Tuning of Compliant Composite Shell Structures for Assisted Living

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The Office for National Statistics' 50-year forecast predicts that the over sixty-five population of the UK will increase by 8.6 millio n [1], reflecting a world-wide trend towards ageing populations. Reduced mobility is commonplace within this demographic often leading to a significantly reduced quality of life [1]. One solution to this challenge is through the use of passive assistive devices, such as exoskeletons, which support natural bio-mechanical motions [2]. We present a design approach for tuning such a device utilising compliant composite shell mechanisms; see Fig. 1.

A suitable design must meet competing objectives — conforming to body shape, enabling bio-mechanical motion and providing adequate support. The use of advanced composite materials allows for lightweight designs that use anisotropic tailoring and pre-stress to tune the mechanical response. In order to fully exploit the potential of composites a robust design approach is required. Large deformation behaviour makes analysis and design difficult. Whilst structural behaviour can be captured using established finite element analysis (FEA) tools, interpreting the physical response presents a challenge to designers. To mitigate this, the stiffness matrix of a key point of interest, *e.g.* the contact point between body and structure, can be tracked as the structure deforms. Next, an eigenscrew analysis of the stiffness matrix is performed to visualise the principal compliance axes of the system in a unified format. This approach allows the effect of design changes, such as anisotropic stiffness, to be compared in an accessible format [3, 4].

We present an optimisation framework for a composite compliant shell mechanism for an assistive brace, which can be generalised to other exoskeleton-type designs. By tuning the anisotropy of the composite material for a fixed geometry, we highlight the potential to develop bespoke devices satisfying an individual's needs.

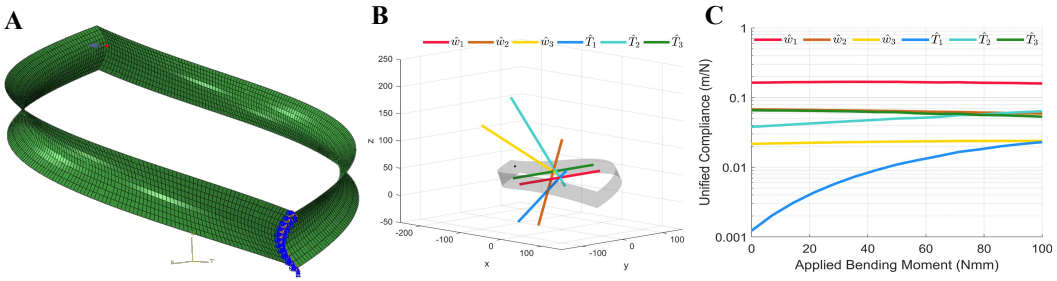

Fig. 1: Design process: (A) FEA modelling, (B) eigenscrew analysis, (C) response characterisation.

[1] A Storey. In: *Office for National Statistics: London, UK* (2018).
[2] H Lee, S H Kim, and H-S Park. In: *Frontiers in Bioengineering and Biotechnology* 8 (2020).
[3] J P Stacey et al. In: *ASME IDETC 2020*. 2020.
[4] J P Stacey et al. In: *Thin-Walled Structures* 161 (2021), p. 107478.