STUDY OF MANUAL GEAR TRANSMISSION

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Abstract - *In automobiles, the engine is a variable drive which transmits power. So gear box is necessary to get required speed and torque. So the main concept of manual gear shift is to shift the gear at a specific rpm in order to get maximum speed and torque.* A manual transmission, also known as a manual gearbox or standard transmission is a type of transmission used in motor vehicle applications. It generally uses a driver-operated clutch, typically operated by a pedal or lever, for regulating torque transfer from the internal combustion engine to the transmission, and a gear-shift, either operated by hand (as in a car) or by foot (as on a motorcycle). Other types of transmission in mainstream automotive use are the automatic transmission, semi-automatic transmission, and the continuously variable transmission (CVT). A four-speed transmission is a transmission that allows a vehicle to operate at four different speeds. This was an improvement on earlier transmissions, because it enabled the vehicles that used the four-speed transmissions to run faster and better than the earlier transmission systems. Most automobile vehicles today use the four-speed transmission.

***Key Words*: Variable drive, Internal combustion engine, Automatic transmission, Continuously variable transmission (CVT).**

1. INTRODUCTION

Manual transmissions are characterized by gear ratios that are selectable by locking selected gear pairs to the output shaft inside the transmission. Conversely, most automatic transmissions feature epicyclic (planetary) gearing controlled by brake bands and/or clutch packs to select gear ratio. Contemporary automobile manual transmissions typically use four to six forward gears and one reverse gear, although automobile manual transmissions have been built with as few as two and as many as eight gears. Transmission for heavy trucks and other heavy equipment usually have at least 9 gears so the transmission can offer both a wide range of gears and close gear ratios to keep the engine running in the power band. Manual gear shifting or manual transmissions come in two basic types: simple unsynchronized systems where gears are spinning freely. Whereas the other one is the synchronized systems, in which all gears are always in mesh but only one of these meshed pairs of gears is locked to the shaft on which it is mounted at any one time, the others being allowed to rotate freely; thus greatly reducing the skill required to shift gears.

1.1 UNSYNCHRONIZED TRANSMISSION

The earliest automotive transmissions were entirely mechanical unsynchronized gearing systems. They could be shifted, with multiple gear ratios available to the operator, and even had reverse. But the gears were engaged by sliding mechanisms or simple clutches, which required a skilled operator who could use timing and careful throttle manipulation when shifting, so that the gears would be spinning at roughly the same speed when engaged; otherwise the teeth would refuse to mesh. Most modern motorcycles use unsynchronized transmissions as synchronizers are generally not necessary or desirable. Because of this, it is necessary to synchronize gear speeds by blipping the throttle when shifting into a lower gear on a motorcycle.

1.2 SYNCHRONIZED TRANSMISSION

In a synchromesh gearbox, the teeth of the gears of all the transmission speeds are always in mesh and rotating, but the gears are not directly rotationally connected to the shafts on which they rotate. Instead, the gears can freely rotate or be locked to the shaft on which they are carried. The locking mechanism for any individual gear consists of a collar on the shaft which is able to slide sideways so that teeth or "dogs" on its inner surface bridge two circular rings with teeth on their outer circumference; one attached to the gear, one to the shaft. (One collar typically serves for two gears; sliding in one direction selects one transmission speed, in the other direction selects the other) When the rings are bridged by the collar, that particular gear is rotationally locked to the shaft and determines the output speed of the transmission.

Our model is based on the unsynchronized transmission where four different speeds are achieved using four gear shifts. Like other transmissions, a manual transmission has several shafts with various gears and other components attached to them. Our research is concerned with a rear-wheel-drive transmission system which has generally three shafts: an input shaft, a countershaft and an output shaft. The countershaft is sometimes called a layshaft. The other components are a speed regulator, a motor, a friction clutch and a gear box with eight gears (4 gear ratios).

2. CONCEPT

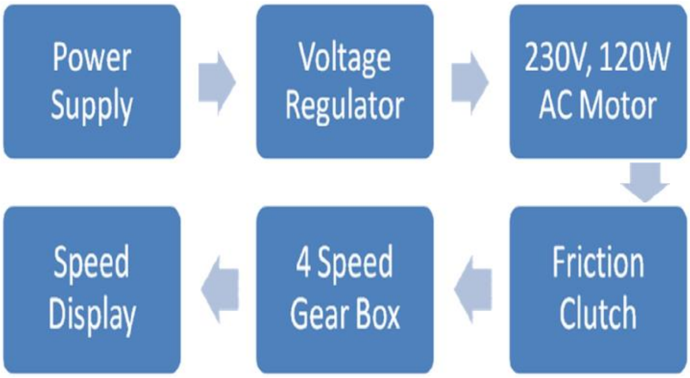

Fig -1: Concept

3. COMPONENTS

3.1 230 VOLTS, AC MOTOR

An AC motor is an electric motor that is driven by an alternating current. It consists of two basic parts, an outside stationary stator having coils supplied with alternating current to produce a rotating magnetic field, and an inside rotor attached to the output shaft that is given a torque by the rotating field. There are two types of AC motors, depending on the type of rotor used. The first is the synchronous motor, which rotates exactly at the supply frequency or submultiples of the supply frequency. The magnetic field on the rotor is either generated by current delivered through slip rings or by a permanent magnet. The second type is the induction motor, which runs slightly slower than the supply frequency. The magnetic field on the rotor of this motor is created by an induced current.

Fig -2: Single Phase AC Motor

Induction motors are of two types based on the power supply: single phase and three phase. In our project we are using the single phase motor. In a single phase induction motor, it is necessary to provide a starting circuit to start rotation of the rotor. If this is not done, rotation may be commenced by manually giving a slight turn to the rotor. The single phase induction motor may rotate in either direction and it is only the starting circuit which determines rotational direction.

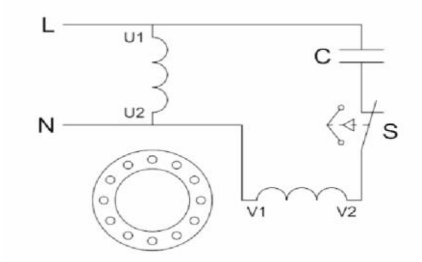

Fig -3: Capacitor connected in series with the startup winding of the motor

A capacitor is connected in series with the startup winding, creating an LC circuit which is capable of a much greater phase shift (and so, a much greater starting torque). The capacitor naturally adds expense to such motors. A capacitor ranging from 3 to 25 microfarads is connected in series with the start windings and remains in the circuit during the run cycle. The start windings and run windings are identical and reverse motion can be achieved by reversing the wiring of the 2 windings, with the capacitor connected to the other windings as start windings. By changing taps on the running winding but keeping the load constant, the motor can be made to run at different speeds. Also, provided all 6 winding connections are available separately, a 3 phase motor can be converted to a capacitor start and run motor by communing two of the windings and connecting the third via a capacitor to act as a start winding.

3.2 VOLTAGE REGULATOR

A voltage regulator is an electrical regulator designed to automatically maintain a constant voltage level. It may use an electromechanical mechanism, or passive or active electronic components. Depending on the design, it may be used to regulate one or more AC or DC voltages. An AC voltage regulator is a type of household mains regulator which uses a continuously variable autotransformer to maintain an AC output that is as close to the standard or normal mains voltage as possible, under conditions of fluctuation. It uses a servomechanism (or negative feedback) to control the position of the tap (or wiper) of the autotransformer, usually with a motor. An increase in the mains voltage causes the output to increase, which in turn causes the tap (or wiper) to move in the direction that reduces the output towards the nominal voltage.

3.3 FRICTION CLUTCH

A clutch is a mechanical device which provides driving force to another mechanism, typically by connecting the driven mechanism to the driving mechanism. Its opposite component is a brake, which inhibits motion. Clutches are useful in devices that have two rotating shafts. In these devices, one shaft is typically attached to a motor or other power unit (the driving member), and the other shaft (the driven member) provides output power for work to be done.

Fig -4: Multiplate Friction Clutch

In all vehicles using a transmission (virtually all modern vehicles), a coupling device is used to separate the engine and transmission when necessary. The clutch accomplishes this in manual transmissions. Without it, the engine and tires would at all times be inextricably linked, and any time the vehicle stopped the engine would stall. Without the clutch, changing gears would be very difficult, even with the vehicle moving already: deselecting a gear while the transmission is under load requires considerable force, and selecting a gear requires the revolution speed of the engine to be held at a very precise value which depends on the vehicle speed and desired gear. In a car the clutch is usually operated by a pedal; on a motorcycle, a lever on the left handlebar serves the purpose. A multiplate clutch has several driving members interleaved with several driven members. It is used in motorcycles, automatic transmissions and in some diesel locomotives with mechanical transmissions. It is also used in some electronically controlled all-wheel drive systems.

3.4 GEAR BOX

On a conventional rear-drive transmission, there are three basic shafts; the input, the output, and the countershaft. The input and output together are called the main shaft, since they are joined inside the transmission so they appear to be a single shaft, although they rotate totally independently of each other. The input length of this shaft is much shorter than the output shaft. Parallel to the main shaft is the countershaft. There are a number of gears fixed along the countershaft, and matching gears along the output shaft, although these are not fixed, and rotate independently of the output shaft.

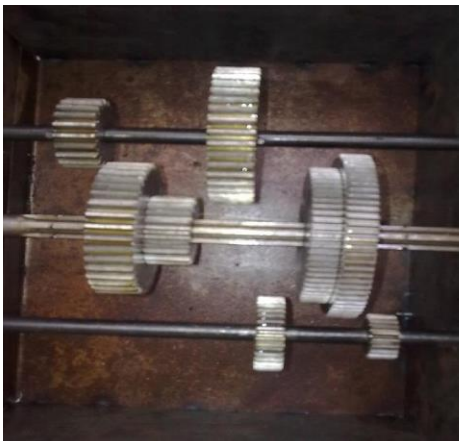

Fig -5: Gear Box

The gears are positioned and engaged just as they are on the countershaft-output shaft on a rear-drive. This merely eliminates one major component, the pinion gear. In our research 4 different speeds will be produced from the set of eight gears arranged in the gear box. The eight gears are mounted on the three shafts. First shaft contains the two gears numbered as “1” & “2”, second contains 4 gears numbered as “3”, “4”, “5” & “6” and third contains the remaining 2 gears numbered as “7” & “8”. The gears used are of different diameters so that gear ratios can be varied and different speeds can be obtained. The movement of the gears on the second shaft enables the meshing of gears.

3.4.1 FIRST GEAR

Let us now understand how four different speeds could be obtained from the set of eight different gears. Meshing of 1st gear with 3rd and 5th gear with 7th gear will give the first gear shift. This gear shift will give the maximum torque. The arrangement is shown in figure.

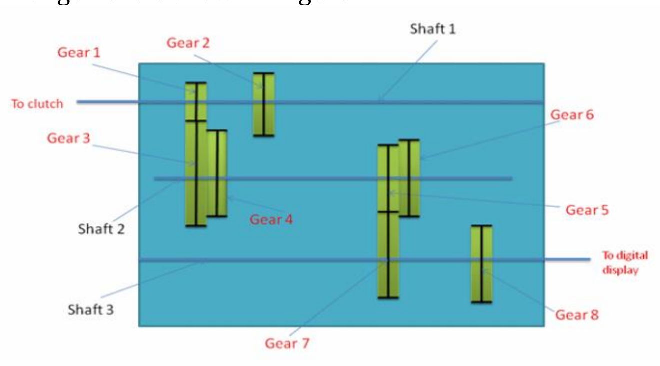

Fig -6: First Gear Arrangement

3.4.2 SECOND GEAR

Meshing of 2nd gear with 4th and 5th gear with 7th will give second gear shift. The speed achieved will be higher than the previous gear shift whereas the torque will be comparatively less. This arrangement is as shown below.

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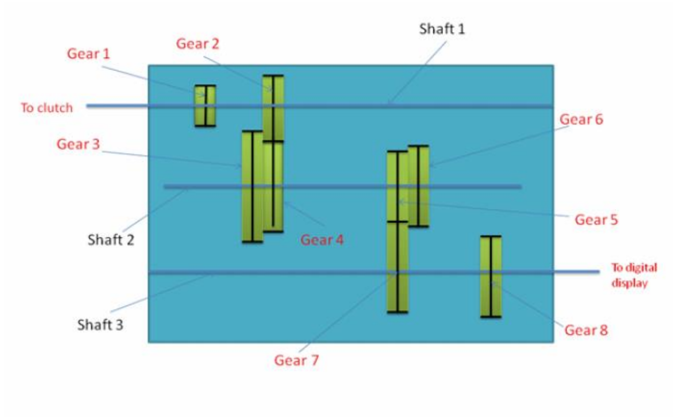

Fig -7: Second Gear Arrangement

3.4.3 THIRD GEAR

Now meshing of 1st gear with 3rd and 6th gear with 8th will give the third gear shift. The obtain value of speed will be higher than that produced by first and second gear shift while the torque obtained will be comparatively less. The arrangement of the third gear shift is as shown below.

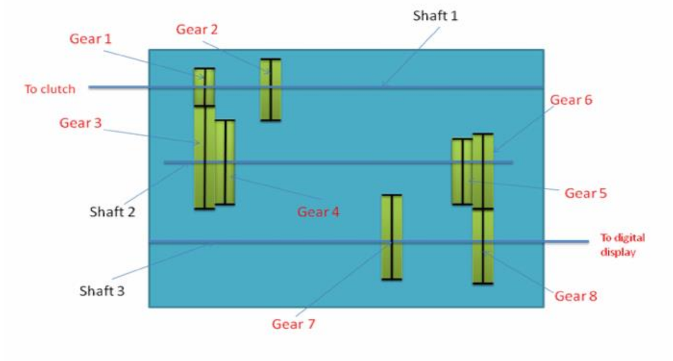

Fig -8: Third Gear Arrangement

3.4.4 FOURTH GEAR

Finally meshing of gears 2nd with 4th and 6th with 8th will give the fourth gear shift. The speed obtained here will be highest whereas the torque will be lowest. The arrangement of the fourth gear shift is as shown in the figure.

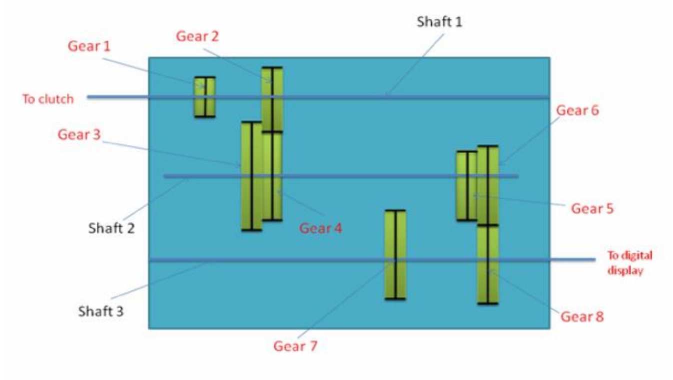

Fig -9: Fourth Gear Arrangement

3.4.5 NEUTRAL

The gearbox will be in the neutral position if none of the gears are meshing. In the neutral position no power is being transmitted and all the gears will be rotating ideally. The arrangement of neutral gear shift is as shown below.

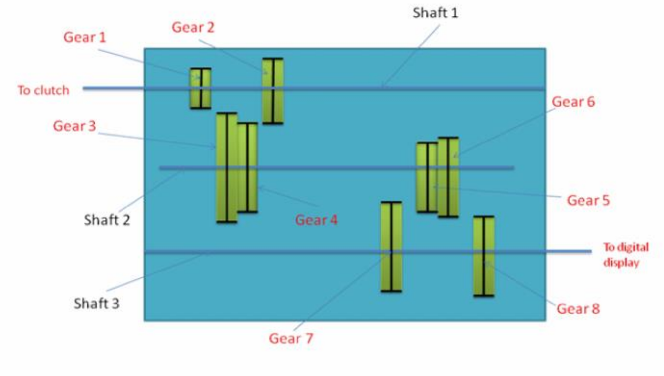

Fig -10: Neutral Position

4. CALCULATIONS

4.1 MOTOR POWER

The power required to drive the designed gear box will be calculated by the following formula:
Power, $P = (13.2 * 10^{-3}) *(K * z * v)*(1.55as)$ Watts
Where,
K = Material Factor = 1.88
z = No. of cutting edges in contact = 1
v = Cutting Speed in m/min = 55 m/min
a = Depth of Cut in mm = 0.6mm
s = Feed/Blade/Rev. in mm = 0.04 mm
ß = Machining Component
Therefore,
P = 97.1 Watts (Calculated Value)
P = 120 Watts (Standard Value)
Hence the standard value of motor with 120 Watts is taken into consideration. Now, based on the power, the torque of required to rotate the gears is calculated.
Torque, τ = Power (P) / Angular Velocity (ω)
Where,
$\omega = 2\pi N/60$
Therefore, τ = 0.796 N. m

4.2 CLUTCH DESIGN

We have used the multiplate friction clutch whose internal and external diameters are calculated as follows:

Transmitted Torque (Mt) = 0.8 N.m
Therefore Design Torque [Mt] = Kw * Mt
Where,
Kw = Factor based on working condition =
K1 +K2 + K3 + K4= 0.5 + 1.25 + 0.38 + 1.8

Hence, [Mt] = 3.14 N. m
Clutch Shaft Diameter Calculation:
d = [(49500*Kw*Kw) / (n [τ])] ^½
Where,
[τ] = allowable shear stress= 700N/mm^2
Therefore, d = 8.86mm= 10mm (approx.)

4.3 SHAFT CALCULATIONS

4.3.1 SHAFT SPECIFICATIONS

Input shaft:
Diameter (d) = 10 mm
Length (l) = 320 mm

Intermediate shaft (spline):
No. of spline = 6
Inner diameter = 10 mm
Outer diameter = 15 mm
Length (l) = 270 mm

Output shaft:
diameter (d) = 10 mm
length (l) = 320 mm

4.3.2 SHAFT 1 DIAMETER

Ra + Rb = F = τr(cos20) = 60N
ΣMa = 0
Therefore,
Ra = 24.54N and Rb = 35.45N
Mc = Mb = 50*35.45 = 1772.72
Now,
$d^3 = \{(Kb*Mb)^2 + (Kt*Mt)^3\}$
Where,
[τ] = 127 N/mm^2 Kb = 2.25
Mb = 1772.72 N.mm Kt = 1.7
Mt = 800 N.mm
d = 5.52 = 6 mm= 10 mm (standard)

4.3.3 SHAFT 2 DIAMETER

Ra + Rb = 192N
ΣMa = 0
Therefore,
(192 * 65) – (110 * Rb) = 0
So, Ra = 78.55N and Rb = 113.48N
Mc = Mb = -113.45 * 45 = -5105.25
Now,
$d^3 = (16/(\pi[\tau])) * \{(Kb*Mb)^2 + (Kt*Mt)^3\}$
Where,
[τ] = 127 N/mm^2 Kb = 2.25
Mb= 5105.25 N.mm Kt = 1.7
Mt = 8640 N.mm
Therefore,
d = 9.07 = 10 mm (standard)

4.4 BEARING CALCULATIONS

The bearings are mounted at the end of each of the shaft to ensure smooth moment of the shaft when the gears are engaged. The bearings will help make movement of shaft smoother. Here, we have used in total 6 bearings out of which 4 are identical and are connected to the ends of the first and the third shaft whereas the remaining two are connected to the ends of the middle shaft. The selection of bearings is done by the following method.

4.4.1 BEARING SPECIFICATIONS

Bearing 1(B1, B2, B5, B6):
B1 = B2 = B5 = B6 = 6300 inner dia. = 10mm
Outer diameter = 35mm width = 11mm

Bearing 2(B3, B4):
Bush:-
Inner diameter = 11mm
Bearing outer diameter = 25mm
Total width = 16mm
Bearing width = 12mm
Bearing:
B3 = B4 = 6305 (0.69 million rev.)
Outer diameter = 62mm
Inner diameter = 25mm
Width = 17mm

4.4.2 Bearing 1(B1, B2, B5, B6)

The deep groove ball types of bearings are selected. The calculation of the deep groove ball bearings is shown below:
6000<= Co = 192 * 10
Assuming,
Fa/Co = 0.25
Therefore,
e = 0.22 and Fa = 48N Now, Fr = 64sin20= 22N and Fa = 0
Now,
Fa/Fr <e
Therefore,
P = XFr = 60N
For 6000, L = $(C/P)^3$ = 0.216 mill. Rev
For 6200, L = $(C/P)^3$ = 0.296 mill. Rev
For 6300, L = $(C/P)^3$ = 1.157 mill. Rev
So,
B1 = B2 = B5 = B6 = 6300
Inner dia. = 10mm
Outer diameter = 35mm
Width = 11mm

4.4.3 BEARING 2(B3, B4)

Fr1 = Frsin20 = 22N
Fr2 = 92sin20 = 66N

Fr = Fr1 + Fr2
Therefore, Fr = 88N
Now,
P = XFr = 88N
L = $(C/P)^3$
For 6005, L = 0.69
For 6205, L = 1.953
So,
B3 = B4 = 6305 (0.69 million rev.)
Outer dia. = 62mm
Inner dia. = 25mm
Width = 17m

4.5 GEAR CALCULATON

4.5.1 GEAR TEETH CALCULATION

Assuming the number of teeth of first gear as 20 and taking the four speeds N1, N2, N3, N4 as 150, 300, 600, and 1200 respectively. Hence the required dimensions of the remaining gears are calculated as follows:
Let,
T1, T2, T3……T8 = Number of teeth of gears 1, 2, 3….8 respectively.
Now,
T1/T3 = 300\1200
Given that, T1 = 20
Hence, T3 = 80
Again,
T2 + T4 = 100 and
T2\T4 = 600\1200 = 0.5
Hence, T4 = 2T2
Therefore, T2 = 33.33 = 34 and T4 = 66

Assuming number of teeth on gear 5 as 20, the number of teeth of the respective gears will be found out as follows:

Assume T5 = 20
Hence, T5\T7 = 150\300 = 0.5
Therefore, T7 = 40
Again,
T6 + T8 = 60 and
T6\T8 = 600\300 = 2
Therefore, T6 = 40 and T8 = 20.

4.5.2 OTHER PARAMETERS

The module of the first four gears is taken as 1.25 while the remaining four gears is taken as 2. Based on the module and the number of teeth, the pitch circle diameter, addendum diameter, dedendum diameter, clearance and tooth thickness is found out from the empirical formula as shown below. Considering 20 degree full depth system, the empirical formula in terms of module (m) is given below:

Pitch Circle Diameter = m * No. of Teeth
Addendum = m
Dedendum = 1.25 m
Clearance = 0.25 m
Tooth thickness = 1.5708 m
Fillet radius = 0.4 m

Table 1: Gear Specifications

Gear no.	1	2	3	4	5	6	7	8
No. of teeth	20	34	80	66	20	40	40	20
Pitch circle diameter	25	42.5	100	82.5	40	80	80	40
Addendum diameter	26.25	43.75	101.25	83.75	42	82	82	42
Dedendum diameter	23.44	41	98.5	81	37.5	77.5	77.5	37.5
Clearance	0.3125	0.3125	0.3125	0.3125	0.5	0.5	0.5	0.5
Tooth Thickness	1.9635	1.9635	1.9635	1.9635	1.9635	1.9635	1.9635	1.9635
Fillet radius	0.5	0.5	0.5	0.5	0.8	0.8	0.8	0.8
Tooth width	12.5	12.5	12.5	12.5	20	20	20	20

4.6 SPEED CALCULATION

The speed of the four gear shifts are assumed as 150, 300, 600, 1200. The assumption is made in order to find out the number of teeth of the gears. Now, the assumed speed will be checked by following formula as follows:
N1 = 1200*(T1\T3)*(T5\T7)
= 1200*(20\80)*(20\40)
= 150 rpm
N2 = 1200*(T2\T4)*(T5\T7)
= 1200*(34\66)*(20\40)
= 300 rpm
N3 = 1200*(T1\T3)*(T6\T8)
= 1200*(20\80)*(40\20)
= 600rpm
N4 = 1200*(T2\T4)*(T6\T8)
= 1200*(34\66)*(40\20)
= 1200 rpm

Now, the difference between the assumed speed and the actual speed is found out and checked whether the assumption made is satisfactory or not. The following table shows the difference between the assumed speeds and the actual speed and the percentage difference between them.

Table 2: Comparison of actual and calculated speeds

Speed	Std. speed	Calculated	Difference	Percentage
N1	150	150	0	0
N2	300	309.1	+9.1	3.03
N3	600	600	0	0
N4	1200	1236.4	+36.4	3.03

5. CONCLUSIONS

Manual transmissions are more efficient than conventional automatics and belt-driven continuously-variable transmissions. The driver has more direct control over the car with a manual than with an automatic, which can be employed by an experienced, knowledgeable driver who knows the correct procedure for executing a driving maneuver, and wants the vehicle to realize his or her intentions exactly and instantly. When starting forward, for example, the driver can control how much torque goes to the tires, which is useful on slippery surfaces such as ice, snow or mud. This can be done with clutch finesse, or by starting in second gear instead of first. An engine coupled with a manual transmission can often be started by the method of push starting. This is particularly useful if the starter is inoperable or defunct. Likewise, a vehicle with a manual transmission and no clutch/starter interlock switch can be moved, if necessary, by putting it in gear and cranking the starter. This is useful when the vehicle will not start, but must be immediately moved e.g. off the road in the event of a breakdown, if the vehicle has stalled on a railway crossing, or in extreme off-roading cases such as an engine that has stalled in deep water. Many types of automobiles are equipped with manual transmissions. Small economy cars predominantly feature manual transmissions because they are cheap and efficient, although many are optionally equipped with automatics. Economy cars are also often powered by very small engines, and manual transmissions make more efficient use of the power produced.

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