No Compromises Allowed For Mobile Drug Pumps

Piezo-Based Ultrasonic Drives Open Up New Opportunities

For many diseases, mobile drug pumps are indispensable to outpatient therapy, for instance, in pain therapy, oncology, parenteral nutrition as well as metabolic disorders. They enable patients to be mobile, therefore contributing to their quality of life. At the same time, therapy costs are reduced, as the patients do not require in-patient or out-patient treatments at the hospital.

There is, however, room for improvement in the standard mobile drug pumps used today, especially when it comes to flexibility with regard to various applications, size, weight and reliability. In this regard, piezo ultrasonic motors as pump drives can open up interesting opportunities (Fig. 1).

Fig. 1 For many diseases, mobile drug pumps are indispensable to outpatient therapy, for instance, in pain therapy. There is room for improvement, however, especially when it comes to flexibility with regard to various applications, size, weight and reliability (Image: PI)

When thinking of mobile drug pumps, balloon pumps are what first comes to mind, as they are light, can be easily handled and operated by patients. But they show significant deviations in regard to the rate at which the medication is dispensed and the injection quantities are difficult to document.

Since the "mobile" patient is usually not in the hospital, it is extremely important to precisely monitor the course of therapy. The physician needs accurate information for a successful treatment. Therefore, a pump system is required which also allows for exact documentation outside the hospital. For such cases, peristaltic pumps are currently the best solution. But due to their considerable weight and size, these pumps severely restrict the patients and are thus not really mobile. They do, however, allow for a precise dosage and programmable volume flows.

Depending on therapy, such flexibility enables drugs to be administered in larger or smaller quantities. It is even possible not to administer any drugs for extended periods of time. Large-volume dosing is also possible, as drug reservoirs with varying capacities can be attached to the pumps. The peristaltic pumps are suitable for various medications, as they deliver a continuous flow (basal rate), but even special injections (bolus rates) are also easy to dose and can be scheduled in any manner. In addition, all procedures can be documented to evaluate specified drug quantities and the course of therapy and to submit relevant data to insurance providers.

Utilizing Potential for Improvement: Mobility and Documentation

This finally boils down to the fact that except for mobility, peristaltic pumps combine all desired requirements. Hence, their dimensions should be as small as possible, they should be light and silent, limiting the user in their mobility as little as possible. Equally important are low energy consumption for a long battery life and reliable low-wear operation for long maintenance intervals. In this context, it is worth examining the drives that are typically used in the peristaltic pumps:

Although the small gear-based electric motors that are often selected generate the necessary high power or torques required for pumping, they are also slow; their mechanical micro-gears are seldom free of backlash and are furthermore very vulnerable to wear. Therefore, this solution cannot be considered to be truly reliable, because short maintenance intervals involve effort and costs.

There are also disadvantages associated with using direct, gearless drives. Depending on the design of the peristaltic pumps, comparatively less power or torque is delivered. Therefore, a larger drive must be selected, which in turn can affect the pump dimensions. In addition, the direct drives may respond faster but are not self-locking because the gear system is absent. To retain a stable position when at rest, they must consequently be supplied with current. For short operating cycles, i.e. if the duration of the medication is short and the rest periods are long, this has a severe impact on the battery life. The motor must therefore be mechanically blocked, even if it involves considerable effort.

All of the above are therefore ample reasons to search for an alternative drive solution for mobile drug pumps.

Compact Drive for Mobile Use

Piezo-based ultrasonic drives can open up new opportunities here. They are very compact, low-wear and self-locking. They therefore maintain their position not only when powered off, but also if they are dropped or hit. Due to their operating principle, their low profile and their individual adjustment options, they can be easily integrated into mobile drug pumps (Fig. 2) and work almost noiseless.

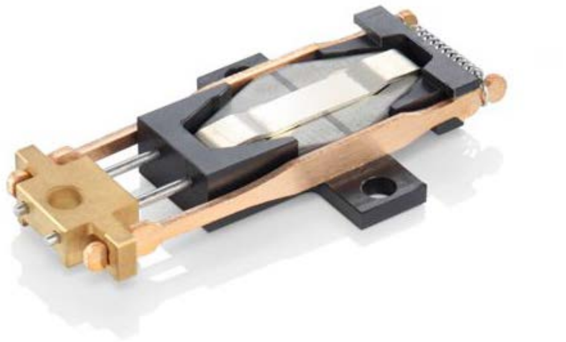

Fig. 2 Due to their operating principle, their flat design and their individual adjustment options, the piezo-based ultrasonic drives can be easily integrated into mobile drug pumps (Image: PI)

It is easy to understand how these compact piezo drives work (Fig. 3):

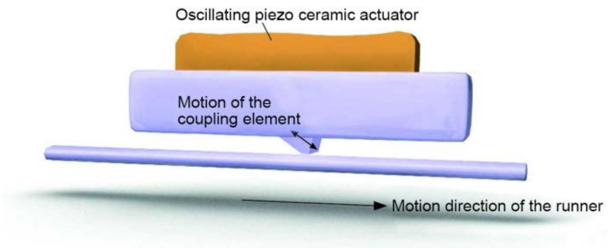

Fig. 3 Oscillations with ultrasonic frequencies of a piezoceramic actuator are converted along a friction bar in a linear motion and thereby drive the movable part of a mechanical structure (Image: PI)

Oscillations with ultrasonic frequencies of a piezoceramic actuator are converted along a moving runner in a linear motion and thereby drive the movable part of a mechanical structure. The core piece of the drive is a monolithic piezo ceramic (stator), which is segmented on one side by two electrodes. Either the left or right electrode is excited to the high-frequency natural oscillations of the piezoceramic element in the range of several hundred kilohertz and thereby determining the direction of motion.

A coupling element attached to the piezo ceramic is thus induced to fast linear motion. In contact with the runner, micro impulses move the movable part of the mechanical system (sled, rotary plate etc.) forward or backward. Each oscillation cycle moves the mechanical system by a few nanometers, thus producing an even motion with a theoretically unlimited travel range.

Various Designs are Feasible

The drives are built in a very compact manner, as they consist only of the piezo actuator and an embedded movable disk or linear axis. The drive electronics can be integrated as a chip and requires very little installation space (Fig. 4).

Fig. 4 Flat and small dimensions due to hollow runner design (Image: PI)

In addition, the solution is extremely low-wear and reliable, as there are few mechanical components such as gears. Dosages are possible in a wide range of speed spectrum. Depending on the design, dosages can be made from a few degrees up to several rotations per second, or, in the case of linear solutions, they can be made from less than 1 mm per second up to several 100 mm per second. Position feedback for the control is available for precise documentation.

Image 5 shows how such a mobile drug pump can be built: The motor consists of a piezoelectric ring (actuator). This actuator is excited in such a manner that a so-called travelling wave is generated. The thin aluminum oxide rings fitted onto the piezo ring (top and bottom) absorb the oscillations.

With the help of the three coupling elements used in the rotor, the absorbed oscillations are transmitted to the pre-loaded rotor and converted to a rotary motion. The piezo ultrasonic drives, which are arranged in a circular form, move the disk. It is built in such a way that thanks to the special geometry, different drug quantities can be dosed.

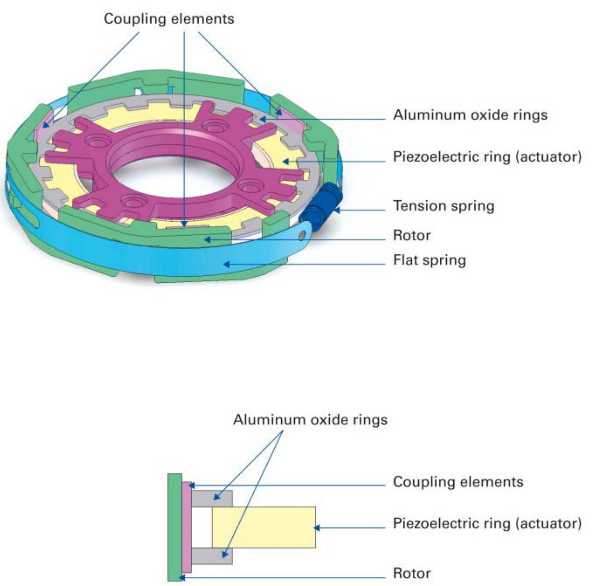

Fig. 5 A compact piezoelectric ultrasonic motor moves the disk. This system is built in such a way that thanks to the special geometry, different drug quantities can be dosed (Image: PI)

Other designs are feasible with piezo ultrasonic drives, too. The piezo actuator can, for instance, also be arranged on the side (image 6) and it can rotate a ring. In the large aperture of this ring other components can be arranged. Drug pumps built in such a manner are particularly small, light and silent. In addition, they offer a high degree of flexibility with regard to various therapies and dosages. In future, even more patients can thus benefit from an outpatient or ambulatory therapy.

Fig. 6 The PILine® motor can also be arranged on the side (Image: PI)

About PI

In the past four decades, PI (Physik Instrumente) with headquarters in Karlsruhe, Germany has become the leading manufacturer of nanopositioning systems with accuracies in the nanometer range. With four company sites in Germany and fifteen sales and service offices abroad, the privately managed company operates globally.

Over 850 highly qualified employees around the world enable the PI Group to meet almost any requirement in the field of innovative precision positioning technology. All key technologies are developed in-house. This allows the company to control every step of the process, from design right down to shipment: precision mechanics and electronics as well as position sensors.

The required piezoceramic elements are manufactured by its subsidiary PI Ceramic in Lederhose, Germany, one of the global leaders for piezo actuator and sensor products.

PI miCos GmbH in Eschbach near Freiburg, Germany, is a specialist for positioning systems for ultrahigh vacuum applications as well as parallel-kinematic positioning systems with six degrees of freedom and custom-made designs.

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