Prosthetic Foot Design And Testing – A Review

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Abstract- *In human locomotion ankle foot system plays a major performance. The prosthetic ankle foot provides dynamic walking by using compliant mechanism. Compliant mechanism has been applied in many quasi-static applications. A flexible generic model is proposed based on multi-body dynamics which facilitates design and implementation of the compliant mechanism in dynamic application. This paper over review about the 3D printing prosthetic foot using compliant mechanism and its properties on stiffness, durability, ultimate strength, density and printability.*

Keywords- Polylactic acid, Acrylonitrile butadiene stryene, Nylon, 3D Printer.

I. COMPLIANT MECHANISM

In mechanicalengineering, compliant mechanisms are flexible mechanisms that transfer an input force and displacement at one port to an output force and displacement at another port through elastic body deformation.
The compliant mechanism is successful applied in many quasi-static applications. One such an example is shown in fig.1. In particular dynamic problems the hinder implement the field power of compliant mechanism of transmission systems. A fast and flexible generic model is proposed based on multi-body dynamics. The proposed methodology is not only applicable to the compliant transmission couplings between parallel rotational axes but further more provides opportunities for the modeling of other compliant mechanism applied in dynamic environment [1].

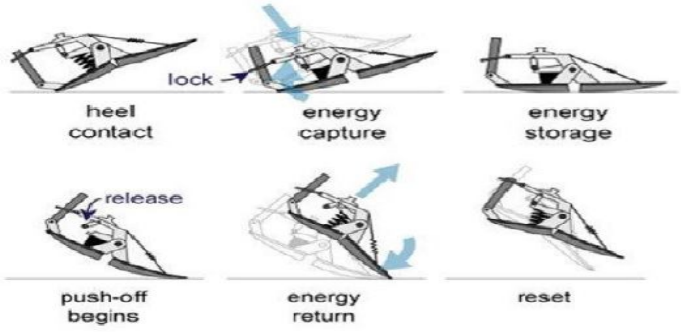

Figure.1 Process of complaint mechanism

In this paper, the aim is to investigate the joint contact forces by a musculoskeletal model in the intact side and to compare with those of unimpaired subjects and to further elucidate in how far increased knee JCF are associated with increased frontal plane knee movements. In result it may explained by an overall positive clinical situation of the subjects , a beneficial prosthesis including proper socket fit and it supports presenting subjects on gait condition other than level walking [2].

The purpose of this study was to present specific procedures and processing methods of complaint mechanism. At the end of this paper will present the result and the conclusion of the three methods. Depending on the intended use for each mechanism and complexity, it can be done by the desired method [3].

The compliance joint level in human locomotion has played a central role in many studies. In a previous study, we have used a human modal to carry out the analysis of compliance in leg joints during level ground walking. The rest positions of the springs and the value of the damper at the ankle, that best reproduce measured human joint trajectories in these walking scenarios. In this they analyzed the stiffness modulation at joint level during single step walking in three different scenarios: Level ground, slope of 15 degree and stairs [4].

II. DYNAMICS OF COMPLAINT MECHANISM

In this development of complaint mechanism based systems with precision motion are the need of industry. The method is implied to this design a four bar complaint mechanism and compared with mathematical results. This method also implemented in Scott-Russell straight line mechanism to conform it effectiveness. As shown in Figure.2 For the development of prosthetic foot by the research progress to examine the properties to be calculated in complaint mechanism of Scott-Russell line of mathematical results [5].

Figure.2 Ohio Willow Pathfinder and Flex-Foot

This paper is about the purpose of study to quantify the total mechanical energy of the natural ankle-foot structure during stance in level-ground steady state walking across various speeds [0.4, 0.6, 0.8 and 1.0]. Accounting for these simultaneous effects, the combined ankle-foot system exhibited increased work-ratios with faster walking. As the result with walking barefoot indicated ankle joint and distal joint structures generally performed opposing roles [6].

The study of this paper is the dynamic modeling and performance for complaint mechanism with inflection beams is presented. Numerical investigations of the dynamic responses of the flexural beam with an inflection point are presented by the 5R D-PRBM. The 5R dynamic pseudo-rigid-body model was developed for the flexural beam with an inflection point and the dynamic equation was obtained based on lagrangian equation [7].

The main function of this study is to develop dynamic models of the mauch S-N-S knee for predictive simulation of a transfemoral amputee gait under idealization conditions. Both dynamic model of this study can be utilized in musculoskeletal modeling studies, to better understand amputee gait and the contribution and interaction of various prosthetic leg components. For transfemoral amputee gait simulation. This type of dynamic model can used to estimate the kinetic performance of the model [8].

The main objective is to estimate the dorsi-plantar flexion moment created by the ventral shell in partial foot prosthesis. The use of a pressure pad enables a biomechanical approach to calculate the moment applied through the shank in different prostheses. The characteristics of the estimated moment applied at the shank fit the dorsi-plantarflxion moment during terminal stance [9].

The walking is of high importance to prosthesis users and may affect walking during baseline observation and evaluation. Margin of stability in the medial-lateral direction and an anterior instability margin (AIM) were used to quantify the dynamic balance of 21 unilateral transtibial amputees during over-ground walking. Participants were assessed before and after a 3-week adaption period on each foot. Our results produce quantitative evidence of the changes in dynamic balance that occur over three week period following receipt and fitting of a new device, regardless of the functional similarity [10].

III. TECHNOLOGY DEVELOPMENT

For developing country they suggested to create low cost prosthetic and assistive devices. A multi face and non-traditional engagement with industry partners developed in course and promising model for development engineering course to afford unique opportunities. As a result the process can exceeded up to 60% beyond the end of class [11].

They developed a mathematical model to find the parameters of prosthetic damper which will provide a similar trajectory for the prosthetic knee joint. It is validated with a simulation process using the data of the able-body individuals. We utilized values of damper parameters of prosthetic knee joint. In this study is to simulate the auto adjustment of damping parameters to improve the co-ordinate between lower limbs. The estimate values from the model can be used by prosthetist as a reference data for the final adjustment of the damper [12].

This method uses ground contact conditions to correct for drift, and state estimation algorithms to improve estimation of angular orientation. Internal sensors measure walks over arbitrary distances, yielding estimates with good statistical confidence. Gait can thus be measured in a variety of environments, and even applied to long-term monitoring of everyday walking. We sought to determine whether foot-mounted IMUs can estimate stride measures from over-ground walking. We devised an algorithm that calculates stride parameters that are drift-stabilized, meaning that errors do not grow unbounded with time [13].

IV. TESTING PROCESS

It describes about the testing process of human running motion and processed to be feed into test machine software. This test shows the capability of this approach to reproduce dynamics of heel-to-toe running motion. Therefore by the test result was shown in Figure.3 as the maximum speed attains by this study was about 60% of real time speed there are ways for optimization [14].

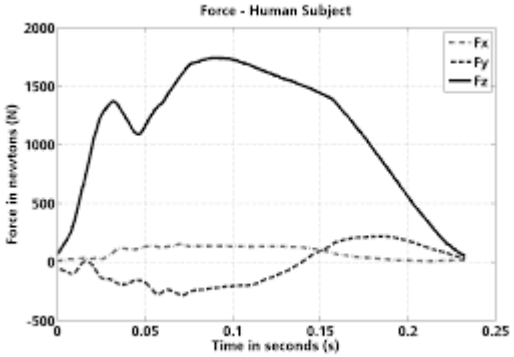

Figure.3 Endurance test performance.

This reported the effects of different prostheses foot were studied they varied hind foot stiffness in an experimental prosthesis foot. In increments of 15N/mm and variation speed of thread mill walking in unilateral transbital at speeds from 0.7 to 1.5 m/s. The result is to reduce prosthetic energy return, increased ground reaction force loading rate and greater stance-phase knee flexion [15].

This paper based on the principle of novel motion platform systems [NMPS] for testing prosthetic knees [PKs] is proposed to limitate the stochastic dynamic processes. The NMPS includes a motion platform, a bio-guided unit, a posture sensing unit, and a control and data collection unit. The figure.4 shows the prototype of NMPS, which indicate that the developed NMPS can accurately imitate the amplitudes and speeds changing in the stochastic dynamic process of the healthy un-amputated individuals thigh. The prototype's ability to imitate the tester's high motions is experimentally at an accelerated/decelerated walking speed [16].

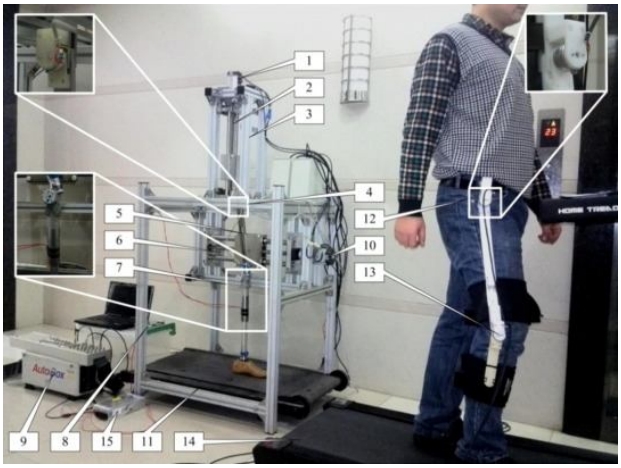

Figure.4 Prototype of NMPS

The stability of finite element analysis for standardizing the mechanical characterization of energy storage and return prosthesis was investigated. A methodology consisting of both experimental and numerical analysis was proposed and trailed for the Vari-flex Modular. Both the energy stored and returned by the prosthesis varied negatively with stiffness, yet over all of the prosthesis were similar for the above mentioned prosthesis. The proposed methodology allows the standardized assessment and comparison of ESAR prostheses without the confounding influences of subject-specific gait characteristics [17].

The main objective was to monitor the internal stresses in the residuum of transtibial amputation prosthetic-users ambulating on different terrains. Monitoring of internal stresses was accomplished using a portable subject-specific real-time internal stress monitoring. They found significant decrease in peak internal stresses and in the loading rate of the amputated limb, using a hydraulic prosthetic foot may protect the distal tibial end of the TTA residuum from high stresses, therefore preventing pressure related injury and pain [18].

In the base of the socket they used load cell to measure the sagittal moments during walking with three objective categories of prosthetic feet in eleven individuvals with transtibial limbs loss. The complaint mechanism category of prosthetic feet was preferred by participants over the stiff and intermediate prosthetic feet, and complaint and intermediate foot. In small cohort of prosthetic users with transtibial limb loss preferred complaint feet with lower peek sagittal moments during gait [19].

This use of motion analysis technique in amputee rehabilitation often utilizes kinematic data from the prosthetic limb. These coordinates were then compared across feet and compared to the contralateral intact ankle joint. Kinematic method that assume ankle constraints based on an intact ankle are subject to systematic error as this does not reflects the real motion of the prosthetic foot. The prosthetic foot tested had varying sagittal plane coordinate positions of the FJC when compared to an intact control foot. For the further purpose of the study was research into the use of FJCs in prosthetic biomechanics [20].

In this study was determined about the taken measurements of torsional and axial stiffness from four brand of periodic prosthetic feet over a range of foot sizes. The methods we taken by applying forces and torques onto prosthesis with a material machine that replaced those exhibited using kinematics measurement for non-amputee toddlers during walking. The axial and torsional methods are reproducible and should be adopted by prosthetic foot manufactures [21].

The effects of reported effects are different prosthetics foot on gait, but the most result are cannot be generalized because of prosthesis properties are seldom reported. We varied hind foot and fore foot in experimental foot prosthesis. A stiffer forefoot resulted in reduce prosthetic side ankle push off and COM push-off work, and increased knee extension and knee flexor moment in late stance. The variation of speed in treadmill walking speeds from 0.7 to 1.5 m/s. The sensitivity test obtain from this clinical prescription of prosthetic foot and further research into mechanism of joint function [22].

In this paper they examined sagittal plane ankle moment versus flexion angle curves from 12 healthy subjects during the daily activities. The slopes of these curves were assessed to find the calculated stiffness during the peak energy return and harvest phases. This development was direct towards the complete data set to determine the torque-angle properties of the ankle joint [23].

In many of the study was limited to mechanical properties for tested prosthesis. Ankle and knee kinematics, prosthetic limb normal ground reaction forces, and net metabolic measured in five traumatic unilateral trans-tibial amputees during treadmill walking on the level side knee changes alignment between conditions. This reduces normal ground reaction force during the loading phase of prosthetic stance and reduced net metabolic cost. Wider range of walking and stiffness conditions would be useful to fully explore these effects in future studies [24].

Analyzed data of leveled walking and ramp descent from six subjects with TFA who used prosthesis without a stance control mechanism. As shown in figure.5 the ground reaction force and joint moment, power, and kinematics were derived from three-dimensional motion capture, combined with force measurement. The individuvals prosthetic knee without a stance control mechanism adapts their gait biomechanics to a slightly declined surface. Compared the level walking, ramp descent increased maximum vertical ground reaction force by 16% of the body weight [25].

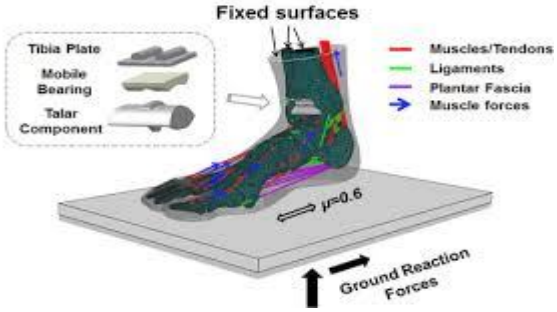

Figure.5 FEA analysis test

V. PROPOSED PROCESS

It is to investigate the proposed prostheses were able to replace the fore foot lever in chopart –amputees upto which extent. An instrumented 3D analysis was performed in 13 subjects. High-profile prostheses with ventral are more suitable to reacquire the last fore foot lever after chopart amputation as shown in figure.6. However, the issue of restricted range of motion in the ankle joint with the clamshell prosthesis needs to be addressed [26].

Figure.6 Bellman prosthesis without and with ankle-foot orthosis and clamshell prosthesis.

The main objective of this paper is about the possibility of using kenaf composite as an alternative material to fabricate orthosis and prosthetics. Both plastic and carbon composites has been widely applied into medical devices such as orthosis and prosthetics. Kenaf composite has a high potential in replacing all the current materials due to its flexibility in controlling the strength to weight ratio properties, cost effectiveness, abundance of raw materials, and biocompatibility. As the result, the kenaf composite has the potential to be used for fabricating an AFO due to its tensile strength which is almost similar to poly propylene's [PP] tensile strength, and the cheap raw material compared to other type of materials [27].

This represents the one of the oldest form of prosthetic limb replacement associated with the skeleton of its wearer in to date. These findings are set against the bio archaeological of the man in order to discuss whether removal of the foot was due to medical causes. The prosthetic device recovered to date or made from iron or bronze, this may have been a prerequisite of higher social classes [28].

This study is about the investigation whether using an articulate hydraulic ankle attachment center-of-pressure trajectory fluctuation under the prosthetic foot compared to a fixed attachment. Centre-of-pressure displacement beneath the prosthetic foot. Reduced centre-of-pressure velocity variability across single-support, increased mean forward angular velocity of the shank during early stance, and increased freely chosen comfortable walking speed [29].

VI. MEDICINAL WAYS

The controlled lower leg foot prosthesis that defeats the outcome challenges. The prosthesis includes a unidirectional spring, designed in parallel with a force controlled actuator with arrangement flexibility. By the result of decreases approach in metabolic vitality utilization, obviously because of diminishments in solid ekertion connected with mediolateral foot situation [30].

The aims of this work is to perform a structural biomechanical analysis of a restorative arthroplasty of the first metatarsophalangeal joint and to analysis interaction between bone and medical grade silicon implants. For that , a simulation of a foot swanson and tornier joint implants suggest that failure is induced in this bone because ,the values exceed the tensile strength reported for phalange trabecular bone, Which may related to osteolysis. Stress and strain values obtained in this work suggest that arthroplasty surgery with swanson implant is more likely to cause postoperative complaints versus tornier implant [31].

In this study is about the daptomycin bone concentrations in patients with DFI undergoing surgery after multiple daptomycin infusions and to determine the daptomycin inhibitory for the predominant gram-positive species involved in DFI. Fourteen aduilt patients hospitalized with DFI treated with daptomycin and requiring surgical bone debridement and amputation were included in this single-center prospective study. Daptomycin penetrates bone well in patients treated for DFI. At an initially recommended dosage of 6mg/kg, bone concentrations are likely to be effective against staphylococcal infections and infections due to low-MIC enterococcus [32].

In this paper is about the pseudomonas stutzeri is infrequently isolated from clinical specimens, and if isolated, more likely represents colonization rather than infection. They has successfully treated with a single anti-pseudomonal agent for 6 weeks. The health care settings are demonstrated by our present cases. Considering the growth of organization [33].
In this paper the total calcaectomy was performed and the detect was reconstructed with a patient matched three-dimensional printed titanium calcaneal prosthesis. The postoperative was uneventful and at 5 month clinical follow up the patient was fully weight bearing with mobile ankle without pain. Short term clinical outcomes were satisfactory and early rehabilitation is possible [34].

VII. SIMULATION PROCESS

This report is the powered prosthetic knee joint powered by artificial muscles. A musculoskeletal system integrating artificial and biological muscles was simulated. The gait cycle was divided into seven modes based on the result of the simulation as shown in Figure. 7, the artificial muscles were pressurized to provide the biological knee torque. The test result shows the powered knee can produce a degree gait characteristics that are similar to normal gait [35].

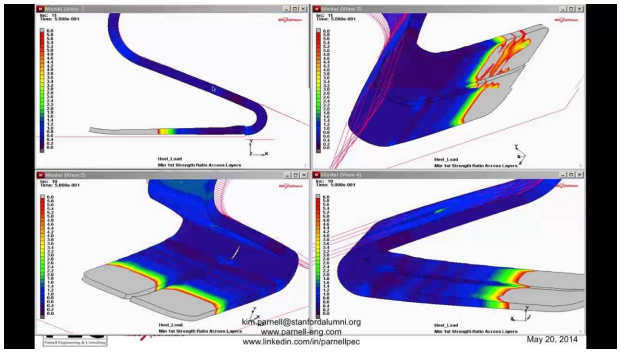

Figure.7 Simulation analysis

The rehabilitation of patient with limb loss requires the skills of many health care professionals to ensure that all needs are being met. Ideally, all of the health care specialties. For the process of fabrication the syme's prosthesis used the same type of prosthetic foot option as used in the traditional transtibial prosthesis, such as stationary ankle flexible endoskeletal foot and solid ankle cushion heel foot. As the result of this paper is to about the designing and fitting a prosthetic socket that is comfortable and meets the needs of the individual is then to the prescription. The expectation of the amputee to ensure that the prosthesis is functional and well used [36].

The ankle mimicking prosthetic foot is an energy efficient bionic foot using the principle of optimal power distribution. The main challenge behind this research is focused on retrieving as much energy as possible from the gait and to incorporate an electric actuator with minimized power consumption. In this article AMP-foot 3 prosthesis mechanism actuator design, control work. In this implies a greater reduction of the power requirements of the motor to only 50W while still being able to produce the peak output torque and power necessary for walking [37].

The prosthetic foot is the key element of prosthetic leg, the basis for a stable and efficient amputee gait. The body weight of a person acting on a prosthetic foot during roll-over was simulated by means of an inverted pendulum-like apparatus. This effective radius of curvature agrees closely

with that found in able-bodied people. This sensitivity of the prosthetic foot properties to alignment may also explain why numerous study failed to identify consistence difference between the tested prosthetic feet [38].

This study was to identify the influence of altered prosthetic foot stiffness on muscle and foot function using forward dynamic simulation of amputee walking. Thus, several muscle compensation were necessary. During the second half of stance, the intact leg to provide increased support and the residual leg results increased energy from the leg trunk for propulsion. Thus the given amputee function deficits, the prescription of appropriate foot stiffness is important for gait performance [39].

VIII. CONCLUSION

Energy storing and return prosthetic (ESAR) feet have been available for decades. These prosthetic feet include carbon fibre components, or other spring-like material, that allow storing of mechanical energy during stance and releasing this energy during push-off. This property has long been claimed to reduce the metabolic energy required for walking and hence improve walking economy. The 3D printing prosthetic foot has adaptive strategies in gait and the influence of different parts for prosthesis on gait. The energy conservation by compliant mechanism provides prosthetic restoration. It improves the physical and the psychological safety, improved quality of life and reaching potential. The stress and strain in prosthetic foot for trans-tibial amputees over the residual limb at phases of the gait cycle to be found using FEA method. The stress value obtained in the mid-stance of the gait cycle is the maximum value. A prosthetic foot design is created which is stable during the normal gait cycle. The stress distribution in load-bearing area of the prosthetic foot was studied. Current findings can prove to be helpful in the design, prescription and evaluation of future prosthetic feet.

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