INSTRUCTION MANUAL

SENSOPTIC FIBER-OPTIC SENSORS

SPOT WELDABLE STRAIN GAUGE

Model SFO-W

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TABLE OF CONTENTS

1 INTRODUCTION

The SENSOPTIC line of fiber-optic sensors are specially developed instruments that can be used in a variety of applications where their small size, high accuracy, broad measurement range and complete immunity to EMI / RFI (electromagnetic and radio frequency interferences) are of paramount importance. In addition, they have an excellent dynamic response, which opens the possibility of combined static and dynamic measurements, according to the specific needs of the investigated structure.

The SFO-W gauge is designed to be installed by a technician without the assistance of a skilled welder. The SFO-W gauge is intended for long-term, precise strain measurements on a variety of structures.

2 EQUIPMENT DESCRIPTION

2.1 DESCRIPTION OF FABRY-PEROT STRAIN GAUGE

The SFO-W sensor is based on a unique fiber-optic strain gauge which constitutes a breakthrough in fiber-optic sensing. The gauge, namely a Fabry-Perot strain gauge, is based on a white-light interferometric extrinsic principle that uses a common multimode fiber.

The patented* principle consists in assessing the length of a Fabry-Perot cavity contained in the strain gauge by means of a Fizeau interferometer located in the readout unit, that optically reproduces the length of the Fabry-Perot cavity and allows to digitize that length on a high density linear photo diode array attached along one side of the interferometer (Figure 1).

The Fabry-Perot cavity is made of two 125 microns diameter fibers facing each other and fused in a 200 microns diameter glass micro-capillary, with a semi-reflective mirror coating on each fiber’s tip. Then, since the Fabry-Perot strain gauge is assembled in the SFO-W sensor, the strain variations transferred to the gauge are converted into cavity length variations.

The length of the Fabry-Perot cavity, as compared to the distance between the fused welding on the fibers, defines the range of the strain gauge, whereas the sensitivity of the gauge is defined by the density of the photodiode array used in the readout unit.

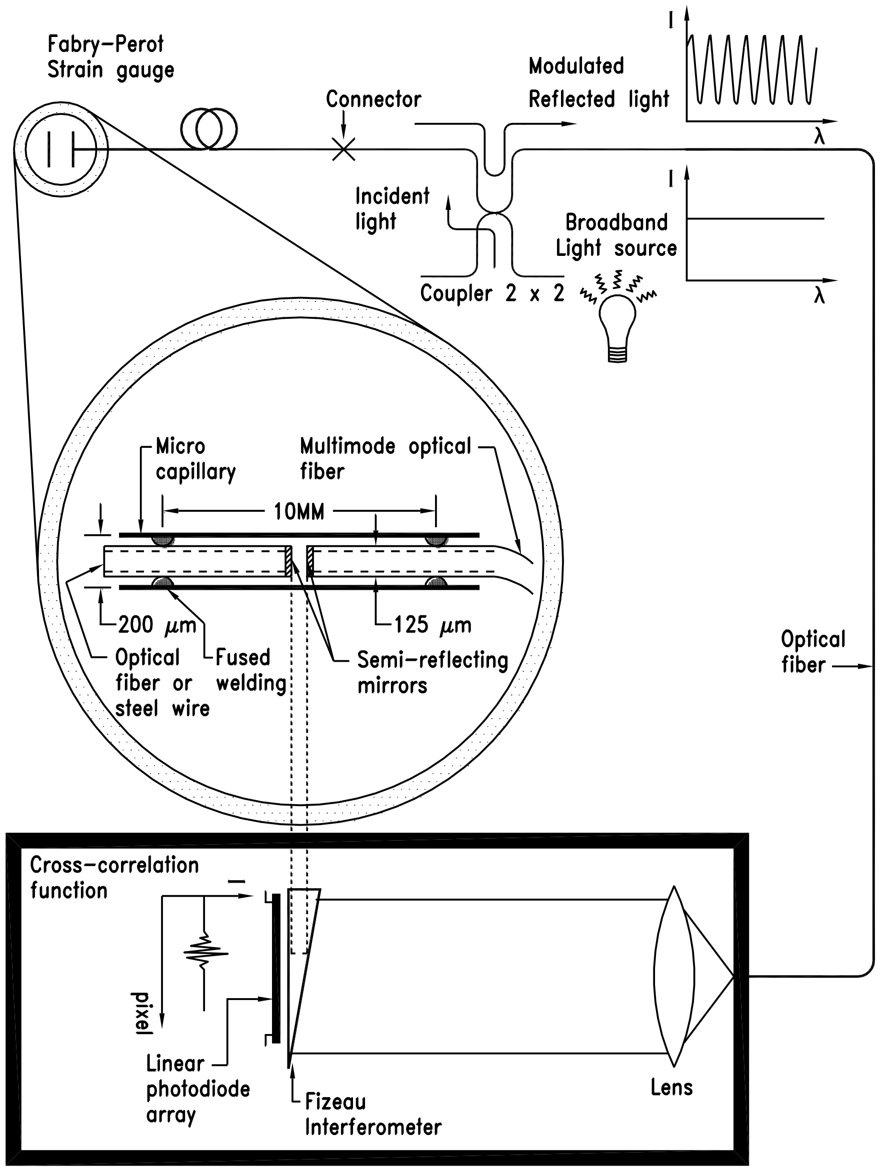

Figure 1: Schematic principle of a Fabry-Perot strain gauge

2.2 DESCRIPTION OF SFO-W STRAIN GAUGE

The SFO-W model is a spot weldable strain gauge. The gauge essentially consists of a stainless steel tube containing the fiber-optic strain gauge. A stainless steel foil, 0.15 mm thick, is welded to the tube. The foil is used to spot weld the gauge in place. The sensor is illustrated with relevant dimensions in Figure 2.

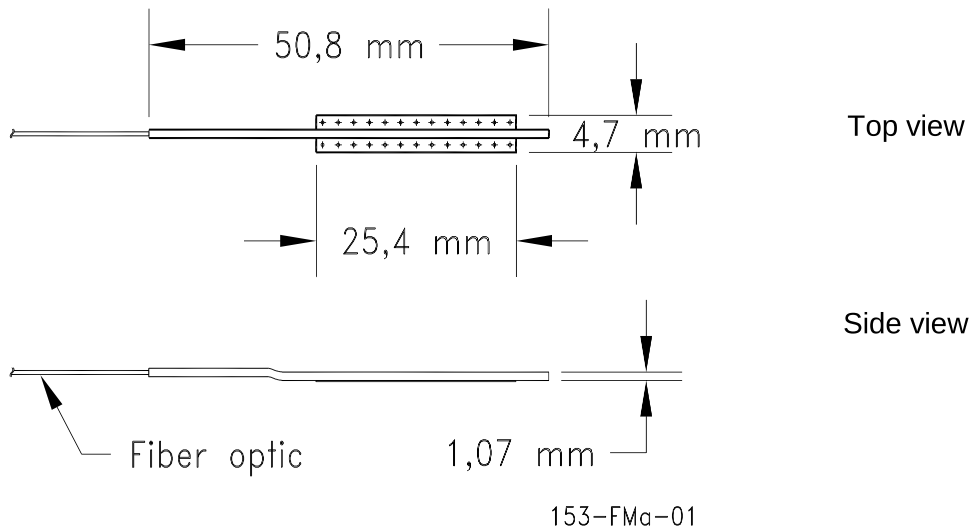

Figure 2: SFO-W Spot Weldable Strain Gauge

3 INSTALLATION PROCEDURE

3.1 IDENTIFICATION OF SFO-W GAUGE

Before installing and using the gauge, you must define it within the readout memory. To do this, you must enter its gauge factor (7 digit number, example: 1004103) in the permanent memory of the readout. After the gauge has been defined, you can connect the gauge to the readout. Please see the instruction manual of the readout you are using for more details.

The SFO-W has been designed to be installed onto steel structure using the portable strain gauge welding unit Model 700 or equivalent. Spot welding is a relatively simple operation requiring little skill, and the procedures to be followed are given in the instruction manual supplied with the spot welding unit.

The SFO-W gauge is designed for flat surfaces. However, it can be used on surfaces where the circular plane is normal to the gauge axis.

3.2 SURFACE PREPARATION

Safety goggles should always be worn during gauge installation to protect the eyes against metal particles both during surface preparation and actual welding.

For efficient welds, the surface to which the gauge is to be spot welded must be free of grease, rust, scale oxides and surface irregularities.

Steps for cleaning the surfaces are:

(1) Degrease the metal surface with an appropriate solvent such as Chlorothene or Acetone.

(2) Using a fine file or silicone carbide paper, remove rust and scale oxide to leave smooth bright surfaces where the sensor is to be welded.

(3) Thoroughly wash off dust using the solvent.

(4) Surface, if ground or filed, should be as flat as possible.

3.3 GAUGE SPOT WELDING PROCEDURES

Before actually attempting to install the SFO-W gauge for the first time, it is advisable to first practice using a small metal strip. Follow the instructions supplied with the welding set, make one spot weld and then pull the metal strip from the test surface; a small slug of metal should be pulled out of the test strip for a correct weld. On the Model 700 spot-welder, the weld energy should be set to approximately 25 for most applications.

Common welding problems include:

(a) Sputtering of the metal around the spot weld: this is due to excessive weld energy or electrode pressure.

(b) Weak weld; test strip pulls off without tearing out a slug: this is due to insufficient weld energy or electrode pressure.

(c) Sparking; this is usually due to insufficient electrode force, a dirty welding electrode or high contact resistance between the gauge foil and metal surface (poor surface preparation).

In all cases, it is essential to have a good electrical connection through the welding electrode to the welder "common" cable.

Gauge setting procedures are as follows:

(a) Align the SFO-W gauge on the metal surface: checking that the gauge foil sits flat on the surface. Read the gauge to make sure it is functioning properly. Next, tack it down in beginning on the side where is the fiber-optic cable and you must alternated on each side of tube.

(b) Continue to spot weld in following the sketch in figure 3 (page 3) to complete the installation. Roughly twenty-six (26) spot welds are recommended.

4 READING PROCEDURE

4.1 READINGS

The basic relationship between the reading and the change in strain in the investigated structure on which the gauge is welded is given by:

$$\varepsilon = \varepsilon_1 - \varepsilon_0$$

where:	ε	=	Total strain change in structure, in μstrains
	ε_0	=	Initial strain, in μstrains
	ε_1	=	Current strain, in μstrains

Example for SFO-W strain gauge:

ε_0	=	3602.0 units, initial reading
ε_1	=	3039.8 units, current reading

$\varepsilon = \varepsilon_1 - \varepsilon_0$ = 3039.8 - 3602.0 = -562.2 μstrains (compression)

Positive values of ε represent tensile strains and negative values represent compressive strains.

5 SPECIFICATIONS

Gauge type:	SFO-W – spot weldable strain gauge
Readout units:	Universal white-light fiber optic signal conditioning from Fiso Technologies and Roctest Ltd

Ranges (micro-strains):	±1000, ±1500, ±2000 (other available on request)
Resolution:	0.01% full scale
Temperature range for proper operation:	-50°C to +85°C, cable dependent
Overall length:	76,2 mm
Overall width:	4,7 mm
Standard fiber optic	
Cable:	Polyurethane jacket, 3-mm diameter, multimode type

6 MISCELLANEOUS

6.1 METHOD FOR INTERPRETING THE READINGS OF SFO-W

This method is proposed as tools for interpreting readings properly but in no matter Roctest should be considered responsible if results obtained are not meeting expectations.

Total strain ε

Total strain ε is the raw strain obtained directly from SFO-W readings

$$\varepsilon = \varepsilon_1 - \varepsilon_0$$

where: ε = Total strain measurement, in μstrains

ε_0 = Initial strain, in μstrains

ε_1 = Current strain, in μstrains

This total strain contains the mechanical strains and thermal strains in the investigated structure. The method detailed below explain how to obtain the mechanical strain due to applied effective stress.

The real strain ε_r (due to applied effective stress) can be computed with the following formula:

$$\varepsilon_r = \varepsilon - \beta \cdot (T_1 - T_0)$$

Where: **ε_r** = Real strain, in μstrains

ε = Total strain reading, in μstrains

T_1 = Temperature reading of the structure, in °C

T_0 = Initial temperature reading of the structure, in °C

β = The expansion factor of the structure in μm/m/°C on which the gauge is welded, generally in the range of 10 μm/m/°C $< \beta <$ 16 μm/m/°C for steel. The β expansion factor can be known from laboratory test.

Numerical example:

ε_0 = 2200.2 units, initial reading SFO-W

ε_1 = 2407.8 units, current reading of SFO-W

T_0 = 20.2 °C, initial temperature reading

T_1 = 26.2 °C, current temperature reading

β = 12.0 μm/m/°C, structure expansion factor

First we find the total strain, ε:

$$\varepsilon = \varepsilon_1 - \varepsilon_0 = 2407.8 - 2200.2 = 207.6 \text{ micro-strains}$$

Therefore the real strain **ε_r** is:

$$\varepsilon_r = \varepsilon - \beta \cdot (T_1 - T_0)$$

$$\varepsilon_r = (207.6) - 12 \cdot (26.2 - 20.2) = 135.6 \text{ micro-strains}$$

Note: Positive values of **ε_r** represent tensile strains and negative values represent compressive strains.