New Trends in Application of Artificial Muscles for Automation Devices used in Non-productive Sector

Marek Fodor, Jaroslav Seminský, Marian Veseliny, Kamil Zidek, Tomas Zupa

Abstract

At present, occurred in the field of artificial muscles a big progress. Application of artificial muscles emerges with the development of new technologies. Artificial muscles have potential to copy the natural function of muscles and their using is still progressing. This type of drive is possible to use in different areas, where using of other types of drives would be difficult or unrealistic. Another positive feature of artificial muscles (for example with in comparison with pneumatic cylinder or DC motor) is multiple higher power-to-weight ratio. The aim of the paper is to focus the attention to the sphere of artificial muscles and to suggest the possibilities of their using.

Keywords: artificial muscles, automation, polymers, bioengineering, rehabilitation

1 Introduction

The areas dealing with artificial muscles are progressing well. Many branches are dealing with wide range of their applications. Currently, the electric motor is the main driving unit of robots. However, its limits of size, weight, complicated power transfer and structure caused change of design so systems. Above-mentioned limits have launched the development of so-called artificial muscles, operating on the principles of natural human muscle. [3] [5]

Artificial muscles with the ability of dynamic motion like human muscle open new therapeutic options for those, who suffer from various paralyses.

At the present time one of the most effective ways to rehabilitate damaged limbs or paralysed limbs, to maintain flexibility, is a soft and smooth movement of joints. This often requires higher attention for a long time, which is frequently impossible for the therapist to be present all along time. From this point of view it seems the use of artificial muscles in rehabilitation technology as irreplaceable.

Artificial muscles belong to the unconventional drives handling devices, which are described in second chapter. [4]

2 Decomposition of non-conventional actuators for manipulating devices

The most important characteristic of nonconventional drive for practice is their power to weight ratio. Currently the main nonconventional drives include:

- Shape memory alloy (SMA)
- Piezoelectric actuators and electrostrictive/magnetostrictive drives
- Drives based on changes in fluid viscosity
- Drives based on electroactive polymers (EAP)
- Pneumatic artificial muscles (PAM)

Shape memory alloy (SMA)

Recently was recognized a potential of using shape memory alloy. Research progressed and shape memory alloy were used gradually for the implementation of dynamic tasks, where they played the role of drives. So constructed alloys belong to a group of thermal drives.

It is needed also to mention the disadvantages of these alloys as are for example:
- Low efficiency
- The ability to achieve small absolute tension
- Slow frequency response

Piezoelectric actuators and electrostrictive / magnetostrictive drives

Piezoelectric actuators have a lot of good attributes. These include mainly excellent positioning accuracy and dynamics, high stiffness and high power-to-weight ratio. However, the value of the maximum growth size varies only about 0.1%, and therefore their application is mainly focused for micromanipulation.

A current with low voltage controls magnetostrictive actuators. Their disadvantage is the need high voltage. Magnetostrictive drives are suitable for applications that use the big strength, fast dynamic response and small distances with great precision positioning even at high temperatures.

Drives based on changes in fluid viscosity

These drives use the features of electrorheological (ERF) and magnetorheological (MRF) fluids. In these materials due to electric or magnetic excitation can lead to rapid increase in viscosity.

The advantage of ERF and MRF drives is excellent dynamics, generated relatively large strength to size and weight. Contrast, the disadvantage is the need high voltage for generating a large output power. These drives have been applied in a variety of interesting prototypes and experimental devices but their use is limited by the lack of technological development.

Drives based on electroactive polymers (EAP)

EAP are responding by changing the shape on electrical stimulation. Compared with SMA EAP a higher rate of response, lower density and better resistance. Accordingly, as they activated are divide to electric and ionic. Electrical EAP can be further divided into two groups -- the electrostrictive polymers and dielectric elastomers. The drive characteristics are based on electrostrictive polymers:
- High powered drive (about 5%)
- High energy intensity compared with piezoelectric ceramics
- Not too large strength, which are suitable for rotary and diaphragm actuators
- Their performance is comparable to the intrinsic muscles of micro and macro
- Are the materials for low cost and used standard techniques of production
- They are efficient, light-weight, particularly suitable for micro-measurement mobile applications
Dielectric EAP consist essentially of a coating film of an elastic dielectric material, which is coated on both sides with another expandable conductive film on the electrode. The reaction rate of dielectric EAP is high and their output strength is large. Dielectric elastomers are useful as drives in robotic applications.

Ions are used for movement in the ion EAP. The advantage of ion EAP is a large elongation at low voltages. Vice-versa, the disadvantages are low speed response and low durability yet. Their mechanical properties similar to biological systems classify then to the category of artificial muscles.

The ion actuators can be divided to:
- Reactive polymer gels
- Ion polymer-metal composites
- Drives from conducting polymers
- Carbon nanotubes

**Pneumatic artificial muscles (PAM)**

Pneumatic artificial muscles have in many aspects similar properties, shape and behaviour as natural human muscles, which allows for easy connection to handling complex installations with multiple degrees of variance. Pneumatic muscles are characterized by extremely high power-to-weight ratio. Pneumatic artificial muscle weight is to 90% less than the weight of the pneumatic cylinder of the same diameter. Extending the length of PAM is usually about 30-35%, which is comparable with native muscle. Of course it depends also on the construction of the PAM. [1] [6]

These muscles practically can be produced with any length or diameter. The main advantages of PAM include:
- Precise and smooth operation between the extreme positions of the muscle
- Low price
- High reliability
- Construction is resistant to contamination
- Minimal maintenance
- High security - which is associated with possibility to use them in wet and explosive environments

The disadvantages include:
- More complex control
- At the rotational kinematical pairs is necessary to use a pair of muscles
- At the large stroke is necessary to use long artificial muscles

PAM muscle consists of a rubber tube and nets, which shortens the length and prevents unwanted deformations. This kind of muscle has power/weight ratios approximately 400:1, this overcomes the pneumatic cylinders and DC motors, where ratio of about 16:1 can be achieved only.

The composition of muscle is shown in Fig. 1 and Fig. 2. The core consists of a rubber hose wrapped in solid net.

Thus constructed muscle with diameter only 6 mm has strength and speed comparable to a fine move with a finger of a human hand. Therefore, use of this type of muscle is particularly useful in the medical field, whether for rehabilitation or other purposes. [2] [10]

**3 Application of artificial muscles**

As described in the previous section, the uses of artificial muscles have a promising future. Each type of artificial muscle is for their specific properties suitable for different application area. As exceptional properties achieved guilloche structure formed nanotubes designate them for use in robotics. Weight of this muscle is comparable in capacity only slightly greater than the mass of air. In a longitudinal axis, in which nanotubes are arranged, the artificial muscle is stronger than steel. Perpendicular to the axis is elastic as rubber. This muscle can expand its width to 220%. A huge advantage of this muscle formed guilloche nanotubes lies in the fact that it can operate in extreme conditions from \(-196^\circ C\) to \(1538^\circ C\), which is higher than the melting point of iron. Robots designed using the artificial muscle may in future find wide application in the space program due to its flexibility, low density and low weight. [9]

Another area of fair use of artificial muscle is the formation of various exoskeletons. It is generally referred to as exoskeleton external skeleton of an animal that provides them with support and protection. The significance lies in the fact that using exoskeleton can carry a greater burden and make it in less effort. These created devices is using by artificial muscles are useful in various areas. Exoskeleton can be used as support for the older population. Using devices designed based on artificial muscles can be significantly helped to regain their lost power.

Example of using exoskeleton is shown in Fig. 3. The exoskeleton shown in the picture is intended for patients suffering from paralysis.

![Fig. 3 Exoskeleton from Panasonic](image)

In the future, these devices may also be used in fields such as Army, as super soldiers that can help exoskeleton run faster, carry heavier weapons and the like.

In the nearest future it is possible to use artificial muscles especially in bioengineering. With increasing population is human muscle becomes critically for necessary organ. For this reason it is closely as possible (artificial muscle) seems like the best solution for his replacement. With the growing number of accidents and thus the associated number of limb amputations is compensation using
artificial muscles and equipment designed using artificial muscles, the best solution.

Artificial limbs created by means of these muscles in future can fully replace the original limb function. However, the control of such facilities is too difficult. Another unresolved question is the link between artificial limbs and a functioning human body part. [11]

The most interesting and the most realistic area of using artificial muscles therefore seem to be the area of rehabilitation. Some research in this area ran, as an example may be mentioned: Rehabilitation glove, which serves people with permanent hand damage. With the help of gloves may handicapped people to perform activities, which are for healthy people obvious.

This rehabilitation glove is shown in Fig. 4.

![Fig. 4 Rehabilitation glove (designed by the Quadriplegic Hand Research Unit at the Royal North Shore Hospital)](image)

Currently the rehabilitation process is carried out by permanent helping of rehabilitation workers. This system is inefficient and with capacity constraints. Therefore, in future there is area for automatic rehabilitation device built and based on artificial muscles. So designed rehabilitation machines will be able to realize rehabilitation of patient without rehabilitation care person. The entire system will be more effective and better. [8]

4 Conclusion

Nowadays, although little used unconventional drives will surely find its application in any production or non-productive sectors of automated devices. Similarity with human artificial muscles makes them suitable for use in the medical field, for example for replace of limbs or rehabilitation devices. It is still a lot of unresolved questions, which is necessary in future to find satisfactory answers. This is mainly to solve the problems with control of pneumatic artificial muscles, or other design question marks in other unconventional drives. One solution to the problem of management "muscles future" is the use of artificial intelligence. By combining artificial intelligence with non-conventional drives can create a future of intelligent machines. Thus constructed device will find application in various areas of automated techniques.

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Fodor Marek, M.Sc., Assoc. Prof. Seminsky Jaroslav, M.Sc., PhD., Veseliny Marian, M.Sc., Zidek Kamil, M.Sc., PhD., Zupa Tomas, M.Sc., Technical University of Košice, Faculty of Mechanical Engineering, Park Komenského 9, 042 00 Košice, e-mail: kamil.zidek@tuke.sk

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