Design of Mechanical Transmission Systems

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Week – 01

Lecture - 01

Course introduction, Evaluation and Application of gearbox:

So, very good morning to you. Welcome to design of mechanical transmission system course aspect. So, this is the very specialized course, advanced course discuss about various transmission systems in automobile industry, particularly we are going to discuss in automobile aspect. The syllabus it has a four units: the first units we will going to discuss about the gearbox system design aspect. So, when we talk about gearbox system. So, we are not going to discuss only the gears or gear design aspect we are going to discuss as a holistic system.

When we say holistic system, it start from the understanding about the machine tool gearbox, then from there construction about a ray diagram based on the given power and torque, then build up about the kinematic diagram, then go for the what is the type, after that we are going to discuss about automobile gearbox this is going to be sliding mesh or constant mesh or synchronous mesh. So, that is the way we are going to do that, then we do the complete design. Finding out based on the bending strength and pitting strength above the model aspect from the model, then move to the development of the gears, then we will go for the shaft calculations, bearing selection, once a bearing selection suitable lubrication system, then finally estimating about whether the system within the design or not, that validation also we will discuss including gearbox losses and our safe life calculation, this is what we are going to focus in gearbox system aspect, then we will move on to the brake system design in brake system design again, we are going to discuss a four different gearbox brakes. So, you will have a friction lining based brakes.

So, you will have a water disc, drum brake system then is called duo servo brake system. So, these are the things we are going to discuss. So, here we not only discuss about the design aspect and also we will discuss about the dynamic, which is very important when you talk about dynamics there the vehicle dimension also will come into the picture how the vehicle dimension chosen, such a way that the brake should able to stop the vehicle. So, that interaction we are going to discuss in detail in dynamics aspect and also we will discuss about the thermal aspect of vehicle braking, then if time permits we will focus for

a apart from passenger car we will go for aircraft, helicopter and hoist. So, this is the one which is focusing on brake system design, further we will extend another thing it is a clutch system design, it is extension of brake because of there is arrangement is same, only the difference is the application.

So, here again we will discuss about we will learning about design, analysis, dynamics and thermal aspects of clutches and we will finally, we will discuss the entire clutch design aspect for automobile clutches and a centrifugal clutches this is the third unit which talk about the clutch aspect. Then the fourth unit the other machine elements talking about design of shafts ,torsion bar, torsion limiting devices, chain, bell drives ,conveyor ,friction joints ,friction drives, those are the things, we are going to discuss particularly I will focus more on the chain, bell drives, friction joints, friction drives, and if time permits I will cover ball screws, splines, bushes and linear motion slides. So, these are the four topics we are going to learn in this course. So, it is a very vast actually and the outcome of this course is once you complete you will be able to design your gearbox your brake and clutch and the other machine elements. So, which comprehensive what happen you will be expertise of a mechanical transmission system designer or design engineer that is how the syllabus is framed to cover various aspects.

So, the references so, they have lot of references because we since this course is advanced course we are going to refer many text books starting from for machine tool aspect Joshi Mehta for machine tool aspect, then we will discuss for gearbox aspect Nomir Peter Linvander Stephen Rajbirch, Jami Jelska, Geethan Mitra, Alan Stokes, U. C. Jindal these are the books for gearbox and for your information, have you heard any text book for gearbox aspect as such there would not be, there is no any text book for the gearbox aspect interestingly. And then you can see that Rothbart and Newcombe and Day Rudalf Limpert, Bert Neiman and these are the for brakes and clutches aspect and Shigley's for the covering a standard design book for comprehensive basic understanding of gears, brakes, clutch and friction elements. So, these are the references. So, prerequisites as you know that the since this is advanced design course obviously, you should know about the strength of materials, that is basics engineering mechanics and design of machine elements, these are the three courses you must have done in the prepared to attend this course this should have knowledge of these courses. So, that it will be very useful. So, design of mechanical transmission systems, in this first system we are going to discuss about gearbox system. And you could see this is the transmission the entire gearbox is given and this is the transmission where select gear selection mechanism. And you can see the very nice gearbox system which comprising of the flywheel, flywheel to gearbox right and all this accelerates are given and prerequisites knowledge before going to the gearbox system you should aware of the gear types you should aware of the gear types when you say gear types is talking about spur gear, helical gear mostly used in automobile aspect. So, nomenclature. So, when you talk about nomenclature you should able to understand about the module,

pressure angle, addendum, dedendum, face width, right and tooth depth also right those things because those are the very critical for the gears, but since advanced we are not going to discuss, we are going to discuss in the module itself. Once you model that is other things are taken care of automatically. Yes, you understand when the gears are measuring what are the forces are acting ok. So, how the tangential force is acting not only tangential force and the radial force, how these forces are responsible for a stresses aspect? We talk about stresses aspect, we talking about bending stress and the fatigue stress this critical two stresses are we are you need to aware of that. So, famous Lewis equation right we have heard Lewis equation. So, that is the equation is going to come into the picture, of course, correction factors also will be there and you should know about the shaft design, bearing section, I am going to touch ok does not matter still I am going to give you a brief introduction. So, that recap of these things and you are able to follow it up then finally, lubrication selection ok. So, these are the thing is going to be as a prerequisites.

Now, we will come back to the actual design of gear box ok. A gear box consist of a mean of a transmitting mechanical torque between two shafts with the structural support between them. Normally it is constrained within the casing which provide structural support and also containment and safety function ok. You could see this very nice the gear box system, this is a input shaft ok the input I am just focusing only the gear box system from there it goes to the you can see this is called counter shaft or else a lay shaft from the lay shaft you will have a output shaft this is the output shaft will goes to the next stage ok. And of course, though you can see that the shift fork and shift rail for selecting the first gear, second gear, third or fourth including reverse gear, right, all the gears at will be selected through the gear selection mechanism using shift fork which is the stick which always there, of course, now you have a advanced automotive also where you can use instead of stick you can just automatic gear system you can just change the knob and change the gears that is also there ok. Question is so, what is the difference between manual transmission and automotive transmission just keep in mind that is one question ok which is good in terms of performance wise in terms of fuel economy wise, ok in terms of comfort of the driver aspect right. So, these are the question I will answer as we go on and do you think the gear box purpose is only for speed aspect? Do you expect any other function apart from selecting the speed? Torque ok torque also there and you can see here this is the generic arrangement normally you will have an engine, engine will give power through combustion, then through engine it goes to fly wheel where energy stored from fly wheel you will have a clutch to transmission, which is a gear box from gear box to a drive shaft and finally, go to differential gear, then a rear wheel this is the how the transmission moves from engine to wheel ok. In fact, you can look at this again top view engine traction clutch transmission differential gear box then you will have a final drive finally, in the axle from the axle goes to wheel, this how the transmission takes place ok. Gear function that is what I said we talk about gear function its structural support for the shaft, bearing, hence the gear loading

also. So, we always thought we always thought gear box only for speed aspect, no it is not only speed and also should able to support the entire structure, that is one thing. Transfer torque reaction to supporting structure or for the drive element ok. So, this is the reason. So, what is the advantage instead of there is no casing just gears alone, do you think that is feasible? It is not because when you want to repair the gear box it is easy to take the entire gear box, that is much easier than the taking the individual gears or shaft that is cumbersome. So, now, we know that why we take it as a gear box, instead of the gears alone.

So, it containment of lubricant. So, when you say the gear box that will sump itself the bottom itself will act as a sump. So, obviously containment lubricant and exclusion of foreign matters, you do not want any debris or dust enter a system that going to affect your the gears. Provision of safety obviously, the important thing noise barrier, you do not want to hear the noise. So, when you drive a nice car you want to have a comfort right maybe you can listen nice music also while driving. So, if your gear noise more than the music what happen? So, it should be the gear noise should be contained as small as possible or as low as possible and more importantly dissipation of heat generated by the friction that has to be removed right, that is need to be removed and ultimately unitisation of assembly, thus aiding testing, installation, and maintenance much be easier as a one unit single unit gear box unit. And more importantly enhancement of visual quality immunity visual quality aesthetic look that is also very important for a gear box system. Yeah. So, now we will go for the types of gear box when talking about physical arrangement. When you talk about physical arrangement, you can see that you can have a parallel shaft arrangement, a perpendicular shaft arrangement, and skewed shaft arrangement. When you talk about parallel, you will have a spur, helical, and epicyclic and a perpendicular bevel, worm and spiroid and this cross shaft is a cross helical, this is the way configuration. And within that we talking about single stage gear come with the stage based you can have single stage two stage and multi stage, you can see this is a nice small gear box given. So, you have an only two gears this gear one and gear two, this is actually a single stage. So, it is going to be reduction, gear box purpose is you want to reduce the speed.

Okay. Let me ask one question before moving to this what is the need of the gear box you have seen the configuration engine, fly wheel, clutch then gear box we have after gear box we went to the universal joint then went to the wheel.
So, can we take off the gear box straight away, joint engine with the wheel is it doable is it doable what is the need of the gear box that was the question. So, what happened if there is no gear box straight away connect the engine to your wheel through other arrangement? So, just think about it. So, this is the gear configuration, two stage you can see that we have a four gears you can see that right, there is a this is one is a missing here then again you will have a from here to here, this is a two stage this is configuration,, then you have a multi stage, you can see that this is a typical automobile gear box it is a multi stage gear

box, you can see this is the gear selection mechanism right you can see the gear these are the gears in between we have a dog clutch and this is a gear selection then you have a output shaft also. So, we will discuss in detail as we go on and this is we are talking now we will move on to the gear box application we talk about machine tool.

Prior to the machine tool what is the typical range you would expert in the automobile gear box usually you will have a four forward speed, right, forward speed one one reverse this is what you configuration otherwise you will have a five forward okay and one reverse, sometime you may have seven gears also seven gears also seven forward one reverse. So, this is this is how arrangement is given okay very small things okay whereas the moment you go for apart from these gears have you heard about any other speeds in the gear box, how about tractor, tractor what will be the tractor speeds how much speeds for tractor maybe 24, 28 speeds. So, we have offload vehicles and different speeds also offload vehicle. So, this machine tool gear box, so the application is different in in automobile gear box, you want to have a specific speed, okay in machine tool purpose you need to have a more precision, more precision for depth of cut, more feed and depth of cut, you need to have a more precision, that is why the normally the machine tool will have a different speed, you can start from 12 speed, 18 speed, 24,right and 28 they will go for a very high speeds and you can see this is the for helicopter again you have rotor remember rotor, that is the important thing right for helicopter aspect which achieved this is actually planetary gear setup you can see that this is actually it is a planetary gear setup which is you can have a high speed ratio reduction. Right this is the one and this is the another important thing is windmill okay you will see that this is your blades then this is the hub from above to the gear box, gear box to generator, okay the unique difference the dynamics difference, here in automobile you want to reduce the speed okay in windmill you want to increase the speed, the more the speed the more the electricity, so both are very different though application right you can understand that okay so in windmill you will have a usually a epicyclic gear train in the first stage, then regular you will have a regular two-stage gear box helical gear box such a way that you can have a high speed, so the dynamics are different, so characteristics you can see that this is the list of the characteristics of the gear types.

It's given a spur, helical, epicyclic, bevel, worm, spiroid and crossed, so against shaft orientation, speed, reversibility, counter shaft, and power weight and mechanical efficiency, so we will focus about the more importantly this speed aspect we will focus on the speed we will focus on the power weight and we will just to understand about and mechanical efficiency if you look at as you move on to a spur and helical the reduction is 60 : 1, 80 : 1 the moment you go you can have a 50 : 1 so high speed reduction or up either way you can use it so this is very advantage of course you can have worm also, the difference is worm is the friction will come into the picture, worm is like a screwdriver it's like a screwdriver the more the friction you can transfer more power, but problem is look

at the efficiency 40 to 80, okay then next one the power weight ratio in a wind mill or machine tool the weight is not a problem right but when you go for automobile the weight is more problem because you want to have a as compact as possible as light as possible so that the fuel economy better okay, so that is very important we talk about gearbox design it's not only the design the gearbox you have to optimize such a way that the fuel economy should be improved optimizing, okay look at this the power weight ratio good for spur, helical also fair and excellent for the epicyclic gear train and if you look at the mechanical efficiency the highest one from spur gears 92, helical 90 and epicycle 85, so they are in the close range, so among them you can see clearly spur, helical are preferred for automobile applications right, you can see that straight away you can see that spur helical are preferred epicycle also there but epicycle will be different application may not be for automobile that's the thing. Now we'll move on to the gearbox design purpose when you talk about when you design the gearbox what is the purpose okay, so we have a lot of purposes okay one is pay reduction, speed reduction or speed up that's one thing is there within the application also you can change the purpose also right that is there so you can have automobile, you can have offload vehicle for not only that home applications or machine to gearbox all those purposes.

Quality when you talk about quality it's a very critical aspect okay let me give you a four important things okay you have a watch you have a watch okay then you have a watch right we have a watch then you have a automobile gearbox no I would not say automobile I will say machine tool, machine tool gearbox and finally you will have a automobile gearbox let me ask you which one will have a higher quality high quality which one for which couple is which application do we need a high quality so watch is the high quality because it's a very precision very very precision okay that is very important thing the next thing is a machine tool because you need to have a appropriate depth of feed and speed, both you need to know that so that's the one, automobile automobile next quality will come okay I will give you example so the vehicle supposed to run 0 to 30 kilometer for first gear so that means you have wide range you can have 25 kilometer also right you can have 30 kilometer also you can even increase 35 kilometer does it going to affect any performance, it won't be it may be little but compared to watch and machine tool machine tool it will affect so you may not have the proper machining operation if you compromise the quality then that will affect your watch function also so the call is very important same thing right.

Talking about torque okay so what is the torque so when you talk about torque again what type of vehicle you're going to use are you going to use the passenger car, are you going to use it for the tractor or truck I'm talking about truck if not machine tool depends on the thing the torque also will plays the vital role. Gear dimensions okay so how big you want to or how compact you want to the gear dimensions very critical. Then gear specifications when you talk about gear specification so gear dimension in automobile most important parameter would be your center distance, do you know what is the reason for center

distance, your space is limited so we have to specify your gear box within the center distance you want to have it okay whereas machine tool also even more specified, watch where the gears are there even more specified okay how about sugar cane you have freedom right for sugar cane we have they have gears right so you have a freedom that should be fine okay so the gear dimensions very critical. Okay, then gear specification we talk about gear specification, what type of gears you are going to use it, whether you want to use a spur gear or helical gear within the helical you have a herringbone also the opposite double helical that is also very important, double helical will remove the axial so that the transmission is very smooth and comfort. Shaft design so once you have done the purpose understanding the purpose, quality, torque, gear dimension, gear specification, top design, then you need to go for the bearing selection, and lubrication what is the lubrication what is the quantity of the lubrication how heat balance is happened if the more heat is generated, then lubricants loses its viscosity obviously the performance goes down right, power losses, and finally gear case dimension, this is how we will do we will do the gearbox design aspect okay thank you.