



ME – PhD Thesis Colloquium



Design and development of tapered Belleville springs as impact energy absorbers

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ABSTRACT

Belleville springs, or coned disc springs, are compact mechanical springs capable of sustaining high loads due to their nonlinear load–deflection characteristics. Their geometric nonlinearity allows tailoring of stiffness through variations in cone height and thickness, enabling linear to highly nonlinear responses. This thesis investigates the application of the tapered Belleville springs (TBS) as passive impact energy absorber for legged landers used in space exploration missions.

During planetary landing, absorbing touchdown impact loads is a major challenge, and passive dampers are preferred for their simplicity and reliability. Unlike conventional honeycomb dampers, which are single-use devices, TBS can absorb impact energy within the null stiffness region and offer potential reusability. The performance of normal taper (NTBS) and reverse taper Belleville springs (RTBS), manufactured from SS-304 and Ti-6Al-4V alloys, were evaluated through experimental testing, nonlinear finite element analysis in ABAQUS®, and theoretical modeling with an analytically derived correction factor. Results show good agreement between experiments and simulations, with RTBS exhibiting higher elastic energy storage than uniform and normal taper springs. Geometric optimization was carried out to maximize energy absorption in the null stiffness zone.

In the second part of the Thesis, dynamic simulations of a single leg of four-legged lander system carried out using ADAMS® compared TBS and honeycomb energy absorber. While both systems absorbed impact energy effectively, the NTBS energy absorber demonstrated similar energy dissipation with reusability option, establishing TBS as a viable alternative for space landing applications.

ABOUT THE SPEAKER

Umesh Singh is a Ph.D. (ERP) student in the Department of Mechanical Engineering at the Indian Institute of Science (IISc), Bengaluru. He is conducting his research under the supervision of Prof. Ashitava Ghosal (Retired), and Prof. B. Gurumoorthy in the Robotics and Design Lab. He received his Bachelor's degree in Mechanical Engineering from the C. V. Raman College of Engineering, Bhubaneswar, Odisha in 2008. He is working as a Scientist/Engr – SE, in U. R. Rao Satellite Centre-ISRO, Bangalore, Karnataka. His research focuses on the design, modeling, and testing of legged lander system for interplanetary missions.

