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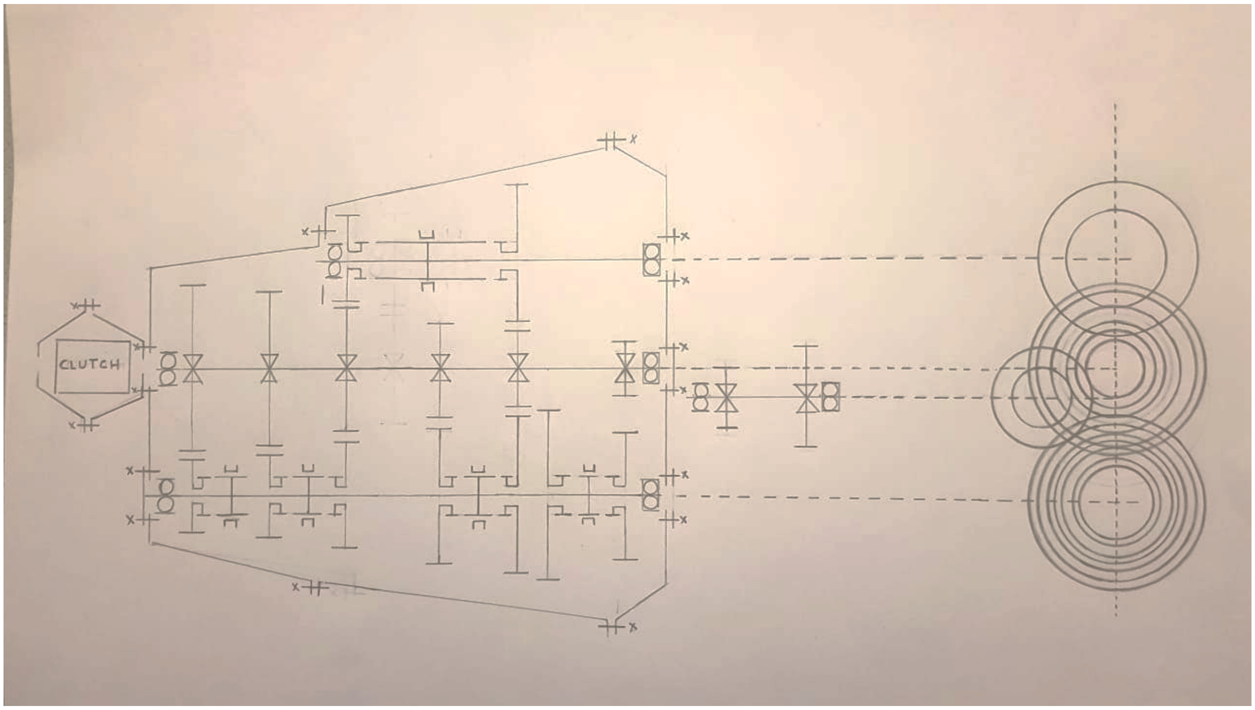
Shift Transmission Concept 1

Principal Sketch



Working Principle

The first concept makes use of a single clutch pack and an additional shaft with another synchroniser to transfer loads to the PTO shaft. This means that the 1st and the 3rd gears of the input shaft will be used to drive the two gears of the PTO output shaft. This is a simple, elegant solution but there are a lot more rotating masses at any given point, resulting in lower efficiency.

Gear Ratio

	Ratio	**Speed (km/h)**
Gear 1	2.138 : 1	5
Gear 2	1.336 : 1	8
Gear 3	0.712 : 1	15

Gear 4	0.356 : 1	30
Gear 5	0.267 : 1	40
Reverse 1	-5.344 : 1	-2
Reverse 2	-2.138 : 1	-5

Calculation of Minimum Shaft Diameter

The minimum diameter of the shaft can be calculated using the minimum shaft diameter equation shown below:

$$d_{erf} \geq \sqrt[3]{16 * \frac{S * M_T}{\pi * \tau_{max}}}$$

wherein d_{erf} is the minimum shaft diameter, S is the safety factor, M_T is the torsional moment, and τ_{max} is the maximum admissible torsional stress the shaft may experience. For this calculation, a safety factor of S = 2 and a maximum admissible shear stress value of τ_{max} = 330 MPa. From the ratios, the maximum torsional moment on each shaft can be calculated:

	Maximum Torsional Moment (Nm)
Input Shaft	505
Countershaft - Reverse	1060
Output Shaft	2700
PTO Shaft	1170

With all the values available, we can use the equation to find the minimum shaft diameters:

	Minimum Shaft Diameter (mm)
Input Shaft	25
Countershaft - Reverse	32
Output Shaft	43.7
PTO Shaft	33.1

Calculation of Minimum Gear Diameter

To calculate the minimum gear diameter, we can use the following equation:

$$d_{min} = \sqrt[3]{2 * \frac{S * M_T}{x_B * B_{Zul}}}$$

wherein d_{min} is the minimum gear diameter, S is the safety factor, M_T is the torsional moment, x_B is the ratio between the width and the diameter of the gear wheel, and B_{zul} is the admissible load value. For this calculation, values of S = 2, x_B = 0.4, and B_{zul} = 5 MPa will be used.

The gear diameters and widths are shown in the table below:

	Minimum Gear Diameter (mm)	Minimum Gear Width (mm)	Chosen Gear Diameter (mm)
Gear 1	120	56.6	272.5
Gear 2	102.6	51.3	230

Gear 3	83.2	41.6	165
Gear 4	66	33	105
Gear 5	60	30	85
Reverse 1 (Input)			100
Reverse 1 (Output)	205	51.3	300
Reverse 2	120	60	210
Countershaft Reverse 1	120	60	120
Countershaft Reverse 2	120	60	210
PTO Gear 1	123	61.6	272.5
PTO Gear 2	61.6	30.8	185.4

Axes of the countershaft and PTO shaft are offset by **200mm** & **212.5mm** respectively from the axis of the drive shaft.

Calculation of Teeth Modulus and Number

The module that will be used can be determined based on the approximate number of teeth required for surface-hardened spur gears and the minimum gear diameter. The number of teeth and teeth modulus can be calculated using the equations below:

$$Z = 14 + \frac{v}{5} + \frac{d}{40} \qquad m = \frac{d}{14 + \frac{1}{300} * d * \pi * n + \frac{d}{40}}$$

Substituting the minimum diameter with d, you can calculate the number of teeth:

	Minimum Teeth Modulus (mm)	Chosen Teeth Modulus (mm)
Gear 1	6.62	8.63
Gear 2	5.22	5.32
Gear 3	3.69	2.95
Gear 4	2.39	2.6
Gear 5	1.97	4.7
Reverse 1	10.03	16.6
Reverse 2	6.56	9.84
Countershaft Reverse 1	6.56	6.6
Countershaft Reverse 2	6.56	9.9
PTO Gear 1	6.88	12.5
PTO Gear 2	5.04	8.5

Based on the table above, as well as DIN 780 and the minimum teeth diameter, we decided that the value of the teeth modulus should be m = 2.5 mm. Finding the ratio between the diameter and the teeth modulus, we obtain:

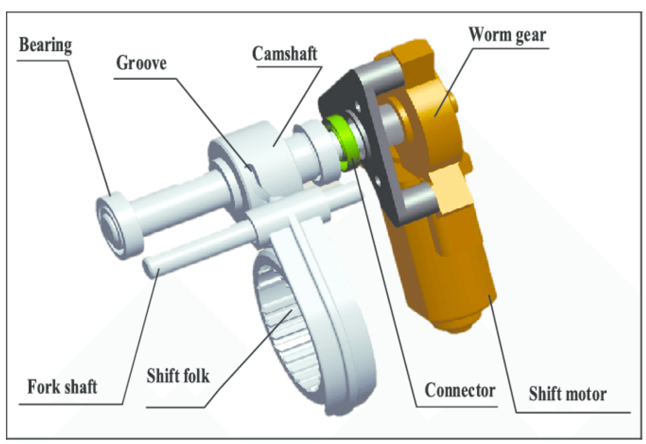
	Number of Teeth (Input)	Number of Teeth (Output)
Gear 1	51	109
Gear 2	68	92
Gear 3	94	66
Gear 4	118	42

Gear 5	126	34
Reverse 1	40/48	120
Reverse 2	84	84
PTO Gear 1	51	119
PTO Gear 2	75	95

Actuators

The gear change takes place via several shift rods, which are fixed in the housing via slide bearings and are connected to the sleeves via shift forks. The gears are controlled hydraulically and automatically and the PTO is controlled by hand. The shift forks are attached to their own shift rods that means that there is 1 shift rod corresponding to each shift fork. The housing through which the shift rod enters will be lined with linear bearings to limit degrees of freedom to only one translatory motion. The housing also sees the use of a compression ring as well as scrapers and/or wipers in order to keep the lubricating oil inside and the harsh farm environment outside in order to ensure smooth operation.

The shift actuators for the drive gears themselves are grooved shafts that are linked to the automatic actuating mechanism. Each groove on the actuating shaft corresponds to one of the shift forks for the drive gears. Each kink of the groove corresponds to one change in position of that corresponding shift fork. So rotating the actuating shaft will result in the different gears being engaged, allowing for quick gear changes that take place in a fraction of a rotation. Below is a 3d representation of one of the grooves and its effect on one shift fork.[1]



[1] TY - JOUR, AU - Hu, Jianjun, AU - Ran, Hongliang, AU - Pang, Tao, AU - Zhang, Yi ,PY - 2016/08/17, SP -

The actuator for the PTO shaft is similar to manual transmission, in that it makes use of the physical linear motion of the shifting gear by the driver to move the shift fork at the transmission linearly, resulting in PTO shaft speed selection with a simple move of a wrist.

Lubrication and sealing Concept

As in the hybrid module, oil bath lubrication is selected for most of the gearbox, sans one bearing. This offers the best balance of simplicity, costs, amount of oil, heat and particle removal. This is also the easiest to maintain. The high RPM ensures that all gears and bearings are sufficiently lubricated due to the spritzing of the lubricating oil by the gears, while maintaining a low oil level to ensure low churning losses.

Sealing at all housing joints are ensured by cheap, reliable paper seals. The sealing at all shafts leading out of the Shift gearbox are realised by the Radial shaft seals and those at the caps are sealed off using ‘O’rings.

T1 - Parameter design and performance analysis of shift actuator for a two-speed automatic mechanical transmission for pure electric vehicles, VL - 8, DO - 10.1177/1687814016664257 ,JO - Advances in Mechanical Engineering