Multiphysics

How to optimise the design of vibration insulators **using ML-ROM**

By Hiroshi Nasuno, PhD, Team Leader of Mechanism Analysis Group, Multifunctional Materials R&D Department, Taica Corporation

Taica Corporation was founded in 1948 and has worked for over 70 years to enrich people's lives worldwide with technology. In 1974, they developed the world's first hydrographic printing process, CUBIC PRINTING. In 1984 they developed an innovative gel material with unmatched softness named αGEL (Alpha GEL). Since 2000, Taica has developed thermal conductive soft materials that combine high thermal conductivity and further advanced the "multi-functionality of αGEL". Taica aims to surprise and impress society by continuing to develop new products in various markets where αGEL can be used, such as sports shoes, industrial equipment, mobile devices, and nursing care products.

One of Taica's main products is vibration isolators for the industrial field. Vibration isolation is extremely important for the high performance of industrial devices. αGEL has excellent viscoelastic properties over a vast frequency range, resulting in increased vibration absorption and isolation. In addition, compared to rubber, the temperature dependence of the complex modulus of αGEL is much lower than rubbers, and it is highly resistant to ultraviolet rays and moisture.

In recent years, customers have felt the need to reduce the time required to develop vibration isolator designs without prototypes in the early stages. Taica has been promoting computer-aided engineering (CAE) to satisfy such customer needs. Specifically, Taica attached the αGEL isolator modelled by a viscoelastic Finite Element (FE) model with large strain characteristics to the Computer-Aided Design (CAD) model of the customer's product under development and perform CAE to predict the vibration isolation performance of the product. In this way, Taica has quickly responded to customers' vibration isolation problems, which have been challenging to design until now, by advancing vibration isolation design in virtual space.

Challenges in vibration isolator design

Although CAE has made it possible to reduce the number of experimental evaluations significantly, many parameter studies still need to be conducted to finalise product specifications. Some customers may not even have that time. Therefore, contrary to CAE technology, there are still cases where it's necessary to quickly select isolator materials based on the "experience" and "intuition" of engineers. CAE is not always needed, and damping materials selected by experienced engineers often rapidly satisfy the required performance. Still, it's one of the factors that makes a vibration isolation design technology "individually dependent". As a global trend in the future, securing engineers expects to become more complicated, and establishing a vibration isolation design method that does not rely on individual experience and intuition is difficult to quantify. Suppose it becomes possible

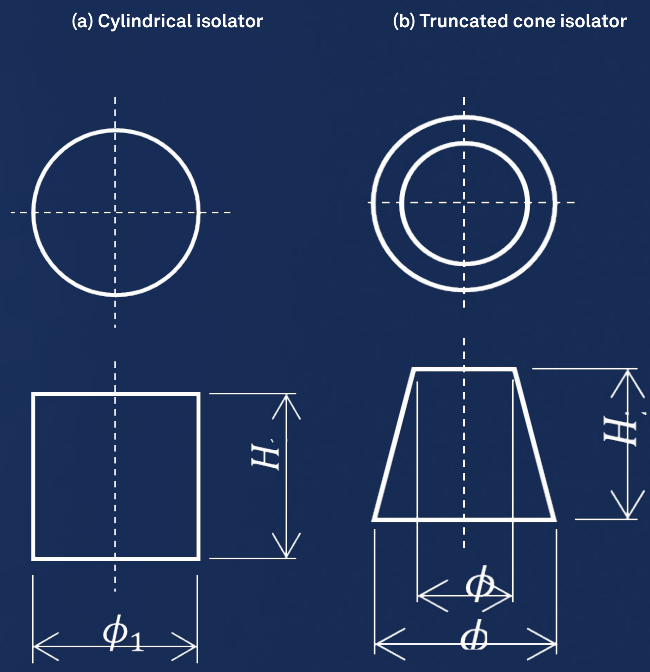

Figure 1: Axisymmetric compressive type of Alpha GEL isolators.

to perform vibration isolation design, which is often thought to be difficult and takes time to master, without relying on experts. In that case, the design work efficiency will increase dramatically, and experts will be able to tackle other more critical design issues. Taica decided to adopt Machine Learning (ML) as soon as possible to solve this issue.

An agile optimisation for vibration isolator design

The current need for our customers is to smooth the way for training future developers of vibration insulators and continue product development unhampered. The objective is to transform the traditional approach and enable non-expert engineers to carry out some aspects of vibration isolation design, thus providing Taica's customers with optimal solutions faster. To this end, it's important to create an environment where non-expert engineers can use ML estimation models to optimise isolators quickly and agilely.

A potential method has emerged to help developers quickly reach the optimal design value of their vibration devices to create ML models. Hexagon's ODYSSEE CAE is a modern platform with an ML-based optimal value prediction modelling engine and parameter study capabilities. ODYSSEE CAE can provide a powerful combination of modern data science technologies and techniques such as pattern recognition, image processing, data mining, process discovery, ML, and design optimisation to workflows. As a result, they can create cost-efficient digital twins using real-time predictive modelling and optimisation for both CAE simulation data and physical test data. Taica is one of the first material manufacturers to adopt this brand-new platform.

A Reduced Order Model (ROM) for design work

Typically, engineers designing a new vibration isolator must consider various aspects, including shape, dimensions, material types, metal bracket design, mass productivity, cost, etc. Taica engineers examined whether it's possible to predict the isolator dimensions, material types, and strain-stress relationship with high accuracy by ML.

ODYSSEE CAE is quite convenient for efficiently conducting such investigations. Taica engineers quickly analysed the principal components of the training data set on the ODYSSEE CAE platform to build and optimise the ML-Reduced Order Model (ML-ROM), revealing correlations between elements of isolator design parameters.

In this study, Taica engineers focused on the axisymmetric compression type αGEL isolators, as shown in Figure 1 and confirmed that ML-ROM accurately predicts the stress-strain relationship of the isolator for unknown design parameters not included in the training data set.

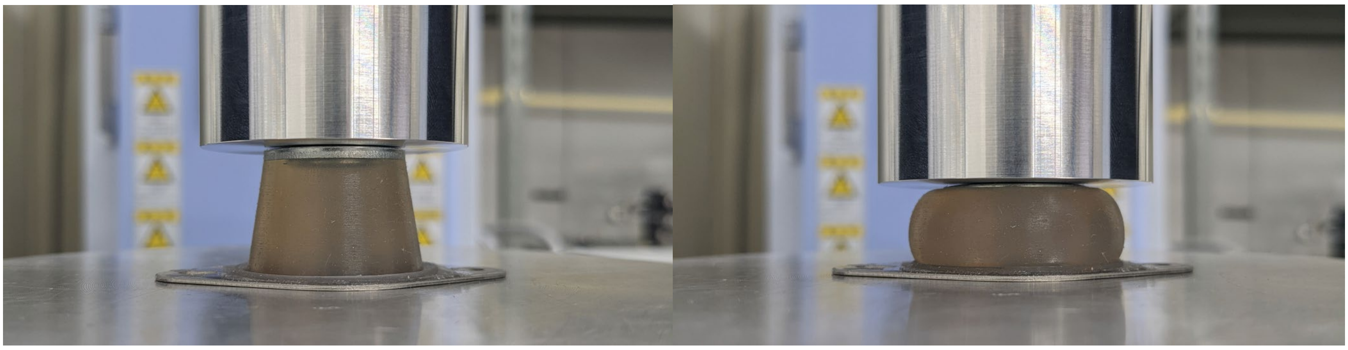

Figure 2: Compression test for axisymmetric Alpha GEL isolator.

Figure 2 shows the compression test of axisymmetric αGEL. A similar compression test in Figure 2 was conducted on different dimensions and gel types to obtain several stress-strain relationships, as shown in Figure 3.

The training data set is significant in determining the prediction accuracy of the learning model. It's possible to quickly determine the data combination to use in the training data set to improve the prediction accuracy of ML-ROM while comparing the results by using the ODYSSEE CAE platform. Furthermore, to improve the accuracy of ML-ROM prediction, it's necessary to determine the types of parameters that characterise the isolator and sufficiently distribute the data within the range of possible design changes so that each data is unbiased. The platform makes it easy to see how the respective parameters are distributed.

In the early stages of Taica investigations, basic parameters such as the isolators' upper/lower diameters and heights were insufficient to create an ML-ROM that predicted the compression characteristics of the Alpha-GEL material with sufficient accuracy. Therefore, the ML-ROMs were prepared in addition to the above basic parameters such as "average area divided by", "average diameter divided by", and "gel volume", etc. obtained from the above basic parameters. Further increasing the accuracy of the stress-strain ML-ROM prediction accuracy requires that the dimensions and material constants of the unlearned isolator materials be included and compared with the experimental results.

As a result, ML-ROM constructed above the primitive training parameters and the average loading area divided by gel height predicts the compressive stress-strain behaviour of the isolator with sufficient accuracy. Figure 4 shows the difference between compression strain-stress prediction results and experimental results as a norm by giving four different design conditions not involved in learning data to various ML-ROMs created with additional parameters to the learning data sets. This figure shows that the prediction accuracy of the ML-ROM created by adding to the basic parameters is most high. Figure 5 shows the measurement results of the compression stress-strain relationship of the Alpha GEL vibration isolation material and the prediction results of the ML-ROM for design conditions 1 and 4 in Figure 4. These results show that the ML-ROM created by Taica accurately described the compression characteristics of Alpha GEL isolator materials.

In conclusion

Taica focused on cylindrical and conical vibration isolators and showed that the prediction accuracy of ML-ROM is improved by using shape coefficients consisting of loaded area and height in the training data in addition to basic parameters such as upper/lower diameters and heights.

Since the shape of the vibration isolator shown by Taica was relatively simple, it's thought that the prediction accuracy of the ML-ROM was relatively high. In the future, when predicting the compression characteristics of vibration isolators with more complex shapes or directly predicting the resonance frequency, data different from the parameters used for training will likely be required, but it will be relatively easy.

One of the most significant advantages of ODYSSEE CAE's ML-ROM approach lies in how it can handle every aspect of the process, from surrogate model creation to parametric analysis, in a seamless manner.

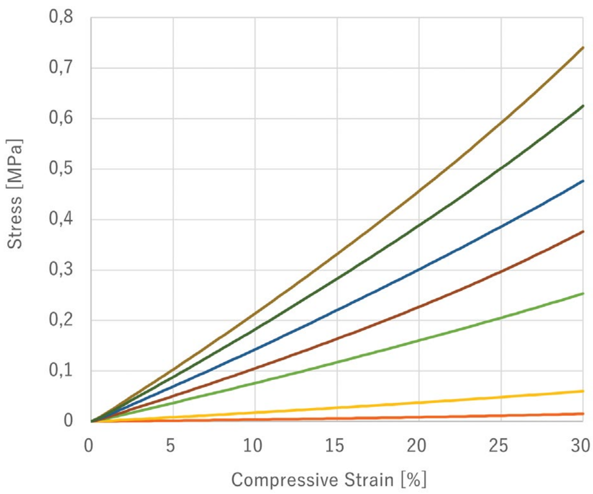

Figure 3: Stress-strain measurement results of Alpha GEL isolators.

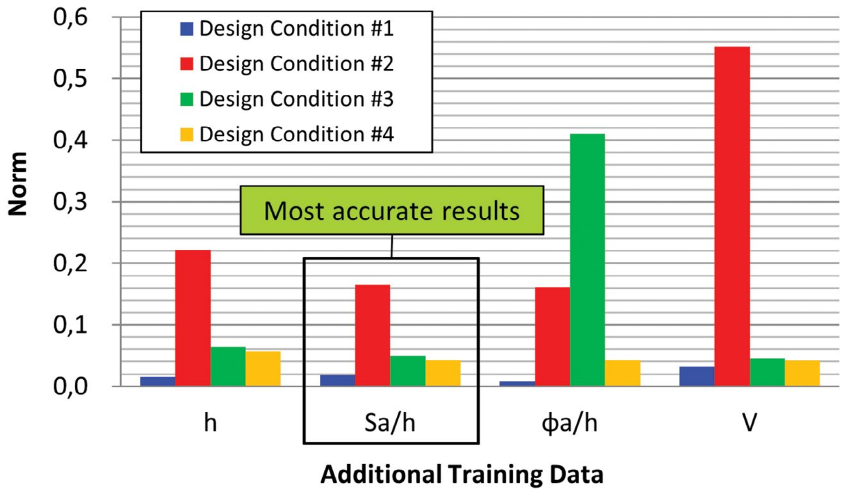

Figure 4: Prediction accuracy (norm) of ML-ROMs using different training data sets.

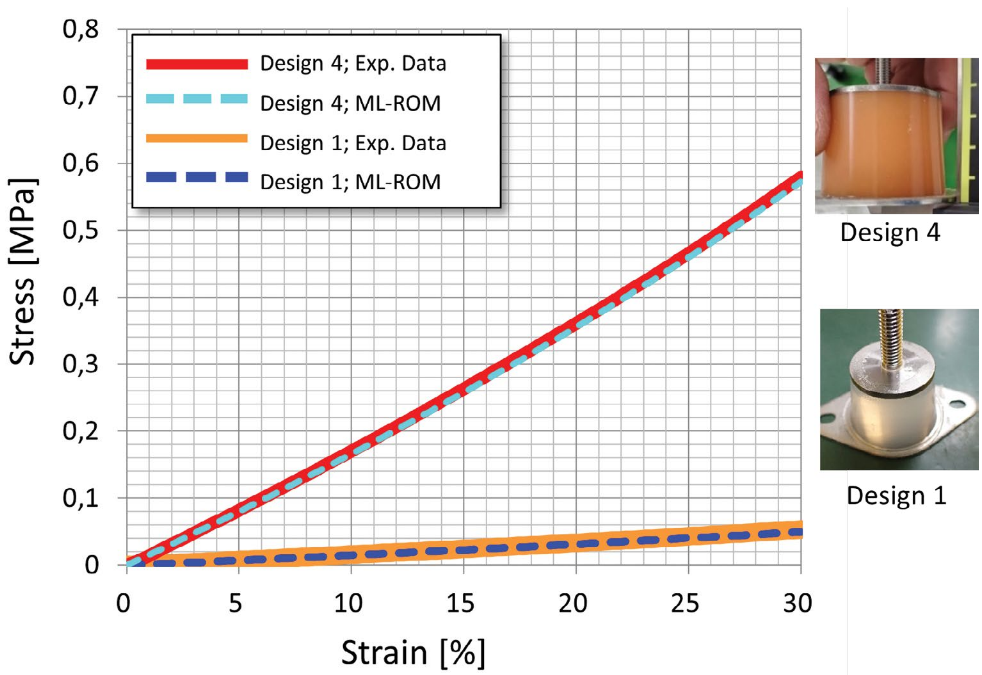

Figure 5: Comparison of experimental results with SS-curves predicted by ML-ROM.

“By parametrically screening experimental data and simulation results to construct surrogate models, vibration insulation design, which has been historically considered the exclusive domain of a few experts, will become relatively easy for anyone to perform. Beyond simply increasing design efficiency, ODYSSEE CAE will be used to quickly quantify and evaluate digital data, thus enabling new designs without relying on a few individuals’ skills.”

“We expect that if sales in charge can propose products and accurate predictions in ML-ROM, experts will be able to tackle more challenging design tasks while also accelerating customer responsiveness.”

“If we can achieve this, we will not only be able to partially optimise the design work, but we will be able to optimise the entire system across internal departments. This process with ODYSSEE CAE is a step toward growing into a company that can quickly provide high-quality solutions to our customers,” says Hiroshi Nasuno, Ph.D., Team Leader of Mechanism Analysis Group, Multifunctional Materials R&D Department, Taica Corporation.