

# Hydrostatic supports in test and measuring equipment

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**Abstract.** The relevance and advantages of hydrostatic supports in test and measuring equipment are shown. Structural and operational features are given when using hydrostatic supports as hydrostatic guides in vibration bars, vibration systems and measuring devices, ensuring minimum friction and smooth movement. The use of spherical hydrostatic bearings in ball joints allowing to create high-frequency pulse systems is shown. Examples of application of hydrostatic bearings in actuators, drives and spindle assemblies of test and measuring equipment are given.

**Supports in test and measuring equipment.** Quality of precision equipment is to a large extent determined by quality of supports providing rotation or relative movement of movable units of this equipment. The test and measuring equipment uses three types of supports: rolling supports, aerostatic and hydrostatic. Each type of support has its own advantages and disadvantages, which are the basis (or deterrent) for their choice in the design of the equipment.

Rolling supports are currently finding the greatest applications. Extensive experience in the design, manufacture and operation of rolling supports makes them indispensable in most machines, mechanisms, measuring, testing and other equipment.

Aerostatic bearings and guides have a number of advantages in rotation or movement accuracy, smooth movement, high wear resistance, etc. These advantages take over for precision equipment. For example, most coordinate-measuring machines are currently produced with aerostatic supports.

Hydrostatic bearings, compared to other types of supports, have a number of operational advantages, for example:

- High rigidity and bearing capacity of supports;
- Possibility of obtaining high accuracy of rotation or translation, which significantly exceeds accuracy of manufacturing of supports themselves;
- High damping capacity, which dramatically reduces vibrations during operation;
- Linear friction characteristic over the whole speed range, which allows to obtain high smooth movement and accuracy of positioning;
- Possibility to control output parameters of support (stiffness, thickness of lubricant layer, lubricant consumption, etc.) [1, 2, etc.].

Hydrostatic supports have a much larger bearing capacity compared to aerostatic supports. At the same time accuracy and other performance characteristics of these types of supports are commensurate with aerostatic ones. Therefore, hydrostatic supports find application in precision heavy loaded measuring and testing and other equipment. We will show the use of such supports on specific examples.

**Hydrostatic supports in vibration bars and vibration systems.** In accordance with national and international standards for quality and safety, most products are subjected to vibration loads during testing. The range of such products is quite large: from phones, computers, household appliances to engines and other units of road and railway transport, missiles and aircraft, etc. Tests are usually carried out on vibration bars (vibration systems), which should ensure the possibility of modeling complex dynamic processes.

SHINKEN Company specializes in the production of vibrostends<sup>1</sup>. If the rolling supports have point contacts, the hydrostatic ones take up the load over the entire surface area. Therefore, the only solution in this case is to use hydrostatic guides, which allows to ensure high strength and rigidity of the device.

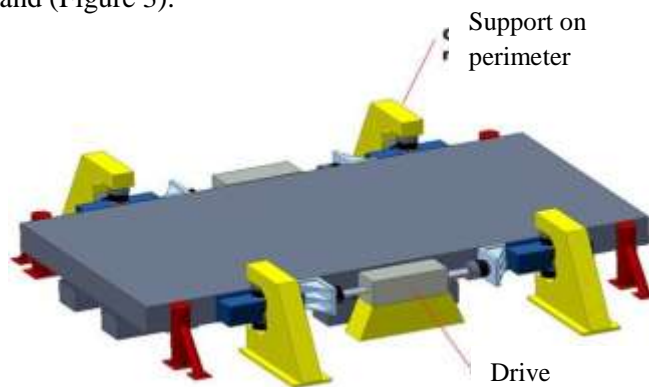
A general view of the Series G6 three-axis vibration test system is shown in Figure 1.



**Figure 1.** General view of SHINKEN vibration test system

The special technology implemented in unique systems with hydrostatic bearings allows to limit mutual influence of loads along three axes, which makes it possible to reproduce conditions of three-component loading as accurately as possible. Vibrostends of this series are capable of receiving load up to 10 kN.

Team Corporation<sup>2</sup> is the leading European manufacturer of vibration testing equipment. Team Corporation's development in vibration testing is used in all areas from weapons, aircraft, missiles and automotive to all types of tools. The quality and reliability of Team Corporation vibrators has been confirmed by many years of experience in their operation. For example, a family of "HydraShakers" test benches with axial hydrostatic bearings are used to test large heavy objects with a shifted centre of gravity. The company uses hydrostatic supports in electrodynamic and servohydraulic vibrations, which have up to 50 mm table travel offset. For these benches, a modular design of Model T8-2.5 hydrostatic bearings (Figure 2) has been developed, which can receive an active vertical load of up to 45.35 kN. Bearings provide easy movement, no play, minimal friction and high centering. In most cases they are used 4 or 6 pieces per stand (Figure 3).



**Figure 2.** Model T8-2.5 Hydrostatic Bearing

**Figure 3.** Arrangement of hydrostatic bearings on the bench

<sup>1</sup> Detailed information about SHINKEN vibration systems can be found in the official catalogue at: [https://testpartner.ru/wp-content/uploads/2018/10/English\\_Catalogue\\_RUSLowS.pdf](https://testpartner.ru/wp-content/uploads/2018/10/English_Catalogue_RUSLowS.pdf)

<sup>2</sup> Official website of Team Corporation (<https://blms.ru/team>)

Team Corporation's great achievement is the creation of ball hinges containing spherical hydrostatic bearings that allow for high-frequency, high-stroke multi-axis test systems.

The ball joint "HydraBall" can deviate 20 degrees in any direction from the neutral position and provide a direct loading path from the test load to the drive rod<sup>2</sup>.

The Asian company Suzhou Testing Instrument develops and manufactures equipment for testing resistance to mechanical external factors. The company produces equipment with hydrostatic guides. For example, electrodynamic vibration stand is used for testing large samples in aviation, aerospace, railway transport, etc. The feature of this vibration stand is the ability to sense an increased tipping moment due to the design of an additional hydrostatic<sup>3</sup>.

SHINKEN (Japan) is one of the world leaders in the development of vibration testing systems. The company produces vibration exciters and systems on both air and hydrostatic supports. For example, a Series G-6 triaxial vibration test system uses a unique hydrostatic bearing system to limit the impact of loads over three axes. This makes it possible to improve the controllability characteristics and accurately reproduce the conditions of the three-component load<sup>1</sup>.

IMV Corporation (Japan) produces electrodynamic systems that allow impact vibration and combination tests. The company produces multi-axis electrodynamic test plants of simultaneous and sequential impact (series "TS" three-axis and series "DS" two-axis)<sup>4</sup> with high rigidity of movable parts. These plants use high-precision hydrostatic bearings.

In Europe, one of the leading manufacturers of electrodynamic vibration stands is TIRA GmbH (Germany). TIRA produces sliding tables on hydrostatic bearings with a special metal sliding coating, the maximum size of which is 2000×2000 mm<sup>5</sup>. Application of sliding tables on hydrostatic basis allows to carry out wide range of testing of large-size objects.

Analysis of the vibration bars produced showed that for horizontal tables there are mainly two types of hydrostatic supports: spherical hydrostatic bearings in ball joints and hydrostatic bearings receiving axial load in guide tables. To ensure stable position of tables and perception of large tipping moments of such bearings, four, six and more are installed. In addition, the bearings are located both from the bottom of the table and from the top (see Figure 3) to provide a force closure. For efficient operation of the table guides, all bearings must have the same operational characteristics, which depend on the accuracy of dimensions, shape, arrangement, roughness of bearing surfaces of the bearing and throttling devices. It is possible to provide strict rationalization of accuracy of all geometric parameters at the stage of design and observance during manufacture and installation, or to use the second way, which is widely used in manufacturing of rolling bearings, sorting after manufacturing into similar groups assembly within one group. The sorting method for rolling bearings is justified by their mass manufacture. For hydrostatic bearings, the first method remains - rigid regulation of geometry. The difficulty is that at the moment there are no engineering calculation methods that allow to determine permissible values of parameters from the specified quality of bearings.

Actuators and drives on hydrostatic supports. GDS Instruments (UK), founded in 1979, is part of Global Digital Systems Ltd and is a global leader in the development and production of test equipment used in geology and geotechnics in both laboratory and field settings.

The company developed grainless drives using hydrostatic bearings, which are successfully used in GDS apparatus for triaxial tests. The three-axis GDS apparatus differs from its counterparts in that the control can be independently carried out in three directions<sup>6</sup>.

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<sup>3</sup> For more information on vibration testing equipment, see the official directory of Suzhou Testing Instrument at: <https://ptgk.ru/wp-content/uploads/2017/02/STI-vibroispytatelnoe-oborudovanie.pdf>

<sup>4</sup> Electronic catalogue of the 6th international exhibition-competition of measuring instruments «MetrolExpo - 2010». (<http://xn--80aajzhcnfck0a.xn--p1ai/PublicDocuments/1008594.pdf>)

<sup>5</sup> Electronic exhibition catalog «Chip-Expo - 2007» (<http://xn--80aajzhcnfck0a.xn--p1ai/PublicDocuments/0713073.pdf>)

<sup>6</sup> Official website of GDS Instruments (<https://www.gdsinstruments.com>)

Agron Fatigue Test Machines (USA) use hydrostatic bearing drives. For example, the 8803 fatigue test machine is equipped with a hydrostatic bearing drive that reduces the impact of lateral load<sup>7</sup>.

Servo-hydraulic fatigue test machines and systems use actuators with hydrostatic bearings. Hydrostatic bearings provide self-centering under side loads, reduce friction, which is relevant in control systems and have other advantages compared to sliding bearings.

Similar hydrostatic bearing actuators are used in HV series servohydraulic vibrators (L.A.B. Equipment, USA)<sup>9</sup>, in LFV 25-100 kN series multi-purpose servohydraulic dynamic test machines (Walter Bai AG, Switzerland)<sup>10</sup>, etc.

In Russia, works on the design of test equipment with hydrostatic supports were carried out at the Tomsk Polytechnic University, the LLP "Systems and Technologies," JSC SKB "Tochradiomash," etc. [3, 4]. In addition, a number of patented hydrostatic supports for test equipment [5, 6] or patented test bench designs using hydrostatic supports and guides [7, 4, 3, etc.] may be noted.

**Hydrostatic supports in precision measuring equipment.** ZOLLERN produces rotary tables (Figure 4, a) on hydrostatic bearings (Figure 4, b) up to 550 mm<sup>11</sup> in diameter for measuring machines that measure deviations in the geometric parameters of large parts. The 1000 mm diameter turntable is capable of receiving an axial load of up to 120 kN and providing an axial run-out of less than 1 μm.



**Figure 4. ZOLLERN Hydrostatic Turntable on Hydrostatic Bearings**

Talyrond 440/450 measuring systems, developed by Taylor Hobson (UK), are designed to perform accurate and complex measurements of the geometry of heavy products in various sectors of the automotive, bearing and aircraft industries. Depending on the design of the part, a rotating table model 440 or a rotating sensor model 450 may be used. The device colon in these models moves on hydrostatic guides, and the spindle rotates in hydrostatic bearings. The radial error of the measuring system is  $0.05 \mu\text{m} + 0.0003 \mu\text{m}/\text{mm}$  above the surface of the working plate<sup>11</sup>.

The following conclusions can be drawn from the analysis:

1. Hydrostatic supports are used in test equipment:
  - As hydrostatic guides in vibration stands and systems, ensuring minimum friction and smooth movement of movable parts of devices during tests of heavy and large-size articles;
  - As ball joints with spherical hydrostatic bearings, allowing to create high-frequency pulse systems;
  - As actuators and drives on hydrostatic bearings, receiving significant axial and radial loads, in equipment during tests for vibration, noise, tension, compression, etc.

<sup>7</sup> <https://www.directindustry.com.ru/prod/instron/product-18463-1949431.html>

<sup>8</sup> <http://studik.net/servogidravlicheskie-ustalostnye-ispytatelnye-mashiny-i-sistemy/>

<sup>9</sup> <https://ostec-test.ru/catalog/equipment/ispytaniya-na-vozdeystvie-vibratsii/servogidravlicheskie-vibrostendy-serii-hv/>

<sup>10</sup> Open repository (<https://docplayer.ru/56285461-Mnogocelnyye-servogidravlicheskie-dinamicheskie-ispytatelnye-mashiny-serii-lfv-kn.html>)

<sup>11</sup> ZOLLERN official website (<https://www.zollern.com/ru>)

2. In measuring equipment, hydrostatic supports are used as guiding rotary tables in large-size coordinate-measuring machines or as bearings in measuring systems of Talyrond type or in other circulars

3. It is shown that for hydrostatic guides inserts are used, representing open hydrostatic bearings with central working chamber of round or rectangular shape. Eight or more inserts are installed in one equipment, which must have the same technical characteristics in order to ensure equilibrium, which must be regulated in design and provided in manufacture. No engineering techniques have been identified for the calculation of accuracy characteristics.

4. Methods used in machine tool building can be used to calculate the characteristics of radial hydrostatic bearings in both test and measurement equipment.

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