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# Study and Analysis of Manual Gear Transmission System for Automobile

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## Abstract

This paper is studied about the five speed manual gear transmission system for Ford Ranger automobile. Power transmission system for automobile is composing with transmission gear box, universal joint, propeller shaft, final drive and drive axle. The transmission consists of a train of gears with different sizes. The main aim of this study is about the investigation of how the five speed manual gear transmission influence on the vehicle's performance. The purpose of this investigation is for the driver's safety and comfort by ensuring good vehicle drive ability. This study is including the gear transmission, torque, wheel torque, tractive effort and vehicle speed.
Index term: *manual gear transmission, torque, tractive effort, vehicle speed*

## I. Introduction

Power transmission system is the next and final stage of the engine generated power before it hits the wheels. The whole system is responsible to couple engine and wheels, driving and adapting the output shaft rotation to a desired speed, torque ratio, a wider range of speed and better as the engine has its own RPM limit and maximum performance value. Power Transmission Systems are divided in three major blocks. They are: clutch, gearbox (Transmission) and differential. Each of them has a specific role transmitting power from the engine to the wheels ensuring correct rotation speed and torque. There are four big types of transmission. They are manual gear box, dual-clutch transmission (DCT), continuous variable transmission (CVT) and automatic transmission.

The manual transmission or manual gearbox contains gearing arrangement to get different speeds. Gears are used to get more than one speed ratios. When both mating gears have same numberof teeth, bothwill rotate at same number of speed. In a typical car, there may be six gear including one reverse gear. Higher gears give progressively increasing speeds. Gears are engaged and disengaged by a shift lever. Manual transmission in cars is usually controlled by an "H" pattern lever. Figure 1 shows the "H" pattern allows to move the shift rod between the control rods for the three forks and move the rods back and forth.

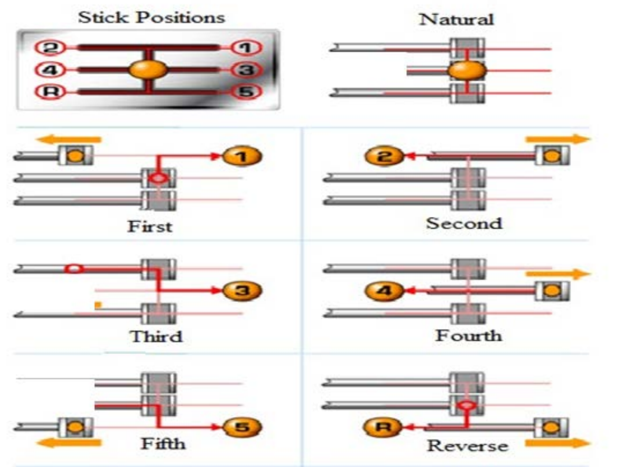


Figure 1 'H' Pattern Gear Transmission

## II.MANUAL TRANSMISSION POWER FLOW

The following sections describe the path of power through a typical five-speed transmission. Multiple gear sets within the transmission provide gear ratios to best utilize the engine's torque. A gear ratio of about 4:1 in first gear provides high torque to begin moving the vehicle. In contrast, a higher gear ratio of about 1:1 reduces engine speed at higher vehicle speeds when less torque is required to maintain momentum [2].

### A. First Gear

First gear power flow is illustrated in Figure 2. Power or torque flows through the input shaft and clutch gear to the countergear.

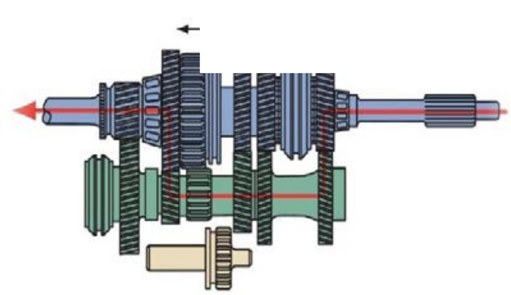

Figure 2. Power Flow in First Gear

The countergear rotates. The first gear on the cluster drives the first speed gear on the main shaft. When the driver selects first gear, the first/second synchronizer moves to the rear to engage the first speed gear and lock it to the main shaft. The first speed gear drives the main (output) shaft, which transfers power to the driveline.

## B. Second Gear

When the shift from first to second gear is made, the shift fork disengages the first/second synchronizer from the first speed gear and moves it until it locks the second speed gear to the main shaft. Power flow is still through the input shaft and clutch gear to the countergear. However, now the second countergear on the cluster transfers power to the second speed gear locked on the main shaft. Power flows from the second speed gear through the synchronizer to the main shaft (output shaft) and driveline Figure 3.

In second gear, the need for vehicle speed and acceleration is greater than the need for maximum torque multiplication. To meet these needs, the second speed gear on the main shaft is designed slightly smaller than the first speed gear.

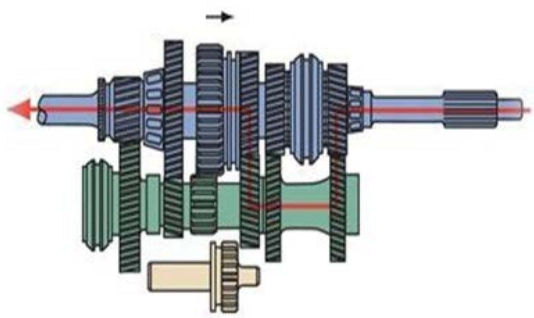

Figure 3. Power Flow in Second Gear

## C.Third Gear

When the shift from second to third gear is made, the shift fork returns the first/second synchronizer to its neutral position. A second shift fork slides the third/ fourth synchronizer until it locks the third speed gear to the main shaft. Power flow now goes through the third gear of the countergear to the third speed gear, through the synchronizer to the main shaft, and driveline Figure 4. Third gear permits a further decrease in torque and increase in speed.

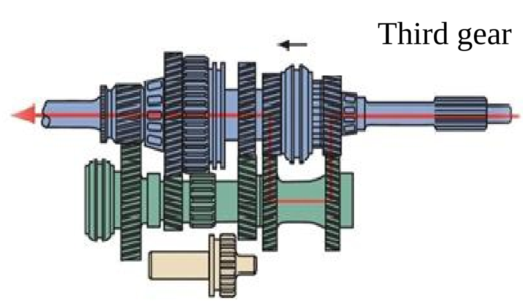


Figure 4. Power Flow in Third Gear

## D.Fourth Gear

In fourth gear, the third/fourth synchronizer is moved to lock the clutch gear on the input shaft to the main shaft. This means power flow is directly from the input shaft to the main shaft (output shaft) at a gear ratio of 1:1 Figure 5. This ratio results in maximum speed output and no torque multiplication.

Fourth gear has no torque multiplication because it is used at cruising speeds to promote maximum fuel economy. The vehicle is normally downshifted to lower gears to take advantage of torque multiplication and acceleration when passing slower vehicles or climbing grades.

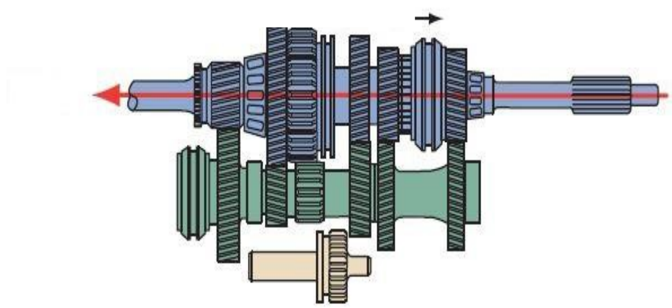

Figure 5. Power Flow in Fourth Gear

## E.Fifth Gear

When fifth gear is selected, the fifth gear synchronizer engages fifth gear to the main shaft Figure 6. This causes a large gear on the countershaft to drive smaller gear on the main shaft, which results in an overdrive condition. Overdrive permits an engine speed reduction at higher vehicle speeds

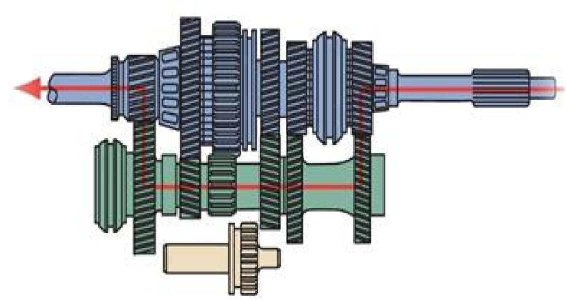

Figure 6. Power Flow in Fifth Gear

## F.Reverse Gear

In reverse gear, it is necessary to reverse the direction of the main shaft or output shaft. This is done by introducing a reverse idler gear into the power flow path. The idler gear is located between the countershaft reverse gear and the reverse speed gear on the main shaft. The idler assembly is made of a short drive shaft independently mounted in the transmission case parallel to the countershaft. The idler gear may be mounted near the midpoint of the shaft. The reverse speed gear is actually the externaltooth sleeve of the first/second synchronizer.

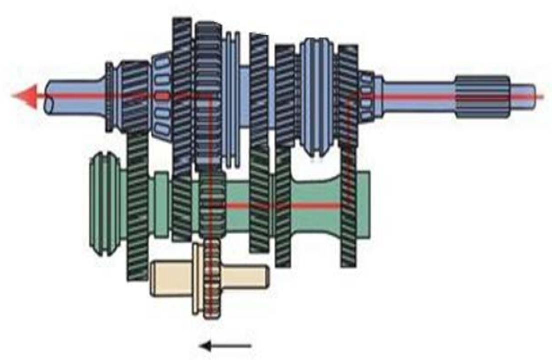

Figure 7. Power Flow in Reverse Gear

When reverse gear is selected, both synchronizers are disengaged and in the neutral position. In the transmission shown in Figure 7, the shifting linkage moves the reverse idler gear into mesh with the first/second synchronizer sleeve. Power flows through the input shaft and clutch gear to the countershaft. From the countershaft, it passes to the reverse idler gear, where it changes rotational direction. It then passes to the first/second synchronizer sleeve. Rotational direction is again reversed. From the sleeve, power passes to the main shaft and driveline.

Not all transmissions use speed and idler gears for reverse. For example, reverse gears in most Ford transmissions are helical gears that are in constant mesh with the first gear.

## III.DESIGN SPECIFICATION OF FIVE SPEED MANUAL TRANSMISSION

The following specifications are rear wheel drive Ford Ranger F-150 five speed (MT).

Table 1: Specifications of Vehicles Engine and Transmission.

| | |
|---|---|
| Model | Ford Ranger |
| Engine | Gasoling |
| Transmission and Final Drive Gears | Gear Ratio |
| i1 | 4:1 |
| i2 | 2.29:1 |
| i3 | 1.5:1 |
| i4 | 1:1 |
| i5 | 0.8:1 |
| i0 | 3.55:1 |
| Reverse Gears | 3.43:1 |
| Overall Gear Ratio | 14.2:1 |

Pmax = 153 kW
Nmax = 4750 r.p.m
Tmax = 353 Nm
Nmax = 3000 r.p.m
Tyre size P235/70/R/17
Width of Tyre = 235 mm

## IV.RESULT DATA FOR FIVE SPEED MANUAL TRANSMISSION

Height of tyre = 0.7×235
= 164.5 mm
Radius of rim = 0.5×17×254
= 215.9 mm
Outer radius, r = 164.5+215.9
= 380.4 mm
Loaded radius of tyre, rd = 0.96 x r
= 365.184 mm = 0.365 m
Rolling circumference = 2 x π x 0.96 x r
= 2 x π x 0.96 x 0.3804 = 2.3 m

The rear wheels drive in a version of the F-150 manual transmission. This was used in the Ford Ranger and number of other vehicles in both two-wheel-drive and four-wheel-drive versions. The following Table 2, shows number of teeth for each gear. Calculation gear ratio for compound gear train of each gear set,

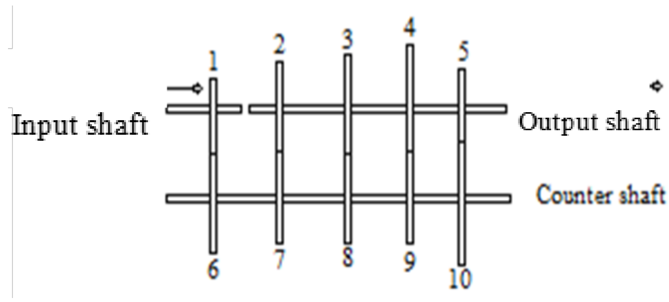


Table: 2. In (MT) Number of Teeth for Each Gear

| Gear | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| Z | 16 | 27 | 39 | 52 | 12 | 16 | 18 | 17 | 13 | 15 |

For Direct gear

16 teeth on the input shaft is divided by 16 on the counter shaft constant gear (driven gear). Ratio 1:1, counter gear rotates at the same of the input shaft. In direct gear is input speed and torque are at the same of the output speed and torque, can be calculated gear ratio by Equation.

$$i_4 = \frac{N_1}{N_6} = \frac{Z_6}{Z_1}$$

$$\frac{16}{16} = 1$$

$T_6$ = 353 Nm

For third gear ratio,

$$i_3 = \frac{N_7}{N_2} = \frac{3000}{N_2}$$

$N_2$ = 2000 rpm
$T_2$ = 529.5 Nm

For second gear ratio,

$$i_2 = \frac{N_8}{N_3} = \frac{3000}{N_3}$$

$N_3$ = 1310 rpm
$T_3$ = 808.37 Nm

For first gear ratio,

$$i_5 = \frac{N_{10}}{N_5} = \frac{3000}{N_5}$$

$N_5$ = 3750 rpm
$T_4$ = 282.4 Nm
For reverse gear ratio,

$$i_r = \frac{N_{in}}{N_{out}} = \frac{3000}{N_5}$$

$N_{out}$ = 875 rpm
$T_{out}$ = 1210.79 Nm
Calculation of Power Transmitted by Torque

$$P = T\,\omega = 353 \times \frac{2\pi \times 3000}{60} = 110 \text{ kW}$$

Calculation of Efficiency

$$\eta = \frac{N_{out} T_{out}}{N_{in} T_{in}}$$

Calculation of Torque on Driven Wheel ($T_w$)
$T_w = i_g i_o \eta T_p$

Table 3. Results for Five Speed Manual Transmission Gear Ratio

| Gear | Gear Train of Number | Formula | Ratio |
|---|---|---|---|
| $i_1$ | 1, 6, 4, 9 | $\frac{z_6}{z_1} \times \frac{z_4}{z_9}$ | 4:1 |
| $i_2$ | 1, 6, 3, 8 | $\frac{z_6}{z_1} \times \frac{z_3}{z_8}$ | 2.29:1 |
| $i_3$ | 1, 6, 2, 7 | $\frac{z_6}{z_1} \times \frac{z_2}{z_7}$ | 1.5:1 |
| $i_4$ | 1 lock with 2 | None | 1:1 |
| $i_5$ | 1, 6, 5, 10 | $\frac{z_6}{z_1} \times \frac{z_{10}}{z_5}$ | 0.8:1 |
| $i_r$ | | $\frac{z_6}{z_1} \times \frac{15}{14} \times \frac{48}{15}$ | -3.43:1 |

Table 4.Result Table for Five Speed Manual Transmission Output Torque and Speed

| Gear | Engine Torque, Tin (Nm) | Engine Speed, Nin (r.p.m) | Ratio | Transmission Output Torque, Tout (Nm) | Transmission Output Speed, Nout (r.p.m) |
|---|---|---|---|---|---|
| i1 | 353 | 3000 | 4 | 1412 | 750 |
| i2 | 353 | 3000 | 2.29 | 808.37 | 1310 |
| i3 | 353 | 3000 | 1.5 | 529.5 | 2000 |
| i4 | 353 | 3000 | 1 | 353 | 3000 |
| i5 | 353 | 3000 | 0.8 | 282.4 | 3750 |
| ir | 353 | 3000 | 3.43 | 1210.79 | 875 |
| | | | | | |

Table 6 Results for Five Speed Manual Transmission Tractive Effort and Vehicle Speed

| Gear | Ratio | Rotational Speed of Driven Wheel | Torque on Driven Wheel | Tractive Effort | Vehicle Speed |
|---|---|---|---|---|---|
| $i_1$ | 4 | 211.27 | 4260.71 | 11673 | 8.08 |
| $i_2$ | 2.29 | 369.08 | 2439.26 | 6683 | 14.11 |
| $i_3$ | 1.5 | 563.38 | 1597.77 | 4120 | 21.53 |
| $i_4$ | 1 | 485.07 | 1127 | 2918 | 32.3 |
| $i_5$ | 0.8 | 1056.34 | 852 | 2335 | 40.38 |
| $i_r$ | 3.43 | 246.38 | 3653.56 | 10010 | 9.42 |

Table 7 Results for Gear Changing Upshift and Downshift

| Gear | Ratio | Rotational speed of Driven Wheel | Vehicle speed |
|---|---|---|---|
| i1 | 4 | | 8.08 |
| i2 | 2.29 | 1717.52 | 14.11 |
| i3 | 1.5 | 1965.08 | 21.53 |
| i4 | 1 | 2000 | 32.3 |
| i5 | 0.8 | 2400 | 40.38 |

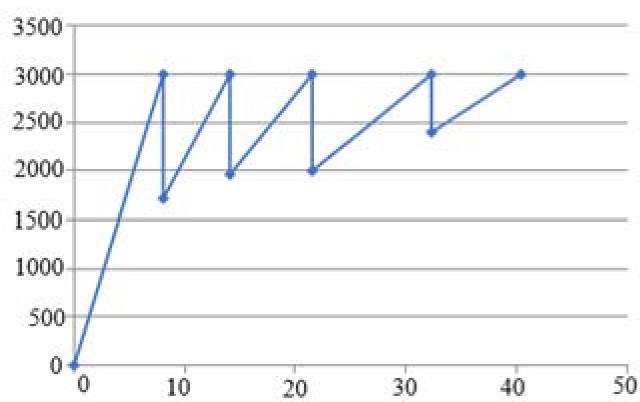


Figure 8 Graph for gear changing between upshift and downshift

## V.CONCLUSION

In the design of manual gear box for power transmission system of Ford Ranger engine, transmission gear ratio, vehicle speed and rotational speed for each of gear shifting are considered. More gear ratios are required as the range of required speed and torque from low to high increased. Helical gear is used more widely as they run more silently than spur gear. In reverse gear of transmission gear box in F-150 engine, spur gear drive is used because it needed to transmit the maximum torque.

After knowing the gear ratio of the gear box, the number of teeth of gears are specified. And then, calculation of vehicle speed and transmission torque and gear ratio are carried out. Based on the result of design calculation, fifth gear (over drive gear) is the maximum speed 40.38 m/s and the minimum torque is 852 Nm. The first gear (lower gear) is the minimum speed about 8.08 m/s and the maximum torque is 4260.71 Nm. According to the result, the vehicle speed and torque reversely proportional. The tractive effort is also considered for each gear shift. The tractive force is the highest at first gear and the smallest at fifth gear.

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