Design of Mechanical Transmission Systems

Prof. Ramkumar

Department of Mechanical Engineering

Indian Institute of Technology Madras

Week – 06

Lecture – 18

Lecture 18_ Brake: Problem Solving

Good morning, welcome back to brake system lectures. In previous lectures, we have done this problem I ask you to do the problem, the second problem a four-wheel automobile aspect. Hope you would have done that if not I will do it again. And also, I would like to emphasize the important thing. This is a free body diagram, where we just few important points I would like to emphasize. This is the pivot okay, this is the pivot, from pivot to where the lining starts right this is the lining starts, that is a θ_1, yeah right. So, from the pivot position to where this is going to be. Then, θ_2 from the pivot to where the lining ends that is θ_2. Please aware of that that is very important. And also, I have mentioned very clearly the center of your brake drum to the center of pivot, the distance or the distance is h yeah and from the pivot where the activation force act on the tip the distance is *C,* okay. *R* is the radius of the drum that is already you know that. And, these are the thing just I wanted to make sure that understand sometime we may get confusion to avoid that just I am emphasizing. And also, I would like to emphasize two things right the activation force this is what I said, when you take the moment probably, I can go back here. So, with rest you this is the pivot you keeping this reference pivot when this load acting right this is load acting you will have moment. There are two type of moment one is normal moment and frictional moment right that is what I said. So, we derived both moments and also, we try to do the balancing. So, we end up,

$$P = (M_n - M_f)/C$$

P equal to activation force. Because of the direction, minus F by C. This will reduce your braking effect. That is why we say that right reduce in the sense the magnitude of the braking effect will be less or efficient, I would say that. So, that is why it is called self-energizing effect. Whereas, the magnitude of activation force would be, this is called leading shoe. I am sure you know that this is the leading shoe yeah. Then another one, when the activation force separates when the activation force zero, obviously $M_n = M_f$. So, obviously you cannot run so you will have a stalling, only the wheel runs the vehicle would not move so that is not advisable. The third aspect where the sign will change so that means you need to have a more activation force.

$$P = (M_n + M_f)/C$$

This is for trailing shoe; this is for the trailing shoe. And, the moment you do reverse direction what happened to the arrangement, the trailing would be leading or the leading would be trailing. To avoid that we will have a leading-leading with the two-wheel cylinder, that is one arrangement. And, as duo also we have done that. I also would like to show, these are the shoes you can see that okay these are the two shoes. This is actually drum brake system right. Can you tell me are they both are leading and trailing or leading and leading. If you look at this

arrangement, it is a leading-leading because of there is no short length of the brake lining I can say this is your brake lining, and this in fact, this is Honda Activa two-wheeler brake shoes. It is from my vehicle, okay. Maybe, I can circulate you can see later stage. So, you can see where is the pivot is coming here which push in pivot, yes, this is the which arrangement normally this is the arrangement right this is what happening the wheels will be there. And, you can see that so brake lining starts and this ends right. So, you can see in detail later stage.

So, let us move on to the next problem, yeah. An automotive type internal expanding double shoe brake is drawn in class. I am going to draw now okay the face width of the line is given 40 mm and the maximum pressure intensity of normal pressure is limited to 1 N/mm^2. The coefficient of friction is 0.32. The angle θ_1 can be assumed to be zero. Calculate the activation force, the torque observing capacity of brake. These are the thing you have to do that so perhaps I will draw the diagram first. So, note down θ_1 is zero, okay. The data is given, the P_{Max} is given the maximum P_{Max} is given as a 1 N/mm^2, that is given. *w* is the width of the pressure lining is given as a 40 mm. And. μ is the coefficient of friction is given as a 0.32 and θ_1 is equal to 0°. And, I will draw the diagram. Then, you will see what other values are given okay.

Just not to scale just for understanding purpose so we have a pivot here the pivot will move like this that is a pivot. Then, the friction lining also will be there, the friction lining is fully attached to the wheel okay that is a friction lining. Then, I will draw the central line okay, then there is one more pivot right. Now, the activation force act in both ways right, we are showing only one direction but I can show both ways. This is your activation force yeah; this is activation force. So, now I will give the information what other information. From the pivot where the friction lining starts okay, friction lining start and ends right the ends is $120°$, okay. Then, from the friction and ends to this position is 30, right. Then, so 30+150, this should be $30°$ right. From here to this position is 30 okay that is given. Then, just wanted to show the *h* value from the center of the drum to the center of the pivot, the dimension is given as a 50 mm okay. Then, activation force we need to find out the activation force from the pivot to right till this position right, pivot to here. So, the entire thing will be *C*. I will give you split up, this is 86.6 okay and 100.9. So, the *C* value 86.6 + 100.9, that is the value is given. The *R* is not given right radius of drum brake drum is not given so radius of drum is 125 mm. So, the question is clearly asked find out the activation force *P* and also torque absorbing for the brake that is what you supposed to do that yup okay.

So, θ_1 is 0 already we know that $\theta_1 = 0$, because straight away start from the pivot right pivot to here is start away straight away started. Then, $\theta_2 = 120°$ that we already we got it from here okay. Then, how about θ_{Max} ? Generally, obvious $\sin\theta_{Max} = 1$, cannot go beyond 1, that is already given. Now, with the geometry *h,* I just wanted to find out what will be the *h,* okay. So, $h = \sqrt{86.6^2 + 50^2}$, if you do that geometry aspect if you do the geometry, you know the distance here you know the distance right, and I you know the distance from there if you able to substitute and you will get $h = 100\ mm$, okay. That is a 100 mm. So, the activation force is assumed that the maximum normal pressure will occur between the lining and the right-hand shoe and the brake drum because we are focusing only on the leading shoe aspect okay. This is your shoe right and this is your friction lining and this lining exactly interacting with the drum right. So, where do you expect the pressure, in this position right the pressure you would expect in this area this is where it is happening yeah.

So, now the step will be we need to find out the with respect to pivot respect to the activation force the M_f as well as M_n, you need to find out. Those equation already I given to you okay those equation already I given to you. Can you find out please? Maybe I will rewrite down the equation,

$$M_f = \frac{\mu P_{Max} Rw\{4R(cos\theta_1 - cos\theta_2) - h(cos2\theta_1 - cos2\theta_2)\}}{4sin\theta_{Max}}$$

This is what we given. So, we know $\mu = 0.32$, and maximum pressure we have taken as $1\ N/mm^2$. We will substitute everything in millimeter. 125, *R* is the radius, the width is given 40 mm, okay clearly given. Then, if you substitute other values right can you substitute, then divided by 4, maximum $sin\theta_{Max}$ we have taken as a 1. Substitute the values please and if you substitute the corresponding the value,

$$M_f = \frac{0.32 * 1 * 125 * 40 * \{4 * 125(\cos 0 - \cos 120) - 100(\cos 0 - \cos 240)\}}{4 * 1}$$

So, thus will give you the closing up. Substitute, what is the value are getting now? You would expect 240,000 Nmm right. this is M_f, this is the value you must. Did you get this value, right. You should have got. Now, similarly this is for M_f. All right.

Now, I will go for M_n, again this is from the pivot with respect to pivot, when the *P* acting on the tip. So, where you will get a normal moment again this would be,

$$M_n = \frac{P_{Max} Rwh\{2(\theta_2 - \theta_1) - (\sin 2\theta_2 - \sin 2\theta_1)\}}{4sin\theta_{Max}}$$

Similarly, you substitute all the values,

$$M_n = \frac{1 * 125 * 40 * 100\{2(120 - 0) - (\sin 240 - \sin 0)\}}{4 * 1}$$

Then, you would expect the value 631,851.95 Nmm, okay. Maybe approximately, we will do as a 631,852 Nmm. So, this is M_n, so we got from the leading shoe right both M_n and M_f we got it okay. So, now we need to find out what would be the torque absorbing capacity yeah, torque absorbing capacity. So, now I want to find out with respect to M_t on the right side okay which is the leading one,

$$(M_t)_R = \frac{\mu R^2 P_{Max} w(cos\theta_1 - cos\theta_2)}{sin\theta_{Max}}$$

So, substitute again this is,

$$(M_t)_R = \frac{0.32 * 125^2 * 1 * 40(\cos 0 - \cos 120)}{1}$$

Are you getting your $(M_t)_R = 300{,}000$ Nmm, torque absorbing capacity on the right hand. So, this is the value you should expect from M_t. M_t is nothing but torque okay. Torque on the right side. So, can we find out what will be the activation force *P* for the leading shoe okay. We will find out. Can we move on, right.

The activation force for right side shoe, okay nothing but leading shoe. We assuming as a leading shoe,

$$P = \frac{M_n - M_f}{C}$$

So, you know the values,

$$P = \frac{631852 - 240000}{187.5}$$

So, can you tell me what is the activation, force you are getting. Are you getting 2089.88 N. You would expect 2089.88 Newton, that is the activation force you would expect at the tip of the shoe, okay. The question is, so far, we are focusing only on the leading shoe aspect. My question, would be what do you expect on the trailing shoe? Do you expect that activation force would be equal, that is one question right or different? And what happen to your M_n, M_f value or they will be different or same, okay that is another question. The third question is, the pressure is given that is the maximum pressure is you would experience between the lining and the drum surface interface right that is there. So, would you expect the same pressure that would occur on the trailing shoe? So, how to proceed, you understand right my question. The three questions, Do you expect the activation force would be same for the trailing and leading? That is one question. The second question is, do you expect the M_n, M_f are same magnitude for both leading and trailing. So, another question, the third question, do you expect the change in the pressure between leading and trailing. The reason why I am saying that as long as for trailing shoe aspect the activation force should be higher, right. $P = (M_n + M_f)/C$, that is what supposed to be so how can we proceed yeah. So, if I want to match that okay because if I want to maintain my activation force for leading and trailing right differently, if in that case right. What parameters do you think will change, which parameter would change, yeah louder. No, they are same, yeah okay. In fact, we do not know what exactly the pressure is acting on the left-hand shoe, trailing shoe we do not know the pressure okay, I will give you information. So, the maximum intensity of pressure for the left shoe is unknown for identical shoes that is what I said. That is why you nicely sayθ_2, no I am giving as an identical shoe. For identical shoe, from M_n, M_f both proportional to the P_{Max} exactly. One of the assumptions is your P_{Max} is variable from the position of the pivot to as you move vertical direction that is what the one of the assumptions means assumption we have taken, okay right.

For the left-hand shoe, the maximum intensity pressure is we will take it as a another P_{Max} right we will take it as a different shoe. For the left side shoe, we will take a maximum pressure is different. The maximum pressure we take it as a P'_{Max} that is what you will say, okay. Therefore, we know that your M'_f, will be proportion to the force, right. Proportion to the what force you are expecting. Already, I know my P_{Max} equal to how much $1\ N/mm^2$, which already given to us. So, based on the proportion of the pressure on the trailing shoe, the corresponding M_f and M_n, would change. So, this is,

$$M'_f = \frac{240000P'_{Max}}{P_{Max}}$$

That is one relationship we got. So straight away M'_f equal to this is one right this is $1\ N/mm^2$. So, you can say $M'_f = 240000P'_{Max}$, that is a one thing we have, equation number one.

Similarly, same for the M_n' also. $M_n' = 631852P_{Max}'$, equation number two okay. So, for left hand shoe, left side shoe or left-hand shoe does not matter, your $P = \frac{M_n' + M_f'}{C}$, this should be okay. Well, let me ask question, I will ask one question. You have seen the video you have seen the video right, so when you press the brake pedal the right due to vacuum due to vacuum and the master cylinder will release the fluid brake fluid. The brake fluid will follow through the brake lining, the brake path then, it will distribute to the front axle rear axle it is okay assuming that. So, we will assuming only at the rear axle at the moment. So, when it goes to rear axle it will go will take the one wheel left side wheel will take it right. So left side will fit it with the drum brake system. So, we said identical shoe so you will have a one cylinder only. When you have one cylinder the braking fluid pressurize the braking fluid will try to move the piston equally right. The piston is a double acting piston so it will equally displace such a way that the activation force should be equal on the leading shoe as well as trailing shoe that should be equal okay. So, when you have equal what happen to your M_n', M_f', that is one thing you need to understand that okay. So, but already I know that, the *P* value what is the P value we got earlier. So, what is the *P* value we got. 2089 yeah, 2089.88 approximately, we can make 2090 N. You do that activation force is given okay. So, activation force already we we have that okay. So, what will be the new P_{Max} that how will you find out now. How will you find out now, right. So, we know *P* value, we know the *C* value then, how can you find out the M_f' or M_n' that is what my question, yeah. I am sorry, yes. Yeah, okay.

So, then I will move on to another aspect. How about the torque activation? What will be the torque activation? Yeah. See please understand, I just want to repeat again your *P* equal to,

$$P = \frac{M_n' + M_f'}{C}$$

This is given. Already, I know what is M_n' here, it is $631852P_{Max}'\ Nmm$. I have just made it as a round value. M_f', what is that value you are getting $240000P_{Max}'\ Nmm$, right. So, already I have substituted this value and I will substitute this value. So, can you bring everything with respect to P_{Max}' right. Can you do that? Can you tell me, what will be P_{Max}' now. What is that value? Excellent! So, you have a $P_{Max}' = 0.45\ N/mm^2$ right. See remember, the activation force should be equal no matter whatsoever that has to be equal right. If you want to make an equal what happened to a pressure, it will change right this is what I wanted to convey right. So, when the pressure is change or basically now if you substitute this value, you will get the value. What is that value here and can I have the value please. Now, you know that 0.45 is given. So, you know what will be your normal moment and the friction moment also. You will find out ok. So, what is the value you are getting, which one yeah. $M_f' = 108000\ Nmm$, right. That is clearly given ok. What about your $M_n' = 284333\ Nmm$, ok.

Now can you see that your M_n', M_f' are different right. Ok. Because you have to satisfy that. One more important thing, the torque we are talking about we need to understand about the torque the activation torque M_t that is also will depends on your proportion of the pressure. Your M_t on the left side is,

$$(M_t)_L = \frac{300000 * P_{Max}'}{P_{Max}}$$

Ok, yeah. So, tell me what is the value you are getting now, $(M_t)_L = 300000 * 0.45$, when you do that, I would expect $135000\ Nmm$, ok.

Maybe, I will rewrite one more time. You have $(M_t)_R = 300000\ Nmm$. $(M_t)_L = 135000\ Nmm$. Now, can you see what happen to your torque now frictional torque. It varies right because of the pressure varies, obviously the torque also varies. So, the question is it asking the total torque absorbing capacity, that means this is for the leading shoe right and this is for trailing shoe. Now, we need to know the entire break leading and trailing right. That is,

$$M_t = 300000 + 135000$$

should be given me $435000\ Nmm$ or else $435\ Nm$. So, this is the total torque acting on the entire absorbing on the brake system ok. Is it clear now? Yeah. So quite obvious you are applying the break through the pedal right, the brake fluid goes through in drum system. Then we have wheel cylinder, so the brake fluid pressurizes the brake, will do activation force equally on the both tips, ok. But we know that the breaking effort will be much better in the leading shoe whereas you need to have more on the trailing shoe, that can be achieved due to the pressure variation right. So, when pressure changes obviously the corresponding momentum of normal, momentum of friction will change, because of the torque also will change. Now do you understand, how the leading and trailing shoe functions right. And also, another is posing, another effect another thing. Instead of having trailing if you have the trailing shoe replaced with the leading shoe then, the breaking effort will be much better more effective. Ok, I think I will stop now so we will continue on tomorrow, thank you.