Design of an Exoskeleton to Prevent and to Take Care of the Spinal Column of Injuries of Low Back Pain

Jean Luna-Ramirez[1], *Guersom Quispealaya-Lazo*[1], *Madai Taype-Mateo*[1], *Grimaldo Quispe*[2], *Heyul Chavez*[3], *Luis Rivera*[3] *and Francisco Dominguez*[4]

[1] Facultad de Ingenieria, Universidad Continental
Huancayo, 15036, Peru

[2] Facultad de Ingenieria, Universidad Nacional Autónoma Altoandina de Tarma
Junín, Perú

[3] Facultad de Ingenieria, Universidad Peruana de Ciencias Aplicadas
Lima, 15023, Peru

[4] Escuela Superior de Ingenieria Informatica, Universidad Rey Juan Carlos
Madrid, Spain

ABSTRACT

Inside Peru and the world, the bigger bordering the force is by the muscles of the human beings to accomplish physical tasks, and the failure of these can cause a damage neuromuscular and articulations. The principal objective of the fact-finding work becomes of Designing an exoskeleton for the prevention of injuries to the spinal column of the workers, to give solution and it improves of the lum-bar unmade problem a lot of effort. The

Design of a lumbar, detachable exoskele-ton with easy maintenance and manufacture are shown, with the characteristics principal stop to comfortability of the worker without causing pain neither dis-comfort.

Keywords: Design · Exoskeleton · Joints · Low back pain · Neuromuscular

INTRODUCTION

Low back pain is in one of the leading causes of the medical consultations, “Rank-ing fifth in causes of admission at hospitals, and the third leading causes of surgery” (Taylor WM, 1994). This causes a very painful and chronic process from the last 7 to 12. (Gómez Conesa & Valbuena Moya, 2005)

Low back pain is considered the main cause of activity limitation in people under 45 years of age. It is shown on the factor of work a bigger effectiveness in interven-tions to patients that they show lumbago sub-sharp or chronic. (Gómez Conesa & Valbuena Moya, 2005)

According to Aníbal Hermoza, a specialist from the Peruvian Occupational Health Society, one million Peruvian suffer of lumbago, this forces to that workers be absent to his works at least for a week or more, and also the cost of treatment of this disease is by 2400 dollars for session which proves to be harmful for the phony individual for the lumbago. (Diario la republica, 2010)

The engineered exoskeleton works in conjunction with a girdle that provides solid support to the lumbar area to keep the spine straight and provide support during load-ing, while helping to support and bond the exoskeleton to the human body for best performance. The sensors are then used on the lower column and identify if the col-umn is deviated and to act sooner.

The exoskeleton has a traction system with a planetary gear system driven by a Nema 17 motor that has an operating torque factor of 4800 g.cm. According to these data, the exoskeleton is willing to provide greater torque by multiplying its strength and thus being able to help load the human body. It has a bank of rechargeable bat-teries which can be easily replaced by a new bank of batteries, while recharging the previously used battery bank.

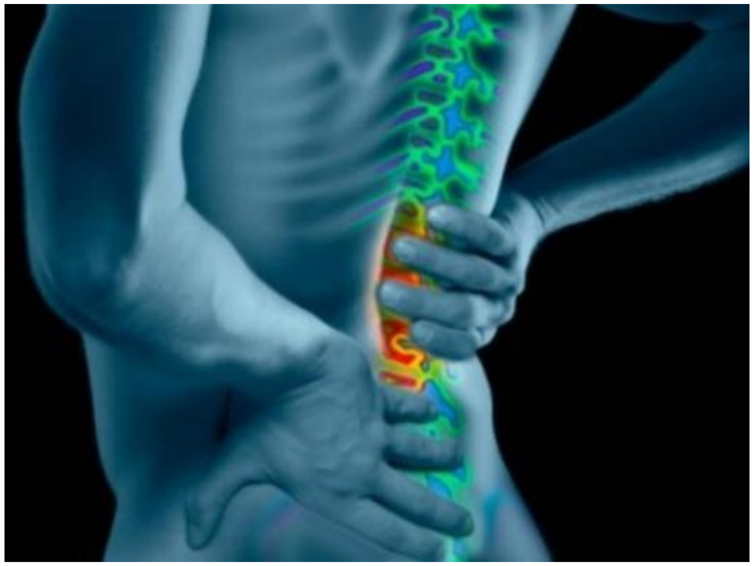

Fig. 1. "Pain zone in case of low back pain" (Annals of the Rheumatic Diseases, 2018)

DEVELOPING HUMAN SYSTEMS INTEGRATION TOOLS TO SUPPORT SYSTEMS DESIGN

The present investigation develop him using the methodology VDI 2221, which is designated as the systematic focus for the design of technical systems and products, this standard was developed by German engineers, which indicates that the need must first be established, which will be reflected In a list of requirements, where the desires and needs for each phase and domain of the project will be distinguished, frequently to it planning, definition of the product and the conceptual designing should be structured.

From now on, Exigencies' lists for command are shown and generally of the exoskeleton in design:

Table 1. List of General Requirement

List of General Requirement		
Category	Exigencies (E) / Dees (D)	Description
Principal functioning	E	The exoskeleton help to raise heavy loads.
Geometry	E	The exoskeleton will be ergonomic for the user.
Mass	D	The exoskeleton should be light and should not hinder work and the user's mobility.

From now on, an exoskeleton's scheme of total show shows up, this scheme represents the total functionality of the system in concrete form specifying its revenues and come up against.

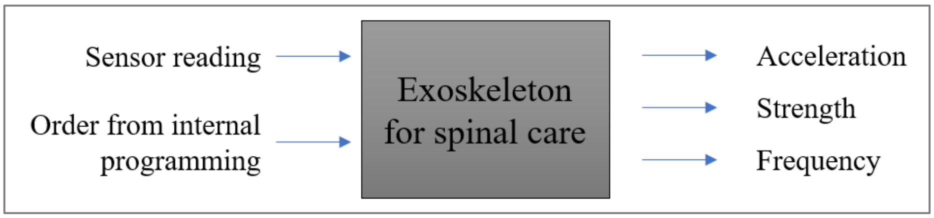

Fig. 2. "Black box of the exoskeleton"

It is had like revenues:

- Reading of the sensors, the kind of activity will determine that the user realize and if force is the adequate in the motors.
- Control from the internal programming, it takes effect after the reading of the sensors for the control of the actuators and of the necessary force.

It is had like exits:

- The Acceleration of the motor will depend on the kind of activity to accomplish this it is important to avoid injuries to the user.
- Force like technique of good show for the articulation in flexing when moment becomes of charging more weight for themselves and no losing tension and force of the muscles.
- Frequency, thanks to this pays out he will be able to deal with could have been done or to accomplish themes of improvement in daily exercises of the patients in therapies.

Calculations for sun gear:

Solar gear. ○ Number of teeth: $Z = 30$ ○ Module: $M = 1\,mm$ ○ Primitive diameter: $DP = Z\,.\,M$ $DP = 30\,.\,1$ $DP = 30\,mm$	○ I pass leaflet: $PC = \pi\,.\,M$ $PC = \pi\,.\,1$ $PC = 3.1416\,mm$ ○ The tooth's head: $A = M$ $A = 1\,mm$ ○ The tooth's foot: $S = PC\,.\,(\frac{19}{40})$ $S = 3.1416\,.\left(\frac{19}{40}\right)$ $S = 1.4923\,mm$	○ Radio of notch: $R = \frac{PC}{12}$ $R = \frac{3.1416}{12} = 0.2618\,mm$ ○ Angle of thickness: $AS = \frac{360\,.\,S}{2\pi\,.\,(\frac{DP}{2})}$ $AS = \frac{360\,.\,1.4923}{2\pi\,.\,\left(\frac{30}{2}\right)}$ $AS = 5.7002\,°$

<table>
<tr><td colspan="2"></td><td></td><td></td></tr>
<tr>
<td>Gear Planet.
○ Number of teeth:
$Z = 50$
○ Module:
$M = 1\,mm$
○ Primitive diameter:
$DP = Z\,.\,M$
$DP = 50\,.\,1$
$DP = 50\,mm$
○ I pass leaflet:
$PC = \pi\,.\,M$
$PC = \pi\,.\,1$
$PC = 3.1416\,mm$
○ The tooth's head:
$A = M$
$A = 1\,mm$</td>
<td>○ The tooth's foot:
$S = PC\,.\,(\frac{19}{40})$
$S = 3.1416\,.\left(\frac{19}{40}\right)$
$S = 1.4923\,mm$
○ Radio of notch:
$R = \frac{PC}{12}$
$R = \frac{3.1416}{12}$
$R = 0.2618\,mm$
○ Angle of thickness:
$AS = \frac{360\,.\,S}{2\pi\,.\,(\frac{DP}{2})}$
$AS = \frac{360\,.\,1.4923}{2\pi\,.\,\left(\frac{30}{2}\right)}$
$AS = 3.4201\,°$</td>
<td>Ring gear.
○ Number of teeth:
$Z = 130$
○ Module:
$M = 1\,mm$
○ Primitive diameter:
$DP = Z\,.\,M$
$DP = 30\,.\,1$
$DP = 30\,mm$
○ I pass leaflet:
$PC = \pi\,.\,M$
$PC = \pi\,.\,1$
$PC = 3.1416\,mm$
○ The tooth's head:
$A = M$
$A = 1\,mm$</td>
<td>○ The tooth's foot:
$S = PC\,.\,(\frac{19}{40})$
$S = 3.1416\,.\left(\frac{19}{40}\right)$
$S = 1.4923\,mm$
○ Radio of notch:
$R = \frac{PC}{12}$
$R = \frac{3.1416}{12}$
$R = 0.2618\,mm$
○ Angle of thickness:
$AS = \frac{360\,.\,S}{2\pi\,.\,(\frac{DP}{2})}$
$AS = \frac{360\,.\,1.4923}{2\pi\,.\,\left(\frac{30}{2}\right)}$
$AS = 1.3154\,°$</td>
</tr>
<tr>
<td colspan="2">Distance between centers.
○ Distance between Soling and Planet:
$Dc = \frac{S+P}{2}$
$Dc = \frac{30+50}{2}$
$Dc = 40\,mm$</td>
<td>Relation of transmission.
○ Relation:
$(R+S).Tp = R.Tr + S.Ts$
$Tr = 0$
$\frac{Ts}{Tp} = \frac{S}{R+S}$
$I = \frac{S}{R+S}$
$I = \frac{30}{130+30}$
$I = \frac{3}{16}$
$I_{total} = I\ x\ I$
$I_{total} = \frac{3}{16}\ x\ \frac{3}{16}$
$I_{total} = \frac{9}{256}$</td>
<td>○ Final Torque:
$T_{Nema17} = 4800\ g.cm$
$T_{Pierna} = \frac{T_{Nema17}}{\frac{9}{256}}$
$T_{Pierna} = \frac{4800}{\frac{9}{256}}$
$T_{Pierna} = 136533.3\ g.cm$</td>
</tr>
</table>

CONCLUSIONS

It has been found that, with the use of light and resistant materials, the lumbar support exoskeleton can be more comfortable to use due to its low weight, in turn the material used for the exoskeleton holding parts is flexible, for this characteristic the movement of the user is not very compromised, thus allowing a more natural movement taking advantage of the benefits obtained by using a lumbar support exoskeleton.

It was determined that the use of planetary gears in the construction of the exoskeleton is the most successful since this gear arrangement allows to have a greater torque gain delivered by an electric motor, this allowed a smaller motor to be used and to optimize energy consumption, since thanks to the planetary gear arrangement 28kg / cm of torque is obtained, which is enough to help reduce the physical effort made by the exoskeleton user.

It was found that the best position to place the electrical circuits and batteries was the rear of the exoskeleton, since it did not prevent movements and did not run the risk of damaging the circuits by any blow caused by the work carried out by the user, and this also allows that no extra parts are added to the exoskeleton in the legs or thighs, thus allowing for a more compact and lightweight design, being comfortable for the user when using it.

It was considered convenient to place sensors in the lower back area to determine when an overstrain is performed in this area, since performing an overstrain produces flexion of the spine and this generates low back pain problems, the exoskeleton when detecting flexion, the lower part of the spine will help correct the user's position to avoid serious injuries to the spine by using the motors that make up the exoskeleton.

The exoskeleton's images:

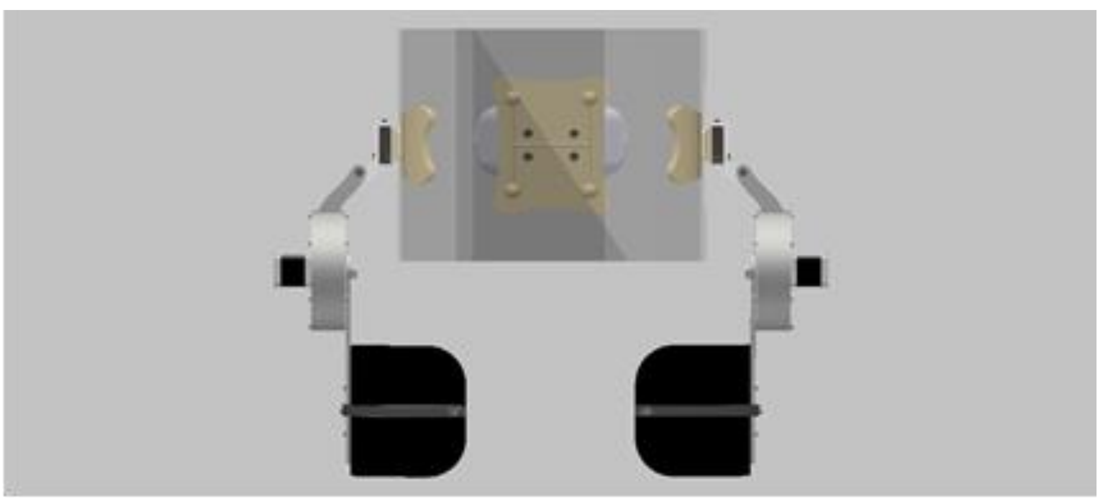

Fig. 3. “Front View”

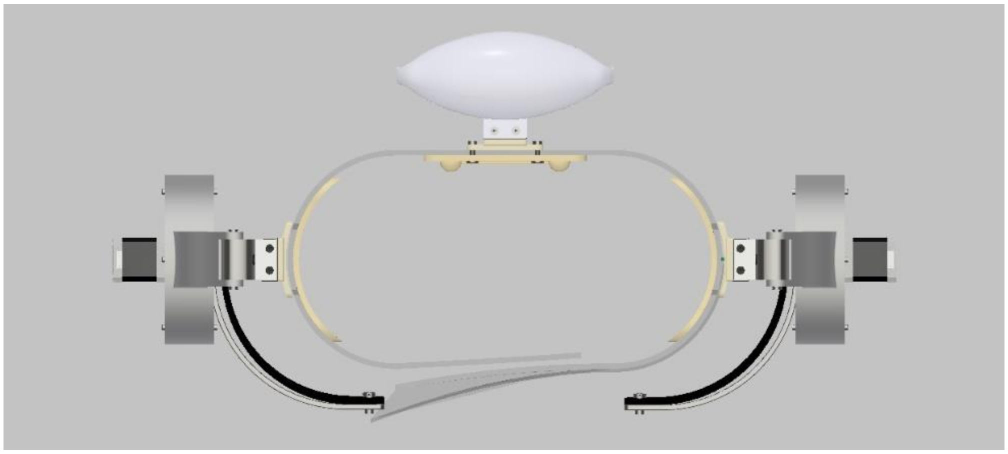

Fig. 4. "Top View"

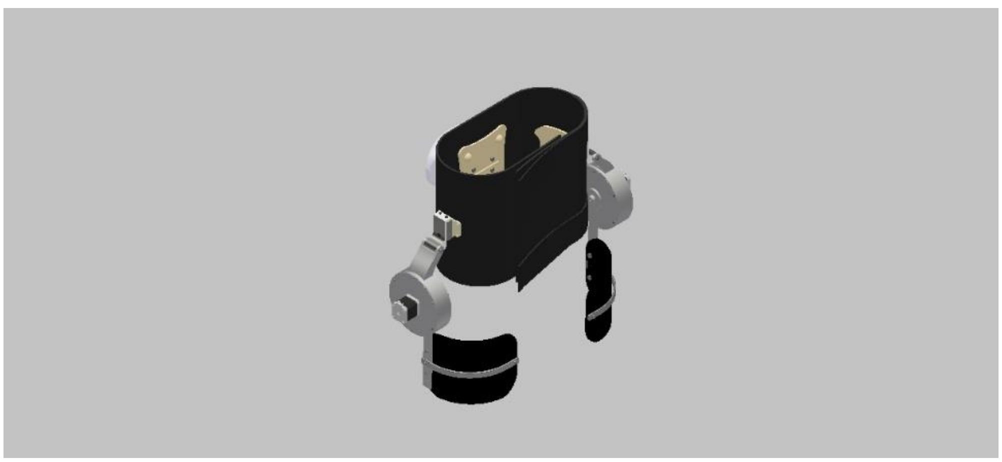

Fig. 5. "Isometric View"

ACKNOWLEDGMENTS

The use of exoskeletons has significant effects in the treatment of neurological pathologies such as cerebrovascular events, spinal injuries and certain processes of musculoskeletal disorders, thanks to the use of these systems, the functionality of these patients is recovered (Cooper, y otros, 2008). Likewise, the studies carried out reveal that people over 65 years of age will double between the year 1997-2025, and the disability will grow at a similar rite,

therefore it is necessary that the technology of the exoskeletons be improved in order to improve the rehabilitation processes (Cooper, y otros, 2008).

At present you can find exoskeletons that assist when performing certain heavy activities such as the load of heavy objects, the robotic exoskeleton of upper limb for the assistance of load and prevention of musculoskeletal injuries in civil construction works is of the passive type being its solely mechanical operation (Mendoza Quispe, 2014), the exoskeleton developed in this report combines mechanical and electrical operation, improving the efficiency of the exoskeleton.

Compared to an adjustable multi-component hip orthosis (Europe Patent No. EP 2 612 625 B1, 2015), the lumbar support exoskeleton features assistance to prevent deviation of the spine thanks to the use of sensors, unlike the orthosis This exoskeleton assists in the movement of the spine and not only serves as a support.

The exoskeleton can generate even many more applications in areas such as the rehabilitation of patients with problems with lumbar discs, reinsertion therapies using the lower limbs.

As future improvements, there would be neural networks for the application and learning of the movements of the person that allows to have much more comfort and security when using the exoskeleton.

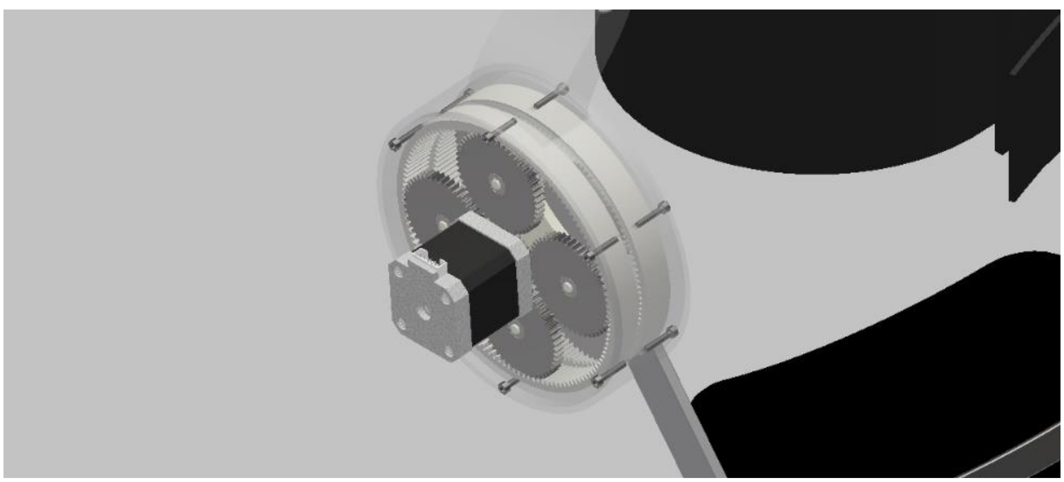

Fig. 6. “Detail View of Gears”

REFERENCES

Cooper, R. A., Dicianno, B., Brewer, B., LoPresti, E., Ding, D., & Simpson, R. (2008). A perspective on intelligent devices an eviroments in medical rehabilitation. *Med Eng Phys*, 1387-1398.

Diario la republica. (Noviembre de 2010). *Cerca de un millón de trabajadores en Perú sufre lumbalgia*. Recuperado el 04 de Mayo de 2020, de La republica: https://larepublica.pe/sociedad/495417-cerca-de-un-millon-de-trabajadores-en-peru-sufre-lumbalgia/

Gómez Conesa, A., & Valbuena Moya, S. (2005). Lumbalgia Crónica y Discapacidad Laboral. Universidad de Murcia. *Catedrática de Escuela Universitaria de Fisioterapia*, 255 - 265.

Mendoza Quispe, A. (2014). *Exoesqueleto robótico de miembro superior para la asistencia de carga y prevención de lesiones músculo-esqueléticas en trabajadores de construccción civil.* Lima.

Morán, J. (30 de Octubre de 2008). *España Patente nº WO2008/129097Al.*

Orthomerica Products, I. (20 de Mayo de 2015). *Europa Patente nº EP 2 612 625 B1*.

Taylor WM, D. R. (1994). Low back pain hospitalization recent United States trends and regional variations. *Spine*, 207 - 1213.