementation of the welding process - FS-FO-2;
- Follow-up parameters - FS-FO-3;
- Assembly - FS-FO-4.

In the implementation phase we introduced the welding process:

1) The approaching of the optical fibers - FS-FO-2-1;
2) Alignment and determination of the cutting angles of the two fibers subjected to weld - FS-2-2-FO;
3) Recognize of the differences in fibers and determination of concentricity of the two fiber-FO-FS-2-3;
4) Electrical arc - FS-FO-2-4;
5) Concentricity measurement and the estimated loss of fibers after welding - FS-2-5-FO.

Briefly, the phases of the weld are shown in Figure 1.

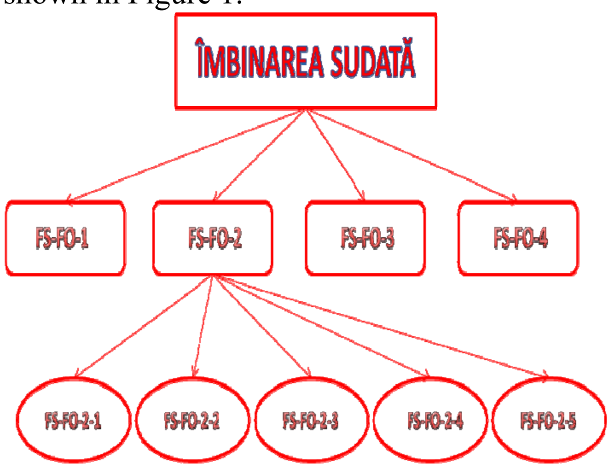

Fig. 1 Optical fiber welding phases

FS-FO-1 - fiber preparation for welding

Fiber-optic cable can be made from a wire up to 432 or more fiber yarn. To solder these wires, the cable must first be stripped. It removes all the outer casing, silk yarn and then the inner shell so as to have access to buffers containing optical fibers (Fig. 2 - Fig. 3).

Fig. 2 - the optical fiber cable after elimination of the protective outer casing

Fig. 3 – Eliminating the inner liner of fiber cable protection

As far as protections buffers are eliminating is observed that are coated with a gel that prevents water penetration. This gel is cleaned using alcohol-based solvents. After removing the gel from the protective tubes (buffers), they are cut with special pliers, that is designed to cut only the plastic casing, without touching and scratching the optical fibers.

FS-FO-2 - implementation of the welding process

For welding optical fibers, we need a special device capable of made this operation, taking into account the size and type of joint. In figure 4 is presented Fujikura FSM 50S device. Its main components are:

- welding mechanism composed in turn of the welding head, micro cameras and mechanism for securing and guiding the optical fiber;
- LCD - where fiber movement can be viewed in real time, welding and weld analysis result;
- heating block where the sleeve shrink after being placed over the fibers stick welding seam, making it integral with;
- the controls body block;
- power supply.

Fig. 4 - Ultrasonic Welding Fujikura fiber type, model FSM 50S

Figure 5 - guiding mechanism, welding equipment and electrodes microcamerele fiber

The welding mechanism is shown in Figure 5[5]

- The welding head consists of two electrodes, a laser with gas or electric, a gas flame, or a tungsten filament through which passes an electric current. In case of the device produced by Fujikura, FSM 50S, the welding head consists of two titanium electrodes that produce an electrical arc capable of creating glass melting temperature;
- Micro cameras placed at an angle of 90 degrees to each other to look at any time at the fiber on both axis;
- Fiber guide mechanism is located on both sides of the electrodes. This mechanism is designed to provide optical fiber and to push fiber toward each other in the welding process to make the merge.

FS-FO-2-1 - The approaching of the optical fibers

Once the fiber that ends to be welded are prepared, peeled and cut, they are fixed in the welding apparatus of the fiber guiding mechanism, leaving a gap of approximately 1 mm to electrode axis. In figure 6 is shown the distance from the axis of the fiber electrodes on the left. Same fiber and space is left on the right, figure 7, then is used a protective shield of the welding head and is pressed the SET button, which starts the welding operation.

Fig. 6 - The attachment of the fibers for welding

Fig. 7 - Distance from the fiber to welding electrodes before the welding process

Approximation fibers (difference or "gap setting") can be seen in figure 8. The LCD screen images appear on both micro cameras that give us the x-axis and y-axis position, fiber at a zoom of 147 times. Thus we can get a first opinion on the surfaces to be welded. If there are irregularities in the surface, the process of peeling and cutting surfaces is restarted. During this phase you can see how the device aligns the two fibers on the two axes.

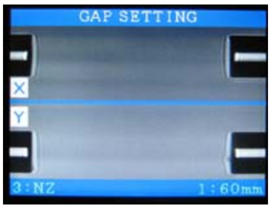

Fig. 8 - Setting gap

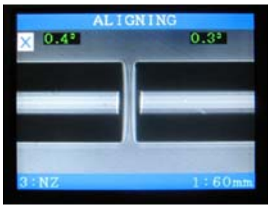

Figure 9 - Align fibers

FS-FO-2-2 - Alignment and determination of the cutting angles of the two fibers subjected to weld

Figure 9 is observed on the LCD screen, a single fiber to come into contact at a zoom of 295 times. Last fine adjustments are made to align the two fibers. It can be seen at the top of the screen the cutting angle of the fiber axis perpendicular to the axis of symmetry. In this case, the left has a fiber angle of 0.4 degrees and 0.3 degrees the right one. If this angle is greater than 3 and welding cannot be achieved, and the operation of the fiber preparation must be repeated.

FS-FO-2-3 - Recognize of the differences in fibers and determination of concentricity of the two fiber

After the fibers were aligned are show the differences in the fiber core at the bottom of the screen as shown in figure 10. In the bottom left it shows the difference between the two axis of the fiber cores, 0.1μm in our case and in the right side shows the difference between the axis of the outer casing of the fibers of 0.2μm in this case.

During this time the fibers are approaching more and more till their gap decreased to zero.

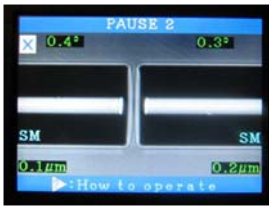

Fig. 10 – Fiber recognition and determination of the two fiber differences concentricity

Fig. 11 – The welding through an electrical arc

FS-FO-2-4 – Electrical arc

When optical fibers are in contact, a brief electrodes discharge is used to burn off any dust or dirt from the fiber ends. At a time that can be set between 1ms and 1s after this initial arc occurs the main arc between the two electrodes, an arc that develops a temperature of 2000°C, which leads to the melting temperature of the fiber in the contact area (Fig. 11). During this time the fibers of the directions mechanism are closer to one another, with 15μm. This distance covers any differences in the fiber cut and after welding is resulted a continuous fiber.

FS-FO-2-5 - Concentricity measurement and the estimated loss of fibers after welding

It is made an estimate of the attenuation of the signal over optical fiber, taking into account the wavelength of light radiation passing through the fiber core diameter, refractive index of fiber core index of refraction of the optical fiber casing of the device and light source intensity.

Measuring principle is based on the refraction of light through different density media. This light is delivered by a source at a certain angle, passes through the coating of the first fiber (in the peeling) is refracted at the contact with its core penetrating core, is reflected within the core, passes through the fiber and the other fused after passing from the core wrapper is captured and measured. Knowing the amount of radiation transmission and reception apparatus is a conversion loss is estimated in the weld as shown in figure 12. It must not be less than 0.03 dB. In the case that it does the steps above are repeated, resuming the welded joint.

Fig. 12 - Measuring the attenuation

Also you can see in the bottom of the screen the influenced concentricity of the fiber core and the outer casing from the weld. In this case, offsetting the core has remained constant at 0.1 mm and the outer casing offsetting decreased from 0.2 to 0.1 mm.

If the welding corresponds qualitatively, in sense that mitigation is less than 0.03 dB, the next process, the hardening of the weld, is made in the end using a heat-shrinkable sleeve.[4]

Place the sleeve over the weld, taking care not to crack, after which the heating device is placed at the top of the welding machine (Fig. 13), where there is an electrical resistance that heats the sleeve. After heating, the adhesive melts and adheres to the inner tube welded the fiber and the outer tube through its contraction causes the metal resistance element to be firmly attached to the two fibers providing mechanical resistance welded weld.

Figure 14 provides a protective sleeve for the mechanical shock and vibration environment. Due to good adhesion, the sleeve provides a protective environment, protecting the welding of liquids and contaminants.

Fig. 13 - The heating device

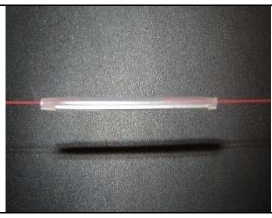

Fig. 14 – Welding protective sleeve

3. RESEARCHES ON THE LOSS LEVEL IN WELDED JOINTS IN WELDING DIFFERENT TYPES OF OPTICAL FIBER

To test these requirements, we have made many experiments on five sets of connecting optical fibers of different types:

1) Single mode fiber (SM) with single mod fiber;
2) Single mode fiber (SM) with modified dispersion fiber (dispersion shifted fiber - DSF);
3) Single mode fiber (SM) with multimode fiber (MM);
4) Fiber dispersion fiber as "nonzero switchover times" (nonzero switchover times dispersion shifted fiber - NZDSF) - Multimode fiber (MM);
5) Multimode fiber (MM) multimode fiber (MM);
6) Modified fiber dispersion fiber (dispersion shifted fiber - DSF) - modified dispersion fiber (dispersion shifted fiber - DSF).

In this set of experiments we measured the loss at the welded joint and the number of attempts to achieve a reliable welding (with less than 0.03 dB attenuation).

Welding machine used was Fujikura FSM50S product.

In the experiments we choose two single mode fiber welding temperatures, i.e. 35ºC, 20°C, 10 °C, 0 ºC and -5 ºC throughout the experiment using Fujikura apparatus FSM50S.

In this set of experiments was also measured the loss of the welded joint and the number of attempts to achieve a reliable welding (with less than 0.03 dB attenuation).

To increase the mechanical shock resistance welding and the forces of pressure and torque, weld is protected by a shrinkable sleeve adhering to the two fibers and has a metal insert that ensures a high resistance to such forces.

The research was conducted on two samples for assessing the loss of single mode fiber at a welding (SM) with a fiber single mode (SM) at ambient temperature 22 º C.

Fibers have been merged shell thickness of 125 mm and 9 mm thick core. After the pre-peeling operations, etching and surface preparation phase of FS-FO-1 has moved to the execution of the welding process, namely SF-FO-2 phase.

Phases of the first evidence can be seen in Figure 15.

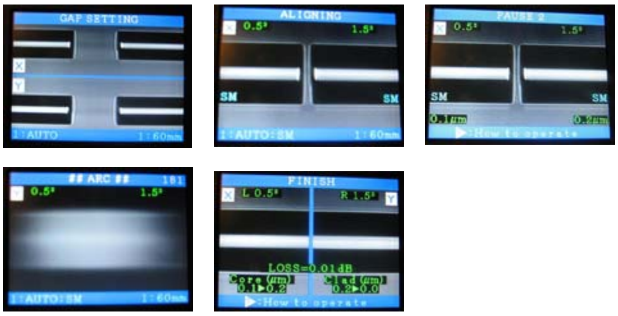

Fig. 15 - Phases of welding the first evidence of a fiber with a fiber SM – SM

In the first image the phase FS-FO-2-1 is observed, respectively the gap between the two fibers. This image is a view on the two axes, two images taken simultaneously with the television camera device. These fiber images are made at a zoom of 147.

The second image shows the phase FO-FS 2-2, at a zoom of 295 and is observed how the two fibers are recognized by the device as single mode and how to focus camera. In the upper left corner is shown the right cutting angle of the fiber on the left and right respectively. In our case the fiber on the left has a cutting angle of 0.5 degrees and 1.5 degrees on the right one. The two angles are less than 3 degrees, so it falls within acceptable limits.

The third image shows the phase-FO-FS 2-3. Once the fibers are automatically aligned to show differences in the fiber core - 0.1 mm respectively in the upper left corner and fiber casing - 0.2 mm respectively in the upper right corner.

The fourth image shows the phase-FO-2 FS-4, the weld. Is observed how the arc is concentrated in the contact area between the two fibers. Arc reflection may well bee seen the outer casing, but also can be seen well defined core area, this light is more dense area. Image two, three and four are zoomed by 295.

In the fifth image of figure 15 is presented the phase-FO-FS 2-5 and is shown the estimated welding loss of 0.01 dB. The core shows that the combined area increased from 0.1 mm to 0.2 mm while the outer casing offsetting decreased from 0.2 mm to 0µm.

Phases of the two samples of welding a single mode fiber with a single mode fiber can be seen in Figure 16.

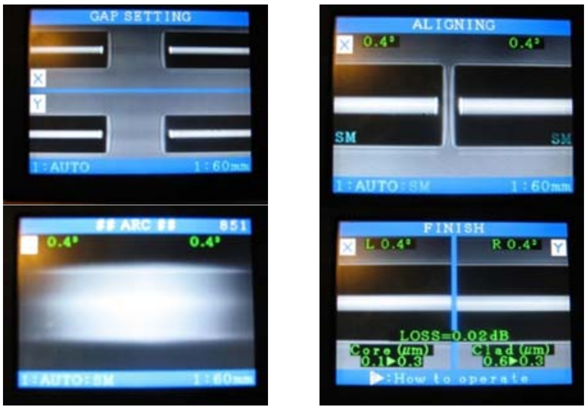

Fig. 16 - Phases of the two samples of welding a fiber with a fiber SM SM

The first image shows the phase-FO-2 FS-1 at a zoom of 147.

The second image shows two phase-FO-FS 2-2, at a zoom of 295. Is observed how the two fibers are recognized by the device as single mode and by the focus camera. In this case the fiber on the left has a cutting angle of 0.4 degrees and 0.4 degrees on the right one. The two angles are less than 3 degrees, so it falls within acceptable limits.

The third picture shows the phase FO-2 FS-4 and shows the welding at a zoom of 295. Is observed how the arc is concentrated in the contact area between the two fibers. Arc reflection can be seen in the outer casing, but also comes from well defined area.

The fourth image of figure 16 presents the phase FO-FS 2-5 and shows the estimated welding loss of 0.02 dB. Also the core shows that the combined area increased from 0.1 mm to 0.3 mm while the outer casing offsetting decreased from 0.6 mm to 0.3 mm.

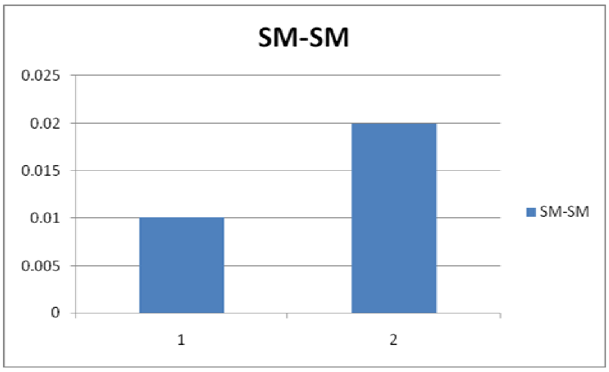

Fig. 17 - Loss on a level of welded joints in welding MS fibers with a fiber SM

4. CONCLUSIONS

Solder joints, from the point of view, is a combination that require a large initial investment ($ 15,000 - $ 50,000), depending on the accuracy of welding equipment purchased, but the cost for a weld is small ($ 0.5 - 1 , $ 5). Typical loss is less than 0.03 dB.

Description of the phenomena of welding sequences for comparison, current and displacement of fibers helps the understanding of arc welding during production.

Introducing the concept of phasing welding FS-FO makes it possible to understand phenomena before, during and after welding of optical fiber telecommunications.

Great importance should be given to cleaning and etching operation because in the presence of protective gel is impossible to weld the optical fibers.

The stripper and the guillotine are special tools, high quality and are essential in the preparation of optical fiber for the weld, the quality depends on how it has been peeled and chopped fiber.

It is easily seen from the summary table that at temperatures approaching 0 ° C problems in welding optical fibers, but not because the device when cooling weld because of its fragility. Following welding of fibers is not recommended in freezing water.

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