PROJECT SEMESTER REPORT

(Project Semester Jan-July 2018)

CAD DESIGN SOLUTIONS

Solidworks & Knee Exoskeleton

Submitted by

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(Deemed to be University)

DECLARATION

I hereby declare that the project work entitled ("Knee-Exoskeleton") is an authentic record of my own work carried out at (Thapar Institute of Engineering and Technology) as requirements of six months project semester for the award of degree of B.E. (Mechatronics Engineering), Thapar Institute of Engineering and Technology, Patiala, under the guidance of (Dr. Supreet Bhullar) and (Dr. Ashish Singla), during Jan to July, 2018.

(Signature of student)
(Name of Student)
(Roll No.)

Date: ___________________

Certified that the above statement made by the student is correct to the best of our knowledge and belief.

Dr. Supreet Bhullar
(Assistant Professor)

Dr. Ashish Singla
(Manager)

ACKNOWLEDGEMENT

I would like to thank Associate Professor **Dr. Supreet Bhullar and Dr. Ashish Singla** had given me his full support in guiding me with stimulating suggestions and encouragement to go ahead in all the time of the report.

I am also grateful to all the faculty members of the Department of Mechanical Engineering for their advice and support.

Arnab Paul

Abstract

We know that the world is revolutionizing fast. The changing world offers all kinds of possibilities and comfort. The technology is progressing everyday and making our lives better. Technology has not only provided comfort and entertainment over the past few years, but it has played a vital role in making us feel safe and secure.

According to population statistics it is estimated that the people aging more than 65 will rise to almost 98 million in the next 40 years which means there need to be advancement in technology that can help old people in maintaining their independence in terms of mobility and strength. For this researchers have developed many exoskeleton devices which use actuators and sensors to help the people in sitting, standing and walking. This seminar work primarily discusses the different type of exoskeletons and CVT that have been introduced in regard of the same and various technological aspects associated with them which includes various control strategies, materials, costs and other characteristics. Exoskeletons are becoming a very powerful tool to help therapists in the rehabilitation of patients who have suffered from neurological conditions, in particular stroke or spinal cord injury.

In addition to this some new concepts are introduced which will help in modification of existing resources and also making this technology available for everyone. Further the areas are discussed which the author will like to work on for his future research activity in field of designing exoskeletons.

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Chapter 1

1.1 Cad Design Solutions

Cad Design Solutions is an education institute, a sub branch of the Ideas Design Solutions (P) Ltd. Founded in 1997 IDSPL has grown rapidly to become the leading providers of CAD/CAM/CAE/PDM/KBE/RE solutions to the mechanical industry in India. With a “Customer Centric” focus, IDSPL has always been very attentive to the changing manufacturing landscape and customer feedback to enhance the product portfolio as well as the customer support mechanism to ensure that our customers get nothing but the best.

Cad Design Solutions provide training in solidworks, certification under Dassault and an opportunity to work in various industries where solidworks is a key software used for designing. It has well equipped labs with good internet speed with systems to work on.

1.2 Dassault Systemes

Dassault Systèmes, "The 3DEXPERIENCE Company", is a French multinational software company that develops 3D design, 3D digital mock-up, and product lifecycle management (PLM) software. Bernard Charlès is the Vice Chairman, Chief Executive Officer. Dassault Systèmes develops and markets PLM software and services that support industrial processes by providing a 3D vision of the entire lifecycle of products from conception to maintenance.

Dassault Systèmes has three sites as headquarters: one in Europe (VélizyVillacoublay, France), one in North America (Waltham, Massachusetts), and one in Asia (Shanghai, China).

1.3 History

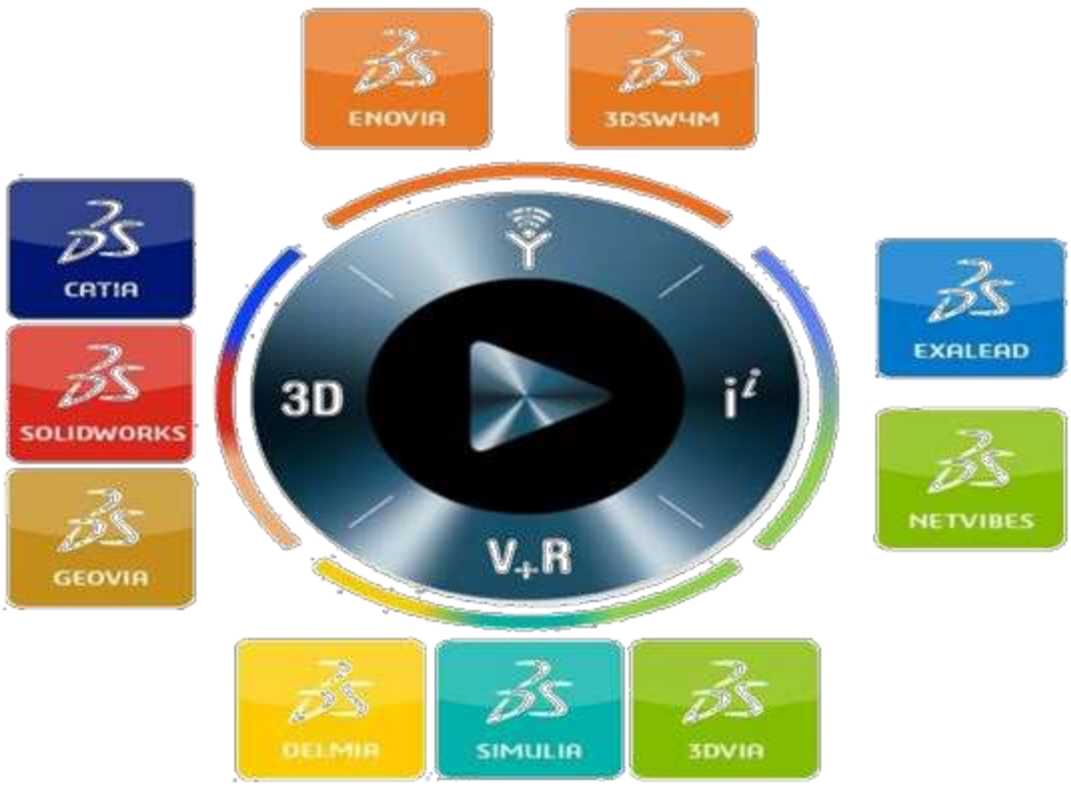
Dassault Systèmes is a subsidiary of the Dassault Group created in 1981 by Avions Marcel Dassault to develop a new generation of computer-aided design(CAD) software called CATIA. Dassault Systèmes moved its corporate headquarters from Suresnes to Velizy-Villacoublay in November 2008. This new European headquarters, located in the south-western suburbs of Paris, is commonly called 3DS Paris Campus. Another campus was established in 2011 in Waltham, Massachusetts, west of Boston (United States) and is called 3DS Boston Campus. Dassault Systèmes was a signatory to the French Small-Medium Enterprise business development Pact (SME Pact) in May 2008.

1.4 Products

1. **CATIA** – It is the leading brand for product design and experience, was Dassault Système's initial product. It is the PLM solution for 3D collaborative creation
2. **SolidWorks** - SolidWorks products span 3D mechanical design software, simulation, product data management, and collaboration. They are used by companies in the machinery, medical, consumer, tool and die, electrical and power sectors, and by suppliers to the aerospace and automotive industries.
3. **DELMIA** - DELMIA is the Company’s PLM digital manufacturing software. It allows manufacturers to virtually define, plan, create, monitor and control all production processes, from the early process planning and assembly simulation to a complete definition of the production facility and equipment.
4. **ENOVIA** - ENOVIA provides a framework for collaboration for Company's PLM software. It is an online environment that involves creators, collaborators and consumers in the product lifecycle.
5. **SIMULIA** - SIMULIA automates standard simulation processes and can be deployed across any organization, distributing workload across the computing resources, and managing the simulation results to improve collaborative decision making.
6. **3DVIA** – It is a suite of products designed to help individuals across the enterprise to search, navigate and collaborate in 3D in real-time over the Internet. It enables users to deliver assembly procedures, technical illustrations, and marketing materials using 3D

images and other 3D data that remain compatible with other products.

7. **EXALEAD** – It is an infrastructure for search engines with search-oriented applications and Internet. Exalead is a global provider of information access software for the enterprise and the Web.
8. **NETVIBES** – It provides intelligent dashboards to monitor and manage Web information in real-time.
9. **GEOVIA** - It delivers solutions to model and simulate the planet, primarily to support mining.



Chapter 2

2.1 Introduction to Solidworks (Dassault Systèmes)

Jon Hirschtick

CEO,

Solidworks Corporation

SolidWorks is a solid modeling computer-aided design (CAD) and computer-aided engineering (CAE) computer program that runs on Microsoft Windows. SolidWorks is published by Dassault Systèmes. Over two million engineers and designers have been using this software at more than 165,000 companies as of 2013. Solidworks Corporation was founded by Jon Hirschtick, a graduate of Massachusetts Institute of Technology on December 1993.

DS Solidworks Corp. has sold over 3.5 million licenses of SolidWorks worldwide. The developer of Solidworks is Dassault Systèmes and it runs on Microsoft Windows. The software is written on Parasolid Kernel.

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2.1 Modelling Technology:

SolidWorks is a solid model maker and it utilizes a parametric feature-based technique which was initially developed by PTC (Creo/Pro-Engineer) to create models and assemblies of parts and structures. The software is written on Parasolid-kernel owned by the UGS Corporation. The key characteristics features of solidworks can be generalized through the following:

2.1.1 Parameters

It refer to constraints whose values shall determine the shape, size and structure for the geometry of the model or assembly. This includes numeric parameters, such as line and its length or circle and its diameters. Geometric parameters include tangent, parallel, concentric, horizontal or vertical, etc. Numeric parameters is associated with each other through the use of relations, allowing them to capture design intent.

2.1.2 Design Intent

It shows how the user creator of the part wants it to respond to changes and updates being done in software. For example, if we want to create a hole at the top plane of a beverage soda can, it will stay at the top surface, regardless of the height/size of the same. SolidWorks allow the user to specify that it is a hole and is a feature applied on the top surface, and will then honor their design intent despite whatever they want to put as dimensions for the can like height and size.

2.1.3 Features

Refers to the building blocks of a part. Shapes and operations that construct the part are the blocks. Shape features starts with a 2D or 3D sketch of shapes such as bosses, holes, slots, etc. These shapes are later extruded or cut to add or remove material from the part. Operation features are usually not sketch-based, and they include features such as fillets, chamfers, shells, holes, applying draft to the faces of a part, etc.

2.2 HISTORY

The history of solidworks has always been surrounded by the company's desire to create easy and user efficient software to develop 3-d models and design. Solidworks was developed by graduate of MIT Jon Hirschtick and a group of engineers in December 1993 and has since led the way into the advanced digital design and simulation after Creo/Pro-Engineer. SolidWorks is currently marketing several versions of the SolidWorks CAD software in addition to eDrawings, a collaboration tool, DraftSight, a 2D CAD product.

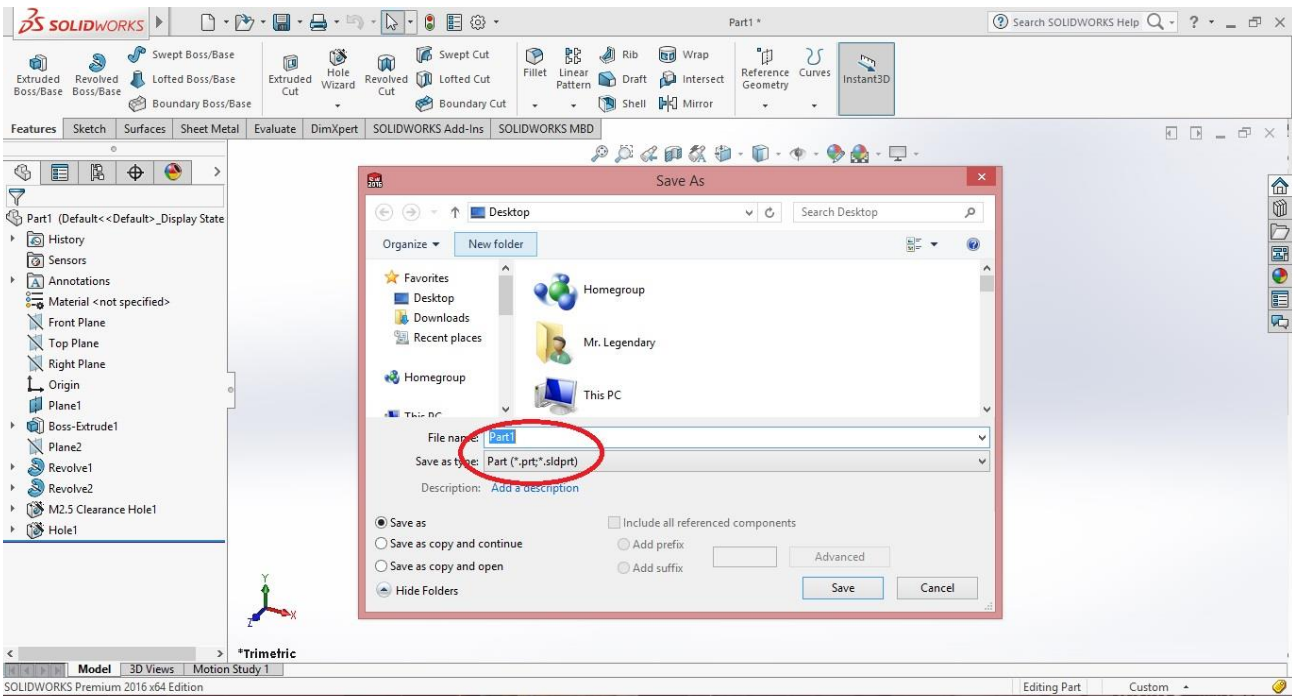
Table **2.2.1Generations of Solidworks**

Name/ Version	Version Number	Version history value	Release Date
Solidworks 95	1	46	November 1995
Solidworks 96	2	270	Early 1996
Solidworks 97	3	483	Late 1996
Solidworks 97 plus	4	629	1997
Solidworks 98	5	817	1997

Solidworks 98 plus	6	1008	1998
Solidworks 99	7	1137	1998
Solidworks 2000	8	1500	1999
Solidworks 2001	9	1750	2000
Solidworks 2001 plus	10	1950	2001
Solidworks 2003	11	2200	2002
Solidworks 2004	12	2500	2003
Solidworks 2005	13	2800	2004
Solidworks 2006	14	3100	2005
Solidworks 2007	15	3400	2006
Solidworks 2008	16	3800	July 1, 2007
Solidworks 2009	17	4100	January 28, 2008
Solidworks 2010	18	4400	December 9, 2009
Solidworks 2011	19	4700	June 17, 2010
Solidworks 2012	20	5000	September, 2011
Solidworks 2013	21	6000	September, 2012
Solidworks 2014	22	7000	October 7, 2013
Solidworks 2015	23	8000	September 9, 2014
Solidworks 2016	24	9000	October 1, 2016
Solidworks 2017	25	10000	September 19, 2016
Solidworks 2018	26	11000	September 26, 2017

2.3 File Format

SolidWorks files (before 2015) use the Microsoft Structured Storage file format. It means that there are various files embedded in each SLDDRW (drawing files), SLDPRT (part files), SLDASM (assembly files) file, including preview bitmaps and metadata sub-files. Various third-party tools (see COM Structured Storage) can be used to extract these sub-files.



Solidworks file extension 1

2.4 Market and Competition

Solidworks is very good for pointing and check the design for weak points and safety issues. However it is not the best in terms of image rendering which can be found to be better in Catia.

However SolidWorks is one of the most widely used CAD programs on the market due to its relatively lower cost, powerful 3D rendering abilities and friendlier-than-average interface.

1	AutoCAD
2	ZWCAD
3	SolidWorks
4	TurboCAD Deluxe
5	PTC Creo
6	SketchUp Pro
7	CATIA
8	ProgeCAD
9	BricsCAD Classic
10	DesignCAD 3D Max

SolidWorks is compatible with DWG, DXF, STEP, STL, allowing us to work with files from AutoCAD and SketchUp Pro as well as 3D print your designs. It also allows you to work with PDFs and various raster image files, so you have more flexibility when working with your designs.

2.5 Specification

<table>
<tr>
<td>User Interface
Ease of Use
Custom Tool Palette
Drag and Drop Functionality
Command Line
Measure Command Tool
Import Existing Designs
Macros
Setup Manager</td>
<td>Operating Systems
Windows 10
Windows 8
Windows 7</td>
</tr>
<tr>
<td>Design Tools
2D Drawing Tools
3D Modeling Tools
Hatching
Textures
Transparency Options
Lighting Effects
Photorealistic Rendering
Wall Tool</td>
<td>Help & Support
Email
Phone
Video Tutorials
Forums</td>
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<tr>
<td>File Compatibility
DWG
DXF
STEP
STL
PDF
Image Files
Mobile App</td>
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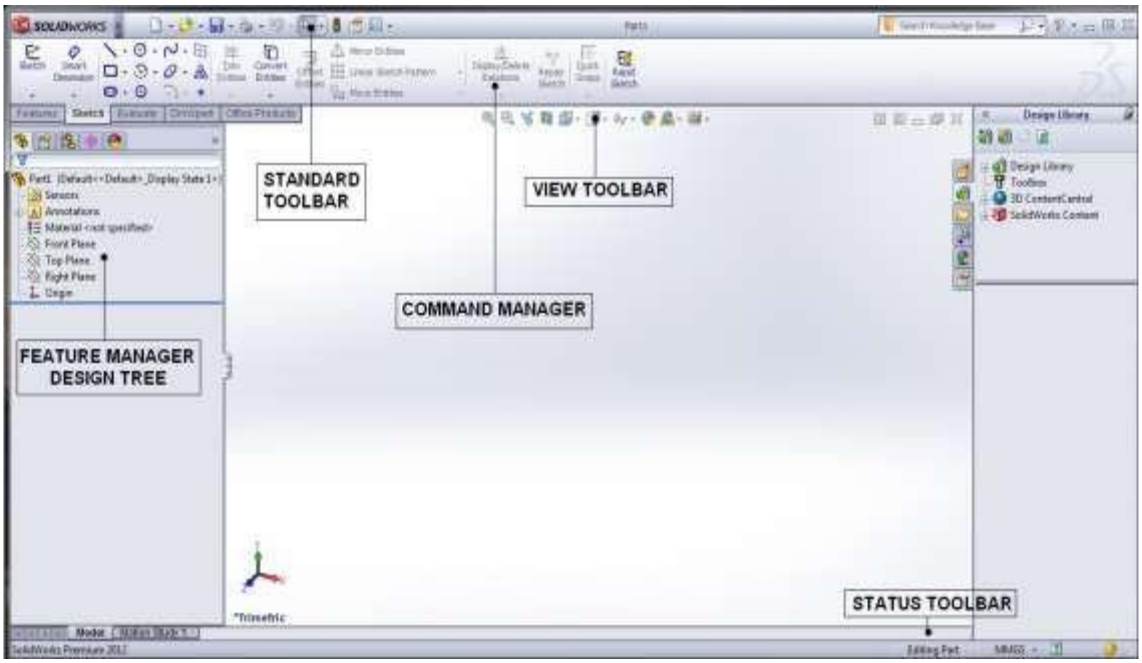
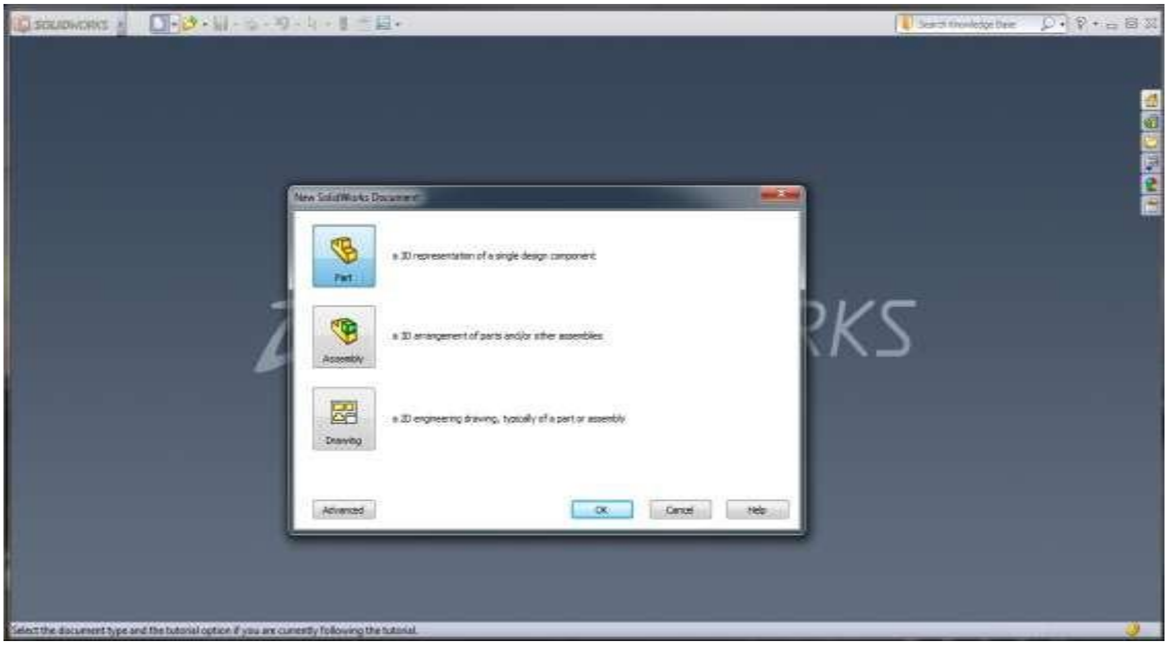
2.6 Solidworks User Interface

The interface is native windows interface and it behaves like window interface.



Solidowrks user interface

2.7 Components or Types



Components or types

- Part- Part constitutes the various sub part or components which can be put together to create a entire machine or subject. Parts can be made using 2-D and 3-D sketch with dimensions and other feature like extrude, revolve etc

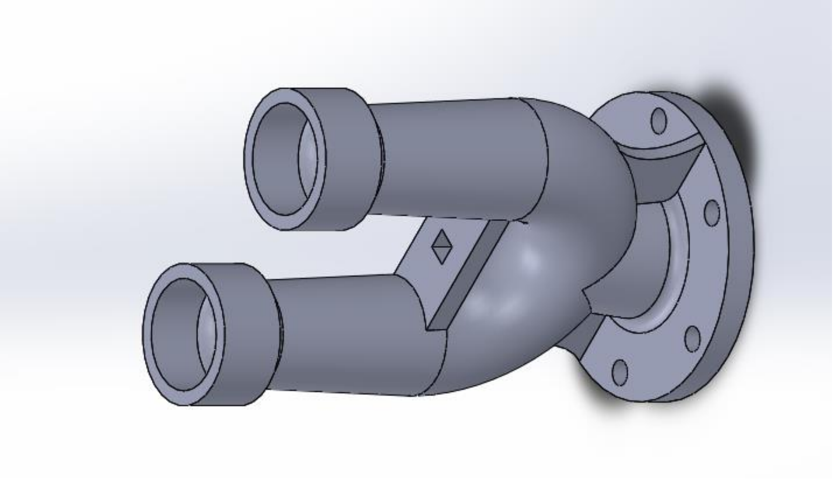
- Assembly- Assembly is combination of parts into making a whole entire system. It constitutes mating each component to the other with some set of constraints like axis-axis coincide, edge to edge coincide, face to face distance etc.

- Drawing- It is the drawing representation of parts and assembly which shows sections, whole parts along with their dimensions and set of instruction which include size and type of hole, screw-type, pattern etc.

Example:

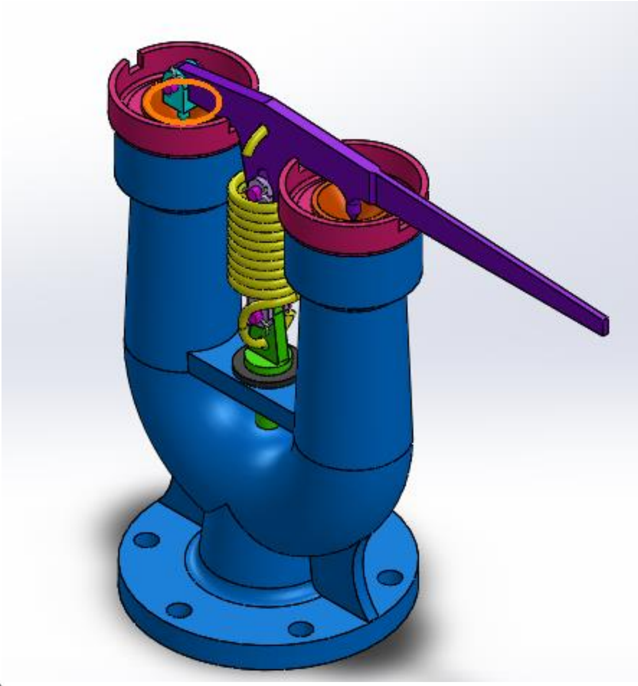
1. **Safety Valve**:

   Parts: It constitutes parts like housing, lever, spring, valve seat, valve etc.



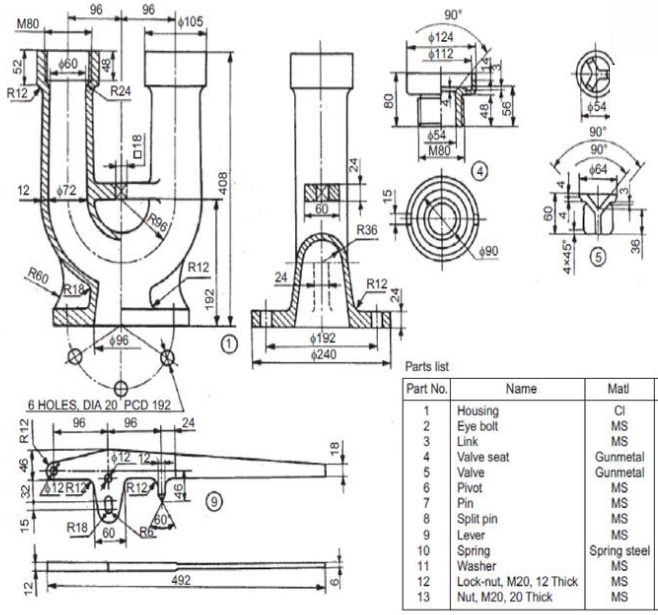
Housing

Assembly: It is the assembly of parts to make the complete setup for the rams bottle safety valve.



Safety Valve

Drawing: From the given diagram we can see that it shows the drawing representation along with dimensions and instructions.



Parts list

Part No.	Name	Matl	Qty
1	Housing	CI	1
2	Eye bolt	MS	1
3	Link	MS	2
4	Valve seat	Gunmetal	2
5	Valve	Gunmetal	2
6	Pivot	MS	1
7	Pin	MS	3
8	Split pin	MS	3
9	Lever	MS	1
10	Spring	Spring steel	1
11	Washer	MS	1
12	Lock-nut, M20, 12 Thick	MS	1
13	Nut, M20, 20 Thick	MS	1

Safety Valve drawing

Chapter 3

3.1 Mahabir Mechanical Works

They are specialist in rice milling machinery, since 1977 such as Pneumatic Paddy De Husker, Paddy Separator, Paddy De Husker, Rice Cone Polisher, Vertical Rice Whitener, Plant Shifter, Mini Type Paddy De Husker, and Horizontal Rice Polisher. Mahabir Mechanical Works is a professionally managed organization which has accepted the challenges to produce quality that sets the standards of the country. Since its inception the company has scaled many unsurpassed heights in the business. The company is led by professionals with distinguished track records. The company's pursuit for excellence is a never ending process.

3.2 Foundary Division

Foundary 1

Foundary 2

3.3 Products

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3.4 Purpose

During the training process we were sent to Mahabir Mechanical Works to learn their process of making hand cut machines and its parts and the principle of each machine. We also learnt the various principles and working of the different machines. The main purpose to visit their industry was to work on a small live project where we had to take dimension of a machine and to render it manually using dimensions on solidworks.

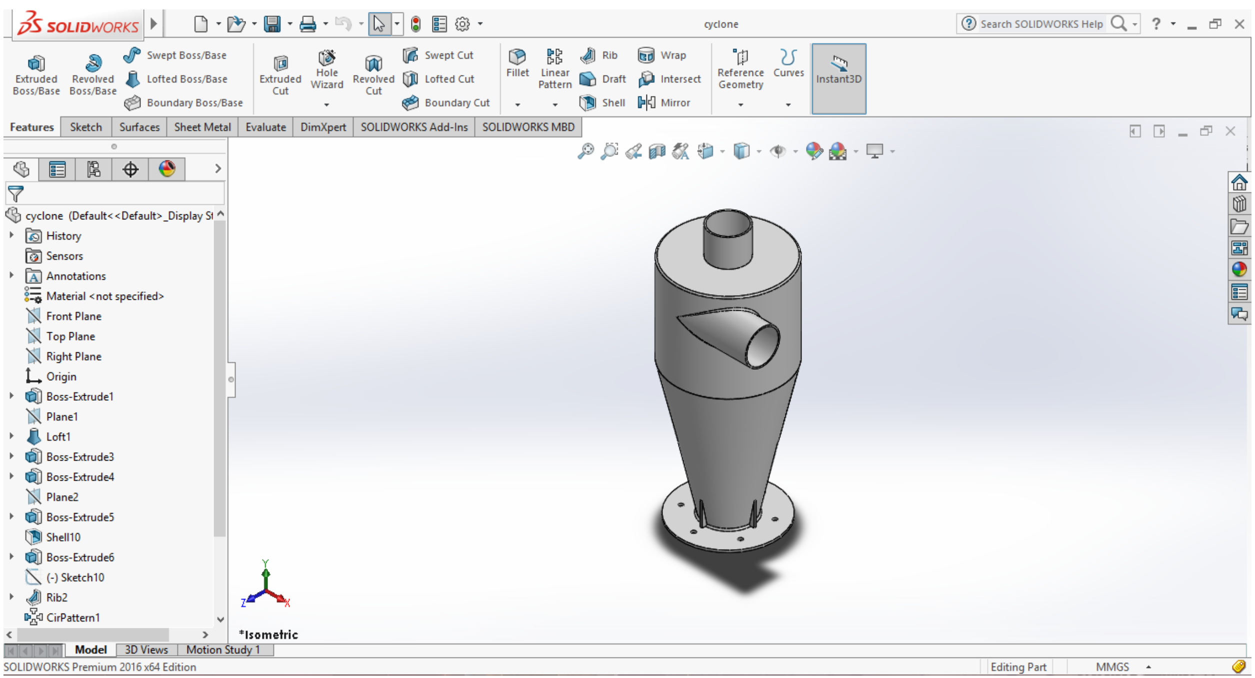
3.5 Observation (production)

- The workers did most of the cutting of the sheets of metal through a torch cutter. They manually cut sheet of metal by using an a cut part of sheet metal that has already been cut and use it for reference to cut out more pieces of the same part.

3.6 Solidworks Render

We were asked to design the overall outline structure of any machine by taking their dimension into consideration and render it into solidworks as our task. We however could not define the internal parts of the machine as we were not allowed with spare parts for analysis of dimensions and mechanism.

I created the design of cyclone portion of the solidworks design of a cyclone separator which gives us the glimpse of how we can render the design of each and every machine and come up with analysis which can be further used in the industry for mass production and learn about the stress strain and other analysis features which can be effective in improving the design of each machine part for better longitivity.



Cyclone Shell of a cyclone separator

Chapter 4

4.1 Vaani Precision Industries

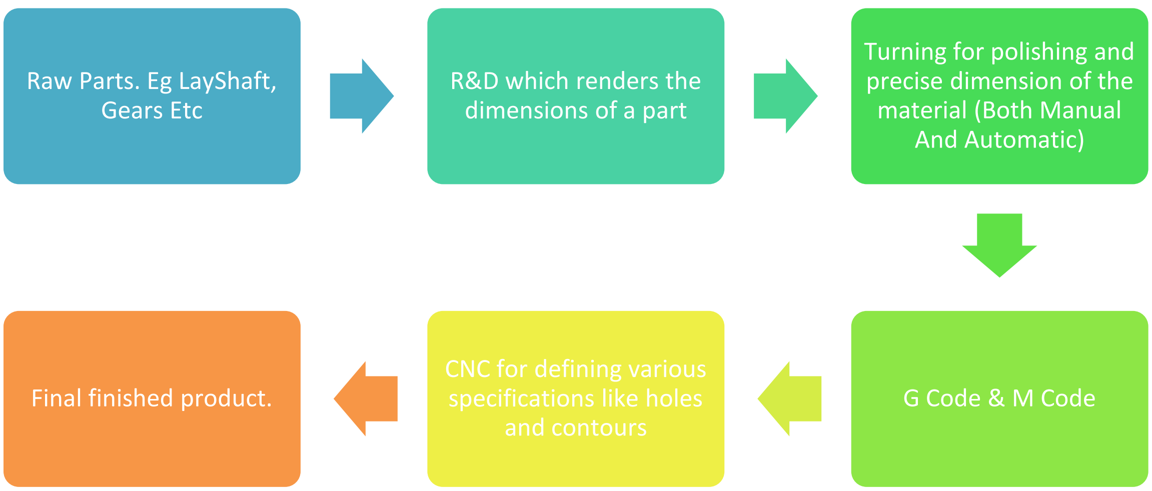
It is a renowned manufacturer of precision components used in engineering industries like Automotive, Defence & Aeronautics and established in the year 2005. We process & manufacture our complete range of components with their latest technology of CNC MACHINES. Managing Director Mr. K. M. Khosla having the experience of three decades into precision engineering, has able to achieve QUALITY, CONTROL & DELIVERY SCHEDULES. We manufacture components as per provided drawing & technical specification according to their end use of the segment.

4.2 Vision

Company specializes in turning process of transmission shafts up to 850mm length along with precision gears & pinions for automotive industry.

4.3 Objective And Manufacturing process

To learn the overall working of cnc and lathe machine.



4.4 Certification

On April 26th, 2018, we appeared for the test of CSWA(Certified Solidworks Associate) which is a certification by Dassault Systemes allowing us to prove our knowledge of Solidworks which will stand us out from the competitive job market.

The CSWA certification is proof of your SOLIDWORKS® expertise with cutting-edge skills that businesses seek out and reward.

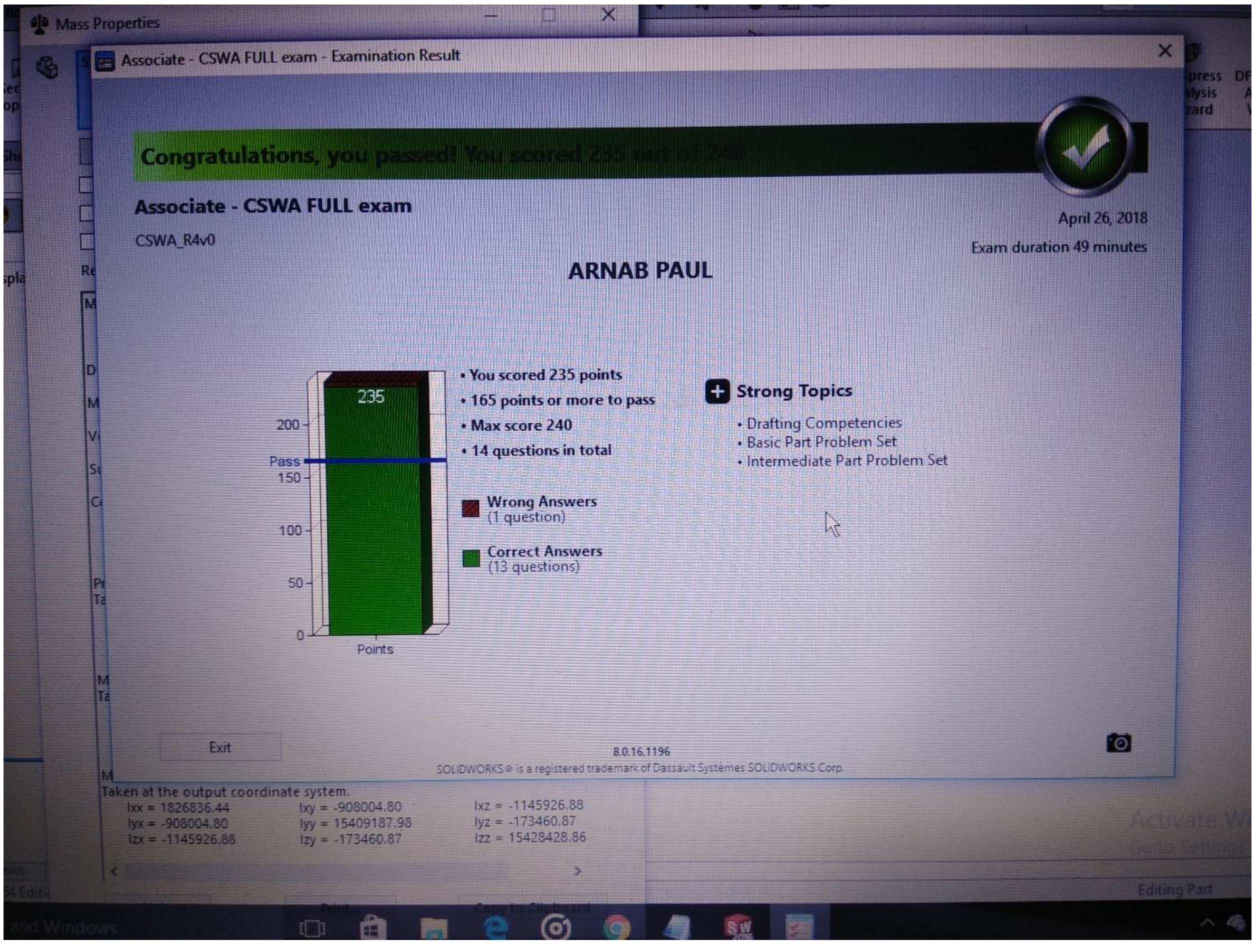
Duration: 3 Hrs.

Exam features hands-on challenges in many of these areas:

- Sketch entities - lines, rectangles, circles, arcs, ellipses, centerlines
- Sketch tools - offset, convert, trim
- Sketch relations
- Boss and cut features - extrudes, revolves, sweeps, lofts
- Fillets and chamfers
- Linear, circular, and fill patterns
- Dimensions
- Feature conditions – start and end
- Mass properties
- Materials
- Inserting components
- Standard mates - coincident, parallel, perpendicular, tangent, concentric, distance, angle
- Reference geometry – planes, axis, mate references
- Drawing views

- Annotations

4.4.1 Certificate



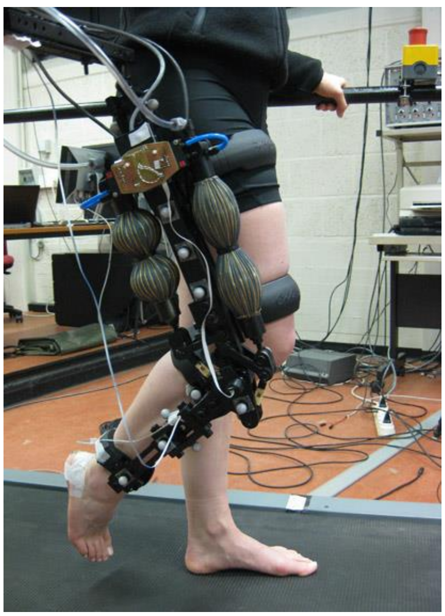
Certificate

Chapter 5

Knee Exoskeleton

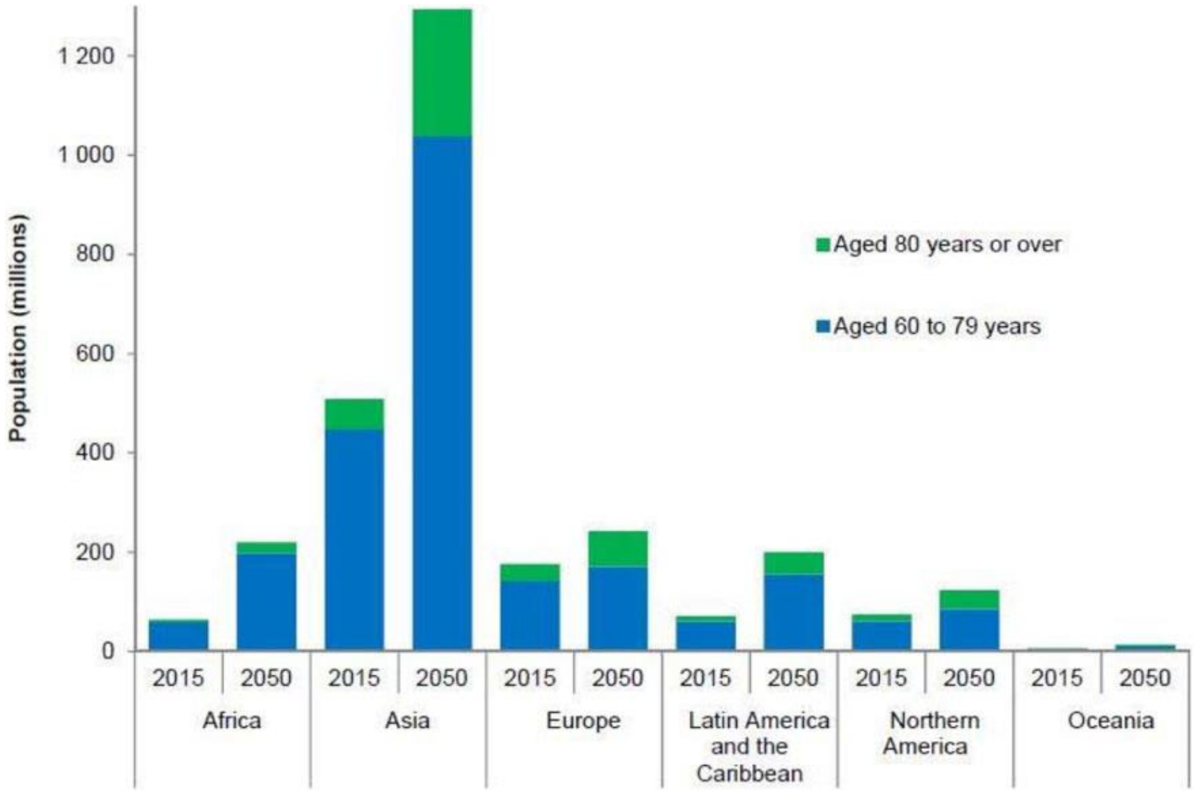
Introduction

The term 'wearable robotics' came into general existence in the 1960s when research efforts started to focus on developing load augmentation and rehabilitation systems,1 and interest continues to grow with new innovations reported regularly. Essentially, such exoskeletons (or 'exos') are wearable systems, which can help human wearers perform a variety of tasks such as pick-and-place heavy objects, carry heavy loads, reduce the burden in physically demanding tasks and apply rehabilitation treatment to patients who have suffered major trauma such as stokes and so on. Exoskeletons can also be used to assist in carrying out normal daily living tasks such as walking, carrying objects, ascending/ descending stairs, perform sit-to-stand transfers (and vice versa) and moving around generally if the physical abilities of a person have degraded.



Exoskeleton

The primary thrust of exoskeleton research has focused on medical applications such as supporting mobility of spinal cord injured (SCI) persons and rehabilitation of major trauma patients as well as some military application to allow soldiers to carry heavy equipment while marching at high speeds in rough terrain. Medical exoskeletons are medical electrical equipment which is used to provide mobility to physically disabled, injured or weak persons, who are unable to walk due to a variety of medical reasons such as SCI, neurological disorders, major trauma like stroke, cerebral palsy and so on.

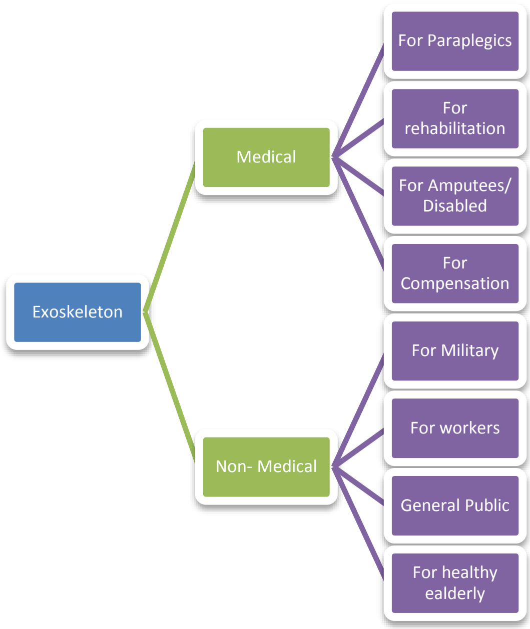


Overall population according to age

Figure shows that the proportion of elderly persons is rapidly increasing throughout the world. It can be noted that the projected elderly population in Asia and the percentage in Europe is growing at an alarming rate, and there is an urgent requirement to develop assistive and medical technologies to meet the needs of this significant segment of the society. Arthritis affects nearly half the elderly population and is a leading cause of disability as arthritis in knee is the price we pay for standing upright whole life. The concept of ‘Off legs’ refers to the elderly patients who were previously able to walk and move actively without any problem but due to sudden deterioration because of some disease or infection in older age, they lose their mobility.

Medical Purpose

In medical exoskeletons, the motion trajectories for individual joints cannot be provided by the wearer as the patient cannot make the required movements, whereas healthy persons can normally possess sufficient physical functionality which needs to be ‘topped up’ rather than having to have it ‘fully compensated for or replaced by’ as in medical situations such as providing mobility provision to SCI persons. This means many technical issues such as user interfaces, control strategies, mechanical interfaces and so on need to be designed specifically to cater for the individualistic needs of the patient/wearer.

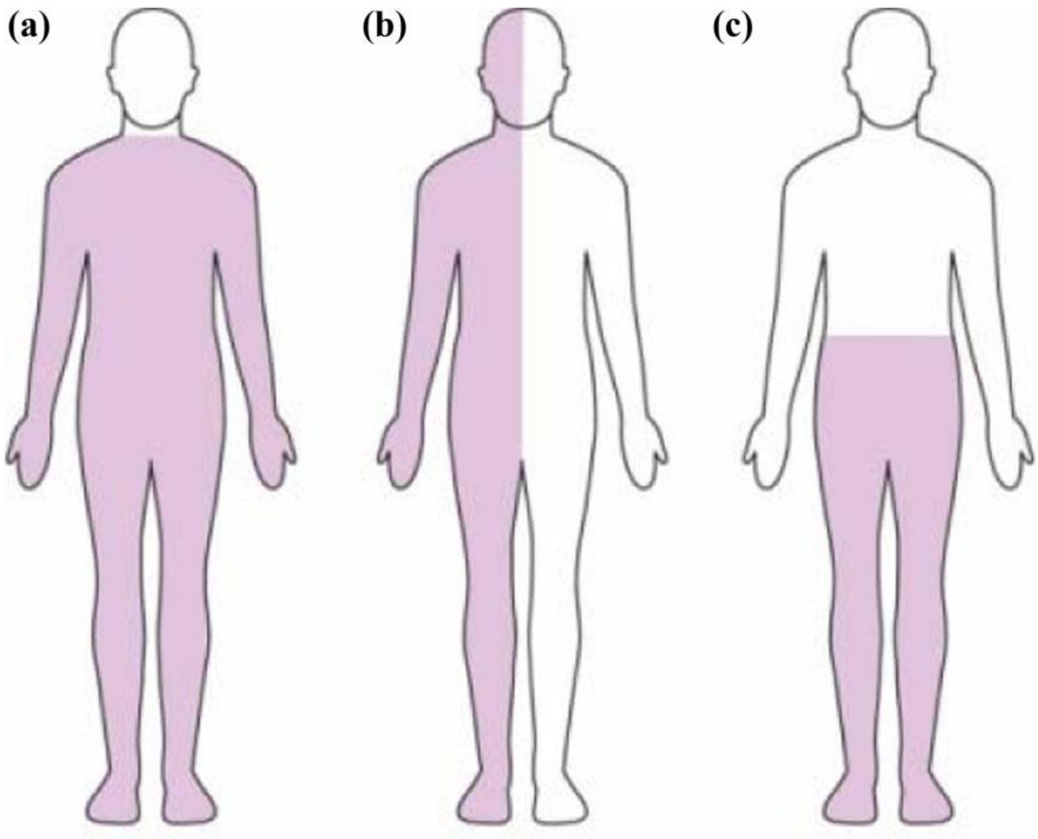


The international safety regulatory requirements (published by ISO/IEC) for medical and nonmedical exoskeletons are different and must be complied with for successful commercialization. For medical exoskeletons, such regulations are still underdeveloped by the joint working group IEC SC62D and ISO TC299 JWG36 (medical robots for rehabilitation), whereas for non-medical exoskeletons,

ISO TC299 WG2 (personal care robot safety) has produced and published the safety requirements for physical assistant robots (restraint and restraint free types).

Medical exoskeletons are designed to help the joint/limb motion of a patient in some specific manner where functionality is limited or lost in terms of mobility and strength. Such exoskeletons include ankle exos for drop foot applications or a hip and knee exos for rehabilitation purposes.

For paraplegics. Medical exoskeletons for paraplegics are used to assist patients suffering a type of paralysis as shown in Figure 3; paralysis is the inability in the sensory-motor functionality of the lower limbs preventing normal motions such as standing and walking. Several conventional methods have been used including braces and crutches, wheelchairs and orthotic devices.



Types of paralysis, where the coloured portion is paralysed. (a) Quadriplegia, (b) hemiplegia and (c) paraplegia.

There are several medical electrical equipment exoskeletons developed for upright walking of paralysed people. A good example is the ReWalk exo which has been developed for SCI patients.

As a patient-worn backpack device, ReWalk is a self contained exoskeleton which uses rechargeable batteries to drive the hip and knee joint motors. It uses a tilt sensor to compute the trunk angle and a wristwatch-style controller to activate different motion modes such as stand–sit, sit– stand or walking. ReWalk has been designed to be used by persons weighing less than 100 kg, height in the range of 157–193 cm and having the adequate upper-body strength to use the medical exoskeleton.

Major advantage of exoskeletons developed for paraplegics and elderly-

- Prevents muscle atrophy by daily use and enhance recovery in case of damage.
- Increase the autonomy of person by allowing the people to do things on their own without anybody's help.
- Improving the psychological state of user.
- It is not necessary to adapt the environment of the person to use an exoskeleton.
- Reduces the energy required to move the joints (knee/hip/ankle) as the load is taken by the suit.
- Specific joints/muscle groups can be targeted for therapy. (using rehabilitation exoskeletons)

Types of amputation: (a) amputation at the hip and pelvis region, (b) transfemoral amputation, (c) amputation at the knee
(knee disarticulation), (d) transtibial amputation and (e) amputation at the foot.

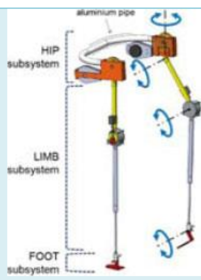
Exoskeleton (image)	Category and subcategory	Name with reference and weight (kg)	Actuation	Key points (cost, control, sensors, materials, joint mechanisms, battery details)
	Medical – Paraplegics	Ekso 20	Hydraulic actuators	_ 6 DOF _ Adjustable assistance levels – 'Variable assist' _ Peak torque of 150 N_m _ Battery, computer and portable compressor in bag pack _ Encoders and linear accelerometers used as sensors. _ 100,000 USD cost _ 6-h battery life _ Costly exoskeleton mainly sold to hospitals _ Wearers 5 ft 2 in–6 ft 4 in tall and weigh <100 kg
	Medical – Paraplegics	ReWalk 23	DC motors	_ Crutches needed _ Control through wrist-pad controller _ Speed up to 2.2 km/h _ 70,000 USD cost _ 2 h 40 min battery life _ Modes include normal walking mode, sit–stand, stand–sit, up steps and down steps

	Medical – Paraplegics	Indego 12	DC brushless motors	_ Can be split into three pieces and then coupled _ Easy to wear and remove _ Wireless operation _ 140,000 USD cost _ 1-h battery life _ Two variants, Indego personal and Indego therapy _ Lightweight system with reduced assistance and fewer control functions but relatively easy to handle and comfortable to use
	Medical – Paraplegics	Rex[16] 38	Linear actuators	_ No need of support stick _ Joystick for control _ Custom rechargeable battery (adds to the weight) _ 150,000 USD cost _ 2-h battery life _ A heavy structure with selfbalancing system _ Non-invasive brain interface (nonrisky) technique for data acquisition directly from the brain
	Medical – Paraplegics	Atlante[17] Not available	Electric motors	_ No use of crutches, joystick _ 12 DOF _ Dynamic balancing control _ R&D by Wander Craft Ltd. _ Cost: 33,000 USD _ 3-h battery life _ Self-contained autonomous device

	Medical – Paraplegics	Univ Wisconsin[18] 27.2	Rotary hydraulic actuators	_ Universal joints at hip/knee _ Four actuators (two at knee, two at hip) _ DC motor driven hydraulic pump _ Off-board computer for control _ Sticks needed for stability _ Comfortable to the user for long duration wear
	Medical – Paraplegics	Tokyo Denki Univ Orthosis[19] 7	Bilateral hydraulic servo actuators	_ Potentiometer for position control _ Pressure sensors in shoes to maintain posture _ 4 DOF per leg _ Can also be used for gait training _ Needs external hydraulic pump for power _ Only used under controlled lab conditions under supervision
	Medical – Paraplegics	MindWalker[20] 30	Linear electric actuators	_ 5 DOF at each leg _ Works on user command _ Centre of mass control strategy for walking _ User needs to hold handrail for walking _ Able to recover balance from external instability _ Developing brain neural computer interface-based control

	Medical – Paraplegics	Exo-H2[21] 12	DC Motors	_ Adjustable control parameters according to patient needs _ Needs support stick for autonomous walking by user _ Lithium powered 22.5 V DC battery _ Can be connected to mobile via Bluetooth for control _ 6-h battery backup _ Limited assistance in sagittal plane via six motors mounted at hip, knee and ankle joints of both legs
	Medical – Paraplegics	ExoAtlet[22]	Electric actuators	_ EMG and torque sensors for control _ Support sticks needed _ Bag-pack for battery _ Climbing stairs possible _ Can also be used for physiotherapy
	Medical – Paraplegics	Modular knee exo[24] 3.7	DC motor	_ One DOF _ Polycentric knee actuator motion _ Four force-sensitive foot insole sensors _ FSM-based control algorithm _ Wireless operation _ Motor driver maximum power 200 W _ LCD display and a buzzer for notification

	Medical – Rehabilitation	LOPES	Series elastic actuator	_ Two modes – robot and patient _ 8 DOF (three at hip) _ Treadmill device with Bowden cable system _ Impedance control strategy _ It is for treadmill training _ Can move in parallel with the legs of a person walking on a treadmill
	Medical – Rehabilitation	KNEXO	Pleated pneumatic artificial muscles	_ 1 DOF at knee joint _ Uses external compressor _ Supports up to 90 kg person _ A ‘zero torque’ mode for unassisted walking _ Interaction-based trajectory controller is used _ Need of pressurized air makes it less mobile _ Lightweight knee exoskeleton with pneumatic artificial muscles for full knee support for safe and compliant physical human–robot interaction

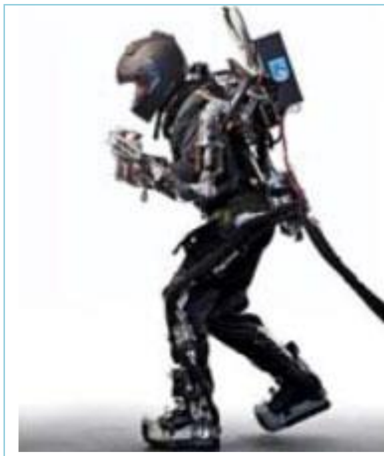
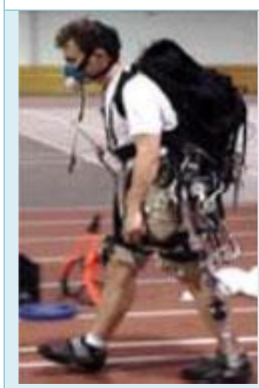
	Medical – Rehabilitation	NE Univ Orthosis	ERF variable damper	_ Modification is done to a commercial knee brace _ Provides resistive torque to user for rehabilitation _ Lightweight aluminium design _ Can be used for other applications, for example, by astronauts _ Electro-rheological fluid actuators allow smaller, simpler and more cost-efficient solutions for rehabilitation but only 25% of needed torque can be provided
	Medical – Rehabilitation	Quasi-passive lower limb exoskeleton	Solenoid actuators 9-24 VDC	_ Multipurpose (elderly/workers/ able-bodied) _ Most useful for persons with muscle weakness _ 4 DOF _ Knee locking mechanism (according to gait cycle) _ Lightweight aluminium frame _ Focus on cost reduction (cheap actuators)

	Medical – Compensation	ETH knee35 perturbator	Brushless DC and flat motor	_ Carbon fibre braces _ Wireless data acquisition _ Hall effect, knee angle potentiometer, torque and screw encoder sensors _ Range of motion 0–120 DEG knee flexion _ Maximum torque 80 N_m
	Medical – Compensation	Honda Leg-Walk assist	Brushless DC motors	_ Lowers the strain of walking _ Rechargeable Lithium-ion battery _ 2 DOF, only at hip joint _ For healthy elderly people. (which need only a few %age of assistance) _ Other variants of Honda-leg include – Stride management and Body-weight support assist _ Battery time 2 hours _ Limited to providing force at hip joint only.
	Medical - Compensation	HAL-ML05 Series25 15	DC Motors	_ Capable of carrying 40kgs load _ EMG (myoelectric signals) used for control _ Rotary encoders and strain gages used as sensors _ Only exoskeleton to get global safety certification _ Linux-based system for parameter adjustment _ $1,950 per annum (Rent)

Non Medical Purpose

For non-medical exoskeleton applications, the methods for measuring 'user intention' are most important so that the actuated mechanisms can be operated to support the user's plans to make the desired motions in as natural a manner as possible. For maximum effectiveness and acceptability, natural interfaces are needed so that lay users can don, operate and doff the exoskeletons easily, quickly and efficiently. The control and stiffness interfaces need to be generic enough to have mass appeal but be sufficiently adaptive to meet the wide range of variations found in the movement patterns of individuals.

Exoskeleton (image)	Category and subcategory	Name with reference and weight (kg)	Actuation	Key points (cost, control, sensors, materials, joint mechanisms, battery details)
	Non-medical – Soldiers	BLEEX36 14	Linear hydraulic actuators	_ Capable of carrying 100 kg load _ 7 DOF _ Designed for a 75 kg human _ 1143-W hydraulic power for actuation _ 200-W electric power for control _ Eight encoders and 16 linear accelerometers for sensing position _ Speed 0.9 m/s with 75 kg load and 1.3 m/s without load

	Non-Medical - Soldiers	Sarcos XOS-2[37] 95	Linear and Rotary Hydraulic Actuators	_ Capable of carrying 84 kg _ Wearer's feet not allowed to bend _ Multi-axis force-moment transducers for sensing and control _ 30 DOF _ Large strength ratio increase of 17:1 _ Speed 1.3 m/s with 68 kg on back _ Able to walk through mud, twist, kneel and squat
	Non-medical – Soldiers	MIT Exoskeleton[42] 11.7	Quasi-passive mechanism and variable dampers	Capable to carry 36-kg load _ Magneto-rheological damper at the knee joint. _ Strain-gauges and potentiometers used as sensors _ 2-W electric power provided by a portable battery (48 V) in bag pack _ Increases 10% metabolic cost

	Non-medical – Workers	RB3D Hercule47 30	Electrically powered motors	_ Capable to carry 100-kg load _ Multipurpose exoskeleton _ Lithium-ion rechargeable battery _ $33,000 cost _ 4-h battery life _ Real-time management of movements via 'ARM Cortex-A8' processor _ 14 DOF of which four are motorized
	Non-medical – Workers	Kawasaki power assist	DC motors	_ Load carrying capacity: 40 kg _ Li-ion battery _ Four DC motors used _ Wearer does not feel the weight of suit while moving _ Less than 1-min put on/take off time
	Non-medical – General	X1 Mina Exoskeleton55 27	DC motors	NASA and IHMC collaboration _ Application in space crafts for astronauts and for paraplegics _ Ensures better health of the user. _ 10 DOF _ Safety system for overloading/ overextension _ Aluminium and carbon fibre used

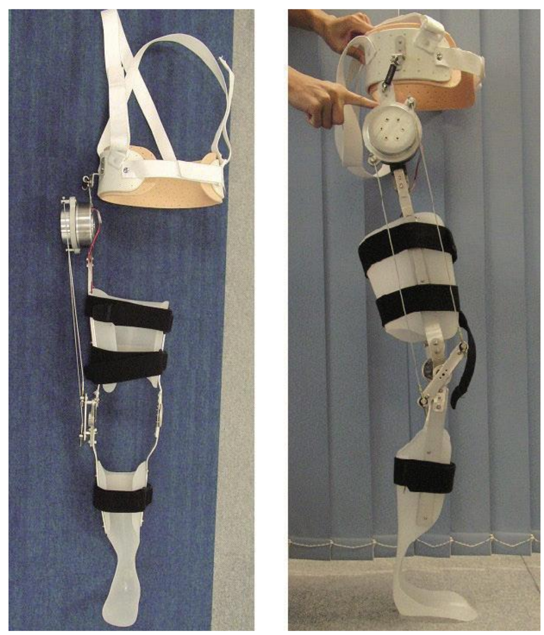
Solidworks Design of Knee Exoskeleton

An ongoing project in Thapar University led us to building a graphical design of a knee brace exoskeleton. It has three main objectives.

- Design of the knee brace in solidworks and motion or DOF
- Design of a mechanical knee joint and the study of motion.
- Purpose and study of the design.

The below given picture is the sample given to us to redesign the model into solidworks.

Design 1



Design 2

Process

Initial Stage:

From the figure we can clearly visualize that the model has following main components.

- *The braces-hip, thigh and cuff*

  We have three Braces that would be in contact with leg that would be in motion according to the movement of the leg. This includes hip brace, thigh brace and knee brace. They would have padding inside for comfortable fit.

- *Structural and connecting rods*

  The Connecting rods and the structural bean is the bse of the entire model as it is the strongest and the main fame of the entire exoskeleton. It would restrict motion perpendicular to the direction of motion and the weight of the machine and the man is completely supported by the same.

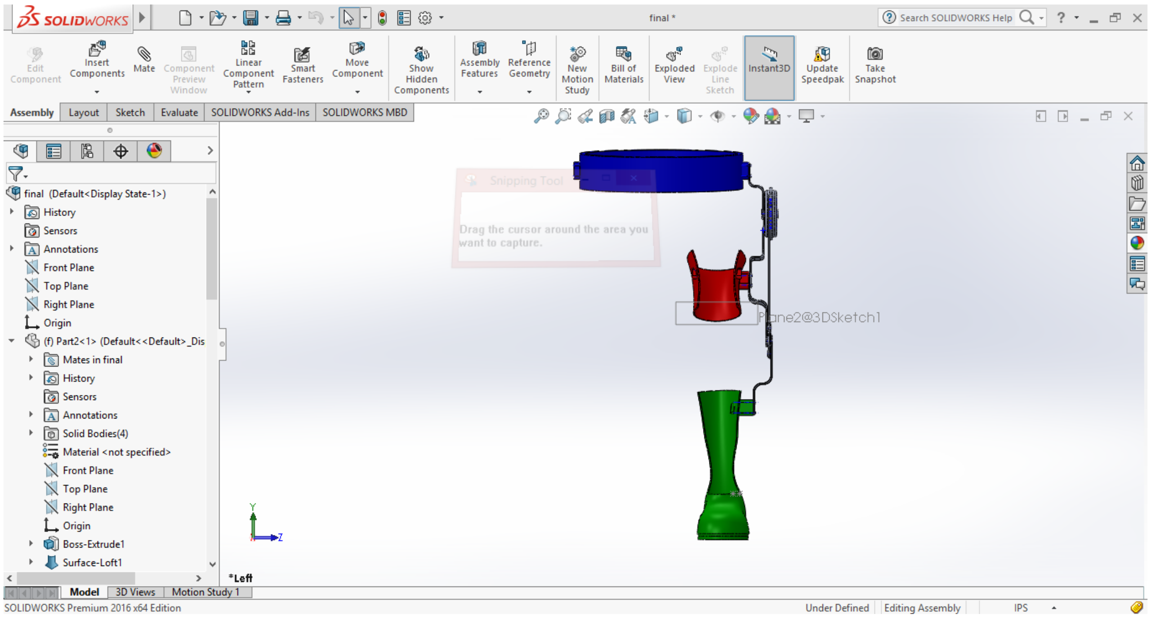
- *Actuator*

  Actuator is the heart of the system as it would restrict and regulate the motion of thighs with respect to the cuffs (knee joint).

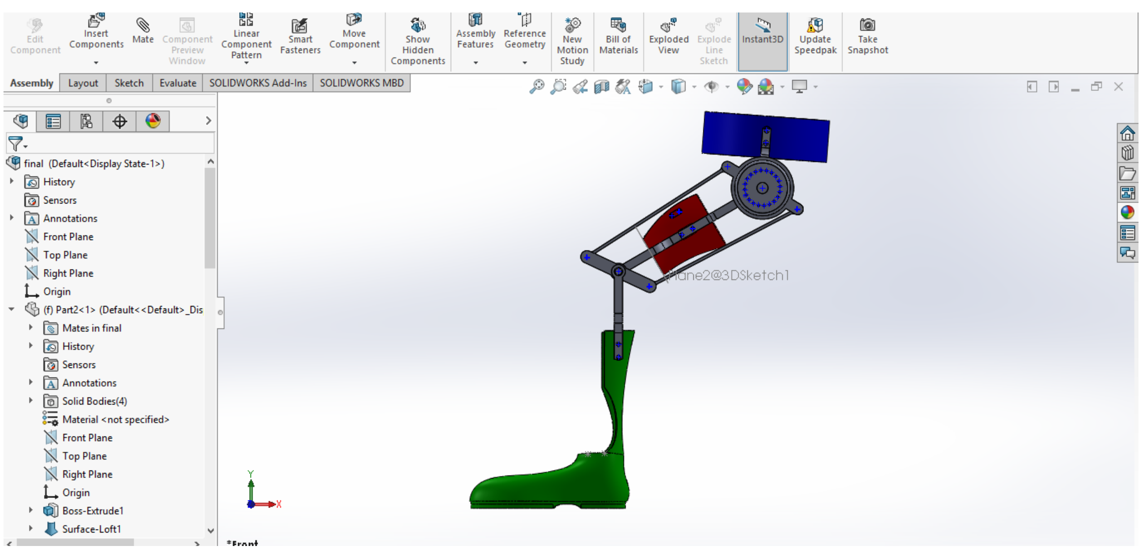
- *Motion of each of the part with respect to each other*
- *Links and others.*

Design

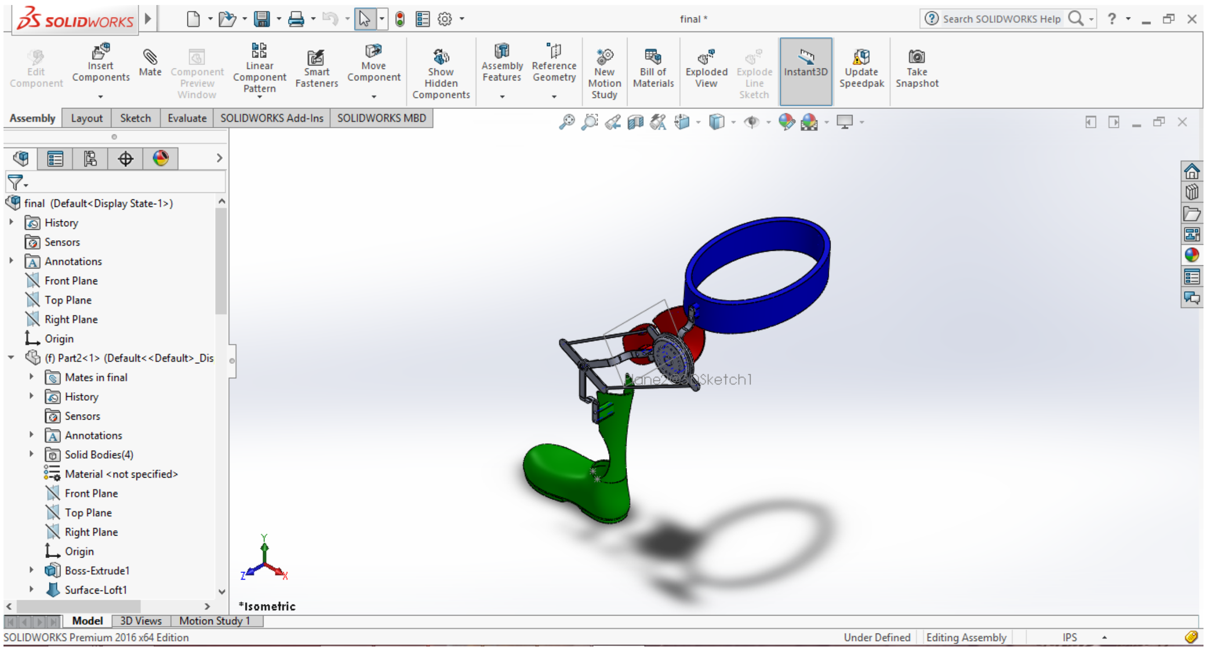
Below are the front, right and isometric view of the entire model after the finished assembly.



Front View



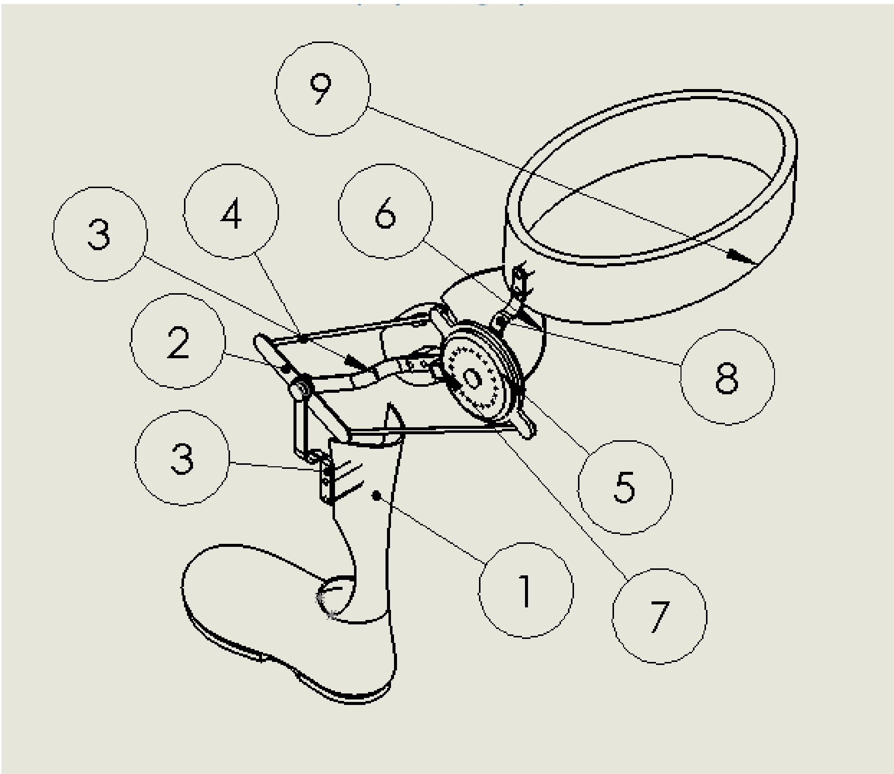
Left side view



Isometric view

List of Parts/Componenets

1. Foot Brace
2. Bar
3. Rod 1
4. Connecting Rods
5. Actuator
6. Thigh Brace
7. Rod 2
8. Rod 3
9. Hip Brace

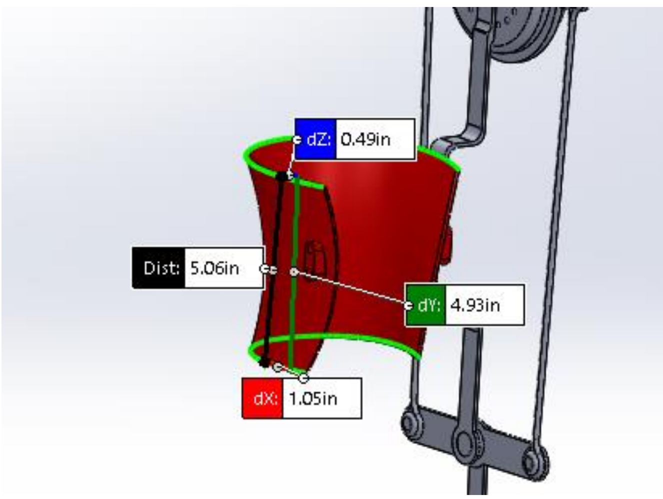


Components

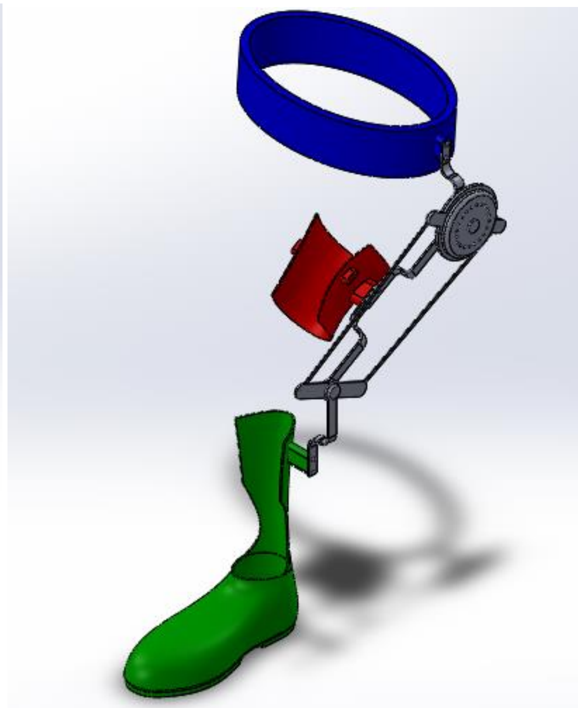
Dimensions

I took the dimension of all the parts of the system according to the dimension of my leg. It has some estimates but the exoskeleton is made to fit according to the dimensions of my leg.

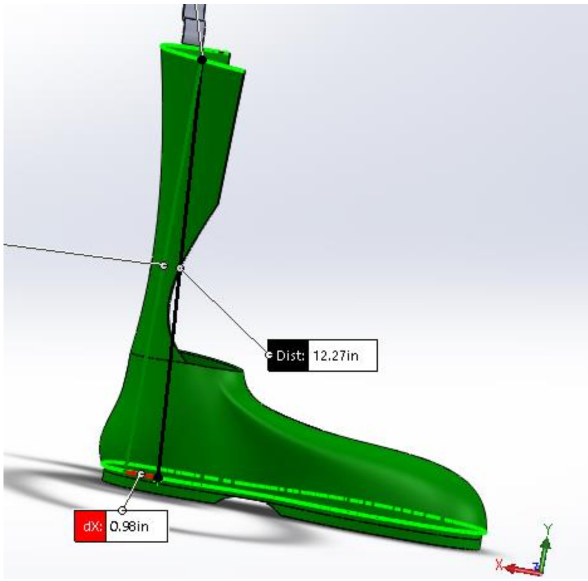
Take the black & green lebel Value into Consideration.



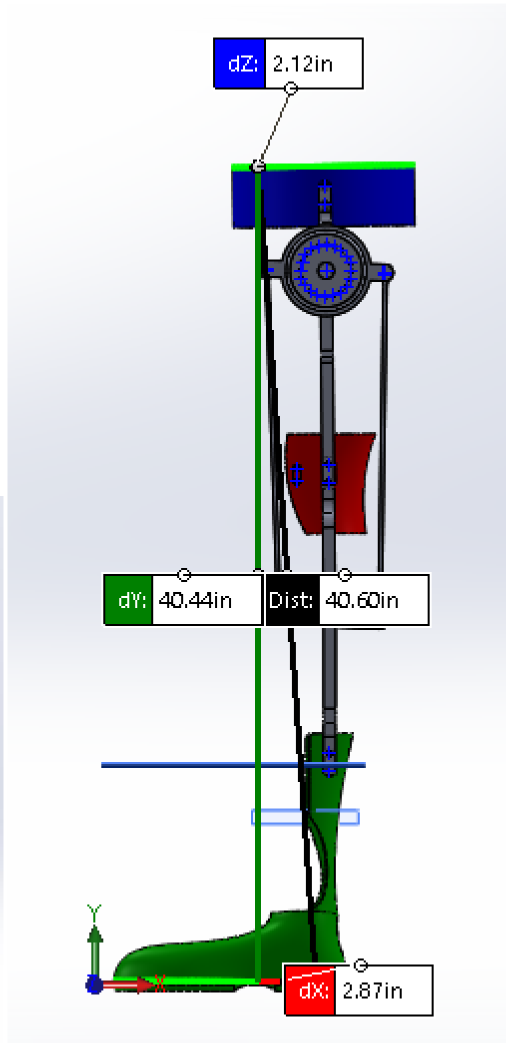
Measurements 1



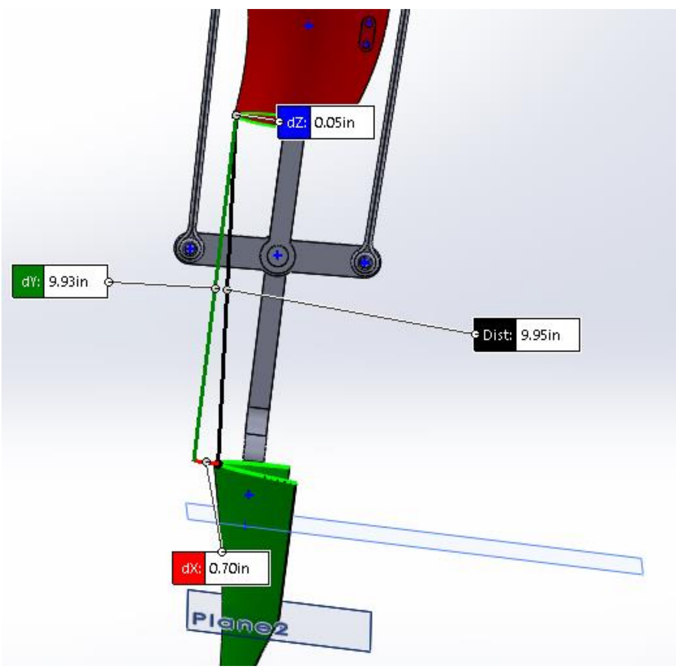
Model



Measurement 2



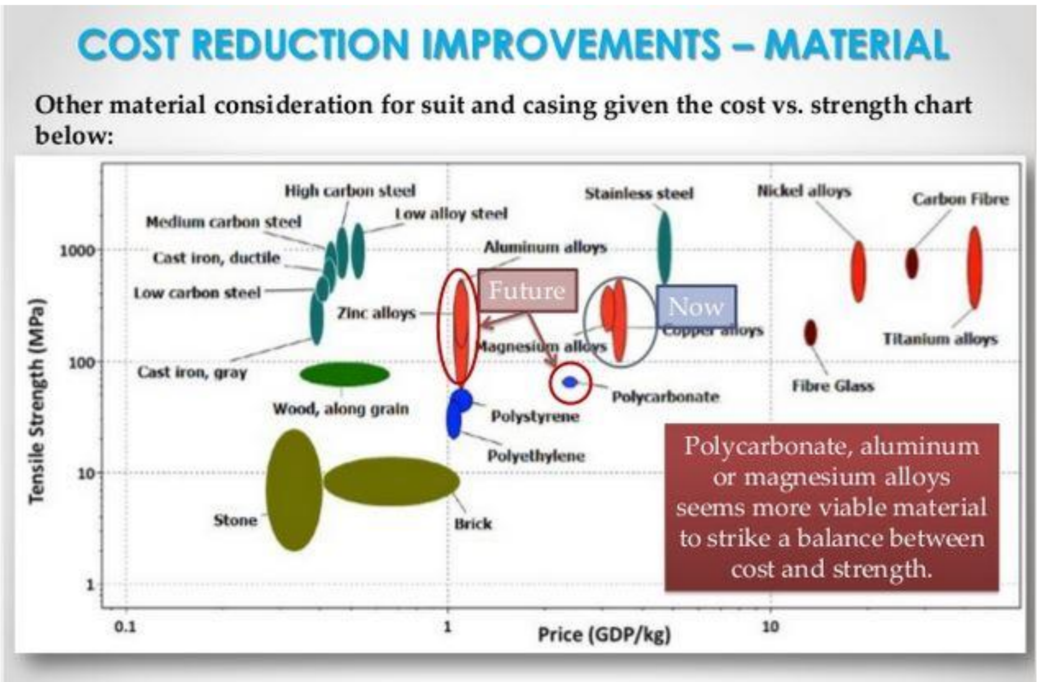
Measurement 3



Measurement 4

Materials Assigned

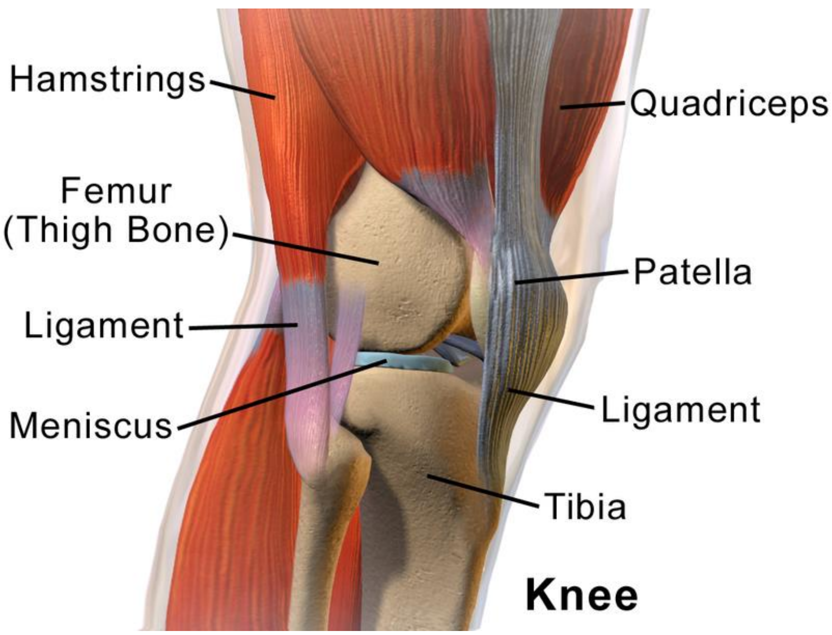
Different compnies built their exoskeleton with different type of materials. INDEGO uses carbon fiber in foot braces which is economically very costly. It uses metal or a mix of ABS and polycarbonate plastic in the rest of the structure which brings the overall cost of the system to be around $80,000 which is a steep price for general public.



Knee Joint

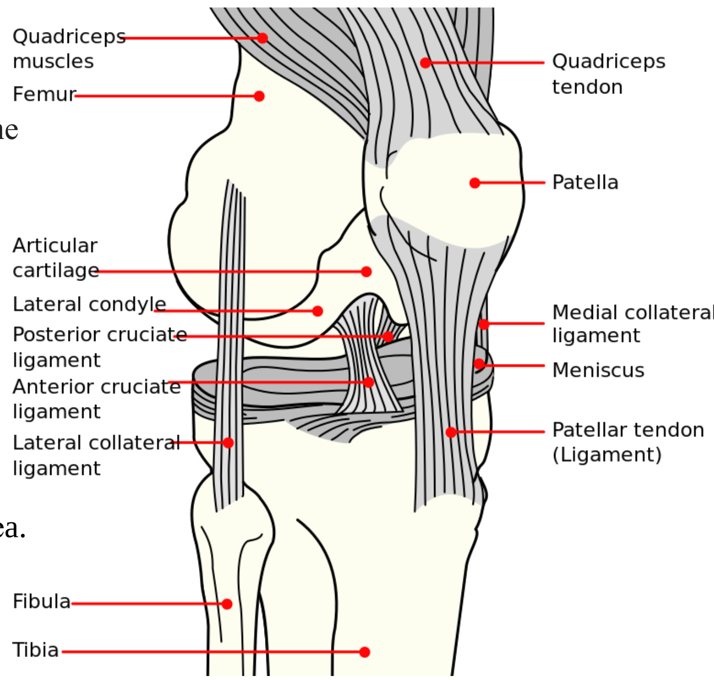
The knee joins the thigh with the leg and consists of two joints: one between the femur and tibia (tibiofemoral joint), and one between the femur and patella (patellofemoral joint). It is the largest joint in the human body. The knee is a modified hinge joint, which permits flexion and extension as well as slight internal and external rotation. The knee is vulnerable to injury and to the development of osteoarthritis.

It is often termed a *joint* having tibiofemoral and patellofemoral components. (The fibular collateral ligament is often considered with tibiofemoral components.)



Ligaments

The ligaments surrounding the knee joint offer stability by limiting movements and, together with the menisci and several bursae, protect the articular capsule.



Ligaments

Intracapsular

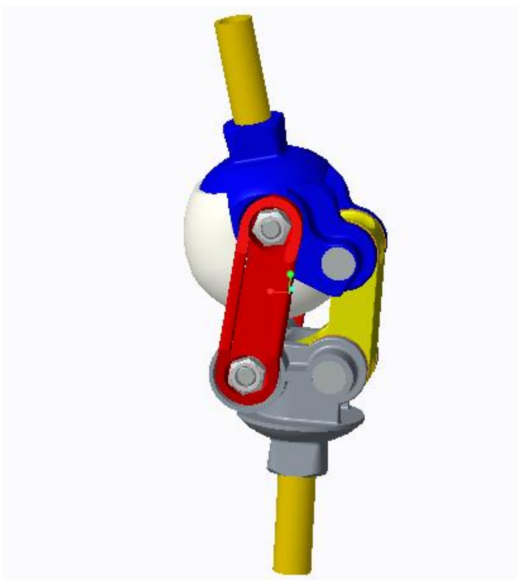
The knee is stabilized by a pair of cruciate ligaments. The anterior cruciate ligament (ACL) stretches from the lateral condyle of femur to the anterior intercondylar area.

Extracapsular

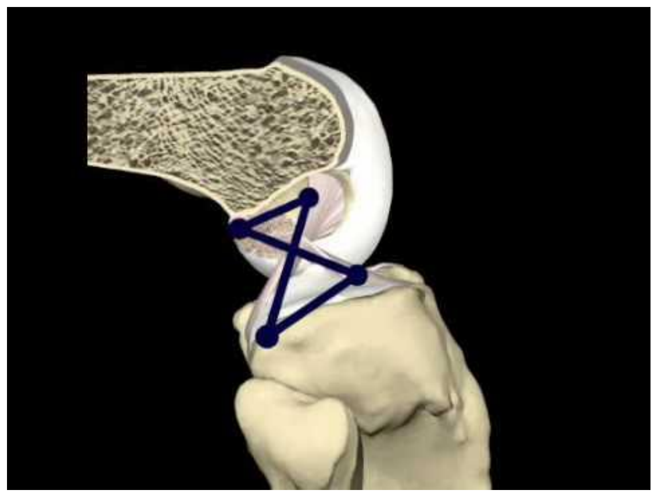
The patellar ligament connects the patella to the tuberosity of the tibia. It is also occasionally called the patellar tendon because there is no definite separation between the quadriceps tendon (which surrounds the patella) and the area connecting the patella to the tibia. This is a very strong ligament helps give the patella its mechanical leverage and also functions as a cap for the condyles of the femur.

Knee Joint Model and Motion

Here is a model of knee mechanical knee joint whose motion can be related to the four bar motion mechanism.



Mechanical version of knee joint



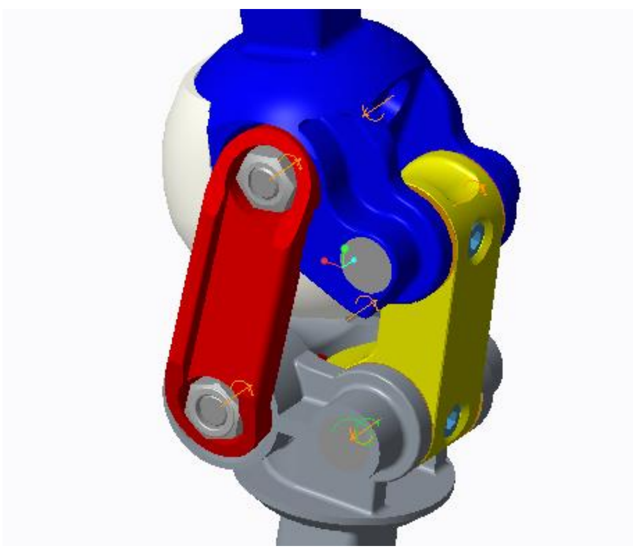
Four bar mechanism in knee joint

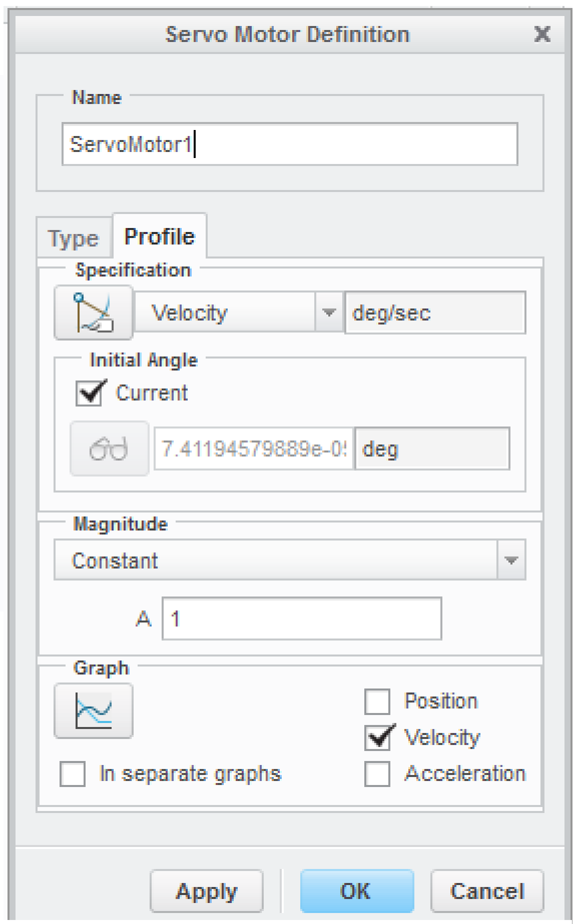
A four-bar linkage, also called a four-bar, is the simplest movable closed chain linkage. It consists of four bodies, called bars or links, connected in a loop by four joints. Generally, the joints are configured so the links move in parallel planes, and the assembly is called a *planar four-bar linkage*. Spherical and spatial four-bar linkages also exist and they are used in practice.

Motion of the Knee Joint And Constraints

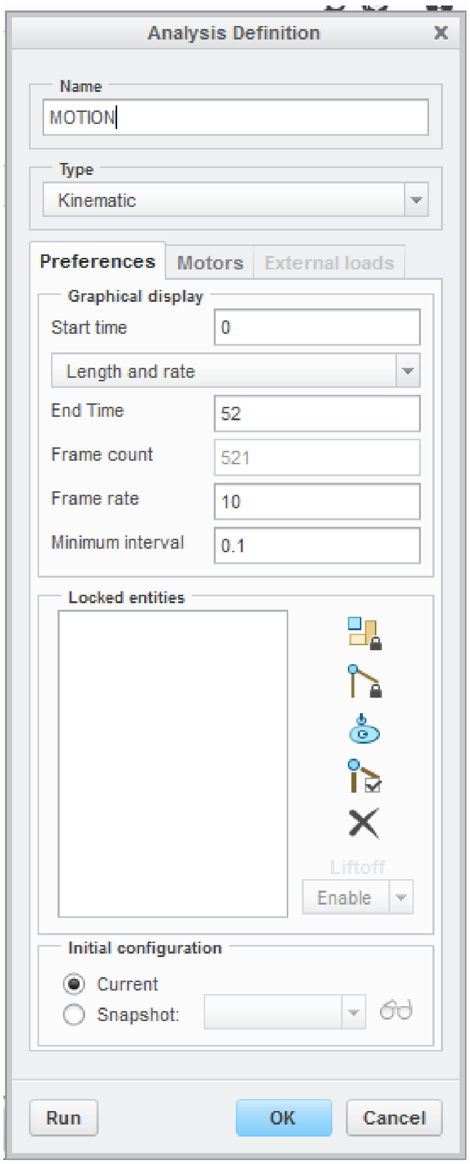
We applied a servo motor into one of the joints (yellow ligament and the base) and defined it to move into certain direction without getting interlocked into one another. This was done by setting constraint of roational motion.

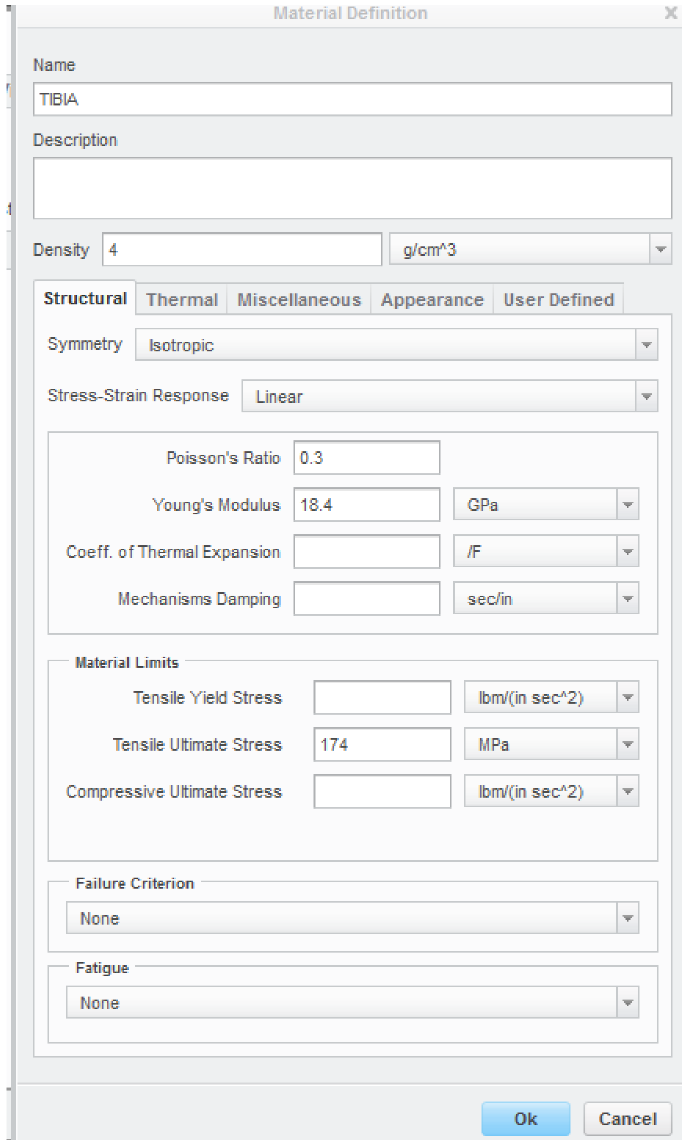
We also have provided with the material information for the better picture of the knee joint.





Servo Motor 1


Analysis Definition
Name
MOTION
Type
Kinematic
Preferences
Motors
External loads
Graphical display
Start time
0
Length and rate
End Time
52
Frame count
521
Frame rate
10
Minimum interval
0.1
Locked entities
Liftoff
Enable
Initial configuration
Current
Snapshot:
Run
OK
Cancel


Material Definition
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TIBIA
Description
Density
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g/cm^3
Structural
Thermal
Miscellaneous
Appearance
User Defined
Symmetry
Isotropic
Stress-Strain Response
Linear
Poisson's Ratio
0.3
Young's Modulus
18.4
GPa
Coeff. of Thermal Expansion
/F
Mechanisms Damping
sec/in
Material Limits
Tensile Yield Stress
lbm/(in sec^2)
Tensile Ultimate Stress
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MPa
Compressive Ultimate Stress
lbm/(in sec^2)
Failure Criterion
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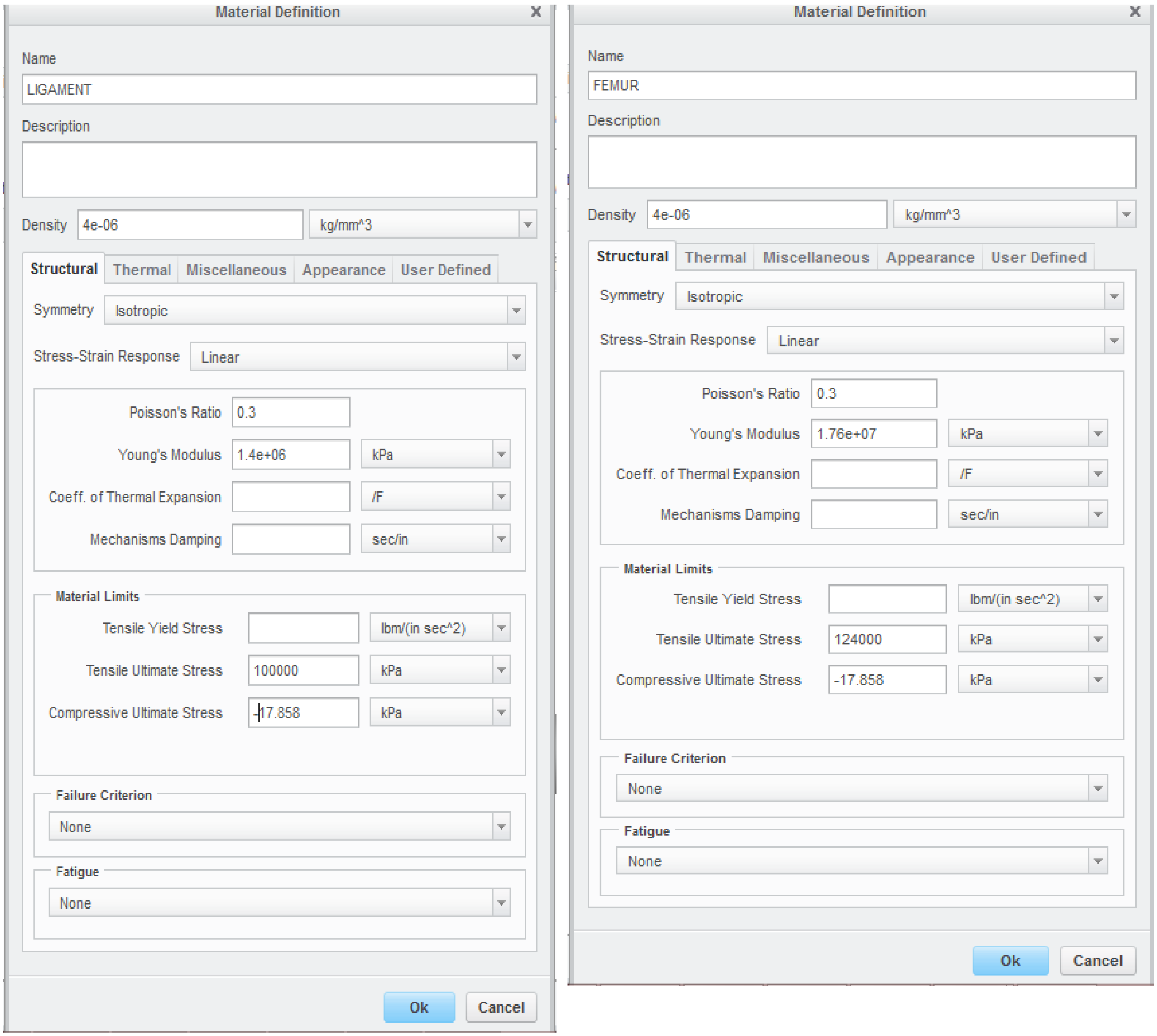
Fatigue
None
Ok
Cancel



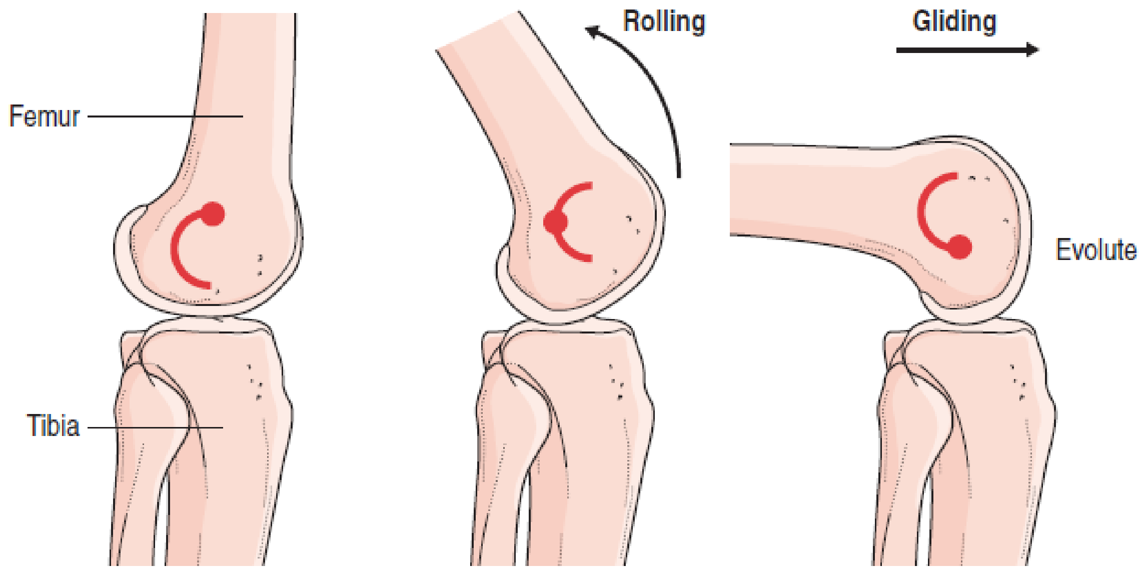
Material Definition

Gait Analysis

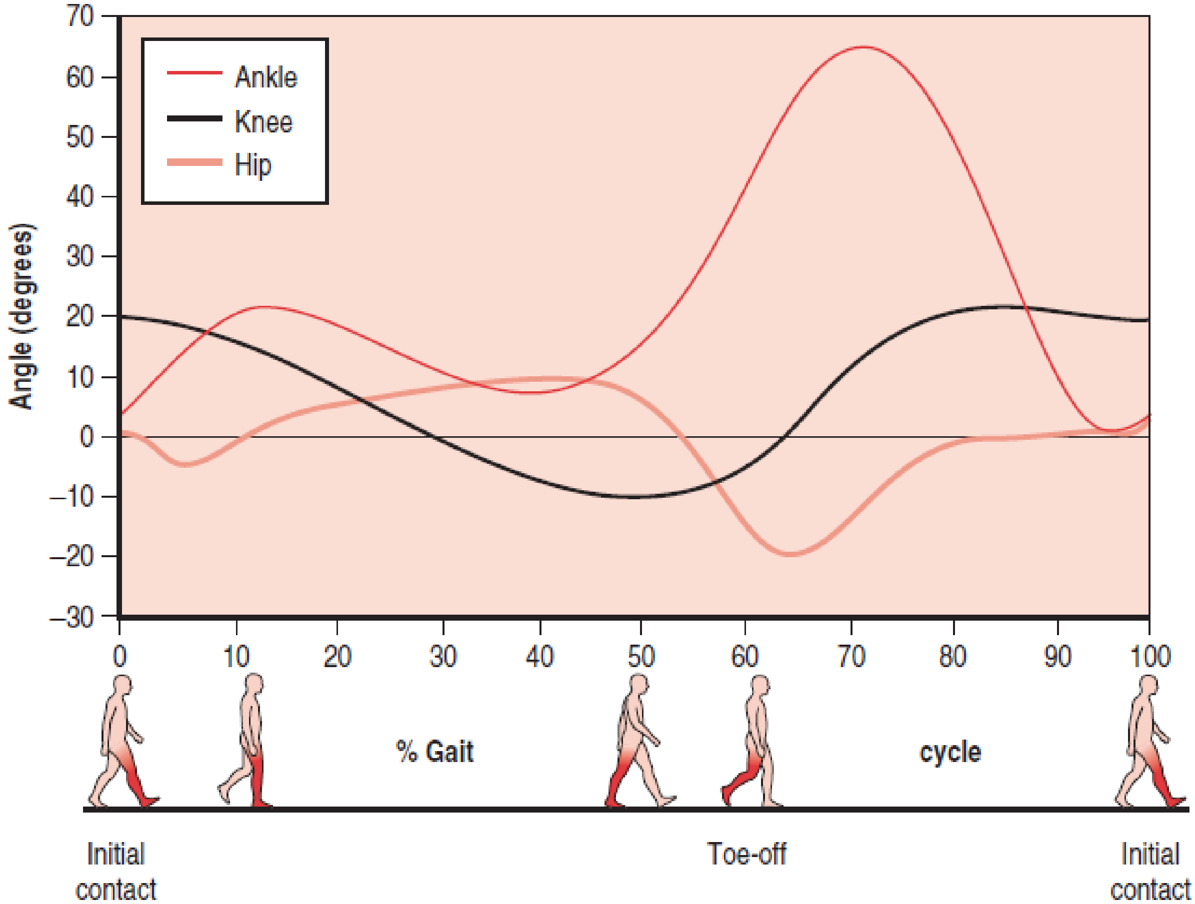
The term *gait analysis* can mean many things to different people, from a brief observation to sophisticated computerized measurements. Surprisingly (given the amount of research done in the field over the last 30 years), no single unifying concept has emerged to explain the motion of the body during gait. Instead, each approach to gait analysis tends to rely on its own paradigm. For example, in podiatric biomechanics, the theories propounded by Root are still influential, although a 'new biomechanics' is growing in popularity.

The key points used in gait analysis are:

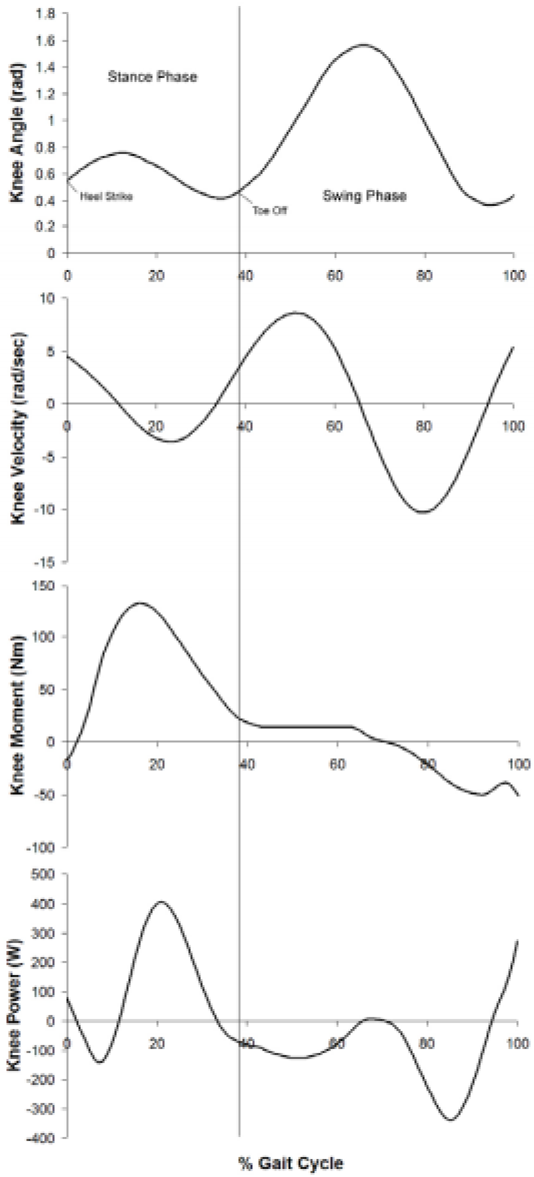
- Temporal–spatial parameters
- Kinematics
- Centre of mass and whole body energetics
- Joint kinetics
- Electromyography
- Joint power

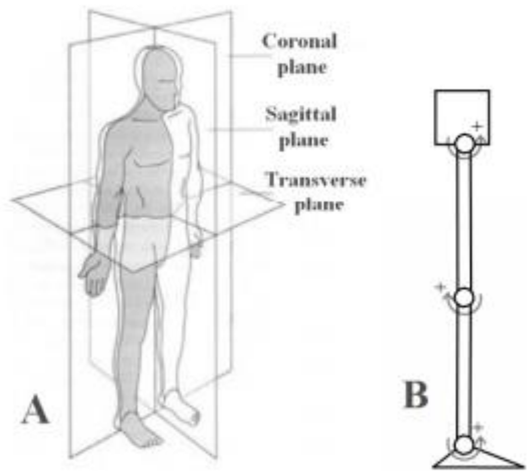


Movement of femur with respect to tibia



Ankle
Knee
Hip
Angle (degrees)
70
60
50
40
30
20
10
0
−10
−20
−30
0
10
20
30
40
50
60
70
80
90
100
% Gait
cycle
Initial contact
Toe-off
Initial contact





Reference plane

Figure shows the typical behavior of the knee during normal, level-ground running at 3.2 m/s (scaled for an 85kg subject). Note that the plots related to knee angle and torque were adapted directly from the same, whereas the velocity was obtained by differentiating the adapted angle data, and the power by multiplying the adapted torque and velocity data (inverted to make absorptive power appear as negative power)

Bibliography

- **Link:**

  https://www.compositesworld.com/blog/post/composites-in-exoskeletons

  https://en.wikipedia.org/wiki/Four-bar_linkage

  https://en.wikipedia.org/wiki/Knee

- **Research papers online**