

DA CONSEGNARE AL COORDINATORE DEL CORSO PER LA PRESENTAZIONE DEL DOTTORANDO AL GIUDIZIO DEL COLLEGIO DEI DOCENTI IN VISTA DELL'ESAME FINALE

SCHEDA INFORMATIVA SULLE ATTIVITA' DEL TRIENNIO
--

- Cognome e Nome ... **Chander, Divyaksh Subhash**
- Titolo di studio posseduto....**MSc Automotive Engineering**.....
- conseguito in data**16/10/2015**..... presso l'Università/Politecnico di**Torino**.....
- Dottorato di Ricerca in **INGEGNERIA MECCANICA**
- Ciclo **33** - Anni accademici di riferimento.....**2017-2020**.....
- Dipartimento ..**DIMEAS - Department of Mechanical and Aerospace Engineering**.....
- Coordinatore: **Prof. Luca Goglio**
- Tutore**Prof.ssa Maria Pia Cavatorta**.....
- Titolo della Tesi di Ricerca (in Italiano e/o in Inglese)
Modelling the Physical Human-Exoskeleton Interface

A. DESCRIZIONE DELL'ARGOMENTO DELLA TESI (massimo 20 righe)
--

Exoskeletons are mechanical devices that augment the capacity of the user to perform a specific task. The user “wears” the device and performs the task. Recently, exoskeletons have received a lot of interest, especially from industries where exoskeletons are seen as a potential method to relieve the operators from stressful work tasks. The more conventional application of exoskeletons has been in the medical field as a rehabilitative device. In either case, exoskeletons are designed and optimized specifically for a task. Thus, biomechanical analysis of the task forms an important step in the design and analysis of exoskeletons. Biomechanical analysis allows to understand the load on the user and where and how much exoskeleton assistance must be provided for a given task.

Musculoskeletal multi body models are often used for biomechanical analysis. Conventionally, exoskeleton is attached to the human model using kinematic joints. Kinematic joints rigidly fix the exoskeleton to the user and allow a limitless reaction force in the selected constraints. The interface forces can be unreasonable as well as limited to specific directions depending on the constraints needed to fix the exoskeleton to the user. In reality, human-exoskeleton interface consists of straps, cuffs or moulded surfaces. There is also some relative motion between the human and the exoskeleton. The thesis developed and tested a new interface model based on contact model that solves the problem of kinematic joints. Further, the contact model allows an estimation of interface forces and pressure that are of interest to understand discomfort from long term use of the exoskeleton.

B. ATTIVITA' DI RICERCA SVOLTA NEL TRIENNIO
--

B.1 descrizione complessiva e sintetica dell'attività di ricerca

The research activities performed during the PhD program can be synthetized in the modelling of the human-exoskeleton interface in the field of musculoskeletal modelling for biomechanical analysis of exoskeletons.

The research work started with the idea of doing biomechanical analyses of exoskeletons through musculoskeletal modelling in collaboration with FCA-CRF. During the modelling work, the problem of modelling the human-exoskeleton interface was faced. Despite the little literature available due to the novelty of exoskeletons, the conventional approach to model the human-exoskeleton interface is to use kinematic joints. As described previously, kinematic joints were not seen as adequate to model the interface. The idea was to use a contact model for the exoskeleton, however none existed specifically for exoskeletons. The literature search, however, did reveal contact models that were validated extensively for ground reaction force prediction. It was decided to use this model and to adapt it for exoskeleton interface.

At the end of the PhD, a contact model for simulating human-exoskeleton interfaces was developed for two different types of exoskeletons. The modelling method developed would be applicable to several exoskeletons. The contact model provides reasonable biomechanical outputs and, additionally, estimates of contact forces and pressure at the human-exoskeleton interface. Further, a comparison of the contact model with the conventional approach is provided in the thesis.

B.2 argomenti di ricerca specifici affrontati

More specifically the research can be subdivided as follows.

In the first year, a relatively simple exoskeleton, Chairless Chair was studied. The use of Chairless Chair resulted in a similar condition as if the support is provided by the ground. The exoskeleton consists of a single interface (the seat) that provides support from one side of the leg in a rather static application. An initial investigation was made on the contact model applied as it is from the studies on ground reaction force prediction. The model parameters were studied, and reasonable results were obtained.

In the second year, the focus was on refining the contact model to simulate curved surfaces. The exoskeleton in question was still the Chairless Chair. In the first year, investigations were made by modelling the exoskeleton seat as a planar surface. However, exoskeleton interfaces are anything but planar. They could be intricately shaped surfaces or straps that revolve around the limb and provide support all around. The approach used was to make multiple implementations of the contact model, to represent the realistic surface of the exoskeleton interface. However, this approach resulted in unreasonable results and required optimization of the model parameters. Such a method to identify the model parameters was defined in the second year.

In the third year, the contact model was applied on another type of exoskeleton for the lower limbs. The exoskeleton presented 3 interfaces (foot, shank and thigh), spanning across the ankle and the knee joint. Each interface also wrapped around the limb. A collaboration was made with Leipzig University of Applied Sciences (Leipzig, Germany), who are developing the exoskeleton. The third year also consisted of a 5-month visiting (formation) period at Aalborg University (Aalborg, Denmark), who are experts in biomechanics and musculoskeletal modelling. Initially, the same approach was used from the second year to model the multiple interfaces of this exoskeleton. However, the approach to identify model parameters did not work in this exoskeleton due to the presence of interfaces across the joints. The contact model was unloading the physiological muscles and giving unreasonable results. Thus, another approach was developed that allowed the use of the contact model across the joints, in turn making the contact model independent to the changes in model parameters.

B.3 risultati più rilevanti ottenuti nel triennio

Development of a new method to model the contact at human-exoskeleton interface.

B.4 collaborazioni di ricerca avute con Università, Centri di ricerca ed Industrie nazionali ed internazionali (specificare il quadro entro cui sono avvenute: contratti di ricerca, periodi di formazione, ecc.)

- FIAT Chrysler Automobiles – Centro Ricerche FIAT (Turin, Italy): research contract
- Aalborg University (Aalborg, Denmark): Formation period / Visiting PhD (5 months)
- Leipzig University of Applied Sciences (Leipzig, Germany): Research Cooperation

B.5 ulteriori attività di ricerca (progetti e contratti di ricerca nazionali ed internazionali)

- EU Project CASTLE - Cabin Systems design Toward passenger wellBeing
- Regional (Piemonte) project HUMANS - HUMAN centered MANufacturing Systems

B. 6 brevetti conseguenti l'attività di ricerca

N.A

B. 7 altre attività che si ritengono degne di menzione

.....

C. ATTIVITA' DI FORMAZIONE

C.1 partecipazione ad attività interne di supporto alla didattica (specificare su quali corsi, e se eventualmente il dottorando sia stato nominato cultore della materia)

Responsible for lab on Siemens Jack in the course "Ergonomics for Manufacturing Systems" –
 Nominated as collaborator for the course

C.2 corsi e seminari più significativi seguiti (interni, esterni, ecc. - indicare solo il tipo ed il numero)

- Internal Courses: Hard Skills (4 courses – 97 hours) / Soft Skills (8 courses – 58 hours)
- External Courses: Hard Skills (2 courses – 60 hours)
- Conferences: 2 International
- Seminar: 1 National

C.3 periodi di formazione esterni al Politecnico (tipo di formazione, luogo e durata)

Visiting PhD at Aalborg University (Aalborg, Denmark) – 5 months (02/2020 – 06/2020)

D. PUBBLICAZIONI FATTE E IN CORSO (indicare il numero e il tipo: riviste nazionali ed internazionali, congressi, capitoli libri ecc.)

- International Journal: 3
- Conferences: 2
- In preparation: 1 (International Journal)

Data, 22/10/2020



(firma del dottorando)