

APPLICATIONS OF THE HARMONIC DRIVES IN VARIOUS DOMAINS

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Abstract

This paper refers to the wide field of application of the HD. Harmonic drives have wide applications in various domains, from large and hard working machine tools, to the medical and electronic equipment with small components and silence functioning, due to its compact construction, high repeatability precision, reliable service life and due to many other advantages offered by this modern transmission.

1. CONSTRUCTION AND FUNCTIONING OF THE HARMONIC DRIVE

The harmonic drive was invented by C.W. Musser in 1955 and in the year that followed it was developed, being now used in different types of top industries such as the space industry, naval industry, robotics etc [6], [7], [8], [9], [10].

These transmissions assure a precise and silence functioning, offering great mechanical efficiency at higher gear ratio, higher gear ratio on one gear, lower jigs and weight, simplicity in construction etc.

The HD was build considering the proprieties of the metal to be elastically deformed and taking advantages of this aspect.

There are many constructive types of HD's, depending on the area of application, jig, gear ratio etc., those constructive types being particularized mostly by the shape of the flexible gear wheel (flexspline) or by the number of deforming arms of the wave generator. We can consider then that these two parts define the type of the HD.

From the view point of the construction elements, a harmonic drive is made up of three main parts as specified next: flexible gear wheel (flexspline), rigid gear wheel (circular spline) and wave generator.

The flexible gear wheel (flexspline) can be a thin cup-shaped, ring-shaped, plate-shaped etc. with external teeth. The bottom of the flexible gear wheel (flexspline), cup bottom, is called the diaphragm. The diaphragm is usually attached to the output shaft.

The rigid gear wheel (circular spline) is a rigid steel ring with internal teeth. The rigid gear wheel (circular spline) has two teeth more than the flexible gear wheel (flexspline) and, usually, is fixed to a casing.

The wave generator is a component with many constructive types with one (not recommended because of the dynamic balancing), two (most used), three or four (not recommended because of the great deformation made to the flexible gear wheel) deforming arms. The common wave generator has two arms and small ball bearings built into the outer circumference of the elliptical cam. The inside raceway of the bearings are fixed to the cam, while the outer raceway is subjected to elastic deformation via the ball bearings. Usually, the wave generator is attached to the input shaft.

The figure below (figure 1) presents these characteristic parts as they look on a harmonic drive with flexible gear wheel with cup shape.



Fig. 1 Component parts of a harmonic drive (according to www.hds.co.jp [4])

The functioning of these transmissions, their principle of motion, is well represented in the figure 2 (according to the Harmonic Drive Systems Inc. - www.hds.co.jp [4]).

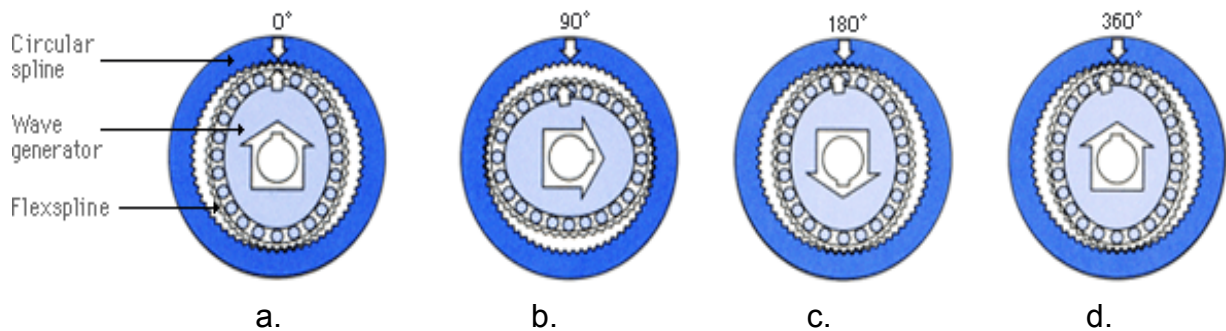


Fig. 2 Principle of motion

In figure 2, a it can be seen the flexspline deflected by the wave generator into an elliptical shape which cause the flexspline teeth to engage with those of the circular spline at the major axis of the wave generator ellipse, but with the teeth completely disengaged across the minor axis of the ellipse. By rotating the wave generator clockwise with the circular spline fixed (figure 2, b), the flexspline is subjected to elastic deformation and its tooth engagement position moves by turns relative to the circular spline. When the wave generator rotates 180 degrees clockwise (figure 2, c), the flexspline moves counterclockwise by one tooth relative to the circular spline and when the wave generator rotates one revolution clockwise (360 degrees) (figure 2, d), the flexspline moves counterclockwise by two teeth relative to the circular spline because the flexspline has two fewer teeth than the circular spline.

2. THE FIELD OF APPLICATION OF THE HD'S

In figure 3, a draft with the various domains that use Harmonic Drive or Harmonic Drives actuators can be seen [1], [3].

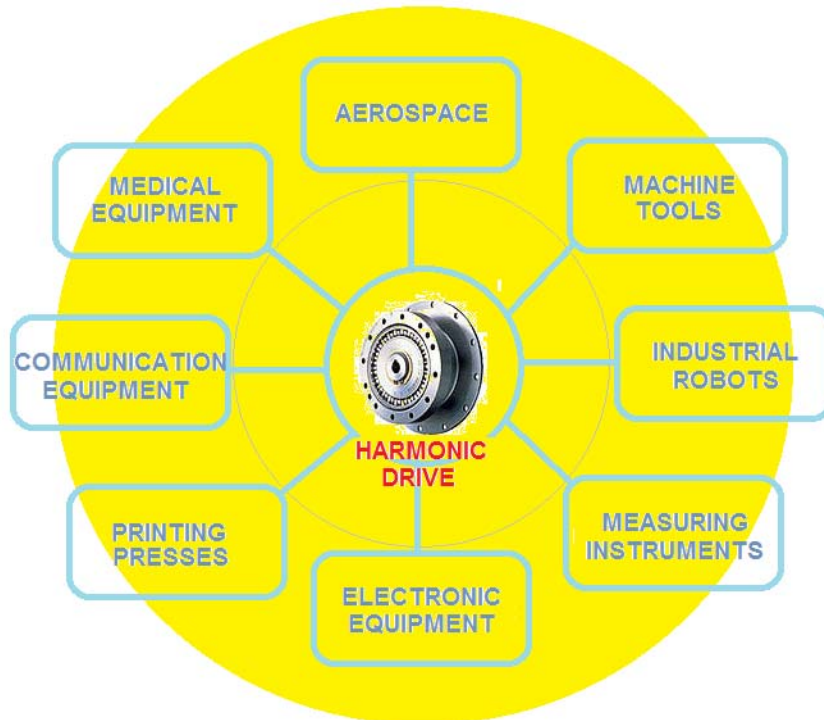


Fig. 3 Harmonic Drive applications

In machine tools, HD are used because of their precision, efficiency and reliable service life and not only. HDs are used as a standard component in a large variety of machine tools, including grinding machines, NC lathes and electric discharge machines. They are used for rotary table, tool changer, pallet changer, indexing axis etc. where zero backlash is required.

In the field of industrial robots, these transmissions are commonly used in different rotational coupling. HDs realize high rotational and positional accuracy required of precision drive mechanisms and control systems imposed by today's advanced industrial robots. They are used for primary axis, shoulder axis, base axis, elbow axis or hand axis assuring zero backlash, high torque capacity, high torsional stiffness and good repeatability.

The compact and precise harmonic drive actuators are widely used in optical spectrum analyzer devices, multiaxis laser systems, where they can provide accuracy in adjustment of the apparatus and other measuring instruments providing micro motion control such as for the universal testing machine torsion axis.

In the production of electronic equipments, microscopic electronic parts, where a high accuracy and precise positioning is required at controlled and variable speed, HDs are the best choice for these equipments.

For printing presses, harmonic drive gears are unsurpassed in performance and flexibility in application, requiring controlled variable speed and phasing of the rotating shaft. The compact shape and size makes for effective stream-lining of these operations.

Communication equipments such as radar or satellite antennas require high positional precision and zero backlash. For that, HDs are used with great success for long time, under harsh weather conditions in numerous antennas systems, assuring the necessary performances.

In medical equipment, HDs are used due to inherent advantages such as high reduction ratio in a compact package, silence functioning thanks to a unique principle which allows for slow speed tooth engagement. For example, the CSF-2UH unit is used to

drive the C-beam of the X-ray machine. The moveable C-beam is used to position the X-ray source precisely above the patient. In this case, the complete C-beam sub-assembly (comprised of the housing, DC servo motor, Harmonic Drive gear and absolute measuring system) was designed and developed in close cooperation with the customer. Another example is the rotary axes of a stereotactic manipulator, which is used for brain surgery.

The final application (according to figure 3) is in aerospace. HD gears offer solutions for satellites actuators, aircrafts, ground support and tracking devices for military applications as well as for commercial applications. In satellite application for example, HD is used for solar array drive for the passage of cables from the paddle and, in aircraft for example, HD is used for passenger aircraft position pick-up unit.

3. FINAL CONCLUSIONS

Due to its advantages, among which high reduction ratio, compact size, light weight, high torque capacity, high efficiency, high precision, low backlash, smooth running and low noise, harmonic drives gear are widely used in various domains, as presented before, with great results in all kind of conditions. They are suited for many applications in various domains. Thus, HDs represent an alternative for classical gears and they also offer the possibility for new and more complex mechanisms to be used in today's industry, in today's life. The capability to adapt in all cases where high accuracy, repeatability, compact package or low noise is required, recommend these modern transmissions.

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