POLITECNICO DI TORINO

Department of Control and Computer Engineering

Master of Science in Mechatronic Engineering

Masters Thesis

ACTIVE SUIT

Electro-pneumatic control prototype of an active suit for upper arm

Mentors: Prof. RAPARELLI Terenziano, Prof. EULA Gabriella, Prof. IVANOV Alexandre, Prof. CHIABERGE Marcello

Introduction

This thesis exemplifies the development of artificial pneumatic muscles suitable to be incorporated into an active dress to develop a prototype of the t-shirt for the movement of the arms with the idea that the use of fabrics instead of rigid exoskeletons. At the same time, it can also solve the issues related to mobility and ergonomics. Traditional pneumatic actuators which are well known are widely used for high power-weight ratio, low cost, ease of installation and robustness; Provide great efficiency, especially in those automated applications requiring a series of repetitive movements or robotic applications in confined environments, such as industrial ones. There are other areas, however, where pneumatic drive devices are operating in unrestricted environments where traditional actuators are not widely used. In certain situations, for safety reasons, movements must be carried out by avoiding that moving parts pose a danger to users. This is the case, for example, in the medical sector of active aids for motor rehabilitation and orthopedic devices, where the patient directly interfaces with devices that have an autonomous movement capacity. In these cases, the actuator must be intrinsically safe; Therefore, it does not have to be a rigid moving system, but it must have adequate compliance. In the above cases, a solution is the use of non-traditional pneumatic actuators designed for specific applications, such as artificial pneumatic muscles, for which several research groups have been engaged in several years of development. Pneumatic Artificial Muscles (PAM) are flexible linear actuators that are made to imitate the human muscle, and are powered by pneumatic energy, increase in volume and contract when doing work. Fluid muscle actuators can operate in hostile environments, with strong temperature gradients, vibrations, dust, and electromagnetic disturbances. They are also able to operate smoothly in the presence of fittings with significant misalignments without introducing tough stresses due to hyperstatic configurations. They are cheap, lightweight, capable of exercising at a great strength in relation to their weight; They are fitted with static seals and therefore, unlike those in creep seals, which are free from frictional leakage and fluid leakage; They are able to operate with different fluids, such as water, air and oil, without special needs. Over the years, various types of pneumatic muscles have been used by researchers to realize countless anthropomorphic and orthotic robots for rehabilitation.

The principle of the functioning of pneumatic muscles is illustrated and an overview of the state of the art of such actuators and of the main orthoses for the handling of the upper limb is illustrated. The orthoses present in the literature are rather bulky devices that use mainly metal exoskelets as a base. For this reason, the main activity of the thesis was the development of lightweight and reliable artificial pneumatic muscles with high power / weight ratios and able to provide contractions close to 30% of their resting length in order to guarantee such performance to make them fit to be applied in an active dress for the rehabilitation of the arms.

Muscle prototypes made at the Politecnico di Torino (prototypes DIMEAS) are presented: the muscles of the fabric and the muscles of the net. The performance of the two different types of muscle is also compared, and the study of the muscles in the net, which are the most performing and absolutely suitable for the purpose, are thoroughly studied.

An arm prototype is shown active for arm movements that can perform the arm protrusion, bending-extension, and forearm-supination. The muscles used to perform the movements provided by DIMEAS are small size prototypes (13 mm diameter) of different lengths, to obtain the contraction needed to produce the different movements. Two proposals for electropneumatic circuits are also presented with relevant control schemes for carrying out two possible therapies for a patient undergoing rehabilitation.