New vibration test rig

m+p international has developed a new rig for elastomer mounts in collaboration with the IDS Institute of Leibniz University and Continental

Noise and vibration inside an automobile can originate from many sources: for example, from the engine, gearbox or road surface; or from the electric motors used to power the windscreen wipers or fuel pump. At low frequencies, the vibration may be sensed through the body or fingertips, while higher frequencies are experienced as noise.

As vehicle interiors have become quieter, noises generated within the cabin, previously masked by external sources, may become audible and more intrusive. To reduce such noise, elastomer mounts can be used to block the path from the source of vibration to the interior of the vehicle.

In order to characterize the frequency response of elastomer mounts over a suitable range (the human ear is most sensitive in the range 1-2kHz), a test rig was developed through cooperation between m+p international, the IDS Institute of Leibniz University and Continental AG, all located in Hanover, Germany. The project was funded by the Central Innovation Programme of the German Federal Ministry for Economic Affairs and Energy.

The initial design had one end of the specimen fixed to a solid frame, with sinusoidal force applied to the other end. In many real-world situations, the force is constant over the frequency range of interest. However, a constant force gives constant acceleration (from force = mass x acceleration), so as the frequency increases, the amplitude decreases proportional to the square of the frequency ($d \sim 1/\omega^2$).

For example, applying a sine wave with a constant force of 10g at 500Hz might typically result in a displacement of around 10µm; at 2kHz the displacement will be around 0.6µm. At these levels, the slightest deformation in the test frame could give rise to measurement errors, even for heavy steel frames. In addition, the frame is likely to have resonances within the measurement test range (approximately 300Hz – 3kHz), which would be very difficult to eliminate.

A better – and simpler – method is to use the inertia of a large mass at both ends of the vibration path – i.e. above the force generator and below the test object. These masses effectively isolate the test rig from the vibration of the item under test.

Figure 1 shows the complete test stand. The frame consists of three aluminum plates connected by four 75mm-diameter columns. The upper and lower plates are fixed, but the middle plate is free to move up and down on recirculating ball bushings, to accommodate test objects of differing heights. The height of the middle plate is adjusted using two threaded shafts on each side, driven by a three-phase motor with a frequency converter controlled by manual switches. To protect the operator, both shafts are equipped with anti-drop devices, and rotation of the shafts is prevented by an automatic brake, which is disengaged by an electromagnet.

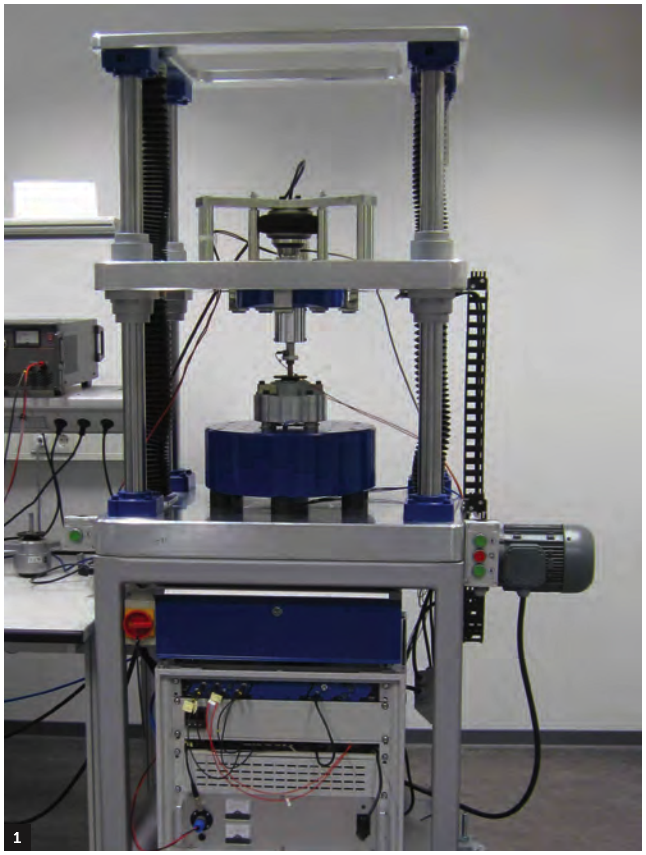
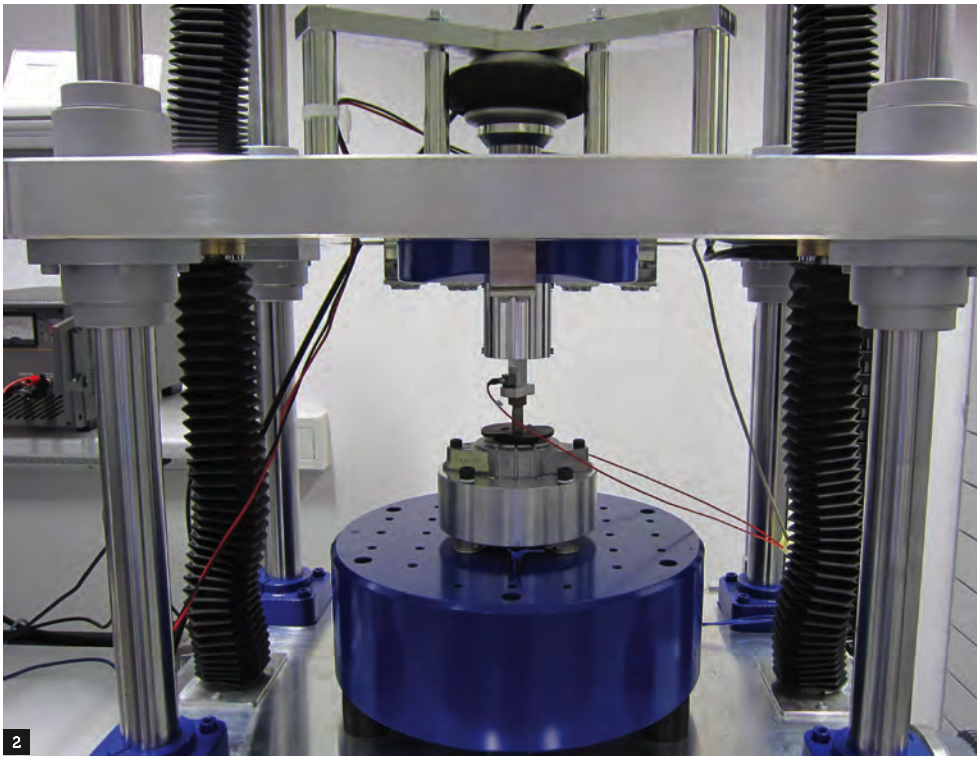


FIGURE 1: The complete high-frequency test stand for elastomer mounts

The middle plate is fitted with six glass-fiber reinforced plastic rods to guide the upper mass of about 33kg so that it can only move in the vertical direction. The mass is



attached to the plate with an adjustable bellows, which is used to deliver a controlled preload of up to 5kN, measured directly with a strain gauge transducer.

Figure 2 shows the core of the test stand in more detail. The actuators are piezoelectric and use the inverse piezoelectric effect, where a voltage is applied to the material to produce a mechanical movement. These devices are particularly suitable for this application because of their low amplitude and high frequency range. In this application, multiple standard piezoelectric actuators working in parallel, contained in a cylinder attached directly below the upper mass, are driven by a special amplifier in a range up to 200V, at up to 10A. The peak acceleration of the actuators is 10g over the range 500-2,000Hz. To avoid hysteresis effects that heat up the piezoelectric material, the actuators are not loaded to their maximum mechanical capacity.

The actuators are connected to the test object – a viscoelastic mount. A control accelerometer is attached directly to the central stud of the mount, to ensure that the input acceleration is not affected by slight movements in the upper mass. Under the aluminum ring holding the test object are four piezoelectric force sensors (4 x 45kN), connected in parallel to a charge amplifier. This provides a very stiff support and keeps the resonances due to the deflection of the sensors well above the measurement range. The sensors are mounted on the lower mass (130kg) – which is much larger than the upper one – to keep the system as rigid as possible. Both masses have soft mountings, and this combination creates a low-pass mechanical filter. This effectively isolates the actuator specimen measurement sensor from the frame and filters out unwanted external interferences; even the unavoidable resonances of the columns do not affect the masses, as Figure 3 shows. It also works in the other direction and prevents the test from interfering with other processes in the laboratory.

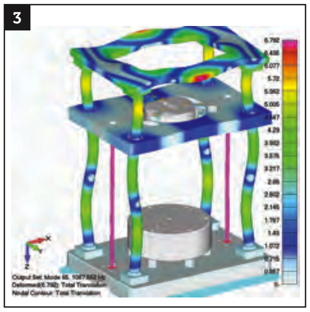


FIGURE 2: The core of the test stand, showing the inertial masses (in blue)

FIGURE 3: Resonances in the test frame don't affect the masses

The lower part of Figure 1 shows the m+p VibRunner front-end preamplifiers for the measured force signals and the power amplifier that drives the actuators. The m+p VibRunner is equipped with eight analog input channels, simultaneously sampled with 24bit encoding at up to 100kHz, plus two analog output channels and an Ethernet port. A laptop is used to administer the tests and for data collection.

At the beginning of a measurement a self-check is performed to ensure that the control loop is closed and to detect possible setup problems.

During the actual test, the actuators exert a constant force/acceleration on the object under test over the required frequency range. Despite the reduction in the amplitude of the vibration, which occurs as the frequency increases, the magnitude of the acceleration is maintained at the set value by m+p international's VibControl software, which is used in laboratories worldwide for efficient vibration testing.

All settings and measurements are written into a result file, together with data from the self-check. These files can be analyzed directly on completion of the test, or used for later analysis, data export, or to generate plots or reports. In addition to the frequency-dependent data, the measurement data versus time can be recorded and stored, although these files can be quite large, particularly if the acquisition rate is high. ❮