

CONTRIBUTION TO THE SYSTEMATICS OF CHANGE-SPEED-GEARBOXES OF PLANETARY TYPE

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The change-speed-gearboxes incorporating up to three differentials can be named as "one-, two-, or three-operation" types depending on how many brakes must be simultaneously operated (locked) to achieve different speeds. The one- and the three-operation types are widely known. Author examined the two-operation types in detail to show their advantages over the others.

Compound differential mechanisms may be constructed by connecting the shafts of the simple planetary gears (differentials). The degree of freedom ("mobility") of compound (M) depends on the number of differentials (n), on the number of connections between the differentials (c), and on the number of the eventually locked (braked) shafts (l). (From the point of view of locking, already the two or more shafts are considered as being one.) According to MOLAIN [1] and SALAMOUN [2, 3] the relationship between these parameters is:

$$M = 2n - c - l. \quad (1)$$

By using this formula, MOLAIN synthesized and listed the compounds incorporating up to three differentials [1]. In his list, there are two families for the single differential, five families for the compounds consisting of two differentials, and twenty-eight families for those consisting of three differentials. The total number of the families is large, because he considered the variations of the locking as separate families. Moreover, there is one family among these (Family No. 35) which, because of its main properties, does not fit into the row of the others. This family consists of three differentials. In reality, it corresponds to two mechanisms, each of these consisting of two differentials. One of these differentials is used doubly. Therefore, this family cannot be regarded as an independent family, but as a special combination of families consisting of two differentials.

In case one does not consider the variation of locking as an independent family and one dispenses with the MOLAIN's Family No. 35, then, one has to consider 10 families for the compounds incorporating up to three differentials (Fig. 1). (In [4] one of the families was erroneously left out.)

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


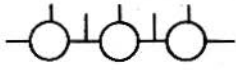
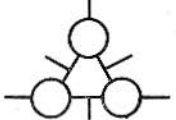
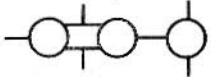
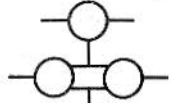
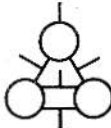
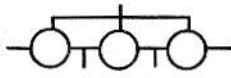
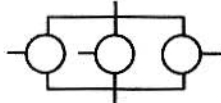
n	Family	c	l	M
1	No. 1 	0	0	2
			1	1
2	No. 2 	1	0	3
			1	2
			2	1
	No. 3 	2	0	2
			1	1
3	No. 4 	2	0	4
			1	3
			2	2
			3	1
	No. 5 	3	0	3
			1	2
	No. 6 	2	0	2
	No. 7 		1	1
	No. 8 	4	0	2
1			1	
				No. 9 
No. 10 				

Fig. 1

Fig. 1 also contains the possible combinations of n, c, l , and M obtained by giving formula (1).

Compound trains are used mainly in automobile change-speed-gearboxes. In this case, as a matter of course, the M has to be equal to 1. From

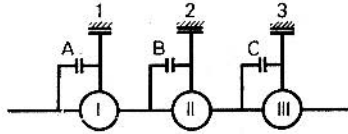


Fig. 2

Fig. 1, it may be seen that for Families Nos 1, 3, 8, 9 and 10, the locking of one shaft, for Families Nos 2, 5, 6, and 7, the locking of two shafts and for Family No. 4 the locking of three shafts result in $M = 1$.

In principle, a brake for locking can be added to any of the shafts. For multi-speed gearboxes, brakes are fitted to several shafts, but of these brakes only that one is operated which is needed.

In practice, one of the differentials in the compound can be blocked by a clutch (instead of locking it). In this way a new transmission ratio is gained (in the most cases this ratio is 1 : 1).

Although Fig. 1 shows only 10 families, by varying the role of the shafts (input-, resp. output-shafts, locked shafts) considerably more variations are possible for the theoretical design of the change-speed-gearboxes.

As mentioned above, for Families Nos 1, 3, 8, 9, and 10, the locking of one single shaft is needed to obtain $M = 1$. These "one-operation" families are characterized by the fact that at the most, as many transmission ratios, different from 1 : 1, can be achieved as many differentials are incorporated in it. Naturally, in this case it is also possible to operate not a brake but a clutch blocking one of the planetary gears. However, this always results in a direct transmission.

The change-speed-gearbox types that may be developed of the one-operation families are described in [5].

On the basis of the "three-operation" family No. 4, only one single rational gearbox can be constructed, and this has already been realized in the Cotal gearbox (Fig. 2). Here, the blocking clutches play a significant role: in most cases at least one clutch is closed. Theoretically, by varying the lockings and the blockings, 8 transmission ratios can be realized; in practice, however, only five of them are used, as follows:

A — 2 — 3 first speed

A — 2 — C second speed

- A — B — 3 third speed
 A — B — C fourth speed (direct drive)
 1 — 2 — 3 reverse

The "two-operation" families (Nos 2, 5, 6, 7) had up till now remained outside the sphere of interest. It was found expedient, therefore, to examine

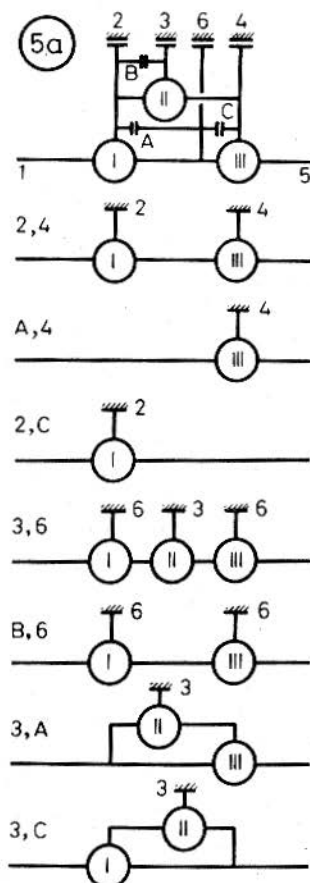


Fig. 3

them further in detail. It is necessary to consider the variety of ways in which input and output can be applied excluding mere interchanges of input and output.

It is not worthwhile to discuss Family No. 2, since this may be considered as a part of Family No. 4.

Family No. 5 can be used in four ways (Figs 3, 4, 5, 6). One can also see how many speeds can be achieved by operating the brakes and the clutches.

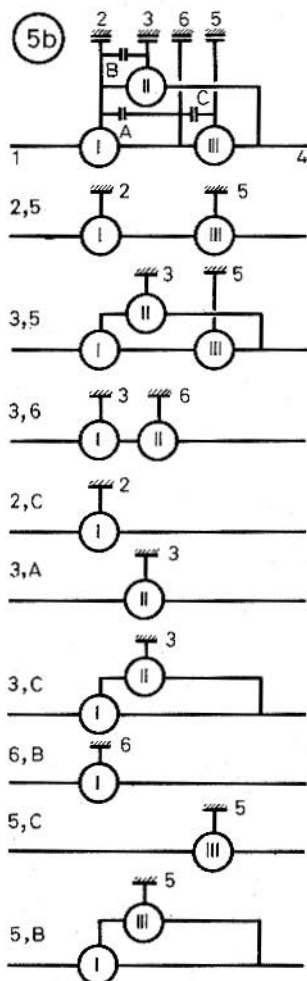


Fig. 4

Family No. 6 can be used in eight ways. However, there are six among these where one or two differentials are in a lateral position, i.e., it is not possible for them to take in part the power-transmission in any one of the speeds. The remaining two ways are demonstrated in Figs. 7 and 8.

Concerning Family No. 7, the situation is the same as for Family No. 6. The two ways which can be used are shown in Figs 9 and 10.

The eight new gearbox types shown in Figs 3–10, appear to have advantages over the existing types, and might replace some of the gearboxes used at present. One of the advantages is that the number of the realizable speeds is considerably greater than that of the differentials incorporated in the

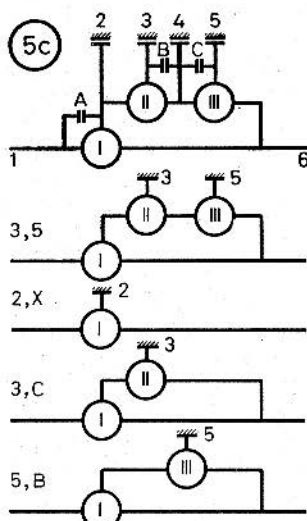


Fig. 5

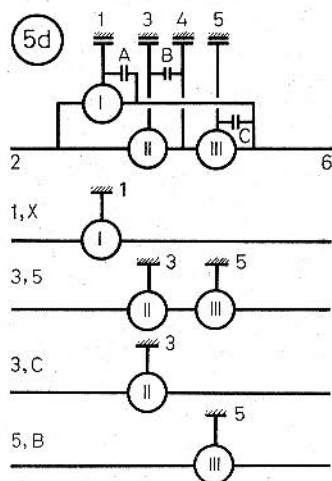


Fig. 6

gearbox. From this point of view especially Type 5b is significant (Fig. 4), since on the basis of it a 10-speed gearbox may be built. (The Wilson gearbox also containing three planetary gears, but derived of a "one-operation" family, possesses only four speeds.) Regarding the number of speeds, Type 5b surpasses even the "three-operation" Cotal gearbox. It has the further advantage that for realizing any of the speeds only two devices (brake or clutch) have to be operated instead of three.

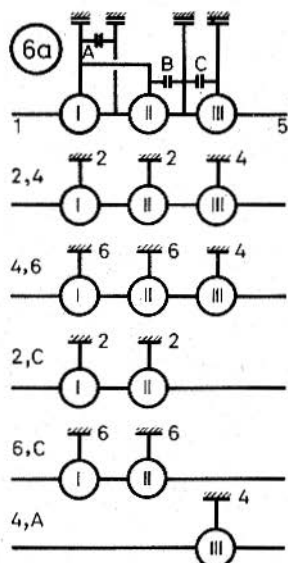


Fig. 7

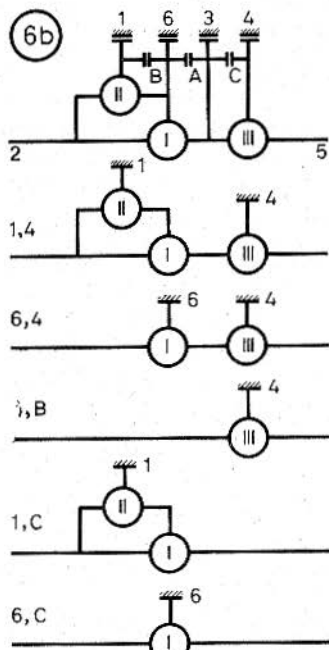


Fig. 8

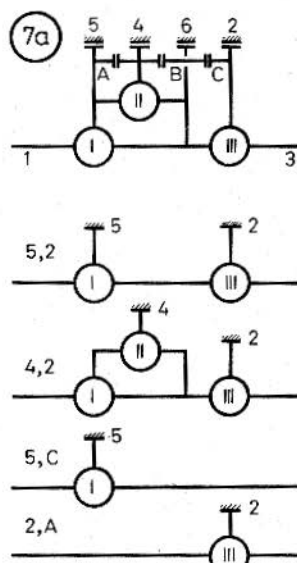


Fig. 9

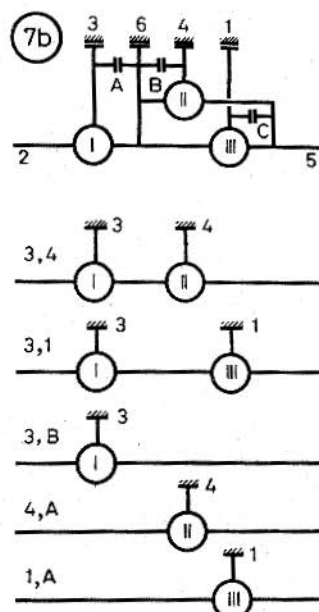


Fig. 10

Though less advantageous than Type 5b, Type 5a also surpasses the Wilson as well as the Cotal-type gearboxes.

Finally, it must be mentioned that the present paper deals only with the so-called "constant internal arrangement" gearboxes. These gearboxes are characterized by the fact that all main elements of all planetary gears (the central gears and the carrier) are in constant connection with the gearbox's main elements (input-, resp. output-shafts, brakedrums). There also exist "variable internal arrangement" gearboxes, where the connection of the planetary gear's elements with the main elements of the gearbox is permutable. The permutation multiplies the realizable transmission ratios [5]. Such types of gearboxes were not considered in this paper.

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Beiträge zur Systematik der Planetengetriebe. Die aus höchstens drei Planetengetrieben bestehenden Wechselgetriebe können »einfach-, doppelt- oder dreifachwirkend« genannt werden, je nachdem, ob zur Erzielung der einzelnen Stufen die gleichzeitige Betätigung von einer, zwei oder drei Bremsen oder Schalter nötig ist. Die einfach- und dreifachwirkenden Typen sind weitgehend bekannt. (Klassische Beispiele sind die Wilson- und Cotalgetriebe.) Der Verfasser untersucht die Zweischaltergetriebe genauer und weist ihre Vorteile nach.

К систематике коробок передач с планетарным механизмом. Коробки передач, содержащие максимально три планетарных механизма, можно назвать коробками передач типа с «одним, двумя или тремя маневрами», а именно в зависимости от того, что сколько тормозов или переключателей надо вводить в действие (или держать включенным) одновременно, чтобы получить по одной передаче (или ступени). Типы с одним и тремя маневрами известны широко (классическим примером можно назвать трансмиссии системы Вильсона и Котала). Автор исследует типы с двумя маневрами; одновременно указывает на их преимущества по сравнению с остальными.