Flexible Parallel Bar for Physiotherapy Purposes

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Abstract—**The utilization of parallel bars in rehabilitative and active recuperation is crucially critical in the medicinal services calling. Parallel bars are utilized to enable an individuals to recover their quality, to adjust the scope of movement, and to have freedom in it. Any individual who is recouping from wounds, ailments, and other crippling conditions will see that the parallel bars are importance things for an active recuperation, recovery, and an exercise hardware. However, there are some obstacles while adjusting the bar height according to patient's height. This is because the height of bar is adjusted manually by a physiotherapist and it will take time to allow patients to use it. Therefore, the Flexible Parallel Bar is developed to address this problem. This project consists of a control unit that will control bar on the left/right and up/down button. Forward reverse motor is used to downward/ upward the shaft according to the desired height. In addition, the parallel bar is a portable tool to allow the patient to use it as recovery and exercise tool at home. It can save time for patient to do the physiotherapy exercises at home or everywhere desired by patient.**

Keywords—flexible parallel bar; physiotherapy; disability.

I. INTRODUCTION

The uses of parallel bars in rehabilitative and physical therapies is vitally important in the healthcare profession. Parallel bars are used to help people regain their strength, balance, range of motion, and independence. People who are recovering from injuries, illnesses, and other debilitating conditions, parallel bars are important items of physical therapy, rehabilitation, and exercise equipment [1]-[2].

Rehabilitation therapists use parallel bars for coordination exercises. These task-oriented procedures help people with balance and coordination problems, typically resulting from strokes or brain trauma. Patients are required to repeat concise movements that work more than one joint and muscle. Parallel bars are also used for ambulation exercises to improve a patient's ability to walk independently or with assistance. Before starting such exercises, some patient's may need to develop or improve the range of motion of their joints as well as to develop any lost muscle strength [3].

Normally, this kind of preparation starts on parallel bars and then advances to strolling with portability helps such as walkers, braces, or strolling sticks. Treatment parallel bars are likewise utilized for general molding works out. This rehabilitative treatment consolidates the scope of-movement, muscle-reinforcing, and wandering activities to neutralize impacts from being in a wheelchair for a maintained time frame or from delayed bed rest and immobilization.

General molding practices are utilized to help heart and lung working and to help reestablishing important blood stream. Parallel bars are essentially imperative for walk preparing. Headed straight toward recuperation, getting ready to walk is a fantastic undertaking requiring tolerance, commitment, an uncommon measure of resolve, and the help of a physical specialist. Regardless of whether a patient can walk, they may discover it to a great degree troublesome without legitimate rehabilitative treatment. A few wounds that relate, for example, to the cerebrum or spine, has usual impact engine abilities and may cause fits. Step preparing can enable patients to recover their typical mobile movement [4].

Article history: Manuscript received 15 February 2019; received in revised form 4 April 2019; Accepted 5 April 2019.

Making any type of rehabilitation to be successful, it is critical to implement a multifaceted, interdisciplinary course of therapy incorporating exercises and techniques that have a broad and comprehensive focus [5]. The use of parallel bars for physical therapy is only a fragment of the entire process. Such therapy should always aim to restore maximum independence to all facets of an individual's lifestyle. It is important to remember that not every process of rehabilitation is the same.

There are times when different strategies are employed on the same patient and other times when the same strategies are employed on different patients. Therapists must be proficient enough to discern their patients weaknesses and needs and thereby develop and administer the designed exercise regimens to increase mobility, strength, coordination, and balance [4]. Alongside the utilization of parallel bars, specialists should consolidate other restoration gear, such as adjusting sheets; practicing balls, hand and finger activities; MediCordz, and protection strings, groups and tubing.

The gait training will improve the balance body of patient. Next it will make the increase of parameter and velocity waling of the patient. Therefore, the patient must always do the gait training to gain their strength [6]-[8]. Amid the recovery time frame the objective of non-intrusive treatment is muscle reinforcing, balance exercises, walk preparing, and practical preparing programs showed little to substantial impact estimate step execution enhancements in individuals while bring down appendage removal. The patient group has some problems. Hence patients with lower limb is divided into two. The first is a patient with a leg that needs training gait, and the second is a patient who has no leg which needs training gait.

The Platform Mounted Parallel Bars are flexible and simple to set up. Height and width estimations stamped on the edge make it less demanding at any time to make custom adjustment to this parallel bar unit. This unit gives a more reasonable and proficient other option to complex mechanized bars, enabling clinicians to invest more energy with patients. This unit is wheelchair open and intended for offices where detached bars are required. The parallel bar can hold up to 400lbs with dimension of length 2.13m, height range 66cm - 99cm and width range 45.12cm - 71.12cm [9].

In this project, to deliver something useful, it must be based on the needs and demands of users at present. Therefore, our aim is to develop flexible and portable parallel bar for physiotherapy patient. Products produced only covers one Circuits Forward / Reverse and remaining mechanical concept that is applied to make the product more flexible.

Circuit Forward or Reverse function as a motor which is developed in the form of control for controlling the movement of Automatic or Manual. In addition, the toggle switch is used in the circuit for switching between Automatic and Manual depending on the situation [10].

Mechanical concepts are applied in development with geared towards making the project more portable and easy to carry to the appropriate places. In addition, the hardware is in a state of prefabricated did not complicate the installation and Manual Book available. Hardware to be connected, stored in a trunk in order to facilitate the preparation.

II. METHODOLOGY

To develop and improve equipment, there must implement user friendly system and comfort for human when using the parallel bar. It more relates to human capability and the equipment. In traditional parallel bar, it can see the screw lock for height adjustment are locate on lies at an altitude of equal distance from one point to another. The height of human is difference between each other. From the analysis journal, it can implement the concept of the lifting of trailer jack. It consists of three main materials which is inner and outer shaft and miter gear that assemble together [11].

A. *Direct DC Motor and Control*

For this part, a DC motor gear is being used to lift up the parallel bar. The DC motor gear has type high torque and soft start. This is because of to lift up the heavy material by using screw gear that attach to the shaft of motor. The advantage of this type DC motor gear is simple to operate and easy to maintenance. Might use motor with wholesale 24V DC motor and 100RPM output speed and gear motor box 37MM Central shaft High Torque ZGA37RG 34.5i-5000.

Fig. 1 Motor DC

The circuit design for forward reverse motor had been design by using Proteus 8 Professional software. Refer to Figure 2, the circuit is completely designed with multifunction switch (SW1). This switch (SW1) is function to separate the circuit between manual and auto to control the rotation motion motor.

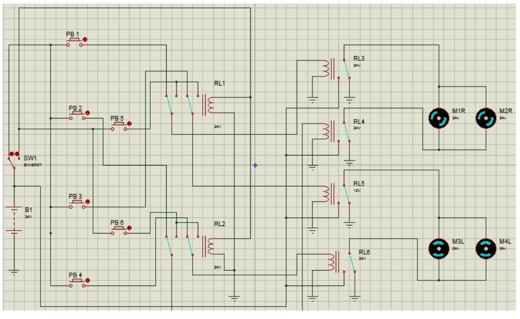

Fig. 2 Forward reverse motor circuit design

In forward bias condition, when the push button 1 (PB1) is pressed, the current will flow through the coil, so the SPST relay 3 (RL3) will energized. Since the coil in relay 3 (RL3) energized, the condition of NO will change to NC. So, the motor 1 (M1R) and motor 2 (M2R) at right will run in forward bias. Figure 3 shows the condition when the circuit operates in forward bias. This condition also uses between push button 3 (PB3) and relay 5 (RL5) to move the motor 3 (M3L) and motor 4 (M3L) at left.

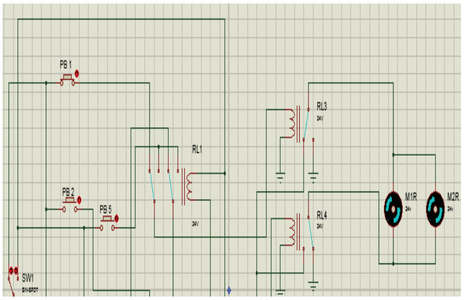

Fig. 3 Forward bias condition in manual

In reverse bias, when the push button 2 (PB2) is pressed, the current will flow through the coil, so the SPST relay 4 (RL4) will energize. Since the relay 4 (RL4) energized, the condition of NO will change to NC. So, the motor will run in reverse bias. Figure 4 shows the condition when the circuit operates in reverse bias. This condition also uses between push button 4 (PB4) and relay 6 (RL6) to move the motor 3 (M3L) and motor 4 (M3L) at left.

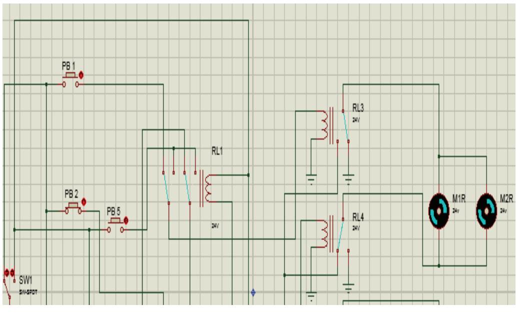

Fig. 4 Reverse bias condition in manual

In forward bias condition, when the push button 5 (PB5) is pressed, the current will flow through the coil, so the SPST relay 3 (RL3) and relay 5 (RL5) will energized. Since the coil in relay 3 (RL3) and relay 4 (RL5) energized, the condition of NO will change to NC. So, the motor 1 (M1R), motor 2 (M2R), motor 3 (M3L) and motor 4 (M4L) will run in forward bias. Figure 5 shows the condition when the circuit operates in forward bias.

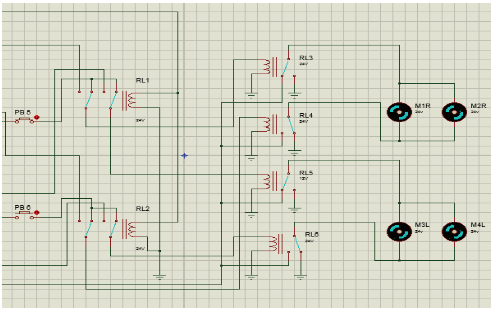

Fig. 5 Forward bias condition in auto

In reverse bias condition, when the push button 6 (PB6) is pressed, the current will flow through the coil, so the SPST relay 4 (RL4) and relay 6 (RL6) will energized. Since the coil in relay 4 (RL4) and relay 6 (RL6) energized, the condition of NO will change to NC. So, the motor 1 (M1R), motor 2 (M2R), motor 3 (M3L) and motor 4 (M4L) will run in reverse bias. Figure 6 shows the condition when the circuit operates in reverse bias.

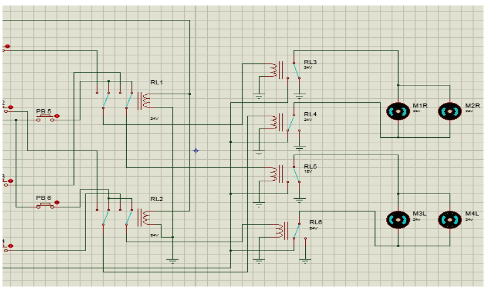

Fig. 6 Reverse bias condition in auto

B. Design Sketch

Figure 7 shows the view of Flexible Bar for physiotherapy that sketch by using Solid Work software. Presenting of the design shows the upper side of project using T jointer to assemble with lower side. Then the base can be separate to make the project being portable. It will include a bag so that it can easily place and used everywhere. The motor will be implement on the bottom of the trunk.

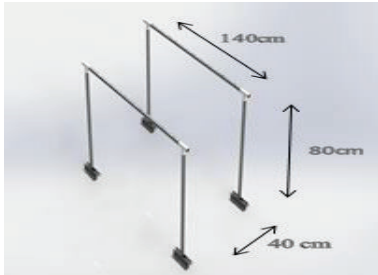

Fig. 7 Design using SOLIDWORKS

After complete the fabricate the prototype, proceed with static test simulation. In this phase, it will focus on static test simulation on the prototype. Figure 8 show the flow chart process on how the prototype was undergoes static test simulation.

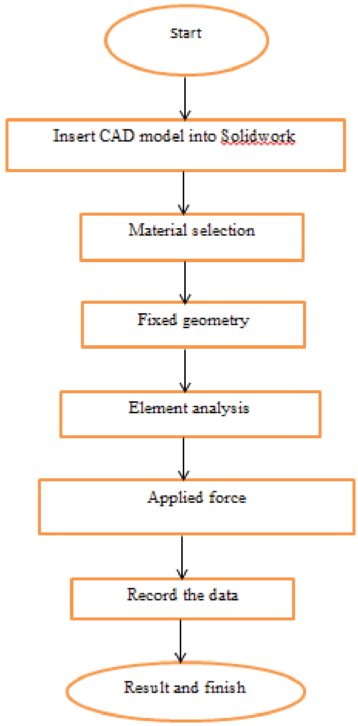

Fig. 8 To testing the static test simulation

The material for the specimen will selected on in the Solidwork library. In this process, AISI 1010 Steel, hot rolled bar was selected. Besides that, the material properties were also provided in the Solidwork software as figure 9.

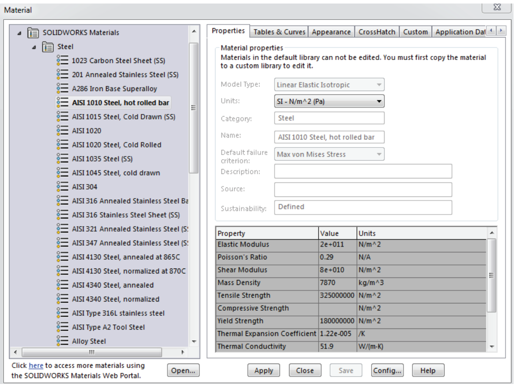

Fig. 9 ISI 1010 Steel, hot rolled bar properties

III. RESULT AND DISCUSSION

In this discussion, before finalized the analysis and data, some steps will be taken. On the simulation, as a starting statics studies were applied in the simulation as first analysis. Next, the material AISI 1010 steel, hot rolled bar will be applied in the statics studies. The fixed geometry and force location need to be specified in static studies. For the CAD model will simulate with a different force value. For the static studies, the force exerted will be 40kg, 50kg and 60kg. All of the load amount value should be converting into newton (N). Next, it will simulate in the software to generate stress, strain and displacement data for the CAD model. On the hardware project, several studies for analysis were applied. There were voltages against load analysis, current against load analysis, power against load analysis and load against time taken with the fixed height. The load that required from minimum 0kg and maximum 18.9kg.

A. *Static study parallel bar 40 kg (392.4 N)*

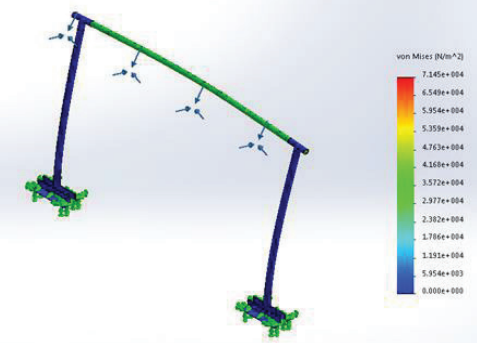

Fig. 10 Von mises stress plot at 392.4 N

In the data von mises stress as Figure 10, the minimum value is 0N/m^2. While maximum value is shown 71446.9N/m^2. When the model was loaded with 392.4N its start to deform starting at minimum value and will be able until reach the maximum value.

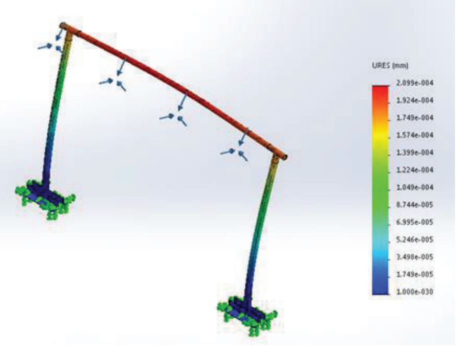

Fig. 11 Displacement plot at 392.4 N

In the data displacement as Figure 11, the minimum value is 0mm. While maximum value is shown 0.000209852mm. When the model is loaded with 392.4N its start to occur displacement starting at the minimum value and will be able until reach the maximum value.

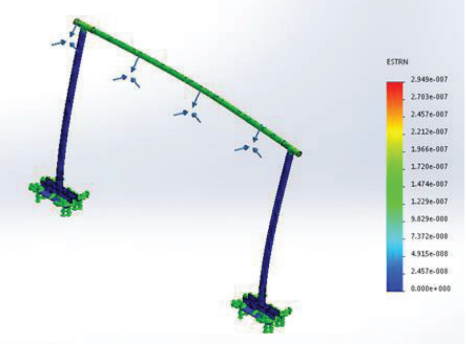

Fig. 12 Strain plot at 392.4 N

In the data strain as Figure 12, the minimum value is 0. While maximum value is shown 2.94871e-007. When the model was loaded with 392.4N its start to occur strain starting at the minimum value and will be able until reach the maximum value.

TABLE 1 40 KG (392.4 N) STATICS STUDY DATA

Force	Type	Min	Max
40 Kg (392.4 N)	Von mises stress (N/m^2)	0	71446.9
	Displacement (mm)	0	0.000209852
	Strain	0	2.94871e-007

As shown in Table 1 data recorded. The data are recorded according to each statics study analysis. Each statics study has minimum and maximum data according to the same load placed.

B. Static study parallel bar 50 kg (490.5 N)

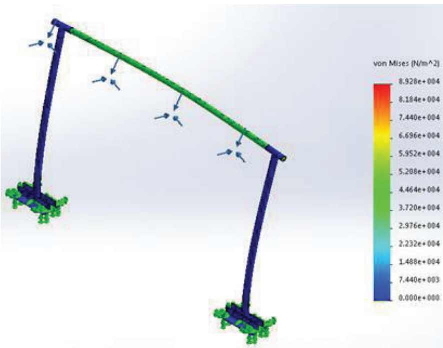

Fig. 13 Von mises stress plot at 490.5 N

In the data von mises stress as Figure 13, the minimum value is 0 N/m^2. While maximum value is shown 89283.1 N/m^2. When the model was loaded with 490.5 N its start to deform starting at minimum value and will be able until reach the maximum value.

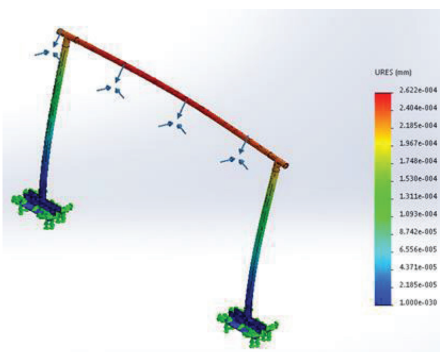

Fig. 14 Displacement plot at 490.5 N

In the data displacement as Figure 14, the minimum value is 0 mm. While maximum value is shown 0.000262249 mm. When the model is loaded with 490.5N its start to occur displacement starting at the minimum value and will be able until reach the maximum value.

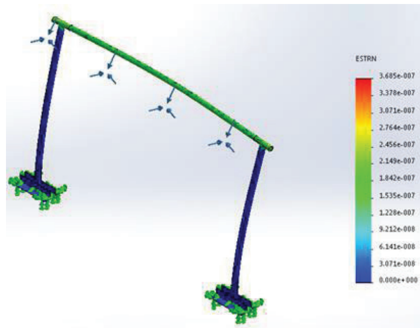

Fig. 15 Strain plot at 490.5 N

In the data strain as Figure 15, the minimum value is 0. While maximum value is shown 3.68475e-007. When the model was loaded with 490.5N its start to occur strain starting at the minimum value and will be able until reach the maximum value.

TABLE 2 50 KG (490.5 N) STATICS STUDY DATA

Force	Type	Min	Max
50 Kg (490.5 N)	Von mises stress (N/m^2)	0	89283.1
	Displacement (mm)	0	0.000262249
	Strain	0	3.68475e-007

As shown in Table 2 data recorded. The data are recorded according to each statics study analysis. Each statics study has minimum and maximum data according to the same load placed.

C. Static study parallel bar 60 kg (588.6 N)

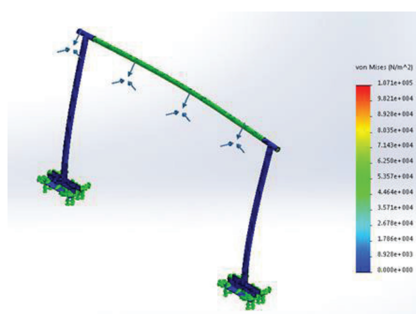

Fig. 16 Von mises stress plot at 588.6 N

In the data von mises stress as Figure 16, the minimum value is 0N/m^2. While maximum value is shown 107139N/m^2. When the model was loaded with 588.6N its start to deform starting at minimum value and will be able until reach the maximum value.

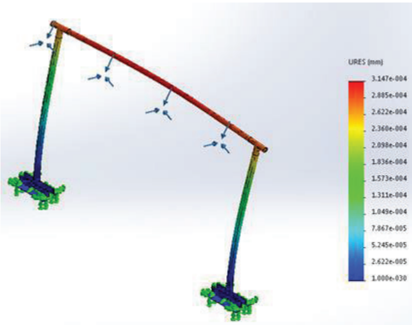

Fig. 17 Displacement plot at 588.6 N

In the data displacement as Figure 17, the minimum value is 0mm. While maximum value is shown 0.000314696mm. When the model is loaded with 588.6N its start to occur displacement starting at the minimum value and will be able until reach the maximum value.

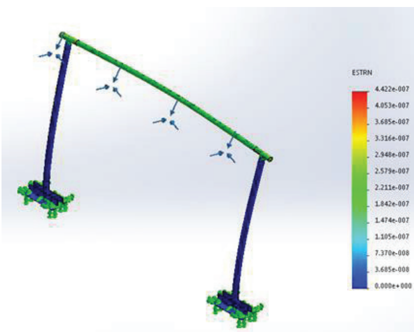

Fig. 18 Strain plot at 588.6 N

In the data strain as Figure 18, the minimum value is 0. While maximum value is shown 4.42179e-007. When the model was loaded with 588.6N its start to occur strain starting at the minimum value and will be able until reach the maximum value.

TABLE 3 60 KG (588.6 N) STATICS STUDY DATA

Force	Type	Min	Max
60 Kg (588.6 N)	Von mises stress(N/m^2)	0	107139
	Displacement (mm)	0	0.000314696
	Strain	0	4.42179e-007

As shown in Table 3 data recorded. The data are recorded according to each statics study analysis. Each statics study has minimum and maximum data according to the same load placed.

D. Analysis on hardware of the project

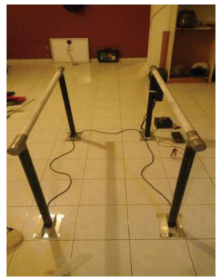

Fig. 19 Project hardware

The Figure 19 above shows the complete assemble hardware of parallel bar. The data of the analysis of this project is shown in Table 4 below.

TABLE 4 READING OUTPUT OF THE PROJECT

Mass (kg)	Motion	Measured		
		AMPHERE	VOLTAGE	POWER
0 kg	Up	0.8A	24.5V	19.6W
	Down	0.7A	24.6V	17.22W
1 kg	Up	0.9A	24.5V	22.05W
	Down	0.7A	24.6V	17.22W
2.5 kg	Up	1.0A	24.4V	24.4W
	Down	0.8A	24.5V	19.6W
5 kg	Up	1.2A	24.4V	29.28W
	Down	1.0A	24.5V	24.5W
8.1 kg	Up	1.8A	19.9V	35.82W
	Down	1.6A	20.5V	32.8W
10.8 kg	Up	2.2A	19.6V	43.12W
	Down	1.9A	20.9V	39.71W
13.5 kg	Up	2.5A	19.4V	48.5W
	Down	2.3A	20.5V	47.15W
16.2 kg	Up	2.9A	19.1V	55.39W
	Down	2.3A	20.3V	46.69W
18.9 kg	Up	3.0A	18.8V	56.4W
	Down	2.7A	19.5V	52.65W

Refer from Table 4 the parallel bar was tested with several load in order to get the output reading. The output reading that have been measured is a current, voltage and power of the parallel bar consumed.

Fig. 20 Sample of load and testing

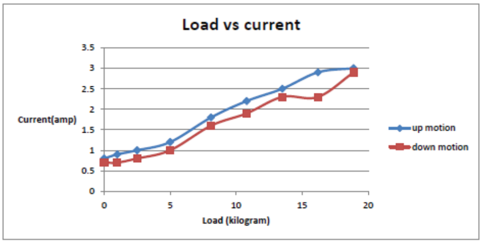

Fig. 21 Load against current

The Figure 21 shows highest current reading is at the weight of 18.9 kg being applied with a reading taken of 3.0A when the bar is in the up condition motion and consume 2.9A when it in down condition motion. Meanwhile, the lowest current reading is at 0 kg of weight with a reading of current 0.7A in down condition motion and 0.8A in up condition motion. This can be said that the higher load consumes a higher current value to operate the parallel bar for height adjusted.

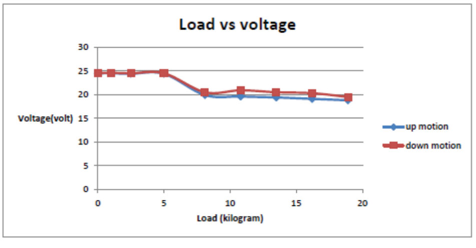

Fig. 22 Load against voltage

The Figure 22 shows lowest voltage reading is at the weight of 18.9 kg being applied with a reading taken of 18.8V when the bar is in the up condition motion and consume 19.5V when it in down condition motion. Meanwhile, the highest voltage reading is at 0 kg of weight with a reading of voltage 24.5V in down condition motion and 24.6V in up condition motion. This can be said that the higher load consume a lower voltage value to operate the parallel bar for height adjusted.

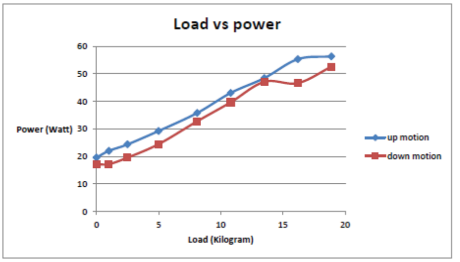

Fig. 23 Load against power

The Figure 23 shows higher power reading is at the weight of 18.9 kg being applied with a reading taken of 56.4W when the bar is in the up condition motion and consume 52.65W when it in down condition motion. Meanwhile, the lowest power reading is at 0 kg of weight with a reading of power 17.22W in down condition motion and 19.6W in up condition motion. This can be said that the higher load consumes a higher power value to operate the parallel bar for height adjusted.

TABLE 5 TIME TAKEN MOVEMENT OF PARALLEL BAR

Mass (kg)	Motion	Time (second)	Height (cm)
0kg	Up	10.59s	3cm
	Down	9.93s	3cm
1kg	Up	10.62s	3cm
	Down	9.93s	3cm
2.5kg	Up	10.88s	3cm
	Down	10.34s	3cm
5kg	Up	11.27s	3cm
	Down	10.54s	3cm
8.1 kg	Up	11.90s	3cm
	Down	10.55s	3cm
10.8 kg	Up	12.03s	3cm
	Down	10.89s	3cm
13.5 kg	Up	12.31s	3cm
	Down	11.58s	3cm
16.2 kg	Up	12.57s	3cm
	Down	11.32s	3cm
18.9 kg	Up	-	3cm
	Down	-	3cm

Refer from Table 5 the parallel bar was tested with several load in order to get the output reading of times. The fixed variable for this analysis is length of height. The length for adjusted was fixed until at 3cm for parallel bar consumed.

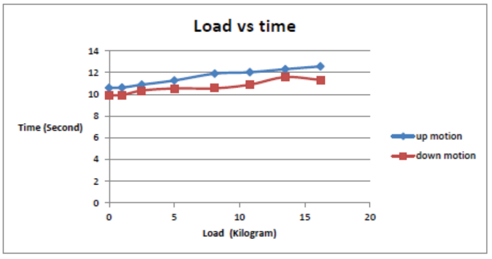

Fig. 24 Load against time

The Figure 24 shows the longer reading of time taken when applied the weight load 16.2 kg which is in the up condition motion at 12.57s and consume 11.32s when it in down condition motion. Meanwhile, the shorter time reading is at 0 kg of weight with a reading of time taken 9.93s in down condition motion and 10.59s in up condition motion. This can be said that the higher load consumes a longer time taken value to operate the parallel bar for height adjusted. For the weight load 18.9 kg the parallel bar lifting does not moving because it reached the limit weight load to lifting.

In this simulation by using the Solidwork software the material that use at holder bar is selected AISI 1010 Steel, hot rolled bar. This kind of material also being used at the project. Moreover, this kind of material is general purpose steel. Often used for a general structure so that this material easy to found at the local hardware store. This material is little bit heavy but its stronger and less bending. Next is this material suitable to use in lower strength application. Therefore, the required material needs to have long life span to accommodate and have not rusting. So that, when patient use it can get positive impact.

Name:	AISI 1010 Steel, hot rolled bar
Model type:	Linear Elastic Isotropic
Default failure criterion:	Unknown
Yield strength:	1.8e+008 N/m^2
Tensile strength:	3.25e+008 N/m^2
Elastic modulus:	2e+011 N/m^2
Poisson's ratio:	0.29
Mass density:	7870 kg/m^3
Shear modulus:	8e+010 N/m^2
Thermal expansion	1.2e-005 /Kelvin

Fig. 25 Material property for AISI 1010 Steel, hot rolled bar

Refer on Figure 25, a material property of AISI 1010 Steel, hot rolled bar. For the properties of material has accuracy for the material selected to produce static simulation test and next to being choose as the structure body of project.

On the analysis for lifting operation in this project by difference load attached we show the decreases number of voltage when the value of load increases and will make the voltage value inversely proportional to the voltage value. The current value increase when the value of load increase and the graph shows directly proportional between load and current. The power value also rises when the load become higher. Finally, the times take for lifting process become longer when the loads become higher. The limit of the load can be attached on this project at 18.9 kg. This is because of the motor movement does not react with lifting process. So that, it can see at Table 4.5 the reading for time taken does not have for 18.9 kg. By that it a can see at Table 4.4 the reading of power, voltage and current limit for 18.9 kg load. This maximum limit for motor required the operation.

Another factor found is from the analysis after the testing of the project in several time that the voltage of battery source become decrease. So that, the motor can't get enough supply to operate constantly and do not operate properly.

IV. CONCLUSION

The development of flexible parallel bar is completed. The project was designed by using CAD software. The reason is to make the testing accordance to the material been used. Then, statics force testing has been made by using the simulation in Solidwork. The materials that have been used for this structure body are able to accommodate the load up to 60 kg. By using four motor gearbox with the specification of 24Vdc and 100 rpm each, it able to lift the several weight. This project can operate in two condition modes either in auto or manual mode. For the auto mode, the parallel bar adjustment height can move together in both sides, while in manual mode, we can choose which side wanted to be used for adjustment. This development has been built up for improvements to the existing parallel bars in hospitals and in places where needs physiotherapy that obviously not portable. It achieves its objectives after it is built. It includes flexible height modification. This project can also be adjusted according to the height of different people. The next project is intended to facilitate a therapist for further height adjustment benefit and comfort to the patient. The project can also be brought anywhere and easy to install. As the conclusion, the flexible parallel bar for physiotherapy purpose design is easy to use and portable for patient to modify the desired height. This project can be commercialized in hospitals and places need physiotherapy.

ACKNOWLEDGMENT

The authors would like to thanks for the support given to this research by Ministry of Higher Education Malaysia and Universiti Teknikal Malaysia Melaka (UTeM).

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