EXTENSION OF TRANSMISSION RATIO RANGE OF FLEXIBLE EPICYCLIC DRIVES I.

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ABSTRACT. The original idea of epicyclic gear drive containing at least one base element having large elasticity, dates back to the middle of the last century. It enlarged the transmission ratio of traditional epicyclic gear drives containing only rigid elements. The ratio realized in one stage was changed from not more then 12 to at least 50. In speed reduction service the ratio range is 2…12 in traditional drives and it is 50…400 in the new drives. Instead of gear drives this paper tries to suggest some idea at the field of flexible epicyclic traction drive to extend the ratio range realized in one stage.

1. INTRODUCTION

The traction drives have no accurate ratio because of slip, creep and elongation of the flexible element. The supposed efficiency of the drive is also moderate. In spite of these disadvantages there are some encouraging characteristics of the drive. This paper is concerned with speed reducers, the output shaft is joined to the flexible (planet) element and the usually rigid annular ring is fixed to obtain a drive with one degree of freedom. The flexible element can be made of steel or reinforced elastomer. The outer ring made of steel, and usually rigid but can also be elastic or can contain an elastic elastomer belt or tubular torroid shape insert. The latter one can be filled by liquid. The operation of the traction drives require initial loads due to the nonpositive drive. This force can be constant or the function of the current load or speed. The ratio of the drives is usually fixed but it is easy to be changed infinitely.

2. THE ORIGIN OF THE DRIVE

Let's start our analysis with the **i** type (having only one inner mesh) epicyclic drive containing only one planet gear shown in **fig1**. The input shaft drives the planet carrier, the output shaft is joined to the planet wheel. $\omega_3 = 0$. The ratio is

$$i_{c2}^{3} = -\frac{r_2}{r_3 - r_2} = -\frac{c_2}{c_3 - c_2} = -\frac{c_2 / c_3}{1 - c_2 / c_3} \quad (1)$$

where c_2 and c_3 are the circumferences of the contact surfaces of the element 2 and 3, respectively.

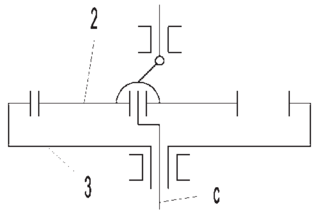

Fig.1. The i type epicyclic drive – the origin of the flexible drives.

3. THE TRANSMISSION RATIO RANGES

As **fig.2**. shows the original ratio range of a flexible epicyclic drive (FED) reducer is between 50 and 400. It also shows the aimed lower and upper ranges.

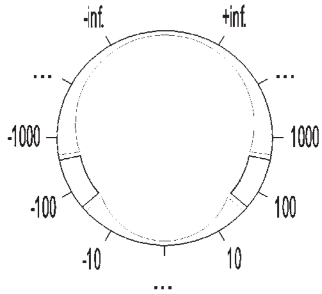

Fig.2. The usual and the aimed transmission ratio ranges

When omitting the gear teeth the only change is the improved elasticity of the elastic planet wheel. The ratio can not be less because of small elasticity of the flexible ball bearing. The ratio is a little bit greater than at the original gear drive due to slip. Changing the original elliptoidal cam wave generator by eccentric disk or spaced roller wave generator, it makes possible to enlarge the difference of contact circumferences, $c_3 - c_2$, consequently the ratio is decreased, due to formula (1). The ratio and the theoretical lower limit are explained by **fig.3**., i. e.

$$i_{g2}^{3} = \frac{(d_3/e - 1)\pi + 2}{\pi - 2} \quad (2)$$

$$d_{sr} = 0 \rightarrow (e = d_3) \rightarrow i_{g2}^{3} = -1{,}75 \; .$$

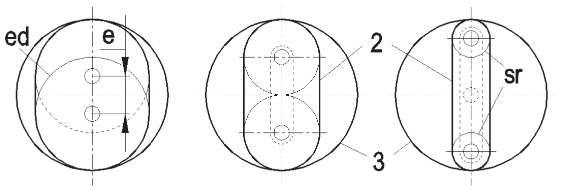

Fig.3. Eccentric disk and spaced roller wave generators

The elastic epicyclic wheels around the eccentric disks (ed) or spaced rollers(sr) were supposed to be in tension as a belt around its pulleys. The ratio is greater when the belt is loose.

The ratio is positive when $\omega_2 = 0$ and the rigid inner contact ring gear is joined to the output shaft, i. e.

$$i_{g3}^{2} = \frac{c_3}{c_3 - c_2} = \frac{1}{1 - c_2 / c_3} = 1 - i_{g2}^{3} \qquad (3)$$

There is another chance to obtain a relatively small positive transmission ratio. When $c_2/c_3>1$ i.e. the circumference of the elastic epicyclic wheel is greater than that of the rigid ring, the ratio will change its sign.

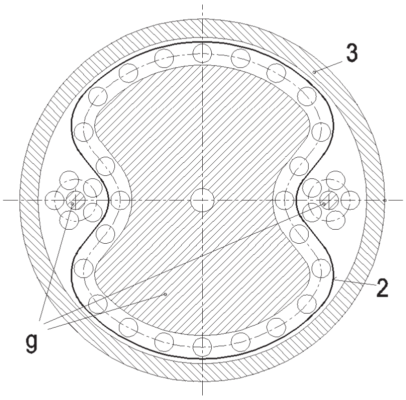

Fig.4. An elastic epicyclic drive with special cam wave generator and ball cages ($c_2 > c_3$)

4. CHANGING THE RATIO INFINITELY

The elastic epicyclic wheel, 2 also can be made of elastomer. **Fig.3.** shows such a drive where the excentricity of the disks or the distance of the rollers should be adjusted to assure the proper traction effect between the elements 2 and 3. Both the creep and the local elongation has got a lage role in the contact regions. These effects can become so large that the original rate of circumferences of $c_3>c_2$ will be changed. The greater the tensioning of the elastic wheel the greater the transmission ratio and it become infinit. Additional radial offset of the rollers causes an opposite revolution at the output shaft, so as it can be followed in **Fig.2**. and **5.**

The control of radial preload require an adjusting mechanism. It seams to be easier to use a steel elastic epicyclic element and an elastic insert in the rigid housing of the circular ring.

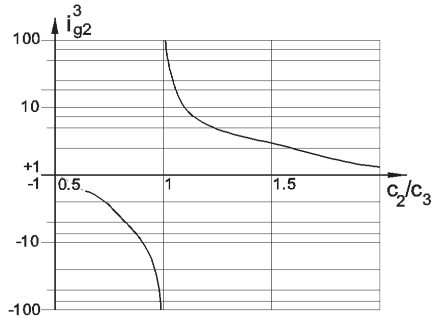

Fig. 5. Transmission ratio of the reducers, as the function of c_2/c_3, $\omega_3=0$

The control of radial preload require an adjusting mechanism. It seams to be easier to use a steel elastic epicyclic element and an elastic insert in the rigid housing of the circular ring. The insert can be tubular, filled in by liquid. Its cross-sectional area should be constant so it has to be reinforced radially. Due to the axial deformation of the circular cross-section the inner diameter of the insert will be decreased. **Fig.6.** shows such a solution.

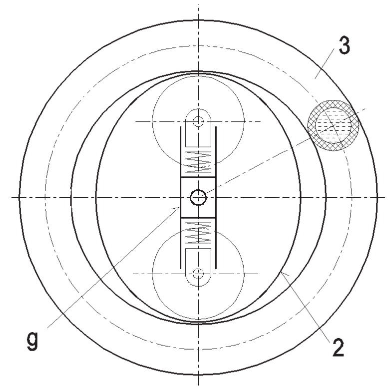

Fig.6. Flexible epicyclic traction drive with with filled tubular torroidal insert made from reinforced elastomer

5.SUMMARY

The epicyclic traction drives which contain at least one elastic base element have got a wider transmission ratio range and there are some surprising characteristics. There is a great chance to control the output speed automatically, using the effect of centrifugal force or by an external intervening unit. The following analyses help us to select between the most advantageous solutions.