Force Sensing Forceps

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Abstract

There is currently limited available data about the strength of tissue when being grasped with a standard surgical forceps. If the pressure from the forceps on the tissue is too concentrated, it tends to result in micro-capillary damage to the tissue. This is not immediately visible, but it can be seen as scarring when observed later. Because this threshold is difficult to teach, new surgeons have to rely on a trial-and-error type method. The design team has developed a surgical forceps equipped with a pressure sensor that tells the surgeon how much pressure is being applied to the tissue. From calibration and testing, the relationship between output voltage of the instrument and force applied was found to be linear. The ratio between force and voltage was 1.264 N for every Volt. The forceps will be used now mainly to conduct research on the forces needed to cause damage to tissue, and could later be developed as a training tool for new surgeons.

Motivation/Current Designs

Motivation

- Develop "force sensing forceps"
- Nothing quantitatively known about forces applied to tissues
- Currently based on "trial and error"
- Used as a training tool

Current Designs

- Force sensing surgical instrument
- Piezomaterials
- Not specific to forceps
- Focused on degradation of medical alloys
- Specific to laparoscopy
- Different type of forceps

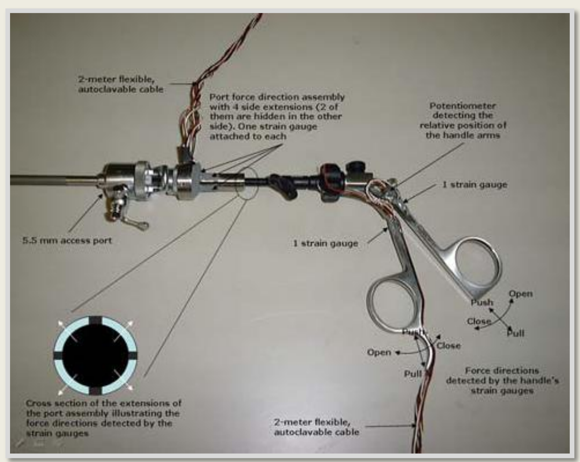


Fig. 1 - Laparoscopic forceps [1]

Design Criteria

Problem Statement

- Training and research device
- Interface with standard surgical forceps
- Measure forces
- Provide quantitative output
- Allow normal use of forceps

Design Criteria

- Production of 1 initial working prototype
- Allow for normal use of surgical forceps holding technique
- Lightweight
- Functional with standard size forceps
- Able to be sanitized
- Provide quantitative forces measurement
- Convenient output

Final Design

- Strain Gages
  - Give voltage output
  - Full-bridge circuit configuration
  - EA-06-125PC-350
  - $55 a piece
- Signal sent to a computer
  - USB bridge amplifier
  - Formatted for bridge sensor readout
  - 5V supply
- LabVIEW programing converts voltage signal to force (N)
  - Force = 1.0248 Voltage output
  - Corrects for +3.5 V offset
  - Can sense a range of 0 – 4N

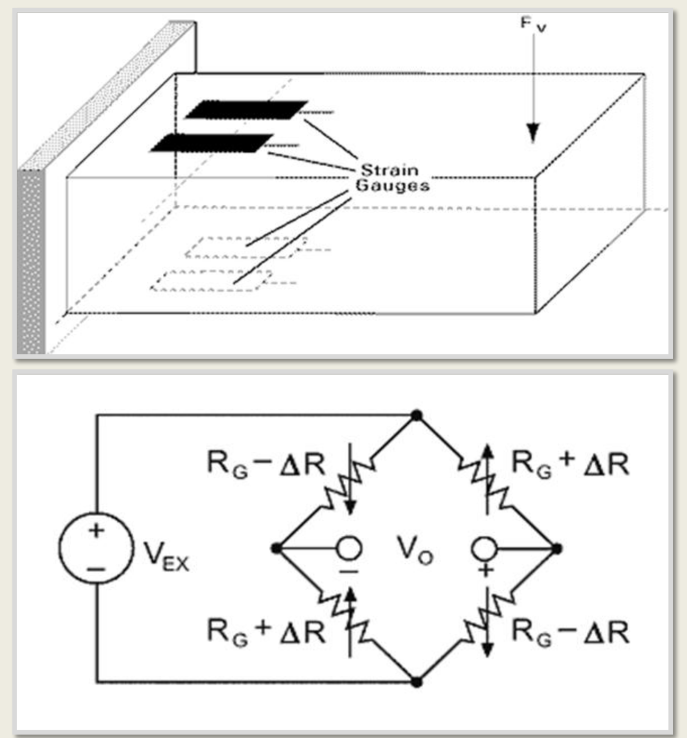


Fig. 2 –Strain gage set-up [5]

Testing

Calibration

- Multiple known weights hung from forceps
- Represents pure compressive force (no crosstalk forces should be present)
- Conclusions: Linear relationship has extremely high correlation value between force and measured voltage

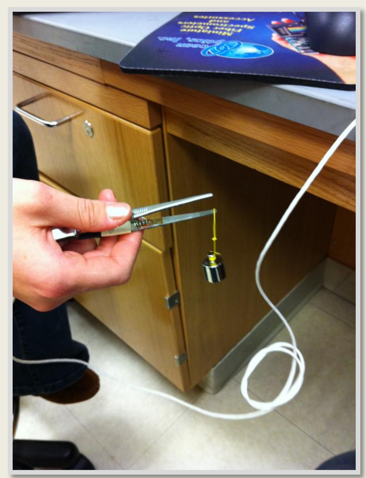
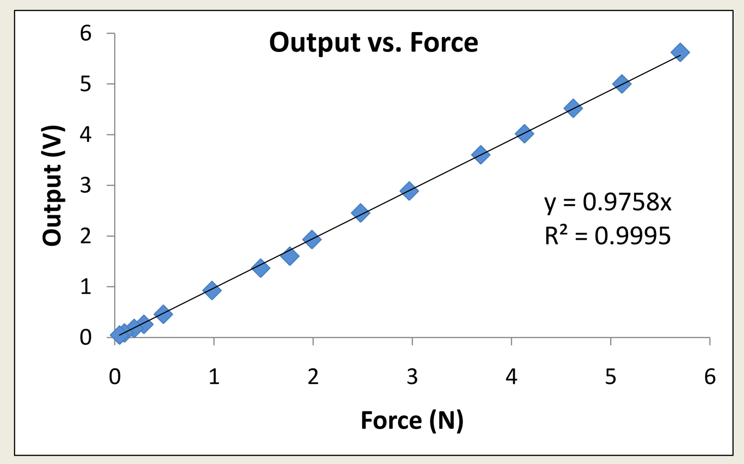
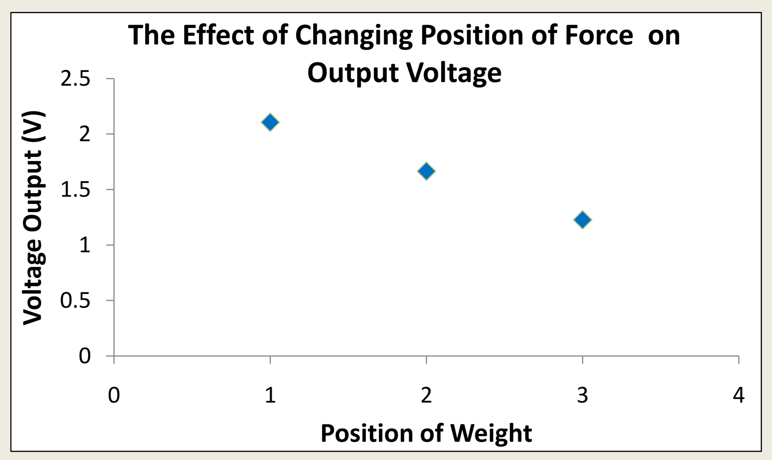


Fig. 3 – Calibrating the forceps



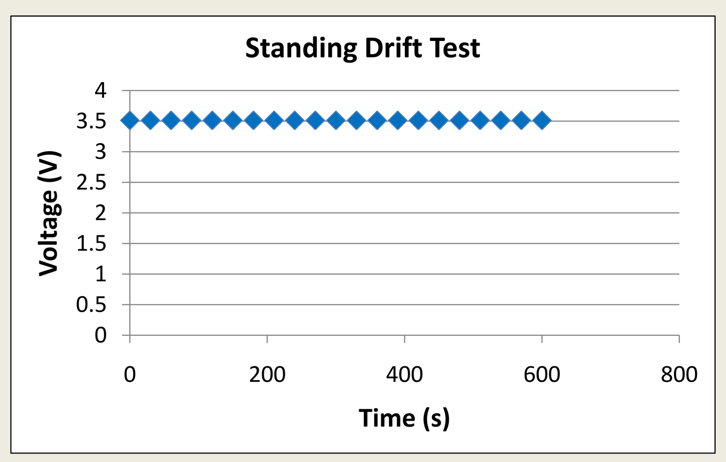
Effects of Holding Position

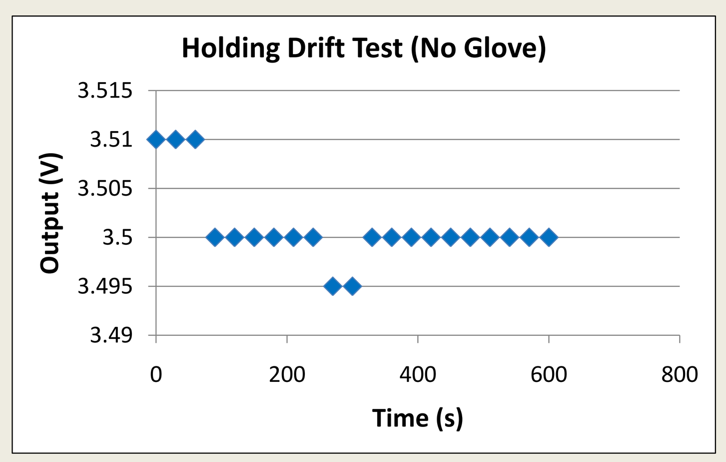


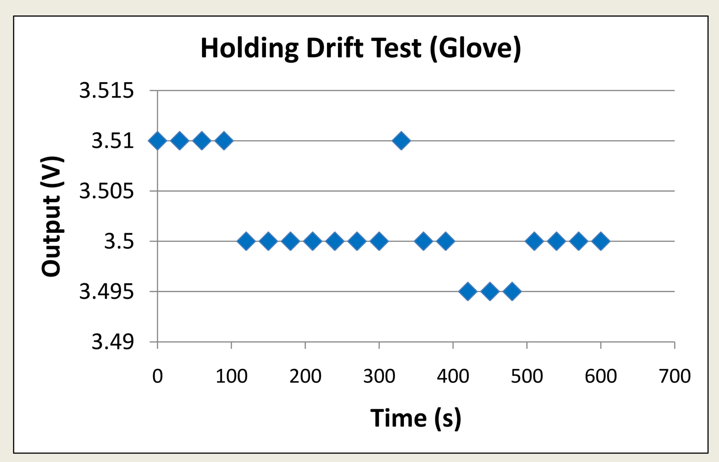
- Single weight hung from forceps - same as in calibration test
- Position of weight was varied
  - Tip of forceps
  - Middle of textured section
  - End of section furthest from tip
- Conclusions: measured voltage output varies fairly significantly from one position to the next
  - Non problematic – tip is where surgeon will generally be grasping tissue

Drift Tests

- Zero force voltage output recorded for 5 minutes
- Conclusions: Drift is not significant to detract from validity of force measurements



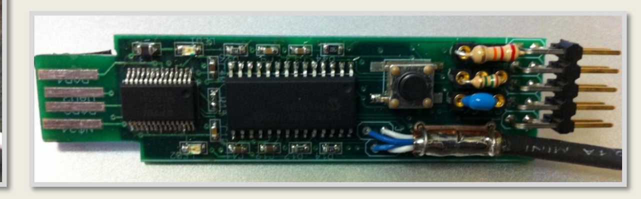


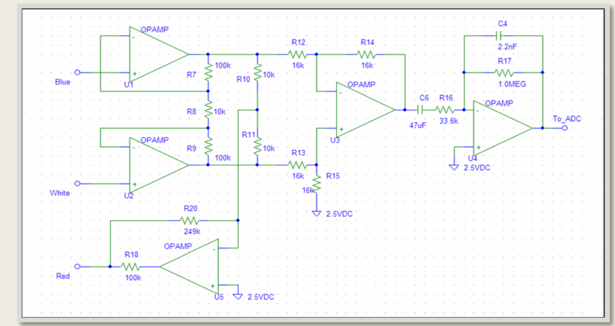


Parts List

- Standard forceps
- Wheatstone bridge strain gage set-up
- USB amplifying circuit device
- Computer with LabVIEW

Fig. 4-8 – Final forceps, USB connection and circuitry set up for the USB bridge amplifier [7]





Future Work

- Include mechanism which prevents excessive force
- Aesthetically pleasing
  - Current design looks "rough"
- Wireless
  - Avoid hindering surgeon's movements
  - Allow for greater range of movement
- Digital display
  - Without requirement to have computer nearby
- Audio signal
  - Differing tones for differing force ranges
- Axial and torsional measurements

References

[1]G. Hanna, T. Drew, G. Arnold, M. Fakhry, & A. Cuschieri. (n.d.). Development of force measurement system for clinical use in minimal access surgery. Surg Enosc (2008) 22:467-471.[2] Jacq, C., Maeder, T., & Ryser, P. (n.d.). Load sensing surgical instruments.

[3] Trejos, Javaraman, Patel, Naish, & Schlachta. (n.d.). Force sensing in natural orifice transluminal endoscopic surgery.

[4] Esteve, D., Giraud, A., & Gue, A. M. (2004). 2D Silicon Macro-Force Sensor for a Tele-operated Surgical Instrument. *Computer Society*.

[5] OMEGA ENGINEERING, Inc. (2010). Retrieved 10 11, 2010, from Omega: http://www.omega.com/

[6] (n.d.). Retrieved from http://www.hbm.com/en/menu/applications/industrial-process-control/technical-articles/ipc-technical-articles-detail-view/datum/2009/03/12/strain-gages-or-piezoelectric-sensors-a-comparison/

[7] Balgemann, T., Klomberg, P., & Nimunkar, A. (2010, April). Electrocardiogram, BME 310 Lab 11. WU: UW – Madison.

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