INTERNSHIP

RESEARCH INTO COMPLIANT BISTABLE MECHANISMS WITH THE APPLICATION IN THE DESIGN OF AN EASY-CHAIR

Indian Institute of Science, Bangalore, India

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Preface

In this report the results of my internship at the Indian Institute of Science (IISc) in Bangalore will be described. It was a great experience to work for prof. G.K. Ananthasuresh in the department of Mechanical Engineering. I learned a lot of working and living in such a different culture. I would also acknowledge the members of the M2D2 lab and especially the team of the easy-chair, Anirudh Katti and Darshan S.

Also thanks to my supervisor from the University of Twente, prof. Just Herder. The discussions with him were always a great motivation to continue with the work for the project.

Content

Abstract

In the world many elderly suffer from arthritis. For these people, the stresses that develop in their limbs when rising from a chair can be uncomfortably high. While there are several existing chairs designed to address this problem, most use electrical actuators or complex hydraulic systems. Since electrical power is not available everywhere for the entire day, especially in developing countries, there is a need for an easy-chair that gives support during rising from the chair without using electrical power.

I worked for about three months at the Indian Institute of Science on a project of prof. G.K. Ananthasuresh to design an easy-chair for the elderly, without the need of electrical power. I did research into compliant mechanisms and its bistable behavior, to use this for the design of a seat for an easy-chair. A compliant bistable mechanism can have two stable positions, where one state is stress-free while the other state stores potential energy. Using the stress-free state of the seat as the upper position and the other state as the seated (lower) position, the energy stored in the mechanism can be used to support the occupant while rising from the chair - going from the seated position up to the upper position. The energy can be released using an addition force of the occupant on the armrests of the chair. To achieve this, a two-port bistable compliant mechanism is developed, where the forces to switch between the two states differs for the two ports of actuation (the seat and the armrests). Additionally, the seat is statically balanced, to reduce the required stiffness of the compliant part and increase the flexibility of the chair for different weights of the occupant. Both a one and two degree of freedom model is developed to describe the behavior of the two-port bistable compliant mechanism. The one degree of freedom model and its application in the easy-chair is described in a paper submitted to the IFToMM congress 2015. A scaled prototype of the easy-chair is developed to test the concept.

The use of a two-port bistable compliant mechanism is interesting to gain mechanical advantage with compliant mechanism while switching between the two stable states. Using proper design of the different ports of actuation and the storage of energy in one of the stable states, the implementation of two-port bistable compliant mechanisms can be useful for many purposes.

Introduction

There are about 576 million people aged more than 65 in the world today. Of these, approximately 350 million people have arthritis. For these people, the stresses that develop in their limbs when rising from a seated position can be uncomfortably high. While there are several existing chairs designed to address this problem, most use electrical actuators or complex hydraulic systems. Since electrical power is not available everywhere for the entire day, especially in developing countries, there is a need for an easy-chair that gives support during rising from the chair without using electrical power.

In November 2014 the Indian Institute of Science officially started with a partnership together with several hospitals and companies, to work on (mechanical) solutions for problems in the work field of medical doctors. The three projects in this collaboration are financial supported by the Department of Science and Technology (DST) of the Government of India. One of the projects is about the design of an easy-chair for the elderly. The leader of this project is prof. G.K. Ananthasuresh of the M2D2 lab, part of the department of Mechanical Engineering at the IISc.

I was involved in this project, together with two other project assistants (students) of the M2D2 lab. One student (Anirudh Katti) worked mainly on the prototyping of the easy-chair, the other student (Darshan S) on the theoretical background and modeling of the chair. Before the project officially started in November, they already created a concept for the chair that is presented at ASME IDSC 2014. I reviewed all the work they did and derived the technical background again. For this I did a lot of research into compliant mechanisms and bistable behavior in this kind of mechanisms. During my internship I've worked on a paper together with Darshan. This paper is submitted for the IFToMM congress of 2015.

The main part of this report is the paper written for the 14th Word Congress in Mechanisms and Machine Science (IFToMM) in Taiwan this year. After this I will give an overview of the work I did beside the paper.

IFToMM Paper

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Overview of the work

It was interesting to review and structure the work they did for the chair in an earlier phase. For the paper I worked on the analytical model for two-port bistability and modeling of compliant mechanisms in general, including the derivation of the energy and the required switching forces of the mechanism. An important contribution of me in the project, is the addition of static balancing - to reduce the required stiffness of the compliant part and increase the flexibility of the chair for different weights of the occupant. During the project we tried to validate my Matlab models with Darshan's simulations with ABAQUS, as shown in the paper. Beside this it was interesting to validate the results with experiments.

After finishing the paper, we were able to create a scaled prototype of the chair and the static balancing of the seat, shown in Figure 1 and Figure 2.

Figure 1 – Prototype

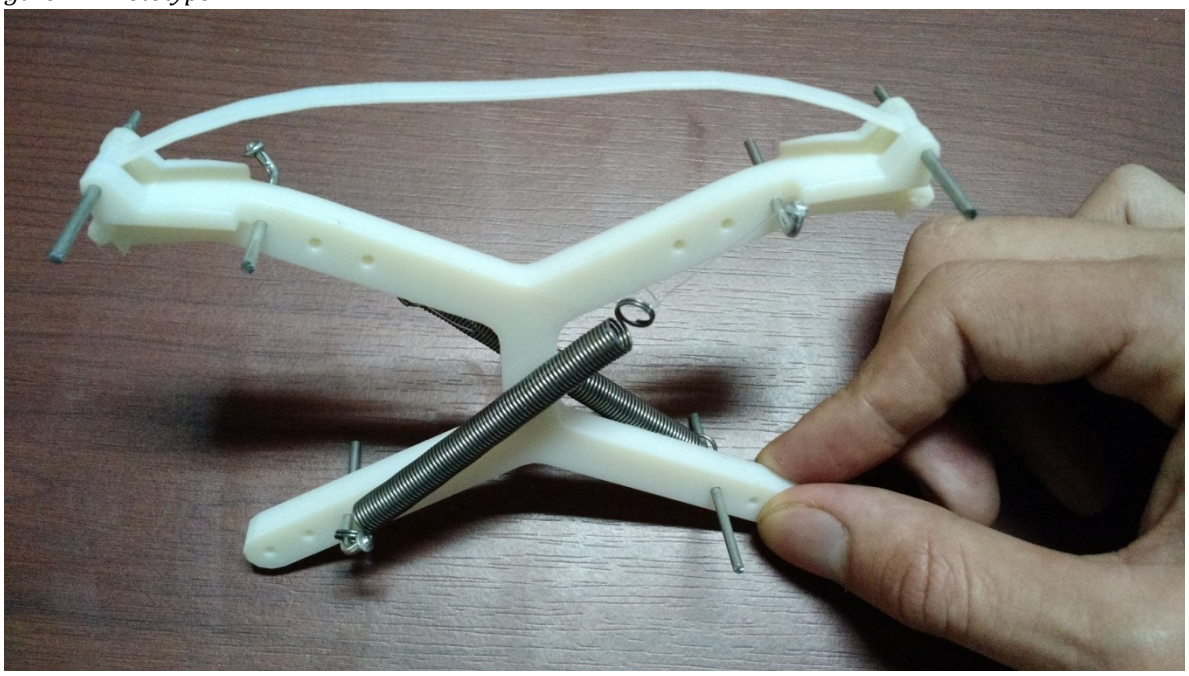

Figure 2 – Prototype static balancing

In the paper a one degree of freedom (DOF) model is described, but I also worked on a 2 DOF model, as shown in Figure 3 and Figure 4.

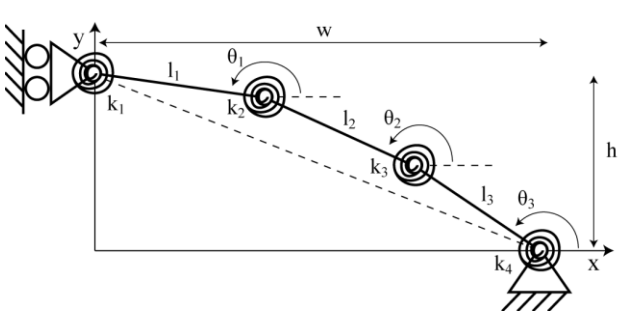

Figure 3 – Five bar mechanism

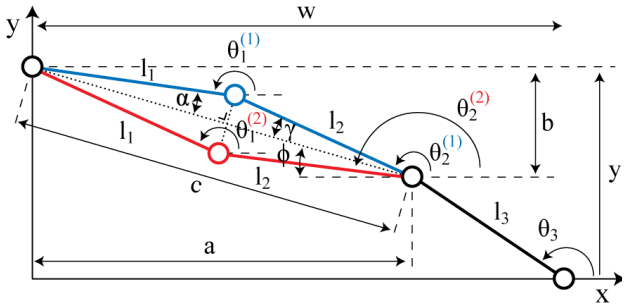

Figure 4 – Five bar mechanism

Using this model, the energy can be expressed as a function of the two degrees of freedom (y_1 and θ_3), as shown in Figure 5. In the figure two energy surfaces can be seen - for both solutions shown in Figure 4. Using the derivative of this surface with respect to the input port (either y_1 or θ_3) the deformation path of the mechanism during actuation can be derived, comparable to the strategy for the 1DOF model shown in the paper. In a comparable way also the required forces along the deformation paths can be determined. An observation during these analyzes is that the mechanism can follow a different path when the force is applied at another port or direction. This results in four different deformation paths for the 2 DOF model actuated at two different ports (y_1 and θ_3). We are still working on a paper with the analysis of the 2 DOF model and I will not describe more details about this in this report.

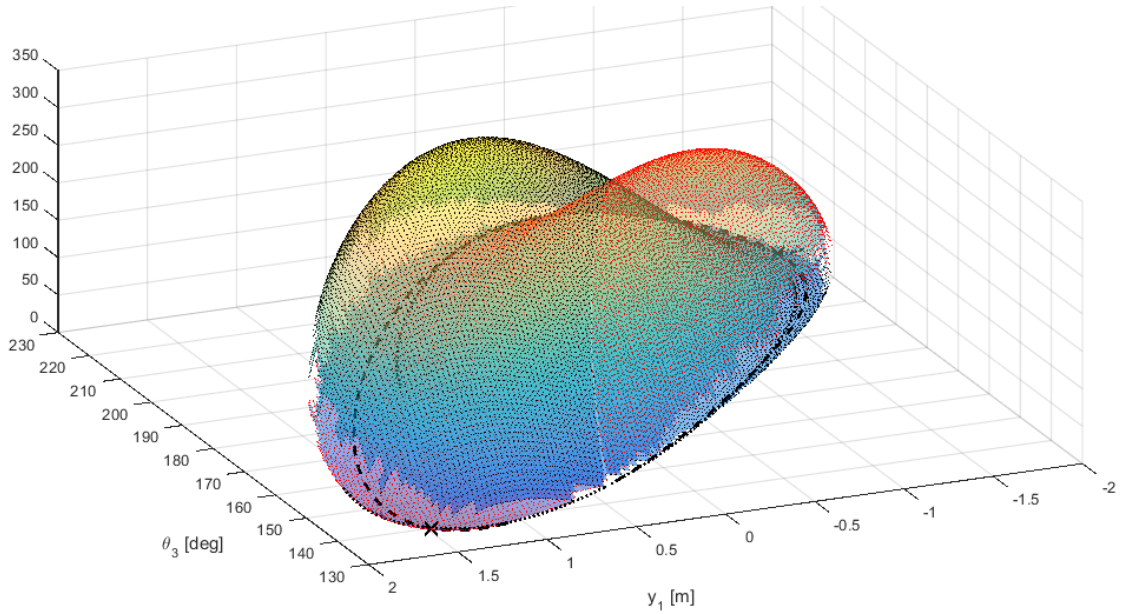

Figure 5 – Energy surface plot for 2DOF model.

Besides the work directly related to the project, I also discussed with other students about their projects and every Wednesday there was a meeting with the whole M2D2 lab with a presentation and discussion on the topic of a lab member. I also attended a workshop about the design of a mechanical ventilator and a PhD presentation of a student from the IISc. It was interesting to see other work done on the IISc and discuss about these topics.