Piezomechanik GmbH

Piezo Vibrations
and
Piezo Shakers

Keywords

- **Acceleration testing**
- **Acoustics**
- **Dynamic sound generation**
- **Fretting test**
- **Fatigue testing**
- **Flaw detection**
- **Microstructure testing**
- **Modal thrusters**
- **Non destructive testing (NDT)**
- **Structure borne acoustics**
- **Structure borne noise**
- **Vibration research**
- **Vibration control**

Piezo-shakers versus electro-magnetic shakers?

Piezo-shakers are covering a different application spectrum than electro-magnetic shakers.

Per actuator volume, magnetic systems provide larger motion amplitudes and limited forces. Piezo actuators are high stiffness devices with high specific forces and limited displacement (solid state actuators: electro-elastic deformation of a solid).

Small sized piezo-electric structures like piezo-mini-shakers show much higher energy densities than magnetic actuators.

The small mass-load of piezo -elements together with high forces results in potentially very high acceleration rates and cycle frequencies.

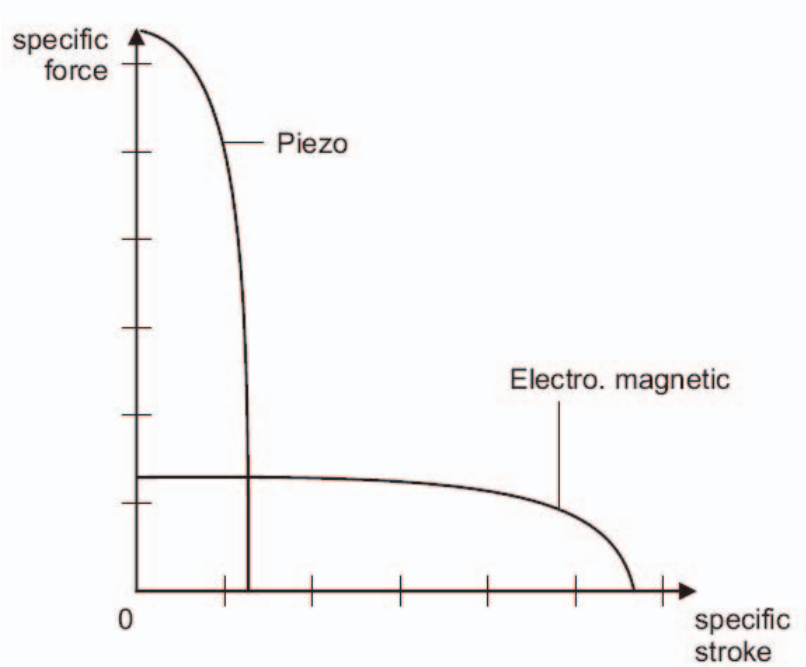

Fig. 1: Schematic of the stroke/force characteristics of piezo shakers versus electro-magnetic shakers per unit volume. Piezo shakers provide higher specific force levels.

Highlights of piezo-shakers

- **High stiffness**
- **High mechanical forces / pressures**
- **High frequency generation capability**
- **Very Compact designs**
- **Miniature dimensions feasible**

Structure borne acoustics amplitudes are ranging in the sub-micro-meter scale, which can be created even by small-sized piezo-actuators.

Due their potentially small dimensions, piezo-shakers can be easily integrated into mechanical structures e.g. to generate elastic deformation even in the low-frequency audio range for structure borne sound analysis.

Nevertheless you can also get big sized piezo-shakers, which handle tens of kiloNewtons.

Piezo-shakers are used for

- **Material characterisation with respect to frequency/velocity/acceleration**
- **Modal analysis**
- **Investigation on structure borne noise/sound of machine parts**
- F**atigue testing of mechanical components**
- **Fretting arrangements**
- **Flaw detection in composite materials**

Piezostack-based shakers most promising features

Frequency ranges:	From audio range up to > 100 kHz (depending on shaker size and amplitude) frequencies are tuneable over a wide range
Amplitudes:	µm to sub-millimeter range (depending on frequency)
Modulating forces:	Up to tens of Kilo Newtons (blocking limit) (depending on shaker's dimensions, shaking configuration and frequency)
Acceleration rates:	>> 1000 g (depending on actuator design and electronic driver) For shock excitation up to 10.000 g => check Piezomechanik's Impactors / Accelerators PIA
Very compact designs:	Millimeter dimensions feasible

Working principle of a Piezo Shaker (PiSha)

A piezo-shaker PiSha uses basically stacks or rings of PZT-piezo-ceramics converting an electrical signal into a mechanical motion by activation of piezo-electric PZT-ceramics as it is widely used for other purposes (e.g. positioning by piezomechanical actuators)
(see brochure “Piezomechanics: An Introduction”)

To handle the shaker-specific high forces / accelerations and high electrical and mechanical power levels in a reliable way, special designs of the shaker structure and driving electronics are a “must”.

Examples of shaker configurations

Geo-Shaker
for harmonic and pulsed soil excitation:

Type of actuator:	bulk stack
Coupling to ground:	via base plate
Force generation:	reaction type
Driving electronics:	switching amplifier RCV1000/7 with energy recuperation

Seismic/inertial mass:	up to 200 kilograms
Max. amplitude:	up to 80 µm
Max. modulation force:	approx. +/- 15 kiloNewtons
1st resonance:	approx. 220 Hz
Operating voltage:	up to 1000 Volts

Fig. 2: Geo-shaker for low frequency excitation of soil or buildings (PC case for comparison of size)

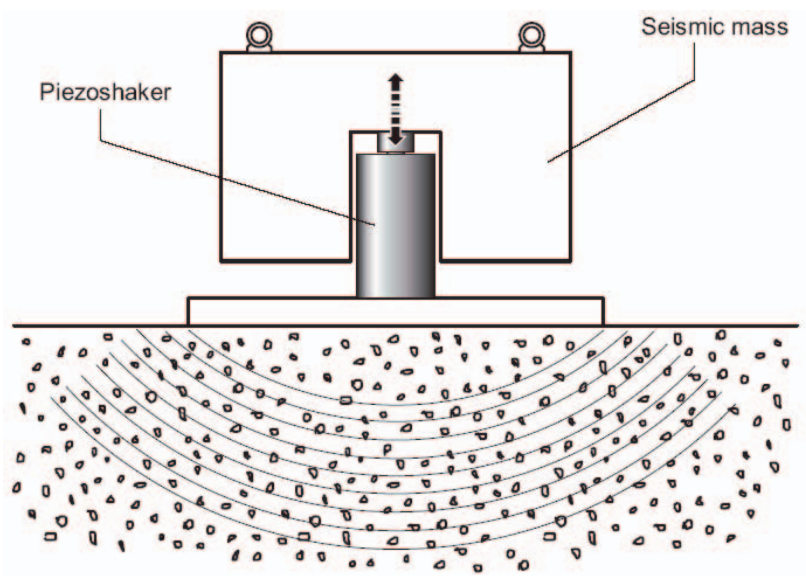

Fig: 3: Schematic of geo-shaker’s operation principle

Micro shaker: washer type
For local mechanical excitation
Mounting: clamped or reaction type

1. resonance:	up to 100 kHz (at reduced amplitudes)
Max. Amplitude:	up to 5 Micrometers
Max. modulating forces:	up to 1000 Newtons (clamped; depending on type)
Operating voltage:	up to 150 Volts
Driving electronics amplifier:	LE 150/100 EBW

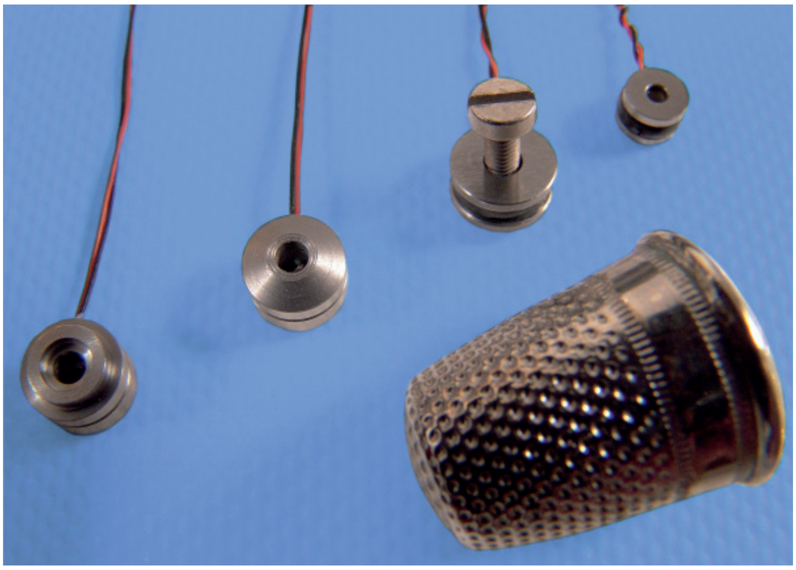

Fig. 4: Set of various types of micro shakers, thimble for comparison of size

Using common ultrasound generators as piezo-shakers?

Ultrasound generators are piezo-based mechanical resonators, running with high efficiency on a fixed single frequency.

Common shaking applications require a frequency tuning over a wide range at reasonable power levels in a non-resonant operating mode.

Broadband shakers and driving electronics require other design principles than resonating single frequency systems.

Using standard piezo-actuators as shakers?

Standard piezo stack actuators are mostly designed for positioning tasks with limited dynamics/ accelerations and powers (both peak and average). To certain extend, they can be used to generate mechanical vibrations with limited amplitudes/power levels.

Piezo-shaking with high powers requires the adoption of the piezo-mechanical converter to the potentially very high cycle rates, high dynamical force loading, high self-resonance levels, self-heating and high electrical current ratings.

Piezomechanik is offering both: normal piezo-actuators and piezo-shakers.
You can be sure to get the optimum solution for your problem.

► **Contact PIEZOMECHANIK**

Mounting examples for piezo-shakers

The mechanical excitation efficiency by piezo-shakers depends strongly on the coupling quality of the shaker to the excited structure. Poor coupling by improper means results in low excitation levels of your test piece and reduced frequency range.

The PiSha-shakers can be used in various mounting configurations like stud-mount reaction type-elements or by clamping with external supports or others.

Conventional shaker excitation:

The shaker body is mounted fix on a solid base/table-top (infinite large mass).
The moving part of the shaker is the front pin, where the test object is mounted onto.

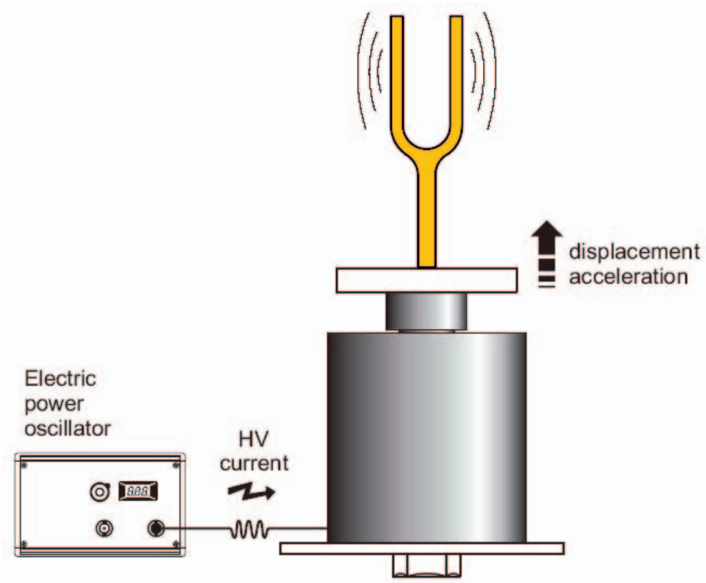

Fig. 5: Schematic of a shaker tester, rigid mounting

The achievable maximum acceleration b depends on shaker's frequency and amplitude according

$$b = a(2\pi f)^2$$ f: shaker's frequency; a: shaker's amplitude

The achieved peak force F is defined by the accelerated mass m of the test-body and the applied acceleration b according

$$F = m\,b$$

Reaction type arrangement

The shaker is mounted via the front pin to the test object (e. g. by a stud or bolt), so the main part of shaker body moves freely relative to the test-object.
Due to shaker's mass, the shaker vibration generates inertial or acceleration forces, which are transferred to the test structure (fig. 6)
To enhance the force generation, the PiSha device can bear a distinct seismic mass SM in its bottom section. For big masses SM, high modulating forces can be achieved even at low frequency levels.

The achieved force levels are the higher, the larger the stiffness of the test structure is.

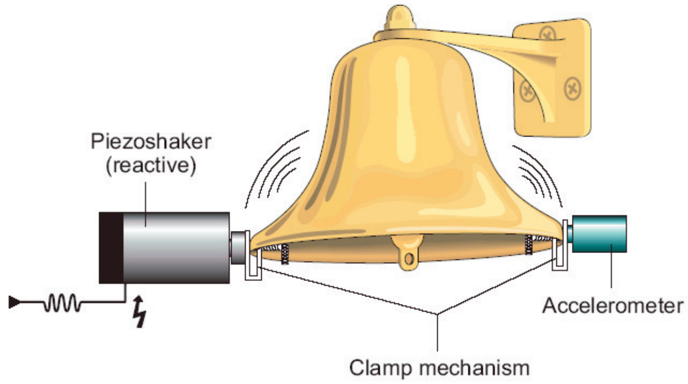

Fig 6: Schematic of structure borne noise/acoustics generation and detection set up using inertial forces (reaction type)

Clamped operation of a piezo-Shaker PiSha

The piezo-shaker is simply pressed onto the test structure (fig.7) by a clamping mechanism.
When the shaker is electrically activated, a force and/or displacement modulation of the test-body (example: bell) occurs.

The theoretically achievable maximum force limit is achieved under blocking conditions of the shaker (no displacement due to an infinitely large stiffness of clamping and test-piece).

Clamped shaker arrangements are used for structural borne noise analysis.
Very tiny piezo-shaking elements can be used for easy integration to the test body.
Structural resonances with high quality factors are easy to detect even with very low excitation levels.

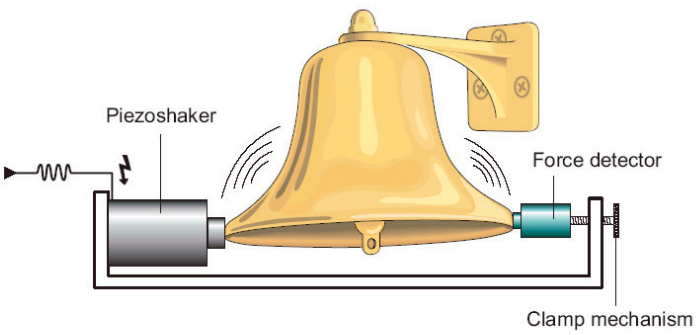

Fig. 7: Schematic of structure borne acoustics/noise generation and detection, clamped arrangement

Special mounting solutions

The above shown examples cover a wide range of applications.
Nevertheless in special cases, new mounting strategies are necessary.
One example is to avoid mechanical damages/modifications of the test structure for mounting the shaker (e.g. inserting of tapped holes for a stud mount shaker into sensitive parts).
PIEZOMECHANIK offers a wide support of defect-free mounting techniques based on magnetism, vacuum or other techniques.

Piezomechanik's offer:

Contact PIEZOMECHANIK for analysing your shaker application to provide the best-matched piezo solution.

PIEZOMECHANIK's shaker and actuator program covers a wide range of mechanical parameters with regard to power, oscillating amplitudes, blocking forces together with well-adapted mechanical designs for matching individual test-arrangements.

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Stand: Mai 2006