

An Endoscopic Grasper Tool with a Supported Piezoelectric Tactile Sensor

Javad Dargahi¹ and Siamak Najarian² (Corresponding Author)

¹Assistant Professor of Mechanical and Industrial Eng., Concordia University, CONCAVE Research Centre, CR-200, Dept. of Mechanical and Industrial Eng., 1445 de Maisonneuve Blvd. West, Montreal, Quebec, Canada H3G 1M8. Telephone Number: (001-514)-848-7967. Fax Number: (001-514)-848-8635. Email Address: jdargahi@alcor.concordia.ca

²Siamak Najarian, Associate Professor of Biomedical Eng., Faculty of Biomedical Eng., Biomechanics Dept., Amirkabir University of Technology, Tehran, Iran.
Present Affiliation and Address: Visiting Professor at Concordia University, CONCAVE Research Centre, CR-200, Concordia University, 1445 de Maisonneuve Blvd. West, Montreal, Quebec, Canada H3G 1M8. Telephone Number: (+1-514)-848-7967. Fax Number: (+1-514)-848-8635. Email Address: snajaria@me.concordia.ca

Abstract. In this study, we describe the design of a tactile sensor based on polyvinylidene fluoride (PVDF). The sensor exhibits high force sensitivity and linearity. This sensor is integrated with an endoscopic grasper tool and can be used in minimally invasive surgeries. It consists of three distinct layers. A rigid micro-machined tooth-like silicon constitutes the top layer of the grasper, and the Plexiglas constitutes the bottom layer and served as a substrate. The middle layer is a patterned PVDF film, which is sandwiched between the Plexiglas and the silicon. In order to predict the behavior of the tactile sensor, finite element analysis is employed. There is good correspondence between the theoretical results and the experimental findings.

1 Introduction

One of the major technical features of a well-designed tactile sensor is to be capable of measuring the magnitude and location of the exerted force between the sensor and tissue [1,2]. Determination of the force and its position on the grasper is the fundamental requirement for handling object/tissue [3]. Measuring the applied forces exerted by the endoscopic grasper can lead to more suitable ways of safe tissue handling. Several investigators have attempted the challenge of designing endoscopic tactile sensors, however, many have reported the problem of complexity and crosstalk [4]. In some designs, there is a limitation in the upper values of forces that can be measured, i.e., forces in the order of a few grams, and additionally, measuring the pressure distribution is highly restricted. The potential applications of using tactile sensors in endoscopic surgeries are vastly in the area of controlled manipulations tasks [5-9]. These applications include, for instance, grasping of internal organs, gentle load transferring during lifting, removing tissues (e.g., gall bladder in laparoscopic surgery and loose bodies in knee arthroscopy), and suturing tissues [10-12]. In the present study, both experimental and theoretical approaches have been adopted in order to analyze the performance of a rigid tooth-like endoscopic grasper into which PVDF sensing elements have been incorporated.

2 Materials and Methods

A photograph of the designed endoscopic grasper tool is shown in Figure 1. This mechanism consists of three main parts, i.e., endoscopic cylindrical tube, grasper jaws, and tactile sensors.

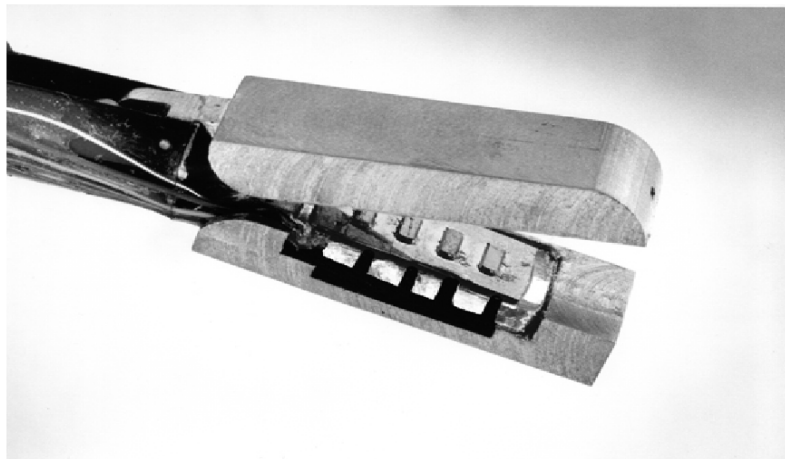


Figure 1: Photograph of the designed endoscopic grasper.

The detailed drawing of the tactile sensor structure is presented in Figure 2. The sensor part of the grasper can be divided into three different layers. The layer in contact with the grasper jaws (the bottom layer) is a flat-shaped substrate made of Plexiglas, while the layer, which can be in direct contact with the tissue (the top layer), is made of micromachined silicon and has a rigid tooth-like configuration. A 25-micron-thick patterned PVDF film is placed between the top and the bottom layers. While in the bottom there is a single common electrode, at the top, there are four strips of aluminum electrodes. These electrodes are positioned directly below the teeth. With this arrangement, the areas of intersection between the upper and lower electrodes are active.

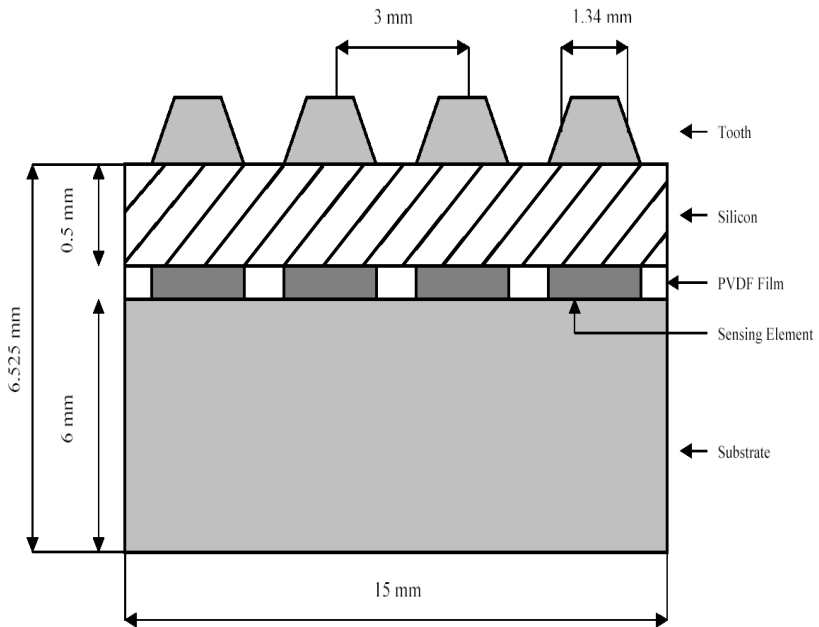


Figure 2: Detailed schematic drawing of the tactile sensor structure.

Various forces were applied using a 2-mm-diameter circular probe. The probe was driven by a vibration unit (Ling dynamic model 201), which was, in turn, driven by a sinusoidal signal of 15 Hz. A charge amplifier (D.J. Birchall model 04) was used to amplify the charge generated by the four piezosensitive regions. An oscilloscope was used to measure the output signals, and a force transducer (Bruel & Kjaer model 820) inserted between the probe and vibration unit measured the applied force magnitude. Finite element analysis (ANSYS package, version 7.0) was used to investigate the shear stress distribution and the deformation of the tactile sensor under various types of loading. Figure 3 shows the theoretical results for the case in which a single concentrated load of 1 N on the 2nd tooth of the designed system.

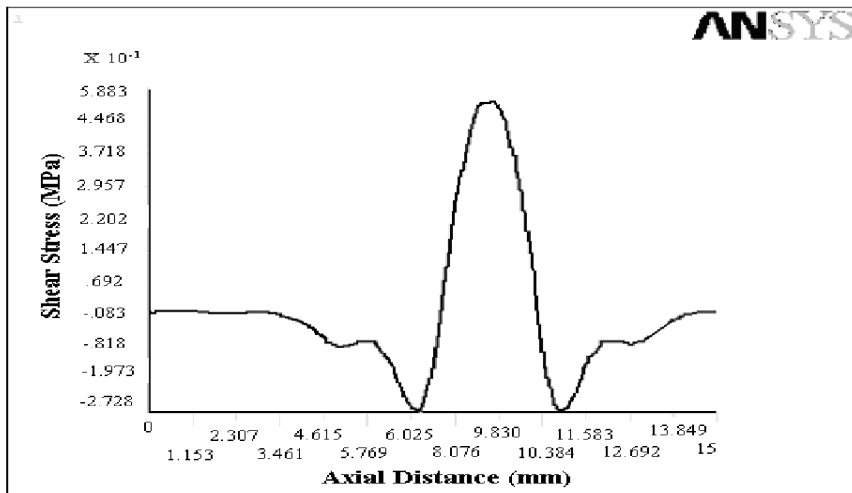


Figure 3: Finite element analysis results showing the variation of shear stress.

3 Discussion and Conclusions

In this study, we examined both the experimental and theoretical aspects of the tactile sensor unit incorporated into an endoscopic grasper. In various experimental runs, a peak force of 1 N was applied to the center of each tooth-like structure. The linearity between the sensor output voltage and the loading on the teeth was also demonstrated experimentally. It was shown that because of the design of the tactile sensing system, it is quite possible to sense the force on the entire surface of the sensor and not just the tooth-like parts. This is a novel effect because in similar systems, which use sensor arrays, the region between the sensing elements essentially has no sensitivity and is inactive. In the comparison made between the experimental data and the results obtained from the finite element analysis of the system, it was found that there is a reasonable correspondence between these two. The difference varied in the range of 4 to 9 percent.

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