03/ 6101 EAP-based artificial muscles as an alternative to space mechanisms

Type of activity: Fast Study (2 months, 15 KEUR)

Background

In order to try and emulate the muscle mechanism, it is required that the metrics that make up a typical muscle are defined. Unlike existing linear actuators that could be considered roughly analogous to muscle (such as hydraulics for example), the muscle is a highly nonlinear, time variant and multivariate component of the animal system. These essential characteristics of non-linearity, time-variable, repeatable performance and exquisite level of control make the imitation of living muscle a difficult engineering challenge. However the engineering benefits of achieving a high-performance artificial muscle are obvious; the range of speed and precision of muscle actuation would, for example, revolutionalise robotics.

How then to imitate muscle? The complex molecular structure of muscle obviously at the moment and for the foreseeable future precludes the direct imitation of muscle at a molecular level. The development of artificial muscle therefore is centred around the search for materials and mechanisms that could conceivably display muscle-like characteristics at a macro-level. There exist at present several materials and mechanisms that are considered as suitable for artificial muscles, such as Electro-Active Polymers (including derivatives such as Ionic Polymer-Metal Composites), Shape Memory Alloys, Reciprocating Chemical Muscles, Series Elastic Actuators, and McKibben Artificial Muscles. Of these Electro Active Polymers (hereafter EAPs) are considered the most promising due to wide range of applications that could result form their superior muscle-like characteristics.

Study Objectives

The objective of this study is the development of EAP-based mechanisms that have potential for application as artificial muscles in future space missions. Of particular interest are the performance characteristics of different types of EAP/EAP-based mechanisms, bearing in mind the wide range of envisaged future scenarios where artificial muscles will be applied, such as deployment on space-craft of arrays, as well as realisation of planetary surface mobility for autonomous agents. Also of particular importance is the suitability of EAPs (of all types) for application within the environments that characterise future space missions, characterised by constraints such as increased radiation, extreme thermal cycling, and interfacing with other space-craft components.

In summary the study objectives are as follows:

- Identify of **EAP-based mechanisms** (i.e. materials, techniques, etc) that have potential for application as artificial muscles in future space missions.
- Discuss **advantages and drawbacks of such EAP-based mechanisms** when compared with traditional mechanisms and other well-developed techniques (e.g. Shape Memory Alloys etc) in similar applications. This comparison of

physical properties will be based on previous work available in literature or resulting from the researcher’s particular experience, and will be restricted to space applications i.e. in-orbit and on planetary surface systems.

- Give indications on likely **system impact issues** i.e. consequences of EAP-based actuators integration in a conventional space system. This should include the evaluation power and thermal requirements and the discussion of other issues such as contamination, (e.g. by out-gassing), material degradation (i.e. mechanism lifetime and reliability), etc
- Evaluate the maturity of other potential capabilities of EAP-based mechanisms, especially its use for **pressure and stress sensing**.

References

[1] Yoseph Bar-Cohen. Electroactive Polymers as Artificial Muscles: A Review. Journal of Spacecraft and Rockets Vol 39, No 6, pp 822 – 827

[2] Bar-Cohen, Y., Leary, S., Shahinpoor, M., Harrison, J. O., Smith, J. (1999). Electroactive Polymer (EAP) actuators for planetary applications. Proceedings of SPIE’s 6th Annual International Symposium on Smart Structures and Materials.

[3] Shahinpoor, M. Bar-Cohen, Y., Xue, T., Simpson, J. O., Smith, J. (1998). Ionic Polymer-Metal Composites (IPMC) As Biomimetic Sensors and Actuators. Proceedings of SPIE’s 5th Annual International Symposium on Smart Structures and Materials.