

TABLE OF CONTENTS

Acknowledgement	i
Abstract	ii
List of Abbreviations	viii
Glossary of Prosthetic and Orthotic terms	xii
List of figures	xx
List of tables	xxx
1 INTRODUCTION	1
1.1 Prosthetics and Orthotics (P&O)	1
1.1.1 Prosthetics	1
1.1.2 Orthotics	7
1.1.3 Materials used for P & O devices	9
1.2 Composite materials	11
1.2.1 Classification of composite material	11
1.2.2 Overview of advantages and limitation of composite material	13
1.2.3 Current status and future prospects	15
1.3 Additive manufacturing -evolution	17
1.3.1 Additive Manufacturing process	18
1.3.2 Research opportunities in AM	20
1.4 Organization of thesis	21
2 LITERATURE REVIEW	22
2.1 Polymers and its composites	23
2.2 Prosthetics and Orthotics technological development	23
2.3 Material, manufacturing and testing of Prosthetic / Orthotics systems by traditional method and advanced manufacturing methods	25
2.3.1 Traditional prosthetic/orthotics systems	25
2.3.2 Prosthetic/Orthotic systems by advanced manufacturing method	29
2.4 Case studies on prosthetic and orthotics elements using finite element analysis, design optimization, and development process	34

2.4.1 Case studies on prosthetic elements	35
2.4.2 Case studies on orthotics elements	40
2.5 Patents	45
2.5.1 Patents related to prosthetic elements	45
2.5.2 Patents related to orthotics elements	49
3 RESEARCH STATEMENT AND OBJECTIVES	54
3.1 Research motivation	54
3.2 Problem definition	56
3.3 Need for study	57
3.4 Research objectives	58
4 HUMAN BODY ANTHROPOMETRY	59
4.1 Segment length	62
4.2 Segment mass and center of mass	63
4.3 Properties of density, mass, inertia and radius of gyration	63
4.4 Forces and moments in shoulder joints	65
4.5 Forces and torque in leg joints	68
5 DESIGN & SIMULATION APPROACH OF PROSTHETIC FOOT	72
5.1 Design approach	72
5.2 Participatory approach	73
5.3 Alternative prosthetic foot models design approaches	75
5.4 Simulation approach	78
5.5 Simulation data summary for various prosthetic foot models	104
5.6 Design for manufacturing of the prosthetic foot model	107
6 DEVELOPMENT & TESTING OF NOVEL PROSTHETIC FOOT	114
6.1 Development process of novel prosthetic foot	114
6.2 The gait cycle's phases	128
6.3 Testing of novel prosthetic foot element below knee amputation level patients	132
6.3.1 Patient's case study	133

6.4	Result and discussion of patient's test	153
7	DESIGN AND SIMULATION APPROACH OF ORTHOTICS ELEMENTS	154
7.1	Human wrist and foot brace	154
7.2	Orthotic manufacturing techniques	156
7.2.1	Conventional techniques for making of orthotic	156
7.2.2	The orthotic additive manufacturing technique	157
7.3	Result and discussion for orthotic devices	164
7.4	Cerebral Palsy (CP) walker	165
7.5	Participatory approach and identify design requirements for CP walker	167
7.6	Design and simulation approach for CP walker	171
7.7	Result and discussion for CP walker	178
8	RESULT AND DISCUSSION	180
8.1	Result and discussion for prosthetics elements	180
8.2	Result and discussion for orthotics elements	183
9	CONCLUSION AND FUTURE SCOPE	186
9.1	Conclusion	186
9.2	Future scope	188
	REFERENCES	190
	APPENDIX	206
A.	Questionnaire for patient satisfaction survey	206
B.	Clinical permission	210
C.	Prosthetic foot various configuration models analysis data	211
D.	CP walker material analysis data	252
E.	List of publications	260