Strong guidance for miniaturisation

Industrial manufacturing of high-precision miniaturised positioning systems to customer-specific designs generally require sophisticated production strategies. As filigrain miniature roller tables can be integrated with **CAGE CONTROL** approaches, they become suitable for highly dynamic applications.

FRANK DEITER

Miniaturisation and system integration are significant trends in many areas of industry. While the compactness of motion systems is an essential basic requirement in medical technology, aerospace engineering and for optical equipment, semiconductor and electronics production specifications also specify a high level of dynamic performance. For pick-&-place, testing, bonding and microscopy applications the demand for greater dynamic performance goes hand in hand with increasingly fine precision requirements in the µm range.

Figure 1. Linear guide with integrated cage control: PM has a vertical integration of 95 percent for the mechanical components

Slimming down as a central requirement

Motion systems and their drive, guidance and measurement systems are following this trend. While numerous standard products are available for large and medium-sized guide rails and slides, suppliers' ranges start to thin out as the level of miniaturisation increases. At the same time, the sheer variety of applications and their specific requirements mean that custom developments or modifications are often essential.

Among the manufacturers that have been establishing a solid reputation for miniaturised linear guides and positioning tables is the company PM, based in Dedemsvaart in the Netherlands. If you thought that the original company name ›Precisie Metaal‹ still suggested a supplier of part-finished products, then now, 56 years after the company was founded, you would be very wrong. Today, the family-run company is a recognised specialist in high-precision linear guides and positioning systems, and is a global leader in miniaturised product variants.

Bert Post, Sales Manager at PM, provides insight into the company's expertise: »Around 90 percent of the market can be satisfied with standard products from established manufacturers. But we focus on high-precision and highly dynamic miniature positioning systems, many of which are only available from us in this form.«

High-vertical integration for mechanical components

The bearing units and structural components are really the heart of the guides and positioning systems and are completely milled, turned, ground, bored and hardened by PM. The company produces 95 percent of the mechanical components in-house, including the bearing cages **(Figure 1)**. Ball screws, piezo

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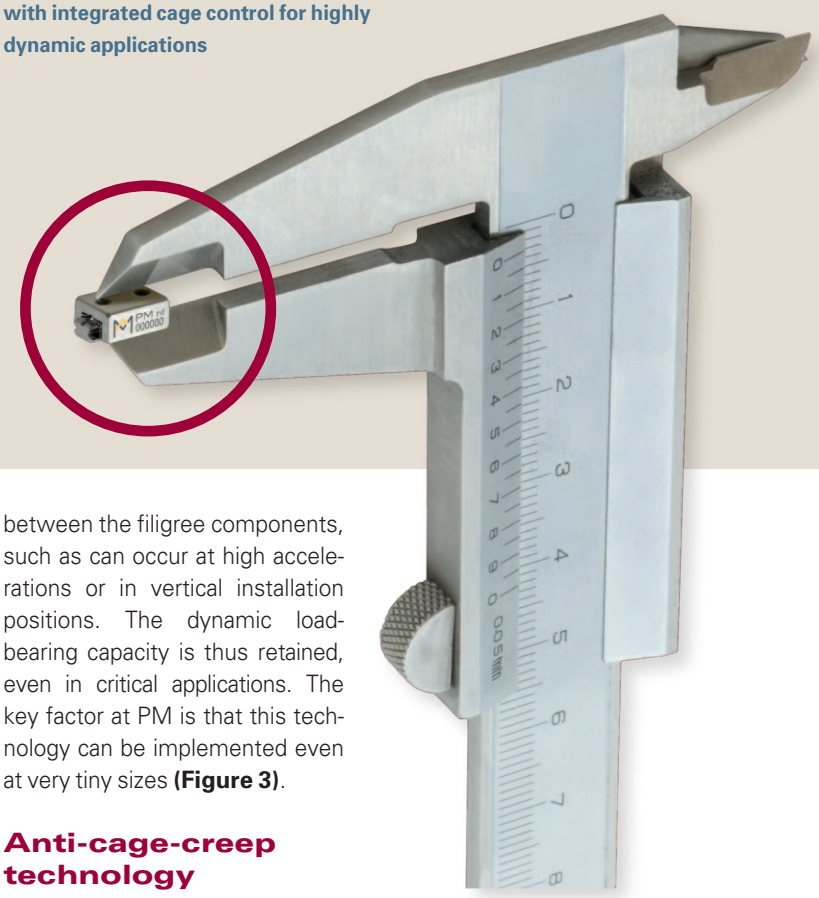
Figures: PM

Figure 2. Nothing smaller: ›MSR‹ microslide with integrated cage control for highly dynamic applications



drives and sensors are obtained from external suppliers. If the guides are used under critical environmental conditions, ceramic components will be utilised to provide exceptional high wear resistance and rigidity.

Already an established specialist in miniature slides and guides, the proportion of catalogue products sold by PM is constantly declining, as Post explains: »Today, only around 50 percent of our orders are for standard products. Most customers want product-specific adaptations, for example in terms of fastening and bore patterns for interface parts, sensors, piezo-drives and encoders.«

Post illustrates how small yet powerful the miniature roller tables can be with the example of the unrivalled ›MSR‹ microslide **(Figure 2)**. The smallest version has a length of 8 mm and a stroke of 5 mm, with a width of 5.5 mm and a height of 3.2 mm. Even at this size, a high load-bearing capacity of 191 N can be achieved. This is made possible by a special cage design and a crossed-roller arrangement. Thanks to an enlargement of the contact surfaces and a zero-backlash construction, even this tiny product can do great things. It can reach accelerations of up to 200 m/s^2 and speeds of up to 2 m/s.

To avoid fluctuations in the friction force and guarantee exceptionally harmonious linear motion, the microslides do not have a circulation guide on the rolling elements. However, a problem with highly dynamic guides with no circulation system is what is known as cage creep. This effect occurs when the ball cage is displaced from its original position due to very high accelerations or decelerations, stick/slip effects, insufficient tolerances or preloading. If this impairs the function, it results in increased friction, a reduction in the stroke and premature wearing of the linear guides.

The use of anti-cage-creep technology is a widespread solution to this issue. It involves holding the cage containing the rolling elements constantly in a defined position relative to the guide rail using a toothing mechanism. This prevents an offset between the filigree components, such as can occur at high accelerations or in vertical installation positions. The dynamic load-bearing capacity is thus retained, even in critical applications. The key factor at PM is that this technology can be implemented even at very tiny sizes **(Figure 3)**.

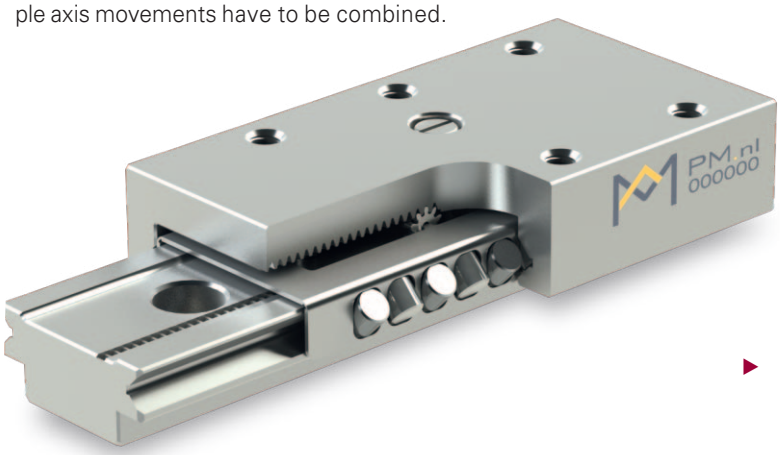
Anti-cage-creep technology

The filigree toothed bars with a modulus of 0.12 and a tooth height of 0.27 mm is either glued into the base of the V-shaped guiding groove or integrated directly using electrochemical processing. Although the microtoothing could be seen as a weakness due to the high dynamic loads, the component has proven itself to be extremely reliable and robust in long-term industrial operation. To push the system to its limits, PM subjects the microslides to extensive endurance tests with an additional load of 20 percent of the maximum value at maximum accelerations and loads, and the microslide can reliably deal with all of it.

From component to subsystem

The extremely compact construction of the MSR microslide proves particularly beneficial where multiple axis movements have to be combined.

Figure 3. Internal view of cage control: The toothed bar is integrated into the hardened material, requires no adhesive and is therefore very robust and reliable



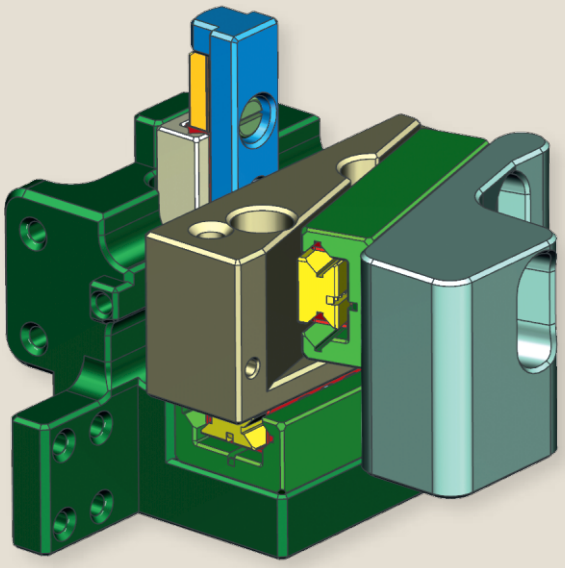


Figure 4. Micromanipulator for wafer clamping (blue component): The combination of miniature slides allows exceptionally compact designs despite the complex kinematics

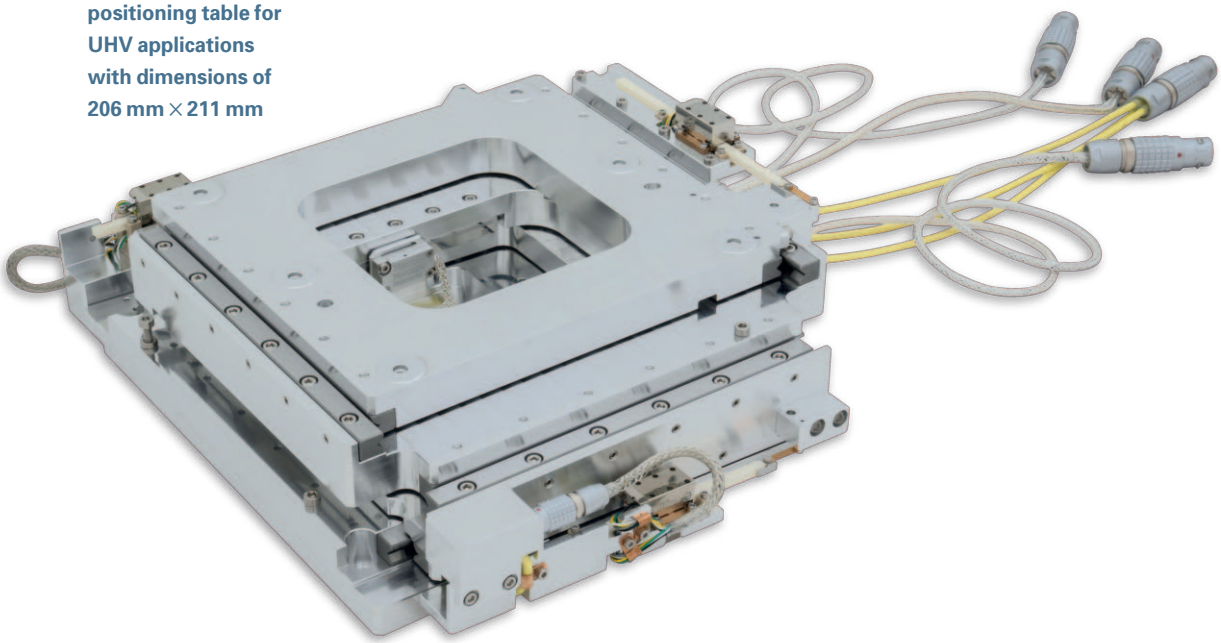
One example of this is a manipulator unit developed by PM **(Figure 4)**. Here, the x movement of one microslide is diverted to another in such a way that a high transmission ratio on the clamping axis (shown in blue) is achieved. A further difficulty was that a high vacuum application was involved, which necessitated adjustments to the selected materials. »Multiple motion directions in a very small space is something we can imagine numerous applications for,« says Jan Willem Ridderinkhof, Head of Development at PM.

But the transformation from a component to a system supplier calls for more in-depth application knowledge. Current DIN ISO standards are only applicable to a limited extent when systems have to be designed for specific applications. Factors to be considered include the influence of changing temperature, special lubricant requirements and the actual dynamic load with the corresponding tilting moments and torsional forces. »For the design of the linear guides we use advanced tools such as FEM calculations, empirical data and extensive practical tests,« says Ridderinkhof. As a result, the systems can achieve a repeat accuracy of 0.1 µm and a long service life, making them ideal for high-precision optical inspection and measurement systems **(Figure 5)**.

Selection and fine tuning of microslides

In practice, the travel forces also play an important role. Even at the very low forces involved, 0.15 N, the aim is always to achieve the smoothest and most consistent force progression. The primary weakness of every slide, even on a miniature scale, remains the wear on the guide surfaces. On the one hand, the specific choice of lubricant is vital, while on the other hand finely ground or even polished guide surfaces are recommended. Extremely accurate coordination of all components is the only way to produce the preload that will permanently guarantee the required zero backlash in tough practical applications. ■

Figure 5. From component to system supplier: xyz piezo-positioning table for UHV applications with dimensions of 206 mm × 211 mm



Figures: PM