Instrumentation of ASTM Tools

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Abstract
This paper will focus on a laboratory experience using a chip level pressure sensor that will be presented as both a force gauge and a level meter. The goal is to present sensors to the students with enough information to allow them to see how sensors can be adapted to collect different data parameters

Background
Laboratory experiments often seem disconnected from the "real world". Examples of instrumentation used in commercial enterprise are used to stimulate conversation and confidence that the material presented is current. Programmable controllers, CNC simulators, computer interface boards, relays, operational amplifiers, and chip level sensors are components that are used in laboratory experiments to show students both how the systems may be interfaced and to allow them to create the interface. Sensors cover a broad range of measurement needs and can be used for many types of data collection. They are application specific so must be used in multiple experiences to show diversity and how the same device can be structured to take different measurements.

This laboratory experiment will use the Motorola MPX5010D pressure sensor to measure water level. The class project will include building a PID controller to regulate the level of a water tank. The 5010 will be the level measurement device. Preparation for this experiment requires that sensors be discussed and during that discussion the 5010 will be presented as it was used in a medical research application. During the case history discussion the student is to consider how to collect the desired information. History of the project will assist the student in understanding how the final device was conceived. A discussion of the problems that were solved and those that were not are given to broaden the scope of the sensor experience.

The Application and Case History
A technique called ASTM (Augmented Soft Tissue Mobilization) has been developed and is under study at Ball Memorial Hospital(1). It has been known that mobilization (rubbing tissue in the direction of the muscle or across the muscle) of soft tissue can stimulate the body's normal healing response(2). Such problems as chronic tendinitis, carpal tunnel syndrome, and adhesions within the soft tissue can be broken down and restored to full function. The populace has always known that if it hurts, you rub it. Massage therapists have use these techniques for years to make their patients feel better. Physical therapists attempt to assist the body in the healing process. Sometimes the body is so damaged that there is nothing that can be done to assist the patient while still outside the skin. In these cases, surgery may be indicated. The purpose of the ASTM technique is to reduce the requirement for surgery and to return patents to the work force(3).

ASTM was discovered and testing was started at Ball Memorial Hospital. The discovery was that a dull edge like a reflex hammer handle could be used to rub the tissue with less force than would normally be applied by hand. The movement of tissue by a force per square inch can be accomplished with less exterior force if it is applied over a smaller surface area. The hands and fingers of a therapist may cover several square inches and the tissue that needs to be moved may be deep. Force applied on a blunt edge is able to penetrate to greater depths. Micro trauma at the site of fibrous growth causes an inflammation response which will result in tissue repair if the proper stretching and healing cycles are maintained. Fibrous growth can be broken down and will grow back. The return growth must be controlled and located where it will support the tissue instead of limiting its movement. Pressure applied to soft tissue causes the body to start healing. The amount of pressure, the actual process, the possible limits, and what tissue is repairable is still under test. Part of the needed data is a record of the force used during the procedure.

Tools used for ASTM need a handle for the operator and an edge appropriate for the surface to be treated. The tools developed were for both large and small muscle groups. Figure 1 shows a crescent shaped tool that was equipped with strain gauges in full bridge configuration[4]. The tool is 8 inches in length, 1.5 inches wide in the center of the crest, and .25 inch thick. Because the leading edge is beveled at 45 degrees to provide a sharpened surface to engage the tissue, there is no flat surface that is square with the primary force axis. Two elements of a full bridge strain gauge were placed on the beveled 45 degree angle leading edge. The other two elements of that set were placed on the top of the device across the thickness and parallel with the long axis. This set of strain gages would indicate pressure applied to the nose of the tool if the therapist used the outside ends as handles. If the operator flexed the tool by holding it tightly or tried to bend it through its thickness, the gauges on the beveled surface would indicate the presence of pressure on the nose. To remove this signal another full bridge was put on the front and back face of the crescent. This set of gages react to flexing forces and not to pressure of the tool nose on the patient tissue. The two signals were amplified and sent to a computer collection device running LabView software by National Instruments. The AT-MIO 16 analog to digital board was used as an interface. It is a 12 bit 100KS/s 16 channel A/D board that was configured to receive two differential channels of input. The board accuracy is +/- 1.5 LSB. Strain gauge power and amplification was provided by a DMD 460 from Omega[4]. The flexing force was subtracted from the primary force strain elements in software. Calibration was configured in software so that a zero primary force would be indicated while the tool was flexed.

Figure 1

This was a first run and many problems were noted. The connecting cable was long (25 ft) from the tool to the DMD 460 and first stage amplifier. Cable noise and cable flex noise were both present. The tool itself was too narrow. The edge was good for the patient but the therapist's hands would get tired holding the tool. The tool shape was not something that would fit into a hand and be supportable. The instrumentation required the operator to hold the tool by the outside edges and would not read correctly if a shift in hand position was attempted. 30N of force was a typical maximum applied to muscle bodies in the thigh area and therapists were able to "calibrate their hands" so that a consistent treatment could be given.

The ASTM tools were redesigned with an intent to ease the strain on the therapist hands and arms. Ergonomically correct tools were constructed so that the hand could easily support the tool and apply force without strain on the operator. Figure 2 shows a tool made from a composite plastic/ceramic mix that has no flat surfaces for strain gauges. An attempt was made to place stain gages on the new composite material but the force directions were uncertain so a new technique was investigated.

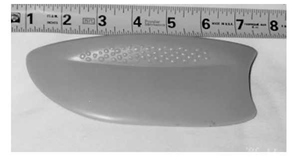

Figure 2

A thin tube was glued to the leading edge of the tool. This made the leading edge have a diameter of 1/8" with a rounded edge instead of the desirable 1/16" beveled edge. By replacing the leading edge with a piece of tubing, it was hoped that the problem of how to hold the tool could be eliminated because the primary force would be the force that would compress the tubing. The Motorola pressure sensor MPX5010D shown in figure 3 was placed inside the tool and connected to the tubing via drilled passageways. Pressure on the tube would cause pressure on the MPX5010. The 5010 is a pressure transducer on a chip. It has a diameter of about ½" and is as thick as two nickels. A self contained package, it contains a diaphragm with silicon strain elements and circuitry to amplify and transmit the calibrated signal. Three leads (power (5 V), common, and the output signal) are required. Holes on the top and bottom of the case allow exposure to pressure from the tubes and atmospheric pressure. The 5010 was glued over the cavity that received the tubes from the leading edge. The other side of the sensor was left open to atmosphere. A tool with the 5010 installed is shown in figure 4.

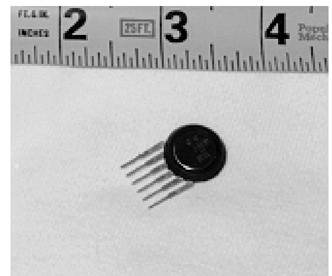

Figure 3

The MPX5010D has a full scale range of 0 to 10kPa that corresponds to 0.2V to 4.7V output. This was received by the A/D board configured to accept +/- 5V. The pressure tube was calibrated to force with a 1kg weight. The weight produced a 3V change which indicates a full scale range for the A/D board of 32.69N (1kg weight is 9.80665N force). Accuracy for the board is approximately +/- 11.97mN and the low end value of 0.2V for compensation by the chip is 0.653N.

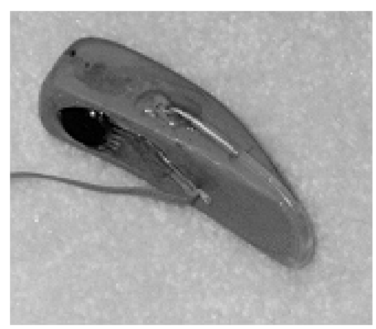

Figure 4

On the initial trials, sensitivity was a problem. The tubing was too hard and would not flex enough to register at the pressures applied. In the end, we used a fluid filled, semi-flexible plastic that would not crack if crushed. Air in the tube would compress and not transmit the pressure signal so the tubing was filled with water. This made sealing the system a problem but transmitted the pressures nicely. The output was single ended and preconditioned so the connection to the computer did not cause any of the noise and cable flex problems previously experienced. The connection to the A/D board and the software program was simplified. Only a single channel was needed and the software required to remove the "tool flex" signal was not needed. This system enabled the therapists to get a feel for the level of pressures being applied to patients and record the results as a spreadsheet file.

Problems did arise. The water or a chip problem affected the thermal compensation of the transducer. Heat from the operators hand and the rubbing of the tube on the patient tissue caused a drift that never stabilized at the desired gain settings. The system was tested for human use at 30N full scale but used in a rat study at 6N full scale. The thermal drift problem did not show itself until the range change made the baseline stability unacceptable. Repeated zeroing was required if a good reference zero pressure was desired. The software was configured so that pressing F8 on the computer would reset zero. This made the tool usable but not ideal. Because the transducer was epoxied inside the tool, replacing the transducer was never attempted. The fat (1/8") tubing replaced the beveled “sharp” edge that had been originally designed into the tool so greater force was required to provide the necessary pressure at depth. The tool material was originally selected for its ability to transmit the “gravel feel” of fibrous tissue. The soft leading edge lost some of the feel that the therapist needed to treat patients. An uninstrumented tool did a better job of transmitting the feel of obstructions under the skin.

Attempts to construct a system with a thicker liquid (soap / shampoo) were attempted. Gluing anything became a problem and since it was still a tube on the leading edge, the idea was scraped. A new configuration is being constructed using the original leading edge attached to a piston going back into the tool body. The transducer will stay inside, the piston will transmit the pressures, an O ring will seal the piston, and a set screw will seal the fill / calibration hole. This new design will allow the original sharp bevel to remain as the leading edge. Testing is needed to determine if the movement of the piston will cause the therapist to loose the “feel” of the fibrous tissue. The thermal stability problem may not show up since the liquid will not be directly exposed to thermal changes and will be easier to change if there is a problem. The transducer is technically capable of operating in the 6N full scale range.

The PID Laboratory

With the previous background history, the student is to analyze the level measurement requirement and see if the MPX5010 can be used as a water level sensor. Calculations of water weight will show the level measurement to be within range of the sensor. 10kPa pressure corresponds to 40.1865 inH2O. Sensors have been made available to the student both as individual chips and glued into a ½" PVC end cap. The PVC end cap will accept the 5010 chip body and allow the addition of a connection tube to the closed end so that a pressure tube can be connected from the water tank to the pressure sensor.

Conclusions

The addition of the case history to the sensor discussion and showing the students what has been built and why it was attempted, provides more of a learning experience than just using the chip as a level sensor. The concept carries more impact if they can see more in the chip than just another device. Pictures of the medical devices have been included in this paper so that it may be used as a case history. The MPX5010D cost is $26. Glue and plastic tubing complete the remainder of the device construction materials. Student construction of both the sensor and the water tank system is reasonable for a junior level course. Time constraints and the desire to cover more material suggest that major components be preassembled so that students can do system construction in a timely manner.

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