Individual Analytical Analysis

Option 1 revisit Torque applied to the user's hip

Mohanad Fakkeh

B9 - Biomechatronic Hip Exoskeleton Team (BHET)

03/13/2020

ME476C – Spring 2020

Instructor: Sarah Oman

Introduction

Purpose of the assignment is to revise the individual technical analysis done in the previous semester (Fall2019) for the project which is to develop the exoskeleton for the hips of a human body which help in walking specifically the children facing cerebral palsy. In this project the main aim to keep the device lightweight so it will not put extra weight and pressure over the human body, and it support the hip in moving the forward and backward linear direction with the help of sensing torque. In this paper the analysis will perform on the torque to determine how much torque will require to push the hips in linear directions that will be safe for the body and for the device.

When the exoskeleton structure is going to push the body in the forward motion or backward motion linearly a torque will generate by the motors that will push the complete structure and posture of body hence support in walking while if the torque will be large enough that it will push the hips in extra amount rather than the required value then it will hurt the human body and also the machine will break.

This has done before in the previous semester as well but in this analysis, it will calculate the torque that can abruptly cause the change in the motion of body which may be terrible for the body. As the torque will generate using the motors so calculating the required torque will ultimately provide the rating of motors that will use in the device. So, in this analysis the maximum range of torque will also calculate which can help in selecting the motors for the exoskeleton.

In the previous semester, results have shown that the torque will vary in the range of 2.2 Nm to 4.3 Nm, and this safe torque for the system but if the torque will cross this limit, it will damage the system. In this semester the torque is going to calculate for the system with the final design and the updated Engineering and customer requirements for the project.

Assumptions

Following assumptions have been made for the previous analysis (Fall2019).

- There is no friction present while the hip is in motion.
- Exoskeleton structure will carry the human body load without any breaking.
- Motion is linear in forward and backward direction.

Assumptions made for this analysis are

- Torque sense the body weight and generate accordingly
- Sensing torque is in the safe range.

Previously torque initial value has taken as

$$Minimum\ Torque = 1Nm$$

New value for this assumption is

$$Minimum\ torque = 1\frac{Nm}{kg}$$

For last semester value the torque was depending on a perpendicular direction, the angle of sitting arm and hip is as

$$\theta = 90^o$$

But now the torque is depending on the weight and the angle of action has assumed

$$theta = \emptyset = 60^o \text{(was specified by the client)}$$

In previous semester it has calculated that body weight action is 25% but, in this semester, considering the real design action it is 90% (was specified by the client).

$$F = 0.25 * Weight\ (For\ last\ semester\ value)$$

$$F = 0.9 * Weight\ (For\ this\ semester)$$

Consider now that the weight is

$$W = 40\ Kg\ (\ For\ last\ semester\ value)$$

$$W = 60\ Kg\ (For\ this\ semester)$$

The dimension for the designs has given and it has not change in this semester in the design, so this value is same as before.

$$Arm\ length = 18.40\ in$$

Equations

The equation for calculating the torque is same and it has not changed it has defined below as

Torque Equation [1]

$$Torque = T = F * r$$

Where

$$T = Torque\ (N.m)$$

$$F = Force\ (N)$$

$$r = length\ or\ arm\ (m)$$

$$Torque = T = Fr(\sin\theta)$$

Where the $\theta = angle\ of\ motion\ for\ the\ body\ with\ the\ skeleton$

Physical Modeling

Based on the final prototype which has developed last semester to see the physical model of the structure and in the physical modeling it has determined that torque varies with the applied weight.

Schematic Model of the Design

Following is the schematic model for the final design is same as in the previous semester and no change has made in the design of the product.

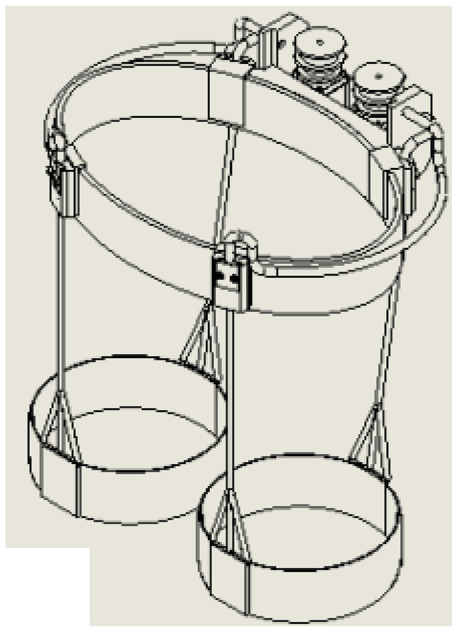

Figure 1: Schematic Model

Calculations

Now calculate the torque in the safe zone which varies over the weight as

$$T = rF\sin(\emptyset)$$

As the angle has defined as

$$\theta = 60^0$$

And the weight has defined as

$$W = 60\ Kg$$

Firstly, calculate the force according to the weight as

$$F = 0.9 * W$$

$$F = 0.9 * 60$$

$$F = 54\ N$$

We have the arm length value as

$$r = 18.40\ in$$

Convert the value in inches to meters as

$$r = 0.0254 * 18.40\ m$$

$$r = 0.46736\ m$$

We have the arm length in meters, and force in Newton, put both the values into the torque equation as

$$T = 54 * 0.46736 * \sin(60)$$

$$T = 21.853\ N.m$$

So, the torque required for the 60 kg body weight is around 21.853 Nm, which is safe, and this torque can easily push the human body during the walk. Now we need to find the range of torque which is safe for the variation. We have the body of 60 kg, so for 60 kg, the range of torque from the angel -30 degrees to the 60 degrees is

$$T = 54 * 0.46736 * \sin(-30)$$

$$T = -12.6187\ N.m$$

The above value is negative but that does not mean we need the negative torque; the negative sign is just showing the direction of torque which is reverse now because the angle is reverse. This can see in the MATLAB for the range of 60 kg body.

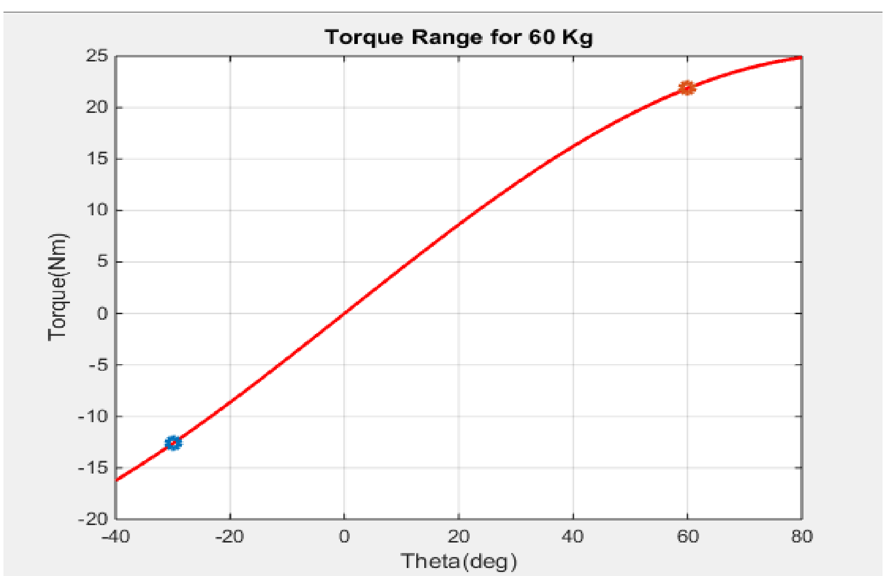

Figure 2: Torque Range for 60 Kg

Graph in figure 2 is showing the range of torque for the 60 kg of body which is from -12.6 Nm to 21.8 Nm, where the negative sign is showing the direction of torque. Hence the range of 60 kg body is this, and we need to see what is the maximum weight we can put on the skeleton, so it has decided to make the maximum weight 70 kg, now see the torque variation from 10 kg to 70 kg with the increment of 10. From this calculation we can see the maximum torque need to push the maximum weight.

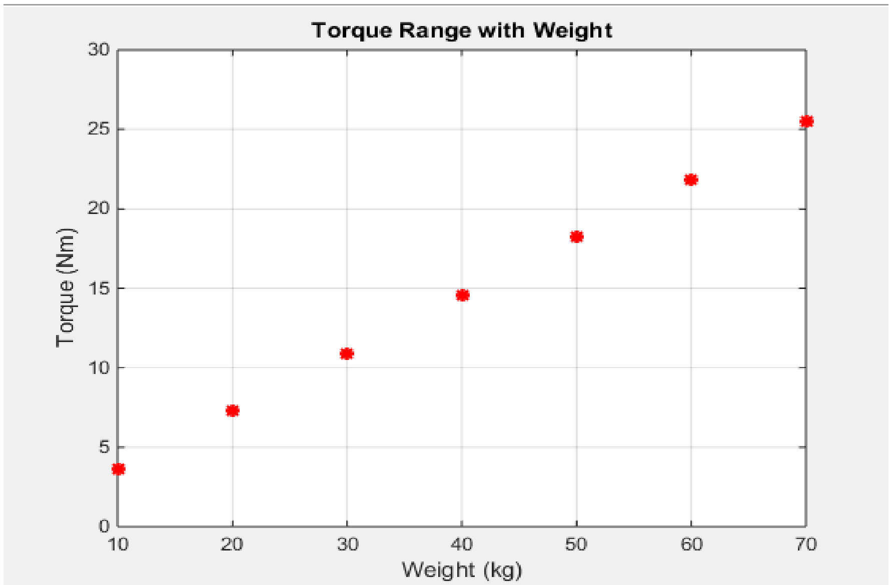

Figure 3: Weight with torque range

Figure 3 shows that the minimum weight of 10 kg, we need the torque maximum of 4.5 Nm, for the body of 70 kg, we need the torque of 27 Nm, hence the maximum torque we need to generate in the safe zone is around 27 Nm, and we have to use the motors which can generate the torque of 30 Nm maximum. And then need to control the motor torque as it will depend on the body and if the body will be light weight then the torque will also decrease.

Conclusion

In this paper the analysis has done about the torque to find the safe zone torque and the range of torque. It has done previously as well but with the latest values regarding the design it has done again. Previously it has calculated that the range is from -2.3 Nm to 4.4 Nm but now it has found that the range of any 60 kg body ranges from -12.6 Nm to 21.8 Nm. There is a big difference in the value hence this analysis has calculated the true torque required for a 60 kg body and this torque is in the safe zone for the structure. Another important thing has calculated in the analysis is the range of torque according to the weight. In this way the range of torque has found, and maximum torque need to generate for the product for the maximum weight 70 kg has calculated. It has shown that 27 Nm of torque need to push the 70 kg of body hence the motors need to generate this level of torque. While for the minimum weight of 10 kg, we need around 4.5 Nm of torque. Relation of torque and weight is directly proportional, so increase in weight need more torque and light weight body need less torque. This torque will help the team in finalizing the motors which can keep the maximum torque of 30 Nm.

APPENDIX MATLAB CODE

```
clc
clear
close all

r = 0.46736;
F = 54;
theta = -40:0.1:80;
Torque = r*F*sind(theta);
plot(theta, Torque, 'r', 'LineWidth', 2)
hold on
theta = -30;
Torque = r*F*sind(theta);
plot(theta, Torque, 'o', 'LineWidth', 3)
theta = 60;
Torque = r*F*sind(theta);
plot(theta, Torque, 'o', 'LineWidth', 3)
title ('Torque Range for 60 Kg')
xlabel('Theta(deg)')
ylabel('Torque(Nm)')
grid on
figure
W = 10:10:70;
F = 0.9*W;
theta = 60;
Torque = r*F*sind(theta);
plot(W, Torque, '*r', 'LineWidth', 2)
title ('Torque Range with Weight')
xlabel('Weight (kg)')
ylabel('Torque (Nm)')
grid on
```

References

[1] K. McDonald, “Load Torque Analysis of Induction Machine”, available [online], http://www.hep.princeton.edu/~mcdonald/examples/torque.pdf

[2] J. Ou, “Torque analysis and comparison” 2016, available [online], https://ieeexplore.ieee.org/document/7695332

[3] S. Seo, “Analytical Torque Calculation and experimental verification”, available [online], https://aip.scitation.org/doi/full/10.1063/1.5006731

[4] I. Hren, “Analysis of torque cam mechanism”, available [online], https://www.matec-conferences.org/articles/matecconf/pdf/2018/16/matecconf_mms2018_06004.pdf