

CARBON FOOT

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Abstract

All, the patient who suffers a lower limb amputation and undergo prosthetic restoration always requires a platonian ankle foot mechanism as a component of their prosthetic system. Prosthetic feet design and construction has progressed tremendously in the past few decades. So it is more important for the prosthetist to select appropriate foot to suit an individual amputee. **Aim-** Permissible flexibility allowing accommodation of uneven terrain with maintenance of balance in initial stance phase. **Case content and methodology:** kinematic gait parameters were analysed for a 25-year-old male individual with Modular prosthesis with carbon foot. **Findings and conclusion:** According to patient, while walking with the current foot design, they are walking effortlessly and a faster walk in even and uneven ground, contrast to SACH foot. They are not feeling fatigue while using the current foot. With 10m walk it provide increased step length and stride length and also increased cadence with compare with SACH foot. It also reduce the energy expenditure of the patient.

Keywords-amputation,carbon foot,sach foot

Introduction-

The human foot is a complex anatomic structure with most versatile three degree of freedom. Provides stable weight bearing, base of support permitting surface impact absorption, generator for dynamic propulsion for normal locomotion. A prosthetic foot is designed to replace many of the functions of the anatomic human foot. In fact the foot module is the only component which connecting prosthesis and ground. So it must mimic the biomechanical characteristic of the human foot as much as possible. However the prosthetic feet can be categorized as per as the motion availability or simulation.

NEED FOR THE STUDY

Not all the new ankle foot system provides a dynamic response, some has been improved by increasing their energy dissipation characteristics, achieving a measure reduction in weight and their requirement for maintainance and in some cases, the ability to easily adjust different heel height.

In this design the inertia energy reentry frame acting as an elastic structure to promote the ground reaction force for reutilization in form of store energy A plethora of new prosthetic ankle foot mechanism have been developed in the last decade including current time is due to the better understanding of the biomechanics of human locomotion and a multitude of technical advancement in material technology which are new plastic resins like poly-urethane, carbon-graphaite composites and synthetic fibers and the combine effect results- durability, weight reduction ,cosmoses, dynamic characteristics

DESIGN CONCEPT

Energy crisis v/s Energy conservation is one of the most even demanding concepts of the time. And it is more often related to design, development, field trial, testing

Design Profile:

The design profile is Schematically drawn with reference to its various components. The basic concept of all prosthetic series must be well defined with energy returning concept.

Material- Sustainable with reduced weight function “F”

Mechanism- Versatile with simplicity “y”

Mobility- Capable of overcoming constraint force “z”

Money- Cost effectiveness as an affordable intrest “k’

F+yz

This Carbon dynamic foot” is designed without sacrificing the biomechanical principle. As it is well known that, the feet is a foundation of prosthesis, so it should transfer weight effectively, serve energy to increase efficiency and does smooth roll over to give comfortable walk. To view on the above demand this foot is designed indigenously.

METHODOLOGY

PHYSICAL CONFIGURATION

Deflection modulator (fig1.1)

Rear deflection controlling sheath

Inertial block(fig1.3)

Kinetic Plate

Screws

Spring(fig1.2)

M10 Bolt





Fig-1.1Stainless steel plate



Fig-1.2 spring



Fig-1.3 Polyurethane

A 2-dimensional graphical representation of the foot was done with proper dimension. Based on the 2D view, the pattern was cut according to the measurement of the forefoot, midfoot, heel width, ankle height and pasted over the cork sheet. Two one way opening chambers were made with cork sheet for keel and lower deflection plate.

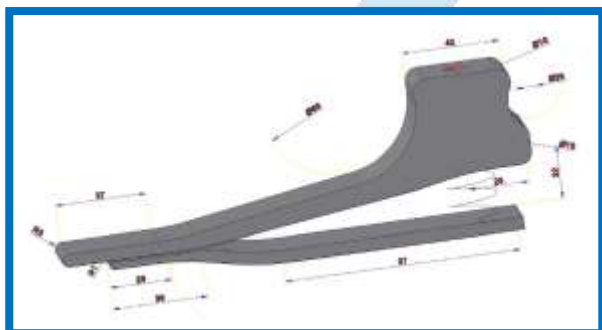


Fig. 1.4- 3D design of the complete Carbon foot

Assembled module

The assembled components (fig 1.7,8) are given in the internal mechanism of the foot which could access to any type of shoe and barefoot also. The carbon fibre foot plate being capable of producing both tensile and compressive stress at heel strike and that could activate again through a “inertial energy re-entry frame” device called potential sheath- kinetic plate, deflection modulator and simultaneously storing appreciable amount of energy with preparation for next phase of stride.

The intent of this design is to store and return mechanical energy during the stance phase of walking thereby partially replacing the function of the triceps surae and reducing the strain at knee and back muscles which causes an appreciable decline of metabolic requirement.

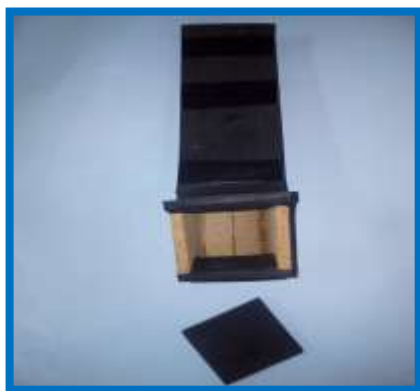


Fig. 1.5 One way opening chamber for lamination



Fig. 1.6 Laminated keel (side view)



Fig-1.7 Finding out the finished keel



Fig-1.8 Finished foot

Case report

A 25-year-old man (height: 171.5 cm and weight: 65 kg) sustained severe crush injury of right transtibial amputee (fig 1.9). He was referred to Swami Vivekanand National Institute of Rehabilitation Training and Research (SVNIRTAR), Cuttack, India, in January 2015 for prosthetic rehabilitation. The aim of rehabilitation was to achieve maximal independence in mobility and self-care activities and to overcome social and vocational problems. Previously he was using Right modular transtibial prosthesis with PTB socket, cuff suspension and ranjor foot. Currently the patient was fitted with Right modular transtibial prosthesis with PTB socket, cuff suspension and carbon foot. After 1 day training with the carbon foot, the **Patient opinion regarding this foot-** Feel comfortable in walking compared to previous, increasing the speed of walking compared to previous one, easier in moving in stair case and inclined surface, relaxing the knee strain and back muscles.



Fig-1.9 Patient walking in level surface

The analysis of different data during the entire gait cycle is mentioned in table 1.1.

	SACH Foot	Carbon Foot
Step Length	0.34m	0.57m
Stride Length	0.71m	0.95m
Velocity	0.62m/s	0.80m/s
Width of Walking base	16cm	12cm
Cadence	62	96

Table 1- Gait analysis of Carbon foot compared to SACH foot

RESULTS

After successful fabrication it has trialed over a transtibial subject and collected data during the gait cycle. During walking it replicates all the three rocker of the gait. It provides the stability during normal walking and standing. During the ascending and descending of ramp and stair it provides stability and comfort to the patient. It absorbs the shock during the heel strike phase by the help of spring of the foot, during the loading response phase of the gait the spring which is placed posterior to the weight line is compressed and stores energy and this energy is released during the pushoff phase of gait which helps in preparation of preswing of gait cycle. Because of the light weight feature of the foot less amount of energy is consumed during walking but the fear is increased due to less base support which will be eliminated by the regular use of the foot. It accommodates in the uneven terrain because of the rocker function system of the foot plate and also it provides little inversion and eversion moment during the late stance phase. According to patient, while walking with the current foot design, they are walking effortlessly and a faster walk in even and uneven ground, contrast to SACH foot. They are not feeling fatigue while using the current foot. With 10m walk it provides increased step length and stride length (table-1) and also increased cadence with compare with SACH foot. It also reduces the energy expenditure of the patient.

DISCUSSION

After several reviews of scientific literatures and patients trial, it has found that this non-articular foot is an effective design to conserve energy and to achieve a smooth gait transition in contrast to SACH foot.

According to Nielsen *et al*, 1989, flexible foot is more stable in an amputee with good proprioceptive control because most likely the flexibility of the foot allows them to keep their balance. It gives a possibility of adaptation to an uneven surface and therefore reduces the chance of falling and incorporates feelings of safety.

Casillaset al. (1995) gives the feedback that plantar flexion of the prosthetic foot is related to balance control. Balance control is dependent on proprioceptive feedback. An increase in initial-stance plantar flexion results in

an increase of knee flexion moment and thereby decreases knee stability. With poor balance control this leads to unsafe situations and therefore these amputees prefer prosthetic feet which allow only limited initial stance planter flexion. Initial stance compression permits a smooth movement. With limited planter flexion, the smooth gait pattern will be impaired.

According to J.Gweeg Kadim, this foot has good planter flexion angle, energy return and fatigue characteristics in contrast to SACH foot. They have measured the fatigue characteristics by fatigue foot tester and planter flexion and energy return characteristics are measured by force plate and testo matric machine. Here also by the calculation of PCI it shows less energy consumption during walking.

LIMITATIONS OF THE STUDY:

Though subjects are giving their own view regarding comfortable walk in any terrain with this foot compared to SACH, but the datas are not significant as experimentally not tested in the gait laboratory hence needs extensive study on gait characteristics with this foot design to get significant result.

CONCLUSION

This new design foot accommodates with the normal gait cycle during walking. It also mimics all the phages and rockers of the gait cycle. It provides a comfortable walking with less energy expenditure. The movement at ankle joint and provides good planter flexion during loading response, advancement of tibia after initial contact and good push-off action. Not only it provides a good rollover action, it also conserves energy due to high endurance limit and good flexibility of carbon fibre. The weight of the new design is very less as compare with the SACH foot. It also provides the stability to the patient during the ascending and descending phase of ramp and stair walking. The patient can easily overcome the obstacles during walking by the use of this design. Only the use of the spring may need maintenance with a frequent use of the foot but over ally it is purely cost effective as compared to other carbon fibre foots. It provides shock absorption during the initial phase of the gait cycle and provides the roll over action and stability during the late stance phase of gait. Because of the less weight patient needs less effort during walking but it increase the fearness in the practice phase of prosthesis but it reduced with increment of the use of the prosthesis.

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