FIBRE-OPTIC STRAIN MEASUREMENT FOR STRUCTURAL INTEGRITY MONITORING

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ABSTRACT

A method is demonstrated for monitoring the structural integrity of large structures, using an optical fibre. The strain distribution along the structure is monitored by measuring the attentuation of light along the length of the fibre.

INTRODUCTION

The development of all-fibre sensors for monitoring a wide range of physical parameters is currently of considerable interest. In this way measurements can be done at a remote location in a hazardous environment, which also may be difficult to access or which suffers from severe electrical interference.

For monitoring the structural integrity of large structures, like off-shore structures, large bridges and aircraft structures, displacements and strain are the most relevant parameters. It is attractive to consider the use of a fibre-optic strain measurement system which is capable of measuring the strain distribution along the length of the structure. Asawa et.al.[1] describe a method for measuring structural bending. Hale[2] uses a fibre which is bonded to the structure and which will break if it is strained due to plastic strain or crack growth. In this way the light path will be blocked which enables the detection of the highly strained area.
In the present contribution we propose a method for measuring the in-plane strain distribution along the structure in a non-destructive way[3].

PRINCIPLE OF OPERATION

It is well known that bending of an optical fibre causes attenuation of the transmitted light by coupling modes from the core of the fibre into the cladding, where they will be absorbed[4] and[5]. When the fibre is subjected to axial strain however light attenuation is hardly influenced. So a method has to be found which converts a strain in the structure to a bending of the optical fibre. This is achieved by zigzagging the fibre over the structure by guiding it along pins or by bonding (Figure 1). In this way the initial attenuation without strain is relatively low. When the structure is strained however the fibre is bent sharply at the fixed positions which will give rise to a strong increase of attenuation.
This principle enables attachment of the fibre to relatively long parts of the structure. Strain distribution along the length of the structure can then be measured by analysing the backscatter waveforms which are obtained using an Optical Time Domain Reflectometer.

EVALUATION OF THE METHOD

To evaluate the method a special OTDR instrument was built (Figure 2). This instrument has been equipped with a semi-conductor pulsed laser (peak power 1 W, pulse width 2,5 ns), an avalance detector (rise time 0,5 ns) and low noise, high bandwidth amplifiers. The amplified detector signal is fed to a boxcar averager and digital signal processor. With this system attenuation measurements are made with a resolution of 0,005 dB and a spatial resolution of 0,25 m. Measurement time for a structure with a length of 100 m is then about 1 minute, independantly of the length of the fibre from the monitoring system to the inspected area.

The sensitivity of the method has been investigated using an aluminium bar which is strained in a simple four point bending arrangement. The fibre is zigzagged over 0,8 m of the aluminium bar by guiding it along pins and bonding it to the bar at both ends of this area. The attached area of the fibre is located several meters from the end of a graded index fibre with a length of 200 meters. Spacing s and diameter d of the pins can be varied. Figure 3 shows some of the results obtained with this set-up. The initial attenuation without strain is indeed relatively low, less than 0,01 dB/m for d = 2 mm and s = 40 mm. The results also show the ability of tuning the sensitivity by varying the period s of the zigzagged fibre. This can also be done by varying the amplitude d of the zigzagged fibre. A mean strain over a length of 0,25 m can be measured with a resolution of 100 microstrain.

CONCLUSION AND DISCUSSION

We have shown that strain along the length of a structure can be measured using optical fibres. The OTDR instrument which was built enables measurements with a spatial resolution of about 0,25 m.
Furthermore we have shown that the sensitivity of the method can be tuned to the needs of a specific application.
Currently tests are carried out to investigate the development of the sensitivity along the length of long structures. To facilitate practical application of the method a special cable has to be developed which contains the zigzagged fiber and which can be bonded to the structure.

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FIGURES

Figure 1 Some ways of attaching the fibre to the structure.

Figure 2 Schematic diagram of the OTDR set-up.

Figure 3 Measured attenuation versus applied strain over a length of 0.8 meter for d = 2 mm, s = 20 mm and 40 mm.

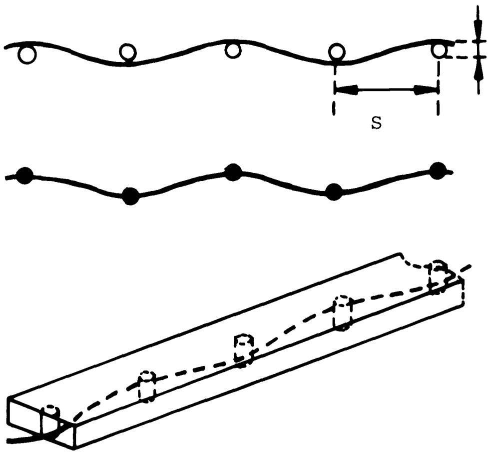

Fig. 1

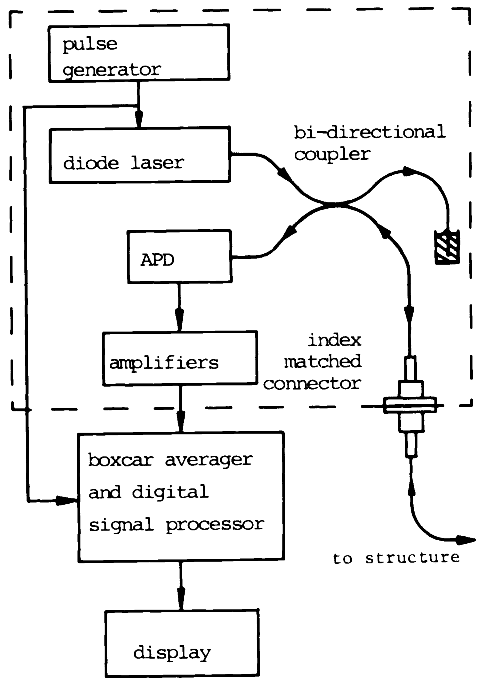

Fig. 2

Fig. 3