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SURFACE ACOUSTIC WAVE SENSORS AND PIEZOELECTRIC ACTUATORS FOR INVESTIGATIONS OF TRANSITIONAL AND TURBULENT FLOWS

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Objective of Project

The objective of this proposal is to (1) use global and local surface acoustic wave (SAW) devices as sensors to characterize the spatial and temporal fluctuations of the normal and shear stresses at a wall exposed to turbulent flow; (2) study the effect of piezoelectric actuators on the flow field and quantify the changes introduced by characterizing the flow downstream; (3) investigate the possibility of using the signals from the sensor to excite the actuators with appropriate feedback loops and signal processing to suppress or eliminate undesirable features in the flow field that lead to increased drag and radiated noise; in other words develop a smart skin. Conventional sensors, such as digital imaging with bubble photographs, 3-D LDA and hot wire probes will be used to compare the results from SAW sensors.

Progress

The water channel in which the SAW sensors will ultimately be tested and calibrated which is in the latter stages of construction. Specifically the test section is being machined and is expected to be ready in early January and functional in early February. In the mean time we are testing the sensors in a wind tunnel with a 1m diameter test section and a flow speed of 20m/s. The test plate is 2m in length. It is planned that the SAW sensor will be flush mounted on the surface of the test plate which will be positioned to produce a zero pressure gradient flat plate boundary layer. The test plate has a 4:1 elliptic leading edge and the boundary layer will be tripped to guarantee a fully turbulent profile at the location of the SAW sensor, 1.5m from the leading edge. The test plate is now ready and the sensor is being mounted on it . We expect to make measurements within the next two weeks. A sensor as described below has been prepared and calibrated outside the wind tunnel. Sensitivity to shear stress or wall friction associated with turbulent flow from an ordinary fan was also tested, as suggested by Dr. Reischman during his visit to Penn State.

A low frequency SAW (Surface Acoustic Wave) sensor was made with a 0.5mm thick PVDF film, and a 18.5mm thick plexiglass plate. IDTs were drawn with silver paint, where each electrode consists of 10 fingers. The size of the sensor is 152mm × 76mm × 19mm (length × width ×

thickness) and delay line length is 125mm. The center frequency of the sensor is 700 KHz. All electric wires were taken to the lower side of the sensor to keep the surface flat and a Rho-C rubber coating was applied to the delay line to produce a smooth surface.

For the measurement of surface forces given by an unsteady flow, the sensor was subjected to air flow from a fan. In the measurement, the SAW was launched both parallel to (upstream) and opposite to (downstream) the direction of the air flow, and its velocity change was measured in terms of the phase shift. The air flow was generated by a ventilation fan and flow quality could not be controlled. The quality of the flow was not high. In addition, the blunt leading edge of the sensor no doubt produced a large separated region over the sensor. The combined effect of all the above factors had an undesirable influence on the SAW velocity measurement and the output signal fluctuated significantly. Initially, the property which we wish to measure is the time averaged mean shear stress. From this crude fan test, results showed that the SAW had approximately a 10° phase shift when propagating upstream and a -3° phase shift when propagating downstream compared with the no air flow condition. The difference between the two phase shifts 13° was proportional to the surface shear stress and the mean value 3.5° was proportional to the normal pressure. Compared with the results of static tests, the amount of phase shift is fairly large. These values seem to be a little exaggerated by the above-mentioned factors. For the simple test that has been conducted, the velocity of the flow was not known and no quantitative calibration of the sensor was performed. In conclusion, the difference of the two phase shifts confirmed that local/global SAW sensors are sufficiently sensitive to unsteady flows. In the next month a wind tunnel will be ready for use, where carefully controlled experiments can be performed using the SAW sensors.