CERTIFICATION OF APPROVAL

Dynamic Analysis and Simulation of Arm Trainer

by

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Approved by,

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(Mr. Azman bin Zainuddin)

UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

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CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

MOHD SYAZWAN BIN MOHD KHAIDI

ABSTRACT

Briefly the project is to design an effective and low cost arm trainer that can be used by a stroke survivor at home. Recent research suggests that stroke survivors can recover significant use of their arms by performing repetitive motor function exercises over a period of time. These days, devices for stroke patient are expensive and commonly can be found at the hospitals and rehabilitation centres. It may be difficult to a patient to go to the rehabilitation centre or a hospital and also it will cost more. To overcome this problem, the project has been developed and the objectives are stated above. The result of the design should not be too complex and detail. The result has shown that the design is simple and not too complicated because it was designed as simple as possible. As for the movement of the arm trainer, it will not be forcing to users because some of the parameters have been studied. As conclusion, this design can be used as an idea to generate more effective and low cost arm trainer in the future.

ACKNOWLEDGEMENT

First and foremost, heartfelt appreciation outstretches to parents, Mohd Khaidi bin Satar and Noriah binti Mat Noh for always being there when in need. Their guidance, love and emotional support are highly appreciated.

Uncountable appreciation extended to Mr. Azman Zainuddin for being a gratifying supervisor with kind guidance, practical criticism and valuable advice throughout the project duration of 28 weeks.

Great big thanks also extended to other family members and fellow friends who had in one way or another contributed to the success of this report.

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INTRODUCTION

1.1 Project Background

Stroke is the third largest cause of death in Malaysia. Only heart diseases and cancer kill more. It is considered to be the single most common cause of severe disability, and every year, an estimated 40,000 people in Malaysia suffer from stroke. Six new cases of stroke occur every hour in Malaysia, Former Health Minister Datuk Seri Dr Chua Soi Lek said. He said it was surprising that about 52,000 Malaysians suffered strokes annually when it is the most preventable of all life-threatening health problems.

Anyone can have a stroke, including children, but the vast majority of the cases affect adults. After a stroke, rehabilitation facilities use physiotherapy to help patients relearn the lost motor functions by repeating meaningful coordinated movements. Insufficient resources results in patients spending inadequate time undertaking rehabilitation activities, which can potentially limit the degree of recovery. Robotic rehabilitation systems can supplement conventional therapy services to increase the intensity and frequency of rehabilitation. There are many devices that have been designed and used to help a person return to the highest possible level of physical function. The devices are concentrating primarily on controlled and balanced movement, increased strength and stamina for greater mobility, physiotherapy lays the necessary physical groundwork on which further functional and independence can be developed.

1.2 Problem Statement

Stroke recovery, stroke rehabilitation and stroke treatment for muscle paralysis following a stroke is now possible with a lot of ways and new equipments. There are two different systems, both developed for home therapy as well as clinical therapy. Currently, devices for stroke patients are quite expensive and hard to find in Malaysia. In this country, therapies and rehabilitation mostly are done in hospitals and rehabilitation centres. Most of the patients have to go to the rehabilitation centres to receive the therapies. Because of this, it is quite costly for the patients to go back and forth for the rehab.

One of the basic therapy movements performed on patients is to move the patient arm about the elbow to recover arm nerves function. The restoration of arm and hand function after stroke has a major role in neurorehabilitation. An early, intensive, and task-specific approach is an accepted principle of upper-limb motor rehabilitation. Repetitive movements can improve muscle strength and movement coordination in patients with impairments due to neurological or orthopaedic problems. Particularly in stroke patients, several studies prove that arm therapy has positive effects on the rehabilitation progress (Carrey et al. 2002, Pang et al. 2006, van der Lee et al. 1999). Besides recovery of motor function, arm therapy serves to learn new motion strategies, so called trick movements, to cope with activities of daily living (ADL). Furthermore, upper extremity movement therapy serves also to prevent secondary complications such as muscle atrophy, osteoporosis, and spasticity.

The designing and development of an arm trainer must consider the several factors such as user friendliness, cost and weight. The device focuses on stroke survivors on relearn how to move their arm. These include practicing movements, or part of a movement, to encourage arm to move. Correct positioning is important to ensure that muscles and joints remain flexible and pain free.

1.3 Objectives

These are the project goals to address the problems above:

- To design an effective arm trainer.
- To design a low cost arm trainer that can be used by stroke patients at home.

1.4 Scope of Study

The project will focuses on the design and the dynamic of arm trainer movement. The movement of the device must be correct with patient arm movement so the patient will be able to do the therapy without feeling the pain. The material used also needs to be considered to avoid side effect to patient if the patient has skin allergic to certain material.

Design of the arm trainer concerns about the arm movement and the stroke patients who use the device feel no pain within their therapy. Detail design of the product and all he part components will be provided in this report.

1.5 Significance of the Project

In a meta-analysis comprising twenty controlled studies, Kwakkel et al. (2004) revealed that increased training intensity yields positive effects on the performance of acute stroke patients. However, manually assisted movement training is labor-intensive, and therefore, the training duration is usually limited by personnel shortage and fatigue of the therapist. The disadvantageous consequence is that the training sessions are shorter than required to gain optimal therapeutic outcome.

In contrast, device assists, arm training the duration and number of training sessions at home can be increased, while reducing the number of therapist hours. A further advantage of using device as therapy is that the robot provides quantitative measures, which allows objective documentation and evaluation of the rehabilitation process.

For this rational argument, the robotic rehabilitation device will be studied thus generating an arm trainer.

The stroke survivors may see this design as a new hope because of its low cost and the effectiveness of the device. The design of the project may give advantage for the designer to compare with the other existing devices that available in the market. The design will be simple and the movement of the device will follow the movement of human arm to avoid any injuries to the stroke patients. If the design cannot be successfully completed, the stroke survivors who cannot afford a high cost treatment for therapy, they may not be survive from the stroke effect in short time because the treatment for stroke should be done quickly since it is a very vital part for stroke survivors.

CHAPTER 2

LITERATURE REVIEW

This project is also relevant to the recent technology of applying mechanical device in medical industry. Intensive therapy using a robot has helped patients improve arm movement years after having a stroke according to a US study. UK stroke experts said the advance was "exciting" but added that robots were still at early stages of development. Both the "robot" group and the other intensive group had significantly improved upper-arm function - measured by how much better they could carry out everyday tasks such as using a knife and fork, opening jars or tying shoelaces. But all of these developments were still at an early development stage and can be improved from now on.

2.1 Armeo®Spring

The ArmeoSpring is based on an ergonomic arm exoskeleton with integrated springs. It focuses the whole arm, from shoulder to the hand, and counterbalances an adjustable part of the weight of the patients' arm, enhancing any residual function and neuromuscular control, and assisting active movement across a large 3-D workspace. This device was developed by a company named, Hocoma. Hocoma is the leader in robotic rehabilitation therapy for neurological movement disorders. The Swiss based medical technology company was founded in the year 1996 as a limited liability company by the electrical and biomedical engineers Gery Colombo and Matthias Jorg and by the economist Peter Hostettler. Hocoma develops innovative therapy solutions working closely with leading clinics and research centers. The pressure sensitive handgrip is not only an input device for exercises, but also a computer interface for the software and computer games, and can be removed for functional training of real life tasks. The ArmeoSpring is based on an ergonomic arm exoskeleton. It embraces the whole arm and offers the following degrees of freedom:

- Wrist flexion / extension.
- Forearm pro / supination.
- Elbow flexion / extension.
- Shoulder flexion / extension, horizontal abduction / adduction, internal / external rotation.

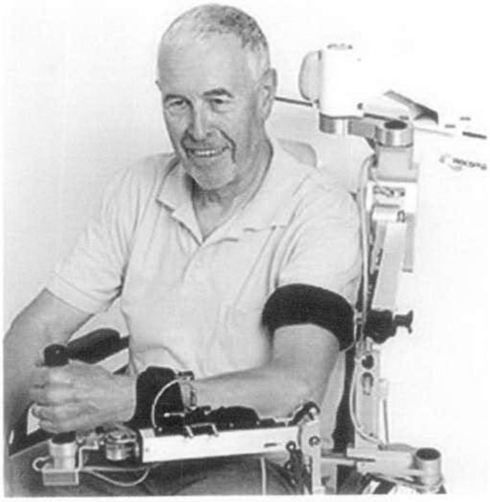

Figure 1: ArmeoSpring

Figure 2: Patient undergoes therapy using ArmeoSpring

This device used as the reference for designing a new and simple arm trainer because of the motor and the part focuses which is arm. For ArmeoSpring, it is a complicated device because it uses computer controlled and also sensors. For this project it only uses motor to move the patient arm as the arm put on the device. For this final year project, it focuses on patient arm but the movement is not the same which only focuses on elbow flexion and extension. ArmeoSpring's movements can be controlled by the patient or can be operated by the motor. For this project, it is only can be operated using motor.

2.2 Nudelholz

The group at clinic Berlin/Charite University Hospital in Berlin, Germany, began studies to promote motor recovery after stroke in the early 1990s. Nudelholz is one of the device that was developed. Nudelholz (Figure 3), with 3 DOF (2 translatory and 1 rotatory), again following the approach of bilateral and distal training. With this device, stroke patients can train three bilateral movement cycles: elbow flexion/extension, shoulder abduction/adduction, and wrist flexion/extension, either isolated or combined. The patient grasps two handles so the movement of the nonaffected side guides the affected hand and arm. An optional cordless computer mouse can be attached to the Nudelholz middle bar. Then the 2 DOF translatory motion of the user-driven bar (forward/backward and left/right) is transmitted to the attached mouse. The mouse movement can be visualized on a computer screen for incorporating visual biofeedback into therapy. Initial clinical case studies revealed significantly decreased muscle tone and improved upper-limb motor control, even in chronic patients. This devices focuses on three DOF while this project on focuses on 1 DOF. The movement of the device is driven by the stroke patient. This device is to drive stroke patient who has improves his/her arm abilities. If the patient is still cannot moves his/her hand, this device cannot be moved. The similarity between Nudelholz and this project is one of the Nudelholz movements which is elbow extension/flexion.

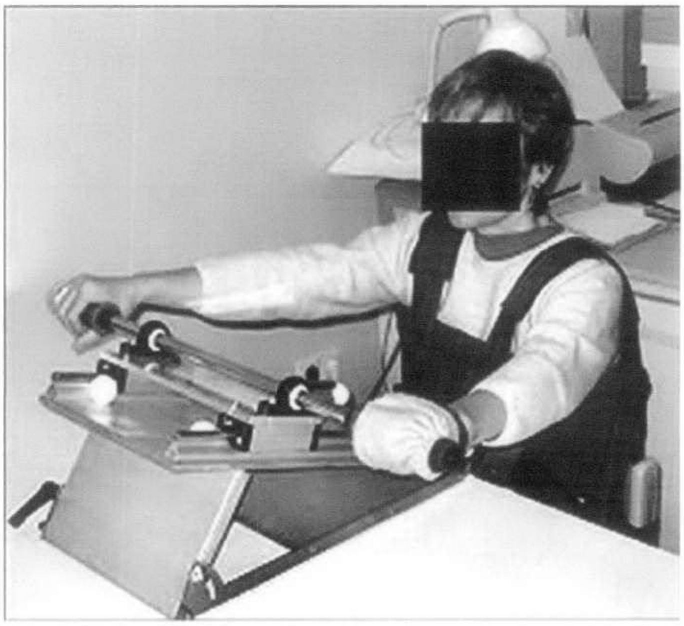

Figure 3: Nudelholz mechanical arm trainer for practicing bilateral soulder, elbow, and wrist movement. Nonaffected limb drives affected limb.

2.3 The Robotic Upper Extremity Repetitive Therapy (RUPERT)

Intensive repetitive therapy shows promise to improve motor function and quality of life for stroke patients. Intense therapies provided by individualized interaction between the patient and rehabilitation specialist to overcome upper extremity impairment are beneficial, however, they are expensive and difficult to evaluate quantitatively and objectively.The Robotic Upper Extremity Repetitive Therapy device, or RUPERT, gives stroke survivors a portable system to retrain their muscles to perform basic tasks such as picking up a cup. As the patient's abilities improve, the robot's computer adjusts the assistance delivered by the pneumatic muscles. The system was developed by Kinetic Muscles, Inc. and Arizona State University's Biodesign Institute.

Figure 4: A robotic device used by stroke patients to retrain their muscles.

For this device, it is quite similar to the ArmeoSpring which it is concentrating on patients' paralyzed arm. This device is assisted by the robot's computer to tell the patients to do a specific job that has been set for the therapy. Similar to this project, RUPERT also focuses on arm movement but in different task, this project is only focusing on simple arm movement which is flexion and extension. Also, this project is only moved by a motor to move patients' hand. RUPERT is also using a very complicated device because it has computer controlled.

CHAPTER 3

METHODOLOGY

This chapter describes on the approach method in developing the arm trainer.

3.1 Process Flow

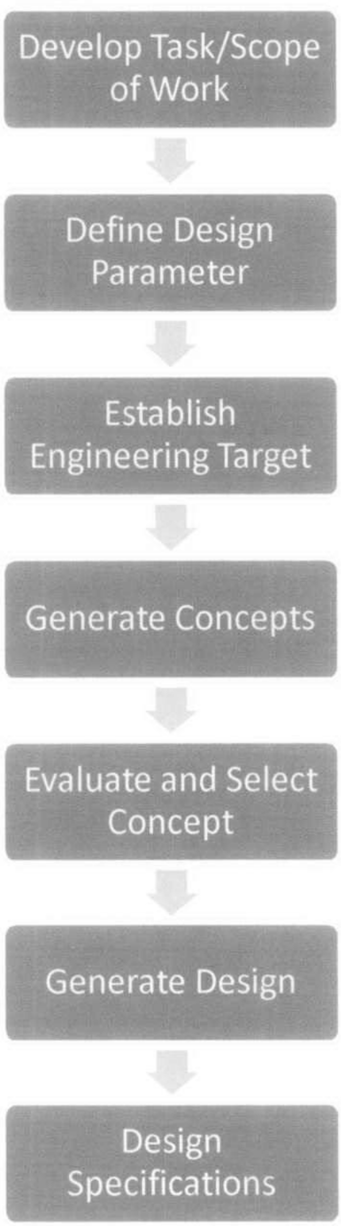

Figure 5: Flow Chart

3.2 Design Parameters

After some researches and reviews on the existing devices, several parameters has been required in order to generate concepts and designs for establishing a new arm trainer for stroke patients. Below are the table of parameters that are being considered:

Parameter	Justification
Degree of freedom (DOF)	1 DOF
Weight	1-2 kg
Velocity of movement	0.2m/s
Energy used	Electricity
Material used	Aluminum alloy
Angular Displacement	90°

Table 1: Design Parameters

One issue the author encountered in designing the arm trainer was that the target population of chronic stroke patients' exhibits a wide range of arm impairment levels. Some subjects can move through a large range of motion at a high velocity, while others have severe range and velocity limitations with stronger coupling of motions between the elbow and shoulder.

3.3 Gantt Chart

No.	Detail/ Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Develop Task/Scope of Work														
2	Define Design Parameters														
3	Establish Engineering Target														
4	Generate Concepts														
5	Evaluate and Select Concept														
6	Generate Design														
7	Design Specifications														

Table 2: Gantt chart

3.4 Project Milestone

The project milestone for FYP 1 and 2 of the project is attached in the attachment behind (Appendix A).

3.5 Tools and Equipment Used

3.5.1 Software Tool

- AutoCAD 2004
- Catia V5

CHAPTER 4

RESULT & DISCUSSION

This chapter concluded all the design criteria, the generated designs and evaluations that have been done for this project. All the results have been gathered with the same methodology as explained in the previous chapter. It also included the current development for the project and the result from the portion that has been done. Comparison and study of the selected devices on their movements, prices, and material used to produce the device and other relevant factors.

4.1 Design Concept

4.1.1 Design 1

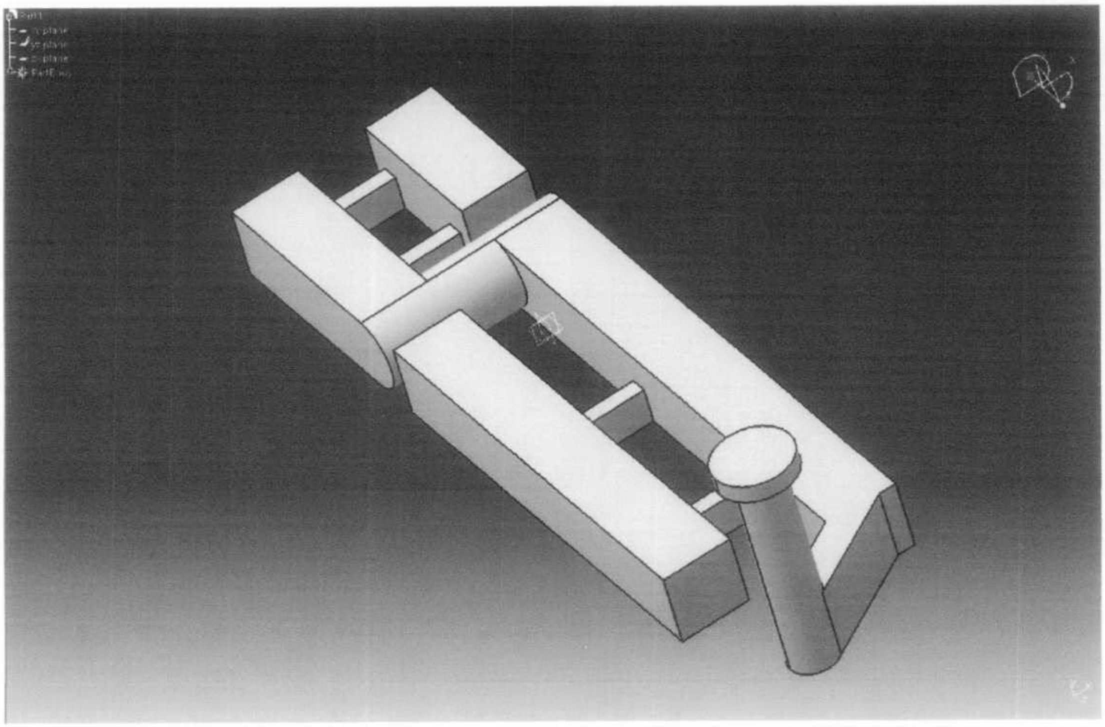

Figure 6: Design 1

4.1.2 Design 2

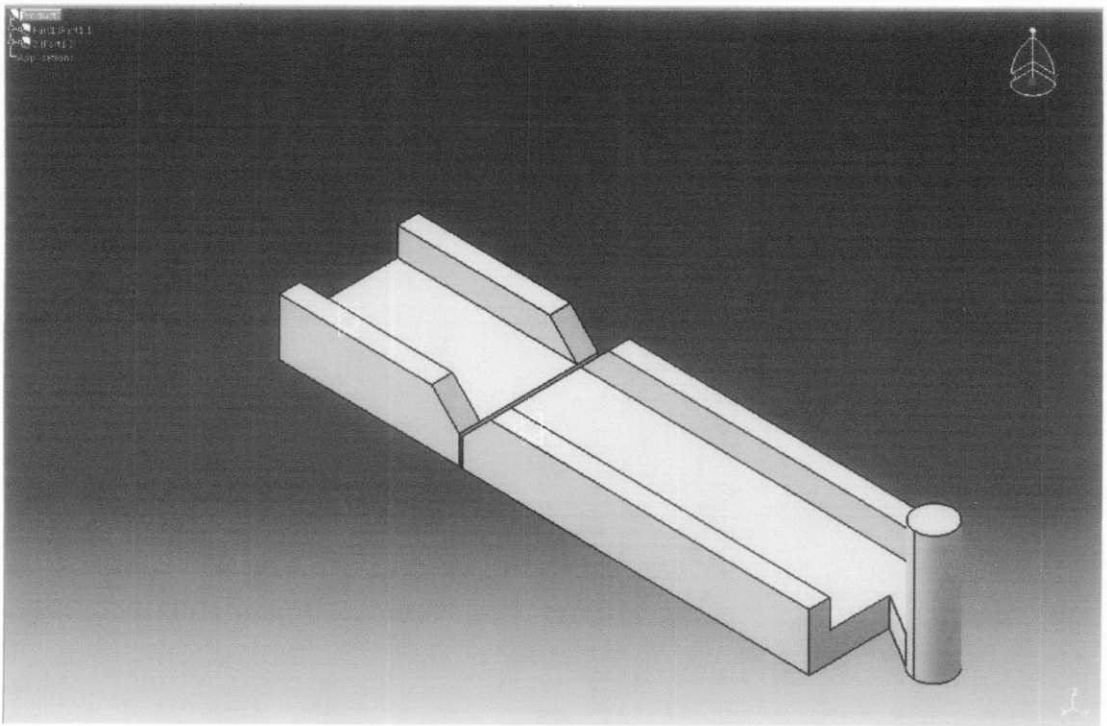

Figure 7: Design 2

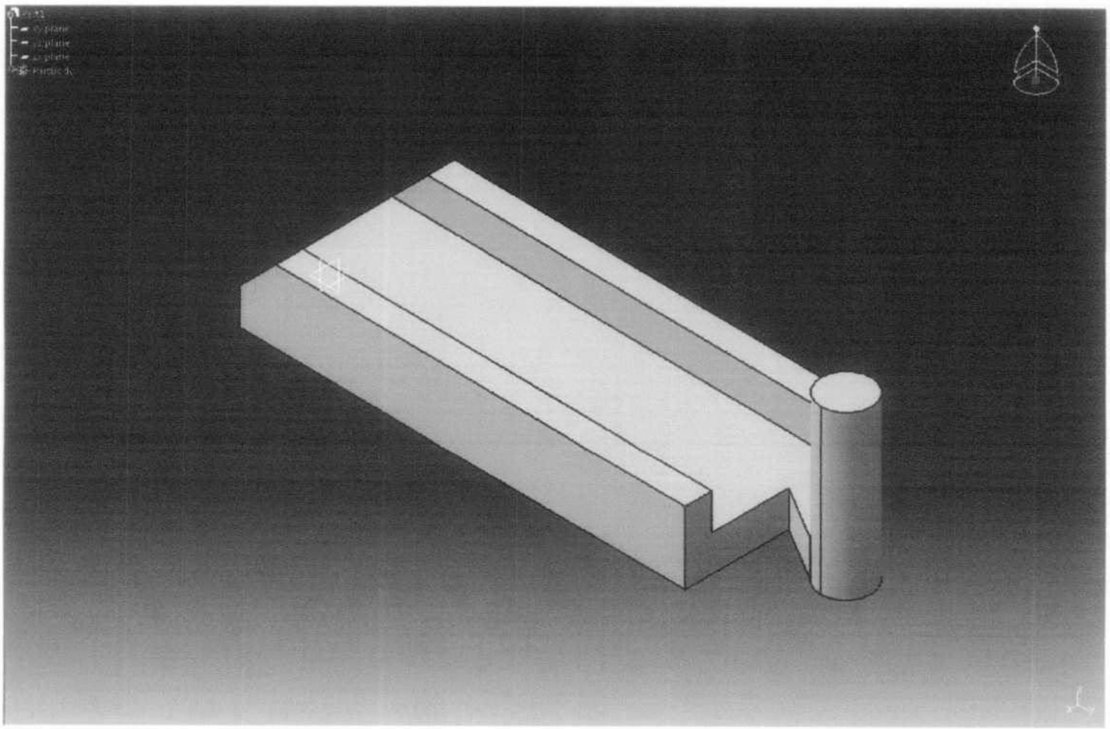

Figure 8: Design 2 Part 1

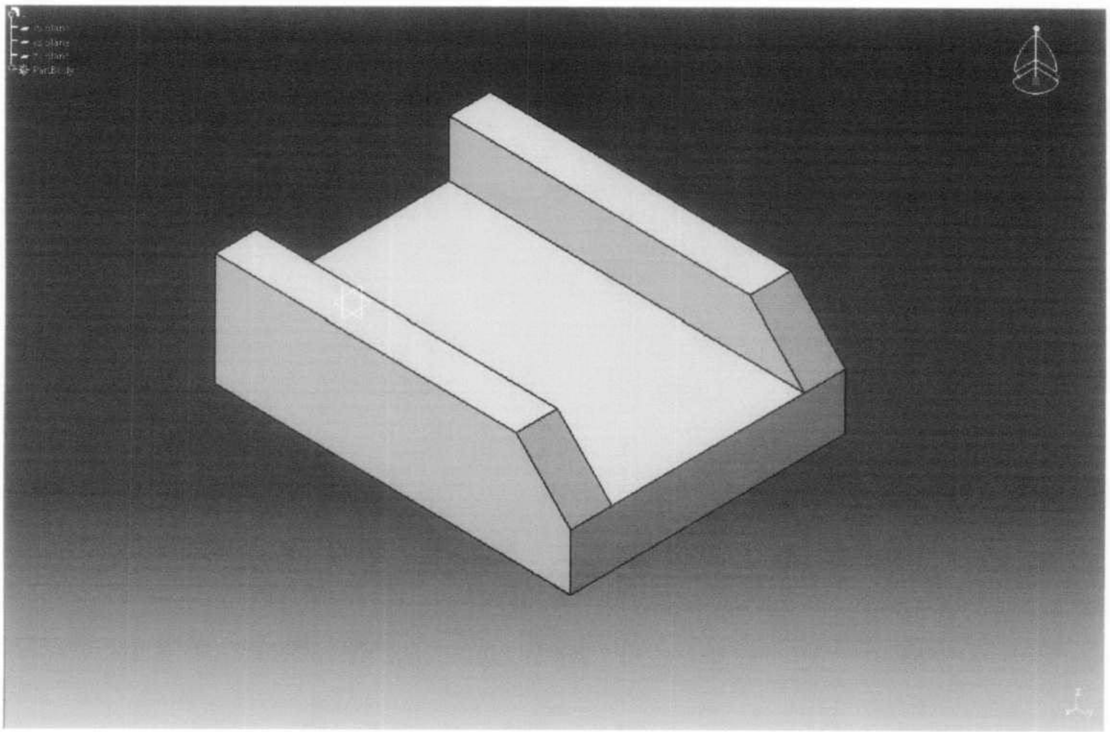

Figure 9: Design 2 Part 2

4.1.3 Design 3

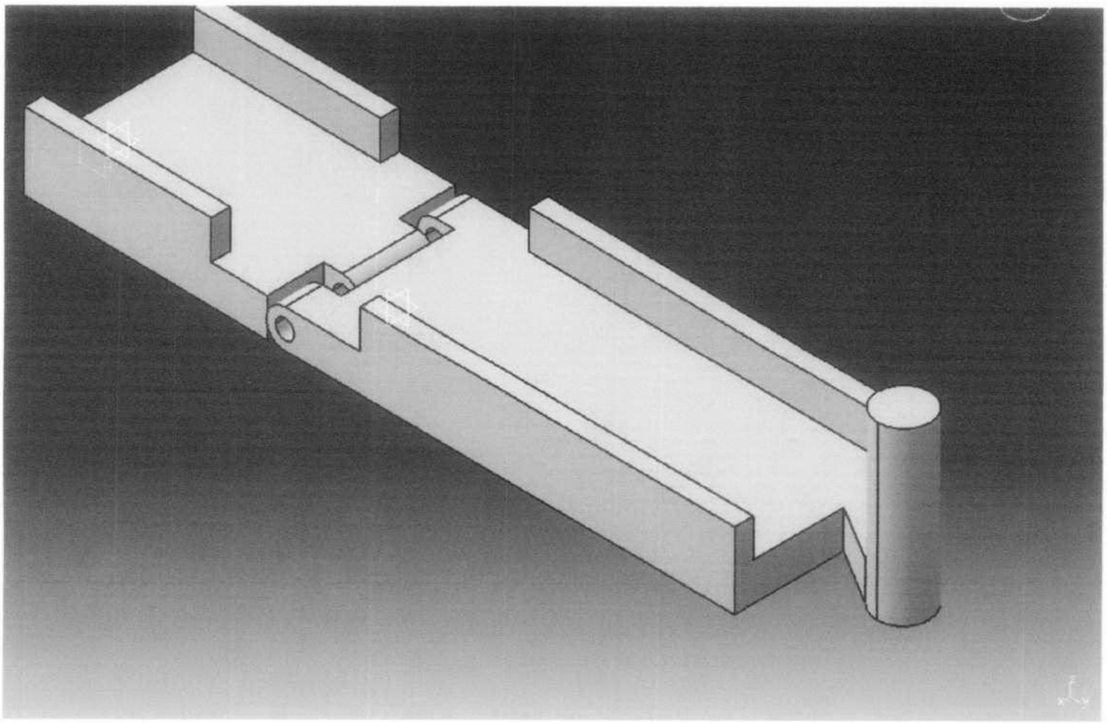

Figure 10: Design 3

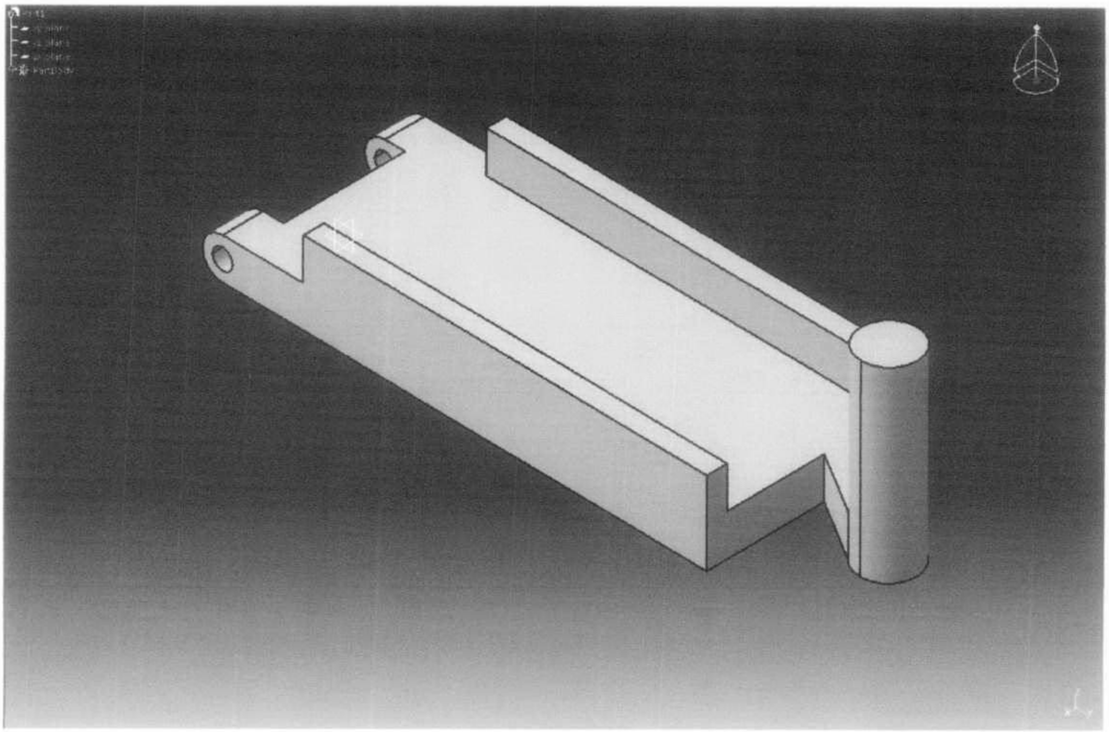

Figure 11: Design 3 Part 1

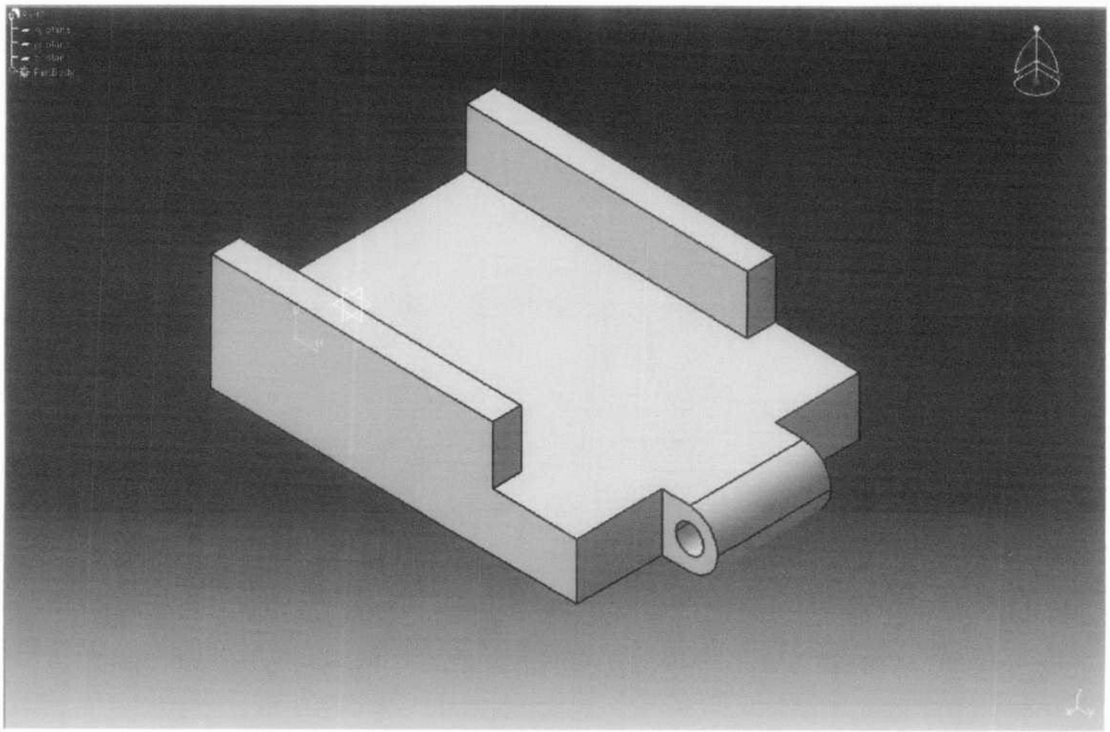

Figure 12: Design 3 Part 2

4.1.4 Design 4

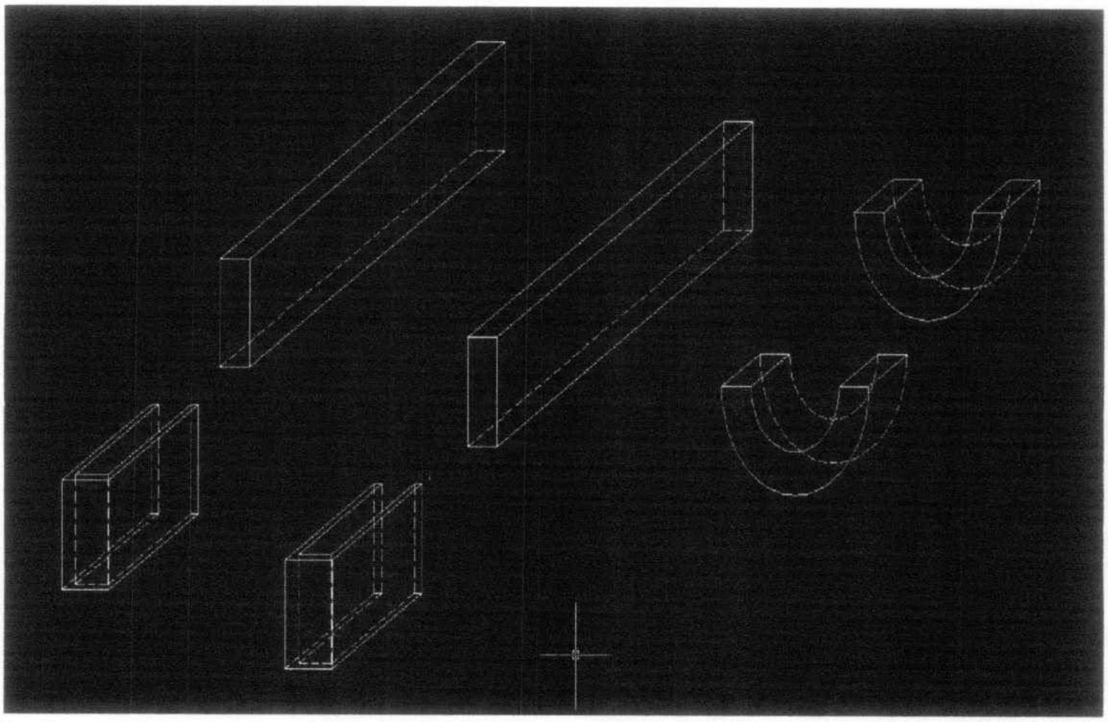

Figure 13: Design 4

4.2 Evaluation of the Design Concepts

All designs may interfere with the movement of patients' arms because of the human elbow. Designs should be concentrating on the arm movement because when the patients undergo the therapy; their arm movement will not be perfect. It is because of no space for the elbow when it is in 90 degree flexion. Next, at the end of all the designs, there is a handle for the stroke patient to hold on to. At first of the therapy, patient may not be able to hold on to the handle because of the paralyzed arm, but after his/her arm's abilities (e.g. elbow flexion and extension, hand grasping), patient can seize the handle while the trainer moving.

As for the patient's arm position, there will be straps for holding the arm to avoid slipping from the arm trainer. The author did not put the strap in the designs because the author is only focusing on the design. Below is the example of a strap. Strap is used because of its flexibility that can be adjusted prior to patient's arm size.

Figure 14: Strap

Figure 15: Concept of connection between two parts of the new design

4.3 Final Design

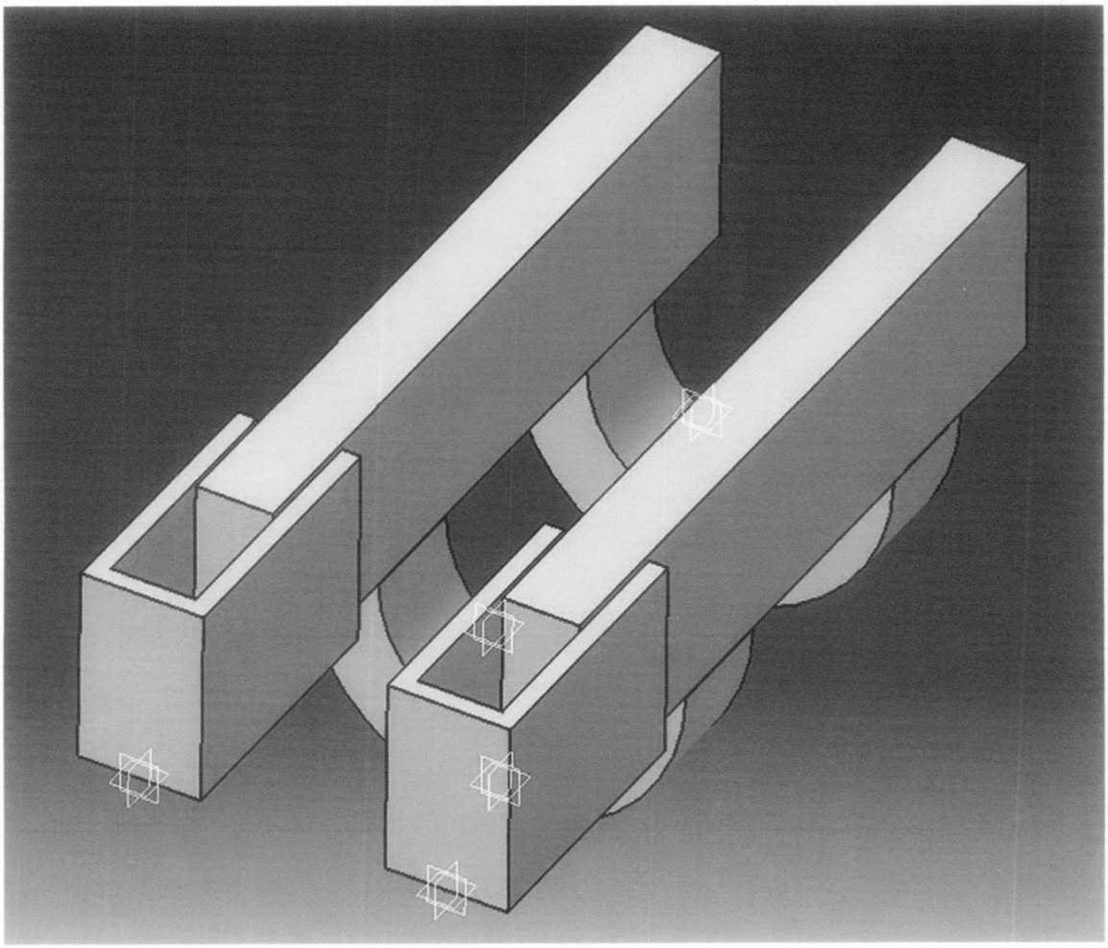

Figure 15: Final design using Catia V5

4.4 Design Specification

4.4.1 Design Movement

There are three different exercises for stroke patients which are:

- wrist flexion and extension
- elbow flexion and extension
- shoulder flexion and extension, horizontal abduction and adduction, internal and external rotation

So, the author selected and focuses on the movement of the elbow flexion and extension to produce an exercise for the stroke patients.

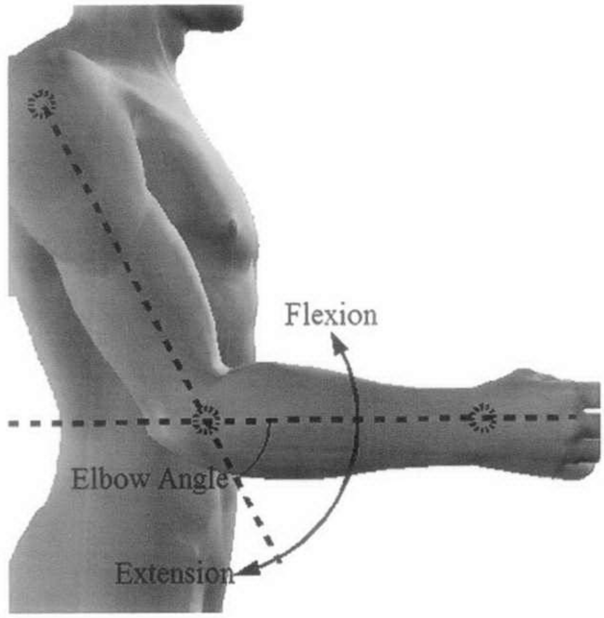

Figure 16: Elbow flexion and extention

Figure 16 shows that the movement of the arm where the area focused by the author is the elbow flexion and extension. The patient will put his/her disable arm within the center of the product. The device will be switched on and the patient can stay using the arm trainer as long as he.she wants. This design does not have any specific session and can be turned on and off by the users when they want to. The arm trainer will drive the patient's elbow to do the flexion and extention movements.

4.4.2 Design Dimension

The design dimensions are shown in Appendix B.

4.4.3 Design Speed

The product will use AC motor to supply the power that will produce speed for the arm trainer. For this design, the speed used is 0.20 m/s. The speed is set to 0.20 m/s because this is the suitable speed for the arm trainer to run for the stroke patient without give any effect to the patient's arm.

4.4.4 Parts of Components

4.4.4.1 Part 1

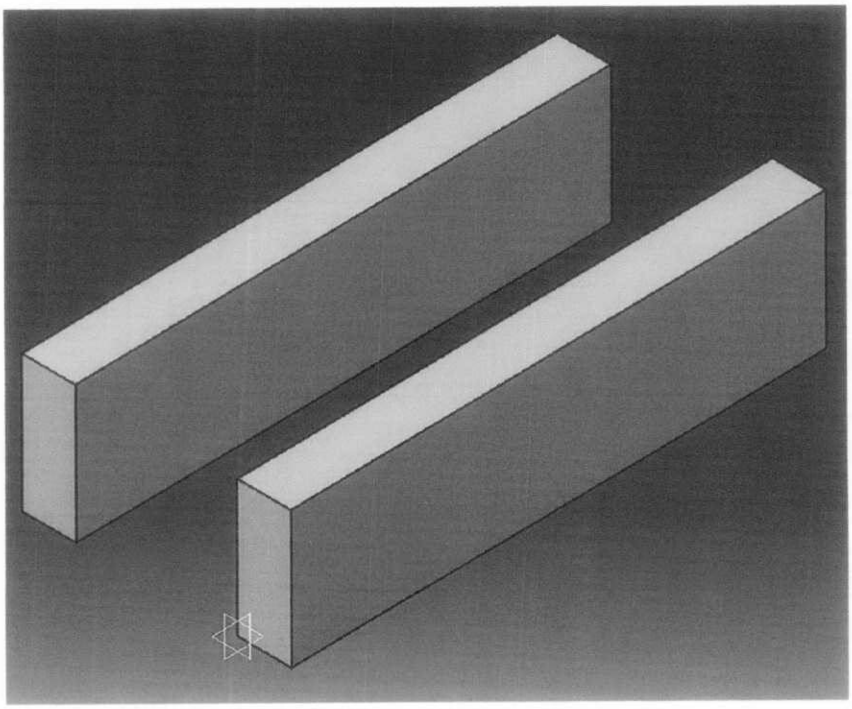

Figure 17: Part 1

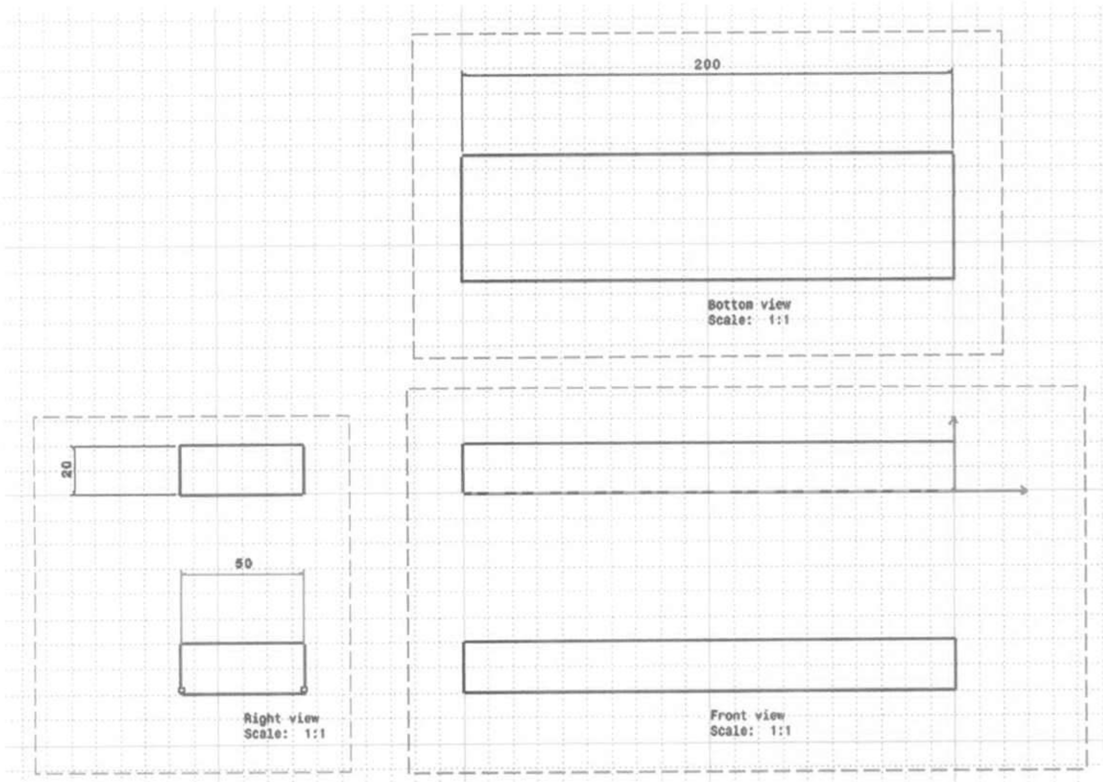

Figure 18: Part 1 Drawing

4.4.4.2 Part 2

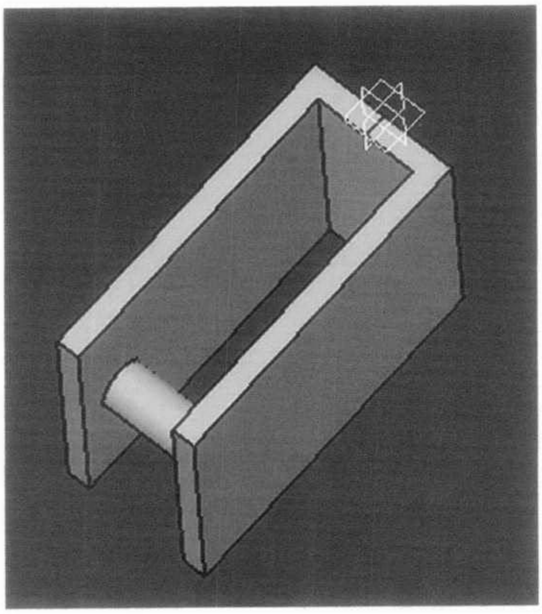

Figure 20: Part 2

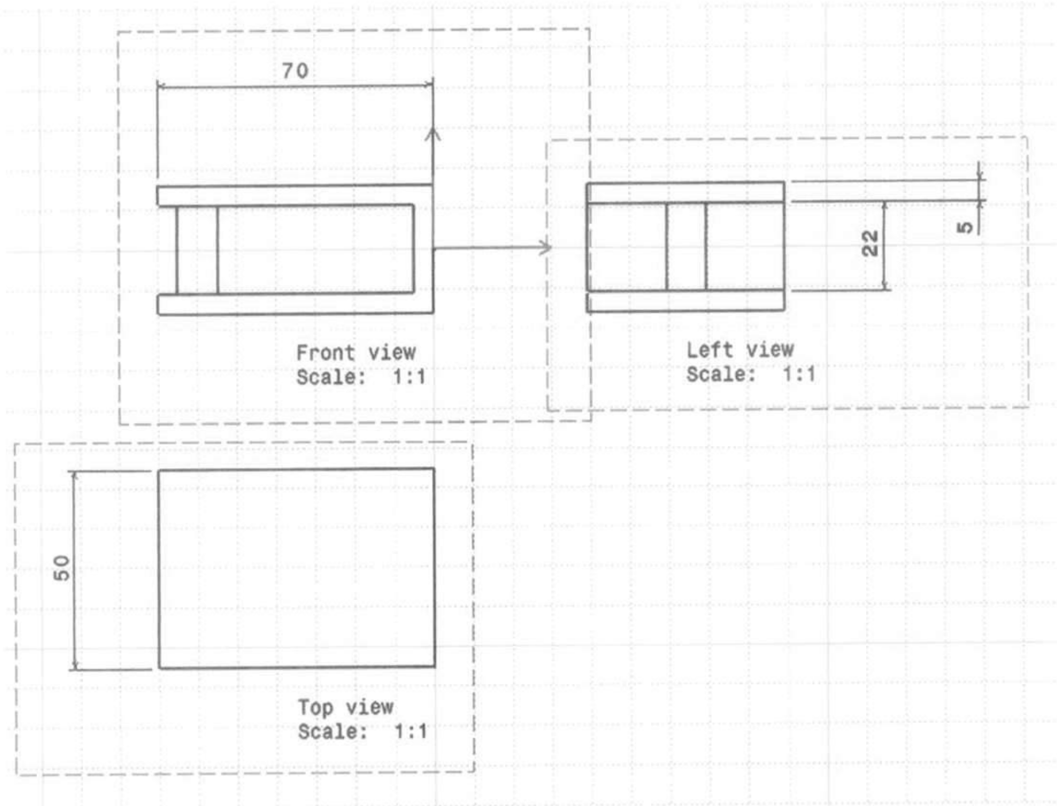

Figure 19: Part 2 Drawing

4.4.4.3 Part 3

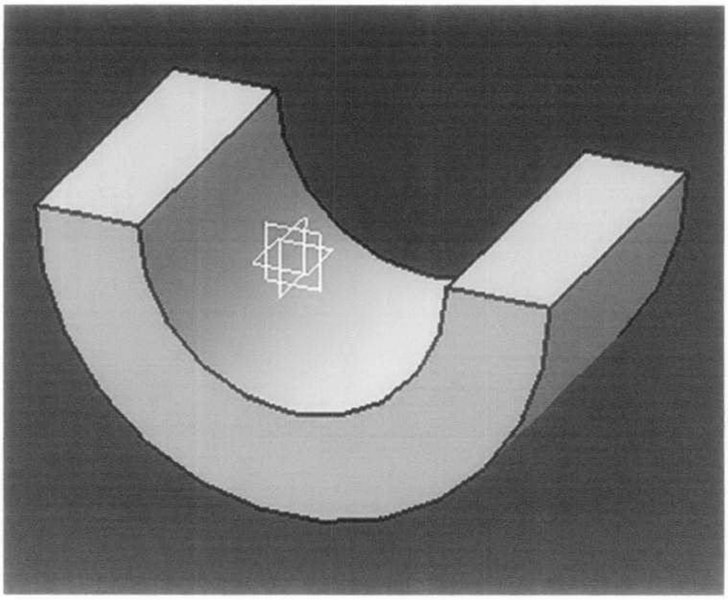

Figure 20: Part 3

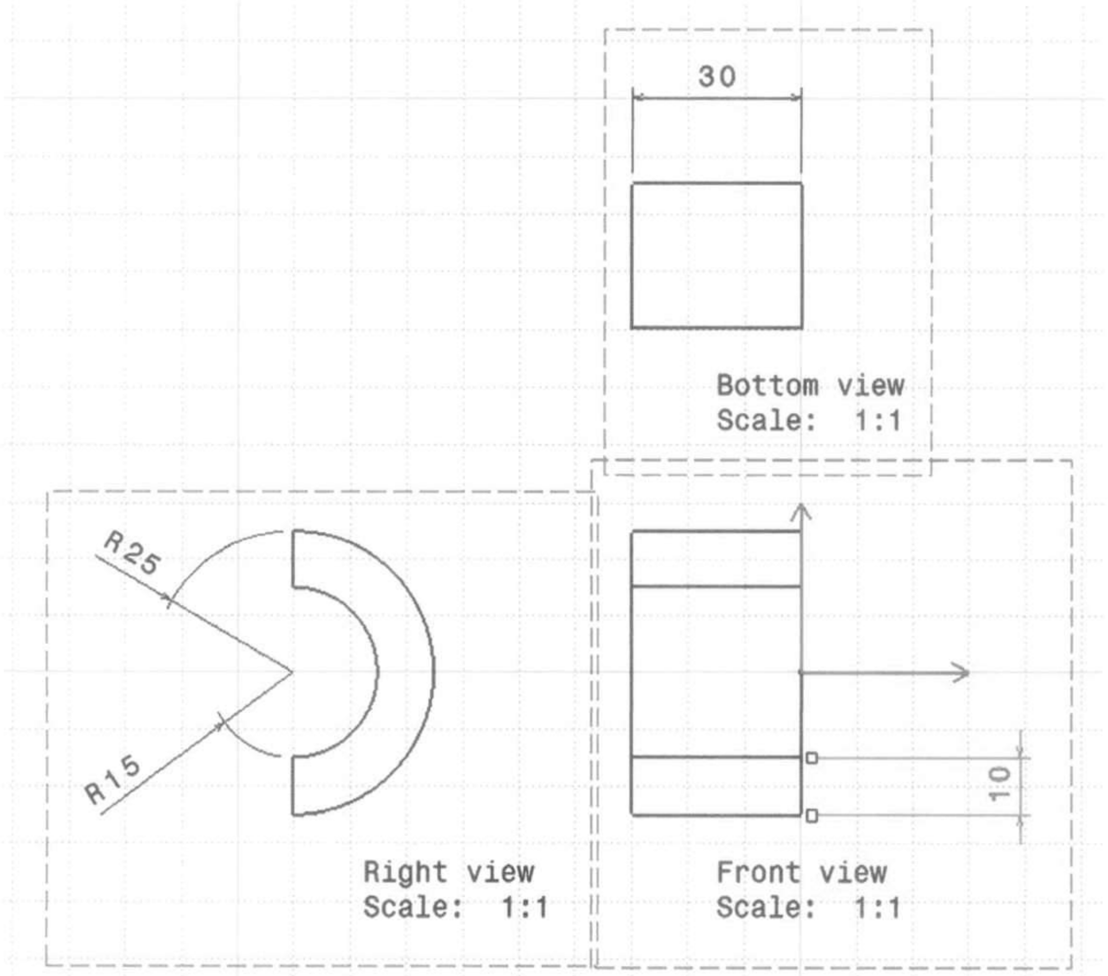

Figure 21: Part 3 Drawing

4.4.5 Material Selection

Material selection is a step in the process of designing any physical object. In the context of product design, the main goal of material selection is to minimize cost while meeting product performance goals.

Some of the material properties that have been obtained are shown in Table 3 in Appendix C.

4.4.5.1 Properties Comparison

Database containing wide range of material and its properties are obtained. The preliminary screening was made to determine candidate materials that fit for the functions of every part in the arm trainer. Database on the screening of materials are shown in the Table 4 in Appendix C.

From the Table 5: Weight Properties Index, copper alloy and carbon steel has about same score. Meanwhile for stainless steel, the score is slightly higher and aluminium gave the highest marks. Aluminum alloy has very low density thus giving lightweight parts, relatively good yield strength, small elongation due to stress, good machinability and high corrosion resistant. So the author select aluminium alloy (1100-H14) as the final material to be used.

4.4.6 Electric Motor Specification

4.4.6.1 Motor Type

The arm trainer will use AC motor to supply power to the device. The suitable type of motor will be used is AC brushed motor because of it is relatively high speed, high torque, and easy to be programmed. The Pulse Width Modulation (PMW) circuit will be used to control the speed of the motor.

4.4.7 Safety

Safety was a main issue during the design of the device. Passive and active safety features guarantee a safe operation. Passive safety includes mechanical end-stops that guarantee that no joint can exceed the anatomical range of motion of the human limbs. Whenever any abnormal event is detected, the safety circuit immediately cuts the power of the motor drives.

CHAPTER 5

5.0 CONCLUSION & RECOMMENDATIONS

5.1 Conclusion

For the conclusion, it shows that it requires a certain engineering steps before a detail design can be developed throughout this project. This report discusses on the reviews of the existing arm trainer, comparisons between existing devices and the concepts of the project. Also, it discusses on the progress of the project which is until generating design concept and the evaluation. Starting of the project is the development of the concept which is to understand the problem statement. The author has to define all the parameters needed and mechanism that will be used in arm trainer design.

After the design concept is developed, the design needs to be generated and evaluated. Based on the design development, there are still some parameters that has to be considered during generating the design. From the result, the arm trainer design achieves the objective of this project which is designing an effective and low cost arm trainer for stroke patients. This device is also light and portable because of the material chosen and its size. Lastly, this project gives opportunity for the author to come up with good design and apply to common engineering problems.

5.2 Recommendation

For further study, some issues which were gained during the completion of this project and the recommendations are based on the main things which are:

- Detail design
  a. As for the design, more detail design should be generated as for the machining workers can fabricate the produce based on the detail design.

- Acceleration of the moving part
  a. The acceleration of the moving part should be obtained to produce a better result on the project. The acceleration and velocity profile also are needed to gain excellent result for design the device.

- Exercises for other part of hand
  a. This device only focuses on the elbow flexion and extension. For further study, a new design should be generated that focuses on more arm movements like wrist flexion and extension, or the shoulder movement.

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APPENDICES

Appendix A

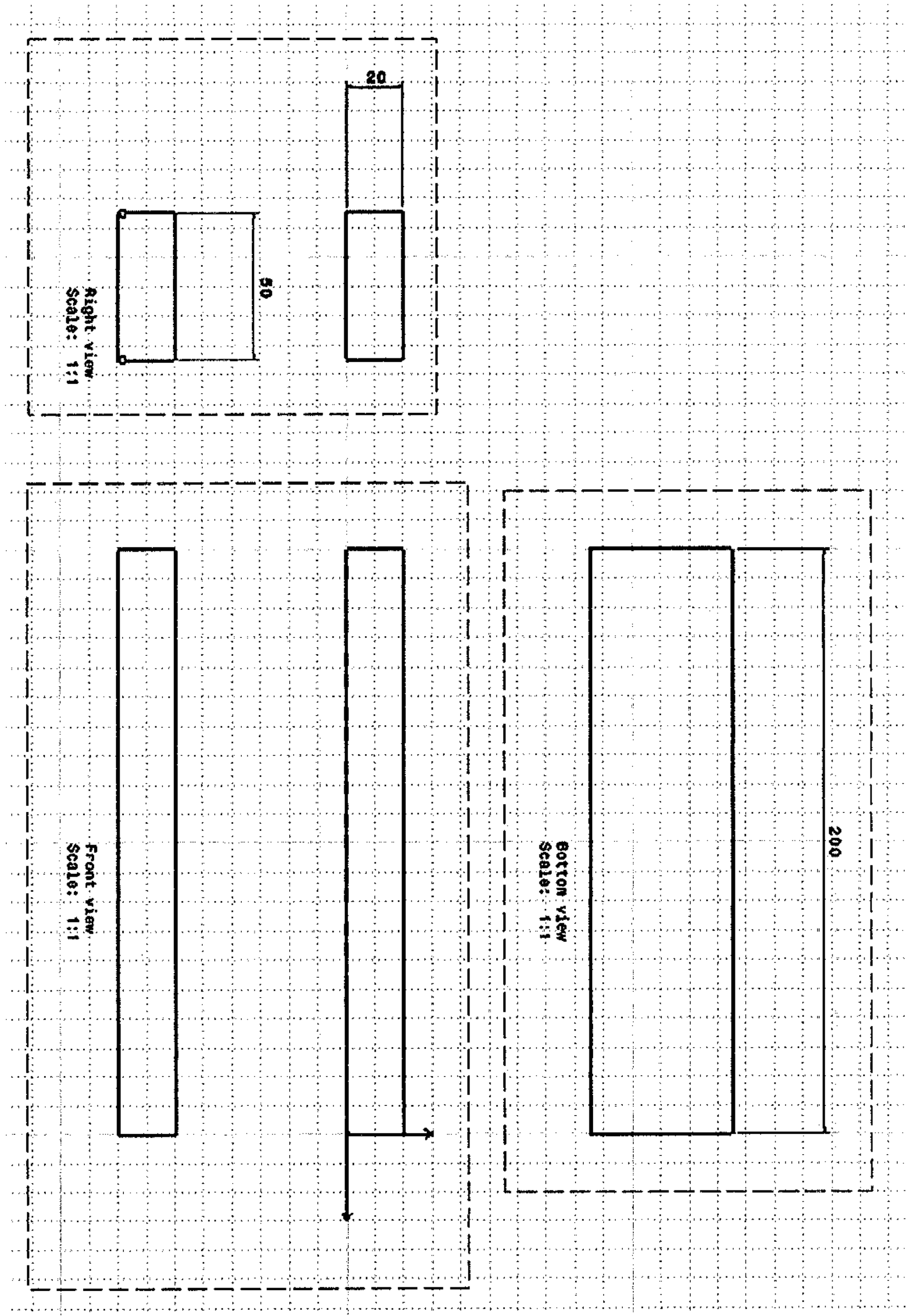
Suggested Milestone for Final Year Project I

No	Detail/Week	1	2	3	4	5	6		7	8	9	10	11	12	13	14
1	Selection of Project Topic	■	■					Mid-semester break								
2	Preliminary Research Work		■	■	■											
3	Submission of Preliminary Report				●											
4	Project Work					■	■									
5	Submission of Progress Report									●						
6	Seminar (compulsory)									●						
7	Project work continues								■	■	■	■	■	■	■	■
8	Submission of Interim Report Final Draft															●
9	Oral Presentation								During study week							

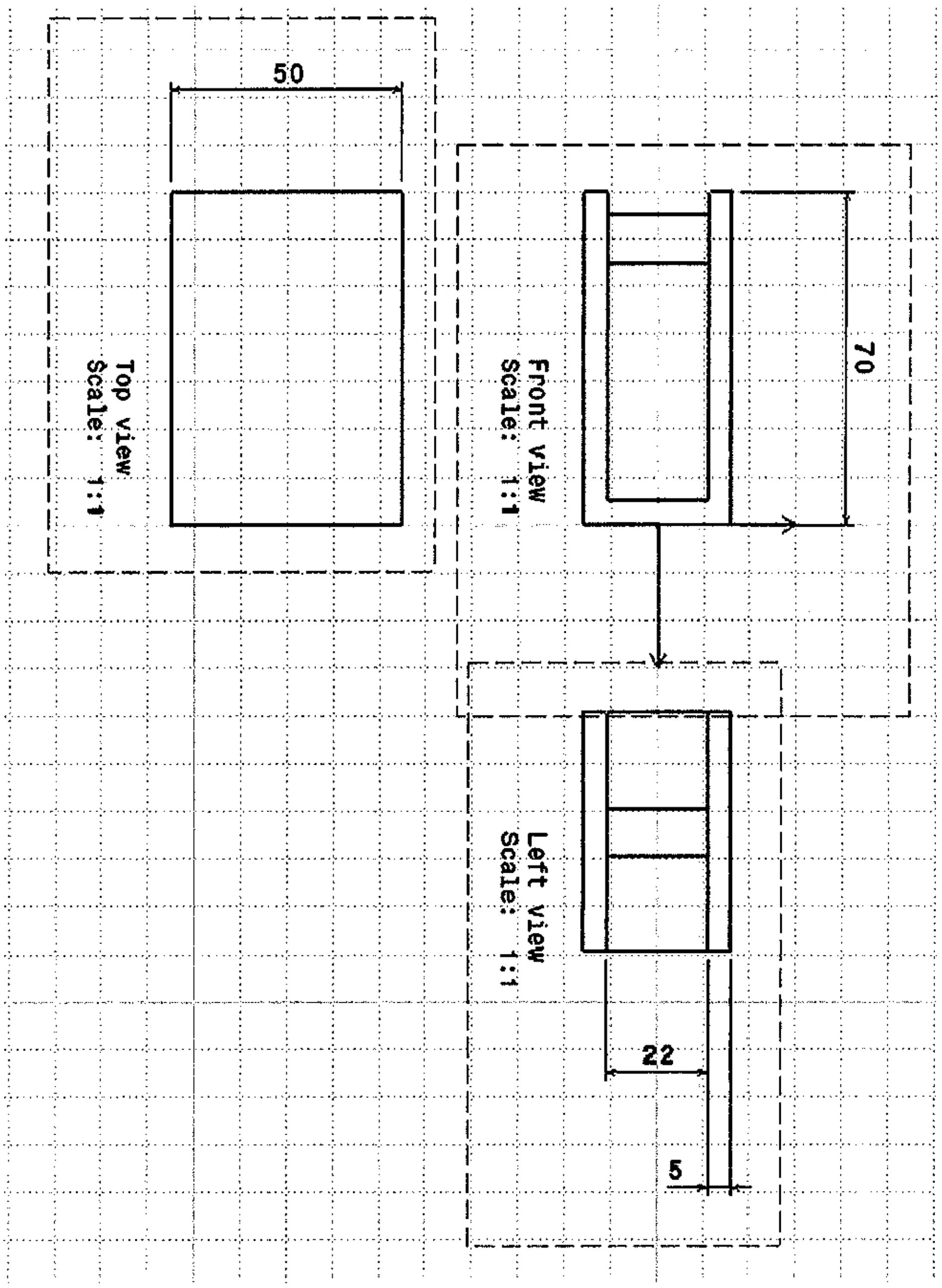
● Suggested milestone

■ Process

Appendix B


20
50
Right view
Scale: 1:1
Front view
Scale: 1:1
Bottom view
Scale: 1:1
200

Appendix B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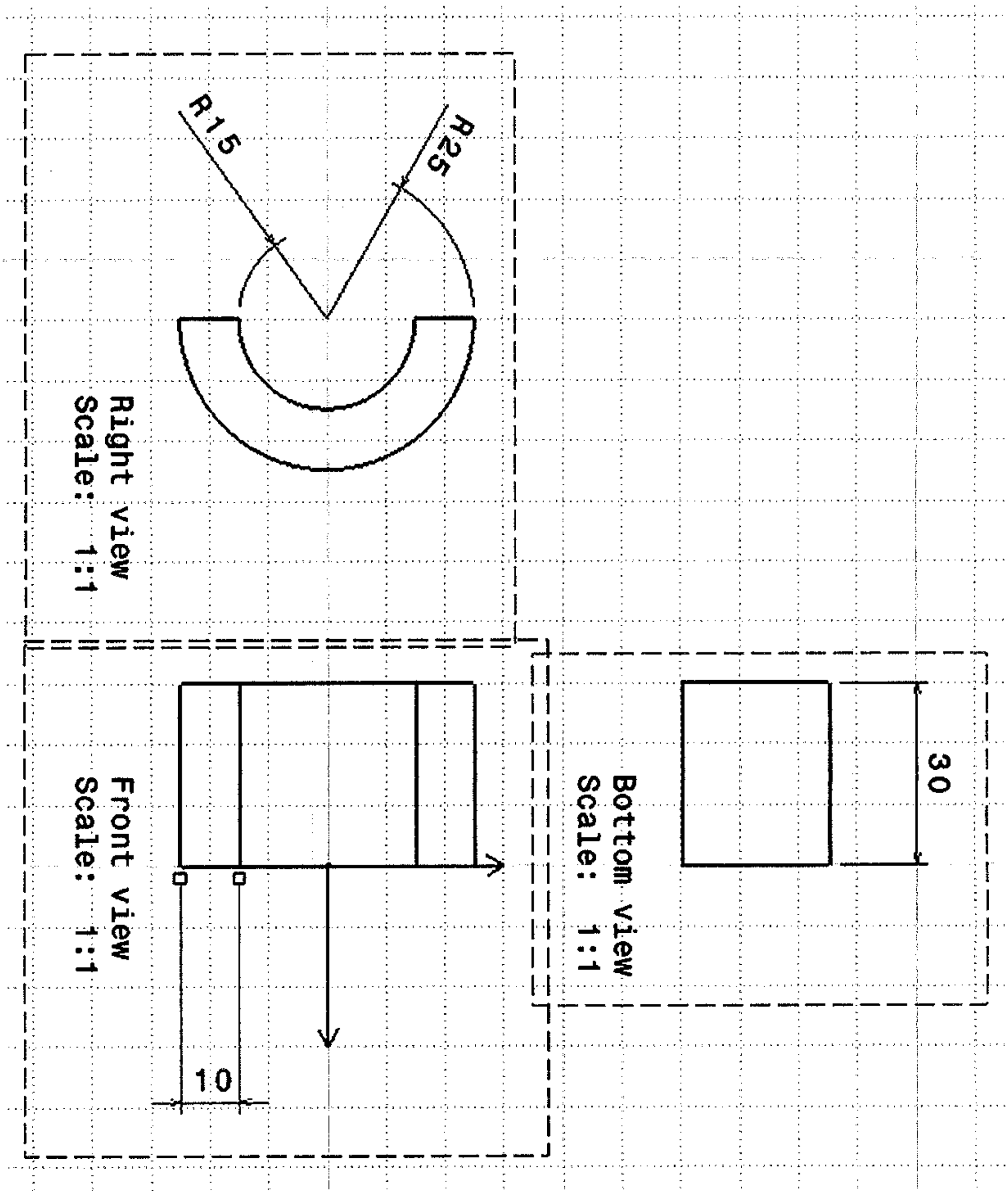
Top view
Scale: 1:1
Front view
Scale: 1:1
70
Left view
Scale: 1:1
22
5

Appendix B


R15
R25
Right view
Scale: 1:1
Front view
Scale: 1:1
10
Bottom view
Scale: 1:1
30

Appendix C

Table 3: Material Properties

Function	Material Properties
Low mass	Density
Exhibit elastic deformation	Yield strength
Minimal deflection	Elongation
Avoidance of plastic deformation	Yield strength
Able to withstand sudden impact	Hardness
Low material cost	Price
Ease of manufacturing	Machinability

Appendix C

Table 4: Screening of Material

Material	Material Properties						Status
	Density (lb/in^3)	Yield str ()(Mpa)	Elongation (%)	Hardness (HV)	Machinability Index (Annaeled)	Price per Pound	
Polyethylene (PE)	0.034	13	600	-	-	0.3	Discard
Nylon (PA)	0.042	62	27	-	-	3	Discard
Carbon Steel (1010)	0.28	305	20	105	100	0.4	Accept
Stainless Steel (430)	0.28	205	22	183	165	1.25	Accept
Aluminum Alloy (1100-H14)	0.098	117	20	32	180	0.73	Accept
Cooper Alloy (C11000)	0.323	365	4	60	150	0.92	Accept
Nickel Alloy (N02200)	0.322	148	50	170	340	5.3	Discard

Appendix C

Table 5: Weight Properties Index

Material	**Material Properties**						**Overall total**	**Weighted Total**
	Density (lb/in^3)	Yield str ()(Mpa)	Elongation (%)	Hardness (HV)	Machinability Index (Annaeled)	Price per Pound		
Weightage	5	1	4	2	4	5		
Carbon Steel (1010)	0.28	275	35	110	100	0.4		
	D	A	T	U		M	0	0
Stainless Steel (430)	0.28	275	20	260	165	1.25		
	S	S	S	+	+	-	+1	+1
Aluninum Alloy (1100-H14)	0.1	117	9	26	180	0.73		
	+	-	+	-	+	-	0	+5
Cooper Alloy (C11000)	0.32	344	4	60	150	0.92		
	-	+	+	-	+	-	0	-3