Influence and Enhancement of Damping Properties of Wire Rope Isolators for Naval Applications

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Wire Rope Isolators (WRI) are well known and used for the protection of sensitive equipment against non-contact underwater explosions (UNDEX) on board Naval Ships, amongst others, which are extremely destructive and can comple`tely impair the ship's combat capability.

Traditional WRI exhibit a number of definite advantages, such as large deflection capability, modularity and insensitivity to aggressive environment when proper materials are used. However, their inherent nonlinearity does not always provide the best solution in terms of shock attenuation. (Stiffening tension characteristics)

Fortunately, there are ways to overcome this problem, namely increasing their damping and/ or changing their aspect ratio. It is the purpose of this presentation to show how to overcome this problem and through analysis, by use of validated models of the shock testing machines. The existing technology will be briefly presented and HDWRI (high damping wire rope isolators) vs. conventional WRI responses will be compared on the US Navy shock testing machines of MIL-S-901D.

The US Navy standard MIL-S-901 defines a physical shock testing machine to impact the target before its approval. Different testing machines are used (LWSM, MWSM, FSP, and new DSSM) depending on the weight and size of the target, and on the deck frequency simulated.

The Socitec Group has developed a full model of the various shock testing machines using its in-house developed SYMOS software package. Currently, the Group is in the process of completing a model for the DSSM.

A Word on SYMOS

SYMOS is a Socitec developed nonlinear, multiple degree of freedom (up to 500-DOF) simulation software suite.The 1 to 6 degree-of-freedom bodies can be activated as needed, and entered as geometries or material points assigned with the proper inertia properties. They are connected by links, which can be nonlinear isolators, from the built-in library, contact stiffness, springs, elastic structure elements, or any isolators which characteristics are known and can be added to the library and imported as text files or spreadsheets.

Any measured or analytical input, including an SRS, can be applied to the bodies within the SYMOS model, and the response of any body or link can be calculated and shown by the program. SYMOS has powerful pre and post processing capabilities, showing time history responses of each body (acceleration, velocity and displacement), as well as SRS and Fourier transform, all of which can be exported again as text files or spreadsheets. Specialized routines can convert back and forth between random signal and time histories. The same is true for SRS's and time histories.

In SYMOS, the models for shock testing machines are divided into a number of rigid bodies connected by nonlinear springs and dampers to which the shock parameters are applied as initial conditions. All model parameters have been carefully verified and calibrated with data from physical tests. SYMOS is in use by esteemed customers, such as the French DCNS, the German BWB, the Norwegian Navy, and many other naval customers worldwide.

Damping in WRI

The friction force at the origin of damping depends on many factors. This includes, but is not limited to, the material and construction of the cable, the number of wires and strands, the lay, the preforming, and the type and amount of lubricant. Further the thermal state of materials, in particular in the clamping area, also affects the developed friction force.

The stiffness force associated with the damping also depends on many factors, including the size of the loop, the number of loops, and their aspect ratio, which is also referred to as eccentricity. (see Figure 1) Relating to a linear equivalent model, the typical damping ratio ranges from 15 to 25% (C/Cc). Improved high damping wire rope is typically twice as much, which is particularly interesting for seismic applications, shipping containers, and underwater explosions isolation.

Small amplitude (vibration) equivalent damping ranges from 0 to 25% for "standard" wire rope. 0% damping would correspond to displacements small enough not to induce any relative displacement between the strands mostly responsible for the friction, which causes the isolator to behave as a pure spring. Larger amplitude (typically 0.1 in) would lead to 25% but depending on the size of the isolator, considered as optimum for most military applications. To be noted that standard is meant to specify the type of cable used in most WRI applications.

By virtue of its geometry, the WRI exhibits a somewhat softening load-deflection curve in compression toward the force asymptote (AF), stiffening however in tension. Under shock conditions, the max acceleration response is usually seen in the tension phase. Therefore the two ways of reducing that peak are

1) Moving further away the so-called displacement asymptote (AD)
2) Reducing the tension excursion with increased damping

This is naturally true for large deflections, typical of shock. As far as small amplitude vibration is concerned, there are some other nonlinearities mostly generated by friction.

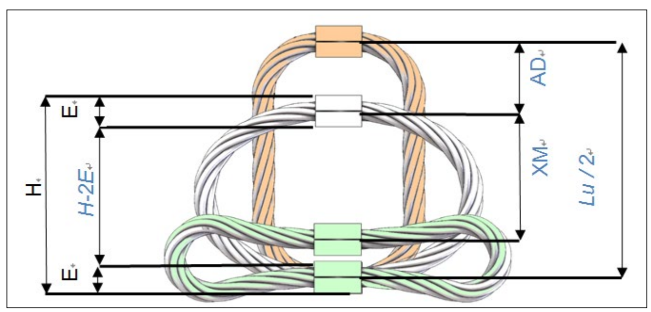

Figure 1. WRI parameters.

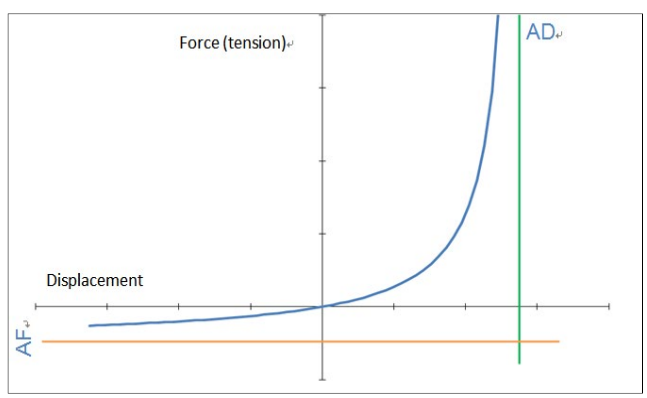

Figure 2. Typical WRI load deflection curve.

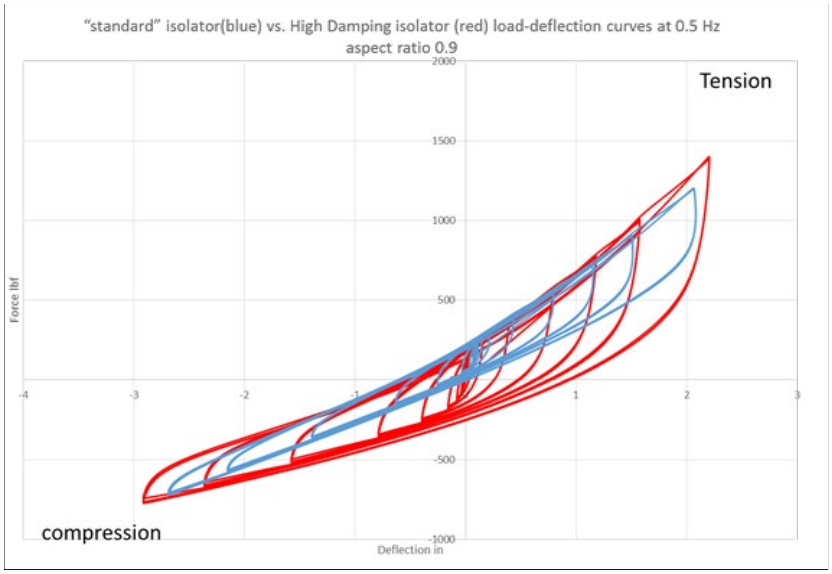

Figure 3. Comparison of load-deflection curves of standard and high damping WRIs.

SYMOS Model of the MWSM of MIL-S-901D

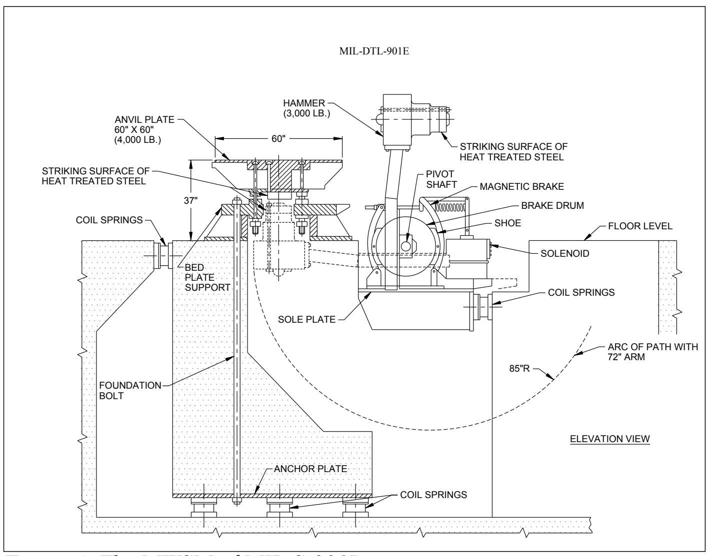

Figure 4. The MWSM of MIL-S-901D.

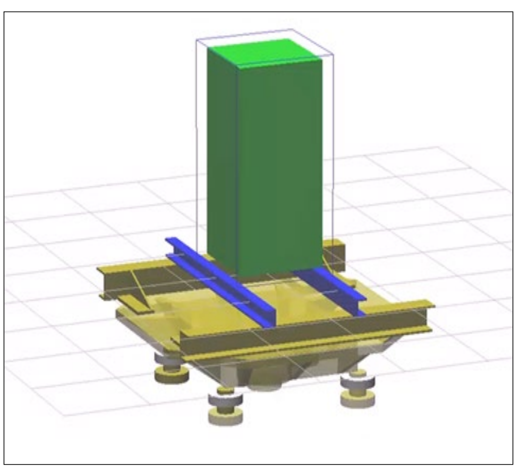
Figure 5. SYMOS model of MWSM.

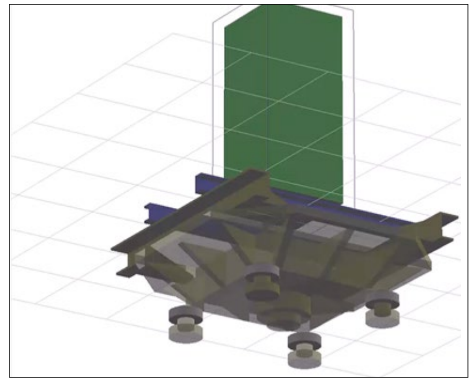
Figure 6. Second view of SYMOS model of MWSM.

Actual Test on the MWSM of MIL-S-901D

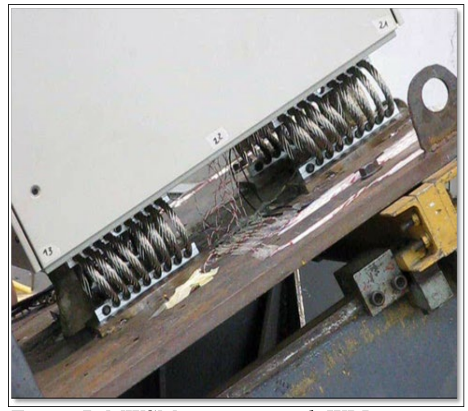
Figure 7. MWSM test setup with WRI.


Figure 8. MWSM test setup with Rubber Isolators.

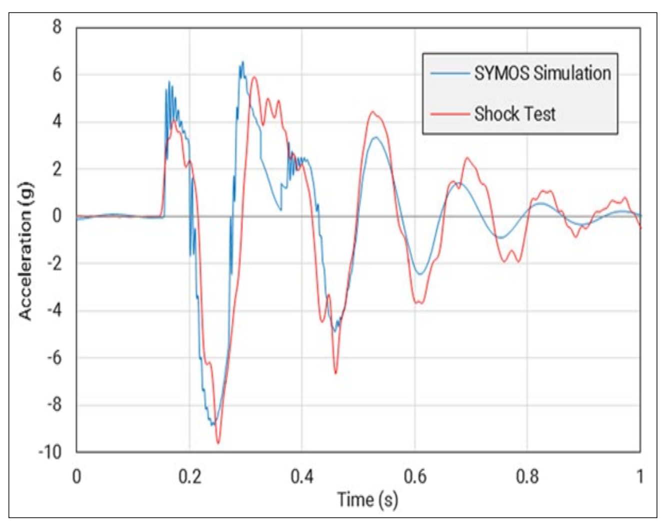

Figure 9. Comparison of measured and calculated curves for MWSM test for 280 kg cabinet with 6 WRI, 2.25 ft, 3 in

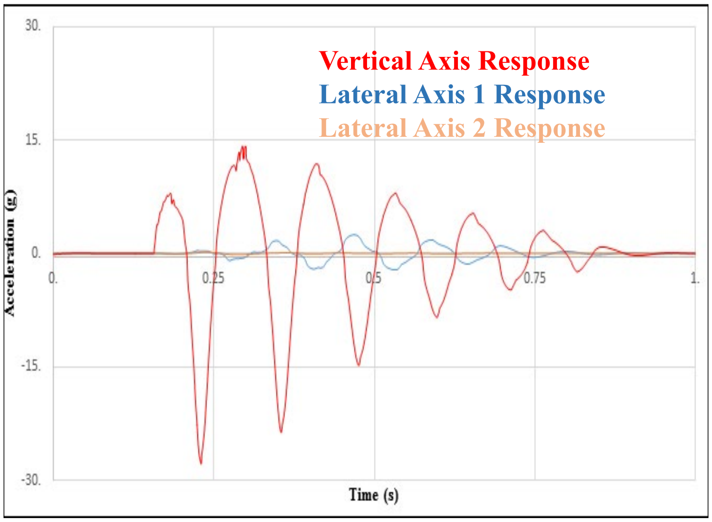

Figure 10. Response of cabinet in MWSM WRI for 280 kg cabinet with 6 standard WRI, 2.25 ft, 3 in.

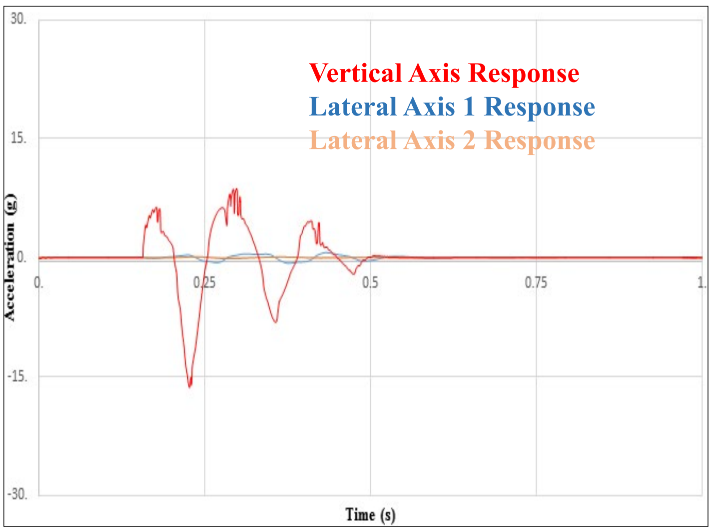

Figure 11. Response of cabinet in MWSM WRI for 280 kg cabinet with 6 high-damping WRI with an aspect ratio of 0.85, 2.25 ft, 3 in.

FLOATING PLATFORM (FSP) OF MIL-S-901D

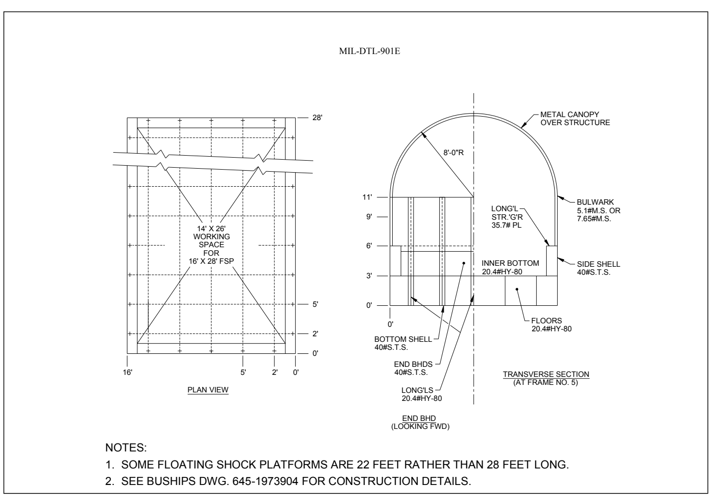

Figure 12. Sketch of floating platform from MIL-S-901D.

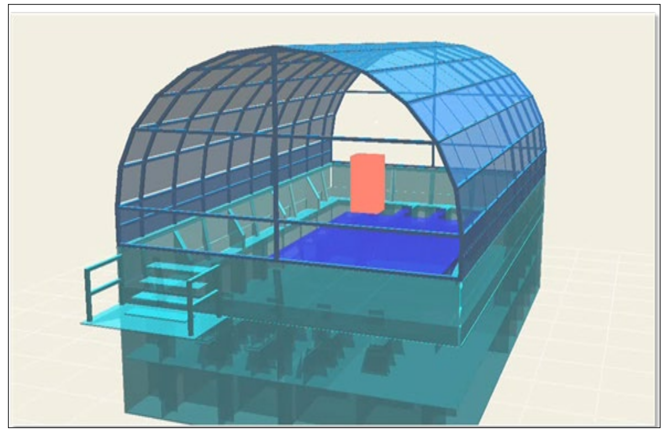

Figure 13. SYMOS model of FSP.

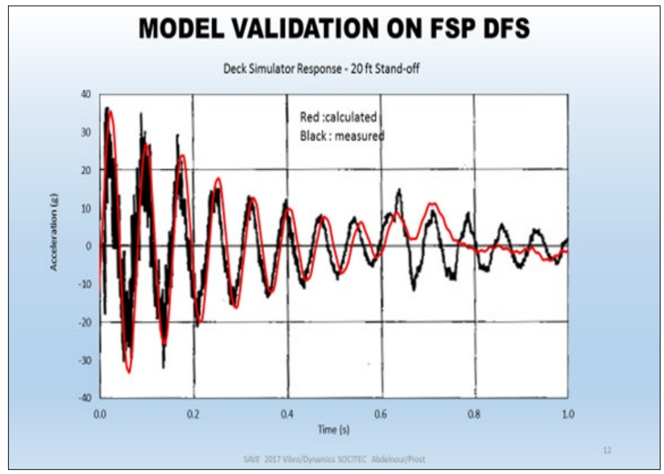

Figure 14. Comparison of measured vs. calculated response for FSP test.

Figure 15. View of FSP test barges.

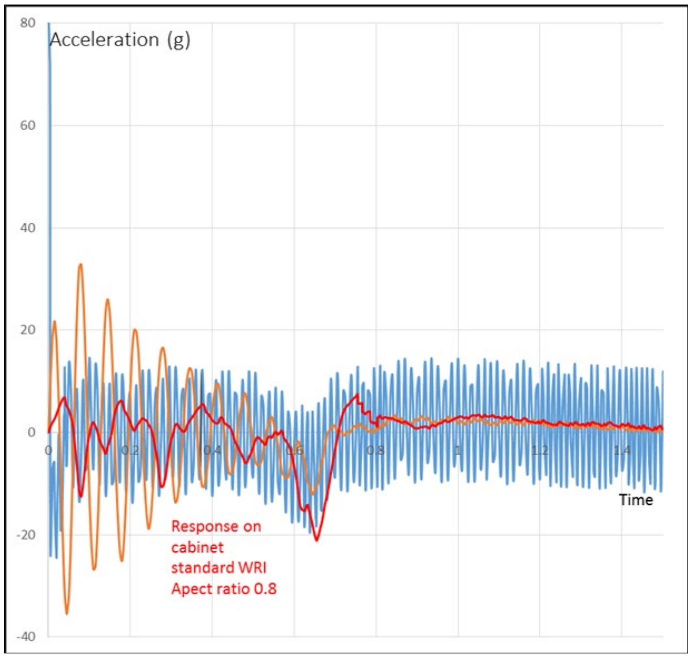

Figure 16. Calculated response of FSP DFS for 280 kg cabinet supported by standard WRI.

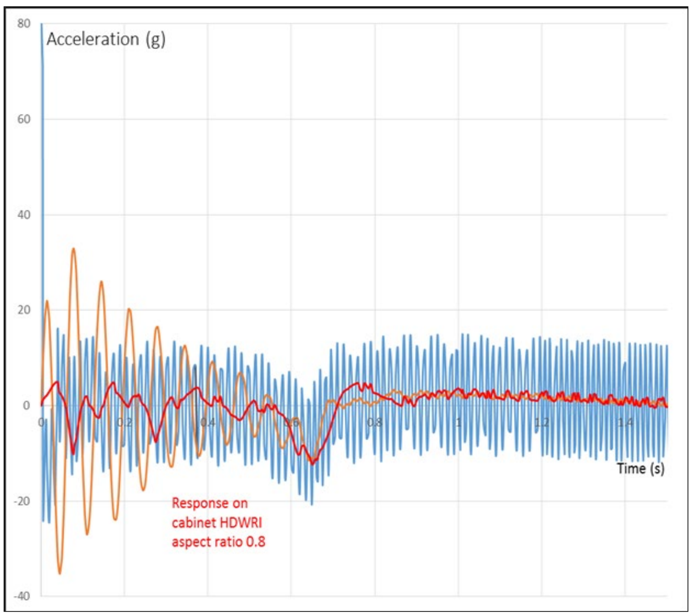

Figure 17. Calculated response of FSP DFS for 280 kg cabinet supported by 6 high damping WRI.

Conclusions

The Socitec Group has been using numerical models of the various shock machines using its SYMOS software package. The evidence presented in this article show that the models are very reliable. The model for the DSSM is still being fine-tuned, but is expected to be ready soon. Simulations clearly prove the advantage of the high-damping wire rope isolators (HDWRI) vs. standard wire rope isolators (WRI). Simulations also prove the advantages of an aspect ratio well below 1 as the complex shocks generated by MIL-S-901 create an upward response from the isolators, even on a surface ship. The lower the incursion in tension, the more a combined highly-damped low aspect ratio isolator helps lower the response in terms of acceleration and displacement, keeping in mind that high damping is an advantage for shock dissipation.

The methods used to achieve high-damping are the result of extensive development efforts by the Socitec Group. These research activities have allowed the Socitec Group to control closely the parameters relevant to the results, including the thermal treatment of the cable in the clamping area, the friction coefficient and tolerances on the wires, strands, and lay.

While units still need to be tested, it is advantageous to have a reliable simulation model at the design stage in order to select the best isolators for the job. This also helps the engineer proceed into testing with more confidence and potentially reduce the number of test iterations.

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OUR AUTHORS

Claude Prost Claude graduated from the French ARTS et METIERS Engineering school, where he also obtained his Masters degree in industrial and mechanical engineering in 1973. He joined the Socitec Group in 1979 after various first time jobs in Production, civil engineering and acoustics. Claude was the managing director of the American-French joint venture, Socitec International, from 1986 to 2001. Then he became Sales and Marketing director of Socitec, France from 2002 to 2013 as well as Director of Socitec UK, since 2007. Now Claude is the Sales & Marketing Director of the US branch of the Socitec Group (Vibro/dynamics LLC), since 2014.
Claude has 35 years of experience in shock and vibration where he was involved in designing isolators, testing, technical sales and software development of a nonlinear numerical model for Shock and Vibration. He delivered numerous presentations in the SV field, including technical meetings at Thales Defence in England, the SV seminar in Norway, the DefExpo in India and Germany, and many others.

Bruno Abdelnour Bruno graduated with a Bachelor degree in Mechanical Engineering from the University of Illinois at Urbana-Champaign, in 2014. He was awarded an athletic scholarship in his time at the University to represent the Division one tennis team, where he earned Academic All-American honors.
In April 2015, Bruno joined the Socitec Group as a technical sales engineer. He has been receiving training from his colleague Claude Prost, who has more than 30 years of experience in the field of shock and vibration. Bruno specializes in dynamic simulation of seismic applications, shock testing machines for the NAVY, and TMDs.