“Development of Waist Power Assistive Suit to Prevent Lower Back Pain”

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I hereby declare that I have read through this report entitle “Development of Waist Power Assistive Suit to Prevent Lower Back Pain” and found that it has comply the partial fulfillment for awarding the degree of Bachelor of Mechatronics Engineering.

Signature : ………………………………………

Supervisor’s Name : DR MUHAMMAD FAHMI BIN MISKON

Date : ……………………………………..

I declare that this report entitle “Development of Waist Power Assistive Suit to Prevent Lower Back Pain” is the result of my own research except as cited in the references. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree

Signature : …………………………………….

Name : MUHAMMAD MAHIR AL HAFIZ BIN MD ARIS

Date : ……………………………………

Dedicated to my beloved family and friends

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ABSTRACT

Waist assistive power suit will be develop to prevent lower back pain for workers in industry. The significant of this research are this product can use by industry worker especially for carries heavy load and also can be used by the patient with a problem to do task normally. The exoskeleton spine are design to follow the 3 different types of DOF such as spine flexion(forward bending), spine lateral flexion(sideways bending, left or right) and spine rotation(rotation around the vertical axis). Each movement has each angle stress limitation on human body, thus the design are created to ensure that the waist assistive suit can protect the posture of human body while help to increase productivity by created a suit that give enough force to do their work productively. The objective of the project is to design and develop waist assistive suit while able to validate the design of waist assistive suit. Waist assistive power suit will use concept of human spine which can move in three degree of freedom (flexion, lateral flexion, and rotation). Hence the design will be concentrate into making a waist assistive suit that are reliable and mathematically proven in weight ratio in required torque to lift a load. The design will start by draw a model by using Solidworks software and the model will be simulate using a simulation in Solidwork software. Then the prototype will be fabricate and the analysis on the mechanism will be take place regarding weight, stress, strain, assistive torque using the spring, motor and material selection. From the result, we know that the maximum yield strength for alloy steel is 54 kg if applied direct force to material. The assistive torque that the spring correspond to the 7 kg load is 2.94 Nm. From the graph it shows that the increase of load and distance will increase the assistive torque produced by spring.

ABSTRAK

Jaket pembantu pergerakan pinggang akan dibangunkan untuk mencegah sakit belakang yang dialami oleh pekerja dalam industri berat. Perkara yang penting dalam kajian ini ialah produk ini boleh digunakan oleh pekerja industri terutama untuk membawa beban berat dan juga boleh digunakan oleh pesakit dengan masalah untuk melakukan tugas-tugas seperti biasa. Jaket pembantu pergerakan pinggang akan menggunakan konsep tulang belakang manusia yang boleh bergerak dalam tiga darjah kebebasan (akhiran, akhiran sisi, dan putaran). Setiap pergerakan mempunyai setiap sudut had tekanan pada badan manusia, dengan itu reka bentuk yang dicipta untuk memastikan bahawa jaket bantuan pinggang boleh melindungi postur badan manusia manakala bantuan untuk meningkatkan produktiviti dengan mencipta satu jaket yang memberikan daya yang cukup untuk melakukan kerja mereka secara produktif. Objektif projek ini adalah untuk mereka bentuk dan membangunkan jaket pembantu pinggang manakala dapat mengesahkan reka bentuk jaket bantuan pinggang. Jaket kuasa bantuan akan menggunakan konsep tulang belakang manusia yang boleh bergerak dalam tiga darjah kebebasan (akhiran, akhiran sisi, dan putaran). Oleh itu reka bentuk akan menjadi menumpukan perhatian ke dalam membuat jaket bantuan pinggang yang boleh dipercayai dan terbukti dalam matematik terbukti dalam nisbah berat dalam tork diperlukan untuk mengangkat beban. Reka bentuk ini akan bermula dengan dengan menggunakan perisian Solidworks dan model akan disimulasikan menggunakan simulasi dalam perisian Solidwork. Kemudian prototaip akan dianalisis mengenai mekanisme akan dilakukan mengenai berat badan, tekanan, ketegangan, tork bantuan menggunakan spring, motor dan pemilihan bahan. Dari keputusan, kita tahu bahawa kekuatan maksimum untuk keluli aloi adalah 54 kg jika digunakan kuasa terus kepada material. Daya kilas bantuan yang tork sesuai dengan beban 7 kg 2.94 Nm. Daripada graf ini menunjukkan bahawa peningkatan beban dan jarak akan meningkatkan tork bantuan yang dihasilkan.

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CHAPTER 1

INTRODUCTION

1.1 MOTIVATION

The economic development in Malaysia evolve through commercialize of car manufacturing industry in 1983. In 2013 the number of worker that are involve with the car manufacturing industry are 26 367 workers [1] compare to 2007 statistic that show that 24 146 workers [2] that worked in motor vehicle manufacturing that year.

Car manufacturing industry recorded third-highest number of Cumulative Trauma Disorder (CTD) related injuries compared to other industry with the incidence rate of 963.5 per 10,000 cases of repeated trauma workers [3]. A study conducted among employees working on the assembly line in the automotive industry shows that 39% of musculoskeletal disorders suffered by the employee is at the bottom spine, followed by the head-neck-shoulder with 18% and the lower body region by 16% [4].

In Malaysia, the occupational diseases problem began to get the attention of various parties. In 2006 there were 14 cases of musculoskeletal injury reported by the Social Security Organization (SOCSO) [5].Exoskeleton upper limb power suit is develop as the waist power assistive robot to prevent lower back pain and can enhance strength and endurance of people especially when they are work.by having this suit it will increase the productivity of the workers.

The idea to develop waist power assistive robot to prevent lower back pain are from the idea to help worker in the industrial manufacturing. This concept helps workers especially on the industrial to work longer without hurt their back. These waist power assistive suits will use concept of human spine which can move in three degree-of-freedom (flexion, lateral flexion and rotation).

From the result obtained, the percentage of people suffers from lower back is increasing with 57.9% in 12 months, 49.5% in one month and 35.1% in 7 days[2]. Due to this, a waist power assist suit to prevent a lower back pain is needed especially to worker industry.

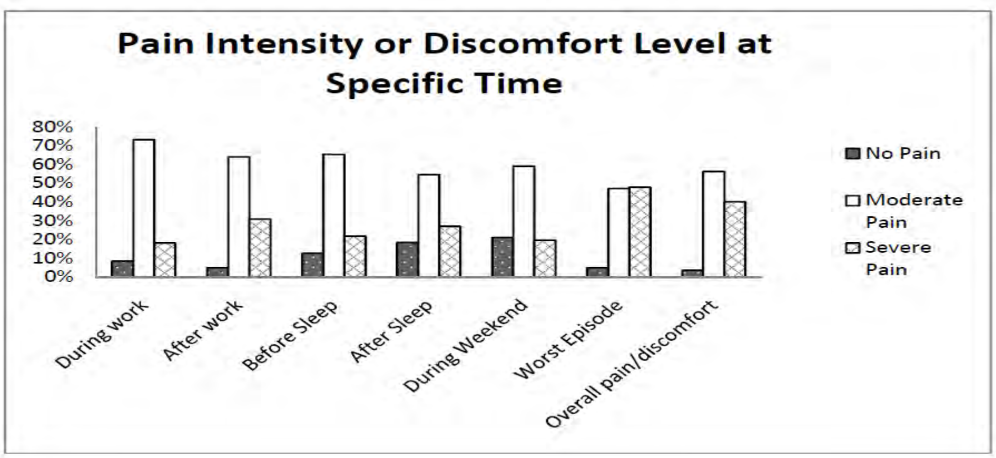

Figure 1.1: Pain Intensity or Discomfort Level at Specific Time [2]

1.2 PROBLEM STATEMENT

This project of designing an electrical exoskeleton is to improve the size and weight of exoskeleton for an ideal operation condition for the user. The problem rise with the mentality to create an exoskeleton that are small but are wise in weight to power ratio considering that there are a lot of machine induced in helping human to carry a heavy weigh. The exoskeleton spine are design to follow the 3 different types of DOF such as spine flexion(forward bending), spine lateral flexion(sideways bending, left or right) and spine rotation(rotation around the vertical axis). Each movement has each angle stress limitation on human body, thus the design are created to ensure that the waist assistive suit can protect the posture of human body while help to increase productivity by created a suit that give enough force to do their work productively.

The first components is modeling the 3 degree-of freedom of lower back suit mathematically in term of dynamics analysis. In this part we will calculate the motor torque that are required at the help. We will see the relationship between motor torque and the load that human can carry versus the angle with regards to the gravity of earth. The second components is to design the assistive torque that can help to distribute the required torque. We will study on the relationship between the distances (angle) of the spring to the assistive torque that the spring can produced. The last components is to analyze the structure of the in term of stress, strain analysis. We will use the simulation in solid work to see the break point of the material use, in this case alloy steel. From that we can see the relationship between the load uses to the break point of the material use.

In terms of actuator, in previous study there are some that incorporated hydraulics and pneumatics system to actuate their exoskeleton but in terms of usage the electrical actuated system is more popular usage of researches. There are some problem regarding the using of hydraulics and pneumatics system. One of the main reason is because of its system complexity, there are need of both hydraulics and pneumatics system for the actuators while the control and sensors system are rely on electrical system. Other than that, in terms of hydraulics and pneumatics system, the oil leakage may occur that reduce the performance and comfortable of the user. [6, 7] Besides that the air compressor produce noise that can distracted the user that need to be fully focused in their field of work. [21, 22]

Even though electrical actuated system are more popular in research studies there are downside that needs to be overcome. The motor that will be used is be minimal in size and weight but can produce a high number of torque. The problem is to find this kind of motor with the price range that are within the budget of the project Exoskeleton upper limb power suit is develop as the waist power assistive robot to prevent lower back pain and can enhance strength and endurance of people especially when they are work. Lower back pain may occurred due to the compression force to the lumbar which exceed a threshold of 3400N [8]. Thus to overcome this, the purposed of waist power assistive suit should be design to hold 100Nm torque. It's possible to find motor that can produce 100Nm but considering the size, weight and price range of the motor it is difficult to overcame this problem.

In the case of considerable lifting heights, high velocity devices are applied with the purpose of shortening cycle duration and increasing the capacity. In the paper, they analysis the relevant influence such as variation of the rope free length, slipping of the elastic rope over the drum or pulley and damping due to the rope frictional friction[9]. The system combining the pulley system and rope system to increase the volume of the weight that the motor can carry at certain time. The length of the rope effect the load that can be carry by the motor. If the load is near the motor, thus the system can lift a heavy load compare a system that has a long rope system that reduce the amount of the load that the motor can carry.

1.3 OBJECTIVE

- To design and develop waist assistive suit in terms of strength of structure and mechanism of the suit versus the torque required and assistive torque to assist the movement of the user
- To validate the design of waist assistive suit using the dynamics analysis

1.4 SCOPE OF RESEARCH

This project mainly on the development of waist assistive power suit. The design will be conducted using the Solid Works software in the Mechatronics Lab before been fabricate. The average of weight of Malaysians people is 61.8 kg, thus with regard of this the human body should support up to 100kg using the normal strength without any help [10].

The waist assistive suit will be actuated by electrical actuator that available on the market. The motor that will be used is be minimal in size and weight but can produce a high number of torque. The problem is to find this kind of motor with the price range that are within the budget of the project. The experiment will been conduct after the prototyping product is done. The experiment is mainly on the measurement of force on the waist assistive suit that will lift loads of 1 kg, 2 kg, 3 kg, 4 kg, 5 kg, 6 kg and 7 kg with the addition of the upper limb of human weight.

The design will consists a pulley system and spring system that will help to reduce the torque needed in the assistive torque provided by the DC motor and spring. In Hooke Law Theory state that if an object applies a force to spring, the spring will generates an opposite force to the object. The theory is valid if the elastic limit is not over than it should. If the spring is pushed or pulled more that it should it should, it will loss it stretchy ability.

CHAPTER 2

LITERATURE REVIEW

2.1 Theoretical Background

Exoskeleton upper limb power suit is develop as the waist power assistive suit to prevent lower back pain and can enhance strength and endurance of people especially when they are work. Lower back pain may occurred due to the compression force to the lumbar which exceed a threshold of 3400N [8]. Thus to overcome this, the purposed of waist power assistive suit should be design to hold 100Nm torque. Rosen et al. stated that when human perfuming daily tasks the gravitational component of the support forces accounts more than 90% of the total force [11].

As the name suggested, the upper limb exoskeleton will be focused on the waist to the neck because of the main objective of the project is to prevent lower back pain by develop a waist power assistive suit. There are other type of exoskeleton that are well known in the industry such as Hybrid Assistive Limb (HAL) develop by Cyberdyne. The suit are develop as a full body exoskeleton to help in nursing home [12, 13, 14, 21, 22].

There are many type of exoskeleton that surfaced this past year, thus to design a suitable waist power assistive suit to prevent lower back pain and can enhance strength and endurance of people especially when they are work many aspects much be taken care such as suitable components and design that are compatible with the system and user.

2.2 State of Art

2.2.1 Biomechanics of Human

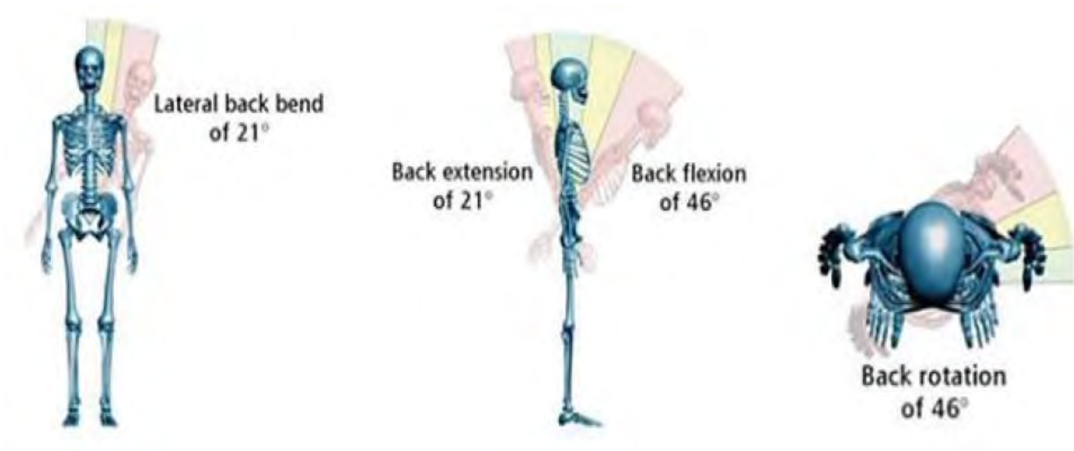

Figure 2.1: Motion Movement of Back Side of Human [8]

There are 4 types of zone that human will encounter while standing or sitting. The first zone is Zone 0 (Green Zero), zone that encounter most of the movement while puts minimal stress on muscles and joints are same with the condition of Zone 1 (Yellow Zone). The 3rd zone is Zone 2 (Red Zone) that gives extreme position for limbs, puts high strain on muscles and joints.While Zone 3 (Beyond Red Zone is the most extreme position for limbs that should be avoided while lifting or repetitive tasks [8].

Table 2.1: Back Range Motion [8]

		Range of Motion			
BACK	Movement	Zone 0	Zone 1	Zone 2	Zone 3
	Flexion	0-10	11-25	26-45	46+
	Extension	0-5	6-10	11-20	21+
	Rotational	0-10	11-25	26-45	46+
	Lateral Bend	0-5	6-10	11-20	21+

The exoskeleton spine are design to follow the 3 different types of DOF such as spine flexion(forward bending), spine lateral flexion(sideways bending, left or right) and spine rotation(rotation around the vertical axis)

- Spine flexion

Spine flexion is most important DOF to lifting while extend total flexion range and allow natural bending postures

- Spine lateral flexion

This motion is to lift up or put down objects that tilted sideways. The required forces always toward neutral position with the consideration to balance the weight of the wearer and the load as their center mass.

- Spine rotation

Rotation motion are used to move the objects sideways or to extend the reach.to prevent large rotation, the supporting torque towards neutral position must been take consideration

2.2.2 Dynamics Analysis

In this section will be focused on the theoretical parts that are related to the dynamics mechanism of the design. The main objective of this art is to find the required torque at the hip and to find the assistive torque that help distributed the load to the power to weight ratio.

Parameter $F_{UP,pulley}$ is the friction component during downward flexion. This similar for $F_{dwn,A4}$, $F_{up,A1}$, and $F_{up,A4}$ with up indicating upward flexion. Parameter $F_{UP,pulley}$ is the friction components relatively to the torque that drive the cables,T_{pulley}, which the sum of the T_{motor} and at the T_{spring}. [12].

$$T_{pulley} = T_{motor} + T_{spring} \tag{1}$$

T_{motor} is calculated as follows when flexing down:

$$T_{motor} = -2 + \frac{M_{hip} - F_{dwn,A1} - F_{dwn,A4}}{TR} - T_{spring} \tag{2}$$

And when flexing up:

$$T_{motor} = 2 + \frac{M_{hip} - F_{up,A1} - F_{up,A4} - F_{UP,pulley}}{TR} - T_{spring} \tag{3}$$