Drive Elements Made of Piezoelectric Materials

The Driving Force Behind Highly Accurate Dosing Applications

Demands on components increase with the advancing miniaturization in process and medical engineering. This particularly applies when small volumes have to be dosed with high precision, and also to aerosol applications or to production of microarrays or biochips. Piezo-based drive solutions are ideal here.

Piezo drives generate linear motions directly and with high precision and have proven to be successful in many comparable applications. They can also be adapted well to the respective application environment. Since they offer high efficiency for the small space they occupy, they can also be used in drives for mobile devices or lab-on-a-chip technology.

Several piezo-based drive solutions for dosing applications are described hereafter:

- Microdiaphragm pumps
- Microdosing valves
- Peristaltic pumps
- PipeJet dispenser
- Aerosol production
- Air-Bubble detectors for flow monitoring

Piezo Actuators: Fast, Precise and Durable

Piezo actuators work with short response times and they move dynamically with resolutions in the sub-nanometer range and frequencies of up to several thousand hertz. Furthermore, piezo actuators are maintenance-free, because they have no moving parts in the conventional sense.

The motion is based on crystalline solid state effects and so there are no rotating or friction-producing mechanical components. Since they do not require any power when they are at rest, the piezos can also score in terms of energy consumption. They can thus be used in a wide range of applications. In process and medical engineering, for example, short dosing cycles can be implemented. The dosing and pumping processes can be finely adjusted and precisely controlled by the variable strokes.

PI Ceramic offers a wide range of piezoelectric components in a variety of shapes, standard as well as custom-made, as well as piezo actuators with and without preloading in different sizes (Fig. 1). The long lived and distinctly robust actuators have already been tried and tested in many application fields, e.g. with microdiaphragm pumps.

Fig. 1 Since very different designs can be created with piezo elements, it is possible to find a custom-made solution for practically any scope since very diverse structures can be implemented

Microdiaphragm Pumps – High Delivery Rates Even Under Backpressure

Microdiaphragm pumps are suitable for the precise dosing of gases as well as liquids. A diaphragm separates the medium to be transported from the drive. The drive can therefore not interfere with the pumped media and vice versa. Passive inlet and outlet valves control the direction of pumping (Fig. 2).

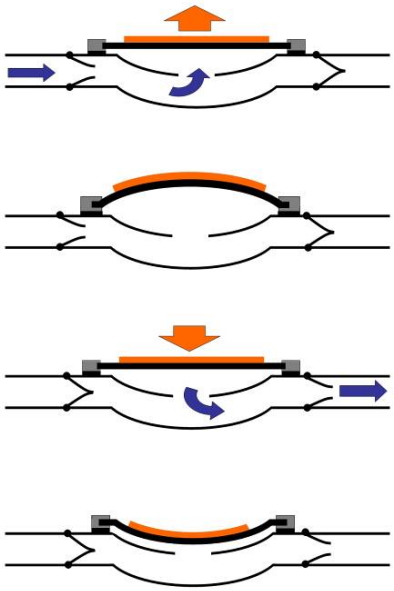

Fig. 2 Operating principle of a micodiaphragm pump

Highly dynamic disk-shaped piezo elements mounted directly onto a metal disc lend themselves as the drive system for the miniaturized versions of this type of pump (Fig. 3). High delivery rates can thus be realized even under backpressure by varying the switching frequencies or the amplitude of the piezo displacement by means of a corresponding control.

Fig. 3 Micro-diaphragm pumps with disk-shaped piezo elements: The space required for this drive solution is extremely small (Image: thinXXS Microtechnology AG)

Typical specifications for such microdiaphragm pumps when dosing liquids are a flow rate of up to around 80 ml/min at switching frequencies of between 25 and 120 Hz and a potential backpressure of between 200 and 500 mbar, for example. When dosing gases, the values are between 0.1 and 250 ml/min, 100 to 500 Hz and 100 mbar.

The possible applications thus cover a broad spectrum. They range from laboratory technology and medical engineering, chemistry and pharmaceutical applications through to mechanical engineering. Piezo-driven diaphragm pumps can dose the lubricants and coolants required with high accuracy, for example. Thanks to their compact dimensions these dosing devices can directly be installed where they are needed and thus usually reduce consumption.

Microdosing Valves: High Flow Rates with Highly Accurate Dosing

Microdosing valves operate in a similar way to pumps. However, the forces required are higher, because a spring force is applied. The usual dosing frequencies here are in the kilohertz range and can practically only be achieved with piezo actuators.

Microdosing valves achieve flow rates of up to a few tens of liters per minute for highly accurate individual and bulk dosing in the microliter and nanoliter range. The low switching times of the piezo actuators here are also important, of course, being in the millisecond to microsecond range.

Various piezo components are used in the microdosing valves, depending on their size, small piezo tubes are used for drop-on-demand methods such as in ink jet printers. Miniaturized valves for dosing tasks in the nanoliter range are produced using piezo disks, for example, which are also used for lab-on-a-chip applications.

Piezo actuators, which generate more force, can be used for valves where the amount of space occupied is not so important, as can piezo drives with lever amplification. They are suitable for longer travel and thus also for applications where – depending on the material properties -– certain drop sizes have to be achieved.

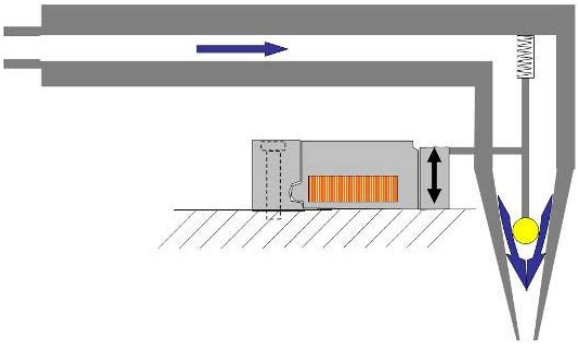

Fig. 4 In micro-valves, particularly where viscous liquids with a tendency towards higher pressures are processed, translational actuators with and without preloading can be used where larger strokes of the valve tappet are required, with lever amplification as well

For instance, microdosing valves are used for the dosing of medication (Fig. 4). Similar applications can also be found in the industrial sector for the fine-dosing of soldering fluxes, oils, greases, adhesives etc. Microvalves are suitable for gases as well as liquids.

Peristaltic Pumps: Uniform and Pulse-Free Dosing

So-called peristaltic pumps are ideal in cases where liquids or gases are to be dosed not only accurately, but also as evenly and with as little pulsing as possible. The external mechanical deformation of the tube forces the medium to be transported through this tube.

The mechanical deformation is effected by piezo actuators (Fig. 5). Peristaltic pumps can be easily sterilized, are non-contact in operation, and can be operated without valves in both directions. The pumping direction is determined by the control of the individual actuators.

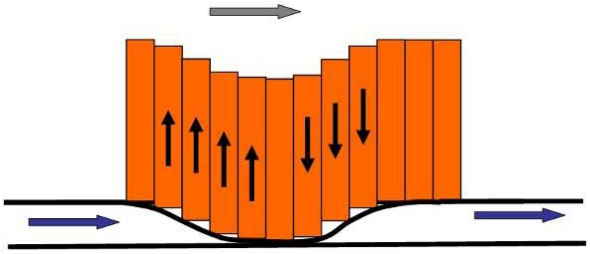

Fig. 5 Operating principle of a peristaltic pump

Those peristaltic pumps can be found in laboratory technology as well as the dosing of industrial adhesives or soldering fluxes, and most infusion pumps also operate according to this principle. The drive element consists of flat piezo bender elements, compact piezo chip actuators or piezo stack actuators, depending on the power and size requirements.

Bender actuators are suitable mainly for applications with low backpressure, for liquids with low viscosity and convince by virtue of the small amount of mounting space required. This means they can very easily be integrated into the pumps. Piezo actuators are better for higher backpressure. They can thus process more viscous substances

PipeJet Dispenser: Piezo-Driven Direct Displacement Method

Particularly interesting is the piezo-driven direct displacement method of the PipeJet dispenser Fig. 6), it differs from the usual piezo dosing methods (Fig. 7) in crucial ways.

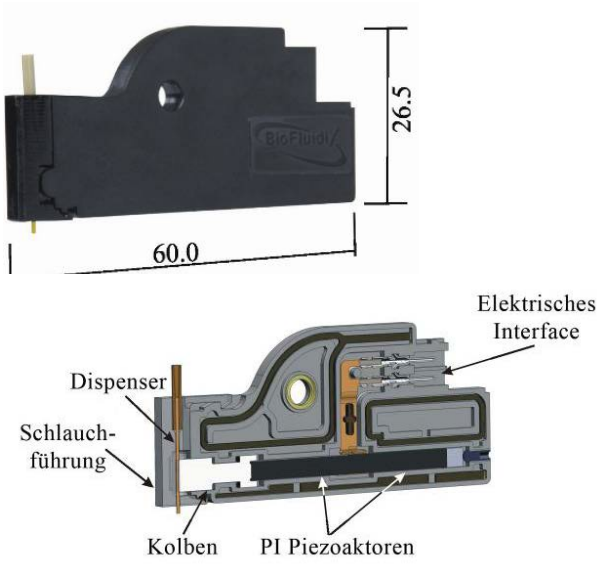

Fig. 6 Cross-section through a PipeJet (Image: Biofluidix)

The fluid line is made from an elastic polymer tube with a well-defined internal diameter. The actuator used, extends along the longitudinal axis and can constrict the polymer tube up to 100 times more than the ring actuators, for example. This means it has sufficient power reserves for the reliable dosing of difficult media. This fact together with the simple fluidic geometry means that fluids containing particles, e.g. paints, bead or cell suspensions, can easily be dosed in precise droplet form.

One example of an application of such dispensers in clinical diagnostics is the Lateral Flow Assays used for diagnostic purposes, i.e. test strips which require a specific dosage of fluids.

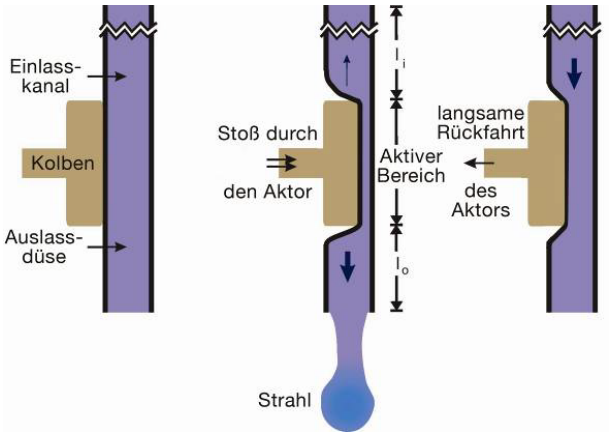

Fig. 7 The PipeJet technology uses piezo-driven direct displacement for the dosing (Image: Biofluidix)

Efficient Aerosol Production with Piezo Elements

In medical engineering piezo actuators are often used in therapeutic devices. For the treatment of respiratory diseases often involves medication being directly applied with atomizers. Conventionally, pressurized air atomizes the inhalation solution into minute droplets.

An alternative method is to generate minute droplets with the aid of piezo technology. Specially shaped piezo disks act as ultrasonic transducers here and excite a stainless-steel diaphragm with several thousand holes to execute ultrasonic vibrations at more than 100 kilohertz (Fig. 8).

Fig. 8 The aerosol production in the atomizer head of the eFlow® rapid Electronic Nebulizer series uses actu-ators to generate ultrasonic oscillations (Image: Pari Pharma GmbH)

This produces particularly homogenous aerosols, which are advantageous for precise dosing – the administration of high-quality drugs can be better targeted allowing access to new therapeutic concepts. The risk of side effects is also reduced. Even the special hygiene requirements which come with medical engineering applications are mastered by piezo ceramics; the aerosol generators can be professionally sterilized in autoclaves, or boiled.

The ultrasonic operation is noiseless for humans, and the low power consumption of the piezo component also allows battery operation. Moreover, piezo technology reduces the time required to atomize medications by up to 50% compared to conventional systems. For patients with chronic respiratory diseases, in particular, this means an improvement in their quality of life.

Air-Bubble Detectors for Flow Monitoring

In medical applications it is often necessary to ensure there is an undisturbed flow with no air or gas bubbles, e.g. in dialysis, with transfusion pumps. This can be done with the aid of ultrasonic technology in so-called air-bubble detectors (ABD) (Fig. 9). The piezo elements in these sensors serve to generate and receive ultrasonic waves.

The sensors are mounted on the outside of flexible tubes and operate without coming into contact with the medium to be transported; they therefore do not interfere with the flow rate, nor is there any danger of contamination. The non-magnetic piezo technology means that, when the electronics are shielded appropriately, it is even possible to operate in an extreme environment, such as in the vicinity of magnetic resonance tomographs.

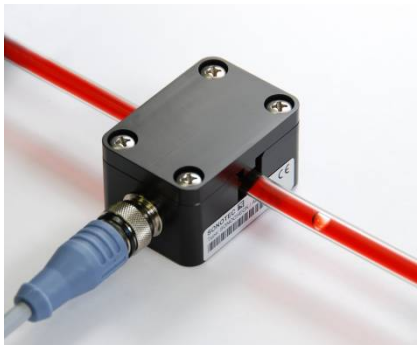

Fig. 9 Bubble detectors based on ultrasound technology provide non-contact monitoring of the flow (Image: Sonotec Ultraschallsensorik Halle GmbH)

Conclusion

Piezo actuators have proven themselves as drive elements for pumping and dosing applications in medical and process engineering. They are maintenance-free, work with short response times and move with resolutions in the sub-nanometer range at high dynamics and frequencies of up to several thousands hertz. Piezoelectric drive solutions can be used for a large number of different systems and sometimes even allow new approaches to solutions. The corresponding drive electronics can also be perfectly matched to the respective application and provide the dynamics required for the short switching times. Physik Instrumente (PI), based in Karlsruhe/Germany and parent company of the piezoceramic specialist in Lederhose, can provide a solution for almost every task.

PI Ceramic in Brief

PI Ceramic is considered a global leading player in the field of piezo actuators and sensors. The broad range of expertise in the complex development and manufacturing process of functional ceramic components combined with state-of-the-art production equipment ensure high quality, flexibility and adherence to supply deadlines.

Prototypes and small production runs of custom-engineered piezo components are available after short processing times. PI Ceramic also has the capacity to manufacture medium-sized to large series in automated lines. PI Ceramic, a subsidiary of Physik Instrumente (PI) GmbH & Co. KG, is located in the city of Lederhose, Thuringia, Germany.

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