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(54) CHANGE-SPEED GEAR UNIT

(71) We, ZAHNRADFABRIK FRIEDRICH-SHAFEN AKTIENGESELLSCHAFT, of Friedrich-shafen-on-the-Bodensee, Federal Republic of Germany, a Joint-Stock Company organised under the laws of the Federal Republic of Germany, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to a change-speed gear unit of the kind comprising a multispeed main gear unit and a secondary gear unit which is coupled thereto and which contains a planetary gear train comprising at least three elements, a first element being continuously connected to the main gear unit, a second element continuously connected to an external shaft (input or output shaft of the change-speed gear unit), and a third element being adapted to be selectively connected by way of a first clutch to the casing to provide a first speed reducing transmission ratio of the secondary gear unit and to one of the other two elements to provide direct drive.

Change-speed gear units of the foregoing kind which contain a secondary gear unit of the planetary type are frequently so constructed that the secondary gear unit is connected downstream of the main gear unit (downstream secondary gear arrangement). The speed ratios of the main gear unit in this arrangement are shifted one after the other with the secondary gear unit providing the first transmission ratio and then one after the other with the secondary gear unit in direct drive.

It is often desirable to have available a finer gear ratio graduation, at least in direct drive of the secondary gear unit. Since with such arrangement the ratio changes in the main gear unit must be uniform, it is customary for the main gear unit to be preceded by another secondary gear unit in order to halve its ratio difference. The additional upstream unit nevertheless increases the overall length of the whole arrangement, which in many cases is not acceptable for lack of space.

The invention aims at obviating the foregoing disadvantages by providing a change-speed gear unit having means providing intermediate gear ratios and acting in a "fast"

speed range, without said means having an adverse effect on the overall length of the gear unit.

To this end, the present invention consists in a change-speed gear unit of the kind hereinbefore set forth, wherein additional gear elements are disposed between the first element and the third element which additional elements are adapted to be selectively connected by means of a second clutch and which provide between the first and third elements a transmission ratio such that a third transmission ratio obtained in this manner in the secondary gear unit provides gear ratios of the change-speed gear unit between the gear ratios provided by the main gear unit.

Thus the intermediate gear ratios are formed through the fact that the existing planetary gear train of the secondary gear unit is driven with branched power by additional connectable gear elements, so that in addition to the first transmission ratio, in which the planetary gear train acts as speed reduction gearing, and the direct drive, in which the planetary gear train rotates as a block, the secondary gear unit is provided with a third transmission ratio which provides the gear ratios of the change-speed gear unit between those provided by the main unit, that is to say which may correspond approximately to the square root of the average ratio between the gear ratios of the main gear unit (or the reciprocal thereof).

In this manner an upstream secondary unit otherwise necessary for providing the intermediate gear ratios can be avoided. The additional gear elements can be accommodated in the existing planetary secondary gear unit without requiring any substantial additional space, so that the space-saving design of a change-speed gear unit containing a planetary change-speed gear is retained and shifts can be made without great expense because the secondary gear unit already contains (for its first clutch) a shift device which can be correspondingly supplemented.

The means providing the intermediate gear ratios can also be fitted to existing units provided that provision is made for the accommodation and mounting on the casing of the additional gear elements.

Advantageously, the third transmission stage

of the secondary gear unit has a partial speed increasing transmission ratio. By virtue of this feature an overdrive is obtained in the highest gear ratio (overall ratio lower than 1).

- 5 In a preferred embodiment in which the planetary gear train is connected downstream of the main gear unit and consists of a sun wheel, a cage and a ring gear and has a first shaft disposed between the main and secondary gear units and is connected to the sun wheel, the connectible gear elements consist of four gears of which the first is mounted on the first shaft, the second and third gears are mounted on an auxiliary shaft parallel to the first shaft, and the fourth gear is connected to the ring gear. This provides a simple space-saving configuration of the additional connectible gear elements. All that is required here is an additional shaft, since of the four gears two can be mounted on respective existing shafts. The second clutch may advantageously be mounted on the auxiliary shaft thereby requiring a particularly small axial space for accommodating the entire arrangement.

- 25 It is possible without difficulty to select two different transmission ratios by means of the second clutch of double construction, thus achieving gear ratios between the gear ratios of the main gear unit, or to save gear ratios in the main gear unit.

- 30 In order that the invention may be more readily understood, reference is made to the accompanying drawing which illustrates diagrammatically and by way of example one embodiment of change-speed gear unit in accordance therewith.

- 35 The change-speed gear unit shown in the drawing comprises a main gear unit 10 having four forward gear ratios and a reverse gear ratio and a secondary gear unit 11 of planetary construction.

- 40 In known manner the main gear unit is of layshaft construction with gears in constant mesh and adapted to be shifted by its shafts, and it contains an input shaft 12, a layshaft 13, and a main shaft 14, by means of which shafts the power is transmitted from the main gear unit to the secondary gear unit 11 disposed downstream of it.

- 50 The secondary gear unit 11 contains a simple planetary gear set 15 having three elements — sun wheel 16, cage 17 with a planet gear 19 and ring gear 18. The sun wheel 16 is continuously connected to the main shaft 14 of the main gear unit 10, while the cage 17 is continuously connected to an output shaft 20 of the change-speed gear unit. A planetary train of this kind has two running speeds, that is to say the rotational speeds of all elements are fixed only when the rotational speeds of two elements are determined. The ring gear 18 of the planetary gear train is adapted to be connected selectively by way of a first clutch 21 to the casing 22 or to one of the other two elements — in

this case the cage 17, thus in the first case (“slow range”) giving a speed decrease ratio and in the second case (“fast range”) direct through-drive with the planetary train rotating as a block. The arrangement described so far is known and provides a gear unit having eight forward speed ratios, of which the four ratios of the main gear unit are first engaged one after the other in the “slow” group range and, after the secondary gear unit has been shifted to the “fast” range, are again engaged one after the other.

In addition to the planetary gear set 15 the secondary gear unit 11 also contains four gears 23, 24, 25, 26 as additional gear elements, of which the gear 23 is mounted on an extension of the main shaft 14 or first shaft, associated with the sun wheel 16, of the planetary train, the gears 24 and 25 are mounted on an auxiliary shaft 27 parallel to the first shaft, and the gear 26 is fastened to the ring gear 18. The gears 23 to 26 together constitute between the sun wheel 16 and the ring gear 18 a transmission ratio which is different from 1:1 and which can be engaged with the aid of a second clutch 28 between the auxiliary shaft 27 and the gear 25 mounted rotatably thereon.

The second clutch 28 is engaged only when the first clutch 21 is disengaged. When the second clutch is engaged, power is supplied to the planetary train on two paths: firstly through the sun wheel 16 directly connected to the shaft 14 and secondary through the ring gear which is driven indirectly by the shaft through the gears 23 to 26. The two power fractions are combined in the planetary train through its planet gear 19 and supplied through the cage 17 to the output shaft. The secondary gear unit thus provides a third transmission ratio which effects an increase of speed and which is calculated on the basis of the numbers of teeth Z_{16} and Z_{18} of the sun wheel and ring gear respectively and of the numbers of the teeth Z_{23} , Z_{24} , Z_{25} , Z_{26} of the gears 23 to 26, as follows:

$$i = \frac{1 + \frac{Z_{18}}{Z_{16}}}{1 + \frac{Z_{18} \cdot Z_{23} \cdot Z_{25}}{Z_{16} \cdot Z_{24} \cdot Z_{26}}}$$

and by varying the numbers of teeth can be so designed that it is suitable for increasing the gear ratios of the change-speed gear unit. If the average ratio difference (ratio between the transmission ratios of two adjoining ratios) in the main gear unit is, for example, 1.37, a transmission ratio of the secondary gear unit, which is additional to the range transmission ratios already provided and suitable for increasing the ratio stages of the change-speed gear unit, is $i = \sqrt{1.37}$ or 0.86 (reciprocal of 1.17 for a speed increase transmission ratio).

The total transmission ratios effective in the individual gear speeds of the change-speed gear unit and the associated partial transmission ratios of the main and secondary gear units associated therewith can be seen from the following Table:

	<i>Gear speed of complete gear unit</i>	<i>Total transmission ratio</i>	<i>Partial transmission ratio of main gear unit</i>	<i>Partial transmission ratio in secondary gear unit</i>	
15	1	9.16	2.67	3.43	} "Slow" range
	2	6.58	1.92	3.43	
	3	4.71	1.37	3.43	
	4	3.43	1.00	3.43	
	5	2.67	} 2.67	1.00	} 0.86
20	5'	2.38		0.86	
	6	1.92	} 1.92	1.00	
	6'	1.65		0.86	
	7	1.37	} 1.37	1.00	
	7'	1.17		0.86	
25	8	1.00	} 1.00	1.00	} 0.86
	8'	0.86		0.86	

It can be seen that despite the three possible transmission ratios of the secondary gear unit ($i = 3.43: 1.00; 0.86$) the change-speed gear unit has only two ranges, and that in the "fast" range shifts are alternately made in the secondary gear unit (between the transmission ratios 1.00 and 0.86) and in the main gear ratio.

In addition, it can be seen that of the additional gear speeds 5', 6', 7', 8' produced by the additional elements the last gear speed 8' provides an overdrive (overall ratio < 1). With a slightly different arrangement of the gears it is, however, also possible for the ring gear to be driven in the opposite direction to the sun wheel, so that the third transmission ratio of the secondary gear unit is a speed decrease ratio. In this case an additional subdividing transmission ratio is obtained between the fourth and fifth gear speeds, while the gear speed 8' is eliminated.

With the aid of the clutch 28, which would then be constructed as a double clutch, it is also possible to insert a second transmission ratio between the auxiliary shaft 27 and the ring gear

18 by means of a further gear mounted on the shaft 27 and a further gear fastened to the ring gear 18.

WHAT WE CLAIM IS:—

1. A change-speed gear unit of the kind hereinbefore set forth, wherein additional gear elements are disposed between the first element and the third element which additional elements are adapted to be selectively connected by means of a second clutch and which provide between the first and third elements a transmission ratio such that a third transmission ratio obtained in this manner in the secondary gear unit provides gear ratios of the change-speed gear unit between the gear ratios provided by the main gear unit.

2. A change-speed gear unit as claimed in claim 1, in which the main gear unit has speed reduction ratios, wherein the third transmission stage of the secondary gear unit has a speed increasing transmission ratio.

3. A change-speed gear unit as claimed in claim 1 or 2, in which the planetary gear train is connected downstream of the main gear unit and consists of a sun wheel, a cage, and a ring gear and has a first shaft disposed between the main and secondary gear units and is connected to the sun wheel, the additional gear elements consist of four gears of which the first is mounted on the first shaft, the second and third gears are mounted on an auxiliary shaft parallel to the first shaft, and the fourth gear is connected to the ring gear.

4. A change-speed gear unit as claimed in claim 3, wherein the second clutch is mounted on the auxiliary shaft.

5. A change-speed gear unit as claimed in claims 1 and 2, wherein one at a time of two of the additional gear elements can be shifted by means of the second clutch.

6. A change-speed gear unit constructed, arranged and adapted to operate substantially as herein described with reference to and as shown in the accompanying drawing.

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