Individual Analytical Analysis

Torque applied to the user's hip

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Introduction

Purpose of the assignment is to do the individual technical analysis regarding 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 pressure over the human body, and it support the hip in moving the forward and backward linear direction using the support provides by the 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. 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. 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.

Assumptions

Following assumptions have made for the analysis.

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

Minimum value that the torque must be is assuming here as

$$Minimum\ Torque = 1Nm$$

Being a perpendicular direction, the angle of sitting arm and hip is

$$theta = \emptyset = 90^{o}$$

If the force required to push the hips is not more than 25% of the body weight.

$$F = 0.25 * Weight$$

Assume that the body weight is

$$W = 40\ Kg$$

And the dimensions for the designs have given, for the arm length

$$Arm\ length = 18.40\ in$$

Equations

Coming to the equation side, in this analysis following equations will use to calculate the required torque.

Equation of Torque [1]

$$Torque = T = F * r$$

In the above equation

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

$$F = Force\ (N)$$

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

Physical Modeling

For the physical modeling, the prototype needs to develop that can apply the force to see how much force is safe to apply.

Schematic Model of the Design

Following is the schematic model for the final design.

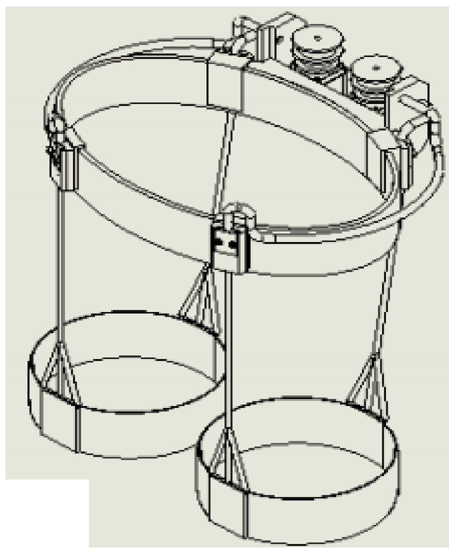

Figure 1: Schematic Model

Calculations

We need to determine the torque which is safe to use, and the equation of torque is

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

We have the angle value, and weight of body

$$\theta = 90^0$$

$$W = 40\ Kg$$

So, the force is

$$F = 0.25 * W$$

$$F = 0.25 * 40$$

$$F = 10\ N$$

And arm length is

$$r = 18.40\ in$$

$$r = 0.0254 * 18.40\ m$$

$$r = 0.46736\ m$$

Now put these values into the equation as

$$T = \ 0.46736 * 10 * \sin(90)$$

$$T = 4.6736\ N.m$$

Now find the safe limit of torque and it can determine using the angle as the angle ranges from -30 degrees to 60 degrees so the safest torque for these angles are as

$$T = 0.46736 * 10 * \sin(-30)$$

$T = -2.3368\ N.m$ (negative sign means in the opposite direction)

And the value for the 60 degrees is

$$T = 4.0475\ N.m$$

So, the safe maximum torque for the leg to move is at the value of 4.047 Nm and above this torque there is a chance of breaking or any damage. And the minimum torque is 2.3368 Nm in the opposite direction.

And it can implement in the MATLAB to testify how the torque is changing with the walking and the graph obtained is showing below

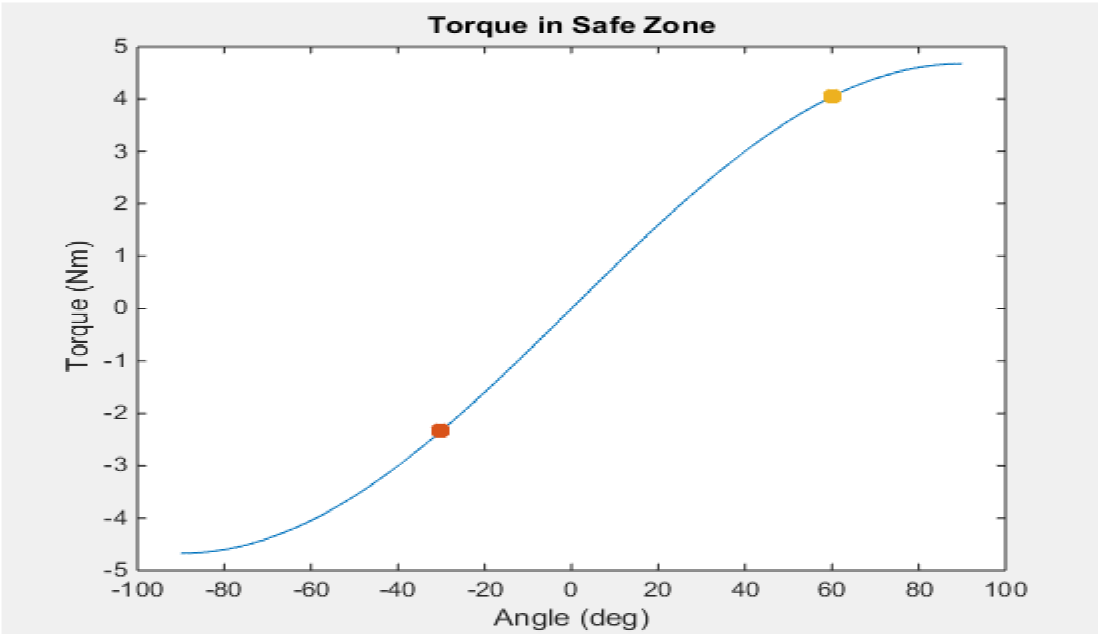

Figure 2: Torque in safe zone

The marks on the line are showing the safe zone for the torque of Hip-exoskeleton machine. In this range there is no chance of any breaking or damage. When the angle in both positive direction and negative direction reaches to 90, the torque value gets saturate because it is the point where any damage can happen.

Conclusion

The project is to develop an exoskeleton structure for the human hips which can support in walking so the design has developed, and it has analyzed in this paper. The analysis performed in the paper was about the torque which applied on the body by the machine to provide support in the walking and from the analysis it has determined that the maximum torque required to apply on the body is around 4.7 Nm, whereas the safe range for the torque to apply is 4.04 Nm. Above this value there is a risk of any damage is present so the machine must provide this level of torque. This analysis will help the team in selecting the motors and power generation that will utilize in developing the design.

APPENDIX MATLAB CODE

```
T = 0.46736*10*sind(theta);
plot(theta, T)
theta = -90:0.1:90;
T = 0.46736*10*sind(theta);
plot(theta, T)
title ('Torque in Safe Zone')
xlabel('Angle (deg)')
ylabel('Torque (Nm)')
hold on
theta = -30;
T = 0.46736*10*sind(theta);
plot(theta, T, '*', 'LineWidth', 3)
theta = 60;
T = 0.46736*10*sind(theta);
plot(theta, T, '*', 'LineWidth', 3)
```

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