Chapter 56
Wearable Power Assist Robot Driven with Pneumatic Rubber Artificial Muscles

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ABSTRACT

A wearable power assist robot to enhance muscular power using actuators is sought after for welfare applications, et cetera. Pneumatic rubber artificial muscles are seen as some of the more useful wearable actuators because of their inherent light weight and softness. In this chapter, the author first outlines the current state of the research and development of this kind of robot before introducing some pneumatic rubber artificial muscles developed in the author's laboratory. The chapter then moves on to explain about the wearable power assist devices driven with these artificial muscles; both the exoskeleton type and the non-exoskeleton are wearable power assist devices. These power assist wear could be considered ideal as a wearable and comfortable power assist device.

INTRODUCTION

With the declining birthrate and growing proportion of elderly people, it is estimated that about 30 percent of the overall population in Japan will be 65 years old or more by 2030. Moreover, the number of younger people working in the medical and welfare fields is decreasing. As such, the development of devices that support independent daily life and the nursing and rehabilitation of elderly and disabled people is in high demanded. In addition, elderly and female workers are expected to be more positively applied in various industrial fields as devices are produced which alleviate hard labor. Recently, attention has been focused on producing a wearable power assist robot satisfying these demands, by installing an actuator, such as motors, in the body and assisting and enhancing muscular power; there has been a considerable increase in research and development in domestic and foreign organizations.

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Various types of wearable power assist robots have been proposed to support the upper and lower limbs, waist, and so on, which are to be used for the operational support of elderly and disabled people, nursing care work, and heavy lifting work in production sites. Some of them have been commercialized and their promotions have been advanced. Their social needs are extremely high, and there is an expectation of further improvements of the assisting effect, installation performance, safety and convenience, and the affordability of the robots.

In this chapter, after the current state of development of this kind of robot is outlined, we consider the development of pneumatic rubber artificial muscles, exoskeleton type standing motion assist devices, and wearable, lightweight, and soft power assist robots without an exoskeleton.

CURRENT RESEARCH AND DEVELOPMENT OF POWER ASSIST ROBOTS

The research and development of power assist robots is very active. Assistance in welfare, nursing, rehabilitation, and heavy manual labor are the main usages of these kinds of robots (excluding BLEEX of DARPA in United States). The assisted body part is different according to each research institution, such as upper limbs, lower limbs, shoulders, waist, or the whole body. Though an electric motor is mainly used for the actuator, there is also a lot of research and development using pneumatic rubber artificial muscles on account of their light weight and softness. Moreover, a supersonic wave motor has been used due to its light weight; with the use of the elastic power of rubber materials. Various power assist robots are being developed at a wide number of universities and institutions, which can be seen in related journals and so on.

Depending on the usage, this kind of power assist robot is required to satisfy the following conditions:

- Effective assistance;
- Safety;
- Wearability and comfort (small size, lightweight and soft);
- Convenience of attaching and detaching (simple mechanism);
- Possibility of wearing during long periods of time and at any time and
- Low price. In particular, the balance of the assist effect with safety and wearability is the important issue.

If using the exoskeleton type driven with a high power actuator, the assist effect can be increased, but the safety and wearability decreases. Moreover, in welfare and nursing fields, the hard exoskeleton type is not favorable for the patient or nurse to have installed for long periods of time. It is necessary to select the mechanism and structure of the robot appropriately according to the assisted body part and the operation.

A small sized, lightweight, and soft pneumatic rubber artificial muscle is useful as the actuator for this kind of robot. A human friendly power assist robot can be achieved by making use of the softness of pneumatic rubber artificial muscles.

PNEUMATIC RUBBER ARTIFICIAL MUSCLES

McKibben Type Artificial Muscle

The McKibben type artificial muscle is a typical pneumatic rubber artificial muscle. Figure 1 shows its structure and operation, which comprises of the rubber tube covered with a woven sleeve. When the rubber tube is pressurized, the radial expansion force of the tube is converted into the axial contraction force by the pantograph effect of each mesh in the sleeve.

Though the McKibben type muscle can generate a high contraction force, the contraction rate (about 30%) is smaller than that of human muscle