New High-g-Vibration-Exciters fill the Gap between Standard Calibration Shakers and Shock Exciters

Common vibration exciters for calibration and sensor characterization available on the market are capable to provide acceleration amplitudes up to 100 g_n (1,000 m/s^2) only. To apply higher amplitudes in a “metrological quality” shock exciters are commonly used. But the transient shocks have a rather broad spectrum that can contain spectral components close to the resonance frequency of the device under test (DUT). Thus calibration or measurement results can depend strongly on the properties of the shock exciter. In the worst case the DUT may even be destroyed by the shock. But how do you check amplitude linearity of a DUT that is not designed for higher frequencies? And if the result of a shock calibration depends on the properties of the transient shock signal, wouldn’t it be better to calibrate even sensors designed for shock measurements on a vibration exciter? There seems to be a gap between conventional vibration exciters and shock exciters in the amplitude range above 100 g_n (1.000 m/s^2) inhibiting such measurements. This article introduces two new vibration exciters that can fill this gap and shows the results of amplitude linearity checks of an acceleration sensor up to 500 g_n (5,000 m/s^2).

SPEKTRAs vibration exciter SE-R101 is designed to allow accelerations up to 400 g_n (4,000 m/s^2) (Fig.1). While conventional vibration exciters try to avoid any kind of resonances, the SE-R101 design uses the resonance principle to reach highest acceleration amplitudes. For this purpose three steel springs with variable length are attached to the exciter armature. Armature and springs constitute an oscillator that is excited by an electro dynamic drive. The resonance frequency can be adjusted by changing the length of the springs. Since only a low electrical power input is necessary to reach the desired accelerations an unwanted heating of the DUT is avoided that may influence the measurements results. Furthermore the springs tend to stabilize the armature allowing a low cross motion within the limits of the ISO standard 16063-21. The vibration exciter comes with an internal reference standard thus no Back-to-Back reference standard is needed which would cause mechanical instabilities and shows base strain effects at these high acceleration levels. Thus the SE-R101 can be used for calibration purposes as well as for vibration testing of small assemblies.

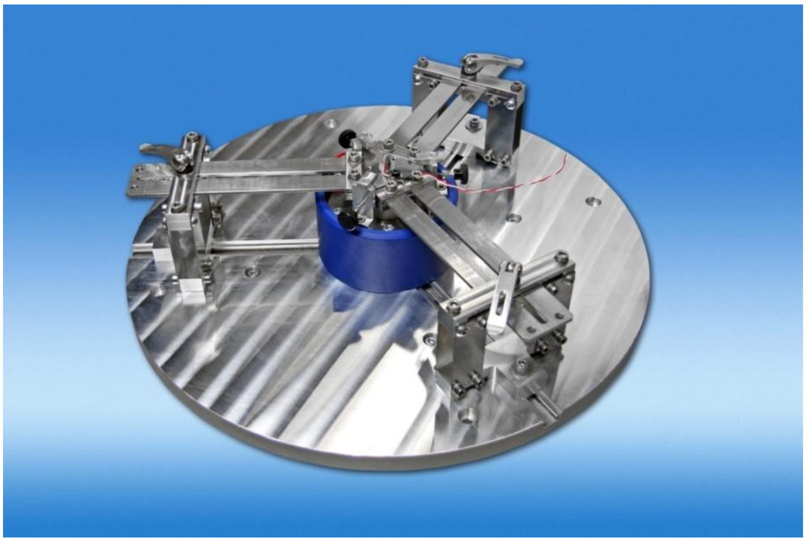

Fig 1 Vibration Exciter SE-R101 for high accelerations

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If even higher accelerations are needed, the operation principle of the SE-R101 comes to some technical as well as handling limits. Thus SPEKTRA developed another high-g-exciter SE-R201 based on the resonant excitation of a rod where one end of the rod is fixed on the armature of a vibration exciter while the DUT is mounted on the other end (Fig. 2). This system can roughly be described as a system of two masses (exciter armature and DUT) connected by a spring (rod). The resonance frequency is mainly determined by the elasticity of the rod and the attached masses. Thus for a certain rod with given length and material it can only be slightly tuned by means of additional masses attached to the rod.

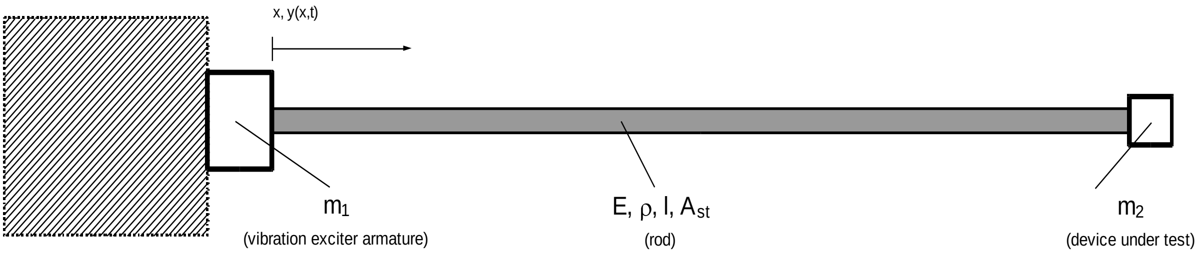

Fig. 2 Schematic drawing of a SE-R201 vibration exciter

The efficiency of this exciter type is mainly influenced by the material properties of the rod. Table 1 shows experimental data achieved from measurements with a metal rod (no. 1) and an alternative plastic rod (no. 2). The acceleration a_1 was measured directly on the armature of the vibration exciter and a_2 was measured at the DUT. The parameter n describes the different vibration modes of the rod.

		Measurement				
Rod	**n**	**f_n [Hz]**	**$a_{1\,max}$ [m/s^2]**	**$a_{2\,max}$ [m/s^2]**	**P_{max} [W]**	**k_{max} [%]**
1	1	1440	3777	10000	16	0,5
	2	3590	1322	10000	42	0,4
	3	5850	279	10000	24	0,3
2	1	300	1100	1100	225	< 5
	2	650	800	1500	225	< 5
	3	1027	700	1450	225	< 5

Tab. 1 Measurement results showing the impact of different rod materials

Equipped with the metal rod (1) the SE-R201 could provide accelerations up to 1,000 g_n (10,000 m/s^2). In all vibration modes the harmonic distortion as well as the required electrical power input was on an excellent low level. With a plastic rod the maximum acceleration was ten times lower although the electrical power input was ten times higher. Thus to optimize the SE-R201 a numerical model of the exciter was developed which describes its properties up to certain limits very well. By means of this model it turned out that this significant decrease in the efficiency of the plastic rod exciter compared to the metal rod exciter was mainly caused by the inner damping of the material. Furthermore the model provided a better understanding of the best balance of the masses in order to achieve the highest acceleration output.

To demonstrate the capabilities of both vibration exciters the following section describes the calibration and amplitude linearity check of an accelerometer that is used to measure accelerations at a rotating shaft (Fig. 3). The accelerometer has a weight of approximately 230 gram.

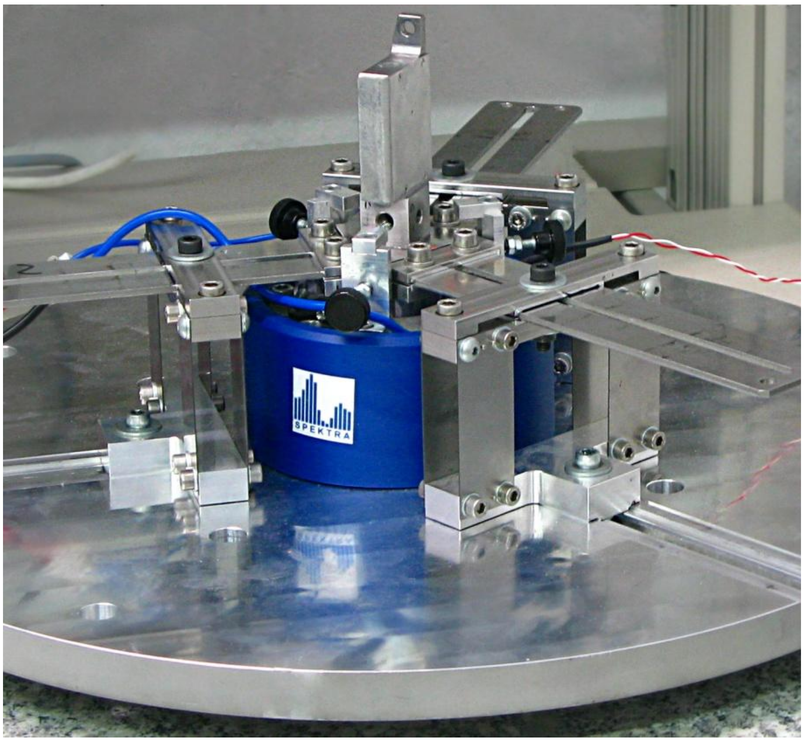

Fig. 3 DUT mounted on a SE-R101

In a first step a sine sweep was performed by means of a conventional shaker with an acceleration of 20 g_n (200 m/s^2). With this test the operability of the sensor and the continuity of the transfer function were checked (Fig. 4). Discontinuities in the transfer function may indicate a defect of the sensor or may at least constrain the usable frequency range. Then a sine calibration on the same acceleration level was performed.

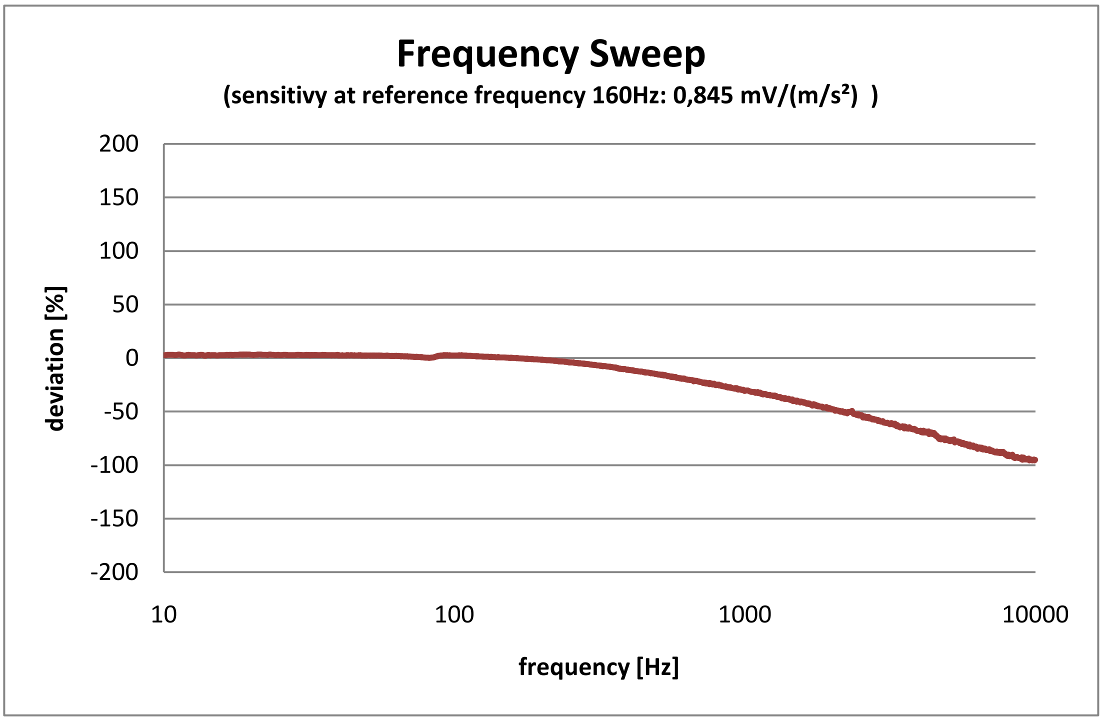

Fig. 4 Sine sweep to check the continuity of the sensor transfer function

After this successful check and calibration the amplitude linearity was tested at two frequencies. Mounted on a SE-R101 the acceleration was varied from 50 g_n (500 m/s^2) to 270 g_n (2.700 m/s^2) (Fig. 5) at a frequency of 370 Hz. The linearity turned out to be good and the sensitivity changed less than 0.5%.

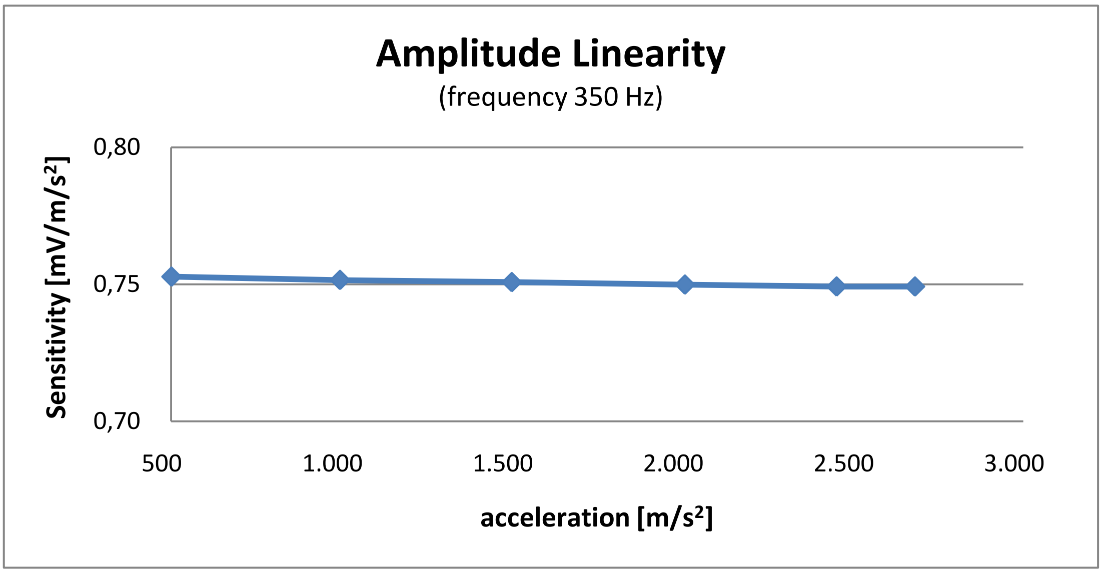

Fig. 5 Amplitude linearity check by means of a SE-R101

To achieve higher acceleration levels a SE-R201 exciter was used. At a frequency of about 850 Hz the acceleration was increased up to 500 g_n (5.000 m/s^2) (Fig. 6). Even at this high acceleration the sensor sensitivity didn't change more than 0.5%.

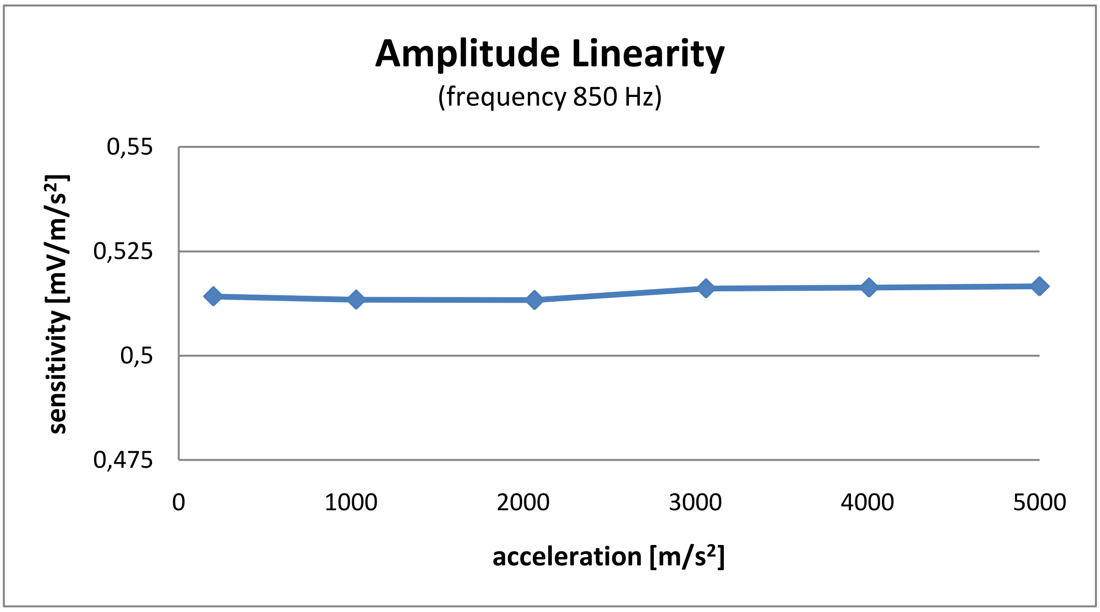

Fig. 6 Amplitude linearity check by means of a SE-R102 up to 500 g_n

Conclusions

Both measurements demonstrate impressively that SPEKTRAs new vibration exciters SE-R101 and SE-R201 are capable to fill the gap between conventional vibration exciters and shock exciters. Even a quite heavy sensor like the one in the measurements above can be accelerated up to 500 g_n (5.000 m/s^2). Due to their excellent signal quality these exciters may be also an interesting alternative tool for the calibration of shock sensors. Since the defined sine vibration avoids problems that can be caused by the higher spectral parts of transient shock signals it should allow more accurate calibration results. Furthermore such a calibration is more convenient and much quicker than a calibration and amplitude linearity check on a shock pendulum. Apparently the application range for such vibration exciters may be much broader in the future. Further research and development will surely enhance the performance limits of the exciters as well as the possible use cases.