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# Element Materials Technology

## Vibration Behaviour of Complex Structures

**E**lement and Rolls-Royce have joined forces in a unique collaboration to offer their vibration testing services to a wide range of industries from aviation and automotive to rail and oil and gas, all of whom can now benefit from their extensive experience in testing and evaluating the vibration behaviour of complex structures.

### An Essential Tool in the Design, Development, Certification and Qualification of Products

Vibration testing of complex structures, such as jet engines, is an essential tool in the design, development, certification, and qualification of products and components. It allows lessons to be learned from the vibration behaviours that manufacturers

can apply when designing new products or structures, giving them a much more transparent estimation of areas that might generate potential issues and a much higher chance for 'right first time'.

Used to ensure that products or components are robust and perform safely during operation or transit, **vibration testing** mimics the conditions that a complex structure might see during its lifetime while under a test environment, detecting performance issues and potential failures before they commence.

The complex stresses that occur during the operation, or transportation, of technical structures must be examined under static and dynamic operational loads to assess the impact of fatigue and to determine accurate in-service life predictions. **The Rolls-Royce state of the art vibration laboratories** based in Dahlewitz, Germany feature electro-dynamic and servo-hydraulic systems that can replicate both low and high-

frequency conditions. The team carries out vibration testing, including structural analysis and data evaluation, by using cutting-edge control systems to test the component or complex structure against specified test levels and performs field data replication to understand precisely how the test item is affected.

In combination with Element's global facilities, the team has access to some of the world's largest dynamics systems for shock and vibration testing. This enables the testing of products with a large footprint, high centre of gravity and off-set loads and provides manufacturers with a high level of scheduling flexibility.

### Understanding and Selecting the Most Appropriate Vibration Test Methods

Using its expertise, the team selects the most appropriate vibration test methods and procedures to accurately

replicate the environmental conditions and in-field vibrations, whether structure or airborne, for a product or component. Understanding each method's different approach and benefits is critical when selecting which vibration test methods to apply to analyse the structural behaviour. Techniques that may be employed include:

## Modal Testing and Modal Analysis for Components and Complex Structures

Modal testing is an experimental means of determining the dynamic characteristics of a structure through mechanical excitation, created by vibrational or impact methods. This excitation creates the mode shapes of the component or complex structure. Measured by accelerometers, the data can then be analysed to develop the structure's dynamic structural characteristics.

Modal analysis helps to determine the vibration characteristics, such as natural frequencies and mode shapes, of the mechanical structure or component, showing the movement of different parts of the structure under dynamic loading conditions. It converts the vibration signals of excitation and responses measured on a complex structure that is difficult to perceive into an easier-to-understand mathematical model or set of modal parameters. A non-destructive test method, operational modal analysis, can be carried out for in-situ measurement of systems in operation.



## Computer-Based Model Updating for Finite Element (FE) Structure Models

Rolls-Royce and Element's **Finite Element Analysis (FEA)** experts use computer-based modelling to analyse the strength of complex structures and systems, determine component behaviour, and accurately predict how products will react under structural and thermal load.

The FE analysis experts work closely with the physical testing team to suggest solutions to client test failures and validate the physical testing simulation.

## Mode Shape Analysis

Mode shape analysis (MSA) uses a scanning laser doppler vibrometer

(SLDV) to provide the data needed to understand the different shapes that can be taken up by the structure during different modes of vibration. Each mode shape has its own corresponding natural frequency, which indicates how the structure behaves under a dynamic load.

## 3D SLDV Mode Shape Analysis and Strain Measurement, Including Stress Calculation

Analysing motion within 3D parameters is the final step to achieving the big picture of the dynamic behaviour of a component or structure part. For 3D mode shape analysis, the 3D SLDV MSA or the 3D Digital Image Correlation (DIC) by video systems are established methods.



The team can examine the vibration behaviour of highly complex structures with 3D Digital Image Correlation, a 3D full-field, non-contact optical technique to measure contour, deformation, vibration and strain on almost any material. This can be extremely useful for intricate pipe systems, reducing the need for multiple strain gauges.

## Strain Gauge Calibration

Strain gauges are used to measure static and dynamic loads in field operations.

With the FEA (Finite Element Analysis) strain results and the operational service measurement analysed strain values, the fatigue lifetime or fatigue resistance could be evaluated.

## Vibration Testing of Rigs

Fatigue testing measures how cyclic forces will affect a product or material over time, using varying loads, speeds and environmental conditions. Our fatigue test

methods, like high cycle fatigue (HCF), are useful for simulating specific scenarios and investigating real-world failures.

The Rolls-Royce and Element equipment allows a very high number of cycles to be run in a short amount of time, simulating a component's service life. HCF tests are usually response-controlled and typically run to one million or more cycles. Testing continues until specimen failure or until a predetermined number of cycles is reached. Once cracking starts to occur, the failure cycle count is recorded, and the component is analysed for performance characteristics and durability criteria.

## Defining Requirements and Developing a Comprehensive Test Plan

The Rolls-Royce and Element team of vibration experts can help manufacturers to define their requirements and develop a

comprehensive test plan tailored to fit their specific needs. The team combines multiple test methods to create a single, complete programme that ensures product safety while saving time and money. The team's expert knowledge of the different methods of analysing the behaviour of complex structures allows for many of the procedures to be planned and executed in ambitious timeframes. Following the tests, detailed professional test reports can be provided to include in certification packages.

**For more information on vibration testing and understanding the vibration behaviour of complex structures, please contact us.**

