Thermal effects on fibre optic pressure sensor during shock experiments

***SA. Sharifian*[1], *DR.Buttsworth*[2]**

1., 2. Faculty of Engineering and Surveying, University of Southern Queensland, Toowoomba, Qld. 4350, Australia

1. sharifia@usq.edu.au

2. buttswod@usq.edu.au

Corresponding author ***SA. Sharifian***

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1. Introduction

Experiments in the study of transient aerodynamics typically require pressure measurements with a high spatial and temporal resolution. Inexpensive pressure sensors based on extrinsic Fabry-Perot fibre optic interferometry are capable of measurement with a high spatial and temporal resolution. However, previous work has shown that such fibre optic pressure sensors are very sensitive to temperature [2,3].

Figure 1 shows a typical fibre optic sensor response to a reflected shock and compares the measurement with a numerical simulation. The fibre optic pressure sensor indicates an increase of pressure after the reflected shock whereas the simulation (confirmed with measurements using a commercial piezoelectric transducer) does not indicate this increase. Two main reasons for this error are: 1) the viscoelastic effect of active sensor parts and 2) sensor temperature sensitivity [3]. The relative contribution of these two effects to the overall sensor error has not yet been determined. This work seeks to identify and quantify these effects.

2. Methodology

We use an engineering software package (ANSYS) to model the thermal effects in the sensor for the reflected shock conditions. Pressure and temperature are derived from experimental measurements in the shock tube and gun tunnel located at University of Southern Queensland, Australia. The maximum reflected shock temperature and pressure are 1000 K and 8 MPa respectively. In the model, in contrast with previous work, we did not assume a uniform temperature distribution on the sensor. An immediate increase of sensor surface temperature following shock reflection is suggested by Buttsworth [1], and a convective heat transfer boundary condition is applied for the rest of simulation[4]. The modelling duration is taken as 20 ms, as this time is typical of the duration before the reflected expansion waves arrive at the sensor. In this model, all thermal properties of material are assumed to be constant.

Three sensors with different structure and material are modelled. The first sensor uses a simple construction based on a zirconia ferrule as the substrate, a liquid adhesive as the bonding layer, and a polished copper foil as the diaphragm. The second sensor (which is being developed at the University of Southern Queensland) uses a direct bonding technique and eliminates the adhesive between the copper diaphragm and ferrule. The third sensor (which is in the final stage of development at Heriot Watt University, UK) also uses a direct bonding technique, but uses a silicia and silicia nitride diaphragm and has a square body manufactured from silicon.

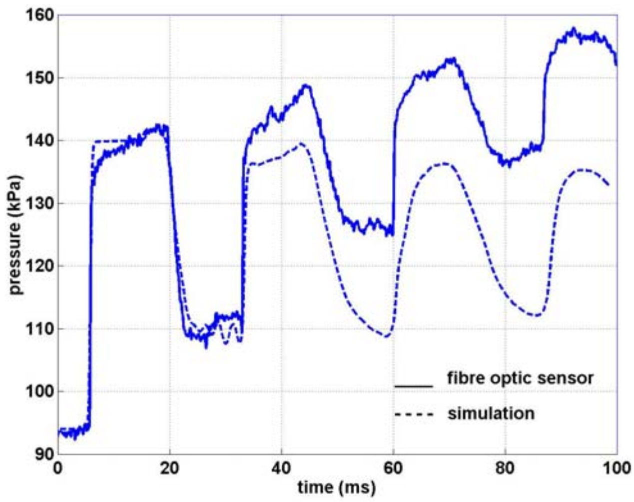

Figure 1 Sample fibre optic pressure sensor response in a shock experiment.

3. Results and discussion

The modelled sensor response for 20 ms after the shock reflection is presented and compared with the sensor response without thermal effects for a variety of reflected shock conditions. Contributions of sensor components to the overall sensor thermal errors are detailed and correction coefficients are presented for some typical reflected shock conditions. Simulations are also performed for a longer time to investigate sensor survivability.

The results show the glue is the main source of error and eliminating it improves the sensor accuracy. Using silica in the third sensor also improved the sensor thermal sensitivity as was predicted.

4. Conclusion

Our results indicate that the fibre optic pressure sensors can be employed in the shock tube without any shielding for 20 ms with reasonable accuracy. However, unshielded sensors in high pressure and temperature conditions will not produce accurate measurements, nor will they survive multiple experiments. At modest pressure and temperature conditions, the first sensor (cheapest) can be employed with reasonable accuracy. At higher pressure and temperature, the second and third sensors (most expensive) can be employed using the correction coefficient.

References

[1] Buttsworth, DR.,“Assessment of effective thermal product of surface junction thermocouples on millisecond time scales”, Experimental Thermal and Fluid Sciences, vol. 25, (2001), pp. 409-20.

[2] MacPherson, WN 1999, “Fibre optic sensors for applications in Turbomachinery research”, PhD thesis, Heriot-Watt University, (1999), UK.

[3] Sharifian, SA., “Fibre optic pressure transducers for disturbance measurements in transient aerodynamic research facilities, PhD thesis, University of Southern Queensland, (2003), Australia.

[4] White, FM., “*Viscous fluid flow*”, 2nd edn, McGraw-Hill, (1991), New York.