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RESIDUAL STRESS DIAGNOSIS IN JACKETED OPTICAL FIBRES BY A PULSE DELAY TECHNIQUE

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The application of a secondary jacketing material such as nylon and subsequent incorporation of a fibre into a cable produces a level of residual stress within the fibre which depends upon the materials, cable structure and manufacturing method. The remaining tension or compression in the cabled fibre is of some importance to cable designers since ideally the fibre should be neutrally stressed if static fatigue and microbending effects are to be avoided. We have found that the precise measurement of the transit time of a pulse within the fibre provides a powerful diagnostic tool for residual longitudinal stress assessment, being capable of detecting a tension as low as a few g.wt in a km length of fibre. We report here the development of the technique, its calibration and the results of stress tests on jacketed fibres.

The apparatus as used is shown in fig.1. Absolute pulse delay is measured with a time delay generator and time-interval counter combination by comparing the reference 8% Fresnel back-reflection from the butt joint with the reflection from an aluminium mirror at the far end of the cable. Long term trigger delay drifts in the timing circuitry have been elimated since they are common to both measurements. The method is attractive for field applications since access to only one end of the fibre is required and test fibres can be easily interchanged without re-alignment of the optics.

The calibration curve of pulse delay against applied tension is shown in fig.2 for a typical germania-doped CVD fibre; the slope reveals a value of 53.7ps/km for a tensile stress of 1MPa, a figure which is ~10% higher than calculated for fused silica. The effect of ambient temperature on the pulse delay is shown in fig.3. It may be seen that the variation is relatively small, the value of 35.7ps km^{-1} $^{o}C^{-1}$ being ~10% less than that for fused silica. Reference to fig. 2 reveals that a change in ambient temperature of $10^{o}C$ produces an error in tension measurement of only a few g.wt.

The application of the pulse-delay technique to assessment of residual stress in secondary-jacketed fibres is shown in fig.4. After measurement of the time delay in an unstressed state, the silicone-coated fibres were jacketed by nylon and subjected to temperature cycling in air, water and brine whilst continuously monitoring pulse delay. The experiment has revealed the following, rather unexpected, results.

i) Application of a secondary jacket of nylon by high temperature extrusion does not produce as large a compressive stress in the fibre on cooling, as might have been expected from the high thermal expansion coefficient of the polymer. The residual fibre compression at room temperature was found to be only 70g.wt, nearly an order of magnitude less than calculated. Clearly this is the result of stress relief in the nylon by plastic creep.

ii) Cooling to low temperatures produces a compressive stress increase, although rather less than would be expected, again owing to the effects of creep. The latter can be seen by noting the stress hysteresis which results from thermal cycling.

iii) Immersion of the jacketed fibre in water and brine produced changes in pulse delay which indicate a decrease in the residual compressive fibre stress. Indeed it may be seen that the ingress of water into the nylon modifies its properties, causing it to expand to an extent that the fibre becomes slightly tensioned. The brine solution had a similar but small effect on stress, but resulted in a large and irreversible increase in attenuation.

The above examples provide an indication of the ability of the pulse delay method of residual stress measurement to monitor extremely small changes in the properties of cabling materials. The technique will thus be useful in assessing the ageing characteristics of cables or the long-term stability of particular installations. Results to date reveal that the application of plastic overjackets produces considerably less residual stress than expected and that the value for nylon jacketing material is dependent on the ingress of water.

The measurements presented here have further application in that they represent a study of the stability of optical pulse-delay in various environments. The results will thus prove useful in the design of fibre delay lines.

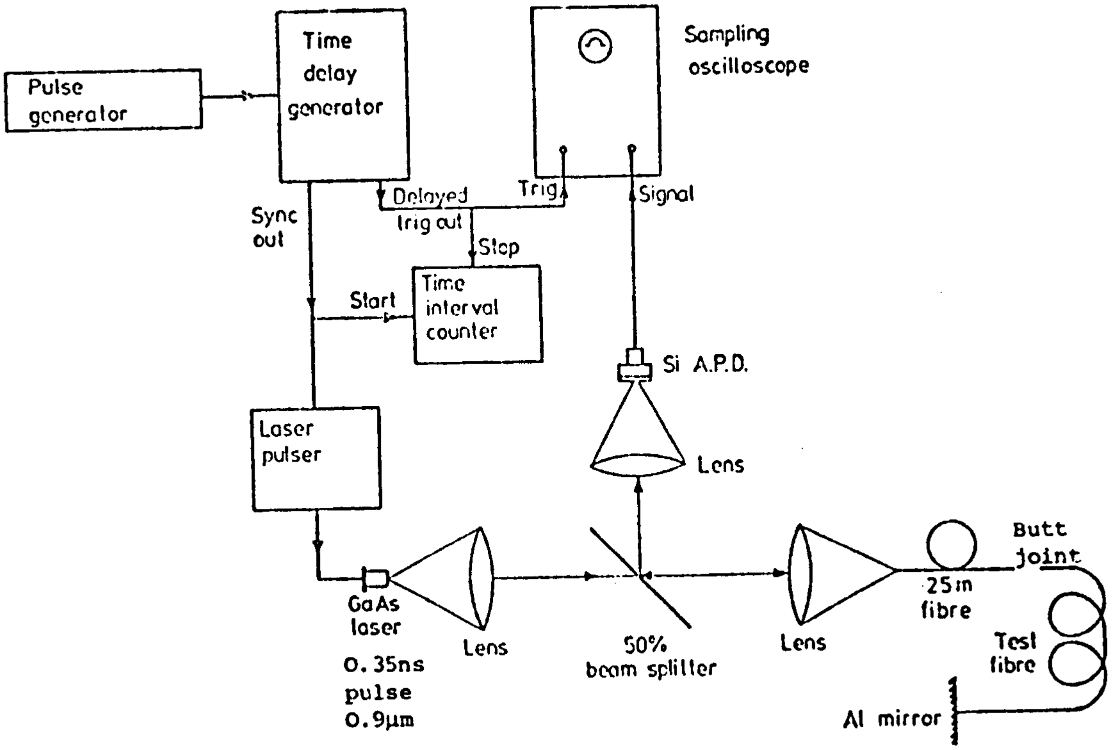

Fig. 1 Schematic diagram of optical pulse-delay measurement experiment

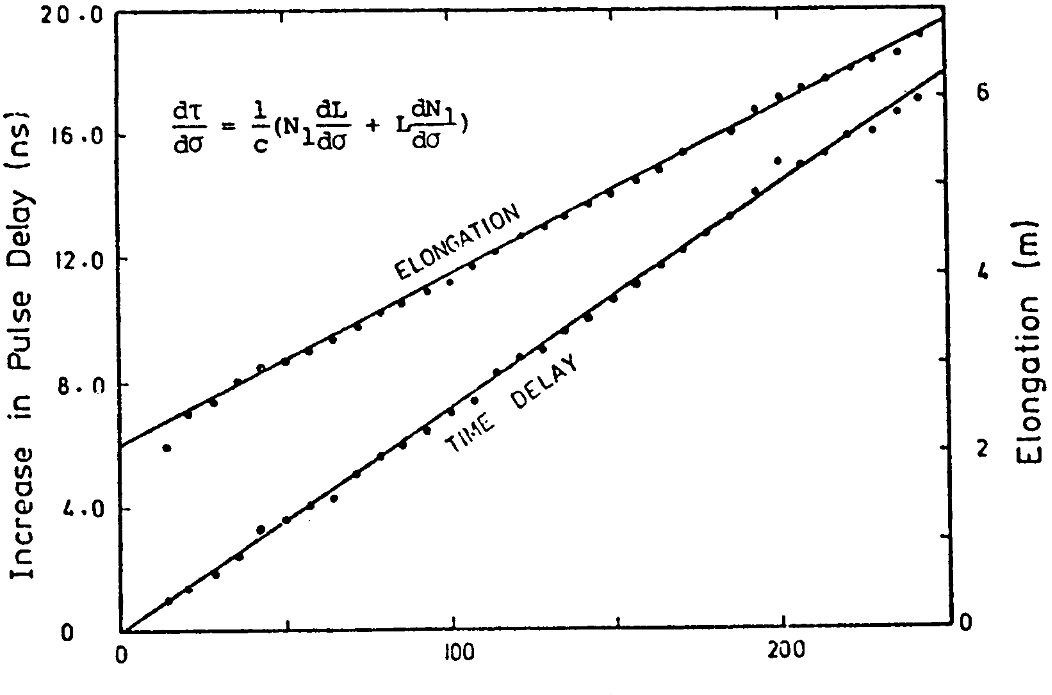

Fig. 2 Variation of pulse-delay and fibre extension with applied tension for a graded P_2O_5-GeO_2 silica fibre. The fibre is unjacketed and has an effective length of 1.6km. NA = 0.21. Core diameter 65μm. Cladding diameter 122.5μm.

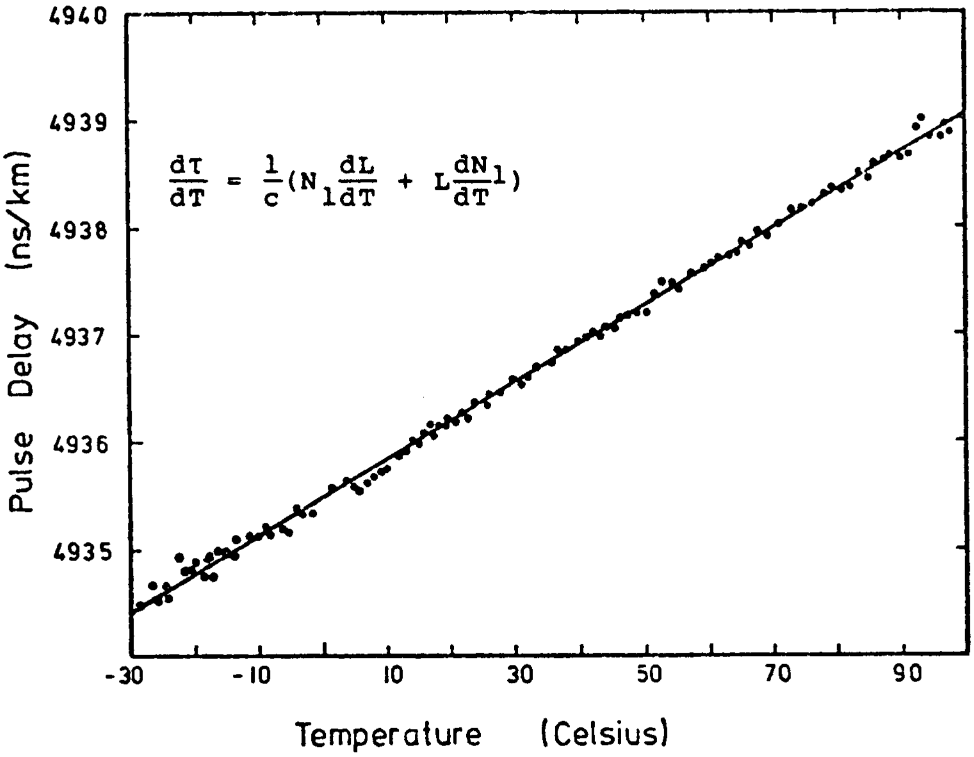

Fig. 3 Pulse delay normalized to a length of 1km as a function of temperature for a P_2O_5-GeO_2 silica fibre (unjacketed). NA = 0.21. Core diameter 65μm. Cladding diameter 122.5μm.

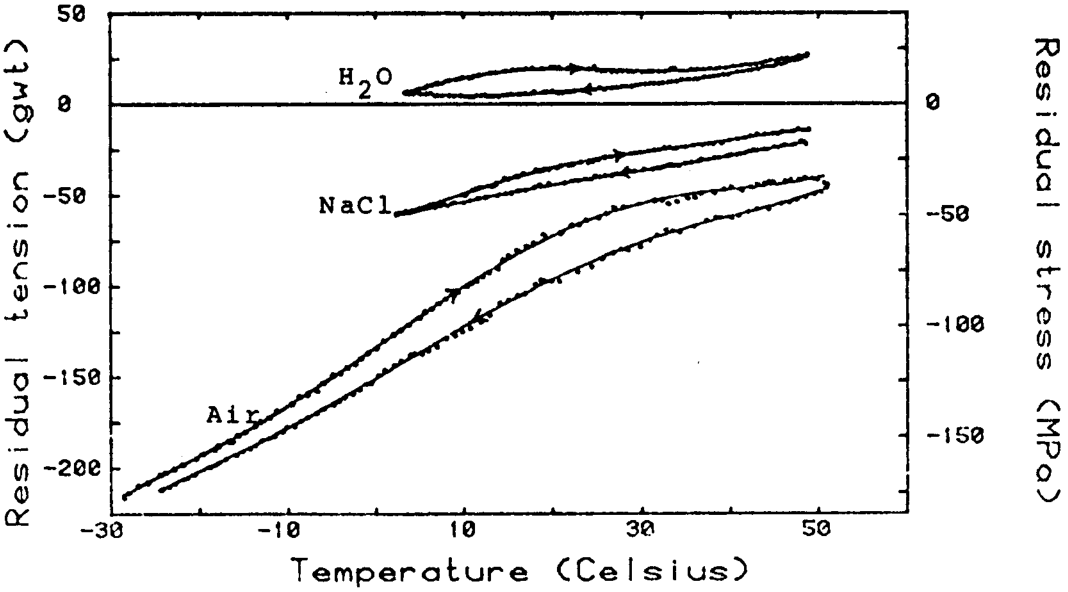

Fig. 4 Stress force exerted on a graded P_2O_5-GeO_2 fibre by its nylon overjacket under various environmental conditions. NA = 0.21. Core diameter 65μm. Cladding diameter 125μm. Silicon coating diameter 250μm. Nylon diameter 500μm.