Fundamentals of Automotive Systems
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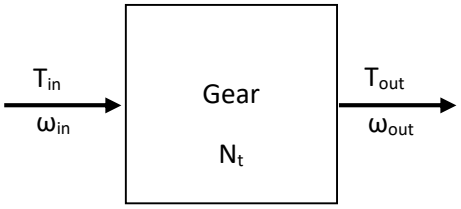
Lecture - 33
Transmission Part 01

Greeting so, let is get started today's class. So, a quick recap of where we are you know like we are looking at the vehicle power train and we saw that what were the ideal requirements as far as a power train is concerned you know with regards to vehicle performance and what were the short comings of an IC engine with respect to them and that motivated the requirement of a multi speed gearbox, and a move-off elements like a clutch. So in the previous class we looked at the construction and operation of a clutch.

So today we are going to look at the construction and operation of a gearbox typically used in a manual transmission. So, if we look at a gearbox and a gear in particular, so, if we consider a gear pair as a block and we provide a torque T in to that gear at the speed of Omega n and T out is that output torque and the speed at which the output shaft rotates is Omega out and let us say Eta T is the for Nt is the corresponding gear ratio, then the definition of Nt is as follows the gear ratio or the transmission ratio Nt is defined as Nt equals Omega in divided by Omega out okay.



The gear ratio (transmission ratio) N_t is defined as $N_t = \frac{\mu_{in}}{\mu_{out}}$

So this is the definition on the gear ratio Nt okay. So it is a ratio of the angular speed of the input to a gear pair to the angular speed of the output shaft on the corresponding gear okay. So that is how the gear ratio is defined. So we will start we will shortly see how to make use of these gear ratios you know like in meeting vehicle performance requirements and also we will.

SPUR GEARS

Figure out you know like given a set Vehicle performance requirements you know, like how do we determine the gear ratios right. So, that is something which we will look at. Now, if you look at the types of gears that are commonly used in automotive applications and broadly spur gears and helical gears are popular, so let us look at that okay. So, this is a simple schematic of a spur gear. So we can see that there is a pair of gears and in a spur gear, the main feature is that the, teeth are cut parallel to the axis of rotation.

So if this were the axis of rotation of the gear, we can see that in a spur gear the gear teeth are cut parallel to the axis of rotation. So as a result it is relatively simpler to manufacture. But however you know when two gears mesh with one another, what is going to happen is that like due to the way in which the teeth are arranged, there is going to be a sudden contact between two teeth and this may result in significant noise particularly when the gears are operated at high speeds. So, spur gear may become noisy when operated at high speeds.

So, although simple the level of noise and vibration may increase with operating speed okay. So that is a limitation. So, what is the alternative an alternative? Which is popular is the helical gear.

HELICAL GEARS

So, what is the helical gear? So, in a helical gear one can observe that the teeth are cut at an angle to the axis of rotation So, when two teeth of the corresponding gears You know like, they essentially approach each other to mesh with one another. The engagement between them is more gradual due to the manner in which the teeth are cut and oriented. So, as a result in a helical gear the noise levels are reduced and consequently they are much more quieter when operated at higher speeds okay.

So helical gears have teeth cut at an angle to the axis of its rotation so, the engagement of the teeth is more gradual. So, consequently much quieter operation, okay when compared to spur gear, that is so that is the advantage of helical gears, but there is a trade-off. So, because of course, helical gears manufacturing is going to be more challenging compared to spur gear and secondly, when we are using helical gears we need to use thrust gearings to support the corresponding shaft.

Why because due to the manner in which the teeth engage with one another, there will be an axial force right, a component along the axis of rotation that needs to supported by means of a thrust bearing okay, when a helical gears pair is used this axial thrust can be canceled out by using what are called double helical gears where you have to teeth of opposing orientation on the same gear, but of course they become very expensive and complex you do not like to use.

So, helical gears are very popular of course they are they have to be used along with thrust bearing. Used with axial thrust bearing. So, to support the force along the axis of rotation, so just sticking to the type of gears, depending on the size of the input and the output gear pairs, we can have various types of gear arrangements. See for example, let us say I am sticking to this to my schematic, let us say this is the driver gear and this is the driven gear okay.

So, then we can immediately see that and the size of the driver gear is smaller than the size of the driven gear. So, consequently, what can we say about these relative speeds of rotation of both gears, the speed of the driven gear is going to be slower than that of the driver gear right. So, such an arrangement where the driver gear is smaller than that driven gear, and consequently the speed of rotation of the driven gear is lower than that of the driver gear is what is called as an under drive gear arrangement.

Okay so, the definition of an under drive gear is that the driver gear is smaller than the driven gear and then under drive arrangement, so consequently the speed of rotation of the driven gear would be lower than that of the driver gear. So, this implies that what can we say about the gear ratio for an under drive gear please recall how it was defined right as the gear ratio is nothing but the essentially the speed of rotation of the input gear to that of the output gear.

So, here in under drive gear arrangement the input gear or the driver gear is rotating faster than the output gear or the driven gear. So, the gear ratio is going to be greater than one, so, in typical multi speed gearbox used in road vehicles, the by and large the of first gear second gear third gear are all under drive gear arrangements okay. So where the gear ratio would be greater than one.

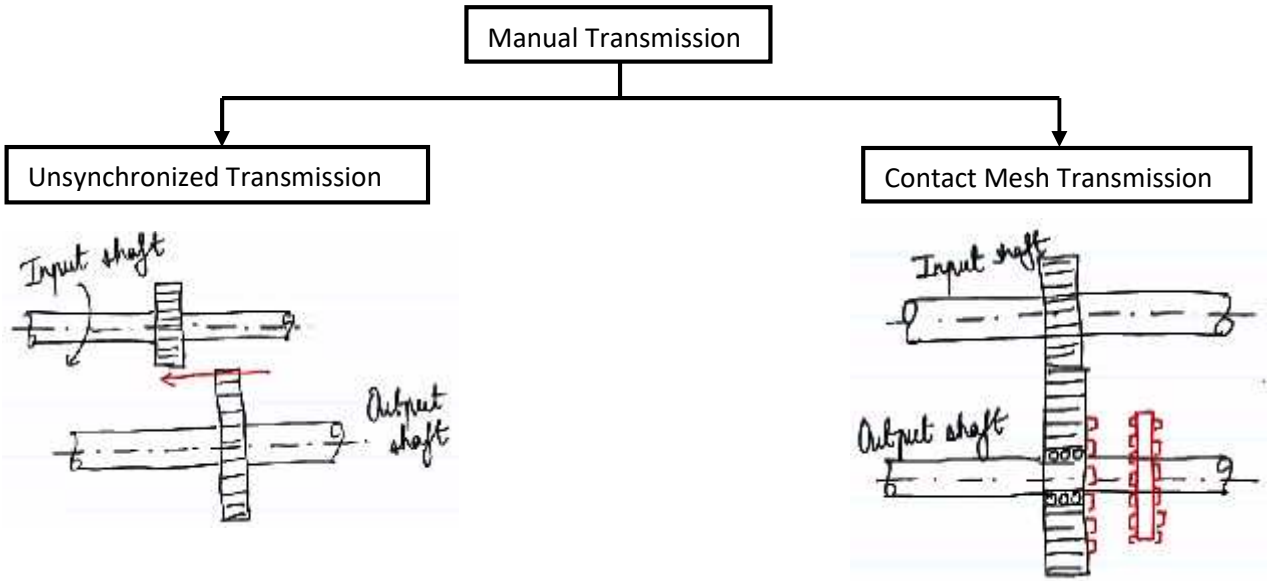
Now, the compliment of this is what is called an overdrive gear. So, as the name indicates here the driver gear is larger than the driven gear in size for example, in that schematic if we swap the driven gear and the driver gear we get an overdrive gear arrangement. So here the driver gear is going to be larger in size than the driven gear. So, obviously the speed of rotation of the driven

gear would be higher than that of the driver gear. So this implies that for an overdrive arrangement, the gear ratio would be less than one.

So in most road vehicles with a multi speed gearbox, if one uses a five speed gearbox or a six speed gearbox and so on, by and large, the fifth gear six gear are all are over drive gears okay, so we will see how to get the numbers and what is the role of these under drive and overdrive gears when we match the transmission to vehicle performance requirements, but this is the definition of under drive and over drive gears.

So now, if you look at manual transmissions from a broad perspective, the basic idea is to transmit the energy from the prime mover to the wheels you know, the clutch essentially connects the engine to the transmission right. So that is the first step, which we looked at in the previous class. Now, the energy which is transmitted from the clutch plate is brought forth into the transmission of the gearbox through an input shaft, because if you recall from the previous class, the clutch plate had splines at the center right.

Those planes are mounted on corresponding splines on an input shaft to the gearbox. So, now what happens you know like once the energy comes to the input shaft of the gearbox, so in typical manual transmission. You know like if you look at the evolution of manual transmissions, we started off with what is called as an unsynchronized transmission. Of course, this was the earliest version.



So what is an unsynchronized transmission? Let me draw a simple schematic to explain. So let us say we have an input shaft and an input gear, so this is my input shaft and that is essentially rotating at some speed. This is connected to the clutch. Now, what happens in an unsynchronized transmission is a following, the output gear or the gear on the output shaft has to be moved along the axis of the output shaft okay for it to be engaged with the input gear so, this is the output shaft.

So, if I have to engage the gear on the output shaft with that of the input shaft what I should do is that like I have to move this gear slide this gear on the output shaft along the axis of the output shaft and make it mesh with the input shaft okay. So, this was the earliest form of transmission which was used and this is called as an unsynchronized transmission. And obviously one can realize the difficulty right in achieving this engagement why because the input shaft and output shaft are going to be at by and large.

At different RPM right at different rotational speeds before a gear engagement is made, then what will happen we need to ensure that the driver adjust the clutch and the throttle appropriately so, that they can engage this two gear which are rotating at different speeds in general before they all meshed that is going to require a lot of skill and it can also potentially cross clashing of the teeth before they mesh properly and at high speeds it becomes even more difficult to do okay.

So these were some limitations of un synchronous transmission. So what happened we went to what are called a synchronized transmissions or constant mesh transmission wherein what happened is the following the gear on the input shaft and the output shaft were now always meshed with each other. So if I draw the gear on the input shaft this is my gear on the input shaft. So the gear on the input shaft and the gear on the output shaft were always in mesh with one another.

So that is the reason it is called as a constant mesh gearbox however the gear on the output shaft is mounted on bearing okay on the output shaft. So, consequently, although the output gear is always in mesh with the input gear and let us say if the engine is rotating and the clutch is

engaged the input shaft to be rotating the output gear will be rotating, but then the energy will not be transmitted from the output gear to output shaft unless otherwise we utilize what is called as a collar.

So, what is a collar a collar is a element which have teeth projected on either side right, which go and engage with teeth that are projected on the side of the output gear. So, what happens is that like when the driver what to say shift the gear engaged engagement lever, this collar this element called as collar is moved is slid along the output shaft and then it has to go and engage with the output gear through teeth on the side of the side surface of the collar and the output gear fine.

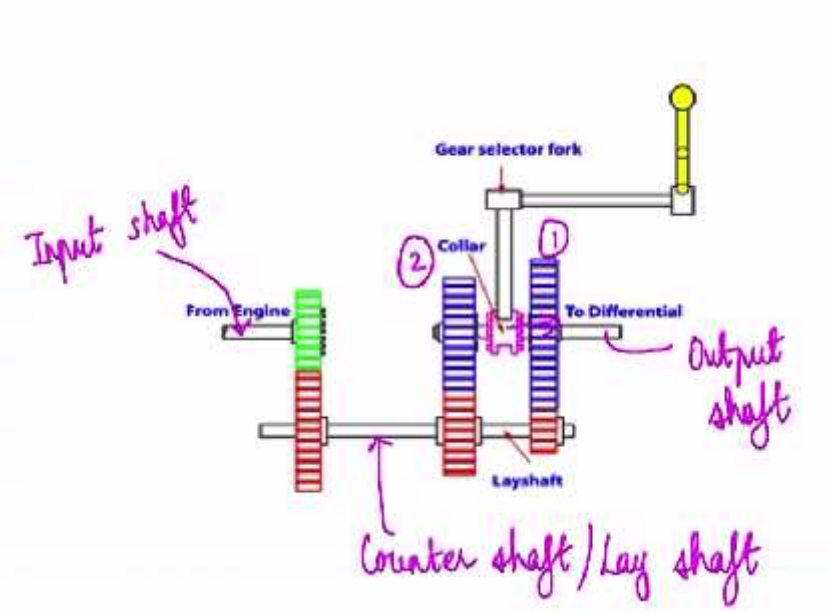
So this although this is an improvement or unsynchronized transmission, this still challenging because like once again the same problem persists because in general before the engagement is made, the output gear and the collar maybe rotating at different speeds possible right. So then how was it solve right even engaging a constant mesh transmission with a collar no require a good amount of skill from the driver and good control over the throttle and the clutch pedal okay.

So then what people thought off was the following instead of having this collar directly engaging with the gear on the output shaft can we think of a mechanism where on the output gear, I do have this teeth but in addition, I have a conical projection which first meshes with a conical cavity on this collar okay, I will come to this shortly and then there are teeth on the side of this element, which will then mesh with the teeth on the side of the gears.

So, when this element is pushed against an output gear, the conical projection and the conical cavity will first come in contact with one another. And obviously, generally you know the RPMS is are rotational speeds are going to be different to begin with, but once they come in contact with one another, they are going to initially slip but then due to friction they are going to overcome the speed differential and once the speed differential is overcome, we go and engage the teeth of the side of the two elements okay.

So, this element with this arrangement is what is called as a synchronizer okay, the collar evolved into the synchronizer okay so due to this reason some people say synchromesh gearbox,

as a constant mesh gearbox that uses the synchronize okay so these are this is how gearbox, which is used in manual transmissions evolved okay from unsynchronized where the output gear had to be physically moved displaced and then engage with the input gear to constant mesh transmission with a collar, then constant mesh transmission of the synchronizer fine. So this is the evolution of the manual transmission.



SCHEMATIC VIEW OF GEARBOX

So let is look at these components in more detail and we look at the operations. So, before we discuss the corresponding schematics, let me also point out what is the what to say configuration that we will be considering. So, in typical if you considering consider a typical you know like front engine mounted, rear wheel driven vehicle. So, what happens is that like the engine is mounted in the front and then like energy is transmitted through the clutch then it comes to a gearbox that is a configuration that we looked at initially yesterday right.

So if we consider a typical front engine mounted rear wheel drive vehicle, the transmission typically will have three shaft okay. So what are these three shaft? So the first one is the input shaft which is connected to the engine through the clutch. This is the first shaft, the second shaft is what is called as a countershaft or lay shaft so countershaft or lay shaft is an intermediate shaft okay which has gears on them and then like it transmits the energy from the input to the output shaft okay.

So, these are the typical shaft which are found in a gearbox with this configuration with this drive configuration. So, we can see in the schematic that this is the input shaft and gear right so, this is the input shaft. So, this is the counter shaft or lay shaft and this is the output shaft so, we can immediately see that the gear which comes from the input shaft meshes with the gear on the lay shaft all the time okay. So, the rotation of the input shaft is transmitted to a rotation on the lay shaft and all these gears on the countershaft are going to rotate at the same speed okay.

So, because the countershaft is going to be rotate at a given speed right now, and these gears on the countershaft are meshed with the corresponding gears on the output shaft. So, depending on the gear ratio the speed of rotation of the output gears would be different. So, if you look at output gear number 1, output gear number 2 right. So, the speed of rotation of output gears one and two would be different in general right. But however, they are mounted on bearings on the output shaft.

So, as long as we do not engage one of the gears, we are not going to transmit energy to the corresponding output shaft. So, if I have to essentially select one of them, what we do is that like we use what is called as a multi rail selector. So, we are going to shortly come and look at how a multi rail selector works, but then if you drive a car all of us would be what to say familiar with the gear selector lever what we call as a stick shift lever.

So, we essentially select different gears. So, when we essentially are displacing that gear selector lever through an appropriate mechanism, this collar or synchronizer in modern transmissions right is shifted either to the right or to the left to engage with gears, 1 or gear 2 so that so this typical gearbox works right here we have considered only 2 gears. So, in general we can see that one collar or synchronizer can be used to engage 2 gears on the output shaft is not it because in this schematic we can see only 1 collar right.

That same collar can be used to engage with either gear one or gear two at any given instant of time by either shifting it to the right or the left okay. So, each collar or synchronizer can be used to engage with. 2 gears on the output shaft okay this is the broad idea.