Fundamentals of Automotive Systems
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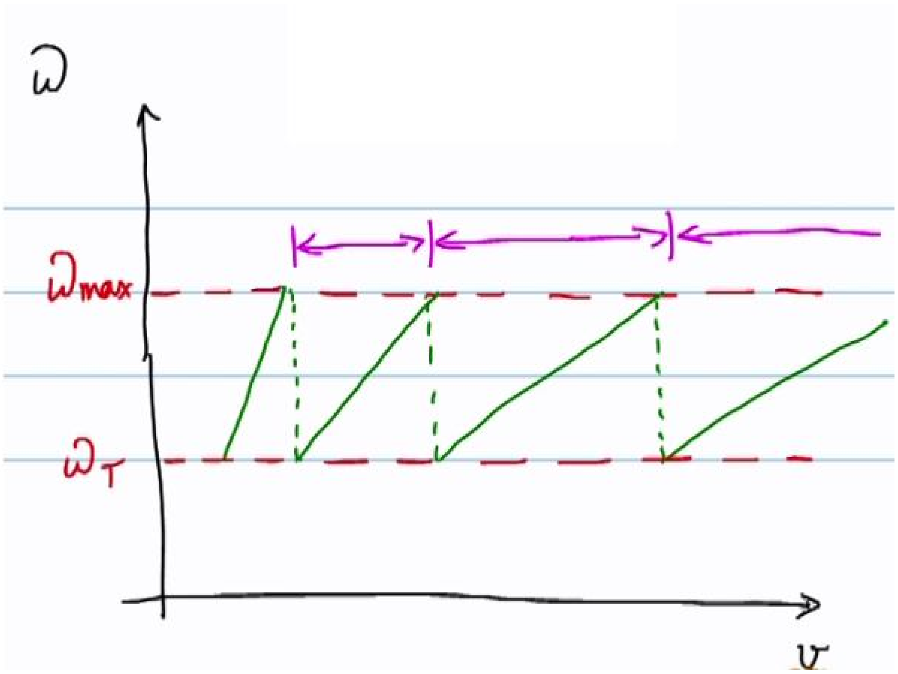
Lecture - 40
Transmission Matching - Part 2



So what is a physical implication? So if I were to draw the plot between vehicle speed and the engine speed. So let us say this is engine speed this is vehicle speed. So let us say we take the two bounds of the speeds where we want to operate. Let us say this is omega T and let us say this is omega max. Okay so what is going to happen is the following in the first gear after it comes to your baseline slip and sorry this omega T the vehicle speed is going to increase linearly with speed right? Because it is in the first gear.

Please note that in this expression we can immediately observe that this expression can be rewritten as v equal to omega e multiplied by r_w 1 minus l lamda N_{ti} , N_d . So let us say if I am on a particular gear ratio and I assume the slip ratio to be almost the same right? So we can see that there is a linear relationship between v and omega “e”, or we can rewrite the other way omega “e” is going to be equal to N_{ti} N_d divided by r_w times 1 minus lamda.

Because in this plot we are plotting omega e on the vertical axis and v on the horizontal axis. So we can immediately observed that the ratio in this ratio of the straight line sorry the slope of the straight line in this graph is proportional to the gear ratio which is selected and obviously as we have discussed the first gear ratio is the highest. The value of the gear ratio decreases as we go from lowest to highest gear.

Okay since the first gear ratio is the highest, we see that the slope is high here. Okay then what happens? We switch from first gear to second gear, so we are going to get a profile something like this. Okay here the slope is going to be proportional to the second gear ratio. Then once we hit omega max, we once again up shift to the third gear. Then once again we once we hit omega max, we up shift and then we go on, right?

So that is what is going to happen. I hope I did not draw it one minute let me adjust quickly. Redraw this you know. I do not want the slopes to be almost equal. So the slopes essentially reduce as we go to higher to sorry lower to higher gears. Okay so that is the idea okay, so this is what happens. So we can see that the speed gap between two successive changes in the gear ratio keeps on increasing right with this choice right.

So here it is just keeps on going right? So you can see that the delta v or the difference in speed between the change in the gears right as we keep on up shifting keeps on extending right? With this mechanism of what to say choosing the gear ratios and deciding upon the upshift sequence. Okay so we can see that this leads to what people typically refer to as a Sawtooth profile. Okay between the engine speed on the vehicle speed. Okay so that is what happens with this particular case right?

So we just plotted this from the equations that we have derived. Okay so and essentially as we keep on up shifting the gap in the gap or the difference in the speeds keep on increasing. So now what we will do is that we will ask one question. Okay and then like we will try to answer that. So the question that we are going to answer discuss is the following. What happens if let us say if n equal to five 5 that is we have a five speed gearbox that is any n greater than four.

Okay I am just taking a particular value n equal to five the question remains the process remains the same. What we are going to discuss remains the same even if N is six and so on right? So we go for what to say gears more than five typically if you want to over drive right. So essentially the 5th gear will be in overdrive, right? What is over drive arrangement in gears? The output shaft speed is greater than the input shaft speed. So obviously the gear ratio is less than one, right?

So that is what is called as an overdrive a gear arrangement. So what happens if in what to say in a five speed gearbox still we need to find the intermediate gear ratios right? Do we not? So let us say even in this case by convention N_{t4} is taken as one. Okay the fourth gear ratio is an direct drive, right? Let us say you know like we can consider we can essentially say that by convention we are going to take the fourth gear as a direct drive and my our intention is to have an over drive.

So that is why we are going for the fifth gear. Okay so now if the fourth gear is in direct drive if we look at the equation for maximum speed, I will not be able to find N_d why? Because the maximum speed will be obtained. Now when I am in a fifth gear. So if I substitute small n equal to 5 I still have two unknowns, right? Because I do not know N_{t5} I do not know N_d, right? This equation was used to calculate and when we had a four speed gearbox and the 4th gear was a direct drive.

So it was very useful. Now we have a challenge, so the question is like how do we address that? Okay so we are going to look at that briefly.

So still we consider the intermediate gear ratios to be in geometric progression considering the set of gear ratios to be in geometric progression. We have N_{t2} by N_{t1} equal to N_{t3} by N_{t2} equal to N_{t4} by N_{t3} and that is equal to N_{t5} by N_{t4} and that is equal to K subscript “g”. Okay so in this equation the in this essentially a sequence we know only Nt4, Nt4 is 1 we do not know the gear ratios neither do we know K subscript g. Now the question is how do we figure those things out?

$$\frac{N_{t2}}{N_{t1}} = \frac{N_{t3}}{N_{t2}} = \frac{N_{t4}}{N_{t3}} = \frac{N_{t5}}{N_{t4}} = K_g$$

The equation for maximum speed is

$$v_{max} = \frac{\omega_{max}}{N_{t5} N_d} r_\omega (1 - \lambda)$$

$$\Rightarrow \; N_d = \frac{\omega_{max} r_\omega (1 - \lambda)}{N_{t5} v_{max}}$$

Okay so now in this scenario the equation for maximum speed is that is we are using the same equation v max is going to be equal to omega max divided by it was N_{tn} right here N is five. So we get N_{t5} N_d r_w times 1 minus lamda I have not done anything else. I had just taken the same equation substituted N equal to 5 right?

So from here we can immediately calculate the value of N_d as v max oh sorry N_d equal to omega max r_w times 1 minus lamda divided by N_{t5} v max, right? So let us keep this equation as it is now the equation for gradeability still we want to claim the steepest grade when we are in the first gear? So we use the same equation. So the maximum torque is T e max times N_{t1} times N_d times N_t by eta r_w which is the wheel radius.

$$\frac{T_{e,max} N_{t1} N_d \eta_t}{r_\omega} = W\left[sin\theta_{s,max} + f_r\right]$$

$$N_d = \frac{W\left[sin\theta_{s,max} + f_r\right] r_\omega}{T_{e,max} N_{t1} \eta_t} = \frac{\omega_{max} r_\omega (1 - \lambda)}{N_{t3} v_{max}}$$

$$\Rightarrow \frac{N_{t5}}{N_{t1}} = \frac{\omega_{max}(1 - \lambda) T_{max} \eta_t}{W\left[sin\theta_{s,max} + f_r\right] v_{max}} = K_g^4 \;\; \rightarrow Find\ K_g$$

Same equation okay I am not essentially changing anything that is going to be w times sin theta “s” max plus f_r right? So this is the same equation okay for matching the powertrain output in the first gear to what is required by the vehicle to climb on a grade. So from this equation also I can get an equation for N_d so w sin theta s max plus f_r r_w Te max N_{t1} eta t. Right now I am sure all of us can figure out where we are headed right?

We have two equations for N_d so we them. All right so we just you equate these two equations I am just directly writing the final one. So this should be equal to omega max r_w times 1 minus lamda N_{t5} v max is it, not right? So what is going to happen here we can immediately see that r_w cancels off then we immediately have N_{t5} by N_{t1} to be equal to omega max 1 minus lamda Te max times eta t divided by w times sin theta s max plus f_r v max.

Right now what is N_{t5} by N_{t1} Kg power 4 so that is going to be K subscript g to the power 4. So this will gives us K subscript g power 4 okay so find K subscript, right? So now the solution is obvious right?

$Find\ K_g\ \ from\ the\ above\ equation.$

$Then, calculate\ N_{t5}, N_{t3}, N_{t2}, N_{t1}.$

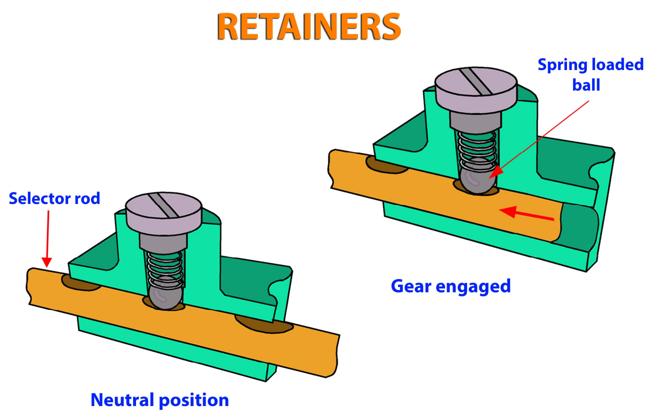
$Then, calculate\ N_d.$

Find K subscript g from the above equation. Then calculate once we know K subscript g what do I do? I go back to this geometric progression I know K subscript g then I can immediately calculate N_{t5} and N_{t3} why? Because N_{t4} is 1 once I calculate N_{t3} I can calculateN_{t2}. Once I calculate N_{t2} I can calculate N_{t1}. So then we can calculate so I am writing in the sequence N_{t5}, N_{t3}, N_{t2}, N_{t1} okay.

The reason I am writing in the sequence is clear to all of us, right? Because we have N_{t4} and Kg we go in this sequence then we can always calculate N_d, right? Because we already have an equation for N_d, right? So we can calculate the value of the final drive ratio. So this is a simple process to adopt when we have more than four gear ratios with the higher gear being what to say required to be over drive right.

Okay? So what we have done is essentialy match the transmission or the powertrain requirements to essentially overcome the loads on the vehicle at a particular operating condition. Right? So this process as I mentioned is broadly known as transmission matching. Okay because we are matching what the power train or transmission can provide to what is required by the vehicle right? So that is the concept.

So before I just quickly close this discussion on transmission. I just want to introduce a functions of two more components then we will close the discussion on transmissions. Okay so the first component is what is called as an interlock. Let me first maybe introduce a retainer. Okay the first sorry about that so the first component which I will introduce is what is called as a retainer.



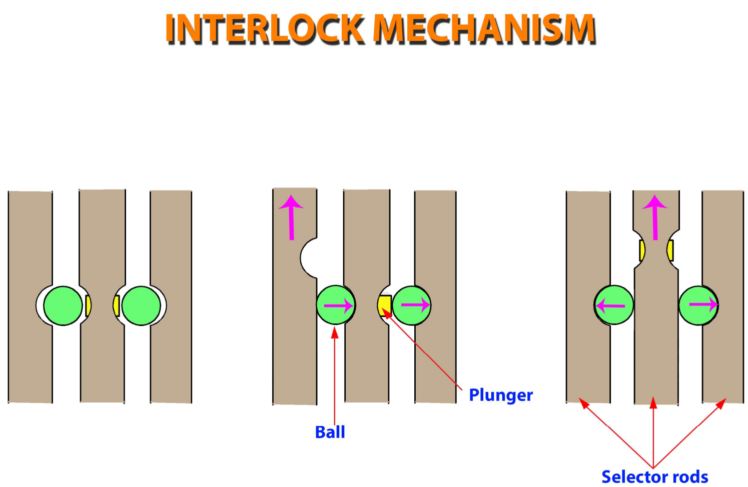
So this goes back to our discussion on the transmission components. If you recall the selector rod in the multi-speed gearbox and so on, right? So that is what we are essentially discussing. So what is this retainer, so we have already looked at this what to say a selector rod and how the gears are selected right? So let us say this is a particular selector rod. Now what happens is that this is when the selector rod is a neutral and the selector rod as we discussed one selector rod can be used to push one synchronizer either side.

So these are let us say two gears okay? So let us say this is gear one this is let us say gear two okay without loss of generality. What happens is that like this retainer is essentially a spring loaded ball okay? So this is what is called as a retainer okay? This assembly so you have these grooves where these balls are located and that is held in place by this coil spring. So when we push the a selector rod let us say you know like we are pushing the selector rod in this manner. Then what happens?

This due to the force applied on the selector rod this ball is pushed into the groove against the spring and the spacing between the grooves is such that it is calibrated to the displacement of the selector rod to engage a particular gear. So let us say for example in the first gear is engaged the ball will fall into this corresponding groove that is this one, right? So what it will do is that it will give you two things.

First it will give you know like a positive feel that a gear has been engaged and it will also ensure that the selector rod is held in its place or retained in its place. Okay even in the presence of some small vibrations so that the gear does not get disengaged even by accident. It is not going to get it is just a failsafe, right? So that is why it is called as a retainer right? I hope the function of a retainers is clear okay.

So, another component which is once again a failsafe mechanism that is used as what is called an interlock. So what is this interlock?



So an interlock essentially ensures that what to say selector rods do not move by even accident. Okay? So as I told it is once again its fail safe mechanism. So what happens is that like an interlock is this mechanism. You can see that typically let us say we have 3 selector rods. So, we have a groove in the central selector rod. Let us say we call this a selector rod one, two and three, right?

So in selector rod what to say two there is a what to say hole and an a pin is fixed in that. And then we have two balls floating in these grooves. Okay so this is the neutral position okay? So when none of the gears are engaged right? Let us say now if we push selector rod 1 up what is going to happen is that this ball is going to be pushed out of the groove and its going to push the pin and its going to push this ball against that third selector rope right?

So the second and the third sector rods are held in the position by this mechanism okay? That is why it is called as an interlock. It locks the other two selector rods. Now let us say even the central selector rod is pushed let us say selector rod two is pushed. What happens is that these two balls are taken out and then they essentially get pressed against the two outer most sector rods one and three here right?

So that the other two selector rods do not move by accident. Okay so that is the function of an interlock. So retainers and interlocks are fail-safe. Okay so I will stop my discussion on transmission with this so let us continue in the next class. Thank you.