Design and Development of Masticatory Robot

1. Binsu Babu 2. Dr. Priam V Pillai

1. Mechanical Engg. Dept., Pillai College of Engineering, New Panvel, India
2. Mechanical Engg. Dept., Pillai College of Engineering, New Panvel, India

e-mail address: binsu18@student.mes.ac.in

Abstract. Design and development of a masticatory robot to measure the forces acting on teeth during mastication. Piezoelectric film bed will be used to measure the forces acting on tooth during mastication. On top of the piezoelectric film bed the lower jaw tooth will be mounted. The lower jaw will be having the upward and downward motion whereas the teeth on the upper jaw will remain fixed. Load cells will be placed on the upper jaw. Load cells would help in recording the forces acting on teeth during mastication of food. During mastication of food, due to chewing of food, the piezoelectric film bed will be deformed which will produce an electric charge that can be mathematically modelled into force by using Labview software.

1. Introduction

Human tooth is subjected to different kinds of forces throughout mastication. In dental analysis, these forces have been recorded as a variable to assess the effectuality of varied dental procedures like prostheses, orthodontic treatment, to review the results of deformities and pathologies on the masticatory system like malocclusion, temporomandibular disorders [1]. Correct determination of forces acting on teeth would help in occlusal treatments like occlusal adjustment, restorative treatment, orthodontics and orthognathic surgery [2]. It has been observed that some people who have dental implants have been reported to be failing within months or a few years after the dental implant has been done. Measurement of forces and moments acting on the implants during chewing of different textures of food will help in reducing the failure rate of dental implants. It will also help in selection of proper materials for dental implants.

In piezoelectric films (PEF) the charge produced varies linearly with load and is independent of loading frequency, due to this PEF are used as force measurement devices. Recently, manufacturing of piezoelectric material in the form of thin foil sheets have been possible [1]. Using these foils as the active element, an occlusal force transducer can be fabricated in less than 2 mm thickness. It helps to measure occlusal forces with lesser jaw separation than in bite force devices using strain gauge transducers. These foils can be cut into any desired shape and size [1]. Devices using piezoelectric transducers have been used for measuring bite force in several studies [1]. In 1977 R.M.Mansour design and developed piezoelectric transducers (quartz crystals, 1.5 mm thick) for in vivo measurement of biting forces in humans [3]. Osteogenic response is accelerated by inducement of piezoelectric charges by the application of pulses of force to teeth. Klempler et al. in 1979 designed and developed pulsating force induced transducer to determine orthodontic tooth movement of maxillary molars. The tooth movement was converted into electrical signals with the help of a strain...
gauge connected to the sensor [4]. In 1991 Douglas et al. developed and configured a silver inked piezoelectric film transducer for dental occlusal analysis [5]. Occlusion Analysis using piezoelectric film transducer was conducted in 2004 by Richter et al. An invivo occlusion analysis was carried out by placing piezoelectric force transducer foils of 33μm thick between pairs of teeth in centric occlusion and patients were instructed to bite as hard as possible for 1 second [6]. On the basis of biomechanical conditions T. Kawaguchi et al. in 2007 developed a piezoelectric force transducer which was inserted into a tooth crown for invivo analysis and measurement of load applied on the teeth[7].

Mastication process involves breakdown of foods due to chewing. To analyze the food dynamics and assess the masticatory efficiency the entire mastication process must be made continuously. Mathematical models have been developed based on the biomechanics of the masticatory system to simulate the human chewing process. The human chewing process has been simulated by developing mathematical models. Development of mathematical models for assessing complex masticatory efficiency is very hard. Development of a masticatory robot that can reproduce the actual mastication process and also help in collecting the detailed information pertaining to the forces applied during mastication and dynamics of food breakdown is thus essential. Temporalis, masseter and pterygoid are the three major muscles responsible for mastication. Keiser et al in 2005 developed a kinematic model of the masticatory robot. The major muscles of mastication (temporalis, masseter and pterygoid) are represented as linear actuators. The upper and lower jaw used in the model is made entirely of aluminum, and the model is maintained at equilibrium using spring-loaded cylindrical joints. Two types of jaw movements such as clenching and grinding movements were performed by the robotic model [8]. In February 2008 Xu et al. designed and developed a linear actuator which represented the temporalis muscle. But as the mechanism of the linear actuator was quite bulky it could not be used as a a linear actuator for the other two muscles of mastication. To overcome this issue in May 2008 Xu et al. developed a compact 6-RSS parallel mechanism mastication robot.[9-10]. In 2018 S.-J. et al. designed and developed a masticatory robot that could directly measure the interaction forces between each tooth and food[11]. The aim of the present study is to use piezoelectric film for measuring the forces and develop an cost effective masticatory robot.

2. Proposed Design

Development of masticatory robot in PCE Panvel research lab capable of measuring forces and moments acting on teeth during mastication of food. A CAD model of the masticatory robot will help in defining proper mechanism to the robot. Once the CAD model is ready the next plan is to develop a prototype of the masticatory robot to help in analyzing any difficulties that may lie during actual development of the masticatory robot. 3D printer would be used for manufacturing the majority of components of the prototype robot. The control system and motor control will be designed on virtual instrument software like LabVIEW. Once the prototype design is fully functional, manufacturing of the actual masticatory robot will be done. The figure below shows the proposed design of the mastication robot.

The teeth on the upper jaw and lower jaw are modelled as cylinders with diameter and height equivalent to the molar teeth. There are a total of six teeth on the upper and lower jaw. The lower jaw is fastened on a sliding base which is coupled with the stepper motor to allow the upward and downward motion of the lower jaw. A piezoelectric film bed is mounted beneath the lower jaw. The upper jaw remains fixed and is connected with load cells. All the different components like force sensors, motors, data acquisition system etc. will be interfaced in LabView to collect various data and the collected data will be calibrated for the desired output.
Figure 1: Proposed design of the masticatory robot.

3. References

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