International Journal of Science and Research (IJSR)
ISSN: 2319-7064
SJIF (2022): 7.942

Ergonomic Foot Switch Design for Electric Biomedical Devices (Bipolar Cautery, Medical Electric Drills and Saw)

Nihal Handigol[1], Mrunal Ketkar[2]

[1]Resident, Department of General Surgery, Bharati Vidyapeeth Deemed University Medical College, Pune
Email: *nihal.handigol[at]gmail.com*

[2]Professor, Department of General Surgery, Bharati Vidyapeeth Deemed University Medical College, Pune
Email: *mrunalnitin[at]gmail.com*

Abstract: ***Surgeons around the world routinely use medical instruments which require control of switching on and off or adjustment of speed of the instrument using a separate sensor, usually in the form of a footswitch. These foot - switch sensors, although reliable, are bulky, experience loss of contact during use, restrict movement of the surgeon around the operating table and cause discomfort on long continuous usage. A novel device was designed to overcome these shortcomings utilizing a new force sensor and piezoelectric sensor. The force sensor and piezoelectric sensors are coupled and placed at the base of a sleeve designed to snugly fit over the great toe of the surgeon. The force sensor measures the amount of force exerted by the great toe and the numerical value is processed in Arduino Nano which forwards the value to the existing electric system. The piezoelectric sensor acts as a safety check which activates or deactivates the device by double tapping of the toe, thus preventing accidental activation of the device. The device decreases the fatigue associated with long usage of the device, eliminates the bulk factor and eases movement of the surgeon around the OT table.***

Keywords: foot switch, ergonomic, biomedical sensor, force sensor, electric cautery

1. Introduction

Electrical biomedical instruments have become an indispensable part of modern day surgeries ranging from electric bipolar cautery, electric drills and saws, to complex modern instruments like CUSA. These instruments have an active component hand - held by the surgeon and an activation/ deactivation or speed control sensor in the form of a foot switch. Foot switches are time tested by surgeons and bio - medical manufacturing companies across the globe to be reliable and robust. These switches however, have multiple shortcomings like movement restriction of the surgeon around the OT table, loss of contact during use due to uncomfortable positioning of the switch, muscle fatigue over the course of the surgery, pressing of wrong switch and accidental activation of the device. As old is the problem associated with the device, so is the quest to overcome these shortcomings. Many such attempts have been made like Shimizu S et al [1]., where a hanging switch is described. The current device is specifically designed to overcome these shortcomings and retain the design components of the traditional foot switch which makes it robust and reliable. The restriction of movement can be associated with the bulky design of the foot - switch requiring an assistant or circulating nurse in the operating room to change the position of the pedal as required by the surgeon. The muscle fatigue can be associated with the requirement of use of the ankle joint while using the switch and the need to hover the foot over the foot switch to avoid accidentally activating it. These shortcomings of the foot - switch not only cause physical discomfort to the surgeon, but may also result in loss of precious time and focus on the procedure and disruption of flow during the surgery to make minor adjustments. The novel toe switch has a slim profile which can be easily fit under the great toe using a sleeve as per the surgeon's requirement, operates on a low voltage system making any potential intrinsic malfunction non - hazardous to the patient and the surgeon, cheap to manufacture as the parts are widely available in the market, has a safety check in the form of a piezoelectric sensor preventing accidental activation of the system, accurate speed and on/off control using calibrated and sensitive force sensor. The sensor can be calibrated to determine the threshold value as per individual surgeon's requirement beyond which the sensor performs its determined functions.

2. Device

The novel device is designed keeping ergonomics and superior functionality as the primary goals. The device is designed using the following components:

1) Force sensor (a transducer that converts an input mechanical load, weight, tension, compression or pressure into an electrical output signal)
2) Piezoelectric sensor
3) Stretchable fabric sleeve
4) Arduino nano

The electrical system of the pressure sensor is based on the principle that the pressure applied over the sensor is measured in an analogue fashion; the data collected is converted to electronic data which inturn is used to control the cautery machine.

The force sensor is designed using a material (Velostat) which has the property of changing the electric resistance with change in shape of the material. The force sensitive material is sandwiched between two conductive material plates (copper plate) in addition to a peizoelectric sensor to form the force sensing unit (FSU) [Diagram 1]. Multiple layers of velostat can be used to improve the sensitivity and the range of pressure sensing. The copper plates are connected to the cathode and anode part of the electrical circuit which in turn is connected to Arduino nano.

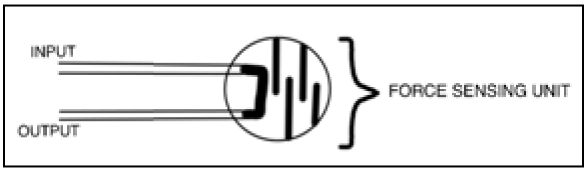

Diagram 1

The Peizoelectric sensor recognises when the surface of the sensor is tapped. The piezoelectric crystals present in the sensors produce a small amount of current when force is applied over its surface. This property of the sensor is used to recognize when 2 consecutive taps are made over the sensor surface. The Aurdino nano recognises this consecutive taps made within short period of time and changes the status of the device to the opposite of the current status i.e. if the device is 'ON' it is switched off after consecutive taps and vice - versa.

The piezoelectric sensor, partition foam and force sensor are stacked upon each other in that order and the entire unit is fixed inside the stretchable fabric to be worn as a sleeve over the great toe of the surgeon where the sensor stack comes directly under the pulp of the great toe. This sleeve has the funtion of not only keeping the FSU in place but also to provide a channel for passage of electrical connecting wires [Diagram 2] The entire system is connected to Arduino nano which processes the information received from the sensors and delivers an electrical signal to the controller electronic box.

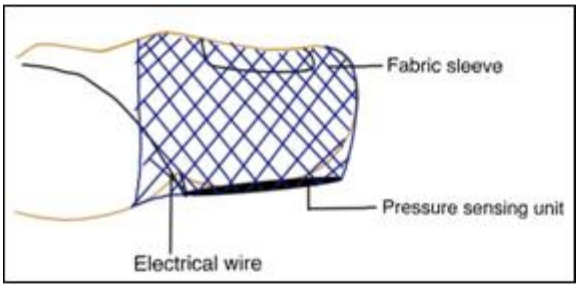

Diagram 2

Software

The device is designed to be simple for routine use with simple user interface. The ankle belt contains a screen with buttons to control the device. The minimal threshold pressure, only beyond which the device will be triggered can be selected to prevent accidental activation even in 'on' mode. The software also recognizes any deviation from normal function of the entire system via arduino nano to stop functioning or acting like a kill switch, adding an additional layer of safety.

3. Discussion

In a study conducted by Van Veelen MA et al., it was found that upto 91% users occasional lost contact with the foot switch, out of which 56% reported it as very annoying, 75% occasionally hit the wrong switch and 53% experienced physical discomfort.93% of users wanted a different method to use electric biomedical devices [2]. Assessment of the problem that surgeons operating in the standing position encountered with foot switches was done in Bharati Hospital and research centre, Pune with a 10 point questionnaire and 20 surgeons, in which it was found that almost all surgeons occasionally lost contact with the foot switch, and reported obstructed foot movement, activation of wrong switch and physical discomfort in the legs and/or feet. These problems, though seemingly with no bearing or consequence on the surgery when seen in a broader sense, were described as irritating, focus deviating and exhausting by the operating surgeons. This device was designed keeping in mind the shortcomings of its precursors and also keeping the good qualities of the precursors intact. The device has following features:

1) Ergonomic design: The device is designed to have a very small and comfortable to use form factor. The FSU is a thin component with thickness limited under 0.3mm. It snugly fits over the great toe of the controller without causing movement.
2) Fabric sleeve: The sleeve can be designed as per the requirements of the user with a variety of fabric materials. These sleeves are porous, hence keeping the toe well ventilated
3) Ankle belt: This is a small belt which can be worn around the ankle, housing the arduino and electronics
4) Light weight: The entire device including the PSU and the ankle belt weighs less than 100 gram making it comfortable to use.
5) Safety: The device has a separate peizoelectric sensor to prevent accidental activation of device and the running voltage in the device which is in contact with the body or in close proximity is 3.5V, which is harmless even in case of any electrical malfunction.
6) Modular system: The system is modular and can be seamlessly connected with any existing electrical cautery unit making its integration with the existing system both easy and affordable.

4. Conclusion

The device proposed in this paper stands superior to its predecessors in all parameters including ergonomics, price, comfort of use and customizability.

5. Future Research Prospects

1) The switch can be designed to be made wireless without any lag in usage
2) A comparative study between the proposed device and existing devices.

References

[1] Shimizu S, Kondo K, Yamazaki T, Koizumi H, Miyazaki T, Osawa S, Sagiuchi T, Nakayama K, Yamamoto I, Fujii K. Hanging foot switch for bipolar forceps: a device for surgeons operating in the standing

position: technical note. Neurol Med Chir (Tokyo).2013; 53 (1): 53 - 5. doi: 10.2176/nmc.53.53. PMID: 23358172.

[2] Van Veelen MA, Snijders CJ, Van Leeuwen E, Goossens RH, Kazemier G. Improvement of foot pedals used during surgery based on new ergonomic guidelines. Surgical Endoscopy And Other Interventional Techniques.2003 Jul; 17 (7): 1086 - 91.