International Journal of Innovative Research in Advanced Engineering (IJIRAE) ISSN: 2349-2163
Volume 7, Issue 03 (March 2020) www.ijirae.com
Special Issue – 6th International National Level Conference- "MEEMIC-2020"

GAIT MEASUREMENT FOR WALKING SUPPORT SHOES WITH ELASTOMER EMBEDDED FLEXIBLE JOINT

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Manuscript History
Number: **IJIRAE/RS/Vol.07/Issue03/Special Issue/01.MRAESCE10084**
Received: 15, February 2020
Final Correction: 27, February 2020
Final Accepted: 10, March 2020
Published: **14, March 2020**
Editor: Dr.A.Arul Lawrence selvakumar, Chief Editor, IJIRAE, AM Publications, India

Abstract: In this study, we experimentally investigated the effect of shoes on gait with new elastomer-embedded flexible joint (EEFJ). We designed the EEFJ to support plantar flexion moments on ankle joints. A strength test was conducted for the EEFJ. According to the results of the test, moments in plantar flexion were significantly stronger than those in dorsiflexion. We prototyped gait support shoes with the EEFJ. The weight of the EEFJ unit for a single foot was 32.5 g. We also conducted gait experiment on a healthy subject with and without the shoes. The results showed reductions in electromyograms of the tibialis anterior muscle in the initial phases of gait.

INTRODUCTION

Walking is one of the most important functions in daily living, and difficulty in walking represents a significant barrier [1]. Therefore, gait training is a high priority in rehabilitation medicine. Due to muscle weakness, stumbles in swing phases and slapping foot at initial contact of gait increase in elderly individuals. Walking supports such as insoles, foot orthoses, and ankle foot orthoses (AFOs) are available. Insoles change the contact plane of the foot so that the weight is evenly dispersed, alleviating pain from the feet [2, 3]. Foot orthoses aim to change patterns of the lower extremity during gait and reduce symptoms associated with lower limb conditions [4].

However, insoles and foot orthoses do not provide support to the ankle. AFO is used for patients who have permanent movement disabilities in the ankles or are in the middle of the recovery process [5]. In general, AFOs have a single axis or are elastically deformable. The pronation- supination motion in the elastic orthoses has some degree of flexibility in its polymeric material. However, the limitation in ankle pronation-supination causes feelings of discomfort and prevents natural ankle motions [6]. Therefore, the rotational axis of AFOs is fixed, and misalignment between the axis and human joint can lead to burden on the user's joint. The use of flexible joints is a potential solution for this problem.

The EEFJ is composed of a C-shaped spring and embedded elastomer. The C- shaped spring easily flexes in dorsiflexion. In addition, the combination of spring and embedded elastomer generates higher torque toward plantar flexion. According to the experimental results, our AFO with the EEFJ (EEFJ-AFO) reduced the burden on the tibialis anterior muscle in swing phases [7]. In addition, it reduced the ankle angle only during the pre-swing phase. We believe that this function is also useful in the walking support for elderly individuals with frailty in ankle motions and functions. Therefore, in our new study, we have decided to develop burden-reducing shoes by using the EEFJ (EEFJ-shoes) for elderly individuals with the frailty.

In the previous report [9], we prototyped a pair of burden-reducing shoes by installing the EEFJ outside the ankle joint. However, allowable deformation was insufficient. To solve the problem, we improved the structure of the EEFJ, and conducted theoretical analysis and strength test in this study. In addition, we conducted gait measurement with/without the support of the EEFJ. Its effects are discussed with statistical analysis.

Motion of EEFJ Joint

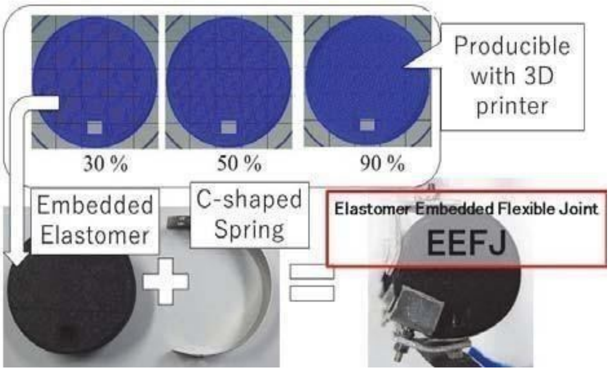


Fig.1: EEFJ

SHOES WITH ELASTOMER- EMBEDDED FLEXIBLE JOINT

DESIGN REQUIREMENTS FOR THE EEFJ-SHOES

With respect to the target values of torque, the resistant torque with eccentric contraction toward dorsiflexion at initial contact (IC) is approximately 0.2 Nm/kg [11] when walking naturally. In cases wherein, the weight of the subject is approximately 60 kg, the resistant torque required in IC is 12 Nm. According to a study [12], the muscle strengths in lower limbs reduced by 30% for males and 20% for females between the ages of 20 and 60 years. As a result, IC requires an additional 3.6 Nm torque to assist the target users in smooth walking. Standard ankle motion of normal gait in IC is approximately 10° in the plantar flexion [10]. The requirements for developing this joint are summarized as follows. In the previous report [9], the EEFJ- AFO achieved the requirement (3). However, we had not tested the EEFJ-shoes yet. Bending angle should be > 45° in dorsiflexion [10].

(1) Additional torque should be > 3.6 Nm at 10° in plantar flexion [11] [12].
(2) Resistance of movement should be relatively lesser than that in plantar flexion.
(3) Its weight should be lighter than a general metal-type AFO (400 g).

When we design walking supports for ankle motions, we have to consider the ankle motion for a stress less design. Figure 2 shows the relative positions between the ankle joints and mechanical joints of the supports. A single-centered joint mechanism has a fixed rotational joint at a point (black dot in Fig. 2a). This mechanism generates high stress between the human and device when there is no negligible error between their joints with misalignment. In contrast, a flexible joint mechanism has single or multiple elastic elements for joint motions (e.g., C-shaped black curve in Fig. 2b).

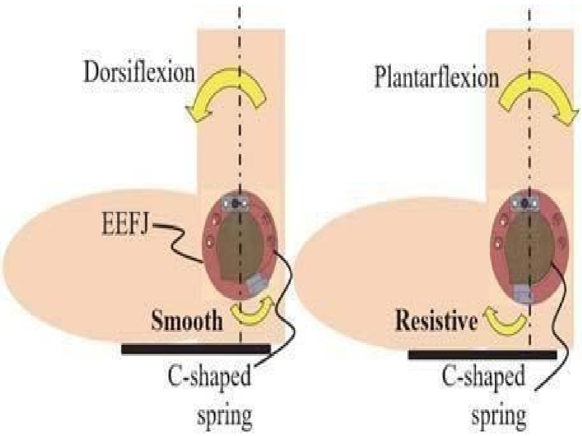


Fig.2.Motion of EEFJ

The flexible mechanism allows some degree of misalignment. The EEFJ is a kind of flexible joint mechanism. Using the EEFJ as an ankle joint support, we can design the multiple elastic properties in dorsiflexion and plantar flexion of the ankle. Our aims are smooth motion in dorsiflexion (Fig. 3a) and high resistance force in plantar flexion (Fig. 3b). Such multiple elastic properties can be adjusted with different elasticities of the C-shaped spring and embedded circular elastomer.

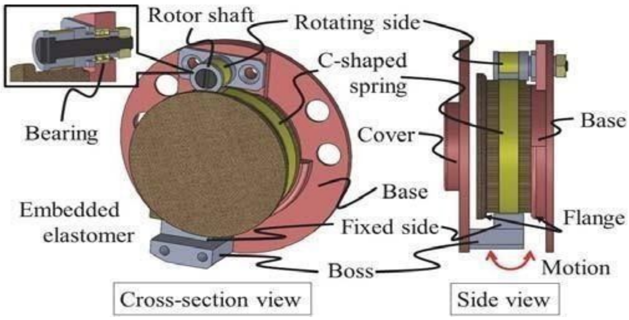


Fig.3. Basic structure of the new EEFJ

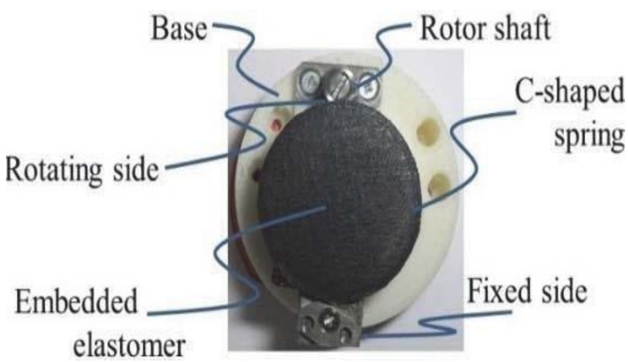
In the previous report [9], we prototyped a pair of burden-reducing shoes by installing a set of the EEFJ unit outside the ankle. However, allowable deformation was insufficient due to the limitation of the elastic range of the material (stainless steel) of the C- shaped spring. To solve this problem, we improved the structure of the spring unit. The structure of the new EEFJ is shown in Fig. 5. The C-shaped spring connects one end to a rotor shaft and another end to boss of a cover. This modification reduced the maximum strain on the spring and enlarged the movable range of the joint.

We also introduced flanges on the base part and circular elastomer in order to prevent the derailment of the C-shaped spring against the side surface of the embedded elastomer, in particular after large movement in the frontal plane (a rounded arrow shown on the right of Fig. 5). The embedded elastomer has attachment bosses on the backplane and is replaceable. We can replace the embedded elastomers with different spring constants to fit the user and ground conditions.

FABRICATION

Fabrication of the joint

The elastic elements embedded in the springs were fabricated with a 3D printer (Bonsai Lab., BS01) and made of a thermal plasticelastomer (PolyFlex^{TM},Polymaker). The filling structure was set to a honeycomb structure. The filling density of the material was set to 80%. Stainless steel (SUS301) plates (4 mm in width, 80 mm in length, 0.2 mm in thickness) were used as the base of the C-shaped springs. The C-shaped spring can easily rotate toward dorsiflexion, thanks to a ball bearing (NSK, MR63ZZ). The total weight of the new EEFJ unit was 29.2 g.



MECHANICAL PROPERTIES OF THE EEFJ

We experimentally investigated the mechanical properties of the EEFJ in dorsiflexion and plantar flexion.

METHOD

We modified the jig used in the previous report [9] to fit the new EEFJ. In this experimental setup, points O, A, B, and B' correspond to the ankle joint, one end (rotation side) of the spring, initial position of the other end (fixed side), and its current position, respectively. Points O and A are fixed on the coordinate on a foot, and therefore, fixed on the setup. An acrylic plate is fixed on the movable side of the EEFJ unit (cover). A tester pushed the outer end of the acrylic plate with a push- pull gauge and measured the relationship between the pushing forces (moments) and deformed angles. The distances between points O and A were set at 5 mm and 10 mm to simulate real life conditions.

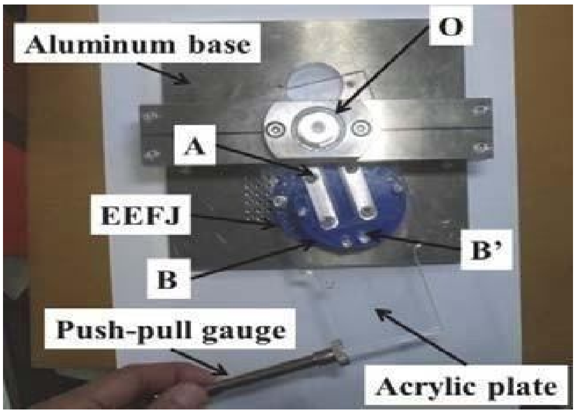


Fig.5 : Experimental setup of the strength test

CONCLUSION

We experimentally investigated the strength properties of the EEFJ in dorsiflexion and the plantarflexion and the effect of shoes with the new EEFJ .The total weight of the shoes with the new EEFJ one leg for 423.5 gram. The result of the strength test showed that the moment in plantar flexion was significantly high a then that in dorsi flexion. Result of the gait experiment showed reduction in burden on IC-FF. According to the EMG of the MG muscle in the phase HO-To, increasing tendencies towards natural gait was seen with these shoes.

REFERENCES

1. Inman V., Ralston H., and Todd F., "Human walking," Baltimore, Williams & Wilkins, 1981.
2. Atrs M.L.J., Waaijiman R., de Haart M., Keukenkamp R., Nollet F., and Bus S.A., "Offloading effect of therapeutic footwear in patients with diabetic neuropathy at high risk for plantar foot ulceration," Diabet Med, 29, pp.1534-1541, 2012.
3. Guidemond N.A., Leffers P., Schaper N.C., Sanders A.P., Nieman F., Willems P., and Walenkamp G.H.I.M., "The effects of insole configurations on forefoot plantar pressure and walking convenience in diabetic patients with neuropathic feet," Clin Biomech, 22, pp.81-87, 2007.
4. McMillan A. and Payne C., "Effect of foot orthoses on lower extremity kinetics during running: a systematic literature review," J Foot Ankle Res, 1, p.13, 2008.
5. Redford J.B., "Orthoses," In: Basmajian JV., and Kirby RL., eds., Medical Rehabilitation, Baltimore, Williams & Wilkins, p.101, 1984.
6. Dr.R.Satish kumar ,Dr.K.Umadevi, "Novel Technique for Measurements of Dielectric Properties and Microwave Heating of In-Shell Eggs without Explosions in Microwave Oven for Pasteurization" International Journal of Innovative Research in Advanced Engineering (IJIRAE) ISSN: 2349-2163 Issue 3, Volume 2 (March 2015).
7. Dr.R.Satish kumar, Dr.M.Y.Sanavullah Theoretical and experimental study of cooking regions for shell eggs in a domestic Microwave oven VL- 4 DO- 10.1109/ICECTECH.2011.5941909 JO - ICECT 2011 - 2011 3rd International Conference on Electronics Computer Technology