Origami Inspired Impact Energy Converter

Shadi Khazaaleh[1,2], Ahmed S. Dalaq[1] and Mohammed F. Daqaq [1,2]
[1]*Engineering Division, New York University Abu Dhabi (NYUAD), Saadiyat Island, UAE*
[2]*Department of Mechanical and Aerospace Engineering, Tandon School of Engineering, NYU, Brooklyn, NY, USA*

Abstract. Springs made by employing the Kresling origami pattern have various unique characteristics that can be tailored by simply tuning their geometrical design parameters. One of these characteristics is the ability of these springs to behave as a simple coupling mechanism that transforms translational motion into rotational motion and vice versa. We exploit this coupling feature to design a structure that can effectively convert the energy incident by an axial load into a rotational energy which can be harnessed through a rotary energy harvester consisting of a magnetic mass inside an induction coil.

Introduction

Over the past few years, origami has inspired the design and fabrication of various structures and materials with unique mechanical characteristics that are useful in many engineering applications. Specifically, the Kresling pattern is a class of non-rigid origami patterns which is used for building springs having several favourable attributes, such as tunable stiffness, multistability, translation-rotation motion coupling, and quazi-zero-stiffness (QZS) to name a few [1, 2]. In this work, we utilize the translation-rotation coupling feature of the Kresling origami springs (KOS) for applications in energy conversion and harvesting. In particular, the special kinematics of the KOS transforms translational motions applied at one end into rotational motions at the other end. The rotational energy can then be exploited by attaching an energy conversion mechanism, such as a harvester, at the base. The amount of energy that is harnessed is proportional to the change in magnetic flux, which, in turn, is proportional to the angular velocity of the magnet rotation inside the coil. Figure 1a shows a schematic of the proposed harvester. To study the dynamic behaviour of the KOS under loading across the design space defined by its main design parameters, we build a computational model, based on finite element methods (FEM) [3], using COMSOL Multiphysics. Simulations are carried out to find the optimum design that maximizes angular velocity and energy conversion efficiency. The results are validated by experimental measurements using an Instron universal testing machine (UTM) and an in-house built impact testing setup. Tested samples are fabricated by multimaterial 3D printing using a polyjet printer (Stratasys J750). Finally, the optimum performing design is used to construct the harvester, and energy conversion is demonstrated experimentally by attaching a magnetic mass and an induction coil at the base.

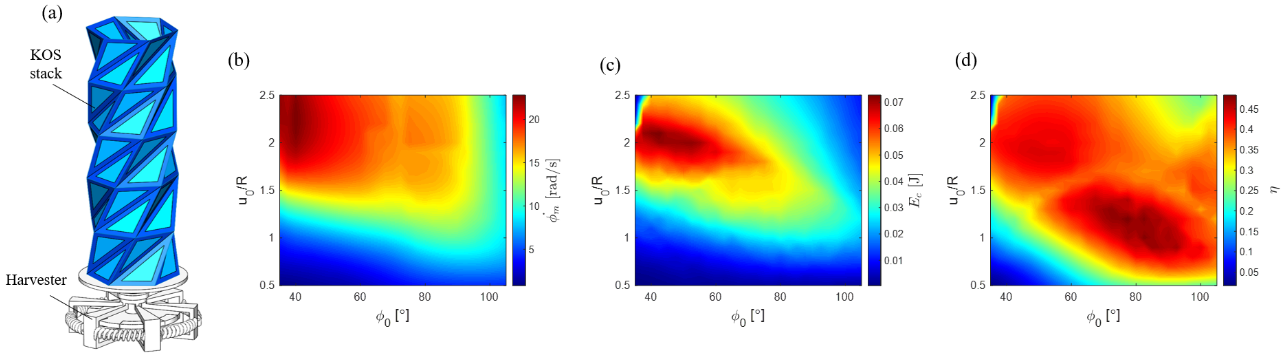

Figure 1: (a) Schematic of KOS stack with energy harvester, and simulation results showing contour maps of (b) peak angular velocity, (c) converted energy, and (d) conversion efficiency.

Results and Discussion

Simulation results shown in figures 1b-1d depict contour maps of the peak angular velocity, $\dot{\phi}_m$, converted energy, E_c, and conversion efficiency, η, across the design space. We fabricated and tested several designs scattered throughout the design space, and compared their behaviour with the simulations, which showed good agreement.

References

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