ASME International

ASME 2017 Conference on Smart Materials, Adaptive Structures and Intelligent Systems: Paper Details

Print

SMASIS2017-3803 (Status: Revision requested) *Technical Publication*

A novel biomimetic torsional actuator design using twisted polymer actuators

Authors

Name	Company	Author Order	Role	Copyright Received
Dr. Michael Shafer	Northern Arizona University	1	Lead Author	
Mr. Diego R. Higueras Ruiz	Northern Arizona University	2	Co-Author	
Prof. Heidi Feigenbaum	Northern Arizona University	3	Contact Presentation and Co-Author	

Symposium 6 Bioinspired Smart Materials and Systems

Name	Company	Phone & Fax	Role
Dr. Eric Freeman	University of Georgia	P:7246306199	Track Organizer

Abstract

Artificial muscle systems have the potential to impact many technologies ranging from advanced prosthesis to miniature robotics. Recently, it has been shown that twisting drawn polymer monofilaments, such as nylon fishing line or sewing thread, can result in a biomimetic thermally activated torsional actuator. The actuation phenomenon in these twisted polymer actuators (TPAs) is thought to be a result of an untwisting that occurs about the fiber's axis due to an asymmetric thermal expansion. Before being twisted, the precursor fibers are comprised of polymer chains that are aligned axially. During fabrication of TPAs, the polymer chains reorient as the precursor fiber is twisted about the central axis of the monofilament. At the end of the fabrication process, the TPA is annealed in order to relieve internal stresses and to keep the fiber in the twisted configuration. The mechanism of untwisting actuation is generally thought to be a result of radially expansion and axially contraction. After being twisted, these radial and axial expansion relationships remain relatively unchanged, but the polymer chain direction is no longer axially aligned. Thus, upon heating the twisted fibers of the TPA, the fibers untwist and torsional actuation occurs. This actuation phenomenon has been used in the past to create linear actuators, but can also be use directly as a torsional actuator. Compared to other torsional actuators TPAs are low cost, lightweight, and can actuate reasonably high torques per unit volume. However, because TPAs are thermally activated, they may not be suitable for all applications. In this work, we present a novel TPA design for use as a torsional actuator for miniature actuation and artificial muscle applications. Our design bundles twisted monofilaments to increase the torque. Both fabrication and testing methods of the new design are presented. Results for temperature versus torsional displacement under various loads give insights as to how these actuators may be used and the reversibility of the actuation process. Additionally, comparisons are made between these bundled actuators and similarly loaded single TPA monofilament actuation.

Presentation Author Biography

Heidi P. Feigenbaum is an Associate Professor in the Mechanical Engineering Department at Northern Arizona University in Flagstaff, Arizona. She received her Ph.D. in Civil Engineering from the University of California at Davis in 2008. Her areas of interest include plasticity modeling, smart materials, biomimetics, actuation, solid mechanics, computational mechanics, biomechanics, continuum mechanics and related areas.

Reviewer Comments

Reviewer 1:

1) Technical Summary: What are the authors trying to do? What are the objectives, goals and outcomes?

The authors are creating a novel, low-cost torsion actuator using twisted polymer actuators (TPA). Objectives are the creation of a new woven design to increase the torque and characterization of this design. Outcomes are a more effective TPA.

2) Significance & Relevance: How is it done today, and what are the limits of current practice?

I've seen woven wax actuators before, but this is a more refined, precise approach. Limits are of course the slower actuation time given the thermal nature and required cooling.

3) Originality: What is new in the authors' approach and why do they think it will be successful?

The authors include a new woven design that amplifies the output. This is also the first time the testing method has been described or demonstrated.

4) Impact & Permanence: What is the impact of the work and what difference will it make?
There is a need for low-cost twisting materials - these are simple and inexpensive, filling a current void. Every smart material has a niche to fill.

5) Quality & Credibility: How are the methods, results, and the outcomes assessed?
The methods, results, and outcomes are assessed directly with a well-explained experimental technique. The methodology is detailed and thorough. The results are assessed as functions of actuator rotation with temperature given a fixed torsional load.

6) Comments for author about style / formatting & suggestions to improve the paper, see ASME guidelines:
Formatting and style are fine, but I've noted a few things in the pdf - see attached. There are a few missing references or formatting errors, and there is room for improvement in the clarity of the figures. These are all minor concerns.

7) Recommendation for / against Conference Publication, state **why or why not** this paper should be presented at the conference:
I recommend the manuscript for conference publication. It is well written, detailed, and of sufficient depth for presentation at SMASIS 2017. A few minor changes are recommended.

8) Recommendation for / against Journal Publication, state **why or why not** this paper should be recommended for the journal:
I think there is room for expansion in discussions of the cycling phenomenon and exploring the impact of the woven angle for monofilament and bundles. How do the bundles scale with the angle/number of filaments? Is there an upper limit?

Reviewer 2:

1) Technical Summary: What are the authors trying to do? What are the objectives, goals and outcomes?
The authors are trying to establish a thermomechanical model for polymer filaments used in torsional actuation for both single twisted polymer configurations and parallel coiled, twisted polymer configurations. The goals are to fabricate both systems, and measure the extent of twisting during applied heating and cooling cycles to find the dynamic response. These goals were met within the context of the paper, although the results are limited to a small number of cases and it is difficult to ascertain a parametric analysis.

2) Significance & Relevance: How is it done today, and what are the limits of current practice?
The current practice for artificial muscle systems typically electroactive polymer systems, shape memory alloys, carbon nanotubes, or other smart material systems, which can be complicated and only optimize one performance metric (total stroke, power, speed of response, etc). Materials similar to the ones used in this work have looked at twisting actuation or linear actuation.

3) Originality: What is new in the authors' approach and why do they think it will be successful?
This approach specifically looks at twisted polymer systems reacting torsionally to thermal inputs. It is a logical next step to the current body of knowledge to create simple thermally activated actuators for various applications. The groups approach sufficiently measures the response of various configurations in a controlled manner to successfully demonstrate the extent of torsional actuation possible.

4) Impact & Permanence: What is the impact of the work and what difference will it make?
This work is a precursor to a more detailed study, such as torsional power. The specific application space of this process is limited due to the amount of preload required for the system to function appropriately, but is a good first step.

5) Quality & Credibility: How are the methods, results, and the outcomes assessed?
The system inputs and outputs are directly measured without bias. The measurement system isolates the parameters of interest well and the results are reasonable. The outcomes are reduced to a few time dependent plots of thermal input against fiber rotation and a dynamic compilation of the same results.

6) Comments for author about style / formatting & suggestions to improve the paper, see ASME guidelines:
There are several format inconsistencies across the paper. The term "Figure" is split between several capitalization and lower case instances. There are multiple spelling mistakes throughout the paper which need to be addressed, such as "cab" instead of "cam" on line 22 of the abstract, "an" instead of "a" in line 6 of the introduction, etc. The word "results" is listed twice in a row in the second to last paragraph of the discussion section. This is not inclusive, and the entire paper should be reassessed for issues such as these. In particular the second paragraph of the experimental results section has confusing grammar and sentence structure. The content of the paper is concise, but at no point is the material for the fibers used clearly given. Additionally it could be noted how the specific chemical structure of the polymer used changes as a result of the twisted configuration would help more clearly understand the actuation mechanism.

7) Recommendation for / against Conference Publication, state **why or why not** this paper should be presented at the conference:

I would recommend this for publication after the above changes. I think the results are significant and lead to a new understanding and future body of work based on this concept.

8) Recommendation for / against Journal Publication, state **why or why not** this paper should be recommended for the journal:

I would not recommend this for journal publication. While the results are interesting, there are several more questions that would need to be answered for this to be converted to a journal publication. I would specifically like to see a parametric analysis of twist angle, number of wires used in parallel configurations, analysis of output system power, a predictive model of these behaviors, and a more clearly listed direct application space for this work before I would consider it impactful enough for a journal publication.

Draft Recommendations/Comments

Comments

Dear Author(s),

Please consider and implement the reviewer(s) comments. Your paper (SMASIS2017-3803) was assigned the decision of "Acceptable with Minor Revisions". Please submit your revised draft for a final review by June 23rd. Feel free to contact us if you have any questions or concerns.

Sincerely, SMASIS 2017 Symposium 6 Organizing Committee Eric Freeman (ecfreema@uga.edu) Yash Tummala (Yashwanth.tummala@gmail.com) Jovana Jovanova (jovanask@gmail.com)

Status

Event	Date
Abstract submitted	**06 Apr 2017**
Abstract accepted	**17 Apr 2017**
Draft paper submitted	**08 May 2017**
Draft paper updated	**09 Jun 2017**
Revision requested	**09 Jun 2017**