Vibration control in electron microscopy suites

Adam Fox, Mason UK

Vibration isolation products are designed and engineered for a variety of scenarios. Scientific laboratories and the equipment typically found within them are often sensitive to vibration. However, for electron microscopes, the conventional methods of isolation are often insufficient. This article describes how scientists at Cardiff University resolved the challenge of operating a large electron microscope less than 100 metres from a major trainline, by partnering with vibration control engineering specialist, Mason UK.

At Cardiff University, a disused railway yard has been converted into a state-of-the-art scientific facility, which now contains world-leading scientific research establishments. As well as an 'occulus' staircase, the new Cardiff Innovation Campus is also home to a large electron microscope.

A challenging specification

Equipment like this is highly sensitive to vibration. According to guidance from the manufacturer, anything above VC-E level would impair the functioning of the equipment. Imaging and analysis at the atomic level means that any external interference that causes a deviation greater than the dimensions of the atom can be a major problem. The new electron microscopy facility is located close to a busy road and just 75 metres from a major trainline, both a passenger and freight line in constant use.

Laboratory building and adjacent trainline

Early site surveys confirmed that the vibration from the trains would interfere with the performance of the equipment unless mitigative solutions were implemented. The acoustic consultant working on this project, Colin Gordon Associates, therefore designed a very tight specification to ensure that VC-E levels would be achieved, despite the vibration-generating activities in the area.

The contractor, Bouygues UK, brought Mason UK on board to try and meet the challenging design criteria in the specification. "Mason proved to be a very knowledgeable and competent specialist," recalled Ashley May, Senior Design Manager with Bouygues UK. "They delivered excellent advice, design, installation and post installation support on this project and went the extra mile with assistance, even after the completion of the contract."

The limits of conventional measures

Spring mounts are often effective at isolating mechanical and electrical equipment, or protecting sensitive instrumentation. They can prevent vibration from equipment from passing into the structure of a building where it can manifest as noise, but they can also protect sensitive equipment from interference caused by outside sources of vibration. Often the ideal solution for low frequency applications, they offer superior performance to rubber mats or pads.

Thermo Fisher scanning electron microscope

Spring mounts are frequently combined with inertia bases. Inertia bases range from simple steel frames through to large concrete filled frames to provide inertial mass. The basic principle is that the increased mass will reduce vibration, lower the centre of gravity and thereby reduce rocking and increase thrust resistance. When combined with the correct acoustic isolation system, inertia bases are the most effective anti-vibration technique for machinery.

Despite the versatility of spring mounts, they would be ineffective at providing the desired level of vibration control, such were the engineering demands of this project. "Springs are effectively stressed metal wires, which have multiple vibration response modes. While this is often not an issue as we are dealing with extremely low levels of vibrational power, it can become a problem for very sensitive applications," explained Adam Fox, Director at Mason UK.

In addition, when springs are engineered to become softer and softer, and therefore more receptive to lower frequencies of vibration, it becomes a challenge to place something on top of them when stability is required. "With softer springs, relatively small changes in loading can lead to excitation. Although rubber and spring combinations can add damping, this also reduces isolation performance and multiple degrees of freedom remain, which means some vibration frequencies can be amplified," added Adam.

Air springs

Air springs are rubber bellows, pressurised with a gas like nitrogen. They are specified in projects like the Cardiff Innovation Campus, where very high levels of isolation are called for. Equipment is mounted on an inertia base and the air springs are pressurised to raise the base from the floor.

"Air springs are self-levelling and have very little resonant response, therefore providing a high level of stability and higher levels of isolation than can be provided by rubber or spring isolators," explained Adam. "They can typically achieve natural frequencies of sub 2Hz, but it is possible for well-engineered systems to go even lower."

Typical applications for air springs include sensitive medical equipment like MRI scanners, or high precision imaging equipment such as electron microscopes. However, this kind of technology, and the expertise required to design and install it, is a very niche area of engineering. There are very few companies that can offer air springs as an option. Air springs are also not a standard, off-the-shelf product. Mason UK designed a bespoke system that was built for the electron microscopy suite at the Cardiff Innovation Campus, working toward the criteria in the specification.

Overcoming challenges

Although the principles behind air springs remain the same, each project poses its own unique and often unanticipated challenges. To get an onerous specification accepted is not a straightforward process, as it requires demonstrating the solution is up to the task. The contractor therefore needed Mason to work closely with them, liaising with the acoustic consultant and writing letters of qualification to ensure the design was accepted.

“Experience of working on projects like these pays off. One significant challenge was the large pit in the floor that was required,” recalled Steve Hart, Director at Mason UK. To provide stability, the air springs were supported on top of columns, therefore necessitating a pit in the floor. While this was fine in theory, the system had to work from an architectural point of view too. One constraint was the depth of the pit. Mason’s engineers worked with the contractor to devise an optimal solution. “Working around this constraint, we calculated the depth necessary to provide sufficient vibration isolation, while still offering a solution that worked architecturally within the existing building,” Steve explained.

Some constraints are not always apparent from the outset. It was also necessary to shield the electron microscope from electromagnetic sources, which would also interfere with the functioning of the equipment. The inertia base therefore had to integrate with the continuous electromagnetic shielding lining the entire room. “Unfortunately, we weren’t made aware of this constraint at the beginning, but we managed to work around it with some additional coordination on site during the installation phase.”

Stainless steel was used where possible, because of the reduced magnetic signature. Extra effort was made to ensure that where anchorage to the structure was necessary, there was no risk of generating additional pathways for conductivity.

The system in action

The electron microscope sits atop a large inertia base which is raised by the Mason system of air springs. The large base provides an exceptionally high mass and stiff foundation, in addition to the exacting passive vibration isolation measures provided by the springs. The block itself weighs approximately 10,500 kg, with the additional weight of the microscope resulting in a total mass of 14,000 kg.

The system is actuated by a remote control box, which controls the pressure to the air springs. Once pressurised, the springs lift the inertia base and microscope from its supports. When in operation, this effectively removes any transmission path for sources of vibration, as vibrations must now pass through the air springs. The low resonant response of the air springs ensures the equipment can be safely operated without any impact from the nearby trainline.

The system has proved even more successful than anticipated. According to Dr Thomas Davies, Experimental Officer with the School of Chemistry at Cardiff University,

The Cardiff Innovation Campus

“the final design exceeded expectations and delivered a measured level of VC-H/I. After a smooth installation, Mason continued to work with us to fine-tune the properties of the block to minimise cross-talk and maximise performance, and this has resulted in a world-class, state-of-the-art ultra-quiet electron microscopy suite.”

Adam is somewhat reluctant to draw too much attention to these performance results. “VC-E level is an extremely challenging criterion to achieve. VC-F and VC-G levels are appropriate for extremely quiet research spaces, but as these levels are often not possible to achieve in practice they are not typically recommended for use as a design criterion, but only for evaluation.” So successful was the performance of the air springs, Adam and his colleagues were wary of publicising the details, less it would falsely raise expectations for others.

However, the team were naturally proud of their involvement on the project. “As far as I am aware, we’re the only company in the UK that can do this sort of engineering,” continued Adam. “Working on these types of projects, where you have to face some pretty novel design constraints, is always challenging. When a high level of isolation is specified, there is a correspondingly higher demand to qualify your design.”

Following the successful completion of the air springs system - including the positive reports from the scientists operating the equipment - Mason UK has been invited to tender for further works on this vibration sensitive project.