Preface

The editors are pleased to present the book *Design, Development, and Optimization of Bio-Mechatronic Engineering Products* under the book series book series *Advances in Bioinformatics and Biomedical Engineering (ABBE)*. Book title was chosen as it converge upcoming technologies in biomedical engineering for the next decade. In present time of interdisciplinary research environment, "Biomechanics" is the key word for all major disciplines and many scholars are working in these areas. This book provides an insight for all researchers, academicians, post graduate or senior undergraduate students working in the area.

Utilising the principles and theories of mechanical engineering to biological systems is a multi disciplinary area known as Biomechanical engineering. It is a bioengineering subdiscipline, which stems from the scientific discipline of biomechanics. Biomechanics, specifically, is the study of biological systems such as the human body, combined with the study of mechanics, or mechanical applications. Using the skills learned from biology, engineering and physics for research and development of components for health care, such as organs that have been made from artificial materials, or new advances with prosthetic limbs. The creation of biomaterial, which is an artificial material that can be integrated into living tissue or can live in sync with biological material, is one of the biggest advances in medicine to this day. Those in this field might also hold the job of not only installing, but also adjusting, maintain, repairing, and providing technical help for all the biomaterial. Biomechanical Engineering is involved with creating and producing a variety of products in everyday use, from environmentally safe plastics to various foods, fabrics and medicines. A combination of engineering and biology, it's a fast-growing field with many new and exciting opportunities in genetic engineering and biotechnology. Students who love science, are good with design and appreciate tough analytical challenges are ideally suited to Biomechanical Engineering.

With advances in science and technology, the efforts to replicate natures work have been bolstered over the years. There are numerous techniques and technologies available today. Mechanical engineering with the aid of electronics contributes towards advancement of bio-mechatronics products like pacemakers, artificial kidney replacement, artificial hearts, and even new joints or limbs and also new advancement for hospital monitoring systems, to better and more accurately monitor human health. The replacement of ailing organs and lost limbs is now a reality. Bio-Mechatronic Engineering Products generally comes under three categories:

Prosthesis (plural: prostheses; from Ancient Greek prosthesis, "addition, application, attachment") is an artificial device that replaces a missing body part, which may be lost through trauma, disease, or congenital conditions.

Orthosis (plural: orthoses; Greek: Ορθός, translit. ortho, lit 'to straighten, to align') is "an externally applied device used to modify the structural and functional characteristics of the neuromuscular and skeletal system"

Replacement is a surgical procedure in which the affected body part is replaced by an implant i.e. dental implant, heart valve etc. Replacement surgery can be performed as a total replacement or a hemi (half) replacement.

Bio-Mechatronic Engineering Products are today playing an important and ever more effective role in improving the quality of life of people who otherwise would not have been able to lead a normal, healthy life. The words prosthetics', 'orthosis' etc. bring to the mind visualizations of plastic legs and arms without any form of articulation. Some even think of the wooden stump which would be used by seafarers as prosthetic legs and the hooks used in place of lost arms. While the history of Bio-Mechatronic Engineering Products does include these, today they could not be further from these popular images. This is a growing field, with new developments and advances being made almost every day. Advances in the fields of medicine and engineering have today given the world a new breed of Bio-Mechatronic Engineering Products which not just look and feel like the physiological part but also resemble them strongly in function.

The chapters in the book have been provided by Researchers and Academicians working in the field and have gained considerable success in the field.

The chapters in the book have been categorized in four sections, namely, Section 1: Review of the State of the Art; Section 2: Scaffold and Tissue Engineering; Section 3: Prosthesis: Design, Machining, and Optimization; and Section 4: Orthotics.

Section 1 contains Chapter 1 to Chapter 3, whereas Section 2 has Chapter 4, Section 3 consists of Chapter 5 to Chapter 8, and Section 4 with Chapters 9 and 10.

Section 1 of the book starts with Chapter 1 which provides a systematic survey of realm of biomechanics with the eyes of a mechanical engineer. A survey may help a beginner to have a general look on the broader aspects of the sub-domains of biomechanics. The chapter overviews the realm of biomechanics and provide an introduction to various areas with mention to researches carried out from a mechanical engineer's perspective. Prominent areas like biomechanics of human motion; bone and joint biomechanics; biomechanics of spine; biomechanics of head, shoulder and muscles; biomechanical analysis of heart and lungs; biomechanical analysis of arteries and veins and MEMS in biomechanics are explored. As the field is a subject in itself so the chapter focuses primarily on few prominent researches made in the last two decades in various domains.

In Chapter 2, a review of development of prosthetics and orthotics of lower body has been summarized. The history of these items is exhaustive yet very colourful. In this chapter, history and development of prosthetics and orthotics of the lower body has been elaborated for better understanding of the current state of the art in the fields. Due to enormous vast field, a historical perspective is provided followed by enumeration of the types of devices and techniques available without going into the form and function of individual products.

Chapter 3, the last chapter of the section, discusses about bioresorbable composites and Implants. The domain of medical sciences is flooded with different biomaterials in the form of ceramics, metal alloys, composites, glasses, and polymers etc. which have gained wide range acceptance. Bio-implants from such biomaterials have been constructed and used widely for different clinical applications. With the continual progress, biomaterials that may be resorbed inside the body have been developed. These have done away with the major challenge of removal of an implant after it has served its intended function. Important factors that are taken into consideration in design and development of implants from such biomaterials are mechanical properties, degradation rate, surface modification, rate of corrosion, biocompatibility and non-toxicity. Given the importance of such materials in clinical applications, the present chapter presents an overview of the bioresorable composites and their implants. The related properties and the functions served have been outlined briefly. Further, the challenges associated and the remedies to overcome them have also been delineated.

Section 2 is dedicated to Scaffolds and Tissue Engineering Applications and contains a single chapter: Chapter 4. The chapter discusses a revolutionary manufacturing process namely 3D bio-printing which is currently being used in medical fields specially in preparing of bone scaffolds and tissue engineering area. With the help of new biocompatible material like polymers, bio-gels, ceramics, this technology have created a new site in advanced tissue engineering and scaffolds manufacturing area. Moreover the beauty of the system is that, with the use of CAD file software, any design can be prepared irrespective of its complexity. The chapter not only discusses the novel technique but also describes and analyses machine's printability characteristic, cross-linking time and biocompatibility of printing objects as well as bio-ink. In this chapter, different types of scaffold preparing methods, bio-printing process are discussed which are used in scaffold and tissue engineering area.

From here the book starts with Section 3 which groups the Prosthesis part.

The first chapter of the section, Chapter 5, illustrates the design of a prosthetic ankle complex. Nature has, over a large span of geological time, engineered near perfect solutions to most problems humans face today. Motion of the limbs is one such area and the cutting edge in the development of effective prostheses is biomimetics. Limb prostheses have been used by mankind for the better part of known history and most of the technology currently available in prosthetics is not exclusively new. However, modern prosthetics either are uncomfortable and the lack of flexion affects the gait of the patient or too expensive for a large segment of the populace. This chapter seeks to study the mimicry of physiological systems through the design for an ankle prosthesis which includes a passive damper and mimics the shape and behaviour of the natural ankle joint.

The real challenge after the design is manufacturing of a prosthetic component. In Chapter 6 a non-traditional machining technique electrochemical micromachining (ECMM) has been introduced to create a proper component which can be used clinically. This chapter aims at developing an optimized model for flow analysis of electrolyte in inter-electrode gap to obtain optimal process parameter for machining. Experimentation has been done to associate the findings of optimized output in ECMM such as material removal rate (MRR), overcut and depth. Influence of voltage, feed rate, concentration, pulse on/pulse off ratio and inter-electrode gap (IEG) was investigated and finally optimized using response surface method. The outcome was validated using ANOVA.

On producing a component for prosthetic application, it is required to ascertain excellent surface finish which is usually in microns. The most sophisticated instrument for identification and measurement for the same is Atomic Force Microscope. But acquisition of experimental data from atomic force microscopy (AFM) sometimes has artefacts that distort the information contained in the image. Such artefacts can be very delirious especially for sensitive applications such as in biomedical and microelectronics. Chapter 7 deals with correction of artefacts and optimization of Atomic Force Microscopy imaging. In order to elaborate the subject a case of thin aluminium films has been considered. The chapter illustrates the correction of the artefacts resulting from tapping mode imaging. It also shows the application of Taguchi optimization technique for reducing artefacts during AFM imaging. Using AFM images of Al films Fourier filtering is illustrated as a useful technique for the correction. Taguchi optimization was employed to determine the optimal scan rate, scan size, integral and proportional gains in minimizing the size and number of artefacts at the imaging stage. The correction technique was shown to improve the morphological information of the AFM images while the Taguchi method was effective for determining the best imaging conditions for AFM analysis.

The next chapter and last chapter of the section, Chapter 8, elaborates another hindrance in the biomechanical product development, the induced stress. During production, machining etc. generally stresses are induced which requires to be minimised for effective service and life span. In this chapter, the induced stress concentrations are minimised via the optimisation of tab design configurations. Stress concentration obtained via finite element analysis were used to develop a full factorial design for statistical analysis and compared with a Taguchi, Taguchi- multi response and Taguchi-genetic algorithm optimisations. The chapter concludes that in order to minimise the stress concentrations, low values of tab stiffness, thickness and taper angle were required while the adhesive thickness was increased. The conclusion was supported with neumerical data.

From here the book starts with Section 4 which groups the Orthosis part.

The section starts with Chapter 9 which reviews the processing and characterization of materials for Orthotic Devices. The recent utilization of fibre reinforced composites as bio-material in fabrication of orthoses have accelerated the research in finding the most favourable and compatible combinations of bio-polymeric composites. The strength, flexibility, biological compatibility, wear strength, durability and fatigue strength can be easily altered considering different combinations of polymers and their reinforced structures. The major drawback presently faced by researchers is the degree of mimicking the behavioural and functional aspects of body muscles and bones, by the synthetic polymeric composites more appropriately. In this chapter, a thorough review of the presently used various types of polymeric composites employed as materials for orthotic implants, their properties, and their applications based on their availability for common people (cheap cost), availability for wide variety of specialized functions and for the best quality and compatibility factor. The common orthotic products mainly used on patients to support their weak joint or limb and their most favourable material properties or material of choice was discussed in details. A few characteristic determination tests for polyethylene composites performed for material properties like ultimate tensile strength, elastic modulus, thermal degradation properties, bending strength and surface resistance are taken into consideration to validate the usability of polyethylene composites and their improvement trend in modification of the combination of fibres and matrix.

Chapters 10, the last chapter of the section and the book, discusses the application of electrochemical micromachining for machining in micro level devices required for orthotic products which are usually made of harden materials. In present chapter a model for flow analysis of electrolyte in inter electrode gap is designed to obtain optimal process parameter for machining. The geometric model used in this simulation consists of cylindrical workpiece, an inlet allowing the flow of sodium nitrate solution as electrolyte to the machining zone and a cylindrical tool with flat end. Electrolytic flow simulation is incorporated using computational fluid dynamics by ANSYS–CFX for finding pressure variation, streamline velocity pattern, turbulent energy, and temperature contour in inter electrode gap (IEG).

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