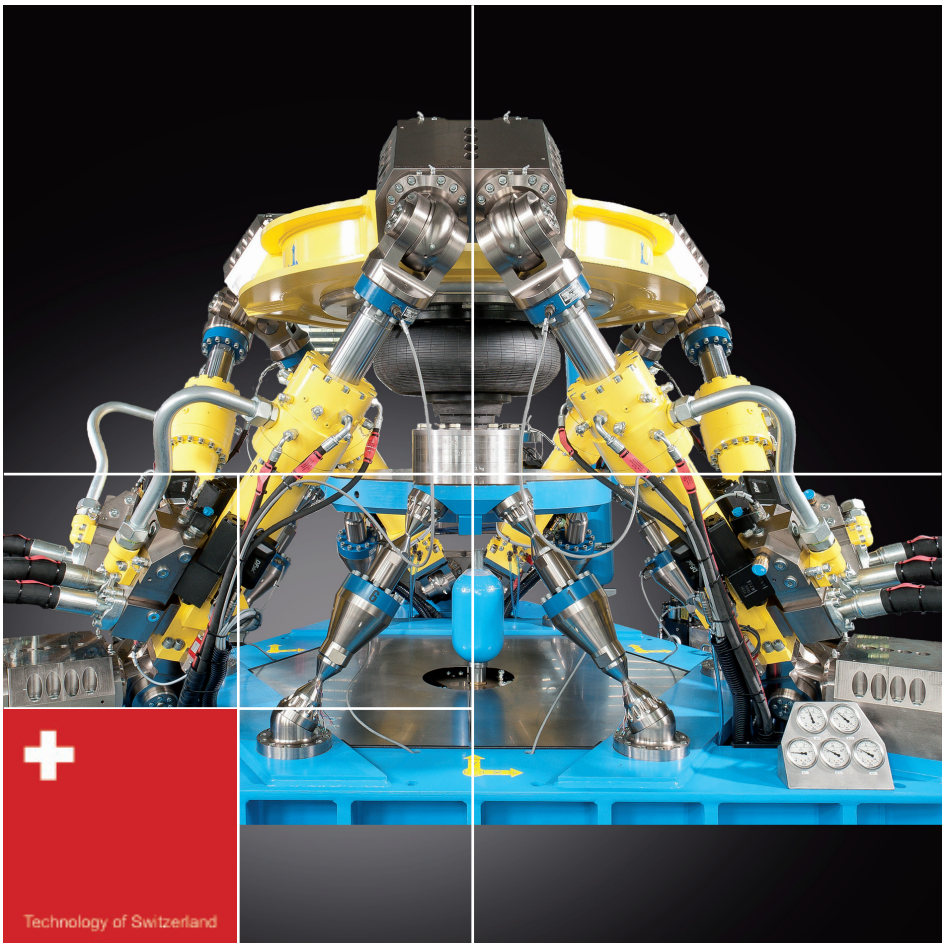
Hexamove –
Movement made easy

One stop solutions - Drives, Electronics, Software



TEST
MEASURING
POSITION
SIMULATE

HAGENBUCH
Hydraulic Systems

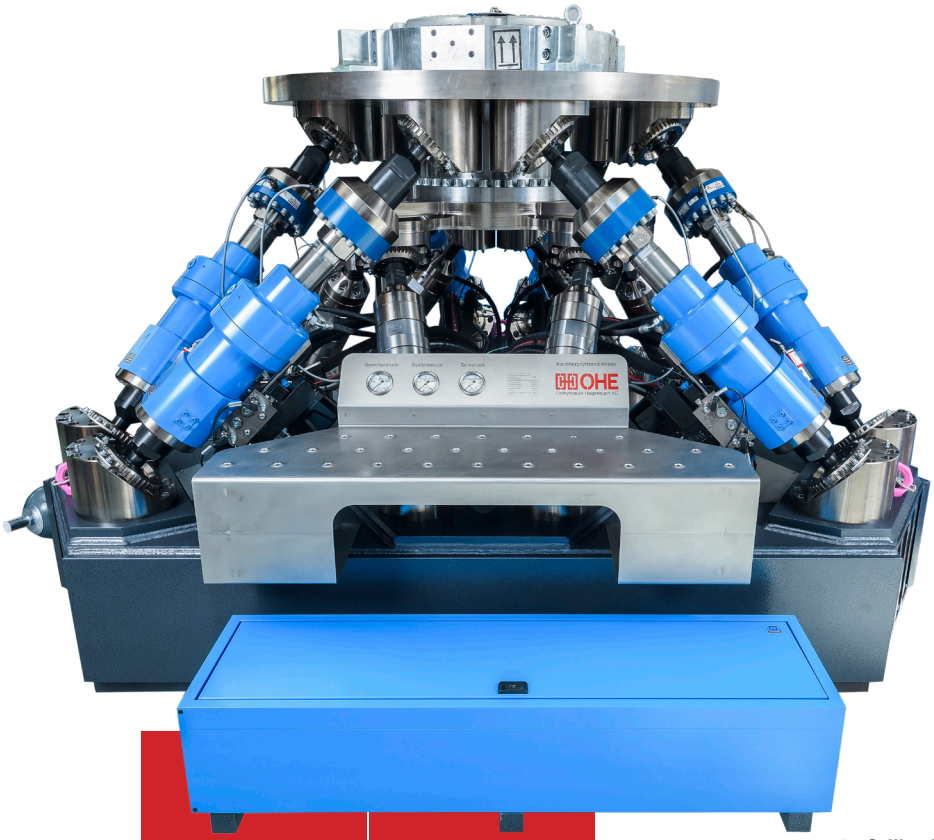
Valued customers, partners and all those interested,

We have been involved with the Hexapod for almost 30 years. The Hexapod story started for us in connection with „motion cinemas“, in which the seats move synchronously with the movie. This was a great novelty at the time! Together with a customer, we were able to install many systems with hundreds of motion platforms.

However, the control technology was still in the early stages of development at the time, so we took the bold step of modernising it by developing the hexapods for other application fields too with state-of-the-art engineering. Meanwhile this has resulted in many testing, assembly, robotics and simulation systems in a wide variety of fields.

As a manufacturer of complete systems technology, ready to use with hydraulics, electrics, control engineering and software, the Hexapod can be regarded as the supreme discipline. We are happy to present the technology to you on the following pages and hopefully to inspire you.

Heinrich Hagenbuch



H 1

1 Calibration test bench up to 50 kN

Hexapod test stations enable novel applications. The controller regulates force and torque at a defined point of application on the workpiece. The workpiece being mounted either to the upper surface or between the moving platform and the inner frame. The equipment achieves astounding precision and at the same time the 6 parallel drives can develop incredibly high forces. This principal has the further advantage that it requires no complicated mounting of instrumentation on the test sample.

Test with Hexamove

Test systems with Hexamove

The Hexamove-System has proven itself as an ideal drive concept for test stations. Depending on application the drives can be configured in various geometries and differing sizes. The test stations distinguish themselves through high precision, high dynamic and enormous flexibility.

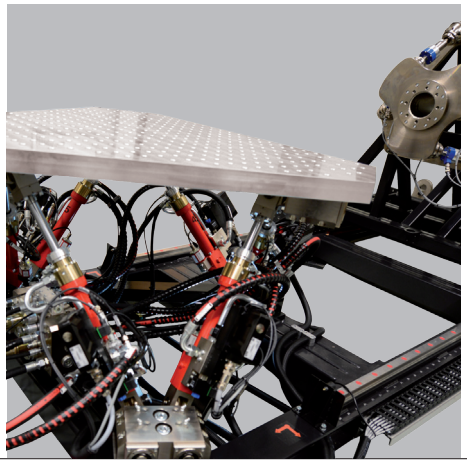
A Hexapod consists of two platforms connected via six drives. One platform is firmly anchored, while the other is subject to controlled motion. This enables many variants of test station where selectively the position or the force (torque) can controlled. A versatile software and control architecture enables easy integration of additional axes and measurement systems.

H **Hydraulic**

E **Electric**

2 Hexamove with an integrated shaker

This unit is actually a 7dof system. The Hexapod can be adjusted horizontally on a machine base with a moveable clamping plate. This allows samples of different sizes to be clamped between a horizontal shaker and the Hexapod. While the Hexapod controls the large movements and rotations in all directions, the shaker can generate movements with frequencies up to 500 Hz.



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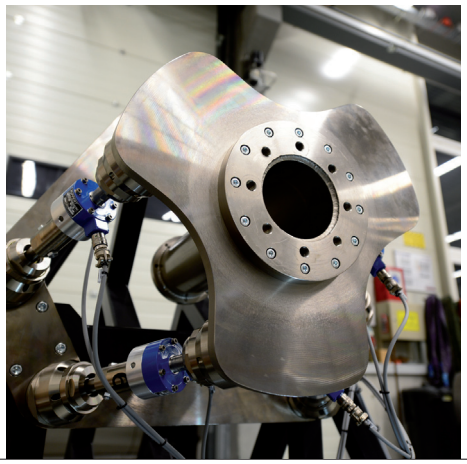
3 6-DOF forces and torque measurement - automotive industry

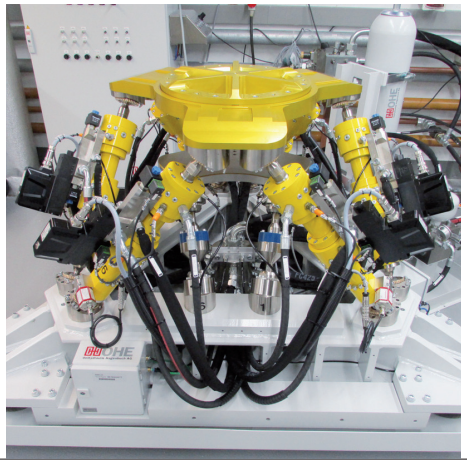
A second Hexapod for the very precise measuring of forces has been used in a series of other applications. In most cases, the so-called reference Hexapod was built into the main Hexapod. In this application there was a different solution: the reference Hexapod for measuring is mounted on an adjustable carriage to the side of the test station, which makes it possible to realize even larger measurement set-ups flexibly. The measurement is very precise and new software allows the specification of characteristic curves and transfer functions. Apart from measuring, the Hexapod can also be regulated according to forces/torques.



3

4 Testing of engine bearings

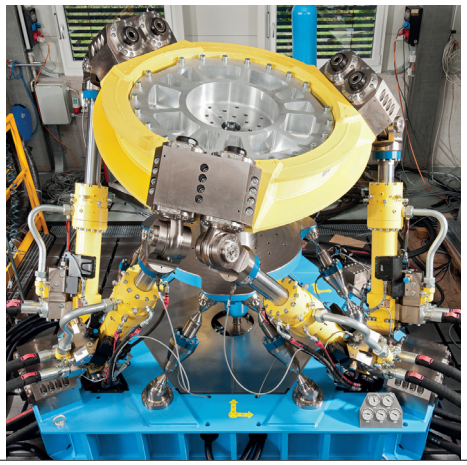
Engine bearings in vehicles are not just springs nowadays, but high-quality components with built-in intelligence, making it possible to adjust the damping properties to the current situation. This test station enables the simulation of a variety of environmental conditions. The determination of transfer functions with sweeps is a further major function, whereby the transferred forces are measured with an additional reference Hexapod.



4

5 Component tests for railway engineering

A leading manufacturer of railway rolling stock uses Hexamove technology to test their individual components or complete assemblies. The test bench fully automatically generates force-displacement characteristic curves for components in all degrees of freedom and under various loads. In dynamic component testing, the test bench also simulates the rough operating conditions for the rolling stock.



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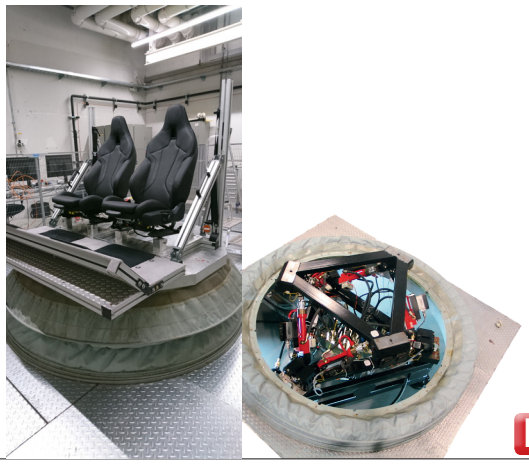
6 Test machines for wheel rims at the Fraunhofer Institut LBF

This system offers the possibility of separately defining the translation and rotation movements for each axis and determining whether forces or displacements need adjustment. The controller can therefore cover very diverse application areas. The illustrated application shows the rim force being tested by the weel being pushed against the shoulders in the drum. This enables the regulation of the side load and contact pressure, as well as control of the inclination of the wheel through angle adjustments. This ensures that test sequences are complete and realistic.

6

7 Driving comfort tests with hexapod simulator

The Hexamove system simulates acceleration measuring data in the laboratory. Driving comfort can therefore be evaluated with different vehicle seats in manner operations. Different measuring data are used for this, for instance data from difficult road profiles and also from typical road conditions. The measuring data are processed with motion cureing for the simulation and simulated synchronously to the movements using HexVideoPlayer software.

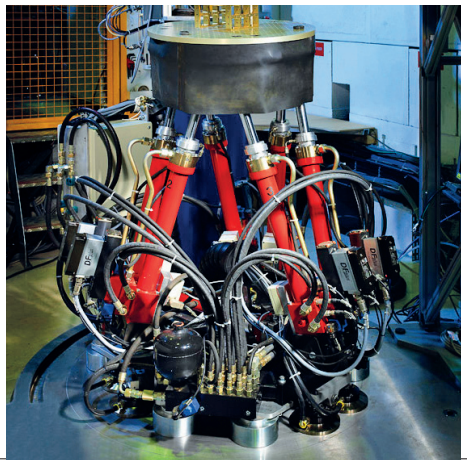


7

8 6-DOF precision positioning at ILL, France

The Hexapod shown here serves as a robotics system for the handling of components weighing up to 1000 kg. The parts, which can have any shape or size, are positioned within a neutron beam with a repeat accuracy of +/- 0.01 mm. This investigative method permits amazing discoveries to be made about materials, right down to their crystalline structure - without touching or destroying the test specimen.

(Source: kindly approved by ILL, Institut Laue-Langevin, France)



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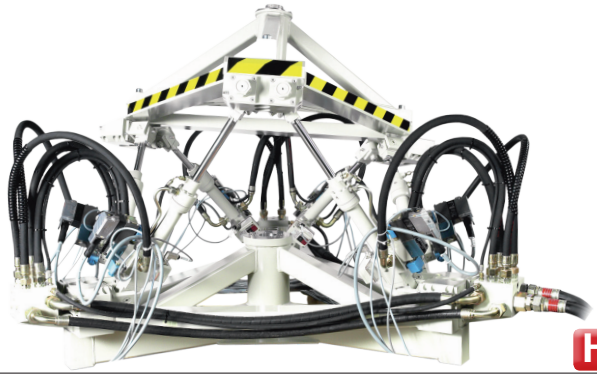
9 Motion platforms on vehicles

Strictly speaking the superimposed motion platform is a tripod and not a hexapod. Still the controls are based on the same software core as the hexapod. A feature of this installation is that the movement programme will be interpolated over the path, not over time. When the vehicle is slow, the motion is slow and with higher velocities the motion is faster. Different calibrating points make sure that the motion is always triggered at the correct position even with worn wheels.

9

10 High dynamic real-motion-simulator for automotive components

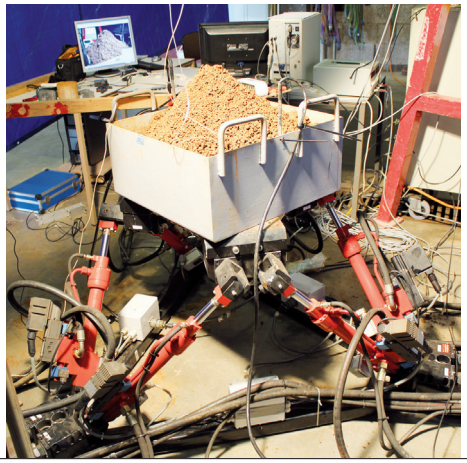
The Hexamove-System is equipped with a special workpiece mount. This allows expansion joints from automobile exhaust systems to be fixed in place. Then the test station runs Drive-Files that were previously measured on a real automobile. To create the realistic test conditions, the test sample is heated to up to 900 degrees Celsius.



10

11 Research for the high seas

This usage with its research work represents a special application. The Hexapod simulates ship movements, whereby aspects such as the heeling angle through asymmetrical loading, rolling at sea and vibration can be viewed in combination. A wide variety of goods, materials or liquids show quite a range behavioral patterns and have different effects on the ship. The aim of the analysis is to make seafaring even safer for people and the environment.



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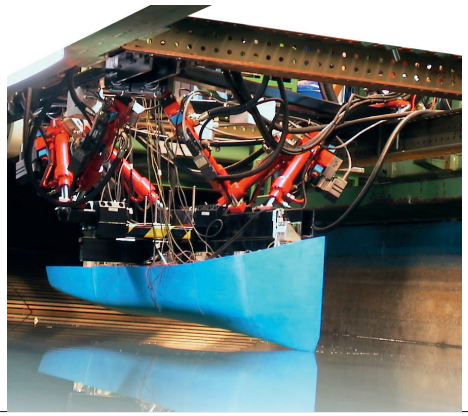
12 Hexapod for flow-analysis

Here, contrary to conventional flow channels, it is not the water but the ship-model that moves. This means the reaction forces are measured during the motion of the model. As a result the measurement system is completely integrated with the control system.



12

13 HGV mirror systems on the test-bench

A typical shaker application: A leading manufacturer of HGV and Bus mirror systems relies on the flexibility of the 6 DOF Hexamove-System for the testing of mirror systems. Using sinusoidal loads or Drive-Files the quality of the complex mirror system including servo-motor and electronics is verified in long-term tests. Particularly interesting: Even when not all 6 degrees-of-freedom are used, the system reduces costs thanks to the reduce setup time.

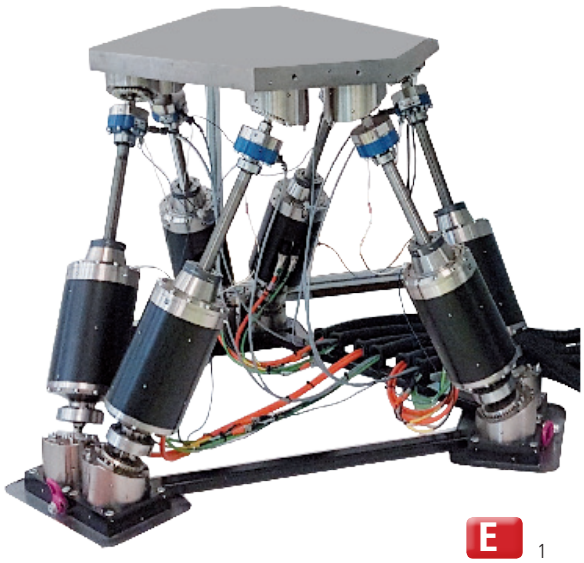
13

Robotics - Positioning with hexamove

Positioning systems with Hexamove

Parallel kinematics offers excellent characteristics for Robotics. Thanks to the parallel drives and an optimal relationship between moved deadweight and payload, large payloads can be moved very precisely.

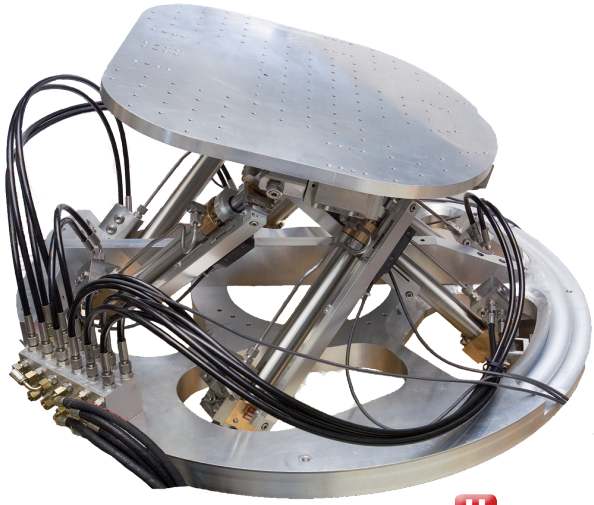
The Hexamove-Kernel is conceived so that it can be adapted to any parallel kinematic structure. The consistent conversion of coordinate systems and the large number control functions ensures a wide range of application.



E 1

1 Robotic system with electric drive

Complex production lines such as those occurring in the aerospace industry require precise positioning of the parts to be mounted on the end product. This electric hexapod allows the desired tasks to be performed exactly. The process calls for movements along a fully arched curve whose length is about 200 mm and which has an accuracy of one micrometre. Used to detect contact between the parts, the hexapod force measuring systems also apply the required pressure and equalise undesired tensions. As soon as the parts are adhered, the hexapod is responsible for delivering the assembled parts to the next phases of the production line.



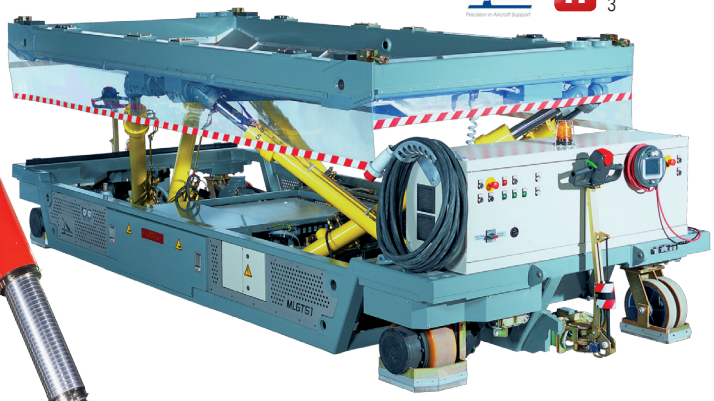
H 2

2 Precision positioning in extreme magnetic fields

This special Hexapod was developed for measurements with neutron beams in extremely strong magnetic fields. The apparatus is completely produced out of stainless-steel and aluminium. The insensitivity of hydraulic fluid to magnetic fields proved itself to be a great advantage. Despite separately installed drives and servo-valves the installation achieves outstanding repeatability of 0.01 mm, e.g. less than 0.001 degrees. Also impressive is the achievable workspace and tilt angles in relation to available installation space.

3 Airbus A380: Undercarriage installation

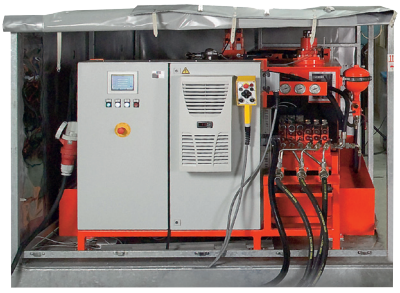
This Hexapod geometry was especially tailored to the demands of the Airbus assembly areas. In its retracted state the equipment is only table high. It can however extend out to up to 3 meter and achieve large tilt angles. All that with a repeatability of 0.02 mm!



H 3

4 3-DOF Lifting equipment for wide-bodied jets

When retracted only 1.7 meter high, yet when extended the noble height of over 6 meter is achieved. Using a hand-panel the jack is easily moved in all translational directions. The forces are simultaneously measured and if desired automatically compensated in order that excessive load on the aircraft can be avoided.



H 4

Bundling innovative strength

Hydro Systems KG is a leading manufacturer of service, assembly and handling devices for the aviation industry. We are delighted to be selected as a partner for technology encompassing parallel kinematics for the projects involving (6-DOF and 3-DOF) parallel kinematics.

H 5

5 Mobile, but still precise....

Rotatable on all axes, moveable in all directions, a great lifting height and precise control options - all in combination with a high bearing load of up to 2 tons. These are the exceptional features of the mobile Hexapod. The machine facilitates the positioning or mounting of heavy loads at a great height. The depicted dumper is transporting robots for the automatic mounting of solar panels to the starting position on a high steel framework. After precise alignment, the robot starts autonomously and place large numbers of solar panels. The degree of automation is decisive for the future reduction of the costs of alternative energy sources.

6 Precise electronic drives for research

The Hexapod positions workpieces with up to 300 kg weight and with a repeatability of under 0.01 mm / 0.001 degrees. To enlarge the workspace a rotating axis with extremely small footprint is integrated under the Hexapod.

E 6

Motion, entertainment and simulation

Simulations with Hexamove

The Hexamove systems open up exciting possibilities in the entertainment sector. It is a great advantage that Hagenbuch has developed the complete technology in-house as it enables them to take on the challenges of very customer-specific task.

Hexamove technology made by Hagenbuch has been impressively proven in numerous installations around the world. Well-known customers, such as Universal Studios in Florida, Futuroscope in France or Lotte-World in Seoul (South Korea) place their trust in the unusual service of the Hagenbuch engineers. Hagenbuch engineers have the right solutions - whether for installations in vehicles, comprehensive safety concepts, position or time-based motion programmes or motion platforms designed to actuate numerous other signals.

It is very important, for holistic and demanding applications, that the drive controller can be optimally integrated within a higher-level control system. The Hexamove control system, as a Motion Controller, also offers various bus systems such as Profibus, Ethernet-IP or even Timecodes such as SMPTE for synchronization with video projections.

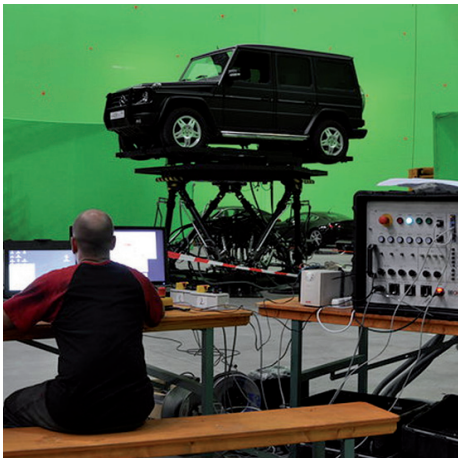
Hagenbuch engineers have also developed comprehensive safety concepts for the constantly increasing safety requirements of such systems. Perfectly conceived safety elements integrated in the control system ensure safe opertion of the equipment and bring guests back securely to their starting position after their exciting experience.

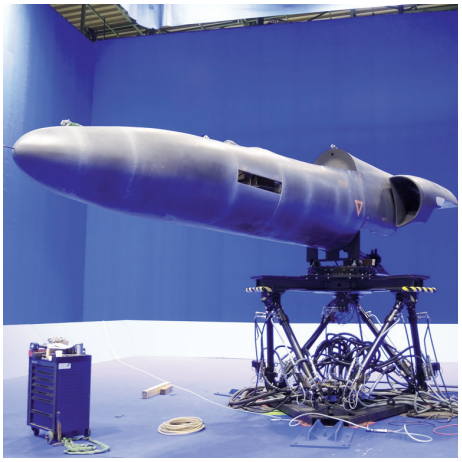
1 Hexamove simulation system

The Hexamove simulation system with its large working area and the greatest possible tipping angle makes unusual simulation applications a possibility. With the additional high load capacity, the platform offers customers highly diverse application possibilities, either in complete simulation cabins (image) or positioned openly in a room. The simulators are characterized by a high level of dynamics.

1

Hexamove – Motion action for Hollywood





Hexamove for the movie industry

Computer technology has revolutionized the movie industry. However, where people encounter virtual worlds, innovative motion platforms extend the possibilities significantly.

Green Screen Technology in combination with motion platforms has established itself to enable the shooting of challenging movie sequences in the studio. Hagenbuch technology supports and accelerates the software development process for this, as the experienced software engineers are very quick to grasp and realize the ideas of directors and the film crew. Many movie sequences are already simulated in advance on the computer and then the movement profiles are transferred to the Hexamove controls. In addition, there are often further special effects that must run synchronously or even require additional drive shafts. For such applications, Hagenbuch delivers a mobile system with up to 12 servo axes (linear and rotation axes) that can be put together flexibly as required.

A highlight for the Hagenbuch engineers was supporting the company Nefzer Special Effects for two major Hollywood productions: «Cloud-Atlas» with Tom Hanks and Halle Berry and «Die Hard 5» with Bruce Willis.

Software and controls for Hexamove

The heart of the Hexamove system

It is only with high-performance controls and software that the Hexamove system really comes to life. In order to meet the very varied and individual customer requirements, this core competence is developed in a completely bespoke manner. This is the only way to fulfill the variety of wishes and to deliver a customized and technically outstanding solution to each customer.

The controller concept is based on a very high-performance master in combination with the ultra-high-speed fieldbus system GinLink. A 2.2 GHz power PC CPU with 4 cores (actually with four processors) makes the controls extremely flexible. The 4-core architecture with a high processing power enables the parallel distribution of the real-time tasks of the 4 individual processors. This makes optimal use of the performance and results in high sampling rates for the regulation. The processing power is so high that it is possible to realize applications with up 90 axes to be regulated. The controller is therefore not only designed for the 6 axes of the Hexapod, but can also synchronize additional drives.

The great flexibility of the system is achieved through the fieldbus system GinLink. With up to 256 individual fieldbus nodes, the controls can be perfectly decentralized and adapted to the application.

Controller, hardware

The latest generation is setting new performance standards for real-time regulation. The heart is a Power PC CPU with 4 cores that works with 2.2 GHz. The real-time operating system enables true multitasking, whereby the tasks are spread in parallel over the 4 individual processors. This enables an absolutely synchronous data transmission and regulation, even for complex signal processing.

Apart from the Hexapod, the controller can incorporate and synchronized additional axes, or alternatively regulate several Hexapods at the same time. The latter is especially necessary for complex assembly applications or for motion cinemas with several motion bases.

The master is configured with a fixed IP address and therefore communicates with all other network participants set up for it.

Most important performance features:

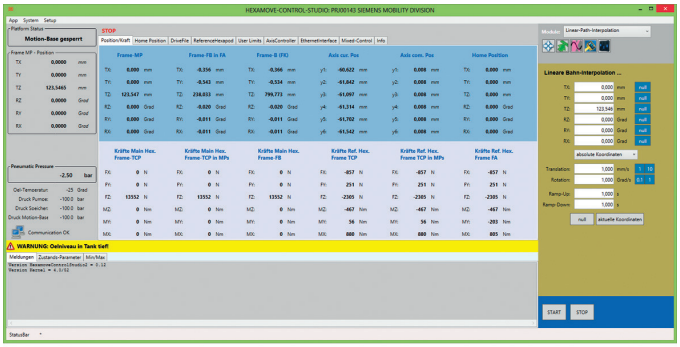
- Interfaces with Hilscher: EtherCAT, PowerLink, Profinet, Profibus, CANopen
- CPU Power PC processor
- Clock speed 2.2 GHz, 4 cores
- Memory: 2 GByte SDRAM, 15 MByte Flash
- Interrupt time: 1 to 16 kHz
- Axes: up to 90

Technical possibilities:

- Up to 12 servo axes (6 for Hexapod)
- Up to 128 analog inputs (+/- 10 VDC, 0 ... 20 mA)
- Up to 128 analog outputs (+/- 10 VDC, 0 ... 20 mA)
- Up to 256 digital inputs 24 VDC
- Up to 256 digital outputs 24 VDC, 1A
- Inputs SSI
- Incremental encoder inputs
- Distances between fieldbus nodes: up to 50 m possible
- High-speed data transmission
- 1 GBit/s transmission rate
- Cycle times from 7.8125 us
- Absolutely synchronous data transmission
- Topology: ring or line
- Reach: 100 m per bus segment
- Jitter time: 16 ns per slave
- Protocol: Gin Frame over UDP (64000 full-size Ethernet-Frames/s)
- Deterministic: FPGA-driven data transmission independent of the CPU
- Data transmission simultaneously with data transfer

With a transmission rate of 1 GBit/s, the GinLink fieldbus has set new standards for motion controlling. The data transmission is independent of CPU through FPGAs. This guarantees the lowest latency periods and a very high synchronicity between master and slaves. The fieldbus is based on tested Gigabit Ethernet technology, which ensures maximum availability for industrial applications.

Software



High-performance controls

High-performance software requires high-performance hardware. The Hexamove controls used are at their core a real-time regulating board with a Power PC CPU, a lot of RAM and complete network integration.

An exceptional feature of these machine controls is the very fast bus system with practically any number of fieldbus nodes. This allows the number of interfaces for control, measurement and other features to be adapted to all tasks. As it is the case for conventional SPS controls, almost all types of signals can be processed, but much faster! Sampling rates of up to 16 kHz are possible, whereby the Hexapods usually work with 1.2 or 4 kHz.

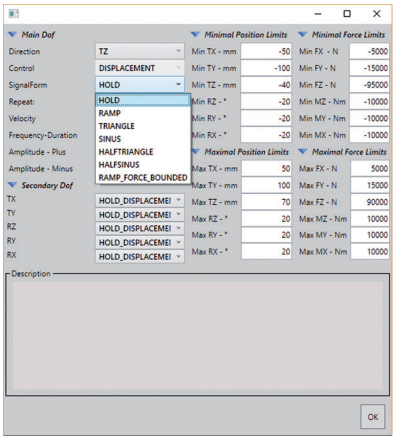
The test procedures can be carried out with the following software modules, which form the basis for the function module:

Software modules:

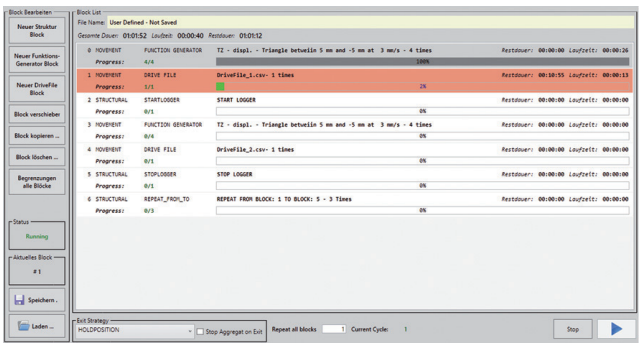
- Path interpolation for precise positioning
- Programmable zero point
- Position drive files with a wide range of options for online parameter setting
- Control pads
- Force regulation (also individual axes)
- Drive files with mixed path and force specifications
- Block programming
- Regulation of acceleration peak values
- Sweep for path
- Sweep for force
- Characteristic curves for path-force
- Characteristic curves for force-path
- Frequency response with frequency sweep
- Frequency response with amplitude sweep
- PDF test reports according to customer design
- Sample management
- Function generator with optimization
- Function generator with manual operation
- Control using Hexapod joystick
- Control using PC games joystick (software driver)
- Control using 3D mouse (software driver)
- Control of all or individual degrees of freedom according to external analog signals
- Moving to a neutral position to clamp samples
- Control in real time by means of Ethernet interface (data stream)
- Video synchronization (SMPTE Time Code or other)

General motion programming

Function generator



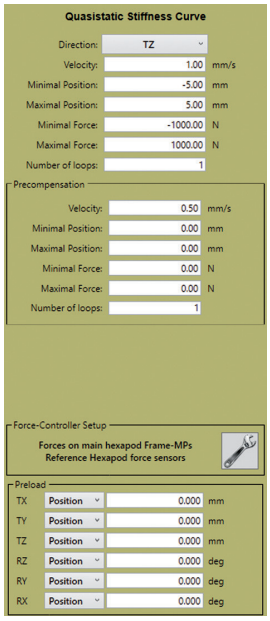
Procedure



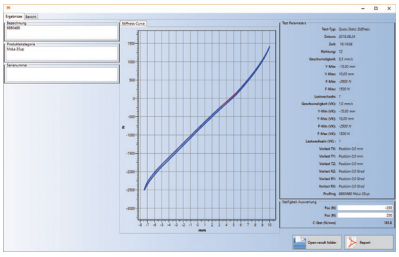
Testing a component

Static → Characteristic curve

Settings



Findings



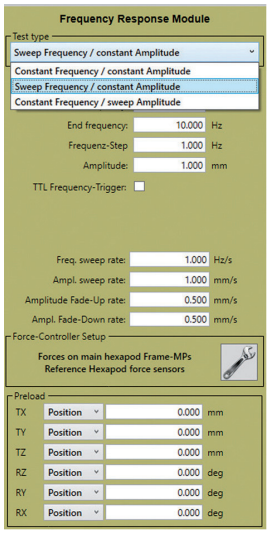
Force-displacement characteristics

Displacement characteristics are path-controlled. The path is adjusted by the requested degree of freedom and the force is recorded. The user can specify respective path- and/or force limits as well as starting points for path and force. The positioning speed is adjustable.

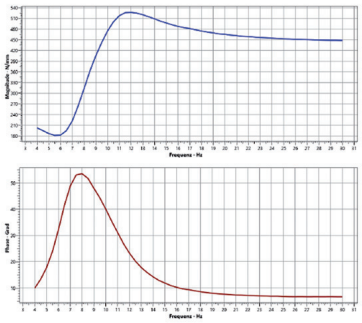
The output, apart from the raw measurement data, is a diagram as a characteristic curve with all specifications. Compensating curves can also be adapted if required, which is especially helpful for characterizing curves with hysteresis.

Dynamic → Frequency response

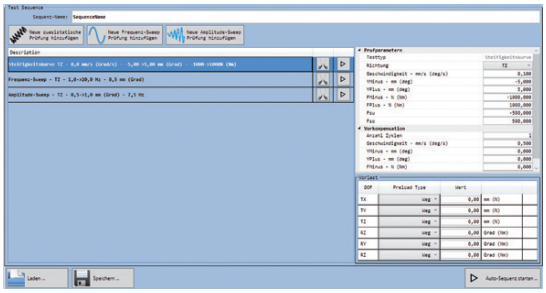
Frequency sweep settings



Amplitude sweep



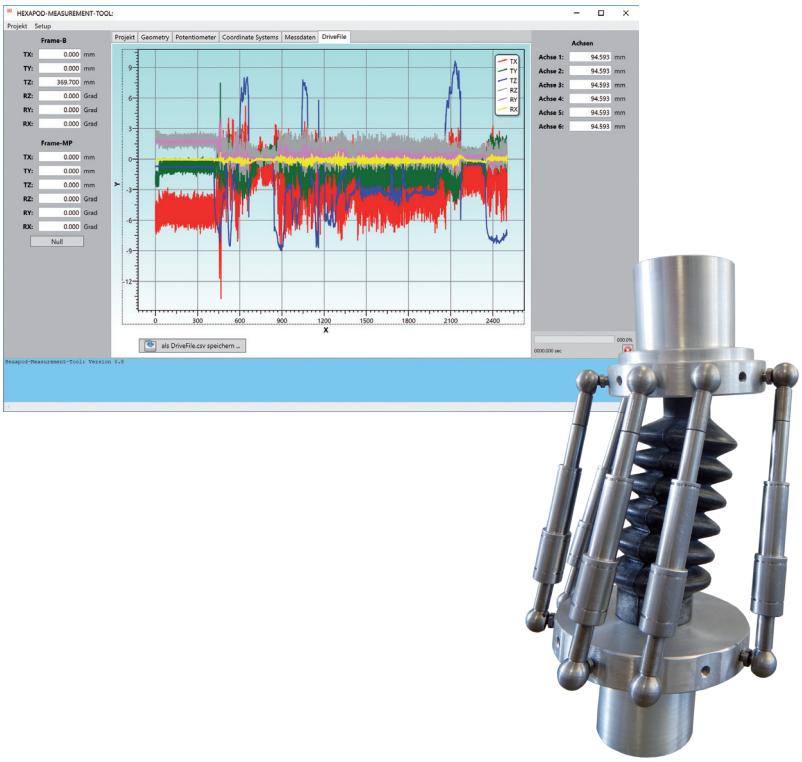
Autosequence



Dynamic stiffness of samples

The stiffness of components can often be dependent on the loading frequency. This behavior can be analyzed with the comprehensive module „dynamic curves“. The controller generates a sweep-frequency, whereas the amplitude is kept constant, or it generates a sweep-amplitude, which keeps the frequency constant. Following the frequency response, the resulting stiffness is recorded and calculated as a property of the component. This software module is therefore especially useful for identifying non-linearity and resonances.

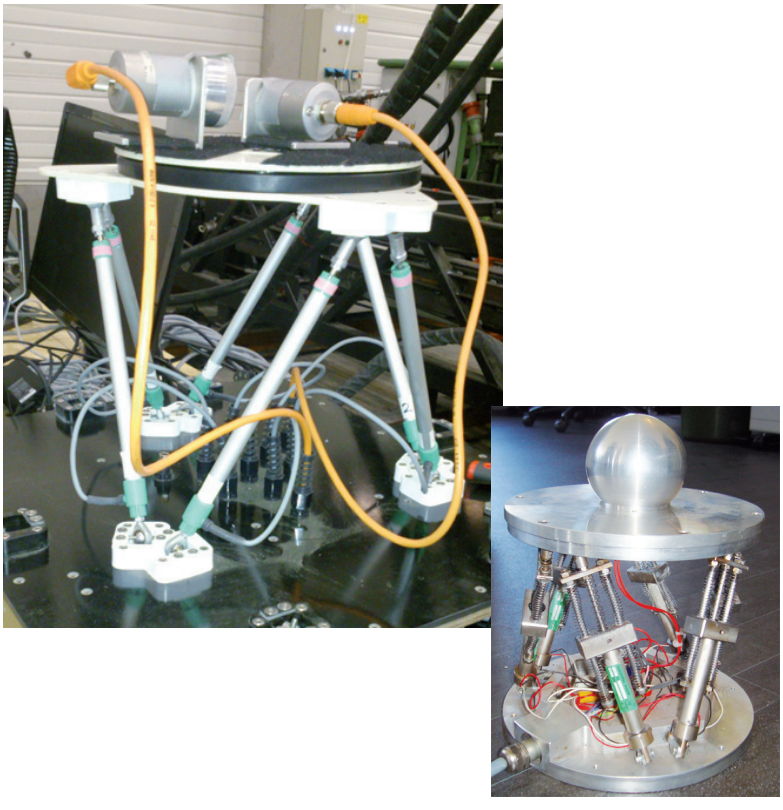
6dof movement measurement of the sample



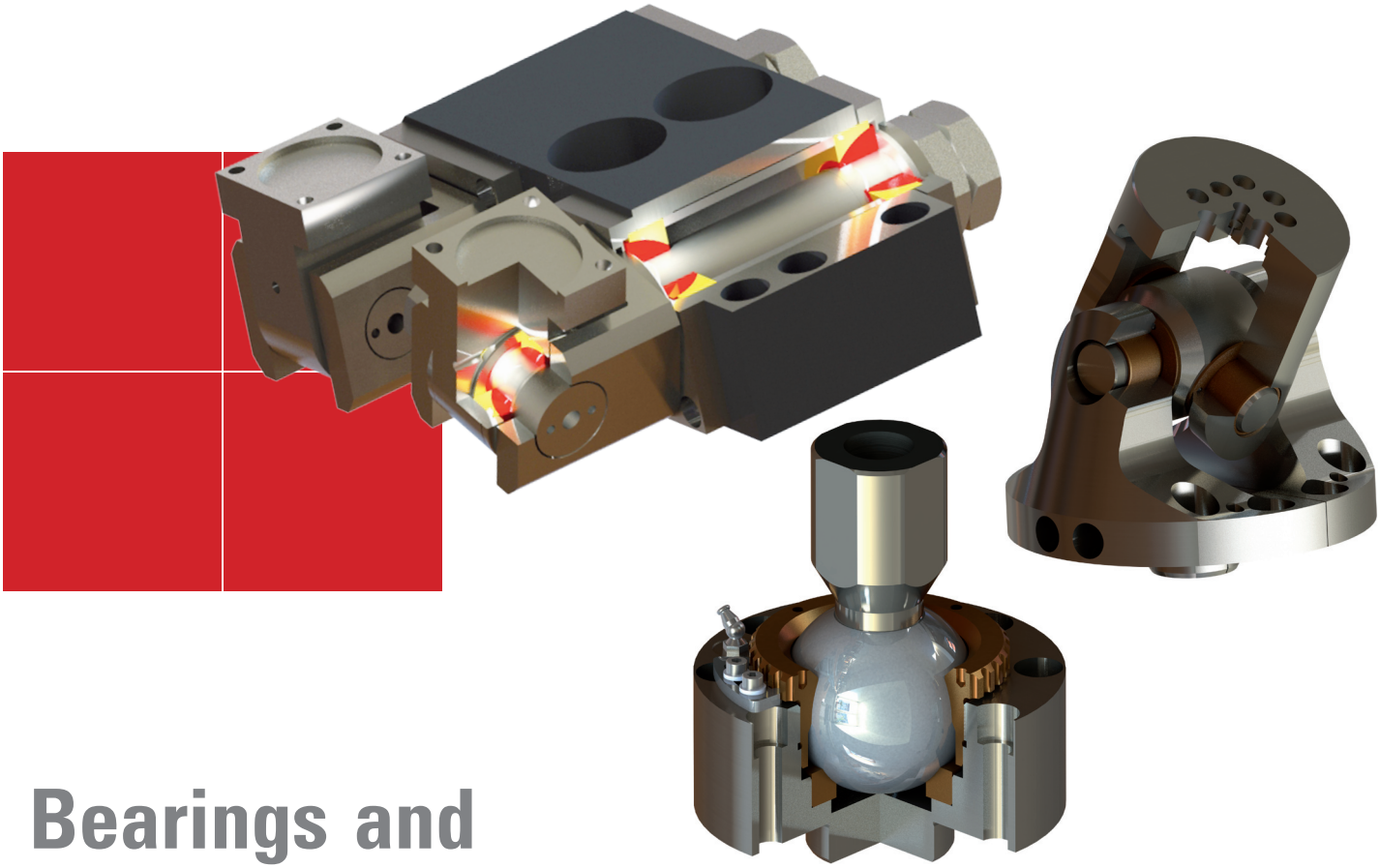
Our **HexMeas** software supports the user in the measurement of movement data. Six measuring systems in the form of potentiometers or in many cases wire-actuated encoders are set out variously between two moveable reference levels. The fact that the geometry does not have to be symmetrical often makes it possible for the measuring systems to be applied in the first place, especially when e.g. one side is not accessible.

The **HexMeas** software then converts this raw data into Cartesian movements. The same coordinate systems as on the Hexamove stand can be used to attribute the movement to a selected reference point. This software supplements the testing stations and supports the customer for data gathering in the field.

Joystick



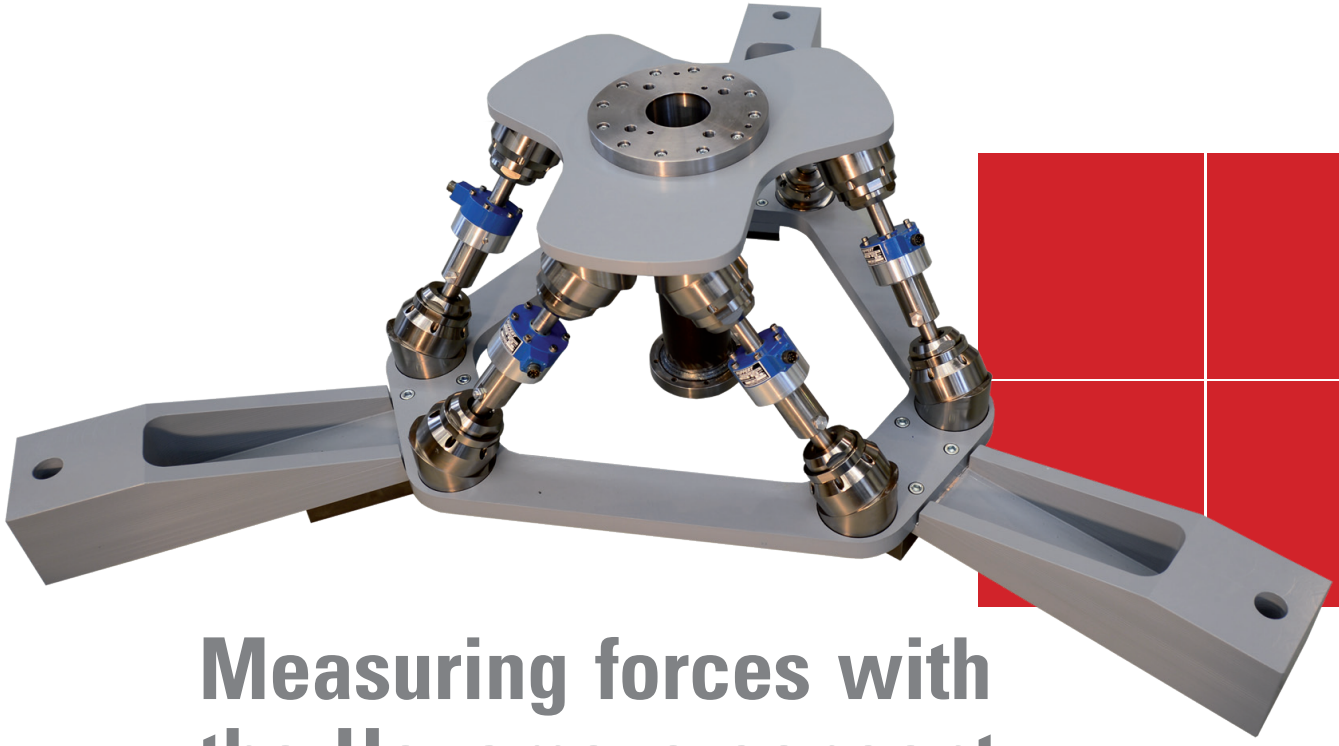
A joystick with its own specific Hexapod geometry is of particular interest for motion controlling in the field of entertainment. The controller converts the real-time joystick movements into Cartesian coordinates and uses these after processing them to specify the movement of the platform. Especially in the case of large platforms, the movement of the model is often more dynamic than permitted by the motion base, due to a great load or because of the foundation. For this reason, speeds and position/angle limits can be set freely. Signal filters ensure that noise effects are not increased. If required, individual degrees of freedom can also be switched off. All signals can be recorded and then used again as movement specifications.



Bearings and joints for hexapods

Depending on the respective application, various joint structures serve to achieve maximum stability, angular range, and bearing load.

Type of bearing	Bearing unit with roller bearing	Bearing unit with slide bearing	Cardan joints	Ball joints
Joint angle	suitable for large joint angles	suitable for large joint angles	suitable for medium to large joint angles	max. +/- 35° (depending on ball size and permissible forces)
Forces	suitable for rather small to medium forces	suitable for large forces	suitable for large forces	suitable for large forces
Vibration application	not suitable	suitable	suitable	suitable
Installation area	large	large	small	small
Maintenance	maintenance required	maintenance-free	maintenance-free	maintenance required



Measuring forces with the Hexamove concept

Measuring forces and torques

The measurement of reaction forces during dynamic movements, and the generation of characteristic curves and displacement diagrams, are very important and even essential in many applications. These forces can be static or dynamic forces during test sequences or even forces produced by vibrations. In a further application, characteristic curves can also be generated from force-displacement diagrams.

There are two options for measuring forces. In simple applications, pressure sensors are built into the cylinder chambers so that the forces are measured in the drive axes of Hexapods. For even more precise measurements, high quality load cells are used. The six axis forces then form six forces vectors that are converted to three forces and three torques via frame mapping on any coordinate system. In addition to the advantage of simple installation, two points are important in this solution: Firstly, the force component caused by the intrinsic weight must be compensated for dependent on the position. This also applies to the additional weights of clamping devices or heavy components. This method delivers very good results for little cost in the case of static applications or low dynamics. However, inertia forces must also be taken into account during dynamic applications.

The compensation of inertia forces is difficult, but is not required if a second reference Hexapod is used, which can also be used as a clamping device for the test specimen. The test bench measures the forces here not on the moving side, but on the fixed side, so that accuracy and sensitivity can be significantly enhanced. The construction is based on a static Hexapod with six load cells in the rods of the parallel kinematic. To prevent interference from bending stress caused by the high forces during deformation, the „legs“ have so-called spring joints that absorb the low deformations. The concept has proven itself in numerous applications, achieving excellent results with regards to accuracy and dynamics. The comprehensive software covers a wide range of applications, including the generation of characteristic curves and the control/monitoring of forces.

1

1 Measurement data acquisition

The standard controller version already offers a comprehensive measurement data acquisition system. Process data can be recorded continuously or on demand at high sampling rates. The hardware can be upgraded as required with modules for various signal types. The rack shown here has 24 analogue inputs and outputs in the form of BNC sockets. Measuring bridges are also supported. The inputs can ideally also be used as limit values for the programming of sequences. Highly precise trigger signals are available for synchronization with external measurement data acquisition systems.

Options

2

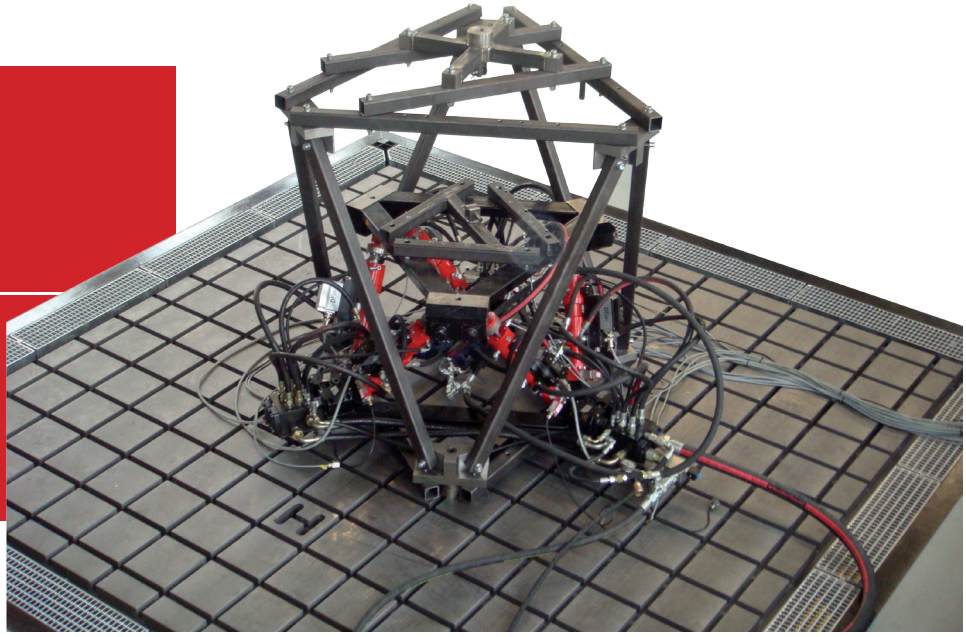
2 Control pads, joysticks and spacemouse

Control pads, joysticks or even a spacemouse: the Hexamove control system offers a variety of interesting interfaces for the safe setup of test structures, programming of motion, etc. The cleverly designed software enables, for instance, reduced pressure with limited speeds for setup and much more besides.

3

3 Synchronization of additional drives

The Hexamove control system can demonstrate its flexibility even more when the specific requirements of the customer become increasingly special. The control system can synchronously regulate or control several additional drives as well as the Hexapod. Drive files can thus contain far more information than for just six degrees of freedom. In the illustrated wheel rim test bench, the drum position, drum speed, etc. is controlled synchronously with a seventh drive.



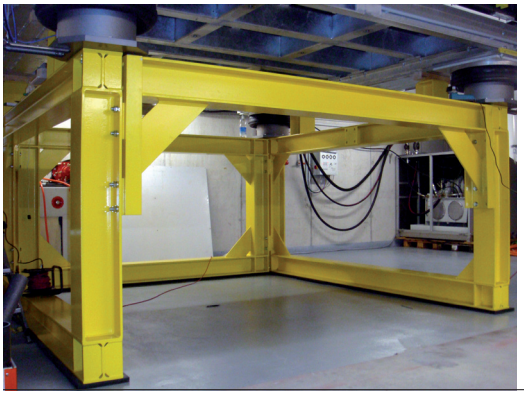
Our testing center
Individual testing for you

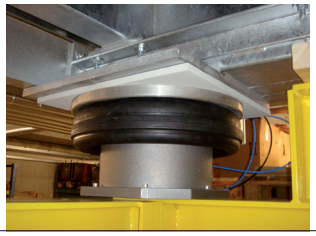
We offer our infrastructure and our expertise

In order to develop high-quality servo technology including drives, controllers, and software it also takes a test site for our engineers. Over the years, we have thus built up comprehensive infrastructure, which we can also make available to our customers. Apart from first-class technology, we also offre comprehensive services and engineering in relation to testing your products.

Our services

- Development of individual testing procedures
- Multiple axis systems with up to 12 axes
- Simulation of free drive files in path and force
- Path/force sinus pulsations
- Shaker with acceleration regulation, up to 250g and 600 Hz
- Sprung foundations for tests with clamping plates measuring 4 x 4 meters
- 6 DOF tests on HEXAPOD
- Measurement of material tension by means of strain gauges





Application areas:

- *Test benches for the automotive industry*
- *Assembly systems for aircraft production*
- *Special equipment for the aviation industry*
- *Simulation technology for motion cinemas*
- *Special motion systems for the entertainment industry*
- *Test benches with force regulation*
- *Precision positioning systems for research*
- *Motion systems for the film industry (special effects)*

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