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Design and Work of Pneumatic Powered Exoskeleton

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ABSTRACT

With improvements in actuation technology and sensory systems, it is becoming increasingly feasible to create powered exoskeletal garments that can assist with the movement of human limbs. This class of robotics referred to as human-machine interfaces will one day be used for the rehabilitation of paralysed, damaged or weak upper and lower extremities. The focus of this project was the development of an exoskeletal interface for the rehabilitation of the hands and in the improvements in the defence services. In addition, the sensor introduces an elastic element between the actuator and its corresponding knee joint. This will allow series elastic actuation (SEA) to improve control and safely of the system. The Leg Rehabilitation Device requires multiple actuators. To stay within volume and weight constraints, it is therefore imperative to reduce the size, mass and efficiency of each actuator without losing power. A method was devised that allows small efficient actuating subunits to work together and produce a combined collective output. This is a very unique equipment in our country which helps uniquely in defence services and to cope up with the handicapped people to do their work in a easier manner. Furthermore, the developments in this project may one day be used for other parts of the body helping bring human-machine interface technology into the fields of rehabilitation and therapy.

***Keywords*: Exoskeleton, Pneumatic, Strength, Rehabilitation**

1. INTRODUCTION

Our project deals with the use of Air pressure to help and support Human body when it requires large amount of energy and work. Power suit, also known as powered exoskeleton, exoframe or exosuit is mobile machine consisting primarily of an outer framework worn by a person, and a power system of pneumatic muscles that delivers part of the energy for leg movement as well as load carrying.

In today's world military combats are becoming very common. These combats require the military personnel to reach and push their limits. They have to carry very heavy loads in very harsh and hostile conditions. These heavy loads make them very fatigue, stressed and unable to perform their assigned task in an effective manner. Sometimes the conditions are so unfavorable that the personnel suffers injury before reaching the actual battleground. To help and overcome such problems various attempts have been made to make a wearable frame which assists the personnel to lift the load without using their own energy. Such a frame or outer skeleton is named as the Exoskeleton. An exoskeleton is a wearable external frame or suit that may be powered by various modes such as pneumatic, hydraulic, electric motors, etc. for increased strength of limb to assist in multiple situations. They may be used for carrying heavy loads without fatigue, by a paralyzed patient, etc.

1.1 Early Exoskeleton

The earliest known exoskeleton was developed in 1890 by a Russian named Nicolas Yagin. The suit used energy stored in compressed gas bags to assist with movements, although it was passive and required human power. Leslie C. Kelley developed a exoskeleton named PEDOMOTOR, which is operated on steam power. Similar to this another exoskeleton was made in 1960s based on mobile machine integrated with human movements, developed by General Electric and the United State Armed Forces and was named as HARDIMAN. It was powered by hydraulics and electricity made for lifting 110kg (220lbs).

The existing exoskeleton depends hugely on inputting power through batteries which drain after some time, has highly sophisticated circuitry and are very costly. To overcome these limitations there is a need for development in exoskeleton with less complicated design, longer life and less circuitry equipment's. Exoskeletons are used in military, industrial applications, rehabilitation, heavy lifting, civil defense and rescuing applications as well. This paper presents to design of a hydraulic lower-body exoskeleton assisting walking of a load carrying human. This exoskeleton system is designed to be appropriate mechanism with human and it operates synchronously with the human body. The purpose of exoskeleton is to provide forces against to external load carried by user during walking, sitting, and standing motions. Thus, it supports walking and large portion of load carrying by the human. Also, it makes the user to spend less energy.

Fig 1: Images of Pneumatic Exoskeleton structure and its parts

2. WORKING

The project is powered by pneumatic power. We are using a small 12V air compressor which will provide compressed air upto 100-150psi. The air will be stored in a small tank, from there it will be supplied to pneumatic cylinder via electromechanical actuators. The actuators will be controlled by a microprocessor, which is being programmed. The actuation of pneumatic cylinders will be synchronized as the human leg muscles work during walking, the main purpose of pneumatic cylinders are to carry the load and pass it to solid frame on which it is mounted.

Fig-2: Isometric view of Pneumatic Exoskeleton (Made in CATIA V5R20)

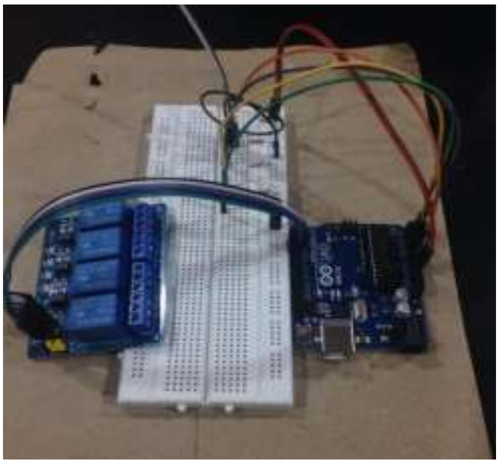

Fig-3: Electrical Components - 4 linear flex sensors relay circuit, Aurduino, Jumper cables, breadboard

3. EXOSKELETON STRUCTURE

Designing an exoskeleton device for functional training of lower limbs is a very challenging task. From an engineering perspective, the designs must be flexible to allow both upper and lower body motions, once a subject is in the exoskeleton, since walking involves synergy between upper and lower body motions. It must be also a light weight, easy wearable and must guarantee comfort and safety. The suit structure is very simple and exposes of an forearm cover, biceps and triceps cover many parts of the human body. It consist, back and Shoulder's cover, leg cover, joints, etc. The technology of exoskeletons or mechanical suit is divided into two parts, lower extremity exoskeletons and upper extremity exoskeletons. The reason behind separating the two parts is that people can envision great applications for either part. Also, the technology of exoskeleton and human power augmentation is still in its early stage. Therefore, further research is required to ensure that both the upper and lower extremities function well independently before having an attempt to integrate them.

- Upper frame work: This includes metal frame work (links) for the movement of hands of the operator and the corresponding actuation system (pneumatic cylinders).
- Lower frame work: This includes metal frame work (links) for the movement of legs of the operator and the corresponding actuation system (pneumatic cylinders).

4. METHODOLOGY

Problem Identification

It has been seriously observed that the earlier exoskeleton were either computer or battery operated or are huge in shape as well as size. The initial cost of such exoskeletons are higher and is not affordable if to be used. To overcome this we have design an exoskeleton which is cheap and Pneumatic powered.

Problem Statement

Considering above discussion we can state that, there are many disadvantages of the earlier exoskeleton in the market. In order to eliminate such drawbacks and to increase the working efficiency of the unit, the following system was designed.

Objective and Scope

The main objective of the system is to increase the human ability and capacity to lift heavy loads such that in case of by military personnel, factory labours, etc. with a very simple, cheap and effective system.Our current developed prototype can be useful by workers for lifting heavy weights and loads. Further developments in the current model will be applicable in wide ranges of jobs or duties including military purpose, civilians, industries etc.

Data Collection

Data collection plays an important role in methodology of the project. The data collection was carried out by doing market survey and carrying out the field research at different sectors such as industrial sector and defense sector.

Design Parameters

The required parameters for calculating the stress and forces on the system were concluded by market survey, studying anatomy of human leg and availability of the material that will be used for fabricating such type of system.

Design Model

Based on the parameters obtained from calculations and survey all the requirements were considered and the basic model was created over the software named "CatiaV5r20".

Revised Design

The final design was created by doing some minor changes which were done in order to make the model more effective, creative and user friendly.

5. DESIGN

Leg Cover Structure

Leg cover structure consists of two pneumatic cylinders for each leg. Both are attached to the metal frame via nuts and bolts. The frame is designed in a way that enables size variability relative to the operator.

Design Calculation

Material of pipe – Stainless steel AISI 304 Yield Strength (MPa) = 2.5 MPa. Axial load on the pipe, assuming load to be carried by human to be 150 kg Assuming thickness of pipe to be 2 mm Therefore,

$$D_i = D_o - 0.002 \ \& \ \text{PRESSURE} = \text{FORCE}/\text{AREA}$$

$$205 \text{ x } 10^5 = \frac{150 \text{ x } 9.81}{\frac{\pi}{}(Do^2 - Di}$$

Therefore,
$[Do^2 - Di - 0.002^2]Do = 0.02384828$ m
Assuming Factor of safety = 1.3
Therefore,
Do = 0.0238482 × 1.3 Do = 0.0310026 m Do = 31.0026 mm
Taking standard outside outer diameter = 32 mm Therefore,
Di = 30 mm

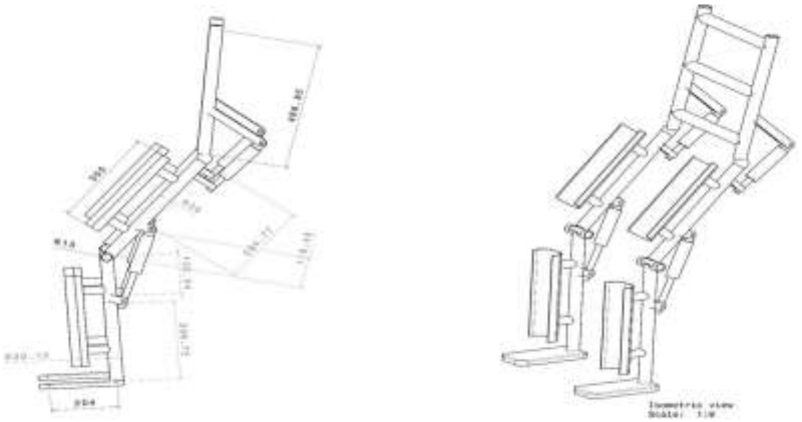

Fig 4: Schematic of Pneumatic Exoskeleton

Chracteristics	Pneumatic	Hydraulic	Electric
Complexity	Simple system composition	Moderately complex system composition	Control systems and motion component can work together in multiple complex configurations
Peak power	High	Very high	High
Control	Simple valves	User must	Flexibility of motion control capabilities with electronic controller
Position accuracy	Very difficult to achieve position accuracy	Mid-stroke positioning requires additional components and user support	Positioning capabilties and velocity control allow for synchronization
Speed	Very high speeds	Moderate speeds	Moderate speeds
Load ratings	High load ratings	Extremely high load ratings	Can be high depending on the speed and positioning desired
Lifetime	Moderate lifetime guarantee- easy to replace if need be	With proper maintanence, it can last a long lifetime	With proper maintanence, it can last a long lifetime
Acceleration	Very high	Very high	Moderate
Shock Loads	Able to handle shock loads	Explosion-proof, shock-proof, and spark-proof	
Environmental	High noise levels	Hydrulic fluid leaks and disposal	Minimal
Utilities	Compressor, power, pipes	Pump, power, pipes	Power only option
Efficiency	Low	Low	High
Reliability	Excellent	Good	Good
Maintenance	High amount of maintanence	High user-maintanence throughout the life of the system	Little to no maintanence except for when replacements are necessary
Purchase cost	Low cost	High cost	High cost
Operating cost	Moderate cost	High cost	Low cost
Maintenance cost	Low costs	High costs	Low costs

Fig 5: Comparison between Pneumatic, Hydraulic and Electric Exoskeleton

6. APPLICATIONS

Medical

Powered exoskeletons can improve the quality of life of persons who have lost the use of their legs, enabling system-assisted walking or restoration of other motor controls lost due to illness or accidental injury. The medical field is another prime area for exoskeleton technology, where it can be used for enhanced precision during surgery, or as an assist to allow nurses to move heavy patients.

Military

There are an increasing number of applications for an exoskeleton, such as decreased fatigue and increased productivity whilst unloading supplies or enabling a soldier to carry heavy objects (40–300 kg) while running or climbing stairs. Not only could a soldier potentially carry more weight, presumably, they could wield heavier armor and weapons while lowering their metabolic rate or maintaining the same rate with more carry capacity.

Civilian

In civilian areas, exoskeletons could be used to help firefighters and other rescue workers survive dangerous environments. Labor's in market stores can also use for lifting heavy food sacks by the use of this machine.

7. FUTURE SCOPE

Advances in material technologies, control systems and sensors, software, and electrical and electronics engineering has helped in the development of new and advanced exoskeletons in the market. The availability of ultra-low-power exoskeleton technology has led to the development of robotic suits. Already the exoskeleton's are available in the market but it's cost is too high so our main objective is to minimize the cost and be available to the market at low cost. Lower body exoskeletons, employed as rehabilitation tools or quality of life enablers, currently lead the sector. However, commercial systems that augment or amplify capabilities will exhibit the strongest growth moving forward. This is especially true for industrial tasks requiring heavy lifting, extended standing, squatting, bending or walking in manufacturing facilities, particularly within construction and agriculture industries. Social imperatives, military requirements and business needs, supported by technological advances, now make it possible to develop commercially viable exoskeleton systems for a wide variety of applications and markets.

It is useful to think of industrial exoskeletons as wearable robots that exploit the intelligence of human operators, and the strength and endurance of industrial robots. Like traditional robots, they address tasks, especially repetitive tasks that cannot be automated using traditional methods that are physically demanding. In this sense, exoskeleton technology can be seen as a bridging solution between the extremes of fully manual work and those tasks that demand typical industrial robots. Body weight support, lift assistance, load maintenance, positioning correction and body stabilization are common capabilities of industrial exoskeletons.

8. CONCLUSION

The idea behind this project is to develop an inexpensive and user friendly system. This project shows that it is simple in construction, design and cheaper. It gives quick response and flexible compared to hydraulic and electrical type exoskeleton. This can be achieved while maintaining simplicity, ease of use, implementation and maintenance.

Our project is not only used to lifts weights but also is applicable in rescue operations, military, industries. It makes physically disabled people to carry weights in their daily life because the maximum load is carried by this pneumatic system.

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