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Development of Robotic Finger Using 3-Axis Load Cell for Violin Playing Robot

Hyeonjun Park [1], Wonse Jo[1], Kyeongmin Choi[1],Hwonjae Jung[1], Jargalbaatar Yura[1], Soongeul Lee [2], Bum-Joo Lee[3], and Dong-Han Kim[1],

[1] Intelligent Robotics Lab, Deptartment of Electronic, Radio Wave engineering
Kyung Hee University
Seocheon-dong 1, Giheung-gu, Yongin-si, Gyeonggi-do, Republic of Korea
{koreaphj, wonsu0513, sm20s, hwonjae, jargalbaatar, donghani}@khu.ac.kr
Intelligent Robotics and Mechatronics system LAB,
Deptartment of Mechanical engineering, Kyung Hee University
Seocheon-dong 1, Giheung-gu, Yongin-si, Gyeonggi-do, Republic of Korea
sglee@khu.ac.kr
[3] Department of Electrical Engineering, Myongji University
Nam-dong, Cheoin-gu, Yongin-si, Gyeonggi-do, Republic of Korea
bjlee@mju.ac.kr

Abstract. This paper describes the mechanism and experimental results of anthropomorphic robotic finger, which is developed to facilitate the performance of violin playing robot. In order to present the feasibility of accurate control, a 3-axis integrated load cell is developed and mounted at the end of finger.

Keywords: Violin robot, Robotic Finger, Force Sensor, 3 axis load cell, Robotics

1 Introduction

Beyond the industry and military field, various service robots have been rapidly developed in cultural, home, and medical field. In order for service robots to be operated with external object, motor skills like human hand are required. Thus, there has been a lot of process in research related to an anthropomorphic robot hand that mimics human hand [1-3]. Based on the current research of violin playing robot, this paper describes the development of a robotic finger that helps to play the violin correctly by pressing the violin strings. A 3-axis integrated load cell is constructed to sense and control the fingertip forces.

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2 Proposed Robotic Hand

When violinist plays the violin, the exact sound is generated by not only locating the bow on the correct string, but also pressing the string with the correct amount of force. Fig. 1 shows the design of proposed robotic hand. To determine the amount of applied force on the string like humans, the 3-axis load cell with strain gauge is designed and integrated at the finger tip.

Fig. 1. CAD design of proposed robotic hand

Table 1. Specification of proposed robotic hand

	Specification	Note
Total DOF	12 DOF	except thumb
Total weight	500g	45g/finger
Num. of joint	16	1 dependent joint in each finger
Actuator	DC motor with reduction gear	V_{in} = 12V
Mechanism	Wire driven mechanism	

2.1 Design of 3-Axis Load Cell with Strain Gauge

In order to measure the accurate force at that time when it is applied and then control the finger, the fingertip part is designed as an integrated 3-axis load cell sensor by attaching strain gauge as shown in Fig. 2. When an external force is applied to the proposed integrated 3-axis load cell, the binocular structure of load cell gets modified and changes the value of strain gauge. Since the change of magnitude in the electrical signal of strain gauge is small at this time, two strain gauges are configured as a half-bridge circuit and then the output value gets amplified using an amplifier.

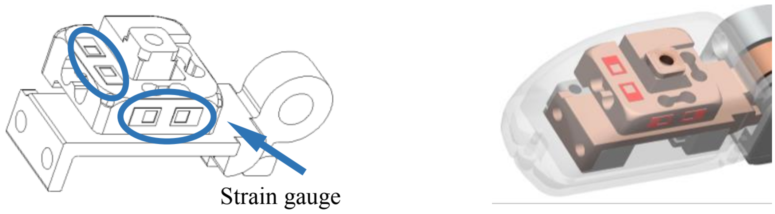
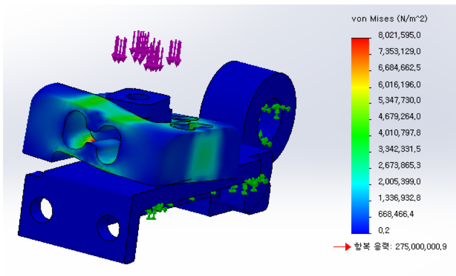
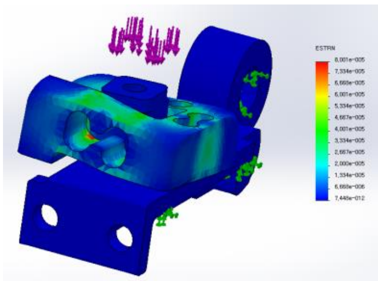


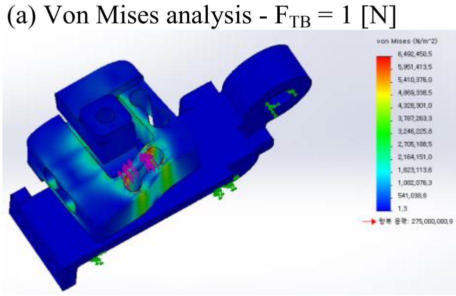
Fig. 2. CAD design of 3-axis load cell with strain gauges



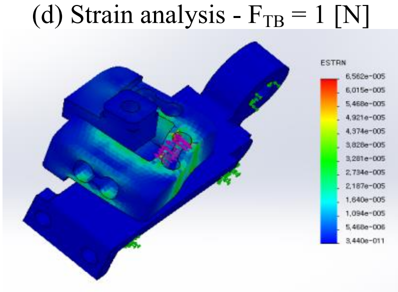
(a) Von Mises analysis - F_{TB} = 1 [N]



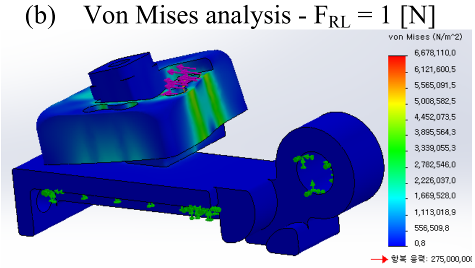
(d) Strain analysis - F_{TB} = 1 [N]



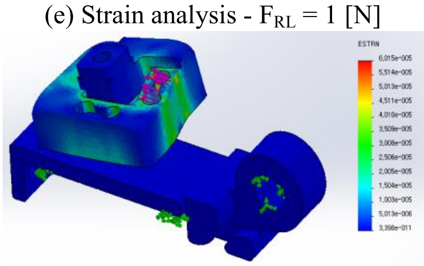
(b) Von Mises analysis - F_{RL} = 1 [N]



(e) Strain analysis - F_{RL} = 1 [N]



(c) Von Mises analysis - F_{BF} = 1 [N]



(f) Strain analysis - F_{BF} = 1 [N]

Fig. 3. Von Mises stress and strain analysis results of 3-axis load cell. Each result is from 'Case F_{TB}', 'Case F_{RL}', and 'Case F_{BF}'.

The integrated 3-axis load cell should be deformed by the load adequately to measure the force properly. Von Mises stress analysis and strain simulations were performed to verify the characteristic of load cell. Material was set as aluminum 6061-T6, which is identical to the actual machined load cell parts. The simulations were performed by applying the force of 1 N in three directions: top-bottom (F_{TB}), right-left (F_{RL}), and back-front ($_{FBF}$) as shown in Fig. 3.

Since the materials were identical, the yield stress was equal to 275,000 kN/m^2 in all three simulation cases. The maximum stress of strain gauge was 5,008.58 kN/m^2 for F_{TB}, 4,869.34 kN/m^2 for F_{RL}, and 6,016.20 kN/m2 for F_{BF}.

The strain varied up to 80.00 nm for F_{TB}, 65.62 nm for F_{RL}, and 60.15 nm for F_{BF} accordingly. Thus, it could be concluded that the designed load cell is appropriate to measure the applied force when the strain gauge is attached.

3 Result

This paper proposed the robotic finger by constructing a 3-axis integrated load cell at the end of finger. Based on the amplified strain gauge value, it was able to apply an appropriate force on the string when playing the violin. Thus, it is expected that learning the motion of pressing the strings from human becomes possible. Developing more precise controller using the current 3-axis integrated load cell value and motor current value are left as a further work.

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