Vehicle Dynamics
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Lecture - 25
Subjective and Objective Evaluation of Vehicle Handling (Part 1)

Let us quickly review what we were doing in the last class. Let us put them the whole thing in proper perspective and then we will go to the next topic on subjective and objective evaluation.

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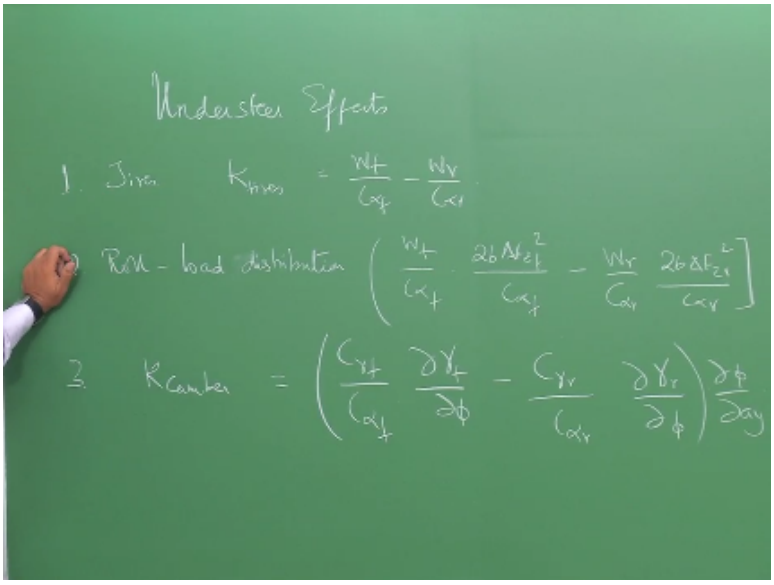

Essentially, what we did was initially to look at understeer gradient from the point of view of the tires okay that is the first thing. In fact, the whole language of understeer gradient was talked in terms of alpha f, alpha r and so on and so forth. So it is the first thing that we started here. When we expended the concept of understeer gradient remember that we were concentrating on the steering input and the corresponding behaviour of the tire.

In other words, whether I have to give more steering input or less steering input this what we came to. We realized that there are number of other factors which are going to play a role when it comes to the steering input. In other words, other factors may make us give more steering input or give less steering input.

In other words, there other factors which are going to cause what we call as understeer or oversteer. The first thing remember we talked about the roll distribution, redistribution during roll, we found that the nonlinearity with respect to Fz of the tier is going to cause a change in the alpha r in other words the slip angle front and rear and so that roll would essentially cause a change in the understeer or oversteer characteristics of the car. This is the first thing we saw. We saw with the derivation.

The next we saw is respect to the camber truss. Remember that we defined camber truss as the lateral force produced because of the presence of camber of the tier in other words the wheel okay. So we saw that the slope of that curve which we -- the camber force versus camber angle which we called as camber truss the—in the slope of that curve that becomes important and that is what we call if you remember C gamma f.

Camber truss is basically forces I should not say that this is the thing but anyway that is the slope of this curve between the force and the camber, right. This we saw that also has an effect. The result that I am very interested to find out what is camber change due to the mechanism the suspension mechanism and that is what we are going to do as a big exercise in the next course on vehicle handling elaborately we will use packages like Adams.

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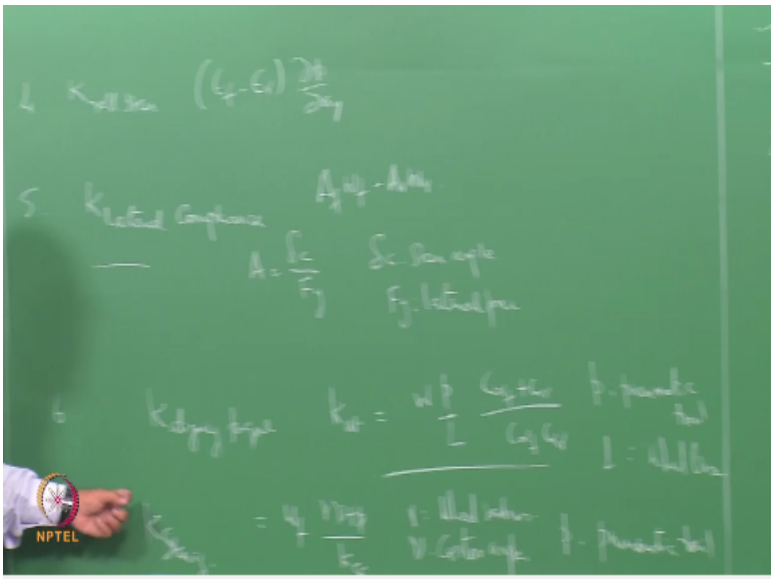

Then we come to what we call as a roll steer. We said that there is a change as the again as again as there is a roll then the there is a change in the angle of this tires and that would again cause behavior where I may have to give more steering input in order to compensate for that change of this tier angle okay and that is what we called as roll steer. Remember, we also defined when it is positive and negative and so on, right.

So essentially what we are looking at is how does the tier take the force change the delta and correspondingly whether it becomes understeer or oversteer. Then we looked at what is called as a lateral compliance steer and again because the force is do not act exactly in center and does not and may cause a yaw because they may be Off-Center and depending upon whether the yaw center is the front or the rear you know the vehicle will turn to the right and the left and so on and all those things we did.

Then compliance steer is a very important concept from that point of view and it has -- this we will distinguish between a front lateral compliance steer and the rear lateral compliance steer and the difference between them would cause the vehicle to understeer or oversteer okay, so that is one of the thing that we introduced. Okay.

Obviously, we made a comment at the end of the class we will compare to the comment. Obviously, aligning torque will have an effect. After all aligning torque is what makes the vehicle go straight it is going to align the torque right sorry align the wheel right. So aligning torque anything which has an effect on the wheel also will have an affect so aligning torch has an effect of course on the understeer gradient and so the aligning torque value is given by this where P is a pneumatic trail, L is the wheel base and so on.

So in other words you have to give more delta that is why this goes as an understeer if because of the aligning torque as it becomes straight so I have to give more delta and compensate for it and so that is the value for the aligning torque. Okay. Note that both p as well as C alpha F okay both of them participate in this particular derivation. And before we close this there is one more thing is this steering.

You know there is lot of things that we talked about steering unfortunately again this course is so crammed we will not be able to look at steering design and so on. Let us see that we will do that the component the automotive structures and components analysis and right now I just want to state that steering also participates obviously, steering participates in understeer characteristic of the tier. Okay, so steering in other words that being the input steering has its own role to play.

So the case steering or the understeer gradient due to steering has an important component okay which is the-- which we call as of course Wf is known which we call as KSS. Okay, so this KSS in fact, this called as let me check, yeah this is called as KSS where we look at the—the stiffness compliances of the steering okay as well as we look at the radius wheel radius we look at the caster angle and the pneumatic trail.

So all these things also participate in what is called as the role of steering on the understeer gradient. Okay.

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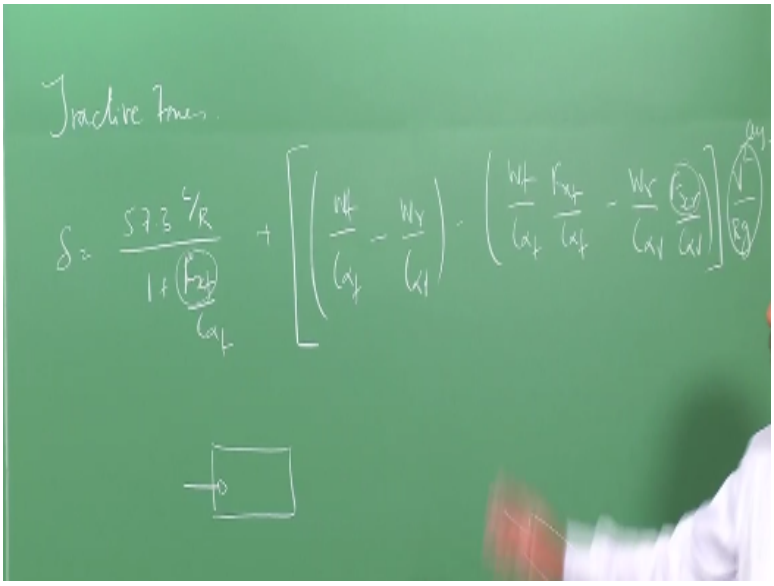

So we will talk a lot about steering in the few minutes okay and its role on the whole of handling itself. And lastly, 2 things which we have left out one is there is a load transfer to the front because of acceleration, deceleration and so on. We mentioned that. We have not taken that into account that like what we have done for the-- you know, rear, sorry rear and front due to roll. Okay, here this is due to pitch.

Unfortunately, the model which we have we will not able to take that into account so you have to go to a much more detailed model if you have to look at how load transfer is going to have an effect, right on this. But when you do testing this becomes an important quantity the way a transfer takes place okay when you when you break or decelerate. Okay the transfer takes place and due to which what would be the difference in the force that is developed in the front and rear is going to have an affect okay.

We are not considering this as a formula here but we will consider that when we look at the subjective and objective. And lastly, the tractive force, you know the other words one is a tractive force. Tractive force is an affect—I leave this this derivation for you to look at in Goolsbee whole of this things as I have told you in the last class the references Goolsbee. So here you would see a very interesting thing.

The Fxf and front and the rear Fxr are the forces that act in the front and the rear. So if this is the rear tiee and this is the-- say for example this is the front tier then those are the Fxf and Fxr okay that act. Say for example if there if its traction and if it is a front wheel derive then Fxf is what you will get and you will, if it is just a front wheel you will not get a Fxr when our—you are accelerating, right.

Now look at this what happens. So even for a neutral steer whether rest of it are not there in other words the first geometric term is affected by the traction okay the very first term is affected by the traction, okay. So what happens higher the term hire this is lower is delta and hence there is a tendency to oversteer or understeer. Yes, because you have to give me give more delta, okay. So you will understand here in every term here.

For example, if you look at this term there will be a more delta is - so it will become an oversteer quantity so that will so delta is less which means that it is oversteer. Okay. So, delta is less here because there is a – term the cars turns to oversteer, okay. So in other words, the front wheel drive as a tendency okay because of traction to be oversteered okay but due to other factors like

A and B the distance between the front accelerate and the center of gravity location okay that is being small has a tendency to understeer. Okay.

So that is one of the contributions or this term is a contribution for the understeer gradient. Okay. So in other words what we essentially what we have done is we have extended the understeer gradient to include 8 different parameters. So if you look at the understeer gradient of a car you have to consider all these things. Okay. Now, we will move further then this you can—if you look at the-- I do not want to interpret this you can do that interpretation in each one of this cases it is quite simple.

So we will go over to how to apply all those things whatever we have studied in order to look at handling. **"Professor – Student conversation starts"**, Is that clear, any questions? What is pneumatic trail? Pneumatic trail, we have already saw that know. The force—lateral force does not act at the center just act the rear you know the-- the moment that we created that distance at which this acts.

And we use the aligning torque multiplied by pneumatic trail gives aligning torque. Okay, so that is what we saw long ago as the Pneumatic trail. Yeah, we will talk about steering right now, okay there are lot of things which are going in the steering we will talk a lot more about steering okay, right now. What lateral compliance, what is it? **"Professor – Student conversation ends"**

We saw that already that the force that acts okay will have a tendency for the vehicle to Yaw the force that acts the rear or the front will have a tendency for the vehicle to Yaw depending upon the whether the yaw that is produced due to the lateral compliance which is in the sense that the force that acts okay depending upon whether it helps you aids you in turning or preventive from turning easily okay.

So when I taking a turn to the right if my lateral compliance very simple terms when I am taking a turn to the right if my lateral compliance aids me in that further turning okay I have a oversteer characteristics, if is my that lateral compliance is going to be making me go in the other direction then I would have a tendency to understeer, right.

So depending upon, so what why is there a difference between front and rear because the Yaw of center is different a front and rears you know the way it is going to yaw just to the front and rear are different so that is why if I use this same notation positive notation you would find that there is a positive to front, okay and a negative to the rear, what is positive to the front the same force is applied at the rear.

Because the yaw into this is this now shifted you will have tendency to go to the right. Okay. So there is a difference that is why we have, okay. So here also the compliance of the steering systems comes into picture okay that is very important and we are going to see that as well. Right, in fact I have to spend lot more time I do not have that time now so I refer to Goolsbee it is a chapter on steering.

But we will move now, we will move away and we will look at subjective and objective evaluation. Okay let me finish this and then I will take the questions. Okay.

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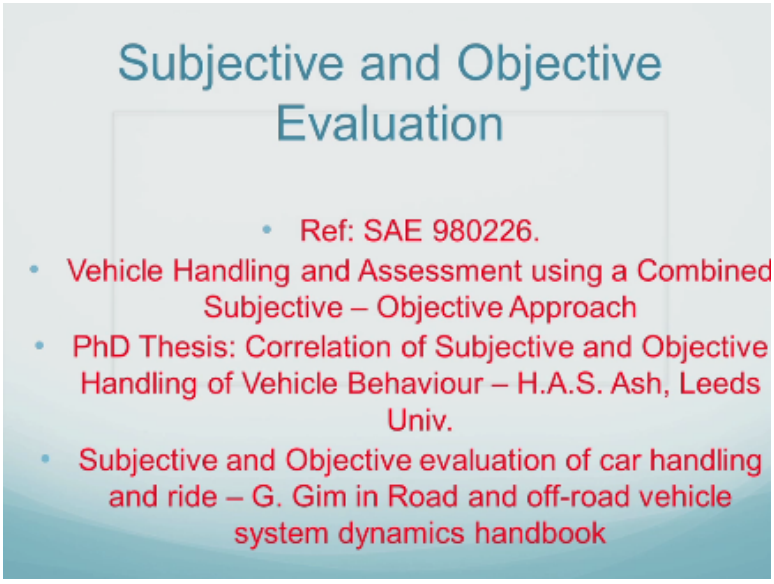

Now there are number of references this is a topic which I would say has been very well researched, a lot of work is being done. So let us look at a few of the work that from where we are going to pick some concepts to understand what is subjective and objective evaluation.

Before we go further these are the references, reference SAE 980226 a group from by Prof. Corolla and others.

So that is then I mean that is the topic is Vehicle Handling and Assessment using a Combined Subjective-Objective approach and then important very interesting paper, lot of data available. It has gone into PhD thesis as well, Correlation of Subjective and Objective Handling of Vehicle Behaviour by Ash from Leeds University. This Leeds university group is done lot of work on this with the help of MIRA- Motor Industry Research Association in U.K.

A very interesting article recently published okay in a book titled Road and Off-Road Vehicle System Dynamic Handbook and one of the chapter there is Subjective and Objective evaluation of Car handling, right by G. Gim that has a lot of information on Subjective-Objective evaluation. Okay.

So basically we are going to follow these people on subjective-objective evaluation; not to say that not others you know that-- there are number of references other references but which is going scratch the surface as far as the subjective-objective evaluation is concerned, huge topic. Okay, let me go back to know further things. **"Professor – Student conversation starts"** You have a question? Yes, sir the formula that we derived (()) (16:55).

Yes, no we are that is a grip; we are not talking about that; we are only talking about that is what is called-- we will come to that what is called limit handling, okay. So we are not talking about that; we are not talking about total grip this gives us an idea, okay that in other words when we talk about this we assume that we have not reached the limiting grip okay. So we are going to talk about limiting grip and at limiting grip what is the problem, okay. We are going to do that.

Sir, if not gone to limiting to (()) (17:34) then why is the? Still, see there are 2 things one is stability okay. Safety is not just ability. The other is the driver's ability to follow a manure, okay or follow or a path rather. Manure to follow a path; he does not want surprises, okay this is very important. How much steering I have to give, that feel should be clean and clear, okay. So it is

not that we all the time talk only about stability, handling as we are going to see now, that is why this is the next topic. **"Professor – Student conversation ends"**

Handling is about lot more things than just stability. Okay. So we are going to see the feel. In other words, what is that you want you want easy driving, someone is going to drive for you fine that is the best thing to you that can happen to you, but if you are going to drive then comfort is very important okay, safety is very important, okay then limit grip, stability all those things. Okay. So all these things, no you are right, I understand your question. Okay.

We are going to talk about that in minutes. In other words, what you are asking is whether this will steal some of the force for Fy, of course it is going to steal okay. Of course it is going to steal – this formula does not bring that out. Of course it is going to steal.

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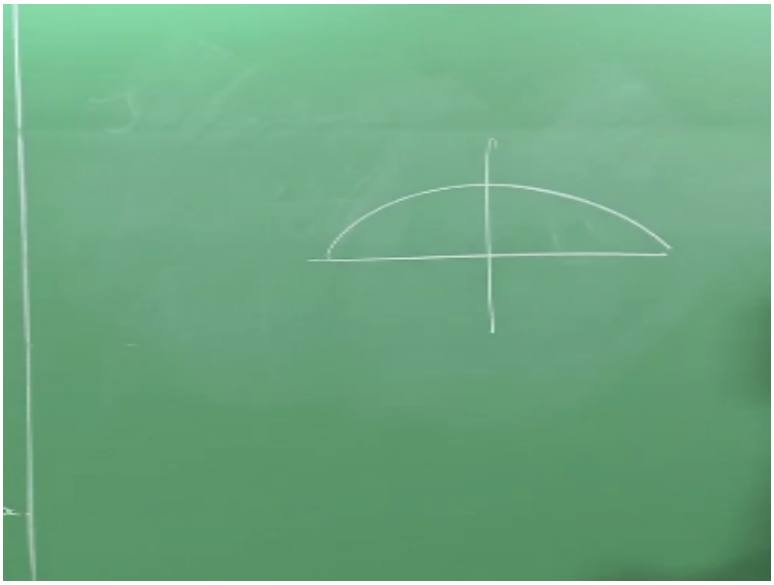

In other words, that is what we call that as a Friction ellipse. Friction ellipse is going to have an effect; we are going to see that, right. **"Professor – Student conversation starts"** Does that answer your question? Yes. So we are not yet there in that friction ellipse; we are not using this formula; in other words we are not using this formula in order to analyze friction ellipse. No, I am only talking about how much delta I have to give and so on, right. Okay.

What is the effect of this Friction ellipse? We have to wait. Yeah. And all these roll steer etcetera are they derived only for the steady state case or is it (()) (19:46)? Yes, that is the good question. You know we had started on this. Okay. Understeer and Oversteer all these things are derived for steady state. So that is why we introduced what is called as a transient understeer and transient oversteer. It is become the very important test for subjective evaluation.

In fact, this becomes so important that there are power off, power on test okay that becomes a bread and butter of some of these tier companies. Okay. Most instances, in fact tier companies are at the forefront in order to understand the subjective- objective evaluation but basically because they are the people who are going to prove why many of the feel which we are talking about. Okay. So there are 3 things now. I have done that before but let me repeat this. **"Professor – Student conversation ends"**

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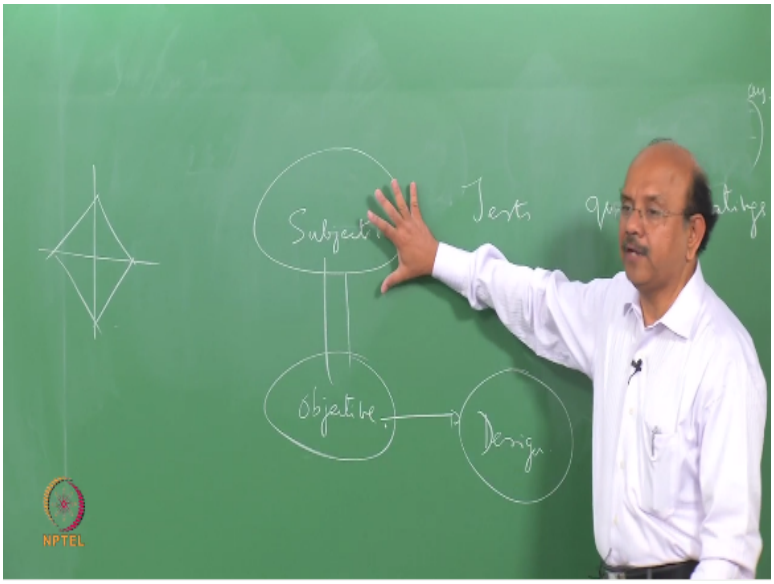

So I have a subjective evaluation. What is mean by subjective evaluation? We have expert drivers not one maybe a number of drivers available, there is a jury maybe available. So this subjective means that it is the perception of these drivers, okay. So they have a questioner. In fact, questioner design, okay there are standards now the questioner design is important.

So you can go and ask him obviously, you are all student so you do and say Hey, how was the car? you know, Did it go well? No man, it is a damn (()) (21:15). You know this kind of things

will not work, right. I mean -- so you have to have a proper questioner and proper a test procedure. So you have to say that I am doing a steady state cornering on a smooth road okay, are you able to hold the line, okay this kind of things.

In fact, Corolla and others have got into about 39 questions, okay and then there is a rating maybe in a 1 to 10 scale, okay. Some people may differ some people may agree, you know like all questions everyone will not agree, okay. So we will typically see these questions a bit later. But I am only telling you that there are number of questions okay. So there are test and there are questions and there are ratings.

Rating maybe 1 to 5 scale or 1 to 10 scale or so on. Now this is subjective, the subjective evaluation has to be interfaced or correlated with objective evaluation. Okay. So there is a test procedure of course.

And this is an objective, what do you mean by objective evaluation. Remember, that we saw one of the models (()) (22:50) model okay which there are many test which shows that (()) (22:56) model is good model and it brings out the effectively the handling of the car the area of that rhombus (()) (23:04) is good enough to tell us whether the car is good or not.

But there been a lot of test or in the literature especially this group from Leeds itself says that this is not adequate, okay the-- there is a Japanese group which says that this is adequate some groups say I is not adequate-- in other words these 4 parameters which this (()) (23:30) model considers maybe not adequate representation is one of the thing, yes. To start with this is good but if you want to go into necessities may not be adequate.

In other words, these parameters start expanding now. Okay, so you at gain at some say 0.4 or 0.7 hertz and so on. They become important. So objective evaluation is many times in the frequency domain most of the time frequency is 1 or 2 time domain that become they are values which can be derived from the measured from the car okay a quantitative value which can be measured that is the objective rating.

So the whole idea in subjective-objective evaluation is to look at that correlation. For example, this correlation in these papers is given by a formula. Okay. This becomes very important it is not very easy it is very easy to say this but if this is not this is not very easy to actually correlate the subjective evaluation, why is these guys saying that during cornering might the car is not holding out, you know why?

He has to—you have to know it so you have to have an objective evaluation or objective or a reason from what you can measure the characteristic of the car okay from a model then the third step which is important is this objective evaluation is then correlated with the design. Now what should I change, if your damping is not good what is having an effect on-- in your damping. Okay. So what is having in effect, so that this whole thing is clear.

So in other words, if a driver expert driver comes and says that this car is has a problem what is called balance FARA or something like that then what is why is that happening, and how can I correct it. So that is the complete root. Okay. Now, let us look at subjective evaluation. So as I told you last time if you want to buy a car let us see what all you will do. Okay. You know this already many of them but it is fun to look at how to evaluate a car.

We will come to a very specific manures later; let us look at a very broad you know, perspective of subjective writing. So we will follow Gim in what we are going to see now.

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We already saw that, please link what we have done so far to what I am going to present now. Yes. **"Professor – Student conversation starts"** Sir, assuming that we have a model for that, I mean if we find out certain diameters of their models assuming that model is exactly what the car will behave right, then we will have all the quantities characterize the cars. **"Professor – Student conversation ends"**

I mean it should be very I mean if we have those 4 diameters and if they quantify the models exactly then it should be adequate. Right, but it is not—your question is well take. This not like look at this careful. This is not like design. For example, you dead goes on finite element analysis or mechanics of material so they for example, finite element analysis you were told that calculate for me the stress or equivalent stress.

And then compare this with your yield okay and then you were told that if it is N the yield say maybe the yield/factor of safety or permissible stress than its fine. So in other words, there you calculated and you had a fantastic in a criteria function which told you that look compare these 2 if they are less fine. Here I do not have a criteria function. Because I have too many parameters, it is not one stress one form is an stress and then done with it.

It is not like that I have so many parameters and I do not know whether it will be < this value or > that value or between this value, I do not know, that is the difficulty of design. Okay, that is

why we are looking at all these things. So running straight what is that you will look at, we have seen all these things. So running straight the first thing you will see is Pull, remember we did that long ago and we had put the blame on the tier and we said that okay the car will drift there is a forces are different, corner city, fly steer right.

So the first thing you would do when you take a car is to find out whether okay imagine that you are going to buy a car okay if you do not have the money you are going to ask your dad so you-- or your mom okay who ever have more money they can pay. Okay, now you have this you go you see how much it is drifting, okay. This is straight away drift, right. This is what we call as residual pull.

Then running straight, this is one of the reasons for it not to not to go down or not to go to one side. Then there can be other things. This—when you run straight, okay the tier may not be the reason for it to drift there may be other reasons where if I now.

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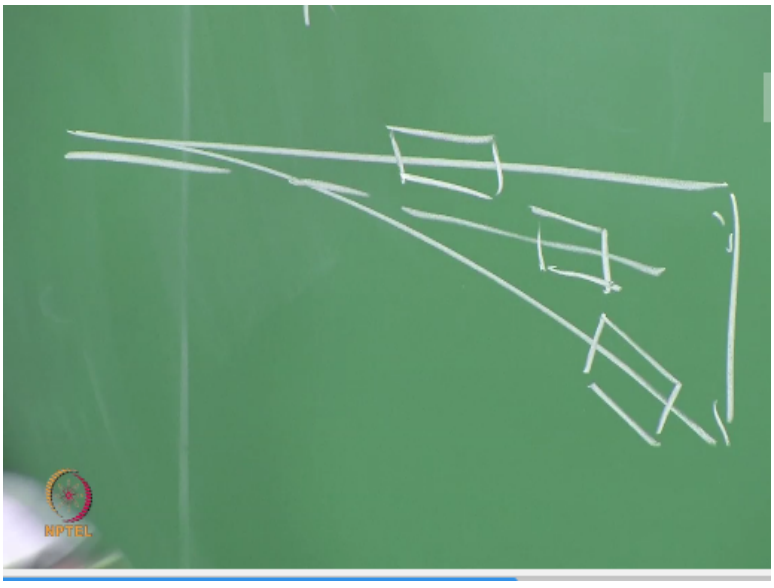

If there is a Pull it may so happen that the vehicle can go like that what is going straight may go like that and that is drift. But the vehicle can also go like this okay it can go straight, here what is the difference here you can turn like this is the Pull, you know this can be drift of the vehicle as you go it may be due to steering system and so on.

Then it can wander it can wander, what is wander it can go like that and remember that when we go over a bump or rough road or whatever it is okay there can be it is possible the steering is not steady and it can wander or it can wander and be sloppy all these things maybe due to external disturbance like cross wind flowing and so on.

So in other words, we are expanding the first thing called drift to take into account a motion away from the straight line due to a cross wind, okay, due to road roughness and so on. The lower it is better, so the first thing you do is to take a car and drive " straight “hey, it is not going straight”, I have to keep my steering all the time okay engaged so that I do not get into trouble, that is not that is not a good situation right. Okay.

So that is the first thing we have to do. The other one is what is called torque steer. Of course Steering happens not by only you steering happens by so many things. Okay. So what is torque steer? So most of the cars that you drive for example or the front wheel driving cars, okay so the torque for the wheels given the front wheel, sometimes it may have—why some time due to so many reasons that the left and the right torque may not be the same and there can be a difference because of which there can be a steer.

Okay, there can be an unbalance in the torque that is given to the front wheel and because of that there can be a steer. So I will have to do a test to look at whether when I accelerate it is going to other direction, when I decelerate afterwards whether it is coming back and so on, right. So what happens during my accelerate and decelerate. First I will go straight, I will not even accelerate I will look at how this vehicle goes.

The dancing here and there that is the first test I will do. Then I will take the car and accelerate okay. See whether loose leave-- hold the steering and see whether it is going to one side because of torque steer it is steering on its own because of this acceleration that I am giving and because of the torque that is available at the wheel, right when I decelerate I am coming back, okay.

In other words, if the car having a path like that first part is acceleration second part is deceleration, so this is what is called torque steer. Okay, that is the next thing I will check, right

or you will check. The other one when you go straight is braking and the performance of the vehicle when you brake, what do I mean by performance of the vehicle and a brake?

When I go fast and brake I would like it not to lose the attitude. In other words, when I go and brake it should straight be straight be straight the nose -- see one of the major things in the drivers feels objectives is they look at this angle and they look at the feel in that steering so these are very, very important. Okay though we talk about wander and other things-- actually the driver will not allow it to wander you know they will keep on correcting the steering.

Okay, this is I am testing in even when you drive there can be a wander and what does the driver do he keeps on adjusting so he knows, knows of the vehicle what is attitude and he keeps on correcting it. The problem is either the tireware will be high or fatigue of the driver will be high. So he does not want his attitude of the car okay, the nose angle does not wanted to go up and down.

So braking straight is the deviation of the vehicle attitude whether it is going to turn or it is going to remind straight eye, right.

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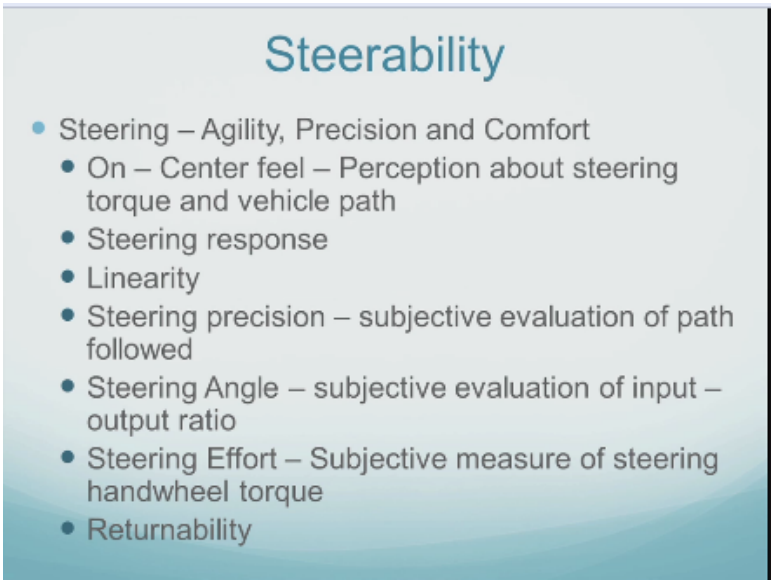

We look at, then Steerability. Okay. There is what we call as look at that On- Center feel. Okay. What is On-Center feel? We talked about steering. We talked a lot about steering and On-Center

is a very practical approach to the steering performance. As it is written there, it is feel a perception about the steering torque and vehicle path, okay. What do you mean by this? What is responsible for this? Let us understand that.

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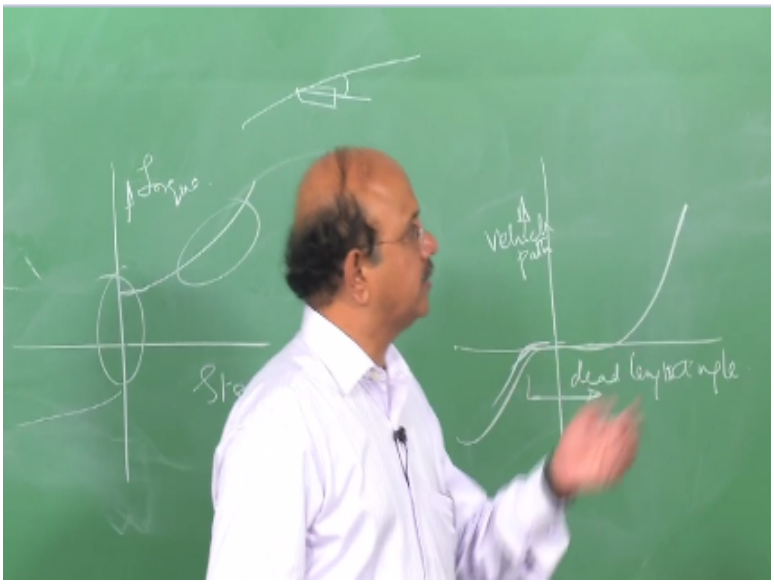

So now if I plot say for example steering angle, okay versus the torque the steering torque, this friction a line of warning whatever we are talking about is evaluating a car not that you are going to assuming that you are not going to drive at 30 kilometers per hour in this crowded roads. Okay. So do not tell me that why are you doing all these things anyway I am not going to drive beyond 30 kilometers subjective evaluation is not there.

So understand the limit of the car. Okay. Right, so there are a lot of athletics. Right. Now if you look at the torque versus steering angle the first thing that comes to our mind is that steering having so many moving parts the friction. Okay. So before the steering angle changes, I have to overcome those friction, okay. So it does not start here, I cannot plot 0 versus 3 so it will start here. Okay.

After this-- there is a compliance of the-- we go into the compliance of this steering system. Okay. So the steering angle versus steering torque makes that kind of turn and so we have so this region we have what is called is the steering effort, the steering effort. Okay. So I have to

overcome friction after which I will then look at how much is the effort that I have to give in order to drive.

I can plot another graph which is very important-- which is the angle versus the vehicle part, angle versus the vehicle path. Okay. How it is going to look like? It is going to look like this. **"Professor – Student conversation starts"** Yeah any question? Which angle is it? This is the steering. Okay. Fine. Okay. **"Professor – Student conversation ends"** So you would see I mean let us say that it is symmetrical about the center-- you would see that look at this.

There is an angle of the steering after which a path change is going to take place. This is very important. Okay. This is called as the dead length. Look at this athletic. This is very important so this-- the friction is very important, okay lot of friction and lot of compliance my driving effort my steering is going to get affected. After all everything depends upon steering for the subjective rating. So in other words, drivers feel what depends upon the steering.

So this is called as the dead length. Okay. So what does it means that if I now play with my steering within that length the cars attitude will not change, okay. Why is this important? What it should be? A difficult question to answer but you can look at the + and the – of this. Assume that the dead length is large. What happens? Then I turn the vehicle attitude will not change okay after sometime after I turn a bit okay then it will start changing oh that is not that is not good.

In other words, the feel is not going to be good. Okay, so the larger it is I am not happy with it. Now, what happens if it is 0 smaller, bring it to 0. **"Professor – Student conversation starts"** (()) (40:11). Yes, that is correct. **"Professor – Student conversation ends"**. So if there are disturbances small disturbances in the road and it is going to have an effect on my steering small vibrations due to that okay, small disturbances on it, it is going to change my vehicle attitude or vehicle path and hence I have to keep on adjusting it.

So this is this, this is together the perception of the torque to the vehicle path you know this is what is called as the On-Center feel. **"Professor – Student conversation starts"** Sir, when you are plotting the vehicle what is that actually mean? The path you want to take-- usually the path

is measured by the nose angle to your path you know how much is the nose angle different from the path you want to take. The deviation since that you want to you can plot that has an angle -- nose angle of the-- so as I told you most of these things when I say that there is a path and deviation from the path we talk about the nose angle okay. **"Professor – Student conversation ends"**

Even when you look at the understeer or oversteer characteristic of the car we look at nose angle. Okay, nose angle is simply the attitude of the car. Okay. So if the car is going to go it has to go like that and if the car goes if this is the car and goes like this that is the, you know attitude or the nose angle. Simply the nose of the car how it is with respect to the path you want to follow. **"Professor – Student conversation starts"** Sir, is it oversteer?

No, no, please note that, no, no we are not talking about oversteer or understeer. Maybe small angle deviation. No, that is exactly what I am saying. This is the characteristic of the steering okay. Yes, you can interpret it in that language that is why we have this guy here, right. So that is what we said that the case steering has an affect okay right that is why we have one affect. So in other words in a broad sense steering has an effect on understeer and oversteer. Clear.

Okay, but this dead zone is not understeer characteristics. It is the compliance which affects the understeer characteristics. Clear? Okay. Sir, you said the (()) (42:41) if the disturbance happens when you are steering handling is not at the dead length. No that is correct. If it is that is what it is called Off-Center. If it is Off-Center okay and if there are disturbances you have to control there is no doubt about it. Okay.

But when you are going straight I do not want the disturbances to be affective, see that directly impacts your fatigue because when you go straight you keep on turning fun is lost. How much would be the value? That is what I said it very difficult to say what should be the value. This would-- see actually if you look at the total steering input it runs to 300 degrees. There is it is not that it is 5,10,20,30.

So this maybe of the order of about 8, 10 or maybe much < that, okay + or – 4, 5 that kind of thing. So a very small value because you would see how much-- actually steering changes okay because when you go straight. So actual steering you would see you go and turn you know the turning is-- the angles are so high. Okay the ratio for example between the wheel and this maybe in the order of 30s. How is that dead length actually realize?

How is it dead length realized? That is what I said that is the steering it is a part of this steering characteristics okay. This is a part of the steering characteristic compliance is due to so many things in this steering and so on. In a dead zone what will be the torque required by that time? That is what exactly I am saying. So that is related by this point, okay. So there is a difference there is a certain difference between this and this. **"Professor – Student conversation ends"**

Here we are looking at the change, okay and torque is not produced to change the vehicle angle. In other words, here we are looking at the correspondence between the steering angle and the wheel, okay that is what we are looking at. Here we are looking at how much the steering angle changes required in order to get the steering torque going, okay that is what we are talking here. In other words, here this is due to the friction.

Okay, so that would be the type of the-- so that is why distinguish between the 2 that drew it in such a fashion that this is the angle and that is the attitude that you look at then you have what is called as the steering response and linearity. Okay. How linear is the steering with respect to the path that is going to follow, is it linear or non-linear; in the sense that if I progressively increase this steering is it that my-- what I want if there is corresponding radius which is followed okay correspondingly for the same velocity.

We are not bringing into affect the concept of understeer as we had learnt now, okay. It is a question of as it changes the angle, I may into surprises. Okay. Or the changes progressively linear so that is what we call as the linearity of this one oh okay I left that steering response. One of the other things that apart from this is that we can look at this response in a time domain, okay in a time domain.

In other words, if I now change this steering okay or the steering angle; now what is the path change and after how long does this path change take place.

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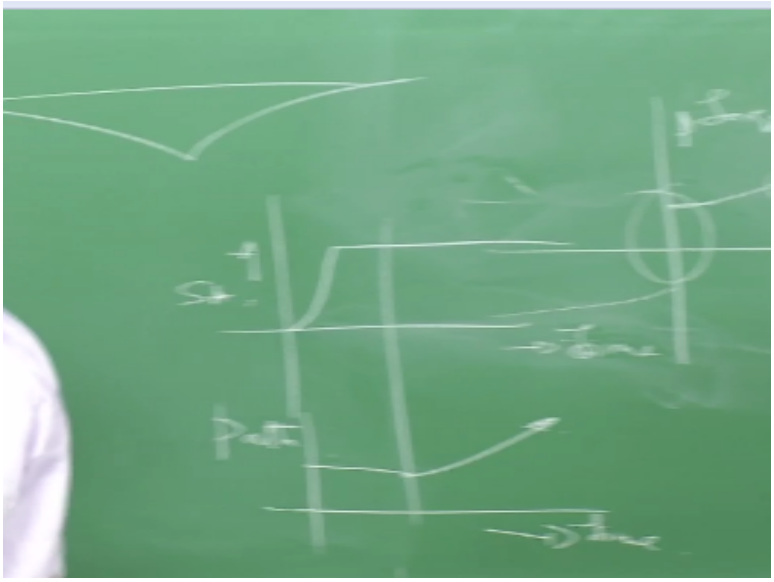

In other words, if I now plot the time you know here I do not have a time I am now plotting it with respect to time, okay Time versus Angle steering angle okay. I give let us say that it is like that. It takes time for me also to give an input, right? So that is what this is. Now, I want to look at after how long does my car start negotiating this manure, okay.

So it may happen that the car which is going straight will keep going straight for some more time which is that response time after which it will start going, right. So if it goes—this-- how much it goes is what we call a steering gain, but this time after which that vehicle realizes that there is a steering input and starts changing the course, okay that is what we call as steering response. **"Professor – Student conversation starts"** Sir, what below the path? Time, time this is time that is the path. (()) (48:30).

Does not matter because I am just going straight that is all; this is only a subjective representation, not a very objective representation. Okay. I am going straight I am changing it that is all. After how long I change that is all is the length, right, okay. So that is the steering response then we have 3 things, you know steering precision, steering angle, steering effort okay all these things followed by what is called as Return-ability.

So how do you test all these things? Okay, we will look at 3 things it is the name indicates what they are. How do you test all these things? So let us say let us you give you the test. Let us not become too technical. Let us say the retunability. What is returnability? Steering has to come back okay and. So suppose I tell you, you design a test so look at returnability. Okay. What will you do?

Maybe sir if you need the steering if you let it come back if you steer and gear away it should does not go back to the same. Yes, but how will you do a test. Is it going to be subjective or objective? Of course we are looking at subjective test. Then we will need lot of users test driving. No, no, no that is all fine but what is that-- see there is a difference between evaluation and a test procedure okay. So how you will do it?

Sir, but what test procedure is subjective--That is what I am asking you. What is the test procedure you think can be done in order that I can test say for example returnability. See that is how you conceive a test. So each one of them will have a test you know. So that is what I said subjective evaluation then there is a test then there is a feel then there is a mark or there is a grade then look at the objective evaluation. **"Professor – Student conversation ends"**

So what is the test? Simple, I go straight I flick the steering, okay it is called flick test, flick the steering okay then how fast the steering comes back. What is my feel that steering comes back? It can also be measured, okay. So these are so for everything there are test, right. And we will talk more about this we will complete this; we will talk about a few of the test at least in the next class.