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KINEMATICS OF COMPOUND DIFFERENTIAL MECHANISMS

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Describes method of types synthesis, lists 35 types, and gives applications to gearboxes and bifurcated-power transmissions.

This paper is published for written discussion. Communications are invited for publication in the Proceedings. Contributors should read the instructions overleaf.

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Discussion

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I found the author's analysis of the planetary gears exceedingly interesting; the Molian–Salamoun formula

$$c+l = 2n-M$$

may really be very well used.

On the basis of this formula, the author drafted 35 families for the cases $n = 1$, 2 and 3. In my opinion, less families than these should be differentiated. Family No. 12, for example, is not real since, strictly speaking, it corresponds to family No. 1 or, respectively, No. 2. There are two possible cases. When the first two of the three planetary gears (i.e. the two locked planetary gears) are uniform, then $M = 2$ for the third planetary gear. We then obtain family No. 2. When the two locked planetary gears are not uniform, they constitute a rigid body locking one of the shafts of the third planetary gear. We then obtain family No. 1.

Families which differ only in form are illustrated in Figs 5 and 6. The following families are identical.

$$8 = 9$$
$$11 = 13$$
$$17 = 18 = 19$$
$$21 = 23$$
$$22 = 24$$
$$28 = 29 = 30$$
$$32 = 33$$
$$34 = 35$$

Omitting the duplications, as well as the faulty family No. 12, only 24 families, instead of 35, can be discussed.

I am going to draft the cases $l = 0$ and indicate the value which l can obtain and at which of the families, as well as the corresponding M values. Fig. 11 illustrates an instance for such an abbreviated classification, as well as nine families. Here I did not draft the planetary gears in one line as proposed by the author. Regarding the drafts, the lockings are omitted. However, one should be clear about the fact that brakes may be allotted to any of the accessible, but not independent, shafts. In other words, one shaft cannot be connected and locked at the same time, while we are dealing with systematics of compounds generally.

In the case of the gearbox design, all the shafts are equal, that is, theoretically any of the shafts (the single ones as well as the connected ones) can be input, output or locked shafts.

In Figs 25–27 the author regards only families 7, 8 and 9 as suitable for designing a 3-speed gearbox. In fact, these families have the advantage that only a single brake has to be engaged in order to achieve any of the gear ratios different from 1:1. At the same time, these 'one operation' types have the disadvantage that an n-speed gearbox, excluding the direct transmission, needs at least n differentials.

In a given case, however, all the other families may be used even more advantageously. In families 5 and 6 two brakes always have to be thrown into gear to obtain

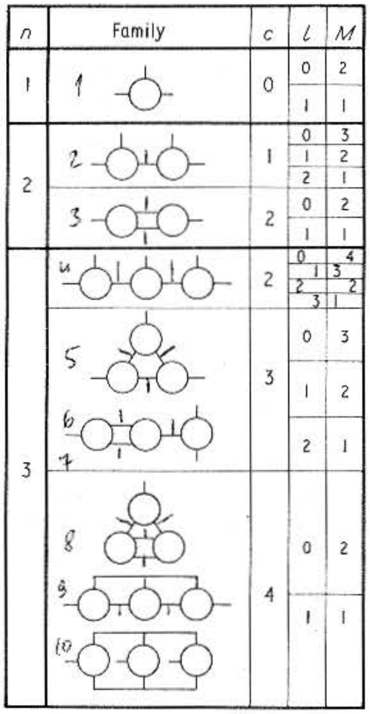

Fig. 11. Abbreviated (shortened) classification of compounds

$M = 1$. In some cases a clutch has to be used instead of one of the brakes; this blocks one of the planetary gears, excluding it from the drive (two operation types). In family 4 three devices must always operate. One or two of these devices may be clutches, but the third must be a brake. Should we wish, however, to establish a gear ratio of 1:1, that is, a direct connection, then a clutch must be thrown in instead of the third brake. The best instance of this is the Cotal gearbox (see Fig. 12).

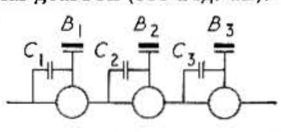

Fig. 12. Cotal gearbox

In the Cotal gearbox, the following brakes B or clutches C have to be used to realize each of the transmission ratios:

speed 1: C_1 B_2 B_3
speed 2: C_1 B_2 C_3
speed 3: C_1 C_2 B_3
speed 4: C_1 C_2 C_3 (direct)
reverse: B_1 B_2 B_3

The two or more operation types provide gearboxes of speed more than $n+1$.

In the 'one operation' families (i.e. families 7, 8 and 9) the method described in (**21**) also proved to be suitable to establish the variations of the gearboxes of this type.

A general draft serving as a starting point of the analyses, which, for the case $n = 3$, is shown in Fig. 13. In Fig. 13, two shafts, three brakes and the places of ten planetary gears can be seen. All the possible modes of their connections to each other are indicated. Since only three planetary gears are necessary for the 3-speed gearbox three of the ten places must be filled by planetary gears. The selection of these three from among the ten places is limited because both of the two shafts and all of the three brakes must have at least one connection to at least one of the selected three places. Therefore, the unit of three places, for example, consisting of 4, 6 and 10, will not be suitable, since not one of these has a connection to the right-hand side shaft. Taking all the variations one by one, we obtained the same 14 solutions enumerated by the author in Fig. 8. It must be mentioned that, although the 3-speed transmissions have only 14 basic configurations, a transmission could be constructed in many ways. This is because the planetary gears have 34 different types (22) and can be built in different ways. Taking into consideration all these, the number of the variations of an actual 3-speed gearbox will be considerably great. According to our computations (23) this number is 48 066 480.

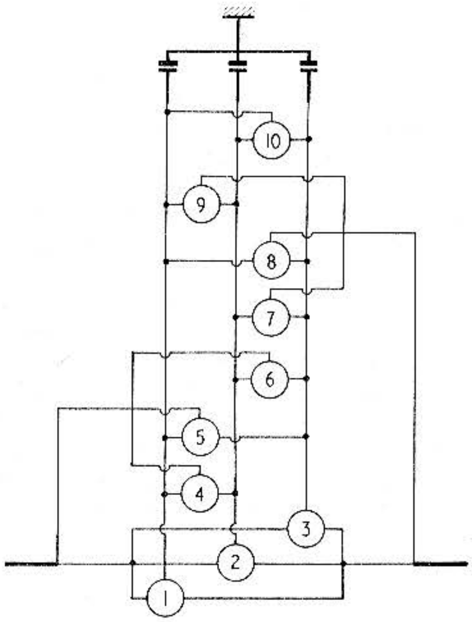

Fig. 13. Complete network for 3-speed gearbox design

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