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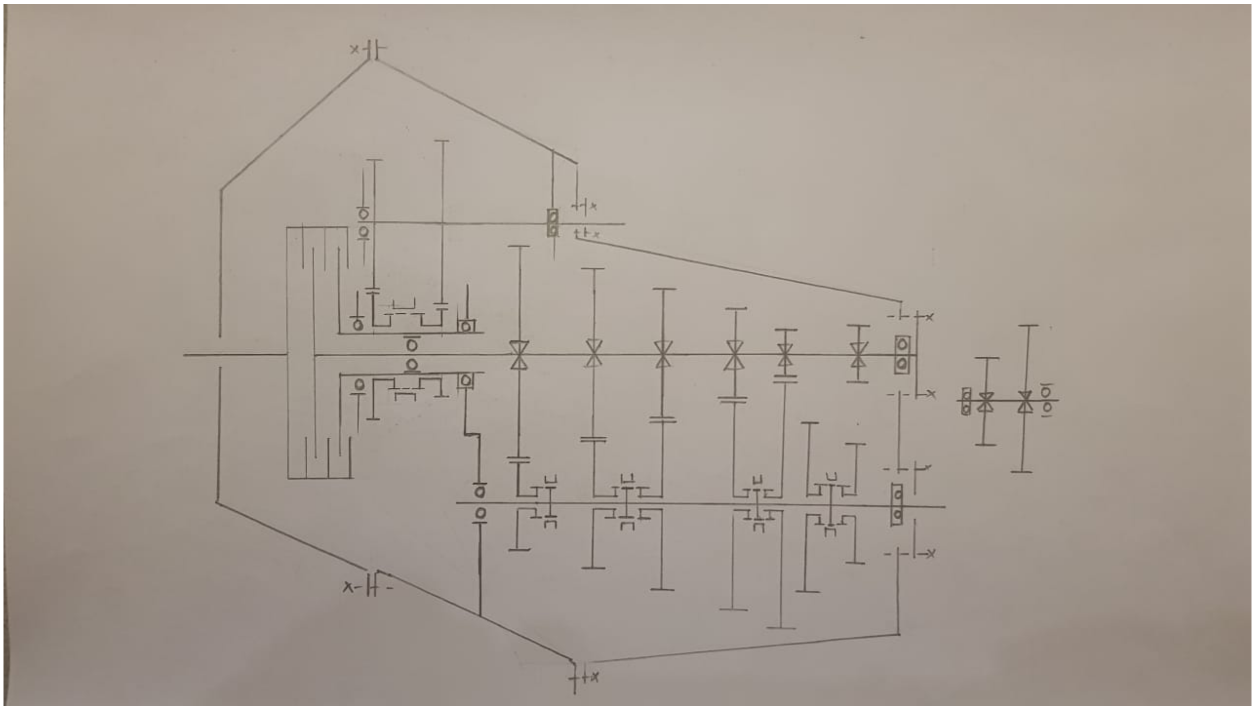
Shift Transmission Concept 2

Principal Sketch



Working Principle

This concept makes use of a dual-clutch pack to divide the load between the drivetrain and the PTO shaft. Each of the clutches transfers torque either to the PTO shaft or eventually to the wheels. They can be separately engaged or disengaged using a Mechanical actuator that is connected in series with spring. This system ensures that design space is smaller,and that the torque loads transmitted through the input shaft is smaller, leading to lower costs. Additionally, the use of clutches produces an inherent safety advantage in the since the torque loads are limited by the frictional force of the clutches which results in power cut-offs without failure to any components. An additional advantage is the fact that when not being used, no power is transferred to the PTO shaft or the drive train ensuring maximum efficiency of each since there is lower moment of inertia, friction and so on.

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 - Driving	505
Input Shaft - PTO	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 - Driving	25
Input Shaft - PTO (Min external diameter)	64.5
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)	Diameters used (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	205	51.3	300
Reverse 2	120	60	210
Countershaft 1 Gear (Reverse)	120	60	120
Countershaft 2 Gear (Reverse)	120	60	210
PTO Gear 1 (PTO shaft)	123	61.6	272.5
PTO Gear 2 (PTO shaft)	100	50	230

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

Calculation of the module and the number of teeth

The module to be used can be determined based on the approximate number of teeth required for surface-hardened spur gears and the minimum gear diameter.

The formula(e) used are :

$$Z = 14 + \frac{v}{5} + \frac{d}{40}$$

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

To calculate the maximum module of the gears, the minimum shaft diameters simply have to be input into the above equations, giving:

	Minimum Teeth Module(mm)	**Used Teeth Module (mm)**
Gear 1	6.62	11.6
Gear 2	5.22	8.63
Gear 3	3.69	5.32
Gear 4	2.39	2.946
Gear 5	1.97	2.57
Reverse 1 (input)		4.69
Reverse 1	10.03	16.6
Reverse 2	6.56	9.84
Countershaft 1 Gear (Reverse)	6.56	6.59
Countershaft 2 Gear (Reverse)	6.65	9.9
PTO Gear 1 (PTO shaft)	6.88	12.5
PTO Gear 2 (PTO shaft)	5.04	8.51

On the basis of this table, DIN 780 and the already specified gear wheel diameter, it was decided that the module $m = 2.5\ mm$ applies to all gear wheels.

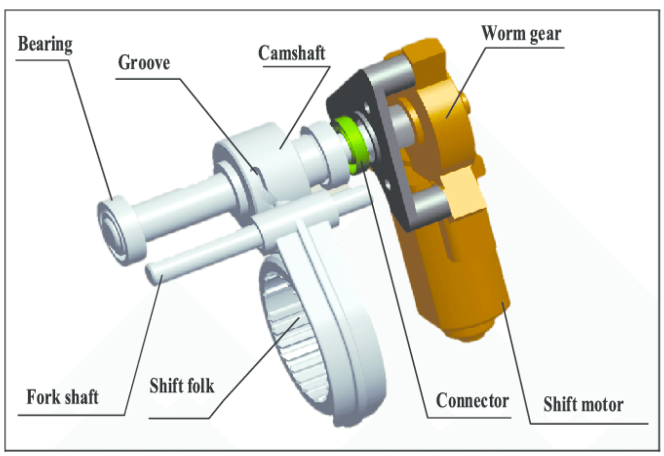
The number of teeth then results with

	Number of teeth on input shaft	**Number of teeth on output shaft**
Gear 1	51	109
Gear 2	68	92
Gear 3	94	66
Gear 4	118	42
Gear 5	126	34
Reverse 1		120
Reverse 2	84	84
Countershaft 1 Gear (Reverse)	40	
Countershaft 2 Gear (Reverse)	48	
PTO Gear 1 (PTO shaft)	51	119
PTO Gear 2 (PTO shaft)	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]

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.

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

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.