INNOVATIVE APPROACH TO FINITE ELEMENT MODELLING OF WIRE ROPE SHOCK ISOLATORS USED FOR CUSTOMIZED SHIPPING CONTAINERS

Dawid Cekus [1]***, Marcin Dudek*** [2]

[1]*Department of Mathematics, Czestochowa University of Technology, Czestochowa, Poland*
[2]*Department of Mechanics and Machine Design Fundamentals, Czestochowa University of Technology, Czestochowa, Poland*

[1]*dawid.cekus@pcz.pl,* [2]*marcin.dudek@pcz.pl*

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During global logistics and transportation, shipping containers are often subjected to accidental drops, impact events, and rough handling that can reduce their ability to protect sensitive cargo. Consequently, purpose-built containers for delicate goods commonly undergo pre-service physical drop-test campaigns to quantify their resistance to withstand transportation loads, identify failure mechanisms, and validate design improvements [1, 2, 3, 4, 5]. However, the presence of internal shock-isolation systems introduces nonlinearity and component-level behavior, complicating the substitution of physical testing with numerical simulation. This work presents an innovative method to model a shock isolation system efficiently, enabling reduced reliance on physical drop testing, lower test campaign costs, and shorter design iteration cycles.

A wire rope isolator [6] is an efficient, commercially available solution for isolating shock waves caused by accidental impacts (as shown in Fig. 1).

The system is widely used because of its simplicity and robustness. However, due to its nonlinear characteristic, its representation using discretized elements in commercial finite element software is challenging, particularly for short-duration, high-rate events. In theory, these packages provide finite elements that allow independent specification of directional stiffness components k_x, k_y, and k_z. In practice, employing these elements to accurately simulate the most advanced impact cases, such as corner or edge drops of the customized shipping container, often leads to numerical instability and deviations from expected motion trajectories.

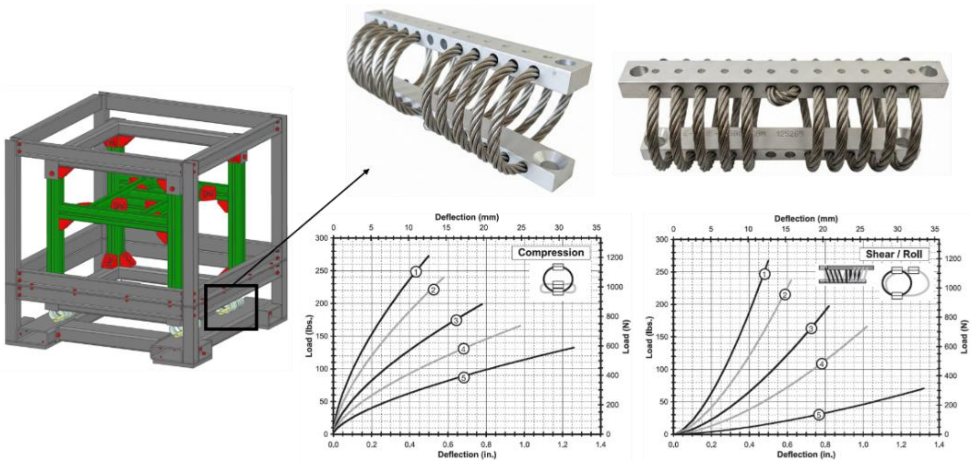

Fig. 1. Example of a shock isolator with nonlinear stiffness characteristics

To address these limitations, an innovative modelling strategy for a shock isolation system is proposed. The approach models the isolation system using three longitudinal spring elements with activated damping, selected to capture the direction-dependent stiffness characteristics of compression, shear, and roll. Although the wire rope isolator has a nonlinear characteristic, for modelling simplicity, the average stiffness data is used for each direction.

The proposed innovative modelling approach for wire rope shock isolators enables the computation of the most complex impact scenarios, i.e., corner and edge drops. Although the isolator discretization method has not yet been validated through physical testing, the numerical results for displacements and motion trajectories are very promising and consistent with the initial assumptions. The next step for the researchers is to perform laboratory testing of the real wire rope isolators under various side-impact load conditions and compare the results with those obtained numerically to verify the system's overall performance further.

References

[1] ASTM D4169 "Standard Practice for Performance Testing of Shipping Containers and Systems", 2016

[2] ASTM D5276 "Standard Test Method for Drop Test for Loaded Containers by Free Fall". 2004

[3] SAE ARP 1967 "Containers, Shipping and Storage, Reusable", 2014

[4] ISO 2248 "Complete, filled transport packages – Method for determination of resistance to vertical impact by dropping", 1993

[5] ASTM D880 "Standard Test Method for Impact Testing for Shipping Containers and Systems", 2015

[6] Enidine, Solutions in Energy Absorption and Vibration Isolation, Wire Rope Isolator Technologies – product catalog, 2020