BENDING RESPONSE OF A SOFT ACTUATOR FOR A WEARABLE HAPTIC DEVICE

António Diogo André (1,2), Pedro Martins (2,3), Majid Taghavi (4)

1. FEUP, Portugal; 2. INEGI-LAETA, Portugal; 3. i3A, University of Zaragoza, Spain; 4. Imperial College London, United Kingdom

Introduction

Human-machine technologies have faced exponential growth in recent years driven due to their enormous potential in revolutionizing our interactive experience with the world [1]. Wearable devices, for example, have transfigured the entire experience of how people communicate in the real world. This interaction would be employed in various applications ranging from entertainment to robotics and healthcare [2]. The receptor for wearable haptic devices is the skin, which is the largest exterior organ of the human body. It is the primary interface for several external stimuli, e.g. heat or cold, and configures a tactile interface, playing a crucial role in detecting mechanical stimuli [3]. Its ability in detecting the real-time touch-based information sent by the haptic device and the user's perception defines the practicality of haptic technologies [1]. The wearable haptic devices need to be equipped with soft actuation mechanisms with broad stimulation modalities and quick action to communicate with the users. The present study aims to understand the actuation speed of the bending response of a piezoelectric material (PVDF ionic film) intended to be applied in a haptic device used for motor rehabilitation.

Material and Methods

A composite material (PVDF/Ionic Liquid-IL) was used to develop the actuation films. The IL (1-Methyl-3-propylimidazolium bis(trifluoromethylsulfonyl)imide) in the structure of this composite increases the content of the β phase, which is mainly responsible for the electroactive properties of PVDF [4]. The IL was mixed with DMSO in a 40/60% w/w (IL/PVDF) ratio. PVDF was then added to the solution in a proportion of 12/88% w/w (PVDF/DMSO). Once a homogeneous and transparent solution was achieved, it was cast into a glass substrate and heated up to 85ºC for 1hr in the oven to evaporate the solvent. Both faces of the films ($30x6x0.1mm^3$) were then coated with thin layers of gold using a hot press. The displacement of the films, as well as their rising time, have been primarily studied. Here we define the rising time as 90% of their maximum bending response. The PVDF film strip has been actuated by a square pulse with a voltage of 20V.

Results

The average displacement of the three trials with the corresponding standard deviation measures 1.30 ± 0.27 mm, while the rising time measures 0.32 ± 0.06 s. Figure 1 represents the response of the PVDF strip when a voltage of 20V is applied.

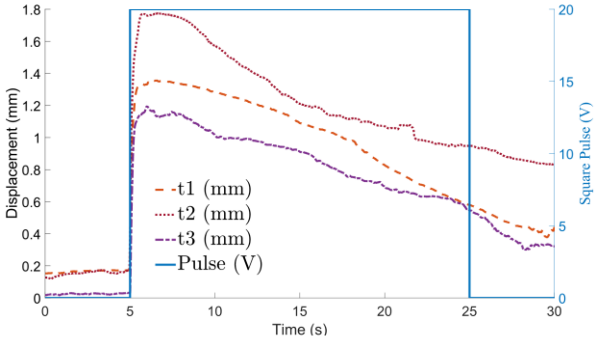

Figure 1: Rising response and the square pulse for 20V

Discussion and Conclusion

When the PVDF strips are actuated by a 20V signal, they bend without a noticeable delay. The film moves by 1.30 mm in 0.32 s (i.e. rising time) which is comparable with the average human reaction time (200ms). The film, however, gradually relaxes just after the peak displacement while the input voltage is still ON. We attribute this to the dielectric loss constant, amplified by the presence of β-phase in the PVDF strips [5]. Unlike the actuation phase, when the input voltage is switched OFF, the film does not show quick relaxation. Ionic liquid crosslinks PVDF, causing memory-shape properties [6]. By the Joule effect, the temperature of the strip increases when there is current passing. Once that voltage is OFF, the temperature starts slowly decreasing, which prevents the samples from quickly returning to the initial position [7]. Reversing the polarity may lead to quicker relaxation. The dynamics of the PVDF strip under various stimuli will be investigated further in the design of the haptic device.

References

1. Ozioko et al, Adv. Intell. Syst, 4, 2021.
2. Dahiya et al, Proceedings IEEE, 10:2016-2033, 2016.
3. Dahiya et al, IEEE Transactions on Robotics, 1:1-20, 2010
4. Correia et al., J.Phys.Chem.C, 123(20):12744-12752, 2019
5. Liu et al, ACS Omega, 7:25999-26004, 2022
6. Aoki et al, Macromolecules, 55:5591-5600, 2022
7. Eken et al, Eur. Polym. J., 114:249-254, 2019

Acknowledgements

A.D.A. and P.M. gratefully acknowledge funding from FCT, Portugal, under grant FRH/BD/147807/2019 and the research unit LAETA. M.T. acknowledges Imperial College Research Fellowship.