

Machine Tools





Our inspiration	03
Product programme	04
Principle of operation	06
Machining Centres (Vertical Spindle)	08
Machining Centres (Horizontal Spindle)	10
Milling Centres	
Turning-Milling Centres	14
Tool Grinding Machines	16
Electric discharge machines	17
Water Jet Cutting Machines	18
Special Machines	19
Gear Combinations	20
Harmonic Drive® Technology	23



Our inspiration

Your business drives us. For every individual set of requirements, we have an equally diverse range of solutions: four out of every five products that leave our company are special versions, developed, designed, and produced to customer specifications – from space saving component sets to customised special drives. Harmonic Drive® Precision Drive Technology based on the strain wave gear principle can be found in machine tools, and of course also in robotics, the aerospace industry, and numerous other key industries.

Our headquarters are in Limburg an der Lahn, Germany, but our marketplace is the entire world. Since the company was founded in 1970, Harmonic Drive AG has grown from a small distribution company to a leading international solution provider with production capability for drive technology – with a parent company in Japan and a sister company in the USA, employees in more than 20 locations worldwide, and a product range of over 23,000 items.

Each product reflects our extensive expertise – and also the conviction that successful innovations are not made for the market, but are created by the market. We are your reliable partner when it comes to developing solutions together that ideally meet your needs – as a result Harmonic Drive AG has been creating pioneering products for nearly half a century.

Find out for yourself: share your next challenge with us and find out how your business can become a driving force for innovation.

The overview shows a selection of Harmonic Drive® Products used in machine tooling and in general mechanical engineering.

Servo products



	Available up to max. torque [Nm]	Application example cf. to page
1 Servo actuators without hollow shaft	647	9, 10, 11, 14, 17
2 Servo actuators with hollow shaft	1840	8, 10, 11, 12, 13, 16, 18, 19
3 Controller (Controllers with interfaces for diverse fieldbus systems, for example CANopen, EtherCAT, SERCOS II & III, PROFIBUS, PROFINET)	_	19

Precision Gears and Special Products



	Available up to max. torque [Nm]	Application example cf. to page
4 Component sets	9180	8, 12, 13, 17
5 Units	6840	9, 11, 12, 13, 14, 22
6 Planetary gears	2920	9, 14, 18
7 Special precision gears	9180	13, 15
8 Cross roller bearings (Customer specific cross roller bearings up to outer diameter 250 mm)	-	9, 11

Principle of operation

Circular Spline

A solid steel ring with internal teeth

A special ball bearing, mounted on an elliptical plug with a central hub

A flexible cylinder with external teeth

c

......

The Harmonic Drive[®] Gear belongs to the group of the strain wave gears. The Flexspline is slightly smaller in diameter than the Circular Spline resulting in it having two fewer teeth on its outer circumference. It is held in an elliptical shape by the Wave Generator and its teeth engage with the teeth of the Circular Spline across the major axis of the ellipse.

As soon as the Wave Generator starts to rotate, the zone of tooth engagement travels with the major elliptical axis.

When the Wave Generator has turned by 180 degrees, the Flexspline has regressed by one tooth relative to the Circular Spline.

Each turn of the Wave Generator moves the Flexspline two teeth in opposite direction relative to the Circular Spline.









1. Start

2. 1/4 Input rotation

3. 1/2 Input rotation

4. 1/1 Input rotation





For decades, robustness and unvarying precision have been the hallmarks of Harmonic Drive[®] Servo Actuators and Gears in the gruelling everyday environment of machining centres. A number of examples are presented in the following diagrams.

B- and C-Axes

These axes use both standard and customised Harmonic Drive® Servo Actuators and Gears, e.g. with a customised output bearing and positional feedback from the output side (see illustration 8.1, 8.2 and 9.1).

Servo actuator (CHA)



Output bearing with integrated angle measuring system Tooth belt input





- Output absolute encoder •
- Hollow shaft •

Illustration 8.2

Linear axes

Linear spindle drives require low ratio gears. Customers apply Harmonic Planetary Gear Series HPG and HPN for instance (see illustration 9.3).



<u>C-Axis</u>





- Customer-specific output bearing
- Absolute Encoder at the output

Pallet changer

In these indexing axes Harmonic Drive[®] Servo Actuators and Strain Wave Gears as well as Harmonic Drive[®] Planetary Gears are applied, cf the examples shown in illustration 9.2 and 9.3. Under

large loads, clamped spur gears may be installed downstream. During machining processes, the actuator is locked on the output side (clamping, indexing).



• Hollow shaft

Large output bearing



- Backlash up to < 1 arcmin
- High dynamics due to small ratio





Harmonic Drive AG also provides servo actuators and direct drives in addition to precision gears for the machining and peripheral axes of machining centres.

A- and B-Axes

On these axes, not only the precision of the output bearing is crucial, but also the torsional rigidity and the transmission accuracy of the installed gear or drive. Accordingly, these axes are always dimensioned with special consideration to the torsional stiffness needed for the application. The solutions feature various Harmonic Drive Products (examples see illustration 10.1 to 11.1).



For drive tasks with high demands to

- Dynamics
- Compactness

For drive tasks with high torque and long service life demands

- Hollow shaft
- Option air purge connection



Illustration 11.1

Unit (HFUC-2UH)



- Customer specific:
- Axial radial bearing as output bearing
- Very short design



Tool magazines and tool changer

These axes require high repeatability, compact size and high dynamic performance. Illustration 11.2 and 11.3 show typical solutions with Harmonic Drive[®] Servo Actuators and Units.

The solutions feature various Harmonic Drive[®] Units and Hollow Shaft Actuators and for high dynamic requirements LynxDrive[®] Series Servo Actuators.





A- and C-Axes

Harmonic Drive[®] Actuators, Units, and Component Sets are available in a wide range of variants for two axis milling heads. The crucial factors are not only precision, compactness, and the optional hollow shaft, but often the diverse options for the individual design of the actuator solution, as examples, see illustrations 12.1 to 13.3. We also provide custom solutions ready for immediate installation with integrated clamping systems, output side positional feedback, optimised transmission accuracy down to ±10 arcsec, and customised output bearings.

Pre-loaded spur gears

When combined with downstream clamped spur gears, milling head axes are possible with an exceptionally high torque capacity and torsional rigidity in a very compact size. Illustration 12.2 presents a detail of the A-axis in a portal milling machine. The depicted gearbox with integrated HFUC Component Set forms part of an arrangement for two-stage reduction. This arrangement features a spur gear that is clamped free of backlash with a split pinion and installed downstream of the Harmonic Drive[®] Gear. This means that the torsional rigidity is influenced primarily by the spur gear. As a result, a Harmonic Drive[®] Component Set with an outer diameter of only 135 mm and an installed length of 53 mm can be used as the input stage on the A and C axis of milling heads with spindle power outputs up to 55 kW (S1).

Further details on the subject of multi stage gears can be found in the section "Gear combinations".

Component set (HFUC-2A)



- Compact dimensions
- High torsional stiffness
- High transmission accuracy

Illustration 12.1

Servo actuator (CHA)



• Very high transmission accuracy and repeatability by using additional output side measuring system.

Illustration 12.3

Unit (CPU-M)



Optimised transmission accuracy (+- 10 arcsec)







- Large hollow shaft ٠
- Axial radial bearing as output bearing Integrated clamping system •
- •



٠

Extended hollow shaft for limit switches •

Large hollow shaft



Turning-Milling Centres

The proven Harmonic Drive[®] Products provide the optimal solution whenever high reliability, robustness, and high precision are demanded in turning and milling centres.

B - Axis

The B-axes use CPU Series Units and in case of higher torque capacity and life demand also CobaltLine[®] Series Units. In addition to their optional hollow shaft, these products also feature a particularly high transmission accuracy and an output bearing with minimised concentricity and parallelism errors (siehe Abb. 14.1).

Tool magazine and tool changer

Here, LynxDrive[®] Servo Actuators which have been optimized for high dynamic applications are often preferred. These very compact gear motors are available with all current measuring systems (incremental or absolute). Harmonic Drive[®] Component Sets and Units are also used.

Linear axes

Owing to their compactness and precision, Harmonic HPGP Planetary Gears are the frequent choice for actuating linear spindles in machine tools.





Hollow shaft

• Precision output bearing with high tilting rigidity



Multi-Spindle Lathes

When the focus is on maximising productivity in addition to precision and high power density, machine manufacturers turn to the reliability and unvarying precision of Harmonic Drive[®] Servo Actuators and Gears.

X-Axis

HDPL linear actuator for tool wear compensation

The unattended operation of cam controlled automatic multi spindle lathes requires autonomous tool wear and temperature compensation over the X axes. This function is performed by the linear drive shown in the example, consisting of an AC motor with toothed belt driving a Harmonic Drive[®] Gear with downstream ballscrew, cf. illustration 15.1. An integrated multiturn absolute encoder allows precise positioning without homing cycle.

<u>Y-Axis</u>

HFUC Component Set

Modern automatic multi spindle lathes can be fitted with optional Y-axes. During gear cutting or hobbing operations, these axes allow e.g. axial tool shifts for longer tool lives. Due to the restricted installation space, this linear axis must be particularly compact. These solutions give preference to HFUC Sets providing zero backlash, high torque capacity, and high torsional rigidity.







The axes in tool grinding machines demand particularly high transmission accuracies and zero backlash from the installed actuators and gears.

A-Axis (dividing unit) and C-Axis

Here often CHA and FHA-C Series Servo Actuators are used, partly fitted with single turn absolute encoders. These highly compact servo actuator variants use their hollow shaft to transfer the output position to the single turn absolute encoder mounted on the motor side. The servo actuator features a high precision output bearing of very high moment stiffness.

Other applications use CPU Series Units and HFUC and HFUS Component Sets.

Auxiliary axes

Also dressers and tool changers use the compact CHA and FHA-C series servo actuators.





• Single turn absolute encoder, hollow shaft



Electric discharge machines

The production of complex 3D workpiece geometries demands the most from the precision of the positioning axes. Harmonic Drive[®] Gears and Actuators are therefore often used in EDM machines.

C-Axis

The positioning precision needed for this axis requires positional feedback on the output side. The described application uses the Harmonic Drive® HFUC Series Component Sets, providing feedback of the output to the encoder mounted on the input side, cf. illustration 17.1. The gear is powered by a hollow shaft kit motor. At these precise rotating axes, high torsional rigidity and zero backlash of the used gears are an important precondition for good machining quality.

B-Axis

While standard eroding machines are equipped with four axes, the eroding of components with complex contours, such as turbine blades, requires 5 or 6 axes machines.





- Hollow shaft
- Backlash free

B- and C-Axes Actuator (LynxDrive®)



- Compact design
- Backlash free

Illustration 17.2





Harmonic Drive[®] Actuators and Planetary Gears are used in the cutter head and linear axes of water jet cutting machines.

Cutter head axes

On water jet cutting machines, the range of workpiece geometries depends greatly on the compactness of the cutter head axes. Therefore these axes use primarily highly compact precision gears and actuators. Leading manufacturers use Harmonic Drive® FHA-C Mini Hollow Shaft Servo Actuators on their cutting head axes.

Cutter head- and linear axes Servo actuator (FHA-C Mini)

Linear axes

Linear axes can fully exploit the advantages of HPG Planetary Gears, partly combined with Harmonic Drive[®] CHM motors. Linear positioning movements and precise contouring with axis interpolation require low backlash and high precision gears with small reduction ratios.

A number of manufacturers utilise the compact design of FHA-C Mini Servo Actuators also for their linear axes. Here linear movement is realised e.g. with toothed belts, and the positional feedback is transferred with linear measuring systems.

Illustration 18.1



- Compact, high power density
- Hollow shaft





The axis described illustrates how compact the actuator solutions are that are created using Harmonic Drive[®] Products.

For the additional linear axis of a machine tool, a Harmonic Drive[®] Hollow Shaft Servo Actuator is used to drive the spindles and support the axial loads within the construction volume available of just 170 cm³. Measuring just 50 x 50 x 65 mm, this product of the FHA-8C Mini Series has a maximum output torque of approx. 5 Nm.

A highly compact, gearless multi-turn encoder is used in the motor. This encoder saves the position information

electronically. Due to a buffer battery located externally in the switch cabinet, the absolute position information is preserved even if there is no power or if the power supply fails. The battery can be replaced during operation without loss of information.

A Harmonic Drive[®] YukonDrive[®] Servo Controller is used as a control device. The control device is available in various performance categories and with interfaces for a range of fieldbus systems such as CANopen, EtherCAT, SERCOS II & III, PROFIBUS and PROFINET.

Auxiliary axis Illustration 19.1 Servo actuator (FHA-C Mini)



• Representation without ballscrew housing and with sectional view upon the motor feedback system





Arrangement for double or triple reduction gears

Gear combinations, comprising a Harmonic Drive[®] Strain Wave Gear and a downstream braced spur gear are used often, in addition to one-step drive solutions in machining and peripheral axes. These combinations are characterised by very high torsional stiffness, torque capacity and transmission accuracy. The very short Harmonic Drive[®] Precision Gears allow the most compact gear combination to be achieved. Table 21.1 compares the characteristics of the most frequently used solutions.

Arrangement for single reduction

Typical drive solutions for the machining and peripheral axes of the leading tool manufacturers are a one step arrangement, comprising Harmonic Drive[®] Servo Actuators or a combination of Harmonic Drive[®] Strain Wave Gears with standard motors.

Arrangement for double or triple reduction (clamped downstream stage)

This solution is used primarily in milling heads with spindle power outputs of 40~60 kW and on the machining axes and pallet changers of large machine tools. Depending on the technical requirement and the available installation space, the spur gear stage downstream of the Harmonic Drive[®] Gear is designed for single or double reduction. For these applications, Harmonic Drive AG provides special gears with transmission accuracies < ±10 arcsec. The reduction ratios of the downstream spur gear stages are typically between 3 and 5, so the transmission accuracy for the described gear combination is typically $\pm 10/4 = \pm 2.5$ arcsec, or $\pm 0.0007^{\circ}$, see also illustration 21.1.

Illustration 21.2 is used to find the best compromise between gear size, torsional rigidity and reduction ratio (defines the max output speed). It presents the relative torsional stiffness (ordinate) that results as a function of the involved gears' torsional stiffness relation (abscise) and the spur gear reduction ratio.

Example: If the torsional stiffness of the downstream spur gear stage is ten times greater than the torsional stiffness of the installed Harmonic Drive[®] Strain Wave Gear, and the downstream gear's reduction ratio is 4, the torsional stiffness of the whole gear combination equals 73 % of the downstream gear stage's torsional stiffness. Illustration 21.2 is based on a downstream clamped gear with 60 % efficiency.

Arrangement for two-stage reduction (electrical clamping)

This solution is used for applications on very large machine tools. These use Harmonic Drive[®] Precision Gears primarily because of their outstanding transmission accuracy, compactness and low weight.



Transmission accuracy double stage gear

Characteristics of gearbox combinations

Illustration 21.1



Illustration 21.2

Standardised torsional stiffness of a double stage gear



Electrically clamped actuators in milling centres

C-Axis

Illustration 22.1 illustrates the C-axis of a machining centre for large turbine components. It is equipped with two electrically pre-loaded drives, each comprising Harmonic Drive® HFUC Series Gear Units and servo motors. The cutting force of the machine is up to 30 kN. The controller varies the pre-load torque depending on the operating mode. For fast feed movements, both drives work together in order to achieve a high acceleration torque. When the axis moves to the set point position, one drive acts as a brake and increases the pre-load torque in order to eliminate the backlash between the pinion and ring gear stage. This arrangement offers considerable advantages in terms of precision and dynamics.

The hollow shaft is used to feed through supply lines for air, oil and hydraulic fluid.

A-Axis

Illustration 22.2 illustrates the A-axis of the milling head where the axis is also electrically pre-loaded using two Harmonic Drive® HFUC Series Gear Units. In the drawing, only one unit is visible as the second one is directly behind the first. The pinions on the output flanges of the Harmonic Drive® Units engage with a spur gear with external teeth. The central hollow shaft is used to feed through supply lines (air, water and oil) for the integrated milling spindle. The max. torque of this axis is 12,000 Nm.

Illustration 22.1



Illustration 22.2



Support with Calculations and Design

When it comes to designing gears and servo actuators for applications with special requirements e.g. in terms of compactness, weight, accuracy or other challenging conditions. We support our customers with calculations and suggested solutions or when required with the development and design of customer specific special solutions. On request, we can also test the customer's integration of our products into a machine. Our specialists combine their years of experience in the field of precision drive technology with the use of state of the art calculation software for drive design, simulation and structural calculations.

Examples

Simulation model of a two-axis saw unit

Illustration 23.1 illustrates the simulation model created by Harmonic Drive AG for the gear and output bearing design of a saw unit. The calculations were made for different cycle times with simultaneous movement of the angle and tilt axis. In addition to the machining force, weight and mass moment of inertia, the gyroscopic motion of the saw blade was also taken into account. Gears and motors were designed for the required minimum operating temperature of -15 °C. Harmonic Drive[®] Hollow Shaft Gear Units are used with specially developed low-temperature Flexolub[®] MO lubricant.

Product and application specific FEM calculations

Illustration 23.2 illustrates the tension distribution for a customer-specific strain wave gear drive solution for a pallet changer. The maximum permissible load was checked using an FEM calculation.

Slimline drive solution for tool magazine

Illustration 23.3 illustrates an ultra slim tool magazine drive, which was implemented by a customer based on a solution suggested by Harmonic Drive AG. The drive solution is based on a Harmonic Drive® HFUS Hollow Shaft Gear Unit with upstream toothed belt drive together with a standard angular gear, which is connected to the motor shaft via a bellows coupling. Technical data:

Width 66 mm, hollow shaft diameter 29 mm, Tmax = 229 Nm.





Illustration 23.2



Illustration 23.3





We reserve the right to make technical changes and modifications without prior notice.

info@harmonicdrive.co.uk

www.harmonicdrive.co.uk

T +49 6431 5008-0 F +49 6431 5008-119