Parallel kinematic components consist of a number of parallel, longitudinally adjustable mechanical struts that are arranged between the machine frame and the main spindle (see Fig. 1). Joints at the ends of the struts provide a pivotal connection between the frame and the spindle. Mechanical in-feed of the tool head is accomplished by means of electronically controlled, varying strut lengths. Switching the struts in parallel will normally move all of the assemblies present simultaneously.

Five degrees of freedom per strut are normally required for parallel kinematics, and these are provided by ball and universal joints.

**Advantages of parallel kinematics**

Parallel kinematics differ from serial kinematics in the three-dimensional framework of their struts. Due to its Cartesian structure, the serial design is susceptible to tensile and compressive forces as well as torsional and bending forces. The joints and struts in three-dimensional structures are subject solely to tensile and compressive forces (see Fig. 2). In contrast to machines incorporating traditional serial kinematics, machines are now available that are not only fast and extremely rigid, but also operate free of bending and torsional stresses. Parallel kinematics with INA components:

- are very rigid since
  - all forces from the joints and struts are always supported simultaneously
  - the kinematics of the joint transforms forces into tensile and compressive forces
  - low lateral forces from linear guidance systems are supported by the struts
- enable high accelerations because components are smaller and thus have lower masses
- operate very accurately since the total error quotient always refers to the struts rather than the sum of all axis errors (X, Y and Z axes), as is the case with serial kinematics (see Fig. 3)
- simplify overall machine mechanics and reduce the number of parts since struts and joints are supplied as complete units
- provide high mobility during the machining process since the low mass of the machine allows it to be moved toward the workpiece
- make machining more flexible since even complex processes can be completed in a single sequence
- are particularly suitable for the guidance and control of tool heads, for robots and for the machining of highly complex workpieces.
Components for parallel kinematics

Ball joints
with three degrees of freedom

Universal joints
with two or three degrees of freedom

Features

Ball and universal joints
Ball and universal joints for parallel kinematics:
- have two or three degrees of freedom (depending on the design)
- transform torsional and bending forces into tensile and compressive forces by means of joint kinematics
- are very rigid and have a high load carrying capacity
- are preloaded and thus clearance-free
- operate smoothly and free of stick-slip
- have pivot angles adapted to the design
- have a defined joint intersecting point
- are sealed
- are lubricated with a special grease and can be relubricated
- are Corrotect®-plated.

Ball joints
- consist of:
  - a ball pin with external threads, a ball cup with centering seat, a hemisphere, a hollow spherical seal carrier and a locknut
  - a large number of small balls. This ensures low Hertzian pressure between the ball cup, the hemisphere, the ball pin and the rolling element.
  - a lubrication adapter for polyamide tube DIN 73 378
- have three degrees of freedom
- have pivot angles from ±20° or to ±30° (optional).

Universal joints
- consist of:
  - a yoke with centering seat, a cross, preloaded and sealed radial and thrust needle roller bearings, and a locknut with lock washer
- have either two or three degrees of freedom
  - third degree of freedom by means of a combination radial/thrust bearing in the head of the cross
- have maximum pivot angles
  - up to ±45° in axis I
  - up to ±90° in axis II
  - up to 360° in axis III.

Ball joint
- GLK
  - hemisphere with ground outer raceway for seals, screw-mounted with ball cup
  - hollow spherical seal carrier screw-mounted to ball pin with locknut
  - full complement set of balls
  - rolling element raceways hardened
  - suitable for temperatures from −30 °C to +120 °C

Universal joint
- GLK 2
  - GLK 3
  - GLK 2 with two degrees of freedom, GLK 3 with three degrees of freedom
  - cross in yoke supported with radial/thrust bearings
  - combination radial/thrust bearing for third degree of freedom, axially located with locknut
  - locknut with lock washer for tight fit with strut
  - suitable for temperatures from −30 °C to +120 °C
Telescopic struts

Telescopic struts for parallel kinematics:

- consist of:
  - a sliding tube and a stanchion, a drive spindle with nut,
    a DKLFA four-row angular contact thrust ball bearing
    and four KUVS linear recirculating ball bearing units
- are equipped with INA ball and universal joints
  - the type of joint depends on the application and/or
    customer requirements
- are equipped with a ball screw drive or a planetary roller
  screw, depending on the rigidity required
  - screw pitch depends on the feed rate and/or customer
    requirements
  - the DKLFA four-row angular contact thrust ball bearing
    permits high spindle speeds with maximum rigidity
- are suitable for high feed rates
- move very accurately and smoothly and are free of
  stick-slip
- are clearance-free in all directions due to the torsionally
  rigid linear guidance systems and the ground raceways in
  the outer surface of the sliding tube
- have a low mass due to the design of the components
- are Corrotect®-plated
- can be supplied either with or without cardan suspension
  - the suspension can be supplied with U-joint bearings or
    with angular contact thrust ball bearings for heavy loads
- are manufactured with sliding-tube diameters of 50 mm
  and 70 mm
  - other dimensions are possible on request
- are supplied with various strokes
  - shortest stroke = 400 mm, longest stroke = 900 mm
- can be matched to customer specifications in terms of
  stroke, rigidity and reactive forces
- allow compact designs with fewer components in
  conjunction with ball and universal joints.
Maximum load capacity
The maximum load carrying capacity $P_{\text{max}}$ of ball joints depends on the:
- size of the joint
- direction of the load (tensile/compressive load).

$P_{\text{max}}$ can be found in Fig. 1.

Figure 1 · Maximum load capacity $P_{\text{max}}$
**Static load ratings for universal joints**

The static load ratings $C_0$ depend on the:
- type of joint
- pivot angle $\beta$.

Only the pivot angle $\beta$ affects static load rating $C_0$. Pivot angles $\alpha$ and $\gamma$ have no effect on the static load rating.

⚠️ Static load safety factor $S_0$ must be $\geq 4$.

INA should be consulted in the case of a deviating load safety factor.

Static load ratings $C_0$ can be found in Fig. 2 and Fig. 3 for each type of joint.

Joint types:
- F-232 098.1 and F-232 099.1 (Fig. 2)
- F-232 919 and F-232 920 (Fig. 2)
- F-233 323 and F-233 324 (Fig. 3).

---

**Figure 2** - Static load ratings $C_0$ with respect to pivot angle $\beta$

**Figure 3** - Static load ratings $C_0$ with respect to pivot angle $\beta$
**Ball joint**

with three degrees of freedom

Series GLK

---

**Dimensions table**: Dimensions in mm

<table>
<thead>
<tr>
<th>Designation</th>
<th>F-Number</th>
<th>Weight</th>
<th>Degrees of freedom</th>
<th>Pivot angle</th>
<th>Dimensions</th>
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<tr>
<td></td>
<td></td>
<td>kg</td>
<td></td>
<td>α β γ</td>
<td>H h₁ h₂² h₃ h₄ h₅ h₆</td>
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<td>3</td>
<td>20×20×360</td>
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1) Easy-connect cartridge for polyamide tube DIN 73 378 Ø4×0.75 with connecting thread M10×1, min. 6 mm deep.
2) Measured and logged.
3) 2 times on circumference.
4) 6 times on circumference.
5) See diagrams on page 4 for load ratings.
<table>
<thead>
<tr>
<th>D</th>
<th>d1</th>
<th>d2</th>
<th>d3</th>
<th>Ma</th>
<th>Mb</th>
<th>Mc</th>
<th>SA</th>
<th>C0</th>
<th>C₀ tensile</th>
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<td>40</td>
<td>32</td>
<td>6</td>
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<td>45</td>
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<td>350</td>
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</table>
# Universal joint

with two degrees of freedom

Series GLK 2

with three degrees of freedom

Series GLK 3

---

## Dimensions table: Dimensions in mm

<table>
<thead>
<tr>
<th>Designation</th>
<th>F-Number</th>
<th>Weight</th>
<th>Degrees of freedom</th>
<th>Pivot angle</th>
<th>Dimensions</th>
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<td></td>
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1) Measured and logged.
2) See diagrams on page 5 for load ratings.
Pivot angles α and β

F-232 099.1 with two degrees of freedom

<table>
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<tr>
<th>h3</th>
<th>h4</th>
<th>h5</th>
<th>h6</th>
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<th>d2</th>
<th>M6</th>
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<th>M2</th>
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<td>M65×2</td>
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<td>×80</td>
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</tr>
</tbody>
</table>

F-232 098.1 with three degrees of freedom
Telescopic struts
Series GLAE

### Dimensions table: Dimensions in mm

<table>
<thead>
<tr>
<th>Designation</th>
<th>Diameter of sliding tube</th>
<th>Dimensions</th>
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<th>D2</th>
<th>d3</th>
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<td></td>
<td></td>
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</tr>
</tbody>
</table>

1) Will depend on the surrounding structure and must be determined by the customer.
2) Depending on type of joint.
Application example
3D Waterjet cutting
Hexapod handling structure