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(NASA-CR-196040) HOLT FILM WALL SHEAR INSTRUMENTATION FOR BOUNDARY LAYER TRANSITION RESEARCH Final Report (Purdue Univ.) 3 p

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Hot Film Wall Shear Instrumentation for Boundary Layer Transition Research: Final Report for NASA Grant NAG-1-1201

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Abstract

Measurements of the performance of hot-film wall-shear sensors were performed to aid development of improved sensors. The effect of film size and substrate properties on the sensor performance was quantified through parametric studies carried out both electronically and in a shock tube. The results show that sensor frequency response increases with decreasing sensor size, while at the same time sensitivity decreases. Substrate effects were also studied, through parametric variation of thermal conductivity and heat capacity. Early studies used complex dual-layer substrates, while later studies were designed for both single-layer and dual-layer substrates. Sensor failures and funding limitations have precluded completion of the substrate-thermal-property tests.

1 Background

Langley grant NAG-1-1201, which began in January of 1991, has supported testing and development of hot-film wall-shear sensors. Most of the work was reported in a recent M.S. thesis [1] and two accompanying papers [2, 3]. A parametric study of sensor size and substrate effects was performed. Langley personnel deposited sensors of varying size on small glass flat plate substrates which were then tested at Purdue, both electronically and through the use of a shock tube. The results showed that frequency response increased with decreasing sensor size, while sensitivity decreased. These results held true in both electronic and flow testing. Later tests with one sensor size on a second substrate with higher thermal conductivity showed again an increase in frequency response and a corresponding decrease of sensitivity. This frequency response–sensitivity compromise may be alleviated through the use of thin insulating coatings as are commonly used on aluminum substrates, for a third substrate material of this type seemed to involve a less stringent tradeoff between the two factors.

Experimental work designed to resolve some of the effects related to substrate thermal properties has been partially completed. Small flat plates of the design used by Moen [3] have been fabricated from four substrate materials: Pyrex (Corning 7740), Zerodur (Schott Glass Technologies), Pyroceram (Corning 9606), and Schott dense flint glass (type SF6). Shock tube tests were attempted using these four sensors, whose properties are summarized in Table 1. This work was carried out during the summer of 1993 by Anastasios Petropoulos. The data are contained in a report titled *Flow Testing of Hot Film Sensors: Experimental Procedures and Data Report*, by Anastasios Petropoulos, 22 August 1993, which is available from the author. Unfortunately, both the Pyroceram and flint glass sensors failed during early testing, and no useful results for these sensors were obtained. Petropoulos' data report contains detailed results for the Zerodur and Pyrex sensors, but since the thermal properties of these two are fairly similar, and the test series is incomplete, comprehensive data reduction has not yet been attempted. Further

Substrate Material	Thermal Conductivity k (W/mK)	Specific Heat C_p (J/kgK)	Thermal Diffusivity α (cm^2/s)	Unsteady Parameter β ($Ws^{1/2}/m^2K$)	Density (g/cm^3)
Pyrex	1.10	711	0.0055	1321	2.23
Zerodur	1.64	821	0.0079	1840	2.53
Pyroceram	3.99	753	0.018	2800	2.61
Flint glass	0.673	389	0.00334	1164	5.18

Table 1: Physical Properties of the Substrates

tests using aluminum plates with polyimide coatings of various thicknesses have not been possible either, since these plates were never completed. Nor have tests of a diamond-film sensor yet been possible either, for the same reason.

Future plans call for completion of the tests involving the glass-substrate sensors. Repair of these sensors is to be completed by Mr. J. Bartlett's group at NASA Langley. It will hopefully then be possible to find unfunded student labor at Purdue with which to complete the test series initiated by Petropoulos.

2 Summary

A parametric study of the effect of sensor size and substrate properties on the performance of flush-mount hot-film sensors has been performed. Conclusive results were obtained for the effect of sensor-size variations. The effect of substrate thermal properties was also studied. Unfortunately, conclusive results for this more complex effect could not be obtained with the available resources.

References

[1] M.J. Moen. Design, testing, and analysis of a high-speed, time-resolved, non-intrusive skin friction sensor system. Master's thesis, Purdue University School of Aeronautical and Astronautical Engineering, October 1992. Included as an Appendix to NASA Contractor Report 191360, November 1992.

[2] M.J. Moen and S.P. Schneider. The effect of sensor size and substrate properties on the performance of flush-mounted hot-film sensors. In *Thermal Anemometry 1993, Proceedings of the Third ASME International Symposium on Thermal Anemometry*, pages 249–261. American Society of Mechanical Engineers, 1993. FED Volume 167.

[3] M.J. Moen and S.P. Schneider. The effect of sensor size on the performance of flush-mounted hot-film sensors. *Journal of Fluids Engineering*, 116:273–277, June 1994.