Life science, not rocket science: Motor optimization for liquid handling stations

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Critical for genomic, drug and vaccine research, automated liquid handling workstations have allowed lab technicians to make the latest scientific breakthroughs. The speed at which reproducible results are achieved is directly affected by the miniature motors selected for these machines, especially those operating on the complex Z-axis of movement. Correct specification can ensure that the next discovery, cure or therapy is delivered faster.

Valentin Raschke, Application Engineer at Portescap, explores the application characteristics of automated liquid handling workstations and compares two suitable miniature motor designs.

Sampling the benefits of automation

Liquid handling workstations take on the repetitive tasks such as uncapping and recapping test tubes; dispensing liquid samples accurately; as well as mixing, stirring, and transporting processed test tubes. Until recently, this work was carried out manually by trained technicians using electronic pipettes. The speed, precision and accuracy of this process was entirely dependent on the skill and experience of the operator. Automating these tasks enables higher throughput, eliminates the risk of human error, and improves the overall reliability and consistency of the process.

Manually operating pipettes is challenging due to variance in dispensing speeds for liquids of differing viscosity and the sheer concentration required to complete long, complex analyses. Consequently, the risk of costly mistakes like splashing and cross contamination is increased. Manual handling is also inherently slower, lowering throughput compared to automated systems, especially those using specialized multi-channel designs with up to 64 parallel tubes.

With automation, more samples can be analyzed faster. Finally, precision and accuracy are improved, helping to deliver consistent results across several iterations of experiments. By removing sources of variation regarding liquid volumes, results can be reproducible, allowing accurate conclusions to be drawn.

Challenges of moving on the Z-axis

There are multiple designs of automated lab machines available for liquid handling depending on the task. For analyzing a low number of test tubes, a single robotic arm with several rotary joints and a gripper might be sufficient. However, for higher volumes and parallel processing of samples, a design based on a cartesian robot with linear motion axes is optimal. In these systems, test tubes are held static while the pipettes are positioned above the test tubes using three linear axes: X, Y, and Z.

Of these, the Z-axis is more challenging to actuate and presents an interesting dilemma regarding miniature motor selection. This axis is where the pipette tip is moved into the liquid for aspiration and then raised after this is successfully completed. Speed must be combined with accurate positioning, with higher throughput balanced against very precise pipetting of liquids with varying viscosities.

The pipette is initially lowered towards the liquid container at high velocities, which demands an actuation system with good acceleration torque and speed for fast movements. Once it gets near the filling level, the head must be slowed as it approaches the fluid. When the surface of the liquid has been detected by a sensor, the pipette is positioned at a defined level below it to allow aspiration. Upon completion, the pipette head is retracted ready for the liquid to be dispensed where required.

Ultimately, any motor selected for this purpose must support slow, accurate movements when precise positioning is required, while offering high acceleration and speed during the lowering or retraction of the pipette head.

Comparing two suitable motor solutions

Due to the limited space requirements and highly dynamic motions of automated liquid handling workstations, power dense brushless DC (BLDC) motors are an optimal selection for driving the Z-axis of movement. There are two predominant designs. Slotless, inner rotor motors, like the Portescap 16ECP24, offer a small diameter but increased length, while slotted outer rotor motors, such as the Portescap 20ECF14, are flatter but at the cost of increased diameter. Combined with an encoder, both can provide high performance and accurate positioning.

The differences between the two motors extend beyond their dimensions. The most important motor characteristic for a drive system in an automated liquid handling workstation is acceleration. This depends on factors such as the rotor inertia of the motor, the maximum motor torque available for acceleration and the load inertia connected to the motor. Acceleration is mainly dependent on rotor inertia and available torque.

The inner rotor design of the 16ECP24 can achieve higher speeds of up to 30,000 rpm, which is an advantage on the Z-axis, but the lead screws and ball screws used in these machines usually set a maximum speed limit of below 10,000 rpm. Also, the linear distance travelled between pipetting may be short, offering little time for the motor to reach high speeds.

On the other hand, the greater moving mass of the 20ECF14 with the outer rotor generates higher inertia than the 16ECP24. This is counterbalanced by the multipolar outer rotor and its larger diameter, which provides a much lower motor regulation factor (change in speed due to change of load torque). Therefore, the 20ECF14 is more efficient and powerful with a 9 mNm maximum continuous torque rating (compared to 4 mNm for the 16ECP24) allowing it to achieve higher peak torque for acceleration. High peak torque generates heat, and the lower thermal resistance of the motor enables this heat to be dissipated more effectively during hard acceleration - another advantage of this design.

Handling motor selection with an expert

Ultimately, both motors are perfectly suitable for the Z-axis application. The 16ECP24 offers lower inertia and higher speeds, while the 20ECF14 offers greater torque capability and heat dissipation. Both have compact footprints to suit a variety of automated liquid handling workstation designs.

Different motors provide differing benefits and performance, so correctly selecting a solution relies on comparing several different factors with reference to the desired machine characteristics. Working with an expert in the field, such as Portescap, ensures that machine builders can benefit from experience and gain a motor that is highly optimized and cost-effective. Specifying the right motor for an automated liquid handling workstation not only ensures better reliability, performance and throughput – but helps shorten the time to the next scientific discovery.

Image captions:

Image 1: The 20ECF14 is more efficient and powerful with a 9 mNm maximum continuous torque rating.

Image 2: The inner rotor design of the 16ECP24 can achieve higher speeds of up to 30,000 rpm.

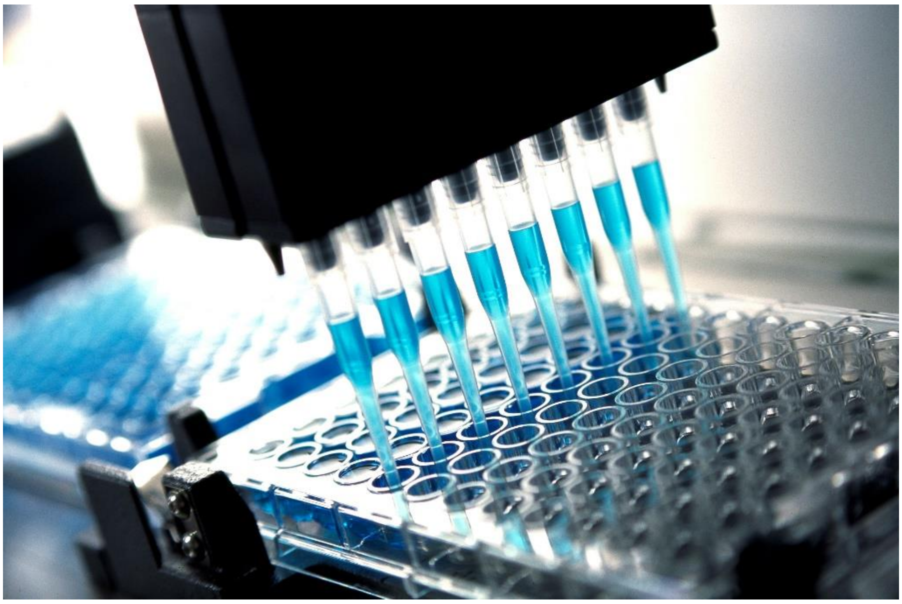

Image 3: Liquid handling workstations take on the repetitive tasks such as uncapping and recapping test tubes; dispensing liquid samples accurately; as well as mixing, stirring, and transporting processed test tubes.

About Portescap

Portescap offers the broadest miniature and specialty motor products in the industry, encompassing coreless brush DC, brushless DC, stepper can stack, gearheads, digital linear actuators, and disc magnet technologies. Portescap products have been serving diverse motion control needs in wide spectrum of medical and industrial applications, lifescience, instrumentation, automation, aerospace and commercial applications, for more than 70 years.

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