
Moon-and-Planet Gear Trains

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Abstract

A special type of superimposed planetary gear train is introduced, in which the axes of the central gears of a secondary planetary gear train are collinear with the axis of the planet gear of the primary planetary gear train. The number of possible variations of such planetary gear trains are dealt with, and the simpler types are shown.

Zusammenfassung – Über Mond-und-Planeten-Getriebe: Z. Lévai.

Es wird ein besonderes überlagertes Planetengetriebe vorgeführt, bei welchem die Achsen der Zentralräder des sekundären Planetengetriebes mit der Achse des Planetenrades des primären Planetengetriebes zusammenfallen. Die Zahl der möglichen Variationen eines solchen Getriebes wird erörtert und die einfacheren Typen werden dargestellt.

Резюме — Планетарные Передачи: Золтан Леваи

Представлена специальная планетарная передача, в которой оси центральных колес вторичной планетарной передачи коллинеарны с осью планетарного колеса первичной планетарной передачи. Рассмотрен вопрос количества возможных вариантов этих планетарных передач и показаны простейшие из них.

IN ONE of our former studies[1] we described the whole family tree of the elementary and simple planetary gear trains (in short: *PGT*). An “elementary” *PGT* was defined as a mechanism which consists of one central gear, one or more planet gears, and one arm carrying the planet gears. A “simple” *PGT* is evolved from an elementary *PGT* by adding a further central gear.

In the course of later investigations we came across a newer type *PGT*, a representative of which is shown in Fig. 1. As can be seen, one takes first a simple *PGT* having both its central gears (1 and 2) and its arm (3), but then the compound planet gear 41+42 is separated into two parts between which another simple *PGT* is built in, securing the connection of the planet gears 41 and 42. An interesting feature of this mechanism is that to the planetary motion of the inner planet gear 4' is added that of the outer planet gear 41, i.e. it presents a doubly compound planetary motion, comparable to the circling of a moon around a planet, which simultaneously circles around its sun. This mechanism may be called a moon-and-planet *PGT*”.

To describe the *PGT* shown in Fig. 1, the same notations are used as in reference [1]: *P* = external gear (positive diameter), *N* = internal gear (negative diameter). With these notations, the new *PGT* of Fig. 1 (c) can be described as =

$$P\{PP(P)NP\}P.$$

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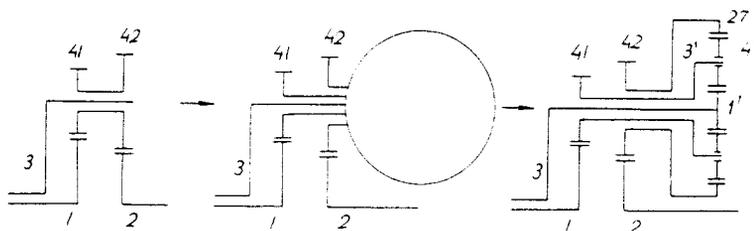


Figure 1.

The two kinds of bracket are used here to differentiate between the outer and inner planetary trains.

After having presented the above example, let us consider in how many different forms these moon-and-planet elementary and simple *PGTs* may appear.

As is well known, the elementary *PGT* has three basic types: $P(P)$, $N(P)$, and $P(N)$. Fig. 2. The inner *PGT* can be built in between the planet gear and the arm of the outer *PGT*. As the *PGT* under discussion is an elementary one, the inner *PGT*

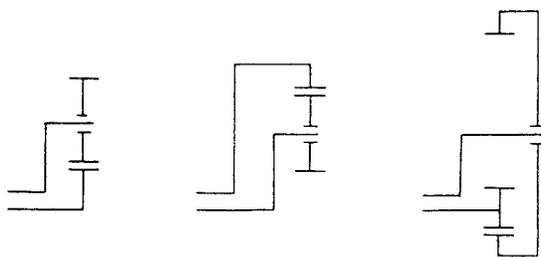


Figure 2.

should also be an elementary one. All three types of the elementary *PGT* can be used both as inner *PGT* and as outer *PGT*, and all three types can be built-in in two ways, as is shown in Fig. 3. In conclusion, it can be stated that there are 18 possible types of the moon-and-planet elementary *PGT*. Such *PGTs* may be found in Buchsbaum and Freudenstein, too [2].

As can be seen by looking at the family tree, the simple *PGT* has 34 basic types. Among these

4 have neither an auxiliary planet gear nor an internal planet gear. Fig. 4,

8 have an auxiliary planet gear but no internal planet gear,

3 have no auxiliary planet gear but have an internal planet gear,

19 have both auxiliary and internal planet gears.

First we will discuss the adaptation of the first four types, since these are the most common in use. In order to insert the inner *PGT*, the planet gears of the outer *PGT* must be cut in two. This process provides identical *PGTs* from the first two types. However, we have to take two variations of it because of the difference between its central gears (one is internal and the other is external). All four types may be used as an inner *PGT* and theoretically each of them can be built-in in three different ways; i.e. from the four most frequently used simple *PGTs*, there are theoretically 48 kinds of

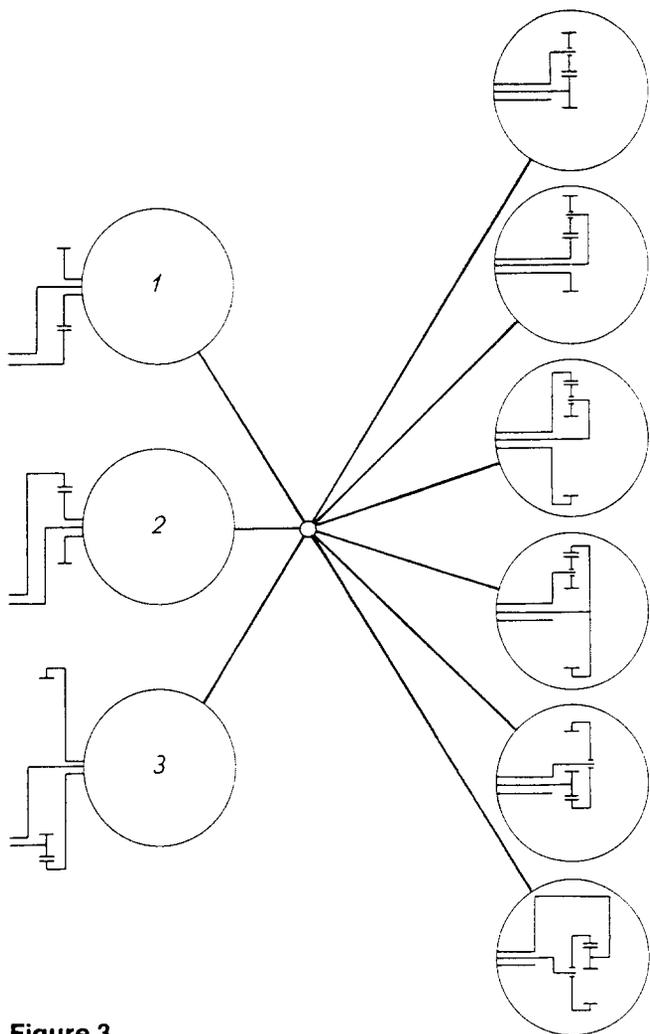


Figure 3.

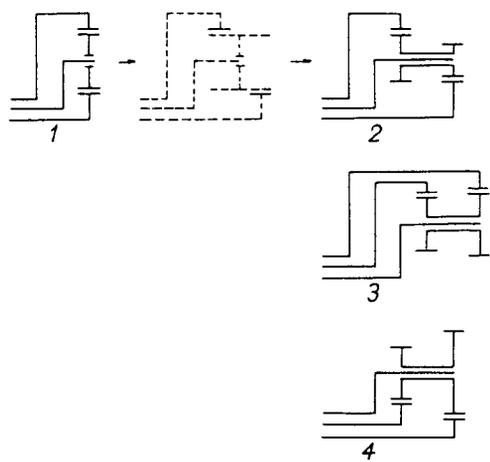


Figure 4.

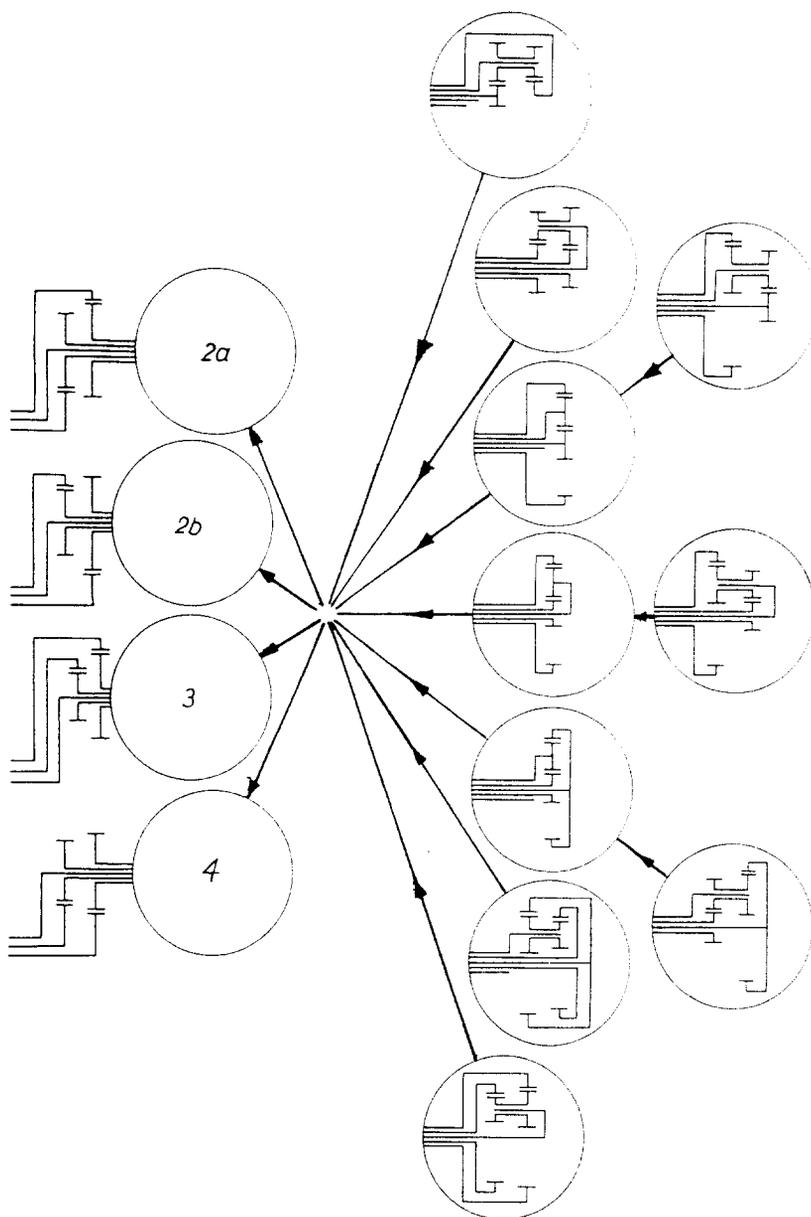


Figure 5.

moon-and-planet *PGTs* which can be obtained. If, however, we choose to make no distinction whether the two central gears of the outer *PGT* are both external or internal, then some of the ways of building-in are found to lead to the same final result. The left side of Fig. 5 shows the four cut-up *PGTs*, while the right side of the same figure shows the possibilities of building-in the simple *PGTs* as inner or moon trains. There are in all 10 such possibilities. Accordingly, 40 kinds of moon-and-planet simple *PGTs* exist, if neither auxiliary nor internal planet gears are taken into consideration.

The number of types will increase, if varieties with an external auxiliary planet gear are also taken into account.

First let us build-in an auxiliary planet gear only into the outer *PGT*. Since it is not at all significant with which of the central gears the auxiliary planet gear is to be in mesh, we have to take into account 8 variations of *PGTs* with cut-up planet gears and with auxiliary planet gears, instead of 4. Therefore, the number of the moon-and-planet *PGTs* of this type is 80.

If compound gears are also taken into consideration as auxiliary planet gears, then the number of outer *PGTs* with an auxiliary planet gear will be 16 and not 8. Accordingly, in such a case the number of moon-and-planet *PGTs* is not 80, but 160. This number would increase still further should we also allow auxiliary planet gears to be internal. Such types, however, have little practical significance.

Thus far, no investigations have been made by us regarding the practical significance of these moon-and-planet *PGTs* in general. At first sight they seem to be rather complicated and sophisticated, but perhaps one or more types will be found to be suitable for generating special motions.

References

- [1] LEVAI Z. Structure and analysis of planetary gear trains *J. Mechanisms* 3, 131–148 (1968).
- [2] BUCHSBAUM E. and FREUDENSTEIN, F. Synthesis of the kinematic structure of mechanisms. *J. Mechanisms* 5, 357–392 (1970).