Design and Optimization of Soft Spring

Vishnu Aishwaryan Subra Mani[1,2]

***Abstract*—Research collaboration between biologists and engineers have pushed research labs to build actuators to mimic biological systems. Yet, the power to weight ratio of current mechanical systems are not able to fulfill the desired performance of a biological joint. The reason behind this issue is the use of traditionally designed 1 degree of freedom (dof) mechanical components like springs (linear or torsional), dampers (linear or torsional) and actuators (Motor (rotary), Cylinders (linear)). With the growing interest in biorobotic systems a single dof actuator will increase the weight of the entire system since it requires multiple actuators to perform the desired range of motion. Thus, the idea of multiple dof actuator motivated us to design a new soft spring which can act along 2 dof (linear and rotary). The paper explains the fundamental relationship between the linear and rotary movement of the spring at different loading conditions. The spring's intricate design helps the spring to achieve damped oscillation rather than being an undamped system which gives it a potential to be used in various applications. The tendons behaviour as mechanical buffer in a muscle tendon system was one of the motivating factor to build systems such as this. Tendons protect muscles against high impact activities during running or jumping [1], [2] by dissipating energy at lower rates across the muscles similar to a suspension system in a vehicle [3].Hence all our landings from a jump are damped. As an initial step with this type of technology we describe the design, manufacturing and testing strategies of the design. An optimization analysis was performed across different wire diameters and number of wires characterizing the behavior of the spring which in the future will help researchers to build new systems by studying biological systems .**

***Index Terms*—component, formatting, style, styling, insert**

I. Design and Manufacturing

The presented spring consists of multiple wires arranged in a 2-dimensional configuration. Hence the spring stiffness is a function of wire diameter, number of wires and the spring height. Due to its complex geometry the manufacturing technique used here is 3d printing. Hence the properties of the materials and the infill plays a major role in the structural integrity of the spring.

II. Simulation Results

For the simulation results shown in Fig. 1, Fig. 2 the material assumed is the 80A Shore durometer [4]. Fig. 1 shows increase in slope value with increase in wire diameter and the number of spring wires. Fig. 2 represents the relationship of the stiffness with the number of coils. The key design of this compression spring is its compact nature. The height of whole spring remains constant through out our simulation.

[1] Research Intern at IHMC (Florida Institute for Human and Machine Cognition),Pensacola, FL 32502 ,[2] Masters student in Mechanical Engineering, Worcester Polytechnic Institute, Worcester, MA 01609, USA. vsubramani@wpi.edu,vmani@ihmc.us

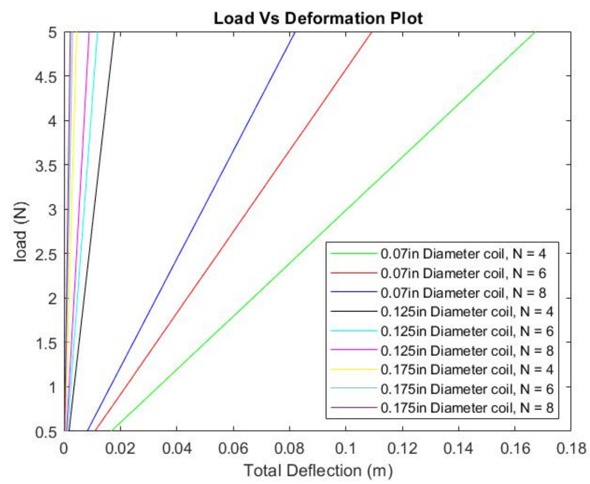

Fig. 1. Load Vs Displacement

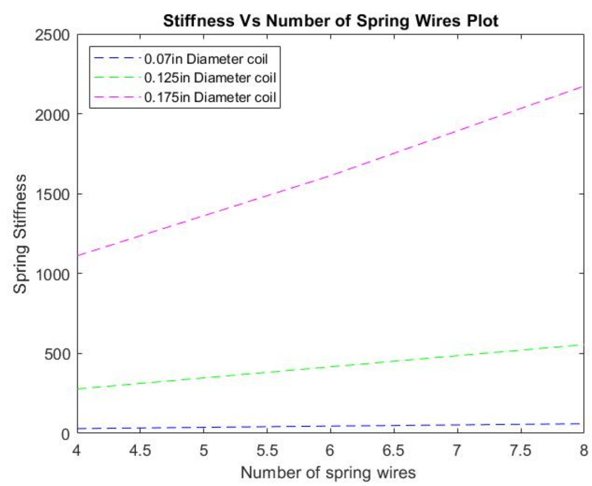

Fig. 2. Stiffness Vs Number of wires

References

[1] T. J. Roberts and N. Konow, "How tendons buffer energy dissipation by muscle," *Exercise and sport sciences reviews*, vol. 41, no. 4, 2013.
[2] N. Konow, E. Azizi, and T. J. Roberts, "Muscle power attenuation by tendon during energy dissipation," *Proceedings of the Royal Society B: Biological Sciences*, vol. 279, no. 1731, pp. 1108–1113, 2012.
[3] N. Konow and T. J. Roberts, "The series elastic shock absorber: tendon elasticity modulates energy dissipation by muscle during burst deceleration," *Proceedings of the Royal Society B: Biological Sciences*, vol. 282, no. 1804, p. 20142800, 2015.
[4] D. C. Maxim Lobovsky, Natan Linder, "Formlabs," $https : //formlabs.com/materials/tough - durable/?utm_source = linkedinutm_medium = socialutm_campaign = t1500launch/$, 2011.