

From Mechanical Engineering to Particle Accelerators

Hexapods and Their Fields of Application



Today, many automation technology sectors require highly precise positioning systems. For multi-axis solutions, parallel-kinematic systems often are the perfect choice. Hexapods are a good example for this, where the travel ranges go from only a few to several hundred millimeters. Even major loads can be positioned accurately to the micrometer using Hexapods.

Their advantages compared with serial, i.e. stacked systems, are that they have much better path accuracy, repeatability and flatness. In addition, the moved mass is low, enabling better dynamic performance, which is the same for all motion axes. Moreover, cable management is no longer an issue, because cables are not moved, and, last but not least, the system features a much more compact design. These characteristics can be used in a wide range of applications, from mechanical engineering and robotics to medical technology and research, as we will show in the applications described in the following.

The product range of PI (Physik Instrumente) includes powerful six-axis parallel-kinematic systems in numerous versions. They are suitable for different loads, come with different types of drives and are designed for all kinds of ambient conditions. On request, they can also be ordered to communicate directly with a master control system (Fig. 1).



Fig. 1 Hexapods come in various designs. The modular design of the Hexapods allows easy adaptation to the requirements of each application (image: PI)

Integrated in the Automation Line, with or without PLC

Due to a direct connection to the master control, Hexapods can be integrated basically in any automated production line in mechanical and plant engineering.

A synchronized clock with other automated components can easily be achieved, for example, for automated supply systems. Consequently, there are numerous areas of application for Hexapod systems, from metal cutting to complex alignment processes. Hexapods can be protected against adverse ambient conditions, for example by bellows. In this case, they even resist the rough ambient conditions in automatic machining units, where coolants are used for metal cutting processes.

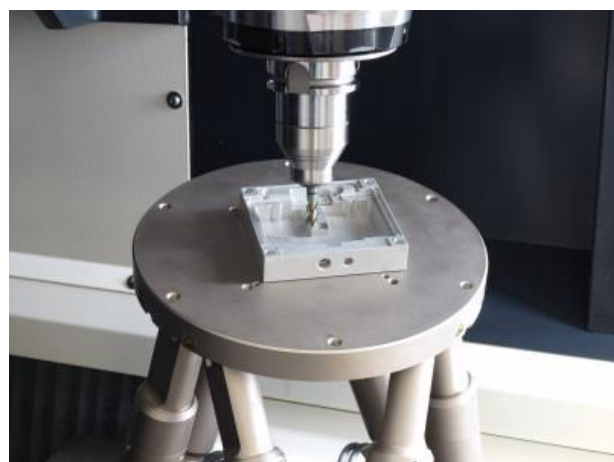


Fig. 2 Standardized fieldbus interfaces make integration easier: Hexapods in automation technology (image: PI)

In such applications, the PLC or CNC can communicate with the Hexapod system over a standardized real-time Ethernet interface (Fig. 2). The PLC acts as master and defines the target position in Cartesian coordinates and the trajectories; in return, it gets the actual positions also over the fieldbus interface.

All other calculations required to command the parallel-kinematic six-axis system are done by the Hexapod controller, i.e. transforming the target positions from Cartesian coordinates into drive commands for the individual drives. In this case, the controller acts just like an intelligent drive.

Adaptable and Flexible

Of course, the Hexapod controller can also act as master for position control. In this case the PLC only issues a position command. During the run, the motion cannot be synchronized with other drive axes, measuring systems, etc. If there is no parent PLC or if synchronizing with other system components is not required, the Hexapod controller can also control the trajectories based on G-code according to DIN 66025/ISO 6983 using linear interpolation. With this method, the Hexapod system can move the tool smoothly with highest precision during the machining process without causing an oscillation of the mechanical structure.

Hexapods from PI come in many different designs. A modular concept allows them to be customized within a short time. The Hexapod struts are designed so that their length can be easily scaled. They include the required electronics for reference point switch, limit switch, position sensor and – depending on the motor – electronic commutation. Their standardized joints allow them to be combined with almost any type of geometry for base plate and top. To find a suitable solution for a certain task is quite easy, since Hexapods can readily position and move even major loads of up to several tons with the high precision that is typical of them.

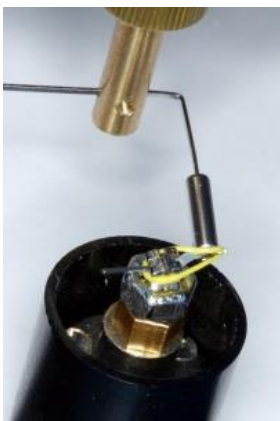


Fig. 3 The force sensor is mounted on the top platform of the Hexapod. It simulates a real tooth and registers the forces and torques acting there. (image: University of Ulm)

Precise Positioning with Six Degrees of Freedom in Measurement Setups

Quite demanding tasks can be solved with Hexapods: A good example of this is the following medical research application. In this example, an experimental setup is used to test how close orthodontic FE models are to reality and to modify them if necessary.

This numerically controlled experimental setup was developed by scientists of the University of Ulm to find out how the tooth, that is embedded elastically in the jawbone, behaves under stress. The setup can measure the clinically relevant forces acting on the moving tooth.

The biomechanical structure of the simulation system (Fig. 3) is based on a Hexapod with a very compact size of only 348 mm in diameter and 328 mm in height. At a repeatability of $\pm 1 \mu\text{m}$ (Z axis) and $\pm 2 \mu\text{m}$ (X and Y axes) and thanks to the high stiffness of the overall system, this system turns out to be the ideal solution for simulating the small motions of a tooth in the jawbone. In addition to that, its pivot point inside and outside the tooth root can be freely defined, a necessary prerequisite for biomechanical simulation.

The standardized elastic behavior of the periodontal ligament is simulated by means of a program especially developed for this purpose. The forces and torques generated by the orthodontic apparatus to be studied act on the phantom tooth via the orthodontic bracket and can be evaluated by scientists.

Sample Manipulation on Synchrotron Beamlines

Synchrotron beamlines are challenging potential applications for Hexapods. In such beamlines, X-ray diffraction and reflections of the synchrotron radiation can be used to investigate the structural properties of thin films as part of modern material research under high-vacuum conditions.

For the direct use of such a beamline, the company SURFACE, leading manufacturer of Pulsed Laser Deposition systems, has developed an all-in-one system that can be used for different types of tests.

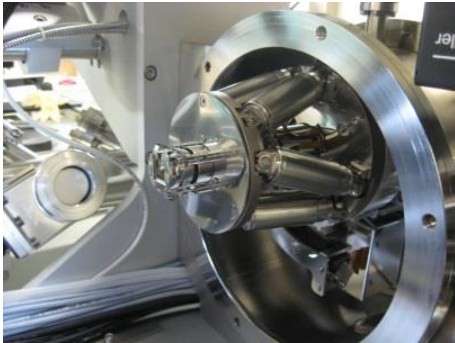


Fig. 4 The Hexapod, designed by PI for use in high vacuum, positions the sample, relative to the incident X-rays. The sample manipulator allows a wide angle range of the X-rays due to its small size even at low substrate heights (image: SURFACE)

For this purpose, the sample manipulator (Fig. 4) holds the 10 × 10 mm² substrates. The Hexapod, designed by PI for use in high vacuum, positions the sample, relative to the incident X-rays. This allows the sample to be tilted by ±5° around the X and Y axes at a resolution of 0.001°. In addition, to compensate for different layer thicknesses, it can be moved in the direction of the Z axis, i.e., vertically to the sample surface, by up to 3 mm. Motions of ±6 mm in the X and Y directions allow scans at different positions of the sample surface. The compact Hexapod, that measures 130 mm in diameter and 115 mm in height, is mounted to a rotary stage and can perform positioning tasks if required.

Heavy Duty Hexapods in Material Research

In synchrotron beamlines, also much larger Hexapods are in use, for example at the DESY research center (German Electron Synchrotron) in the city of Hamburg, Germany. This heavy-duty Hexapod (Fig. 5) is implemented in a beamline for material research.

As the “heart” of the experimental setup, the Hexapod allows for the measurement of material characteristics, that occur e.g. during material modelling and in

consequence give information on material aging and expectable useful life and lifetime.

Here effects can be proven down to the level of domain or crystal structures. With its high load capacity of up to one ton, the Hexapod carries the entire setup including the structure where mechanical forces are applied. Here the Hexapod positions heavy loads, such as cylinder block, turbine parts, sintering furnaces or cryogenic chambers as well as welding apparatuses or other machining tools, over travel ranges of 400 mm with an ±1 µm accuracy.

With these examples of application, Hexapods prove their versatility, and there are many more fields of application where these precise positioning systems will display their potential, ranging from automation technology and robotics to space telescopes or the particle accelerators described.

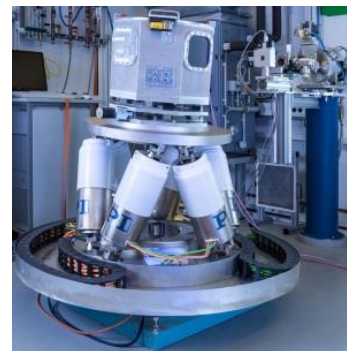


Fig. 5 A heavy duty Hexapod is implemented in a beamline for material research. As the “heart” of the experimental setup, the Hexapod measures material properties (image: Physik Instrumente (PI), Helmholtz-Zentrum Geesthacht (Centre for Materials and Coastal Research) at DESY, N. Schell)

Author



Dipl.-Phys. Birgit Schulze, Marketing & Products at PI (Physik Instrumente)

About PI (Physik Instrumente)

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 ten sales and service offices abroad, the privately managed company operates globally.

Over 700 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 our 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.



PI headquarters in Karlsruhe, Germany: More than 350 employees work on high-resolution drive systems and positioning systems