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Development of Efficient Drive Based on Self-help

G. NÉMETH[1], J. PÉTER[2]

[1]University of Miskolc, Faculty of Mechanical Engineering and Informatics, Institute of Machine and Product Design, machng@uni-miskolc.hu
[2]University of Miskolc, Faculty of Mechanical Engineering and Informatics, Institute of Machine and Product Design, machpj@uni-miskolc.hu

Abstract. The efficiency and the life rating are essential characteristics of mechanical drives. The traction drives with proper geometry can avoid the geometrical slip and their efficiency can exceed that of the gear drives. The elements has hardened steel surfaces, the lubricant is rheopectic. There is no danger for thinning the oil film and consequently for connecting the asperities. The traction drives are relatively noiseless, they are applicable for increasing speed in particular. There are some problems to be solved in friction drive. This is the necessity of clamping force. A simple machine element usually make a constant clamping force, a tensioning mechanism can be too complicated. The ideal solution is a simple design which assure a clamping force that is proportional to the instantaneous external load requirements. The authors suggest a modified machine element – a helical torsion spring, an elastic one, instead of the original, rigid annular wheel – that comprises both the driving and clamping functions, and the latter one is proportional to the external load, so that the principle of self-help operates.

Introduction

There are a huge many principle of embodiment design, one of them is the principle of self-help [2]. When we develop a new machine element or a new machine structure so that the maximum stress occur only at the maximum load, we use the previously mentioned principle. Let us consider a pressure-cooker. The sealing force is increasing with the increment of the inner pressure. The experience is the same in case of the operation of mechanical seals. Of course, an initial sealing force should be applied to the seal at the beginning of operation, to assure the proper sealing also at shut down. The supplementary force is generated by the increasing pressure.

There are drives where the forces and torques acting to the elements can be proportional to the external load, almost automatically. In the case of a form closing drive, like a gear drive, the elements are unloaded when there is no external torque acting and the flank or root of teeth are loaded proportionally to the external torque. The friction drives are not so simple structures, considering this point of view. The geometry and the needs of manufacturing is less but not the proportional loading of the machine elements. Usually an extra machine element or mechanism is required to assure the proper compressive (or clamping) force between the mating elements, or to assure the proportional clamping force, not to overload unnecessarily the elements.

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The simplicity is also a useful principle. We can try to integrate the function of the proportional clamping force and the power transmission into a single machine element, or we can compensate the uneven thermal expansion of the rings of a roller bearing.

1. Examples from the industrial practice

There are some clutches, as the spring type clutch where the friction force is increasing proportionally with the increasing torque needs [2]. The helical torsion spring that connects the input and output shafts, works as a friction type free running clutch. It operates in unidirectional service, and the dominant load of the connecting element (bending moment) is proportional to the external torque. A similar structure is the helical spring bearing that eliminates the unequal heat distribution and from that a special epicyclic traction drive can be originated. The models of the clutch and the bearing are shown in Figure 1.

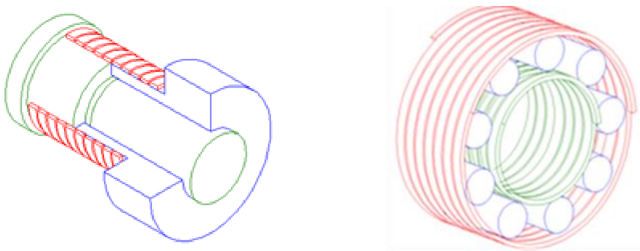

Figure 1. Spring type clutch and helical spring bearing.

2. Opportunities of new designs

Let us consider a simple epicyclic traction drive having one external and one internal connection. The self-aligning of the planets should be assured. The annular wheel, the sun wheel or both of them can be substituted by helical torsion spring. When the planetary wheels are installed to the planet carrier with radial space, the tightening mechanism (clamping device) can be omitted. The models of the original and the modified designs are shown in Figure 2.

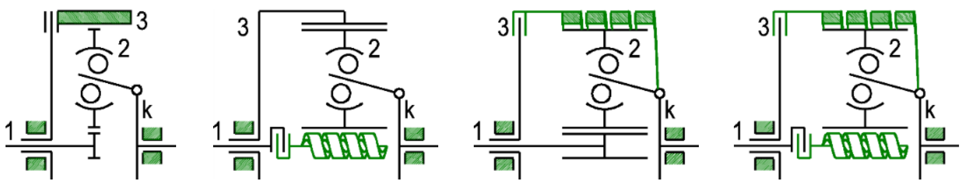

Figure 2. Models of the original and the modified epicyclic traction drives.

3. Developing a new design

Substituting only the original, rigid annular wheel by helical torsion spring, the third model of Figure 2. should be considered. The helical spring has got a special load, due to the great number of contacts with the planet wheels, shown in Figure 3. One of the end of the spring, 3 is connected to the housing tangentially, permitting the radial displacement and the swing of this point. The other end is free. The rigid sun wheel, 1 and the planet wheels, 2 are in contact with each other due to radial movability of the planet wheels in the planet carrier, C. The input torque, T_1 acts to the sun wheel from the prime mover, and the output torque, T_C acts to the planet carrier from the driven unit or load. The traction drive reduces the input speed. The inner diameter of the unloaded spring is less than the diameter of the circle drawn around the planet wheels, so the spring grips the planets and force them against the sun. The inner diameter of the spring in the vicinity of the free end should be less so that this greater clamping force produce a greater friction force, resulting the spring to be wrapped around the planets and increasing further the normal force. The figure shows a global (xyz), Cartesian coordinate system and a local ($\xi\eta\zeta$) one, connected to an arbitrary point of the helix.

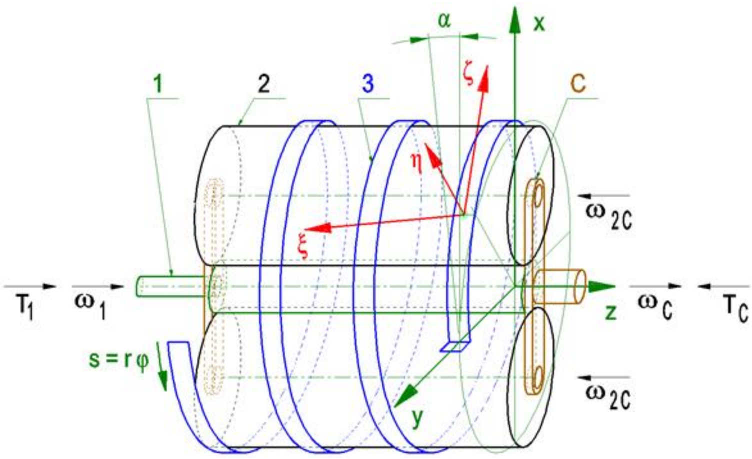

Figure 3. Modelling of the special epicyclic traction drive.

3.1. Production technology of the spring

The production technology of the spring can be manufacturing, for the more accurate mechanical properties. Another advance of the manufacturing is the easy variability of the spring – e.g. for the proper initial tensioning the cross section at the free end, see Figure 3., can be increased. Hopefully the drive where the elastic element is stationary, can work in noiseless service and with low slippage. Another advance of the manufactured spring is the merging of the functions, decreasing forward the number of elements.

3.2. The dominant load of the spring

The load can be calculated analytically at any cross-section along the strip [3]. The main load of the strip (the helical spring) is the bending around axis ξ. When the lead angle of the helix is small (less, than 5 deg), the other loads of the cross-sections, e.g. the other bending and the torque, are negligible. The function of the main load of the cross-sections is

$$m_2 = r \cdot \sum_{i=1}^{j} \Big\{ \{s(\alpha)t(\alpha)[g(i) - \varphi]c(\varphi) + c(\alpha)[s(\varphi) - s[g(i)]](\varphi)\} F_{ri} + \{s(\alpha)t(\alpha)[g(i) - \varphi]s(\varphi) + c(\alpha)[c[g(i)] - c(\varphi)]\} F_{ti} \Big\} \, , \tag{1}$$

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where the meaning of the symbols of functions are

$$\mathrm{c} \rightarrow \cos; \mathrm{s} \rightarrow \sin; \mathrm{t} \rightarrow \mathrm{tg};\ \mathrm{f(i)} \rightarrow (i-1)2\pi/N; g(i) \rightarrow i2\pi/N \quad (2)$$

and *i* is the serial number of the contact points, counted from the free end, and

$$j = \mathrm{ent}\left(\frac{\varphi}{2\pi/N}\right) \quad (3)$$

is an integer function that inform about the whole number of contact point from the given cross-section as far as the free end. F_{ri} is the radial force at the point of *i*, and F_{ti} is the tangential force at the same point. The maximum value of the latter one depends on the capacity of the traction fluid that lubricate the contacting hardened steel elements.

3.3. The design of the developed traction drive

The traction drive has got a relatively rigid design as the Figure 4. shows. The planets are built up from a serial of deep groove ball bearings. The sun wheel is made of a hardened, grinded steel pin. The shafts are simple. The hosing is made of hollow cylinder, the bearing housings are turned and the other parts are made by laser cutting. The inner parts should be lubricated by traction oil or traction grease. The necessary dynamic seals are radial lip seals and and V-rings, the static seals are O-rings.

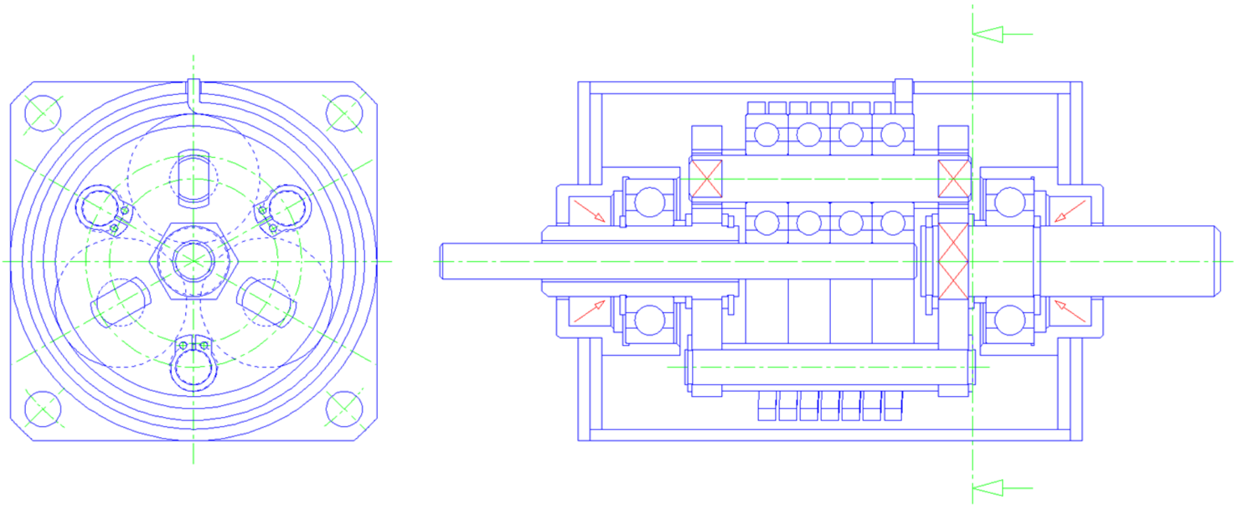

Figure 4. A possible design of the drive.

4. Conclusion

The principle of self-help is an applicable knowledge during the development of an epicyclic traction drive. In a planetary drive, one of the main element is the annular wheel. This element was substituted by a helical spring. This spring combines the functions of tensioning and driving.

The main load of the helix can be calculated, but it requires further analysis like any strain energy method. The authors suggested a possible design which is relatively simple compering with other traction drives and relatively noiseless compering with gear drives.

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