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SIMULATION TECHNIQUES FOR BIOLOGICALLY ACTIVE PROSTHETIC FEET-AN OVERVIEW

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In the prosthetic field of study simulation aspect has now been the centre of research for many years. There have also been various applications of artificial limbs in case of natural limb dis-functioning patients. But both simulation and control modeling techniques are indispensible for knowing system performance and to generate an original approach of artificial organs. An overview of the applications of control theory to human prosthetic legs is being presented in this paper. This overview focuses mainly on control techniques, by far a theoretical overview and fusion of artificial limbs trying to mimic the efficacies of biologically active human limbs.

Keywords: Prosthetic Feet, SACH Foot, Dynamic Elastic Response (DER), Prosthetic Socket

1. Introduction

The act of balancing the distribution of mechanical stress, body weight and floor friction in contact makes the design of prosthetic legs a challenging task for the researchers. Stress much be distributed in such a way that load tolerant regions gets higher stress, in compared to regions of low load tolerance. Computer Aided manufacturing process have substantially advanced the field of limb prosthetic research, which led to various works on prosthetic limbs. An overview of all these recent works, with a focus on control strategies is being presented in this paper.

2. Control Strategies for Biologically Efficient Prosthetic Feet

The artificial feet concept has been around throughout several years and is developed chronologically by various researchers in this field. In ancient times, Rig Veda [1,2], the books of Greek historian Herodotus [3] give the earliest evidences of prosthetic feet. Throughout the years the concepts of prosthetic feet has been chronicled and was developing from time to time[4,5]. In the middle ages philosophical thoughts were progressing about prosthetic feet[6,7] and decades later Dutch surgeon, Pieter Andrannszoon Verduyn (Verduuin) published the first non-locking, below knee prosthesis similar to today's thigh-corset prosthesis[8]. In 19 th century wooden foot creating noise, which was referred as the' Clapper Leg' and later the 'cork Leg' were invented[9,10] which bears a striking similarity to today's modern prosthetic feet. Researches about prosthetic gait have been accumulated on the basis of kinematics, kinetics and energy expenditure.

Winter showed that the ankle produces more works than knee and hip muscles in Human walking analysis[11].The researchers found that the basis of the development of prosthetic feet is dependent largely upon human ankle-foot biomechanics[12].TT prosthesis, evolution from CF, via ESRF, upto current bionic feet is developed chronologically. The net energy generated in the ankle system in the time of stance and the total ankle-joint stiffness is measured by plotting a graph between ankle angle and ankle torque [12].Comparison between gait characteristics and energy expenditure of walking with conventional feet to walking with ESR feet were carried out in different studies. Menard [13] took biochemical measurements on TT amputees which generate a medial heel whip when wearing Flex-Foot Differences in self selected walking speed and energy expenditure during ambulation with a flex-foot versus conventional foot were investigated in Nielsen's study [14]. Walter's report showed that self selected speeds for both Flex-Foot and SACH foot were below normal values [15].

"Ambulation with a Flex-Foot at higher speeds tended to conserve energy", this concept was enhanced and reported by Macfarlane et al[16] and in the same year, a comparison between the use of a Flex-Foot and a conventional foot using subjective ratings 10 items of movement was carried out by Alaranta [17].Seattle foot, SACH foot and Flex foot on TT amputee gait were examined by Gitter in year 1991[18]. Again, a comparison between energy storing capabilities of

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SACH and Carbon Copy 2(CC) prosthetic feet during the stance phase of gait came out in a study of Barr[19]. In 1994,casillas made an investigation on the metabolic performances of both a Proteor foot and a SACH foot[20]. The experimental results of Perry and Powers showed that there are no significant differences in energy cost occurring among different feet from metabolic point of view[21][22]. Stiffness plots of human ankle during walking are presented and discussed in [23]. The design of a muscle like pneumatic actuator for TT prosthesis is discussed by Klute et al[23][24]. Concept and working principles of the specific actuator and also the different approaches to control PPAMs are discussed in [25][26]. A recent study by Sup et al represents the design of a pneumatically powered transfemoral prosthesis[27]. Au et al have structured a power prosthetic foot capable of mimicking normal ankle behavior[28]. The system was consisted of a spring and a 'Series Elastic Actuator' to provide desired requirements for normal walking[29][30]. The controller design is presented in[31][32]. But, due to some limitations in conventional prosthetic feet (SACH, Single-axis, SAFE, etc.) the rapid development in dynamic elastic response (DER) design (Seattle-lite, Flex Foot, Spring-lite, etc.) incorporating modern, light weight and elastic materials has been started[33][34][35][36][37]. Despite substantial improvements, new designs were unable to lower the metabolic energy cost of walking [38][39]. Further, the electromyographic studies carried out increased activity, both with respect to magnitude and duration, of the quadriceps and hamstrings during early stance as a major source of the energy cost[40][41][42][43][44]. Mechanical interface between a residual limb and prosthetic socket is considered to play a major role in design of lower limb prosthesis. So, the interface stress in prosthetic design its high sensitivity to features of socket wall and liner has been highly recommended [45][46]. Krouskop and Childress suggested computer-aided design in prosthetics to design the socket shape to achieve an interface stress distribution prescribed by a clinician [47][48]. FE models are applied to prosthesis later from a recent publication of Silver-Thorn et al [49]. FE estimates of interface normal stress on one subject's limb for three different types of AK socket shapes were compared with experimental measurements of interface pressure was modeled by Brennan [50].

3. Future Directions

Such encouraging results from the study of artificial limbs paves the way for a more promising future of artificial feet which is a great contribution to medical science, and further works for its improvement is going on.

4. Conclusion

During the last few decades, lot of clinical and research works have been carried out which points towards the future development of prosthetic studies. Our chronological overview study is an effort to visualize all the recent works based on human prosthetic feet as much as possible. This overview is not intended to be an exhaustive survey on this topic, though a sincere effort has been made to cover all the recent works as much as possible and any omission of other works is purely unintentional. Future works aims at making smarter prosthesis, by better integrating the state of art-neuroscience with the state of art- engineering, medicine, computer and social science.

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