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Dynamic Acoustic Detection of Boundary Layer Transition

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Abstract

The 1995 LARSS Research for J.r Grohs is a wind tunnel investigation into the acoustic nature of boundary layer transition using miniature microphones. This research is the groundwork for entry into the National Transonic Facility (NTF) at the NASA -- Langley Research Center (LaRC). Due to the extreme environmental conditions of NTF testing, low temperatures and high pressures, traditional boundary layer detection methods are not available. The emphasis of this project and further studies is acoustical sampling of a typical boundary layer and environmental durability of the miniature microphones.

The research was conducted with the 14 by 22 Foot Subsonic Tunnel, concurrent with another wind tunnel test. Using the resources of LaRC, a full inquiry into the feasibility of using Knowles Electronics Inc. EM-3086 microphones to detect the surface boundary layer, under differing conditions, was completed. This report shall discuss the difficulties encountered, product performance and observations, and future research adaptability of this method.

Introduction

Within traditional wind tunnel testing conditions, detection and study of the surface boundary layer can be found in variety forms. Resources such as hot film, pressure transducers, and pressure sensitive paint are a few such methods. However, within the adverse operating conditions at the National Transonic Facility (NTF) at NASA -- Langley Research Center (LaRC), such techniques are impossible to use. Therefore, the investigation of acoustical measurements of a boundary layer with miniature microphones was initiated. While acoustic testing of aerodynamic properties has been conducted previously, it has not emphasized on undisturbed measurements along the surface of an airfoil.

The groundwork for this study was research into the resources available to collect such measurements and information on the topic. Using the previous investigation of Agarwal and Simpson [1] as background information, an initial plan to place miniature microphones within the surface of an airfoil was started. Through the acquisition and comparison of dynamic acoustic data, the feasibility of measuring an active boundary layer could be studied.

Approach

Provided with the Knowles Electronics, Inc. EM-3086 microphones, the author designed and had fabricated an aluminum plate to incorporate a set of the microphones into the upper surface of a preexisting idealized flat plate model. Through a direct connection in the interior of the airfoil, data from the microphone was extracted and analyzed through a portable HP Dynamic Signal Analyzer and oscilloscope. The entire setup was then entered and floor mounted into the 14 by 22 Foot Subsonic Wind Tunnel to the rear of an High Speed Civil Transport (HSCT) Test. Data was accumulated at a dynamic pressure of 85 psf.

The setup of the microphones was such that differing conditions of a boundary layer could be determined simultaneously along the entire plate. Figure 1 shows the orientation of the setup on the upper surface, Figure 2 provides a model cross section and Figure 3 includes a microphone schematic. Note the offset of the streamwise row of microphones, used to remove any effect of a

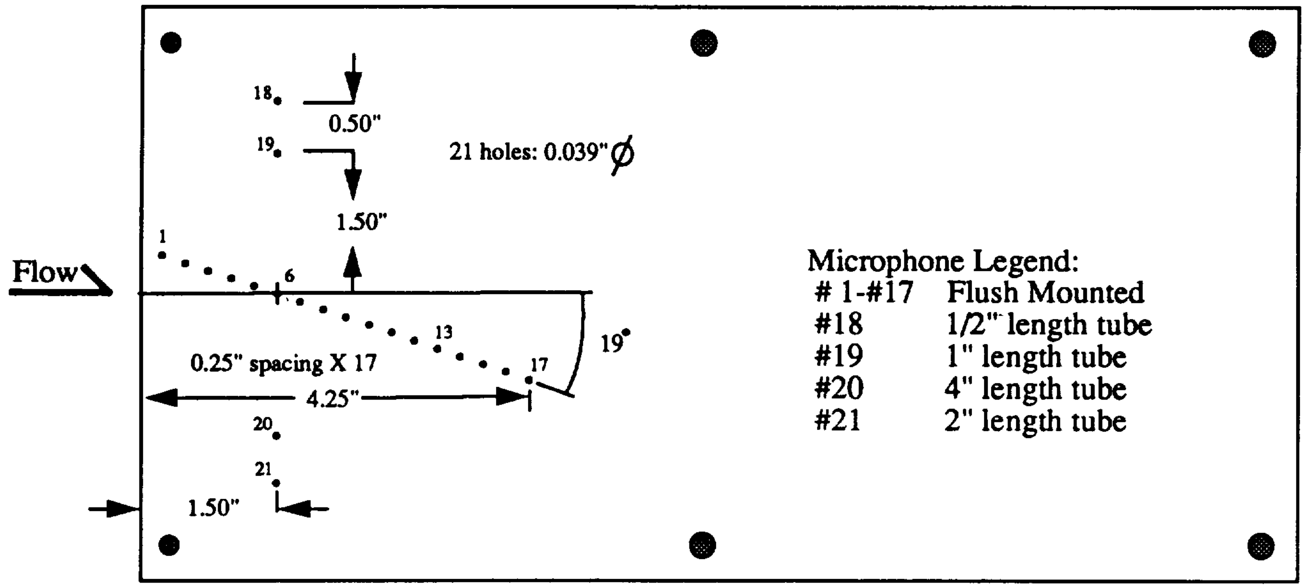

Figure 1: Upper surface attachment with microphone port locations

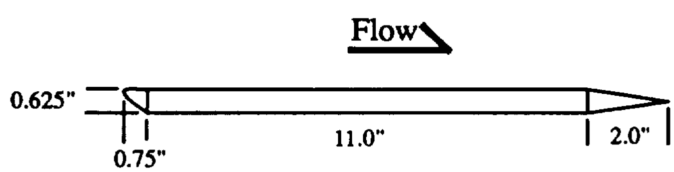

Figure 2: Model Cross Section

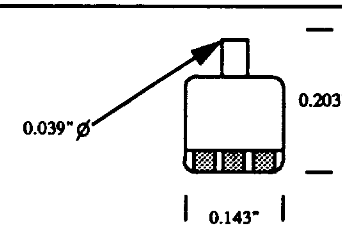

Figure 3: Microphone Schematic [2]

previous microphone port's wake from disturbing downstream microphones. Due to equipment restraints, many factors limited the availability of every data possibility, but the designs for this project included many ideas for future research opportunities. For example, the four spanwise microphones were included to eventually investigate signal attenuation of the boundary layer signal, given different metal tube lengths connecting the port with the microphone. The priority of the current research was to establish a baseline system and to begin taking data on the feasibility of measuring the acoustic signals of the boundary layer of the plate.

The majority of the research time was consumed in the actual buildup process of these microphones, leaving very little time to pull real-time data. Initial concerns of this technique included wake effects from the HSCT model disrupting the flow over the microphones, the microphone ports themselves tripping the flow into transition, the actual detection of the boundary layer over the background noise, and the ability to differentiate between transition, laminar flow, and turbulent flow. Through preliminary real-time signal analysis, it was determined that the boundary was detectable and different types of flows could be observed, given certain conditions. Thus, to address as many of these problems as possible, a schedule of runs was established to test each plausible condition. Through the use of grit, to trigger transition in the flow, cover tape, to remove the effects of the microphone ports on the flow, and timing, to prevent the HSCT model's wake from disturbing the flow, the signals of different boundary layer regions could be determined. As a side investigation, a speaker was also installed to determine the audio difference in such conditions.

Results and Conclusions

Through the run schedule, it was determined that the microphones can distinguish between boundary layer types only after removing any adverse flow effects. The microphone ports were found to be disturbing the flow just by being exposed, causing some concerns. Note that pressure ports, frequently used in wind tunnel testing to determine the pressures along an airfoil, are approximately the same size as the microphone ports, and thus can be influencing the airflow directly over the ports. While a small disturbance would not alter a non-dynamic measurement such as a pressure, it does introduce an error in any such calculation, thus addressing the issue of pressure port accuracy.. For the affected dynamic acoustic signals, measures must be taken to remove this effect.

Through the use of cover tape, beginning from the leading edge and sealing the microphone ports to provide a smooth surface, it was found that dynamic acoustical data of the boundary layer was still obtainable. Although dampened, the difference in a laminar boundary layer and turbulent boundary layer, can be distinguished. Figure 4 demonstrates laminar flow while Figure 5 samples turbulent flow. These graphs were obtained using the same microphone, once with forced transition, and once without. Transitional dynamic signals were also recorded as an entirely different pattern of vertical spikes as shown in Figure 6. Note that this data was obtained under another configuration without cover tape, thus the difference in output voltages. Therefore, through the implementation of cover tape, the research to determine the feasibility of detecting the boundary

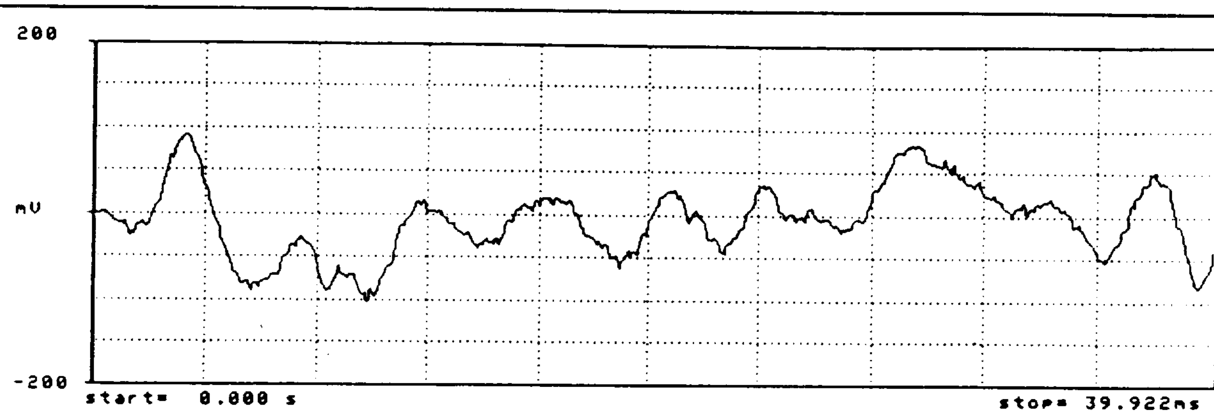

Figure 4: Dynamic acoustic signal of a laminar boundary layer (Gain -- 10)

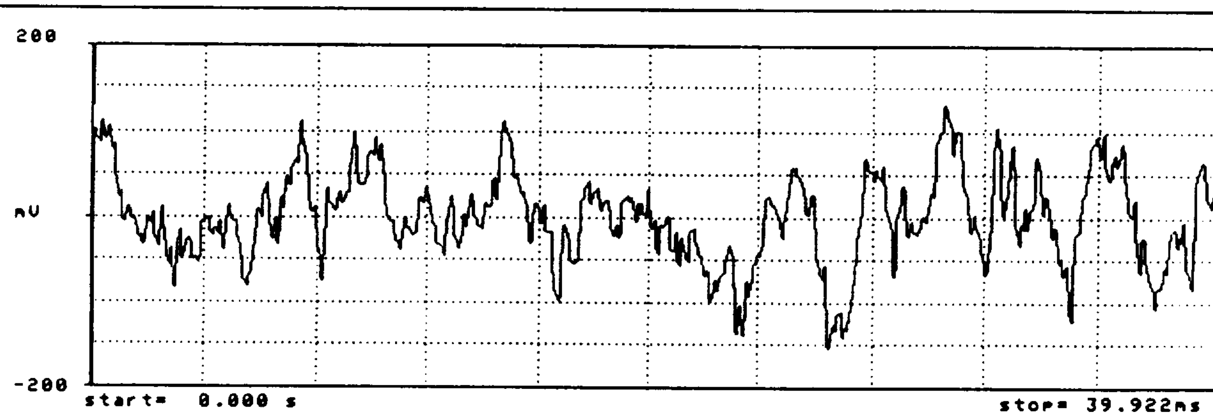

Figure 5: Dynamic acoustic signal of a turbulent boundary layer (Gain -- 10)

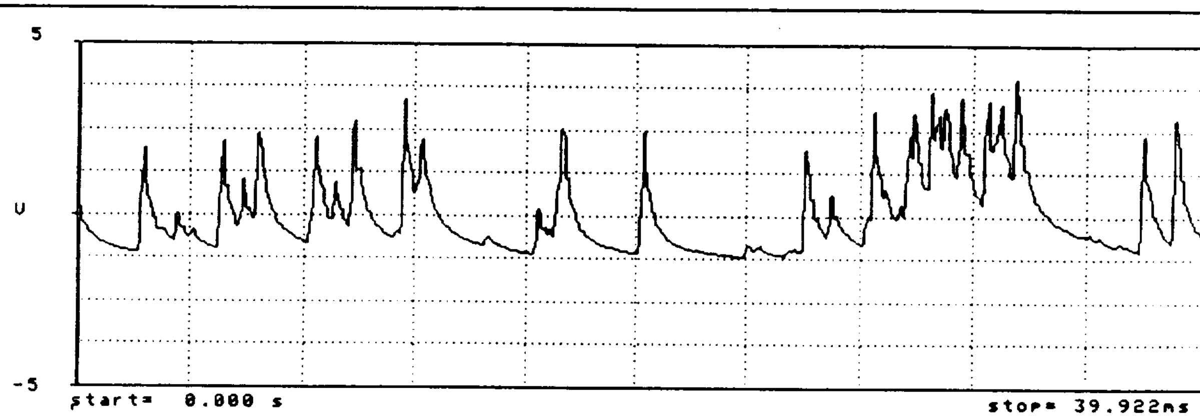

Figure 6: Dynamic acoustic signal of a transitional boundary layer (Gain -- 10)

layer was a success.

Many possibilities of this project are still to be researched, prior to actual testing within the confines of the NTF. Aspects such as physical durability to both pressure and temperature., and tube length attenuation are to be investigated in the near future. Some groundwork has been conducted, and the burden of research development has been removed in the original setup of this experiment. Through further study, similar dynamic acoustic data could be used to determine the precise flow over an airfoil surface in facilities that lacked the ability previously.

Acknowledgments

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References

[1] Agarwal, N.K., and Simpson, R.L., "A New Technique for Obtaining the Turbulent Pressure Spectrum From the Surface Pressure Spectrum." *Journal of Sound and Vibration*, **135**, 346-350 (1989)

[2] Knowles Electronics, Incorporated, EM-3068 Microphone Schematic