ACTIVE FLOW CONTROL

Instrumentation Automation
and
Experimental Technique

Research and Technology Group
Fluid Mechanics and Acoustics Division
Flow Modeling and Control Branch

Student
N. Wes Gimbert

Mentor
Rich W. Wlezien

ABSTRACT

In investigating the potential of a new actuator for use in an active flow control system, several objectives had to be accomplished, the largest of which was the experimental setup. The work was conducted at the NASA Langley 20x28 Shear Flow Control Tunnel. The actuator named "Thunder", is a high deflection piezo device recently developed at Langley Research Center. This research involved setting up the instrumentation, the lighting, the smoke, and the recording devices. The instrumentation was automated by means of a Power Macintosh running LabVIEW, a graphical instrumentation package developed by National Instruments. Routines were written to allow the tunnel conditions to be determined at a given instant at the push of a button. This included determination of tunnel pressures, speed, density, temperature, and viscosity.

Other aspects of the experimental equipment included the set up of a CCD video camera with a video frame grabber, monitor, and VCR to capture the motion. A strobe light was used to highlight the smoke that was used to visualize the flow. Additional effort was put into creating a scale drawing of another tunnel on site and a limited literature search in the area of active flow control.

Introduction / Background Information

The motivation for investigating active flow control is based on the notion that overall performance of an aircraft can be dramatically improved with active systems as opposed to the traditional passive aerodynamic schemes. In pursuing active flow control, it is apparent that the system can be broken down into three subsystems. These are the sensors, the control scheme, and the control mechanism. The dramatic increase in computational and material technologies over the past years has begun to make the realistic implementation of each of these possible. Computer technology is currently capable of completing the necessary nonlinear computations for the control scheme, and MEMS technology is promising to deliver cheap and reliable sensors that could be embedded within a composite material. This experiment investigates the use of a high deflection piezo actuator, develop at NASA Langley Research Center, as a means of controlling a turbulent flow. The actuator is controlled by means of a voltage which makes the system relatively light and easy to implement. The experiment was performed in the NASA 20x28 Shear Flow Control Tunnel.

In setting up the experiment, LabVIEW virtual instruments (VIs) were developed to automate many common wind tunnel data acquisition procedures. Effort was made to produce a modular system that is easily portable to tunnels with similar configurations. This is desirable in order to reduce the setup time and effort that will be necessary for future research. VIs were required to monitor tunnel flow conditions including speed, atmospheric and dynamic pressure, temperature, viscosity, density, as well as the relative humidity in the room to be used in future humidity based corrections. An additional set of VIs was developed to produce waveform functions at various phase angles, frequencies, peak-peak amplitudes, and DC offsets on two independent channels that could be phased together if desired. Attention was paid to usability in all cases to further increase it's usefulness in other lab settings. The experimental setup also made use of a smoke generator, a strobe light, and a means of recording the motion by means of a VCR and a video frame grabber.

This setup was performed both for the experiment that it facilitated, as well as for the experience of conducting a wind tunnel experiment from start to finish. Additional experience was gained by producing a scale drawing of the NASA 2x3 Boundary Layer Channel Flow Tunnel. This was necessary for the design of planned tunnel modifications.

Summary of Research Project

The research was initiated by a short study of the LabVIEW graphical programming language and the GPIB bus. This was conducted by means of the National Instruments tutorial and other pieces of documentation that were included with the package. Based on this, and by using many of the device drivers as supplied by National Instruments as examples, the necessary virtual instruments (VIs) were written.

The first VIs were written to control the HP 3245A Data Acquisition / Control Unit, and it's accessories, through the GPIB bus. The accessories included HP 44705 multiplexors and a HP 44701 integrating voltmeter. These were use in conjunction with Barocel differential pressure transducers, and a pitot tube, to determine the dynamic pressure and the difference between the static and atmospheric pressures. This required becoming familiar with the HP BASIC programming language and many of the machine independent commands for each device. Due to the unsteady nature of the airflow, the measurements are averaged over a specified time in intervals of 1/60 seconds by means of the integrating feature of the voltmeter. The 1/60 interval eliminates the interference of the electrical line noise and produces a more accurate measurement. The VI also took advantage of machine generated interrupts in order to signal the host computer when the operation was completed. This allows the user to average the pressure over long periods of time while not demanding the computer to repeatedly check for the answer.

Other readings were taken by a high precision pressure transducer to record atmospheric pressure and return the result to the computer via the GPIB bus. The initial stages of a TCP/IP client-server system was also developed so that atmospheric pressure reading could be taken from a remote site if the transducer was not locally available. This works by the client addressing the server computer, where the atmospheric pressure transducer would be present , with a request. The server computer would then prompt the devise for a reading and pass the result back to the client computer. This would be effective since atmospheric pressure tends to vary only slightly from room to room on a given day. The high cost of the devices makes the small error associated with such a system acceptable due to the large cost savings associated with purchasing only one devise for multiple laboratories.

A similar VI was then written to determine the temperature based upon an RTD positioned in the flow and a 4 wire resistance reading. The 4 wire method is used to eliminate any resistance due to the electric leads, which reduces the uncertainty of the measurement. The 4 wire method works by taking the resistance across two of the wires as in a standard resistance measure. The other two leads are then used to measure the voltage drop which eliminates the internal resistance of the wires. Lastly, a General Eastern relative humidity sensor was used to determine the percent relative humidity and was read by the computer based upon an output voltage. Since several of the parameters can vary based upon humidity, and due to the relatively high humidity associated with the south-eastern Virginia climate, this could prove to be a valuable correction when high orders of accuracy are needed. Based upon the measured parameters, the remaining ones including density, speed, and viscosity were then determined. Speed was based upon the definition of the dynamic pressure along with the density that was determined based upon the ideal gas law. Viscosity was based on an empirical correlation based upon temperature.

The next phase of the research then consisted of writing a user friendly LabVIEW interface and set of VIs for the HP 3245A universal source. The resulting VI makes use of most of the capabilities of the devise. This includes producing both standard and arbitrary waveforms for two independent channels. The standard waveforms include sine waves, square waves, and ramp waves. For additional flexibility, the frequencies, phase angle, DC offset, and peak - peak voltages or currents can be determined. The user has the option to synchronize the phasing of the two channels, so that they can be used together. All these features are available at the push of a button or the turn of a dial. If an arbitrary waveform is desired, the user may either manually input the required 2,049 points, or may input the numbers from a text file generated in a spreadsheet such as Excel. A separate VI was also written to modify the phase of a given channel in real time. This allows the user to vary the relation of two phase synchronized channels during the course of an experiment, without interruption.

In setting up the experiment the above mentioned VIs and equipment were used. The first set of VIs were used to monitor the conditions of the flow, and the universal source VIs were used to control and synchronize the strobe light and the actuator. The strobe light was a General Radio 1540 Strobolume, which was desired for this experiment because of it's intensity. The strobe was controlled by means of a TTL wave produced by the universal source which was inputted into an optically isolated triggering device built for this application. The triggering device would then trigger the external trigger connection on the strobe light within 3 microseconds. The strobe light was used to light up the smoke so that it would be visible to the camera. The strobe light was positioned directly above the model and the light passed through a narrow Plexiglas window directly above the model. This allowed the smoke to be effectively lit while maintaining contrast between the smoke and the black background that was painted to the left of the model. A CCD camera was positioned on a tripod to the right of the model so that it watched the model in profile with the black background immediately behind the model.

The model was mounted on a Bakelite plate that was manufactured to fit in the middle of a flat plate that is the third of three interconnected aluminum flat plates that run the length of the 15 foot 4 inch test section. Trips were applied at the leading edge of the first plate and on all sides of the tunnel just after the contraction. The first plate has a rounded leading edge and a flap is located at the trailing edge of the third plate. The flap was adjusted until the flow remained attached on the upper surface. Since the plates were mounted towards the bottom of the test section, the tunnel floor caused blockage effects which tended to move the stagnation point below the leading edge. By raising the trailing edge flap, the stagnation point was moved back to the leading edge, thereby preventing separation. This was tested by applying oil to the plate and observing it's motion while the tunnel was running with various flap settings.

In between the first and second plates, a small gap was made through which the smoke was introduced. The slot was about 2 inches wide and located at the center of the gap between the plates. The edges were all filled and the remaining portions of the gap were covered with duct tape. The slot was fitted by means of an adapter to a one inch plastic tube that passed through a hole in the bottom of the tunnel and into a wooden plenum that was produced to cool the smoke. The smoke was generated by means of a F-100 Performance Smoke Generator. The water and glycerin based smoke is hot as it leaves the device. It was feared that this would cause a buoyancy effect when the smoke entered the flow. It was assumed that the hot air would remain at the top of the plenum and would fall as it cooled. Thus the smoke was pumped into the plenum by the smoke generator and was pulled up from the bottom of the plenum by the plastic tube due to the low pressure produced by the air moving over the slot in the tunnel.

The actuator was powered by means of an external amplifier that was in turn connected to the universal source. It was run with a sine wave that was synchronized with the strobe. The camera was connected to a monitor, a VCR, and a Computer Eyes/RT video frame grabber that could digitize a frame or make a Quicktime movie of any observed phenomena.

The air would become tripped just after the leading edge of the first plate and form a turbulent boundary layer. Then flow would then proceed down the plate where the smoke was injected and was carried along with the flow. It is assumed that the smoke particles were light enough to accurately follow the flow. The smoke would then proceed downstream and cover the actuator where the actuators motion should produce some sort of disturbance. This disturbance should be followed by the smoke which will be lit up by the strobe and in turn captured on the VCR while being viewed in the monitor. The purpose of the experiment was to observe what sort of effects the actuator will have on the flow.

Results / Conclusion

The results of the experiment were as yet undetermined when my term was ended. The setup seems to work as described in a useful and predictable manner. The most useful result to date was the experience gained in working with a developing technology, and in the fine points of conducting a wind tunnel investigation. Specific experience was gained in setting up the instrumentation. This included use of the GPIB / IEEE 488.2 bus, and learning both HP BASIC and the LabVIEW graphical programming language. All of these are general enough to be useful in future experiments. Additionally, the experience of working with a tunnel technician, and by getting hands on experience in working with much of the equipment, I feel better equipped to conduct in future wind tunnel I might encounter in the future.