Roller Gearing Mechanism: BOGARDRIVE

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Bogár, István: inventor of the Roller Gearing Mechanism [1]

Gearwheels have been applied for thousands of years. Even primitive gears had to fulfil two primitive conditions:
- equal pitch on both wheels
- interference free tooth profile.

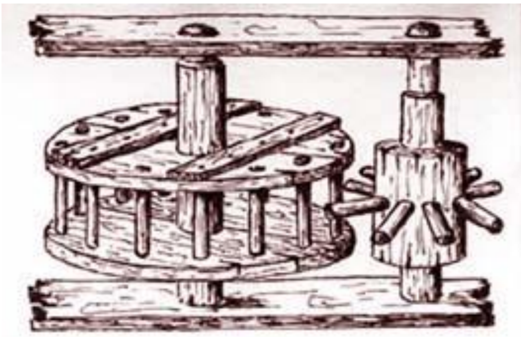

Fig.1. Ancient gear

Modern gears not only fulfil primitive conditions but they also have constant gear ratio during rotation. Conventional gears can be characterized by sliding friction and difficult discharge of backlash.

Fig.2. Modern gearwheel with involute profile

BOGARDRIVE is a good solution to these problems. There have been a lot of attempts to develop this gear.

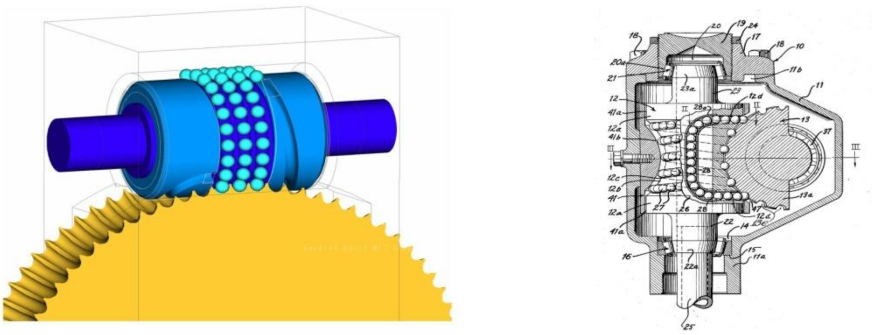

Fig.3. Two solutions before BOGARDRIVE

Common features of them are a worm with its groove filled with balls and a wheel connected to the worm interference-free. A CAD-model was created and investigated, and the result showed that rolling motion could be perceived only in some points. The velocity of the central point of the ball wasn't equal along the spiral way. There wasn't a pure rolling motion.

During the development of BOGARDRIVE we used this approach the other way round.

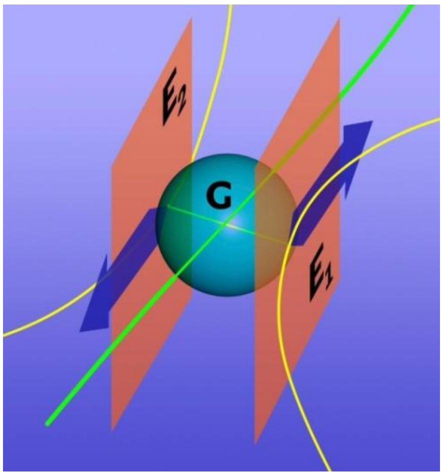

Fig.4. Rolling ball and curves

First we considered the motion of the ball while it was rolling on the grooves of the wheels. The green curve is the path of the center point of the ball. The grooves of the wheels are connected with the ball while moving along this path. This is the **coupling path**. The ball in connection with the grooves has contact points on the yellow curves. These are the **rolling curves**. The tangent planes in the opposite contact points (E1, E2) are always parallel because it seems to be the best condition. The motion of the rolling ball can be described with the **linear differential equation system**.

Input parameters are:
- gear ratio
- axis distance
- axis angle
- ball diameter
- information about direction of force on the ball
- **relative direction of rotation** of the wheels. What makes this parameter interesting is that conventional gear wheels rotate in opposite directions. This is the first big difference between conventional and roller gear.
- **one point of the path of the center of the ball** (coupling path). This means that the ratio of the dimensions of the roller gear wheels is independent from the gearing ratio. This is the second big difference.

Softwares have been developed on the platform of Mathematica to provide solutions to the differential equation system that describes the motion of a rolling ball.

Results from the solution of the equation are the following curves:

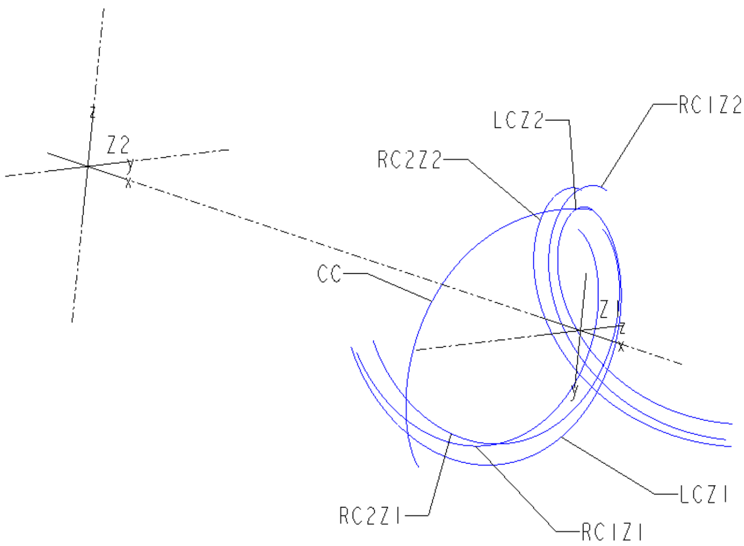

Fig.5. Result curves

- Z1: driving wheel (it's axis is coaxial with z axis of Z1 system)
- Z2: driven wheel (it's axis is coaxial with z axis of Z2 system)
  axis angle is 90° in this example
- CC: coupling path (see before)
- LC: leader curve: it is the path of the center of the ball in a coordinate system moving together with the wheel
- RC: rolling curves (see before). There are two rolling curves in the solution. One pair of them works in one load direction and the other in the opposite load direction. For example there are two load directions in the differential of a car and only one load direction in the gear of a crane (no matter if the mass is moving up or down).

When the ball exits the coupling path we must lead it back to the entry. This happens along a **recirculating path**. In addition to the curves described before we can calculate the entry and exit path sections of the ball. The ball moves with different velocity along the coupling path and along the recirculating path. When the ball leaves the coupling path we must slow it down to the velocity of the recirculating path, and when the ball enters the coupling path we must accelerate it, because the velocity of the ball along the coupling path is usually not equal to the velocity it has along the recirculating path.

Fig.6. CAD-model of the wheels

By applying coupling path, entry path, and exit path sections we can construct the envelope surfaces of the wheels in CAD. By applying leader and rolling curves we can construct grooves. The cross section of the grooves can be calculated and optimised with the Hertzian theory of contact pressure.

Final information about the direction of forces is the result of the solution, too. The method was developed to determine the quantity of the forces by using the CAD model. With the forces and the CAD model the load capacity of the roller gearing mechanism can be computed. There is a software developed for this purpose. After that the bearings are calculated and selected, and the full geometry of the **ball guiding elements** are designed.

Fig.7. An example of BOGARDRIVE with bearings and ball guide elements

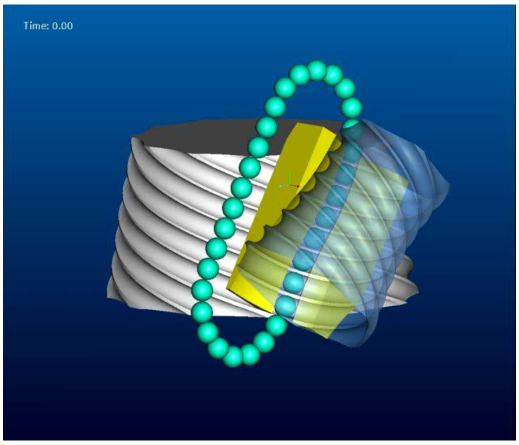

FIG.8. How does BOGARDRIVE operate?

BOGARDRIVE operates as the following method (FIG.8.). Given that the driving wheel is blue and the driven is grey. The yellow elements are for guiding the balls. Their role is similar to the role of the cage of the roller bearings.

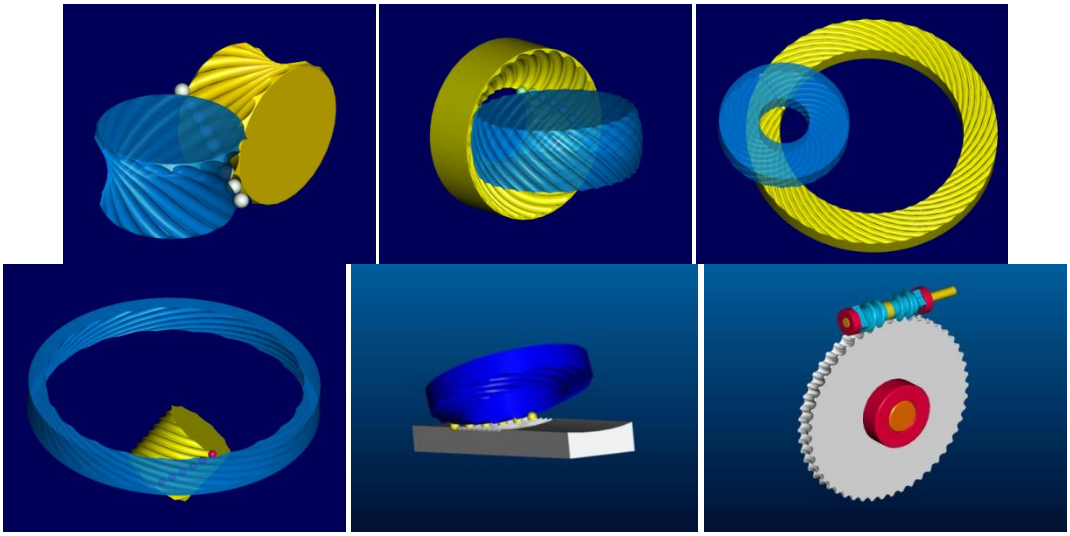

FIG.9. Some variations of BOGARDRIVE

There is a **unitary mathematical theory** for the dimensioning of roller gearing mechanisms, and by applying it we can calculate various types of applications only by changing the input parameters:
- non-intersecting axis type gear,
- gear with intersecting axis: it is an alternative bevel gear,
- parallel axis gear: the grooves are in plane perpendicular to the rotation axis of the wheel,
- internal toothing version,
- gear rack: you can create gear racks with variable angles of driving wheel axis and rack plane,
- worm gear-like solution: a method was developed for creating roller gears with high gearing ratio. There is a prototype which has got 50 gearing ratio and successfully operates as an accelerating gear.

The technology is universally applicable for…
- all gearing problems
- any shaft angles
- crossing or non-crossing axes
- internal or external coupling
- planetary systems and worm gears
- linear drives and gear racks.

BOGARDRIVE is…
- highly flexible and rich in design
- highly optimisable and customisable
- very different from conventional.

BOGARDRIVE is more like a generalised ball screw or roller bearing. It has high efficiency - both static and dynamic. It is independent from types of roller gears. BOGARDRIVE has low starting torque, and many rollers in coupling. It is easy to eliminate backlash by pre-loading.

Flexibility:
- diameter ratio of the wheels and gearing ratio are independent from each other,
- relative direction of rotation is an input parameter,
- The differential equation system can be solved even if the gearing ratio depends on the angle of rotation, and the function is not necessarily monotone! This was the basis of a new concept for Dual Mass Flywheel (DMF system) we developed for engines. If there is a conventional gearwheel pair with variable gearing ratio, the conventional driven wheel never changes the direction of its rotation. With the roller gearing mechanism this is possible.

Possible areas of application:
- high efficient gears (specially gears with non-intersecting axes)
- backlash-free gears
- accelerating gears
- lubrication-free gears
- gears able to operate under extreme conditions (cold places, vacuum, space)

Tested prototypes:

FIG.10. Wheels of rotary table gear

A pair of 10 gearing ratio wheels was constructed for a CNC rotary table (FIG.10.). Maximum rpm of the original conventional gear mounted rotary table was 90, the same rotary table with the roller gear was 300 rpm. It had up to 60% less power consumption.

FIG.11. Wormgear shaped BOGARDRIVE

This is a wormgear shaped solution for the higher gearing ratio. Gearing ratio is 50 nevertheless the gear works perfectly as an accelerator.

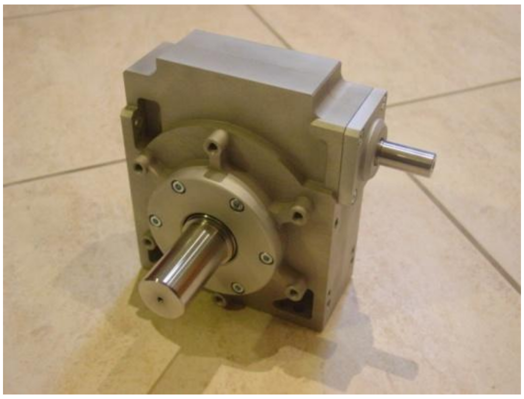

FIG.12. 10 ratio BOGARDRIVE

The 10 ratio gear will be the basis of a standard gear family (FIG.12.). Losses measured by a German technical university are 2-3% as oppose to conventional gears with similar features. Similar mass produced conventional gears have losses about **30-35%**. The investigation of gear lifetime is in progress.

Roller Gearing Mechanism, BOGARDRIVE in education:

- student's design exercises and diploma works at the Technical and Economical University of Budapest, Hungary
- phd. dissertation at the Technical University of Cluj-Napoca, Rumania
- diploma work at the Technical University of Kaiserslautern, Germany
- diploma work at the University of Applied Sciences Kiel and Porsche Engineering Services GmbH Biettigheim-Bissingen, Germany.

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[1] Bogár, István: Roller Transmission Gearing Mechanism
Pat. no.: EP1969254