PULMONOLOGY

DESIGN AND IMPLEMENTATION OF AN AUTOMATED PROBE TRAVERSING SYSTEM

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ABSTRACT

This report describes the design and development of an automated probe traverse mechanism to be used in future fluids research. This instrument was designed to collect low speed airflow measurements from a probe over a range of pitch, yaw and roll angles, with pressure, mass flow rate and velocity probes. The report consists of the design and development of the various mechanical and electronic components to construct an instrument which manipulates the probe in a 2-d plane. Based on the study of various probe traverse mechanisms and the consideration of the future experiments to be conducted, the basic manipulation requirements for the probe were found out. On the basis of the manipulation requirements, and the worst (design conditions) experimental conditions the components of the instruments are been selected and designed. The robustness, accuracy and the strength were the primary design criteria for the design of the manipulation (traverse) mechanism. As the mechanism is to be controlled autonomously during the experimentation the electronic components are to be selected such that they provide highly repeatable and accurately reliable results. After the design and manufacturing of the whole setup including the calibrating tunnel, the probe is to be manipulated in certain fixed criteria, for that peculiar motion planning the control algorithms are been developed . Also to provide extra freedom to the experimenter the manual mode is also been provided in which the operator can manually manipulate the probe using the electronic knobs provided. In the future scope of the stated setup the CTHP (cylindrical three hole probe) and the various probes are to be manufactured and to be calibrated using this setup to test and verify the outcome of the setup.

KEYWORDS: Probe Calibration, Probe Traverse Mechanism

INTRODUCTION

Probe calibration allows for high accuracy measurement of flow parameters, and is particularly important in experimental fluids applications. Effective probe calibration equipment needs to be suitable for a variety of probe types and have a high resolution in probe positioning, in order to produce high accuracy experimental measurements. In the previous days for the manipulation of the probe for the calibration purpose was carried out manually in which the stand for the probe is provided and the manually operable knobs are provided. But, the method was incorporating human intervention in the manipulation, so the results were not satisfactory. So to avoid human effect in th probe manipulation, the automated mechanisms were developed, which had following advantages.

- Considerable less error in the experimentation
- High accuracy
- Closed loop control of the manipulation
- Simpler analysis of the data aquisited etc.

This report describes the design and development of an automated probe traverse mechanism to be used in future fluids research. This instrument was designed to collect low speed airflow measurements from a probe over a range of pitch, yaw and roll angles, with pressure, mass flow rate and velocity probes. The report consists of the design and development of the various mechanical and electronic components to construct an instrument which manipulates the probe in a 2-d plane.The mechanism consists of the linear , pitch and roll motions in which the probe is being manipulated. The parts of mechanical assembly are selected to be rigid and robust even in the 3 times the worst condition of the experimental condition.The robustness, accuracy and the strength were the primary design criteria for the design of the manipulation (traverse) mechanism. As the mechanism is to be controlled autonomously during the experimentation the electronic components are to be selected such that they provide highly repeatable and accurately reliable results. After the design and manufacturing of the whole setup including the calibrating tunnel, the probe is to be manipulated in certain fixed criteria, for that peculiar motion planning the control algorithms are been developed . Also to provide extra freedom to the experimenter the manual mode is also been provided in which the operator can manually manipulate the probe using the electronic knobs provided.The functions are used to teach applied fluid mechanics, demonstrate how mathematical models compare to experimental results, demonstrate flow patterns, and learn and practice the use of instruments in measuring flow characteristics such as velocity, pressures, and torques.There are other uses of wind tunnels which vary from ordinary to special: these include uses for Subsonic, supersonic and hypersonic studies of flight; for propulsion and icing research; for the testing of models and full-scale structures, etc.

LITRATURE REVIEW

- Paul, Eathen, Daniel and Stephan ,Worcester University[Design and Development of velocity probe calibration rig]

The research was used to judge and to select the primitive design of our traverse mechanisms as the research provided us several primitive traverse designs and their advantages and the disadvantages. The objective of the project was to develop a probe manipulator with pitch and yaw ranges of 180 degrees. However, after taking into account the stress limitations on each of the manipulator arms this objective became unachievable. Rather than achieving 180 degree ranges of pitch and yaw, the new objective became maximizing the achievable ranges of both rotary tables by choosing optimal positions for each of these devices. From the primitive designs provided by this research, the selected motions for the manipulation of the CTHP were the linear motion, the pitch and the rolling motion about its own axis.

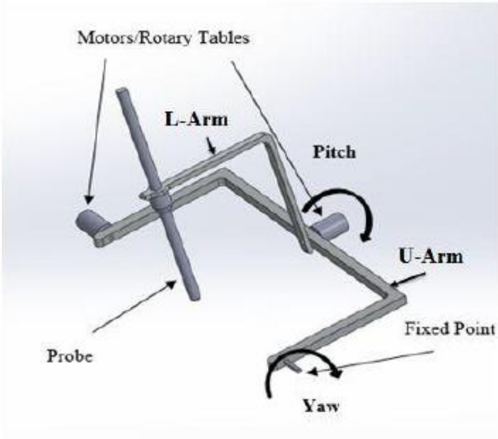

Fig 1 Assembly model of 2-axis probe traverse

From the above shown traverse mchanism, some of the key points were deducted , as

- The probe holder should be d esigned such that the probe is re attachable to the traverse
- The head of the probe must be far away from any other physical entities to prevent the effacts of the other bodies on the result of experimantation
- The rigidity and the robustness should be the prime goals to structure design.
- Dantec Dynamics Motorised pitch-yaw-roll manipulator

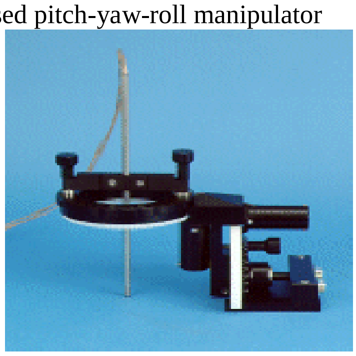

Fig 2 Dentec Dynamics motorised calibrator

Directional calibration of triaxle probes can now be fully automated using Dantec Dynamics's motorised pitch-yaw manipulator. Controlled by the Streamline software, it inclines the probe in relation to the flow and rotates it through 360°. The manipulator is mounted on top of the calibrator. The motorisation feature speeds up directional calibrations and makes them more accurate than those achieved with manual calibration. It facilitates mapping of how the pitch and yaw factors are influenced by velocity and angles a feature that can also be used to improve overall measurement accuracy.

- Dantec Dynamics Hot-Wire Calibrator

Fig 3 Dantec Dynamics hot wire calibrator

The Dantec Dynamics Hot-Wire Calibrator is a simple, but accurate, device for 2-point calibration of most hot-wire probes used with Constant Temperature Anemometers. The calibrator produces a free jet, where the probe is placed during calibration. It requires a normal pressurized air supply and is able to set velocities from 0.5 m/s to 60 m/s. It is primarily designed to provide two-point calibrations of standard wire probes, but can also be used for multi-point calibrations. By combining two sets of measured velocity-voltage values with a generic uni-curve transfer function it is possible to create a calibration function for an actual probe, which is valid for the entire velocity range

- AeroLab Probe Traverse Systems

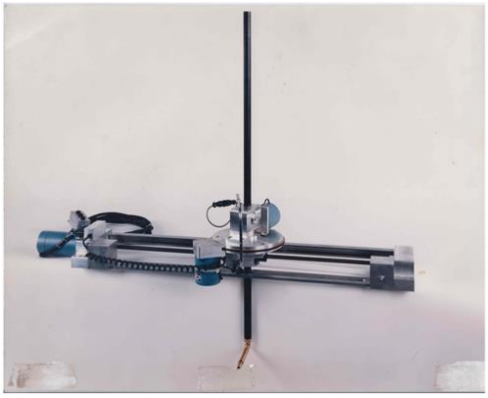

Fig 4 Aerolab Probe Traverse mechanism

The research helped me in selecting the basic motion and manipulation requirements to design the traverse for the probe. It also helped me with some of the design requirements for designing the basic mechanical componants for the traverse mechanism. Also from this product from AEROLAB provided me a taste of the selection of the basic componants as well as the electronic motor controller and the main controller requirements.

DESIGN AND SELECTION OF MECHANICAL DRIVE COMPONENTS

Basic Design Requirements

After studying various traverse mechanism and the analysing the requirements of the calibration methodology the following manipulation modes were selected to be incorporated in the design of the traverse mechanism.

- Linear motion of the probe about X-axis
- Pitching motion of probe about Y-axis
- Rolling motion of the probe about its own cylindrical axis.

These three motions are to be provided by the motorised action, constructing and automated traverse mechanism. The following data was provided by the researchers working on the calibration tunnel as their output speed and the nozzle opening against which the probe was to be calibrated.

Design constraints for the given mechanical drive mechanism can be characterized as follows

- Max. wind velocity : 40 m/s
- Nozzle Dia. : 5 cm
- Max. Pitching required: over 45 degree range.

Considering above data the manipulator was to be designed to withstand the wind force and manipulate the probe robustly and repeatedly against this wind force. Also the following accuracy measure were decided looking forward to the experimentation range over which the experiments are to be performed.

- Accuracy/Resolution for linear motion : less than 1 mm
- Accuracy /Resolution for pitching motion : 0.5 degrees
- Accuracy/Resolution for pitching motion : 0.5 degrees

Design of Linear Drive and Rotary Drive Components

The major components to be designed that are incorporated in the linear motion are the, 1.)Selection of linear actuator 2.) Linear shaft and bearing assembly 3.) End support for the linear shaft 4.)The base and the carriage assembly.5.) The Motor Selection for Roll and Pitch Motion 6.) Links and other mechanical componants

Selection of Linear Actuator

The criterion for the selection of the linear actuator can be characterised as, 1.) Maximum linear travel (stroke) 2.) The resolution of the close loop servo feedback drive 3.) The load carrying capacity. Based on geometrical requirements the max linear is required up to 100mm. As the calibration of the probe requires the high amount of degree of precision the linear drive possibly requires the travel accuracy up to 1mm. Concerning These requirements, various available products in the market have been searched and the final selected product was "Firghelli L16" linear actuator, having 100 mm maximum stroke and high feedback accuracy.

Motor Selection for Rotary Drives:

Based on the basic requirements, selection of the rotary drives are the most important task to be performed concerning the scope of the pertinent project. Given the basic requirements for overall manipulator, the refined design criterion for the rotary drives namely for the pitch and the roll motion can be termed as following. 1.) Min. torque required: 2 Nm 2.) The feedback sensor (encoder) accuracy: 3 degree (approximately) 3.) High axial load carrying capacity 4.) No or very negligible backlash. Concerning the above requirements the DC motor was selected. The exact product was , "DC Servo with Encoder" from Robokits India Pvt Ltd.

SELECTION OF BASIC ELECTRONIC COMPONENTS

Based on the requirement of the mechanical drive system as well the motors, the motor drivers as well the microcontroller is required. Along with that the other hardware element such as power source capable of handling the 3 motors and the electronics is required.

Selection of motor Driver and Microcontroller

The selection criterion for the motor controller can be termed as: 1. Operation Voltage and Current: 12v DC, up to 6A. 2. Operation Mode: Pulse width modulation (PWM) 3. Feedback mode: Quadrature Encoder (operating between 0 to 1024 bits. The servo motor driver was selected for the pitch and roll motion in the pertinent probe manipulator system. In addition the H-bridge type motor controller was used for the control and feedback for the prescribed linear actuator. The main micro controller had selection requirements as follows,1.) Operation Voltage 12V DC 2.) Analog Inputs : 6. 3.) No. of Interrupt enabled pins : 4. 4.) UART communication pins 4. So, taking into account of these parameters along with the ease of programming and hardware interface, an open source hardware namely "Arduino Mega 2560" was selected to perform as main microcontroller to control its peripherals.

Selection of Power Source

The power required for the proposed system can be reckoned as below,
Power requirements by DC servo motors: 12 volt x 3 Amp
Power Consumption by Linear Actuator: 12 volt x 1 Amp
Hence, to overcome these power requirements an AC to DC power-source of 12V and 5A supply capacity was selected.

FINAL ASSEMBLY

After designing and selecting the mechanical as well the electronics, the final assembly was prepared.

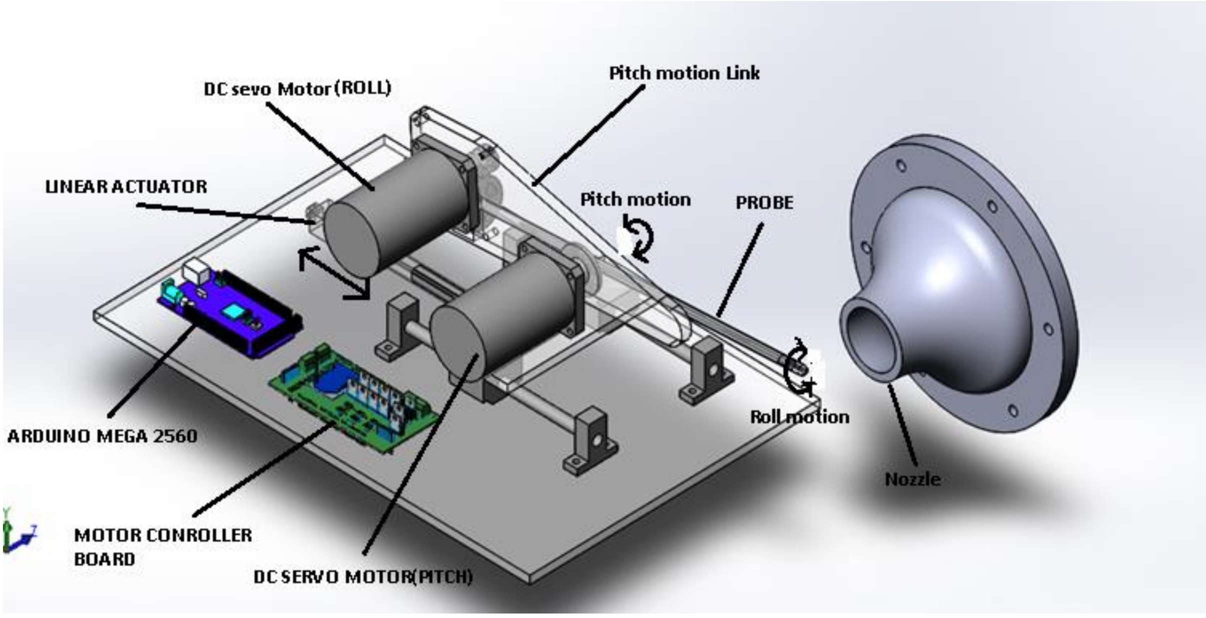

Fig 5 probe Traverse Mechanism Assembly (CAD model)

The figure above shows a CAD model of the whole probe manipulator system with a reference of the wind tunnel nozzle. As the figure suggests the linear motion was carried out by the linear actuator operating from left to right from the figure perspective. In the similar manner, the pitch and the roll motion direction have been indicated. The whole assembly is to be rested upon a flat acrylic sheet which in turn be mounted on the table of the experimental wind tunnel setup.

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