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STUDY ON A HIGH PERFORMANCE INSOLE WITH HUMAN COMPATIBILITY

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ABSTRACT

In recent years, accidents of bone fracture with elderly people increase because of tendency to fall by a little step in a house. As one of this cause, it is considered that a center of gravity position with foot parts of elderly people is changed. Therefore, in order to solve this problem, we propose a new type of insole with high performance by making use of sponge-core-soft rubber actuator (SCSRA). In this study, we apply the actuator to an insole in order to support walking motion. That is to say, a new type of insole to distinguish the foot motion (Pitch or Roll motion) is proposed. To clear the performance of the insole, we develop a test device that is constructed with rotary actuators and a cylinder. In this paper, the mechanism of the proposed insole is explained and basic performances of the proposed mechanism are clarified through some experimental results.

KEY WORDS

Insole, Soft rubber, Stiffness, Stable walk

NOMENCLATURE

F : External force estimation value
P : Pressure
P_0 : Initial pressure
T_i $(i=x,y,z)$: Torque
θ : Pitch angle
φ: Roll angle

INTRODUCTION

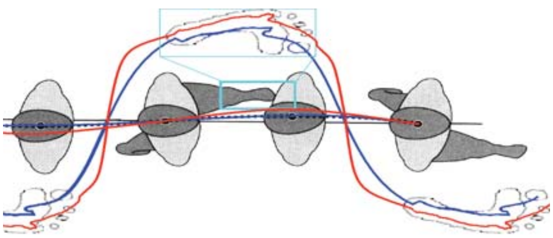
In Japan, the number of elderly people increases. On the other side, the number of young people decreases. As the result, it is reported that elderly people have to care another elderly person. In order to solve this problem, many kinds of support machines have been developed[1]-[4]. However, with respect to an elderly person who is not physically handicapped, the bone fracture in tendency to fall sometimes becomes a big issue. For example, when the elderly people fail in a little step, some of them sometimes have trouble of bone fracture. Especially, the number of aged person who comes to keep bed increases by reason of the bone fracture of thighbone cervix in the tendency to fall[5]-[8].

With respect to this problem, it is reported that the main cause of tendency to fall is change of gravity position with each foot. That is to say, when elderly people walk on the road, the center of gravity position moves to edge side of the sole as shown in Figure 1. This is because

that the angle between the innominate bone and the thighbone is decreased by the muscle force depression of lower extremities. As the result, the elderly people are easy to stumble over.
Therefore, in order to solve this problem, we propose a new type of insole. The insole is constructed with compound rubber elements that a sponge rubber is covered with silicon rubber[9]-[15]. With respect to the element, since the sponge is coated with silicon rubber, air can be charged into the sponge chamber. As the results, it is possible to control the stiffness of the actuator by controlling pressure in the sponge chamber. Therefore, when some actuators are arranged in parallel, the actuators can estimate the distribution of external force that acts on the actuators. Thus, by making use of control of inner pressure of each actuator, the actuator can adjust torque that acts on the insole.
In this paper, we explain about the structure of insole that is constructed with the elements. Further, a test device to clear the effectiveness of the proposed insole is explained. Moreover, by using the test device an adaptive shape of the insole to distinguish between a roll motion and a pitch motion of the foot part is cleared. From these experimental results, basic characteristics of the proposed insole are clarified.

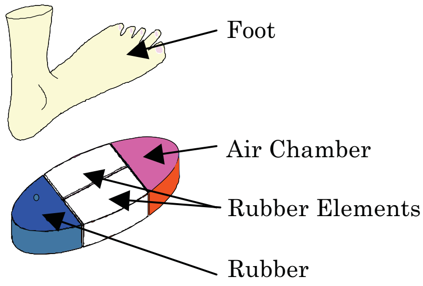
HIGH PERFORMANCE SHOES

The structure of proposed insole is shown in Figure 2. The insole is constructed with compound rubber elements, a rubber compressor and a tank chamber. When a subject walks on a road with shoes that has the proposed insole, air is compressed by the deformation of rubber compressor according to the motion of heels. Further, the compressed air is charged into the air chamber of the tiptoe part in the insole. Since pressure in the rubber element is measured by a small size pressure sensor, the stiffness of each rubber element can be controlled by pressure in the air chamber. With respect to the control circuit of the insole, a test circuit as shown in Figure 3 is developed. The main MPU is ATmega64 and each valve is controlled by the MPU.

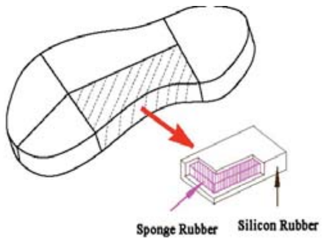


Red Line: Elderly person
Blue Line: Person who is not physically handicapped

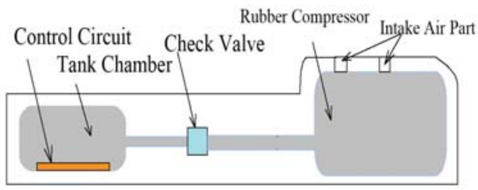
Figure 1 Trajectory of center of gravity



(a) Appearance of the Proposed Insole



(b) Element of Rubber Actuator



(c)Cross Section of the Proposed Insole

Figure 2 Structure of High Performance Insoles

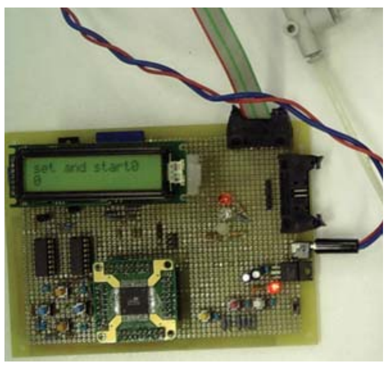
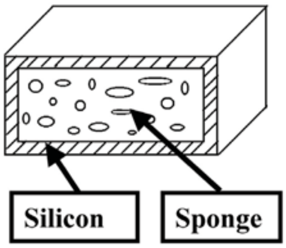


Figure 3 Sample of the Control Device



(a)One Layer Structure

(b-1) Initial State

(b-2)Pressurized State

Figure 4 Schematic View of Pneumatic Rubber Element

PNEUMATIC RUBBER ELEMENT

In order to develop a new type of insole, we consider a pneumatic rubber element. The structure of the element is shown in Figure 4(a). The actuator is made of two materials. One is silicon rubber and the other is sponge rubber. The sponge is coated with silicon rubber, and air can be charged into the sponge chamber. As the results, it is possible to control the stiffness of the element by controlling pressure in the sponge chamber.
The initial state of the element is shown in Figure 4(b-1). Further, the pressurized structure is shown in Figure 4(b-2). That is to say, since the modification of one layer type element is hardly changed when air is charged into the sponge chamber, the element can maintain safety for users.

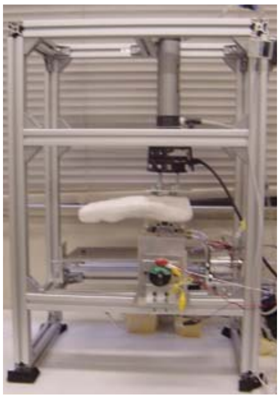
INSOLE TEST DEVICE

When a person uses the shoes that has a high performance insole, the shape of the soft rubber element (SCSRA) is changed by external forces to the insole. This is because that the foot consists of a tiptoe, heel and the arch of a foot. Therefore, in order to clear the performance of the proposed insole, we developed a test device for an insole as shown in Figure 5. Figure 5(a) indicates a whole device and Figure 5(b) shows a foot plate (Ground) whose angles (a pitch angle and a roll angle) are controlled by pneumatic rotary actuators. Further, a foot model is attached to the 6 axis force sensor that are set to the tip of the cylinder rod that is driven in the direction of z axis as shown in Figure 6.
In the experiment, two pairs of SCSRA are put on the floor (Figure 5(b):Ground). Further the foot model is put to the elements by using the cylinder as shown in Figure 6. At this time, the floor is driven by each rotary actuator. Thus, the inner pressure in the actuator is measured by a pressure sensor and the both torque and force in the direction of each axis that acts on the ankle part is measured by the 6 axis force sensor (Figure 6).
By using the insole test device, we investigate an adaptive shape of the insole to distinguish the difference between a roll motion and a pitch motion of the foot. This is because that the main motion of falling down is a roll motion of the foot as shown in Figure 1. Therefore, we measure difference pressure between each element by using pressure sensors in the elements. Thus, we clarify the adaptive shape that the difference pressure does not be changed by a pitch motion but the pressure changes just only by a roll motion of the foot part.

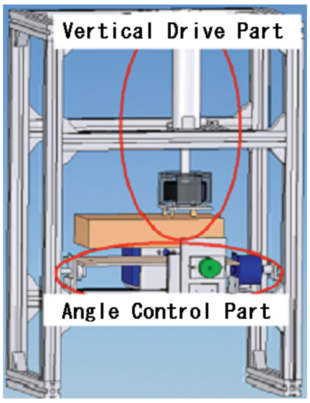
SUTABLE SHAPE OF THE ELEMENT

In order to clear the adaptive shape of the element to distinguish between a roll motion and a pitch motion of the foot by value of inner pressure, we investigate the shape of the rubber element that the difference pressure between each rubber element is almost zero when the foot rotates in the direction of pitch motion. In the experiment, we use 2 types of rubber element. Figure 7 shows each shape of the element. Figure 7(a) is a symmetric type and Figure 7(b) is an one side inclination type. By using these elements, we clear variation of the difference pressure between each element with respect to both a pitch angle and a roll angle.
Figure 8 shows the result with the symmetric type and Figure 9 is the result with the one side inclination type. The condition of each experiment is as follows.

[Condition]
(a): Force(60N), Pitch Angle (θ : -10°～10°)
Roll Angle(φ : 0°)
(b): Force(60N), Pitch Angle (θ : 0°)
Roll Angle(φ : -10°～10°)

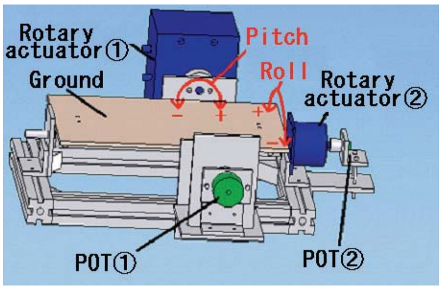


(a-1) Photograph



(a-2) Structure

(a)Test Device



POT: Potentiometer

(b) Mechanism of Foot Plate

Figure 5 Structure of Test Device

From these results, it is cleared that in the case of the symmetric type, the difference pressure changes as the foot rotates in the direction of the pitch angle. On the other hand, in the case of one side inclination type, the value of difference pressure hardly changes when the foot rotates in the direction of pitch angle.
As the result, it is clarified that the one side inclination type element can distinguish the motion of the foot by the change value of difference pressure between each element.
Further, the torque variation of the ankle part with respect to the one side inclination type element is shown in Figure 10. In this experiment the foot model is rotated in the direction of pitch motion. From this result, it is cleared that the variation of torque in the direction of roll motion is almost zero. Thus, by using the proposed element, the ankle is hardly damaged regardless of the shape of the one side inclination type.

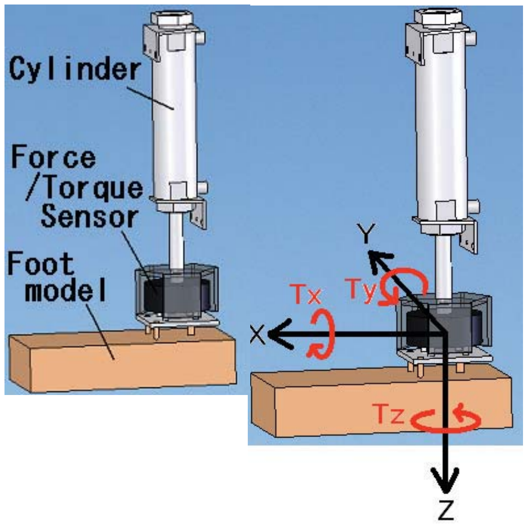


Figure 6 Structure of 6 Axis Sensor Part

CONCLUSIONS

In this paper, we proposed a new type of insole using rubber elements. Further, we cleared the adaptive shape of the element to distinguish the roll motion of the foot by variation of the inner pressure of the element.

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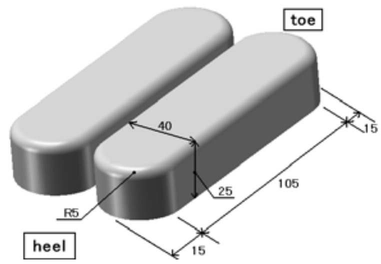
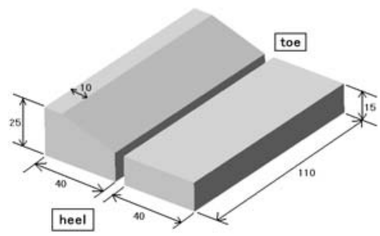
REFERENCES

1. Walking and Fitness Testing in Elderly Women, Fitness for the Aged, Disabled and Industrial Worker, Human Kinetics Publishers, Tokyo, Japan, 1990, pp. 84-89.
2. M.P. Murray, et al., Walking Patterns of Healthy Old men, *J. Gerontology*, **24**, 1969, pp169-178.
3. S. Inoue, K. Saitou, et. al., Influence of Fall Prevention Exercise on Walking Movement and

Body Sway, JSME *Dynamics and Design Conference,* 2003
4. M. Miyamura,Movement physiology studies, Shinkou Trade Co., Ltd., Medical Treatment Publication Department, Tokyo, 1996.
5. S.Oobuchi, Tendency to Fall and Prevention of Elderly People, Journal of Biomechanism, 2005. 27-1, pp.2-5. (Japanese)
6. Ikehara, Tanaka, Tamiya, Hukatani, Development of Walking Assist System of Elderly People, Con ference of Robotics and Mechatronics, 2006, No. 06-4, 1p1-A09. (Japanese)
7. Tanaka, Omata, Ikehara, Nagamura, Ikejyou, Mus culus Activity in Supporting Walk Machine Moun ting to Assist Lower Extremities, Conference of Robotics and Mechatronics, 2006, No.06-4, 2p2-A 07. (Japanese)
8. Y. Hayakawa, H. Mori and R. Tsuda, Basic Study to Develop an Active Supporter with Human Compatibility, *Proc. of the Symposium on Welfare Technology*, 2001.
9. Y. Hayakawa, H. Mori, M. Aichi, T. Kodaka, and S. Higashiura, Study on an Active Supporter Using Pneumatic Foaming Rubber Actuator Coated with Silicone Rubber, *Proc. of the Second European Medical and Biological Engineering Conference, Austria*, 2002.
10. Y. Hayakawa, H. Mori and R. Tsuda, Basic Study to Develop an Active Supporter with Human Compatibility, *Proc. of the Symposium on Welfare Technology*, 2001.
11. Y. Hayakawa, H. Mori, M. Aichi, T. Kodaka, and S. Higashiura, Study on an Active Supporter Using Pneumatic Foaming Rubber Actuator Coated with Silicone Rubber, *Proc. of the Second European Medical and Biological Engineering Conference, Austria*, 2002.
12. Y. Hayakawa, K. Morishita and M. Aichi, Control Performance of a Pneumatic Silicone Outer Fence Mold Actuator, *Proc. SICE Annual Conference*, Fukui, Japan, 2003
13. Y. Hayakawa, K. Morishita and M. Aichi, Study on a New Mechanism of a Silicone Outer Fence Mold Actuator, *Proc. Seventh International Symposium on Fluid Control, Measurement and Visualization*, Italy, 2003.
14. Y. Hayakawa, M. Aichi and K. Morishita, Basic Characteristics of a Silicone Outer Fence Mold Actuator with Human Compatibility, Proc. First International Conference on Computational Methods in Fluid Power Technology, Australia, 2003, PP.595-602.
15. Y. Hayakawa, H. Morishita, M. Aichi and R. Tsuda, Development of a Silicone Outer Fence Mold Actuator, *Journal of JSME*, Series C, **70**, 2004, pp. 433-439.

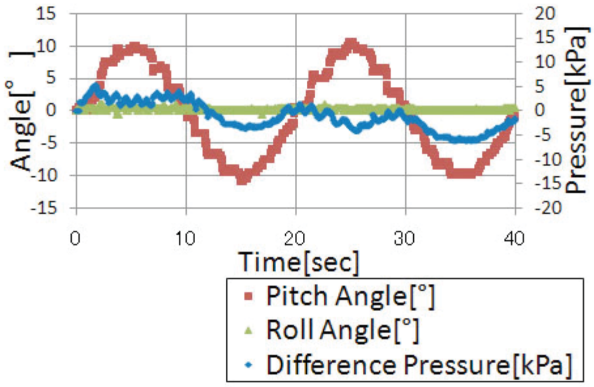


(a) Symmetric Type

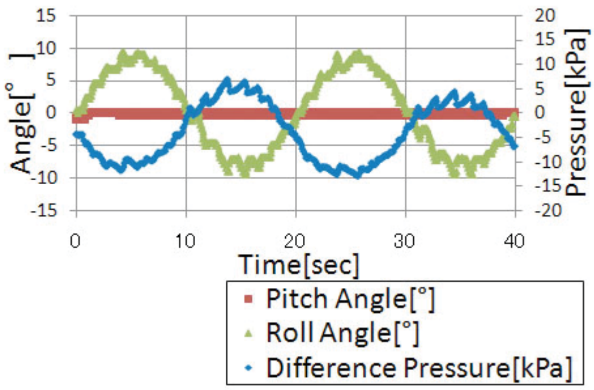


(b) One Side Inclination Type

Figure 7 Rubber Element (Right Side)

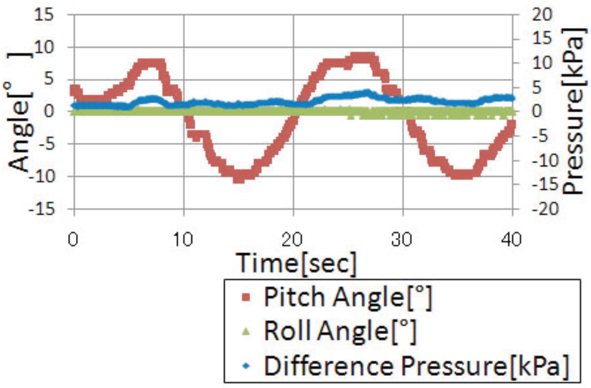


(a) Variation of Pitch Angle

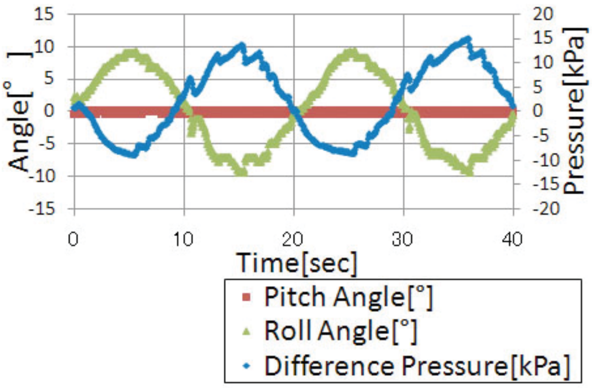


(b) Variation of Roll Angle

Figure 8 Difference Pressure of Symmetric Type



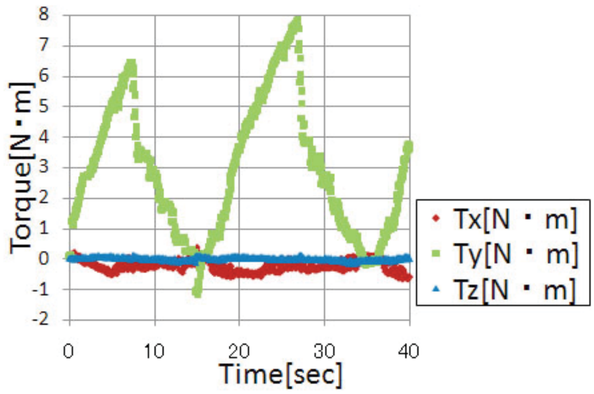
(a) Variation of Pitch Angle



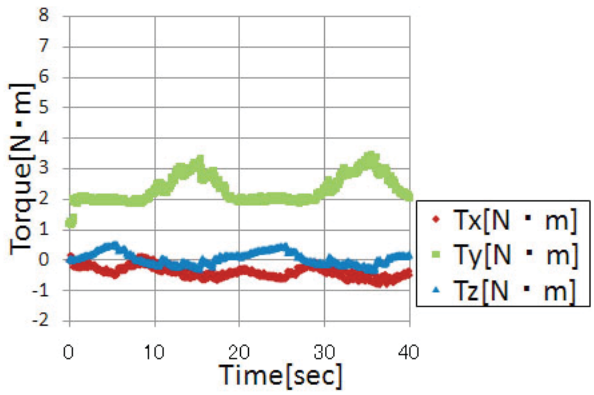
(b) Variation of Roll Angle

Figure 9 Difference Pressure of

One Side Inclination Type



(a) Movement in the direction of Pitch Angle



(b) Movement in the direction of Roll Angle

Figure 10 Torque of Ankle Part

(One Side Inclination Type)