Experiment No. 6A: Calibration of Pressure scanner

1. Objective

To study the calibration procedure of pressure scanner

2. Apparatus

- Electronically Scanned Pressure sensor: 32-HD ESP scanners **are differential pressure measurement units**. Pressure range of this scanner is ± 2.5 KPa. It houses an array of 32 piezo-resistive sensors. The output of sensors are in voltage. Pressure sensors are connected to multiplexers which can acquire data at rate up to 1 KHz. Each pressure port consisting of a Wheatstone bridge diffused onto a single silicon crystal. This scanner need 12 V DC supply to operate and 5V for excitation of sensors. These scanners have two-position manifold, one is run-mode and other one is calibration mode. The manifold position can be changed by applying a momentary pulse of control pressure. Run-mode is used to acquire a pressure data and calibration mode is used for calibration of pressure ports. In calibration mode position, all sensors are connected to a common calibration pressure port. The accuracy of the scanners is maintained within ±0.05% of full scale pressure range through their periodic calibration. The frequency of calibration is dependent on ambient conditions and it changes with time. Calibration performed immediately before a set of data is acquired assures the highest accuracy of the scanners.

- Multiplexer Unit: Each sensor output is selectively routed to the onboard instrumentation amplifier by applying its unique binary address to the multiplexers. The multiplexed and amplified analog outputs of the scanners are capable of driving long lengths (up to 30fts) of cable to the remote A/D converter of DAQ board. Scanners require 12V DC power supply for the operation of built-in analog/digital devices and a +5V DC power supply as the excitation voltage source for the sensors.

- Digital Interface and Line Driver (DILD) unit for ESP Scanners: The DAQ board provides 5-volts (TTL) logic level signals through its digital I/O lines, whereas the pressure scanners require 12-Volt (CMOS) logic level signals for binary addressing. Thus, there is a logic (TTL-CMOS) level mismatch between DAQ board and scanners. The logic level shifters of the DILD unit compensates for this logic level mismatch. The DILD unit also provides digital fan-out to drive up to 8 pressure scanners, and long cable (30 ft) drive capability. The regulated DC power (12V and 5V) required for the operation of pressure scanners are also supplied by this unit.

- Data Acquisition Board: A 14-bit high speed data acquisition board from National Instruments is used for the pressure measurement, which acts as an interface between sensors and computer. The data acquired is digitized and transferred to computer by the DAQ board.

- Pressure Data Acquisition and Analysis Software: Data acquisition and controlling is done by the LabVIEW 12.0 application software. In-house developed pressure data acquisition and analysis software is capable of acquiring the data at desired data acquisition parameters, analysis, and presenting in the engineering units.

- Digital manometer: It is used to directly measure the gauge pressure between the two terminals.

- Calibration Setup: The electronic output of the ESPs is calibrated to convert electronic signals to pressure data. For that purpose, known pressure is applied using hand pump measured using digital manometer, which is used to calibrate the electronic data from the ESP.

3. Precautions

- Ensure that the maximum pressure at any port should be within the range of the sensor.
- While calibrating, sufficient time should be given for the pressure to stabilize.
- Make sure that there are no blockages or leakage in the tubes.
- The excitation voltage given to the scanner must be within the range of 5V.
- There should not be any obstacle near the entry or exit of wind tunnel flow causing disturbance in the freestream flow.

4. Procedure

Calibration of Pressure scanner

- Connect pressure scanner reference port of run mode and digital manometer to hand pump via T-joint pressure tube.
- Apply multiple pressure using hand pump.
- Save voltage output of scanner and pressure output from digital manometer (negative pressure will obtain as pressure is applied on reference port)
- Plot voltage vs pressure to obtain slope and fits equation of sensors.

5. Error Analysis

a) Systematic Error: These arise due to improper calibration of instruments or some other unknown reasons. They can be eliminated by proper calibration of instruments or rectifying the fault. This defines the accuracy of the measurement made. The lesser the bias, the higher the accuracy. These are biased in nature.

b) Random Error: These occur due to the natural disturbances that occur during the measurement process. These cannot be eliminated. This defines the precision of the measurement made. These are statistical in nature.

6. Results and Discussions

- Mention the name, specification and need of PXI system, DAQ card and ESP scanner used for the experiment.
- Plot pressure vs voltage for pressure scanner.
- Obtain equation and R^2 of plotted graph for channel given in sheet (Refer: Workbook AE351A Experiment 6A.xls).

7. References:

- Schlichting, ``Boundary Layer Theory,'' McGraw Hill Book Co., New York, 1960.
- Equipment manual

Fig. 6A.1: Hand pump

Fig. 6A.2: Digital manometer

Experiment No. 6B: Calibration of six component force balance

1. **Objective:**

   To study the calibration procedure of a six component force balance

2. **Apparatus:**

   - Six component force balance: It is a cylindrical body, with maximum diameter of 5 mm and length 210 mm, on which an aerodynamics model has to be mounted to measure forces acting on it. It consist of 2 normal force gage stations for determining normal force and pitching moment, 2 side force gage to determine side force and yaw moment , two axial force measuring bridge and one rolling moment bridge. The load range for the 6 component balance are 5kg for Axial force, 15kg for N1 force, 15kg for N2 force, 5kg for S1, 5kg for S2 and 100kgmm for Rolling moment.

   - Calibration body: It is used to facilitate loading of the balance with pure loads (in specific directions at particular locations) in order to calibrate it.

   - Calibration rig: It is a truss structure with levelling screws on which the force balance fitted with calibration body is mounted to apply the desired pure loads. The levelling screws are required to align the force balance in horizontal position under the action of the force due to dead weights.

   - precise level gauge: A digital level gauge is used to align the balance in horizontal position.

   - Dead weights: These are used to load the balance with constant loads.

   - NI SCXI-1520: is an 8-channel universal strain gage input module that offers all of the features you need for simple or advanced strain- and bridge-based sensor measurement.

   - NI SCXI-1314 terminal block is used with the SCXI-1520 universal strain/bridge module enabling you to conveniently connect strain gauges through screw terminals.

   - Data acquisition card: The voltage output of the strain gauges is required to be measured under the loading on the balance. For this a data acquisition card PXI1002 with maximum of 16 voltage input channels is used.

   - Labview software: Labview software facilitate to provide/acquire the input/output voltage signals to/from the strain gauge bridges using a specially built VI program.

3. **Procedure:**

   - Fix and connect force balance to DAQ system.
   - Perform bridge nulling to remove force generated due to empty pan weight.
   - Put load of 992 gm on pan and note down N1 force.
   - Exceed load in step manner.
   - Rotate force load balance by 90^0.
   - Perform bridge nulling to remove force generated due to empty pan weight.

- Put step loads on pan and note down S1 force.
- Measure the output voltages of the bridges at all locations (AX, N1, N2, S1, S2, RM) at each known applied load at a particular bridge location (say N1).
- Repeat steps to obtain other loads also.
- Evaluate the coefficients of calibration matrix using the data in step two and find its inverse.
- Write the equations for evaluating the orthogonal forces and moments at the force balance centre acted upon by a random force.
- Write the equations for real orthogonal forces and moments acting on a model (attached to the force balance) at a reference point by a random aerodynamic force in terms of loads measured by the force balance.
- Follow the detailed calibration procedure given in the force balance manual available in the low speed aerodynamic lab.

4. Result and Discussion:

- Plot and obtain equation for Weight vs Voltage.
- Calculate voltage for given load and discuss (Refer: Workbook AE351A Experiment 6B.xls)

5. Reference :

- Low-speed wind tunnel testing - W. E. Rae, Jr. and Alan Pope.
- Fundamental of Aerodynamics - J. D. Anderson.
- NI manual for DAQ cards used.

Fig 6B 1. Installed Load cell (for N1 force measurement)