ME – PhD Thesis defense

Dynamics of Single Shallow Arches and Statics of Connected Shallow Arches and their Applications

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ABSTRACT

The methods developed in this thesis enable computationally efficient dynamic analysis of shallow arches. They also facilitate insightful design of arches for different applications. The first design study considers person-specific dynamically offloading insoles for therapeutic footwear to keep the plantar pressure below a threshold and thus reducing the risk of foot ulceration. This necessitated the study of dynamics of snapping arches under a time-varying load. We observed that an arch slows down as it switches from one stable state to the other under force-controlled loading condition. This delay in the switching increases as the applied force approaches a critical value of the force. Dynamic analysis of arches enables us to compute the switching force of arches for a linearly varying time-dependent loading, which further helps us customize the insole based on person's walking speed. We prototyped such footwear and observed a maximum of 57% offloading in the forefoot region and 34% overall. To further increase the efficacy of the proposed self-offloading insole, we propose connected pinned-pinned arches where two arches of opposing curvature are joined together at a common pin joint. We demonstrate that this arch configuration is more effective as they not only help offload the high-pressure regions but also redistribute the pressure to other areas of the sole. In view of design of connected arches, we derive analytical criteria for bistability and flipping. We also obtain a closed-form bilateral relationship that correlates the two stable state configurations of a connected arch.

The second analysis and design study considered in this thesis is one of the simplest embodiment of mechanical logic gates and processors. Here, the total number of deformable parts or arches is limited to the total numbers of inputs and outputs required for a particular logic operation. For example, for an AND gate or OR gate, we need only three connected pinned-pinned arches—two for the inputs and one for the output. Along with the AND gate and OR gate, we also present an Encoder and De-Multiplexer logic processors. Taken together, this thesis is a systematic investigation of dynamic behaviour of snap-through and bistable arches for analytical or semi-analytical solutions, design criteria, and practical applications.

ABOUT THE SPEAKER

Priyabrata Maharana is a PhD student in Department of Mechanical Engineering at IISc Bengaluru. He is working with Prof. G. K. Ananthasuresh in Multidisciplinary and Multiscale Design and Device (M2D2) laboratory. He completed BTech from GCE Kalahandi, Odisha, in 2014, and MTech from IIT-Guwahati in 2017. His research interests include compliant mechanisms, nonlinear dynamics, topology optimization, and biomedical device design. He is currently employed at BosonQ Psi.