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Flexure future

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Publication date
2017

Document Version
Final published version

Published in
Mikroniek: vakblad voor precisie-technologie

Citation (APA)
Herder, J. (2017). Flexure future. *Mikroniek: vakblad voor precisie-technologie*, *57*(3), 4-4.

Important note
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EDITORIAL

FLEXURE FUTURE

In precision mechatronics, flexure mechanisms have become commonplace but developments haven't stopped. Therefore, this issue of Mikroniek is devoted to recent trends in flexures, or rather compliant mechanisms, as their family name has come to be, usually defined as those mechanisms that move due to deformation. They lend themselves very naturally for high precision as they lack friction and backlash, and no lubrication is needed, which is beneficial in hostile environments such as vacuum, underwater or in the human body. On the other hand, their design has some inherent complications: there is always mechanical stress involved in any motion, and the behaviour is dependent of the load case. This implies that kinematics (motion) and kinetics (load case) must be treated simultaneously and that the concept of degrees of freedom fades in compliant mechanisms, because they behave differently for any load case. Many efforts have been undertaken to arrive at workable definitions of mobility, for instance by defining compliance ellipsoids of the point of interest.

Over time, various configurations of wire and leaf flexures, also known as compliant architectures, have been identified that are less affected by the above complications. While their design principles remain of vital importance, there are several drivers for renewed interest in this field. Increased computer power resulted in desktop tools for the analysis of compliant structures right from the drawing board. Although non-linear phenomena like buckling and large deflection remain very tricky, a first impression of linearised behaviour is now at our fingertips. More important is the development of new modelling theory which supports the synthesis of compliant mechanisms directly.

A simple example is so-called pseudo-rigid-body modelling (PRB), where virtual joints emulate the effect of distributed deflection. This results in models with very few parameters, and provides a portal to the large domain of known linkages. Another new modelling approach is the freedom and constraint topology method (FACT), which is based on spatial kinematics and its duality with statics. This method allows one to find the solution space for a given motion or load task, rather than a single solution, giving more freedom to the designer. Also topology optimisation (TO) is maturing and becoming accessible, while the irregular shapes that tend to come out can now be produced by additive metal manufacturing, a promising combination. Interestingly, TO results oftentimes appear organic, providing a link to biomimicry and bio-inspiration, which is very topical.

The drive for miniaturisation has revived interest in methods for manufacturing compliant mechanisms from flat layers of material, i.e. compatible with MEMS technology. Effort into so-called lamina-emergent mechanisms (LEM) has led to a hype in engineering origami and pop-up where spatial compliant structures are created that are hard to produce otherwise. Generalising the idea of origami has also given rise to the development of shell mechanisms, i.e. spatially curved compliant structures, and methods for their synthesis helping the designer create and understand these complex shapes.

Actuation of compliant mechanisms is always a challenge, typically solved by ensuring that part of the mechanism motion is compatible with a given actuator. Avoiding this challenge, and exploiting the large deforming surface, distributed actuation and sensing technology is under investigation where besides piezo layers also polymer-based types are used for driving the mechanism or reducing the adverse effects of undesired degrees of freedom.

Clearly, a lot is going on in compliant mechanisms, with many promising directions for more than incremental progress being explored and included in modern educational curricula.

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