Fundamentals of Automotive Systems
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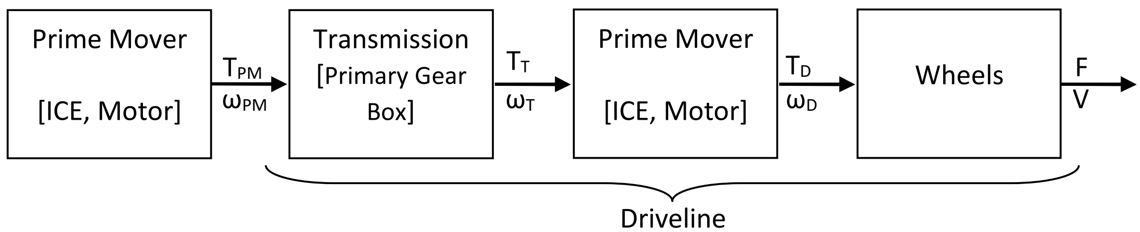
Lecture - 29
Automotive Powertrain Part 01



Greetings, welcome to this class. So, today we will get started with transmission. So, we were looking at IC engines. So, if we look at the overall automotive power train, we could write it realize it as a few blocks first block is the so-called Prime Mover. So, we have looked at the internal combustion engine, so I am abbreviating as ICE. So, there is a very common prime mover so one can also have an electric motor as a prime mover in electric vehicle, one could also have a combination of the IC engine and electric motor as a two prime movers . So, the prime mover delivers some torque.

Let us say we call it as some TP at some, let us say speed omega. So let us say I put it as T_{PM} Omega PM okay . So, the prime mover delivers some torque, T subscript PM at some speed omega PM and it provides this torque to what is called as the transmission. The term transmission by and large in you know like in the automotive domain is used to represent one element in the overall power train and typically the what is called as a primary gearbox is what is referred to as the transmission.

So, we are going to define these terms more carefully shortly. So, the torque gets multiplied in the transmission by the gear ratio and the primary gear box delivers some torque let us say T subscript T at some speed omega subscript T which then goes to what is called as a final drive. So, we look at all these blocks in this module. So, a final drive like a differential unit right So, typically will Split the torque that is coming out of the gearbox and provided to the wheels it is suppose let us say the vehicle is such that you know the front wheel are driven.

So the final drive we will split the torque that is coming out on the gearbox and provide that work to both the left and the right wheels. So that is what the final drive will do. And this delivers some torque TD at over speed omega D. This is ultimately provided to the wheels and the wheels through the contact between the tier and the road interface generate traction force it that and the vehicle moves at some speed, so ultimately this is the flow of energy transferred through this system okay.

So, this force F is as what is called as tractive force okay. The entire set of components from the prime mover to the wheels is what is called as the power train. So let us write down a few definitions. The first term is power train so the term power train essentially refers to the prime mover which can be engine or an electric motor or a combination of them and the drive line that transmits the energy to the wheels okay that is a power train. Now if we leave out the prime mover what are the components that are left behind in power train they constitute what is called as a driveline.

So, the term driveline includes all the components excluding the power prime mover, in the power so includes all the components from the prime mover but not including the prime mover okay. So that is the definition of driveline okay. And the term transmission is typically used to refer to one unit in the drive line and by and large it is the primary gear box okay. So these are the definitions. So, if you look at it from a macroscopic viewpoint, we are going to look at the entire powertrain persay right but in this module we are going to focus mainly on the transmission okay.

And once we learn about transmissions, we will learn how to combine an engine and transmission and achieve certain vehicle performance requirements. So that in broad is what is called as transmission matching or power train matching so that is an analysis view as I do.
But before we look at transmissions let us first reason out what are all the expectations from an automotive powertrain Right, then we will be able to better understand what the current

powertrain provides and why the transmission is realized the way it is currently so because if you look at most vehicles today, that are powered by IC engines, so we will have a multi speed gearbox right, which the driver controls to get the output from the powertrain. So what is the reason for that right and how does one choose those gears.

Right so those are questions which are important for us to understand, so to answer those questions, first let us understand what are the expectations for an automotive powertrain. So, let us list on what are all the requirements from an automotive powertrain. Okay so, the first requirement is that it should transmit energy required for propelling the vehicle okay and this energy should come from that prime mover and transmitted to the wheels.

So that is an important requirement of an automotive powertrain. Another important requirement which we by and large you know like experience when we start a car and then like we want to move is that like one of the important requirements is that like when the car is started, we have to enable the car to be moved from rest and that is something which an automotive powertrain should provide for so, the powertrain should ensure that the vehicle or should enable the vehicle the move from rest.

So that is another important requirement of an automotive powertrain and the powertrain also should adjust the torque and the speed or the force output coming out from it to which is available to propel the vehicle. Such that, the requirements of various operating conditions are . So, for example, let us say a car starts from rest, we would require high force to proper it because we need to overcome inertia and move the car to a certain speed at a certain acceleration.

And let us say a car is cruising on a flat road at a high speed still we may need to overcome some resistances and enable the car to cruise at that speed. So that the level of forces are tractive a force that will be required in that scenario would be different from the first case. In another scenario, let us say a car is going on a flyover right or on a hilly terrain. So, we have to essentially go up on a grade. So, then the vehicle should be able to overcome the corresponding resistances and ensure that the vehicle car can move up the grade at some speed.

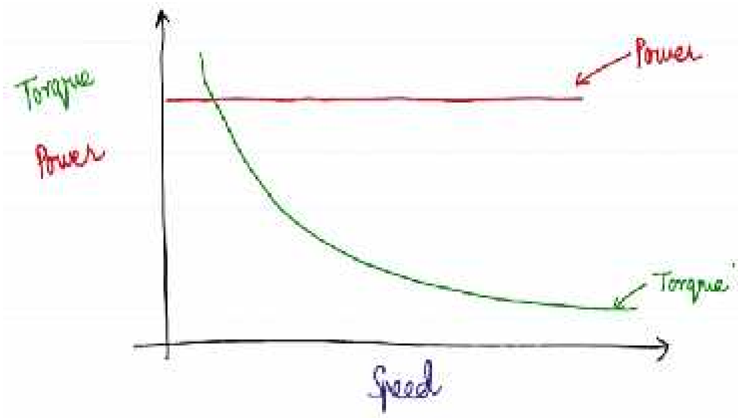
So, under each scenario, the requirements that are expected out of a powertrain would be different. So the power train should adjust the torque and speed depending on the operating conditions. So that is a very important requirement of a powertrain. So, the output from the power train should be automatically adjusted you know like depending on the requirements of the vehicle okay and as a vehicle designer, you know, we would also have some expectations of the powertrain, so let us say a vehicle designer comes to a powertrain designer.

The vehicle designer, may want the powertrain designer to design the powertrain for the particular vehicle to meet some expectations, what can be his expectations that can be they can be certain specifications in terms of what is the maximum acceleration that the vehicle can vehicle should achieve That is like let is say 0 to x kilometers per hour in y seconds. That is a specification right is it not and what should be the maximum longitudinal speed at which the vehicle should travel.

So someone might say, hey, the car that you are designing should be able to travel at a maximum longitudinal speed of let us say 160 kilometers per hour that is an expectation. Someone may say, I want my car to claim the grade with a gradeability of let is say 20%. So we will see what the gradeability means, right. So, once again, we are stating our expectations. And someone may say, my I want my powertrain when fixed.

When essentially installed along with the car and operated on a particular driving cycle right, or driving pattern should provide me with so much of fuel economy that is a fair expectation, in terms of mileage and fuel consumption and so on. So the question is, how do we convert those expectations into ratings of the powertrain components. So that is also a job of a powertrain designer right.

So a powertrain should enable the realization of vehicle specifications such as maximum acceleration, maximum longitudinal speed gradeability. We are going to look at all these specifications as we go and do when we do transmission matching fuel economy, range etc. So range becomes important because nowadays with.



IDEAL PRIME MOVER CHARACTERSTICS

Growing emphasis on electric and hybrid vehicles right one would want to say hey, what is the distance that I can travel before I have to recharge my batteries right, so, essentially range becomes an important specification. So, one way is basically inform the powertrain designer that design the powertrain such that the range of the vehicle is 200 kilometers so, the battery has to last 200 kilometers in a single charge.

So that is a specific expectation. So given these expectations what are the ideal characteristics of a prime mover which would be desirable. So, if we brought the torque and power of a prime mover, speed an ideal prime mover should be one which provides constant power across all speeds and since power equals torque times omega the torque profile would be hyperbola. So if the power were constant torque will be some constant divided by omega, so this will be the torque. And how can we reason it out.

So suppose if I am at low speeds, my regular starting from rest or going at low speeds on the main resistance that I would want to come when I start from rest is the inertia of the vehicle m times A so there I required more torque correct. And even if I am driving my vehicle on a gradient, at low speeds, let us say 15 kilometers per hour or 20 kilometers per hour, if the slope of the gradient is the angle of the gradient is. Let us say some theta I need to overcome MG sin theta.

So, that also typically turns out to be a significant number. So, when we are operating at low speeds, we would require high torque okay, from the powertrain and speed keeps on increasing. Let us say we go to high speeds, let us say we are going on a highway and driving at 100 kilometers per hour. You would see that the resistance forces that are going to come and which need to be overcome by the power train.

The magnitude of the resistance forces will drop off there are going to be resistance forces we will identify what those resistance forces are when we do the analysis, but the magnitude is not going to be as high as at low speeds. So we need progressively lower forces as we go along. So, that is why at low speeds we require a high torque and as speed increases the torque requirement decreases.