Fundamentals of Automotive Systems
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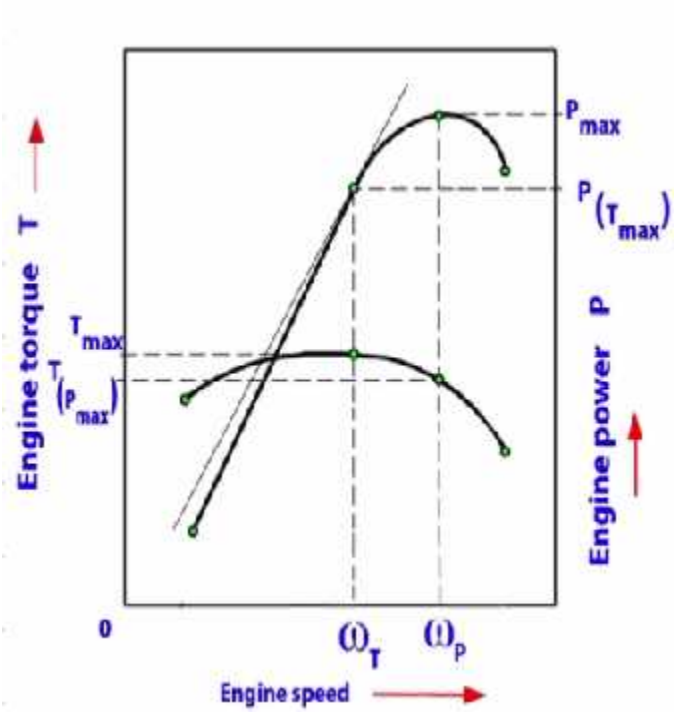
Lecture - 30
Automotive Powertrain Part 02



ENGINE SPEED VS POWER CHARACTERSTICS

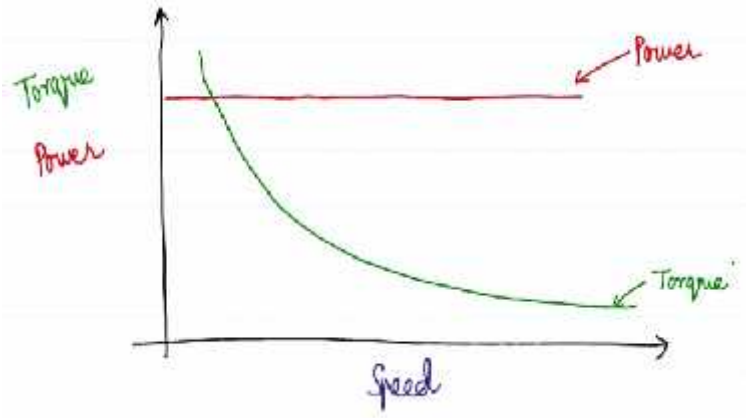
If we take a typical internal combustion engine and look at its torque speed and power speed characteristics. So, the plots are going to look something like this. So, the torque output is first going to increase its speed and then it will reach a peak at a speed which we are labeling as some omega t and beyond the engine torque starts to fall okay. So, you can immediately see that the engine torque output increases at speed reaches a maximum and then starts falling okay.

Now, another point which we have to observe that like in an internal combustion engine the engine itself provides very little torque when the speeds are low and practically no torque when the speed is close to 0 right. So, that is why when we operate with an internal combustion engine

we require what is called as a move of an element okay. So, to remove the vehicle from rest, so that is something which we are going to discuss shortly.

Now, if you look at the power speed curve, so, the power keeps on increasing with torque because power equals to torque times omega right and when the torque is the highest the power reaches some value after that even though the torque falls down the power keeps on increasing, but at a lower slope because torque is falling speed is increasing, but since the torque is falling down the power increases, but the rate at which power increases with speed essentially starts dropping down and then power reaches a maximum point okay.

Beyond which the torque starts to decrease so rapidly that the power also starts to drop. So, the speed at which we get the maximum power we call it as omega p. So, this is the maximum torque what is called as a rated torque and this is the rated power okay. So, now, we can immediately observe that the shape of the torque speed curve of the internal combustion engine is nowhere close to what we require.



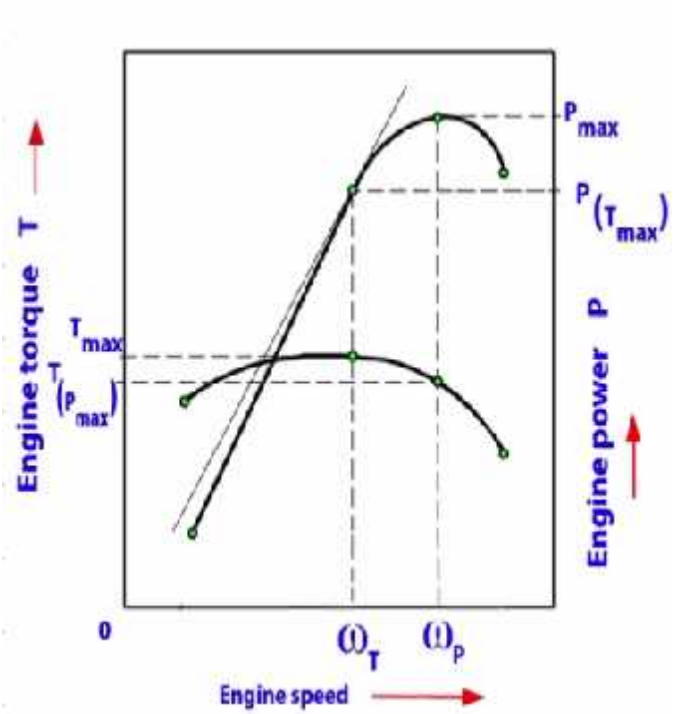
IDEAL PRIMEMOVER CHARACTERSTICS

So, what did we require? We wanted a shape in the form of hyperbola. So, this hyperbola is what is called as an ideal traction hyperbola okay. So, this sort of characteristics where the power is constant and the torque behaves like a hyperbola that characteristics is what is called as an ideal traction hyperbola that is what we want ideally right, but then you see that the IC engine torque speed characteristics is something like this.

So, it is not even in the shape of a hyperbola right. So, it is highly different from what we want and that is one primary reason why we go for a multi speed gearbox when we want to operate a vehicle with an IC engine okay. So, let me first write down what are all the limitations of IC engine which then motivate you know the transmission as we use it today right. So, the IC engine it cannot provide sufficient torque at near 0 speeds.

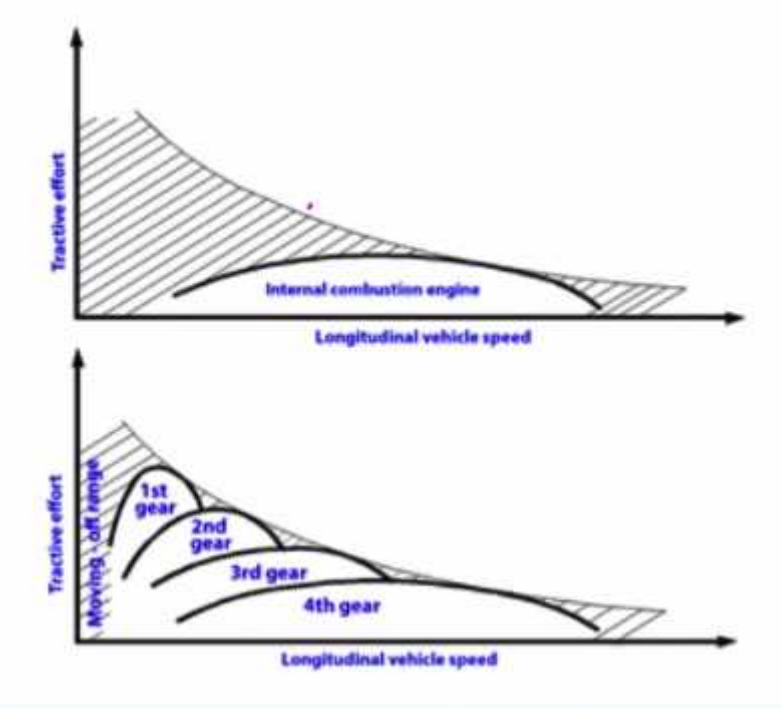
So, this implies that we require what is called as a move off element like a clutch to move a vehicle from rest because to overcome the limitation of the IC engine okay at very low speeds then we can observe that the engine can provide maximum power only at a certain speed. Hence, the IC engine persay cannot meet the ideal traction hyperbola. Okay so this we will observe shortly then it requires a multi speed gearbox.

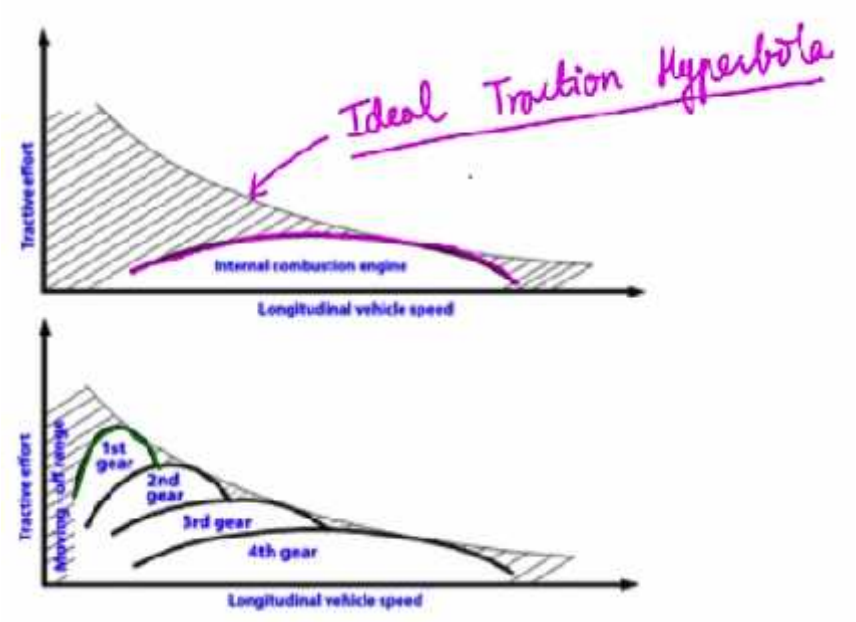
And another limitation of the IC engine which becomes important when we want to look at it from the perspective of fuel economy is that like, although not directly visible from this plot.



ACTUAL ENGINE CHARACTERSTICS

So, fuel consumption in an IC engine is strongly dependent on the operating state or point. So, that is another aspect of IC engine that we need to keep in mind. So, if we are not able to meet the ideal traction requirements with this characteristic how do we do that.





NEED FOR MULTISPEED GEAR BOX

So, let us quickly take a look at how it is done at least of philosophy then as I mentioned when we go for the analysis, we will do the actual calculations. So, why do we require these multi speed gearboxes? Something which we will discuss. Okay so, before we come here why do we think IC engines are still popular you know like why are they used so, I talked about limitations of IC engines right. So, we can see that we want a traction curve is in the form of hyperbola right we are not even getting a shape that is close to being a hyperbola.

So consequently, we require so many other elements, multiple gears, and very low torque at low speed. So we need a clutch, and a move of element to move the vehicle and so on. So, despite these limitations of IC engines from a perspective of a power train, from a perspective of an ideal prime mover.

Why do you think the internal combustion engine is still popular so, from the perspective of power train few advantages of IC engines because we should, have a balanced viewpoint so, obviously, there must be a lot of good things about IC engines. You know, like that enable it to have been used for a long time and still being used from the perspective of powertrain. So, what are these advantages? So, the first advantage is the internal combustion engine as a high power to weight ratio.

So, that is a very important advantage. So, in other words, if you want us particular power output from an internal combustion engine, you know like the mass of the entire prime mover will be pretty low comparatively okay compared to other choices which are available okay so that is a very good advantage of an internal combustion engine. Another advantage which this is also like beneficial or adds benefit to the use of IC engines in this application is that the fuel which is used has high energy density.

So, that means that if you look at the amount of energy which we get by burning unit quantity of the fuel in an IC engine that is going to be pretty high okay. So, this implies that is we are going to essentially have this advantage of relatively compact energy storage and that is a big advantage or a plus point for an IC engine even today if you take even like alternatives like batteries, fuel cells and so on right.

So, the energy storage system from the perspective of energy storage systems you know like IC engine still have a tremendous advantage and added to this, you know, like some practical advantages of you know, like faster refueling and essentially, you know, like availability of the infrastructure already in place for refueling and so on, you know, like, have sustained the application of IC engines in this domain.

So but we are going to be interested in the from the perspective of the engineering side. So why do we use a multi speed gearbox you know like internal combustion engine so let us look at that perspective. So as we just discussed, so if I plot tractive effort with, this is vehicle speed, this is the ideal traction hyperbola. So, as indicated here let us say this the characteristics of the IC engine, so if it is used as a it stands, we can see that there is a huge mismatch between the ideal traction hyperbola and the IC engine characteristic right.

So, the shaded region indicates the mismatch in the traction that is required and the traction that is available from the engine. So, what do we do we use a multi speed gearbox. So, typically when we use a gearbox and we provide a input and we get an output torque by and large in most automotive gear boxes in the lower gears, the so called gear ratio is greater than one. So, that means that the output torque is going to be more than the input torque.

So, what happens is that like if you look at this first gear the question becomes how did this curve become like this? So what happens is that when you multiply it by, let us say a factor of let us say four I am the staking some right, so, what happens to this curve is that the torque output gets amplified by that factor right, gets multiplied by the factor. So, as far as the curve is concerned it is gets shifted along the vertical axis.

But what happens to the horizontal range that gets shrunk and shifted to the left why? Because the output torque is going to be the gear ratio multiplied by the input torque okay, but the output speed is going to be input speed divided by gear ratio. So, if I am magnifying the input torque by a factor of 4, I am also scaling down the input speed by a factor of one fourth is it not. So, the

speed range is going to be shrunk and it is also going to be shifted to the left and that is how we get this right.

So, you see that the engine output curve is modified into the curve which is shown under first gear similarly, under second gear, third gear and so on okay. Now, when we are driving a car okay, let us say we engage in first gear and then we start moving. So we can immediately observe that we are going we are going to go from close to the ideal traction hyperbola still there is a mismatch right so, we go close to the ideal traction hyperbola.

And let us say as we go to higher speeds, what is going to happen is that this scaled curve is going to move away from the ideal traction hyperbola then you will see will feel the engine dragging because the engine output is not able to meet the requirements right which do which are essentially coming on the powertrain. Now, we switch to the second year. So what happens the operation of the transmission goes like this.

So then we go along the second year, and then after some time, even when the gear is in second gear, the torque speed characteristics of the other transmission output starts moving away from the ideal curve. So, then what we do we shift to the third gear and the curve goes like this. And so, you see that you know like, we essentially try to follow on the profiles of the various scaled curves corresponding to the different gear ratios while remaining as close to the ideal traction hyperbola as possible.

Still, there is going to be some mismatch and the fit is not exact some mismatch, but we can see that with the multi speed gearbox we have largely reduced the mismatches. So, that is an advantage. Of course, higher the number of gears better will be the match right because we can have a finer resolution as far as the speed range is concerned in which we can switch gears okay. So but then the cost of the gearbox would obviously increase. So there is a trade-off between the numbers of gears the complexity and cost of the system.

However, we still have to solve one more problem. So this is the philosophy behind how a multi speed gearbox essentially addresses this mismatch between the engine characteristics and the

ideal traction hyperbola right. Of course who changes the gears. If you have a manual transmission, the driver changes the gears, so we should know when to upshift and downshift and we get a sensory feed right .

When this point of transition is these are all points of transition from one gear to another so, we get a tactile feel of when to change still we have to address one issue what is that, What is this right no matter you know like whether we use a gear high first gear or not the high value of gear ratio the first gear or not still if you want to move off from rest, we need a clutch, we need a move off element okay. So, that becomes extremely important when we want to essentially move the vehicle from rest.

And not only that, a clutch also becomes important when we want to change from one gear to another, so we learn about all those functions of a clutch and how a clutch is actually realized in practice in the next class okay, so I will stop here for today. What we have done today is essentially to have a broad discussion of what a power train is what requirements are and what we actually have with an IC engine and why we need multi speed gears. Yes, we will continue with clutches in next class. Thank you.