

# Development of an Ankle Foot Orthosis for Hemiplegic Children

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**Abstract**—Hemiplegia is a half body paralysis which causes disability in mobility function. Hemiplegia is normally discovered since early birth and is not curable. Treatment such as physical therapy can be carried out for the hemiplegic patient to prevent muscle contraction, especially at the early age. In this research, a tool for the physical therapy and gait assistance known as ankle foot orthosis (AFO) was developed for the hemiplegic children. The AFO was based on the active concept that mobilised the ankle by preventing excessive plantarflexion and allowed dorsiflexion. A linear type DC (direct current) motor was used as the actuator. The maximum range of motion (ROM) was +20° for the dorsiflexion and -20° for plantarflexion movement. The prototype was fabricated using 3D printing. Simple control for the device was developed using Arduino kits. The development of a new AFO is hoped to support the rehabilitation of the hemiplegic children.

**Index Terms**—Ankle Foot Orthosis; Dorsiflexion; Gait Assistance; Hemiplegic

## I. INTRODUCTION

Hemiplegia causes impairments on one side of arm and leg. Hemiplegic children are facing a problem with the affected leg and interrupted by the shortening of muscles [1]. As a result, abnormal gait patterns would occur among the hemiplegic patients. Rehabilitation is conducted to support hemiplegic patients by means of both physically and psychologically. One of the basic management is to keep the hemiplegic children to stay active for preventing muscles contraction.

Ankle foot orthosis (AFO) is used as a tool for the physical therapy. The key usage of AFO is to restrict, control and assist the range of ankle's motion at the desired angle during gait phases. Most of the orthosis devices were concentrating on the restriction and control function on dorsi-plantarflexion. The design of orthosis was based on imitating the normal human gait [2]. Thus, the normal gait pattern was investigated and recorded especially at the ankle's angle. Dorsi-plantarflexion is one of the most crucial motions that involved in walking.

AFO can be divided into static and dynamic types. Solid ankle foot orthosis (SAFO) is the example of static types of AFO. SAFO is the simplest type of orthosis device. The device consists of single rigid bracing that moulded to suit the heel by using straps. The rigidity of the device allowed restriction for both dorsiflexion and plantarflexion. According to [3], the SAFO is more suitable for patients with higher level of impairment due to the high restriction function and stability.

Hinged ankle foot orthosis (HAFO) and active ankle foot orthosis (AAFO) are examples of dynamic types of AFO. HAFO was designed by implementing hinges on the ankle that allowed freedom of dorsiflexion and plantarflexion motion. The design of flexible ankle joints encountered the weakness of SAFO by preventing plantarflexion and allowed more dorsiflexion. It was concluded by [4] that HAFO helps enhanced the gait pattern in the way of stride length, walking with higher velocity, preventing plantarflexion, improving hip flexion and knee kinematics.

Active ankle foot orthosis (AAFO) is an innovating hinged AFO that applied with the powered actuator, control or sensors. The AAFO would help significantly in therapy management with providing assistive power at the affected ankle [5]. The design of AAFO was aimed to improve gait and assist in therapy by having more control on the ankle movement such as stiffness, authorises the control on plantarflexion angle, receives and gives feedback according to the data detected by sensors. In this paper, the design, fabrication and control of a new AFO based on the active concept are discussed.

## II. MATERIALS AND METHOD

### A. Design Process

The design process is referred to the different phases involved to develop the ankle foot orthosis (AFO). It includes conceptual, embodiment and detailed design as proposed by [6]. The conceptual design refers to the drafting process that aimed to visualise the initial ideas generated for the new product. Pugh concept selection, a decision analytic tool using score rating was used to narrow down multiple design concepts, from types of AFO to material selection to generate the best design.

The embodiment refers to the configurations of the selected design concept. The arrangement of parts such as a hinge, foot braces and motor were decided in this phase. Product architecture helps visualised the possible parts and elements needed in the design. Besides, analysis of related factors such as the ground floor reaction and range of motion were carried out during embodiment design phase. The analysis was conducted to identify the specification of the actuator to be used. The constructed product architecture for this research is shown in Figure 1(a).

The new AFO was based on the active concept. The AFO was designed with one degree of freedom that allowed movement of dorsiflexion and plantarflexion as shown in Figure 2. Since the mechanism was developed to restrict uncontrolled plantarflexion and support the movement of