

## DECOMPOSITION OF DRIVING SYSTEMS SPECIFIED FOR REHABILITATION MACHINES

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VEGA 1/0198/15, Innovative approach to processing driving units and construction of transportation and handling facilities, with a view to reducing emissions and increasing level of technical reliability.

**Abstract:** The rehabilitation engineering deals with a proposal and design of mechanical devices that are helpful to disabled persons during individual phases of the rehabilitation process. The main task of the mechanical support, which is specified for the motoric rehabilitation, is measuring and evaluation of the physical status of the rehabilitants with regard to objective determination of the diagnosis, selection of the suitable therapy and performing of controlled manipulation with the treated motional segment of human body in order to improve physical abilities of the rehabilitant. The assistance devices are using specific driving systems designed for increasing of the loading forces, for keeping of constant speeds and for positioning of patient. An important part of the driving system is the gearing mechanism. This article describes gearing systems applied in design of the rehabilitation machines.

**Keywords:** Rehabilitation, system drive, backlash-free movement.

### 1. Introduction

Threat of very serious illnesses that require demanding diagnostics and therapy is always actual in spite of the technical and medical progress reached during development of a mankind. The rehabilitation engineering is a biomedical branch of science, which integrates and applies knowledge obtained from the various scientific disciplines, namely from the medical and technical sciences. The main task of the rehabilitation engineering consists in design proposal of special mechanical systems determined for disabled persons and applied during the individual periods of the rehabilitation process. The driving system is an integrated part of every rehabilitation machine.

### 2. Drives of rehabilitation machines

Process of development in the rehabilitation area is very dynamic also thanks to a progress, which was made within the framework of the robotic equipment design. Architecture of apparatuses designed for motoric rehabilitation can be characterised by the specific constructional features taking into consideration the anthropometrical, biomechanical and medical aspects, as well as by the safety aspects relating to the man-machine interaction. The rehabilitation equipment can be divided according to the rehabilitated parts of the human body. There are applied special individual rehabilitation devices intended for rehabilitation of the following human body parts:

- head and neck,
- vertebra,
- upper limbs,
- lower limbs.

Another possible classification of the rehabilitation equipment is according to the kind of loading or loading forces acting against the patient's body during application of the given rehabilitation equipment, i.e.:

- rehabilitation devices with loading,
- rehabilitation devices without loading (suitable for the patients just after surgery)
- combined rehabilitation devices.

Design solutions of the rehabilitation machines are as follows:

- pedestal-type,
- bed-type,
- multifunctional.

The mechanically supported motoric rehabilitation allows measuring and evaluation of the rehabilitant's physical status with regard to objective determination of the diagnosis, selection of the suitable therapy and possibility to perform controlled manipulation with the treated motional segment in order to improve physical abilities of the rehabilitant. The rehabilitation supporting devices are equipped with various driving systems intended for increasing of the loading level, for keeping of constant speeds and for positioning of patient.



Fig. 1 Rehabilitation equipment

### 2. Simulation of situation

The gearing mechanism is an important constructional part for each of the driving systems. There are applied in the medical machines the high-precise gears, whereas they are usually analysed with regard to their constructional adaptability, dimensions and own mass reduction.

Backlash-free mechanisms belong into the group of high-precise gears. These gears are produced at a very high precision level of the functional surfaces. The value of the applied accuracy tolerances is approx.  $1\mu\text{m}$  using the pre-stressed assembly and minimal internal friction among the rolling bodies. It is possible in this way to reduce heat generation in the gearbox and consequently there is also reduced dilatation of the internal elements with a positive influence on the gearbox operation accuracy.

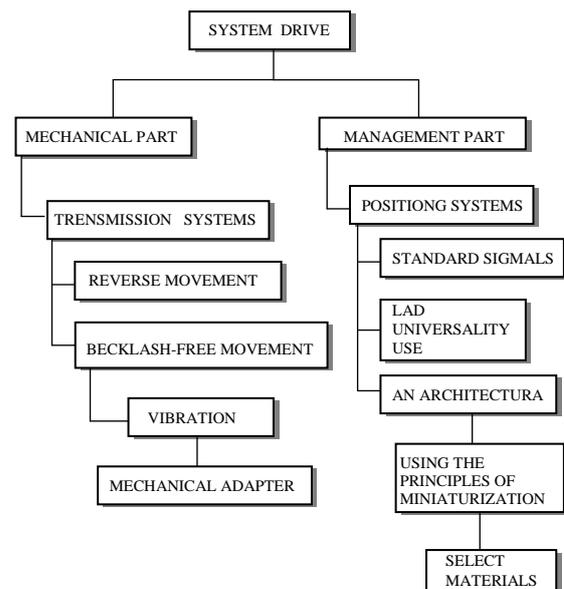


Fig. 2 Drive system - block diagram of hierarchical ties for therapeutic tools

### 3. Utilization of mini and micro harmonic gear units in medical equipments

The Micro Harmonic Drive gear is now established in the precision machine market as an ideal solution for precise positioning applications. Harmonic gearboxes recently found application in health care. Micro gearboxes are not particularly recent development and micro-gears are available in excellent market for several years. But these products suffer from poor application position in the machine. The above solutions will be done, or only allow very light load. What is needed are micro-gears, which are not only very small size, but also have high repeatability without play, a fairly large reduction and low parts count. These requirements inspired the development of new micro-gearing Micro Harmonic Drive. These transfers for medical technology, the use of high quality materials such as stainless steel alloy that our micro wheels corrosion resistant. This makes them very well suited for use in medicine, because they are made of materials that can be sterilized. Two thousand sterilization cycles in a vacuum steriliser have impressively confirmed this possibility.

### 4. Types of mini harmonic gearbox

Miniature gear CSF-Mini and PMG is characterized by compact design and high torque transmission. Are either to an output shaft, or a stepper motor. Inlet side can be supplied optionally with shaft or flange.

Board CSF-Mini (Fig. 3) - the mini transmissions are restricted due to component board HFUC, with higher accuracy, higher-transferable torque and higher torsional stiffness. Its benefits are transfer without backlash with high torque transmission, with increased speeds and cut-off corresponds to the torsional rigidity and accuracy, square bearing solid output with the output shaft or flange, various options for input and output elements and very low weight. Further possibilities harmonic gear is in the motors. The external dimension of 13 mm 51.1 mm do, maximum torque of 0.21 Nm to 28 Nm and a gear ratio of 30 - 100.

Council PMG (Fig. 3) - consists of components Council HDUC, Gearbox, output shaft and creates a unit with large compact dimensions. This series provides high precision and compact dimensions. PMG is the advantage of high precision torque, high positional accuracy and repeatability, high torsional stiffness, zero backlash, high efficiency. The outside dimension from 20 mm to 50 mm, maximum torque of 0.55 Nm to 14.70 Nm and a gear ratio of 50 - 110.

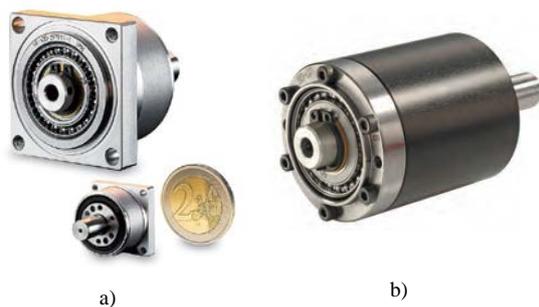


Fig. 3 Mini harmonic gearbox: a) CSF-Mini, b) Gearbox PMG

### 5. The Micro harmonic drive

Micro gears are not a particularly recent development and micro-spur gears or micro-planetary gears have been available in the market for a number of years. Micro Harmonic Drive - the world's smallest backlash-free precision gearbox.

The Harmonic Drive gear provides a unique combination of precision, torque capacity and power density. These features have made it the preferred solution in a wide range of machines and devices. However, a new market is emerging for ever smaller gears and actuators, for a new generation of compact, lightweight

machines and portable devices that can be manufactured with a minimal use of material and can operate precisely, quickly and efficiently.

Key requirements for innovative microactuators used in positioning applications are not only miniature dimensions and low weight, but above all precise and backlash-free positioning capability.

By combining new microtechnological manufacturing techniques with the unique Harmonic Drive operating principle, a new standard has been set with respect to positioning accuracy, high torque capacity, high reduction ratios, compact dimensions and low weight.

The basic components of the transmission system flat type are wave generator and three gears - flexspline, circular spline and dynamic spline (Fig. 4).

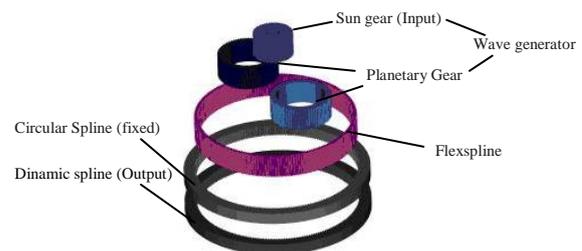


Fig. 4 Micro Harmonic Drive

The Wave Generator deflects the elastically deformable Flexspline elliptically across the major axis. Due to that the teeth of the Flexspline engage simultaneously with the two ring gears - Circular Spline and Dynamic Spline - in two zones at either end of the major elliptical axis. Across the minor axis of the elliptically deflected Flexspline there is no tooth engagement. When the sun wheel of the Wave Generator rotates, the zones of tooth engagement of the Flexspline travel with the angular position of the planet wheels of the Wave Generator.

To enable simple integration in machines or devices Micromotion has developed a new range of micro gearboxes. These can be easily combined directly with common Micromotors or can be provided with an input shaft, allowing the motor to be mounted in parallel. An optional hollow shaft allows a laser beam, optical fibre or air supply to be passed along the central axis of the gearbox (Fig. 5)

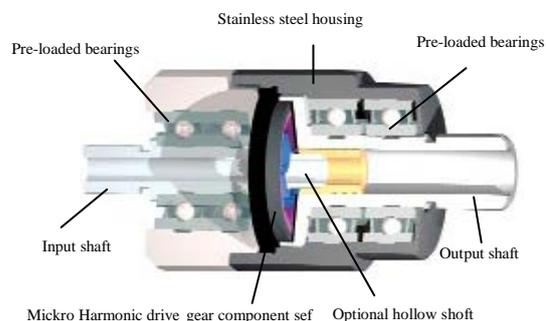


Fig. 5 Micro Harmonic Drive - components

This solution provides the machine designer with numerous advantages:

- Miniature dimensions yet zero backlash - the Harmonic Drive gear stage is backlash-free by nature and the elastically.
- Excellent repeatability for precise positioning - the zero backlash of the Micro Harmonic Drive gear provides a

repeatability in the range of a few seconds of arc. This enables positioning tasks to be carried out with sub- $\mu\text{m}$  accuracy

- c) Very long operating life - the MHD Micro gearboxes have an operating life of 2500 hours at rated operating conditions, that is, at rated input speed and rated output torque.
- d) Very high reliability - the MHD Micro gearboxes have an operating life of 2500 hours at rated operating conditions, that is, at rated input speed and rated output torque. This corresponds to many million operating cycles in practical applications and the operating life of the Micro gearbox is typically equivalent or longer than the expected operating life of the machine in which it is used. The "life-cycle-costs" are therefore considerably lower than for other solutions with a lower initial cost.
- e) High efficiency to avoid power losses - the Micro Harmonic Drive® gear has an efficiency of up to 82% at rated operating conditions.
- f) Hollow shaft capability - the optional hollow shaft can be used to pass laser beams, air / vacuum supply or optical fibres through the centre of the gear or actuator along the central axis of rotation.
- g) Applicable under extreme environmental conditions - the use of high quality materials, such as stainless or high-alloy steels for the gearbox housing, input / output shafts and bearings, provides a high level of corrosion resistance, even for standard MHD Micro gearboxes.

## 6. Conclusion

The main task of the rehabilitation engineering consists in design proposal of special mechanical systems determined for disabled persons and applied during the individual periods of the rehabilitation process. The driving system is an integrated part of every rehabilitation machine. He presented decomposition therapeutic plant and the subsequent design of the drive system based on the requirements to meet the target and the objective function, in to ensure the quality of the therapeutic process with the comfort of using modern methods of construction and IT technology. The work presents and discusses the application of tool selection offered partial elements of those may be generated by the system.

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