Transportation Engineering -II
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Lecture - 4
Track Resistances, Hauling Capacity

Dear students, I welcome you all back to the course lecture series of transportation engineering 2. In this lecture series we have already discussed up to previous lecture, the coning of wheels and the permanent wheels. Now in continuation of the permanent wheels today we will be discussing the things about the track resistances and their effect on the hauling capacity of locomotives. In this lecture series the outline of today's lecture will consist of the resistances to traction, the hauling capacity, the tractive force effort of a locomotive and the classification of locomotives. So, we will be starting first now with the resistances to traction.

Now what is traction? Traction can be defined as the source through which the locomotives derive power. In the case of a train as we have, we know that it is a combination of different wagons which are being driven by a single locomotive or at times by the combination of locomotives.

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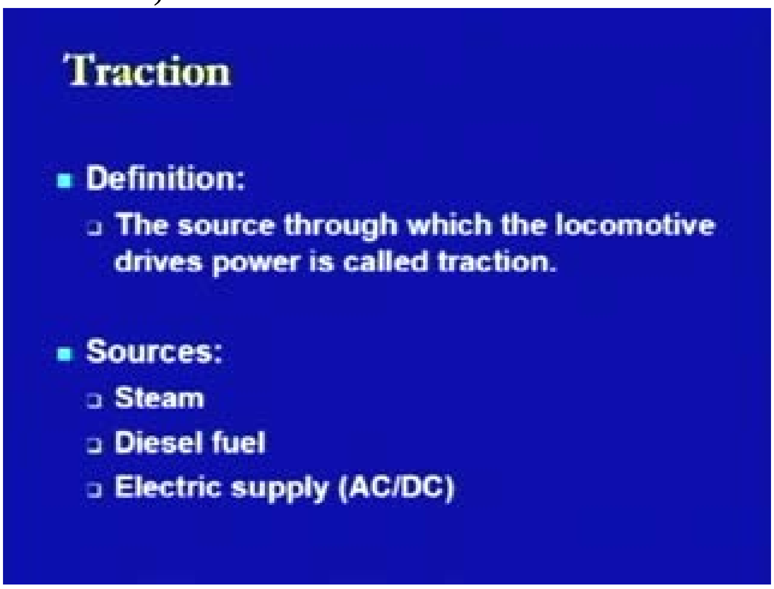

In such conditions the total driving power remains associated with only the locomotives and the rest of the wagons are simply following that driving power.
On the basis of the different sources these driving power may be attained using either the steam or the diesel fuel or the electric supply. In the case of the electric supply we have two types of the supplies which are available and which have been used at different sections throughout the world. There are A C tractions or D C tractions. We will try to look at some of the aspects related to these sources and their comparative conditions which will be there if you use a diesel locomotive or electric locomotive a little later.

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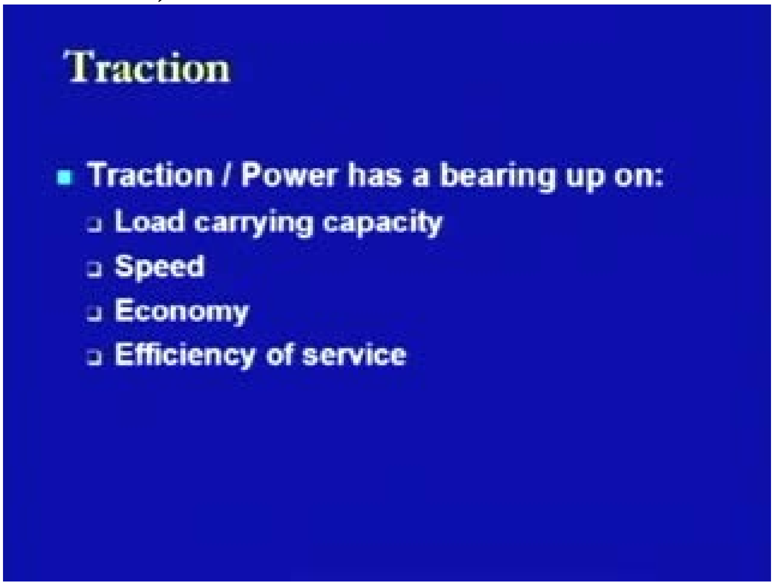

In the case of traction or the power it has a bearing upon certain things. We have to choose what type of traction is to be provided and this is going to be governed by some factors as listed here. The very first factor which defines the total power or the tractive effort which is to be provided for any locomotive is a load carrying capacity. This load carrying capacity is different for the passengers and it is different for the goods. Therefore, we have to look at that what is the total amount of load which is to be carried on the basis of that we have to select any locomotive.

Another aspect related to locomotives is the speed of movement, that is, how much time it is going to take between the two points. This is very important point as far as the commodities are concerned. At times, we have different freight or commodities which are perishable in nature specifically when we talk about the vegetables or such type of commodities. These commodities need to be transported in a shorter period of a time and therefore speed takes significance.

Then the next point which comes into consideration is economy. Economy has to be talked in terms of not only the economy being obtained during the operation or maintenance but it is also to be talked in terms of the economy when we are procuring the locomotives having different power or tractive efforts, we have to transfer a large amount of loads from point A to point B.

Now, in this case if the amount of load is quite heavy, therefore we can go for a combination of locomotives or there is a possibility, then we can install some more power on the same locomotive depending on what is the size of that locomotive.
So therefore, we have to look at what is more economical whether the installation of one more power unit on the same body system is economical or the installation or using of a combination of locomotives is more economical and finally whatever are the conditions we take upon, whether we are talking about a load carrying capacity or we are talking about the speed of transportation or economy, final thing which comes into picture is the total efficiency which can be obtained out of that power. So, this is the most important thing because all the things need to be rooted again and again

between the different points, that is, horizons and destinations. So, we have to achieve efficiency in that case.

Now, as I have told you, we have different sources of tractions as being defined by steam, diesel or electric. Now-a-days we are more dependent on diesel locomotives or electric locomotives. Slowly and slowly, more and more sections of the railways have been converted into electrified tracks. Therefore, now we are trying to look at the certain points with which we can compare the diesel tractions or the electric tractions.

In the case of these tractions a very first point is the source of energy. In the case of the diesel locomotive as we know the source of the energy comes from the diesel oil which is being used for the carrying of that locomotive whereas in the case of electric locomotive there is no such source of energy as of fuel. It is in terms of the electricity which is being driven or generated at some other point of place maybe on the basis of certain other fuels or by conventional, unconventional methods.

The next point is regarding the engine. In the case of engine we can look at two aspects; one is in the design and another is the weight. In the case of the design of the locomotive for the diesel engine it is a little complex as compared to the stream engines but when we go to the electric locomotives they are more complex as compared to the diesel engines. As far as the weight is concerned, weight is going to be defined by the type of the locomotive being constructed with a specific purpose that is whether that locomotive is going to take a load of passengers or freight or it is going to take the load in a mixed condition or whether it is being designed to take heavy loads or light loads or the standard loads. So that is another aspect related to the engines. So, therefore the weights can be different in that section. Of course, in one of the comparisons where we will looking at different types of the locomotives we will look at the different axle weights which can be there depending on the type of the locomotive.

So another aspect of comparison is the overload capacity. This overload capacity is defined as the total capacity by which it can carry the certain more loads over it. In the case of the diesel engines this capacity is quite less as compared to the electrified engines.

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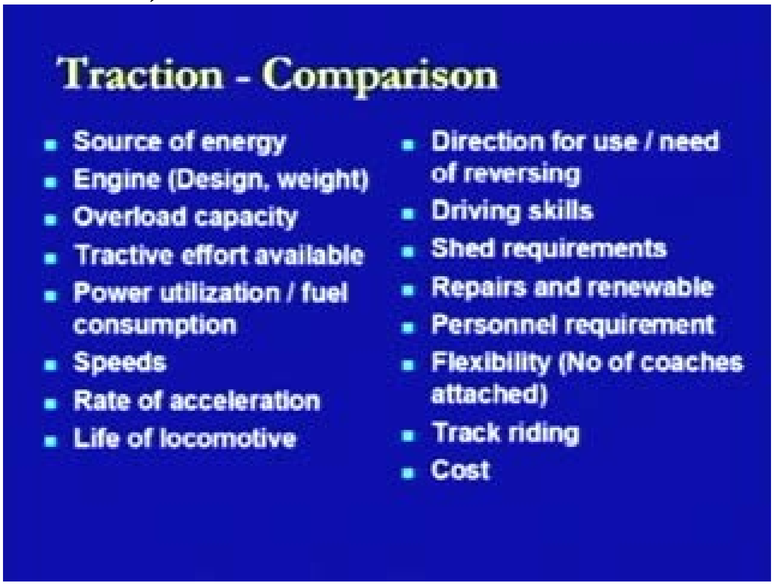

It is somewhere around ten percent in the case of diesel engines whereas in the case of electrified engines it is around 50 percent more. The tractive effort available, now this tractive effort is available through the different engines and they are transferred into the mechanical engine power so as to move the vehicle, so that in the case of tractive effort which is available based on the diesel or electrified engines.

Then, the power utilization or the fuel consumption, as far as the fuel is concerned, in this fuel consumption is not there in the case of the electrified locomotives directly but it is there in the form indirectly because some fuel is being consumed at a point or at a place from where the electricity is being generated. In the case of the diesel engines there is the fuel consumption directly on the locomotive. As far as the power utilization is concerned, this power utilization is there in terms of the total weight or the tractive power. The ratio of these two things can be taken together and in that sense we can define the total amount of power which is being utilized in both types of the locomotives. In the case of electrified locomotive, it is little better as compared to the diesel locomotive.

Then speeds are there, the speeds of the case of the diesel locomotives are high but in the case of electrified locomotives they are very high. The rate of acceleration again it is related with the speeds and therefore and the rate of acceleration is better in the case of electrified locomotives as compared to the diesel locomotives. The life of locomotives in the case of diesel locomotives, the life is somewhere up to around 30 years whereas in the case electrified locomotives it is more than 30 years.

Another aspect which was a difficult condition in the case of the steam engines was to direction of use or the need of reversing the vehicle or the locomotive when it is to be used in the other direction but in the case of the diesel and the electrified locomotives, now this requirement is not there and the vehicle or the locomotive can be used in both the directions.

As far as the driving skills are concerned the things have become little more simpler now and there is no such specific driving skill required as far as the driving of diesel locomotive or electric locomotive is concerned. The shed requirements, in the case of the shed requirement this is mostly related to the maintenance aspects. In the case of diesel locomotives, the maintenance required is something around 20 or 21 hours per month whereas in the case of the electric locomotives it is only 4 hours per month.

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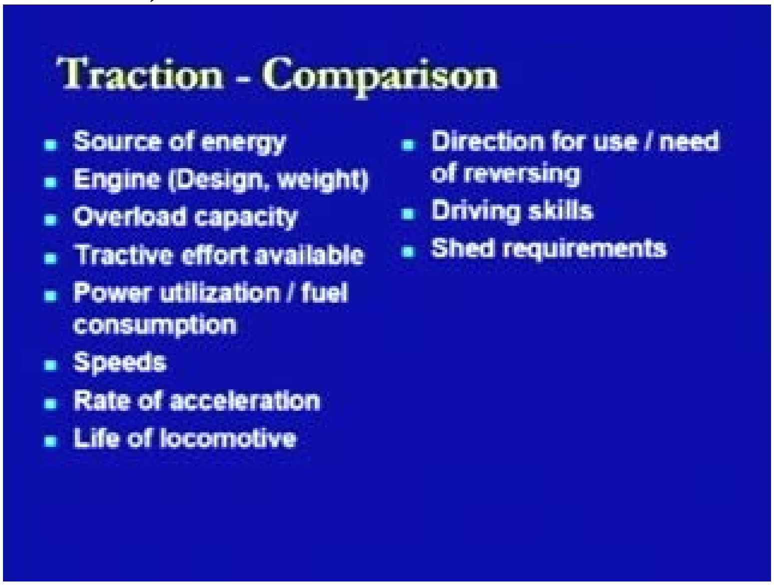

If we compare the same thing with respect to the steam locomotives which have been used previously it was 70 hours per month. So, that is how the business of the shed or the total requirement of the shed is much different in the cases and it is little simpler in the case of electrified tracks.

The repairs and renewals are quite easier in both the cases. The personnel requirements, there are very less personnel who are required in both the cases. Mostly they are talked in terms of the movement of the vehicle, that is, the number of drivers who will be required for driving of those locomotives and they are mostly a single driver can drive those locomotive. The flexibility here is being defined in terms of the number of coaches which can be attached to the same locomotive. Today, we are running 18 to 24 coaches with one locomotive. If there is an emergency and there is a need of incorporating some more quantities between two points, that is, the origin and destination, that flexibility is there in the case more in the case of electrified locomotives as compared to the diesel locomotives. This is because of the condition that there is a possibility of installing some more powerful unit on the same locomotive as compared to the diesel locomotive where another locomotive is to be used if more coaches as been attached. The track riding in both the cases is quite smooth and safe.

Cost- cost is a little higher in the case of the electric locomotives as compared to the diesel locomotive or something of around 20 to 25 percent more. The working hours per day, they are something around 20 or 21 hours per day and that is more or less common in both the cases. The monthly kilometers are also more or less similar. It varies from 9000 to 10000 kilometers in a month for which they can be used.

Pollutions and hazards- as far as fire is concerned, there is no such problem in both the cases but there is a little smoke which comes out in the diesel engine as compared to the electrified engines. The availability for services is another aspect though mostly both the locomotives are available readily for use, but in the case of the diesel locomotive it has to be kept in a readied condition, that is, the engines have to be switched on so that they remain warm and they can be used readily but this type of problem is not there in the case of electric locomotives.

Then suitability, as far as suitability is concerned, that is, we can talk about the suitability to the adding the different type of the traffic; the bus traffic or the mix traffic or the passenger traffic. We can talk about the comparisons with respect to the fuel or the speeds or the different types of the operations and more or less it has been observed that both the type of locomotives can be used for the varied conditions. Therefore, as far as the suitability is concerned there is no problem as such.

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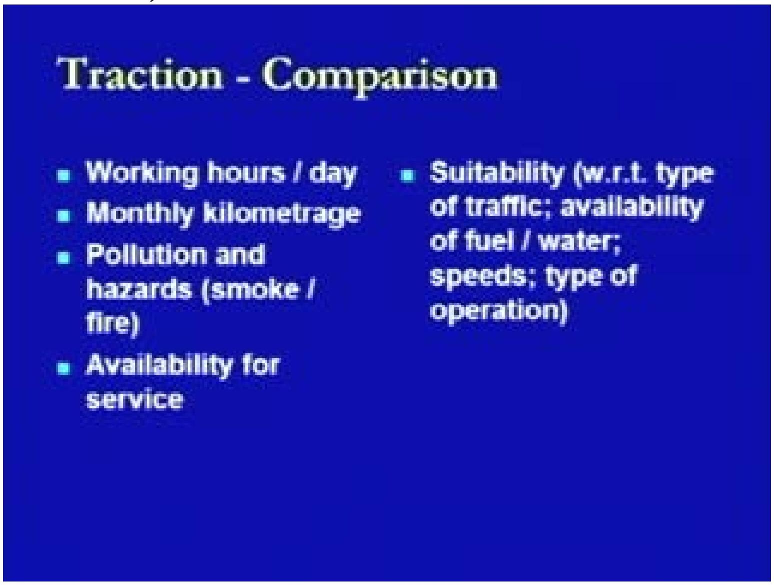

The thermal efficiency, in the case of diesel locomotives this thermal efficiency is something around 25 to 30 percent but in the case of electric locomotives the thermal efficiency can be attained up to as high as 90 percent. So, that is another big change over in the case of the thermal efficiency between the two types of the locomotives.

The adhesion or the slipping of the locomotives on the tracks, that is, if this sort of a interaction between the wheels and the track being laid down and the values remain more or less similar depending on the type of the electric or the hydraulic traction which is being provided and it varies between point 22 and point 33.

Now with this aspect in to mind, that is, the different types of conditions for which the electric or the diesel locomotives can be used, we have some information regarding what are the type of things which can happen ,which can create a problem for the traction. Now, here in this chart we are trying to look at the different types of resistances which are offered to the locomotive and which need to be taken care of while trying to find out the total tractive power of any locomotive. When you look at this one, what we found is that the resistances can be divided into the four categories as such. The resistances due to rolling stock, the resistances due to the track profile, the resistances due to the tractive effort and the resistances due to certain climatic or atmospheric condition specifically the wind.

Under the rolling stock condition again there is a further classification of the different resistances which are offered and these are either speed dependent or independent of the speed or atmospheric other than the condition which is being taken care of in the atmospheric conditions taken at the previous level.

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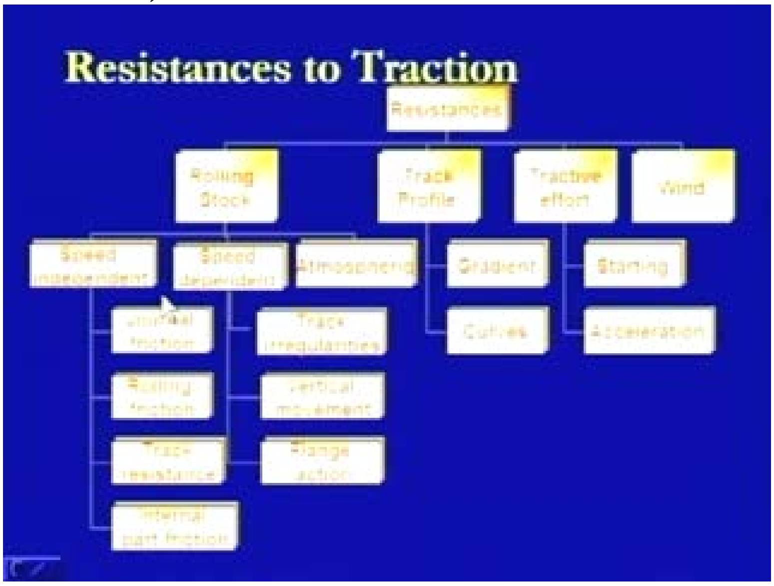

Similarly, in the case of the track profile, the various resistances can be there because of the physical features of the track and they are the gradients and the curves. In terms of the tractive effort, these are related to the starting of the locomotive and providing the acceleration to the locomotive.

Further, there are divisions within the speed independent or the speed dependent resistances and we will be trying to look at the different resistances in the case of a speed independent case that is journal friction, rolling friction, track resistance and internal part friction. In the case of the speed dependent we will be looking at track irregularities, vertical movements of the wheels and the flange action that is it is oscillations with respect to the lateral direction. So, we will be starting with the different types of these resistances. We will try to find out the equations or the values by which we can compute them and finally we can find out the tractive effort.

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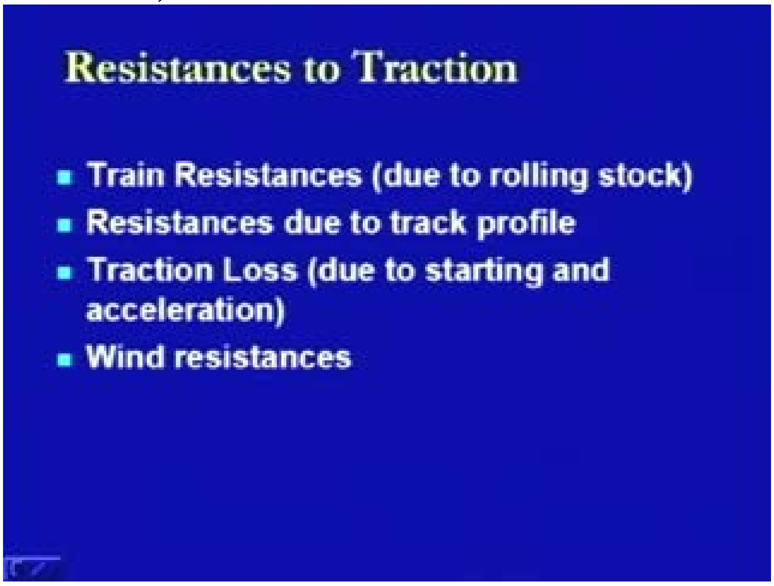

So, we come to the resistances to traction. In the case of resistances to traction as been shown in the previous slide or chart, what we have found out is that they are the train resistances which are due to the rolling stock, they are resistances due to track profile, the tractive losses which are caused due to the starting of the locomotive or the acceleration of the locomotive and the wind resistances.

Now, we will be starting with the first type of a resistance, that is, a resistance being caused due to the rolling stock which is also termed as the train resistance. In the case of train resistance as been defined previously there are three types of cases; the resistances which are independent of the speed, the resistances which are dependent on the speed and the atmospheric resistances. So we will be looking at all these types of resistances one by one.

The first one is the resistance independent of speed. There are different causes which creates this resistance. One because is the friction, the friction which is being imposed due to the different components of the train. Here we are not looking at the friction which is being imposed between the interactions of the wheel with the rail section because that is going to be governed with the speed, there is a movement associated with it. In this case, the frictions which we are looking at, they are the frictions because of the locomotive parts of the wagons or the compartments and these frictions are known as journal frictions.

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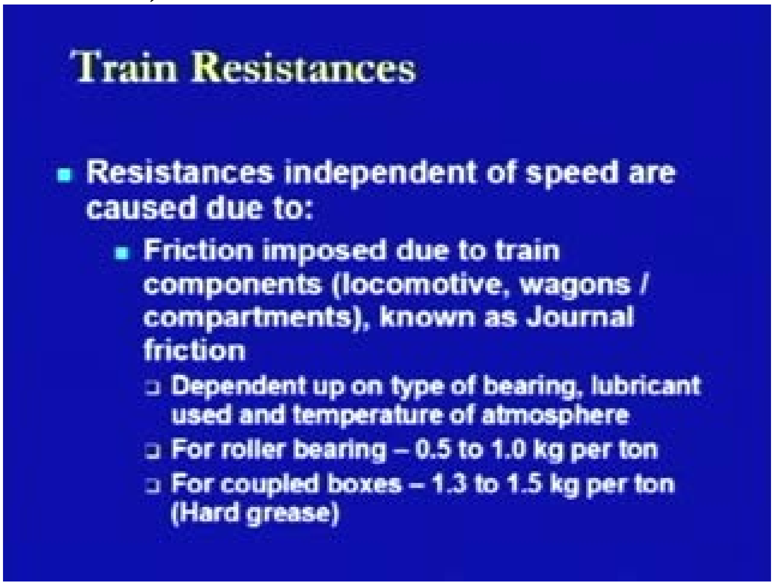

These are dependent onto different types of the bearings being used, the lubricants used and the temperature of the atmosphere. This temperature has a bearing on this lubricant or the types of the bearings being choose and if there is a high temperature then obviously the friction is going to be low. In this case we have two cases being defined here and the one case that we are using is the roller bearings, then in that case the friction is taken as point 5 to 1 kg per ton, whereas in the case of the coupled boxes conditions where the hard grease is being used, in that case it is being taken as 1.3 to 1.5 kg per ton. Then there are certain other things which are happening. Here, we are talking about some friction which is the steel wheels and the steel rail friction.

There is a track resistance which is causing, coming up in terms of the wave action of the rails. This wave action of the rail is being caused because of the transfer of the load from the top to the bottom through wheels. Whatever load comes at any of the wheel, this is transferred to the rail. Now when this is transferred to the rail then there is going to be a certain depression at that point. Now, this is a depression with respect to the previous or the forward condition and this is what is a sort of a wave which is created. As soon as there is a movement, this wave will start moving with the vehicle, that is, the locomotive or the wagons. We will be looking at this wave action of the waves when we take up the creeps. There we will be having a little more discussion on this section. Another resistance which is coming, which falls under independent of the speed condition is the resistance due to the internal part ,that is, the cylinder and rim of the driving wheels and similar type of conditions.

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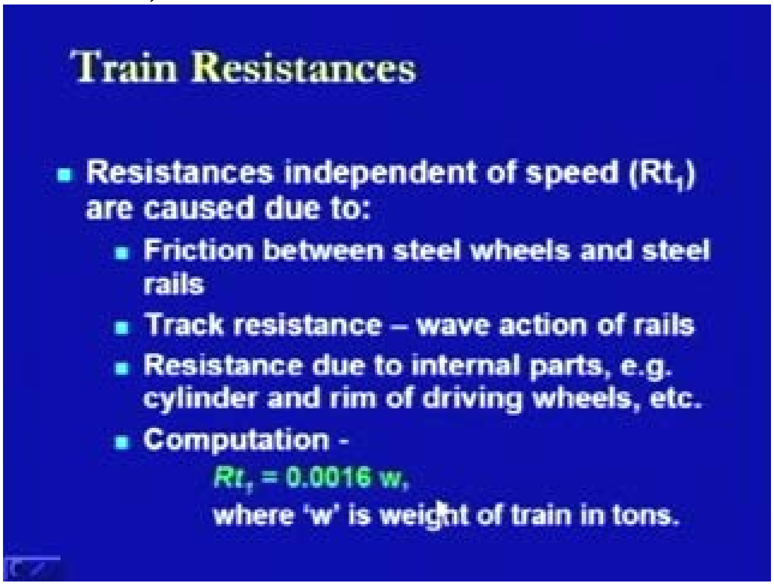

On all the basis of whatever types of the reasons are there which causes the this type of resistance the computed value of this resistance which is defined as a Rt 1 here is given as point 0016 w, where w is the weight of the train in tons. So, this is how all the efforts have been taken into consideration and finally this equation has been found out.

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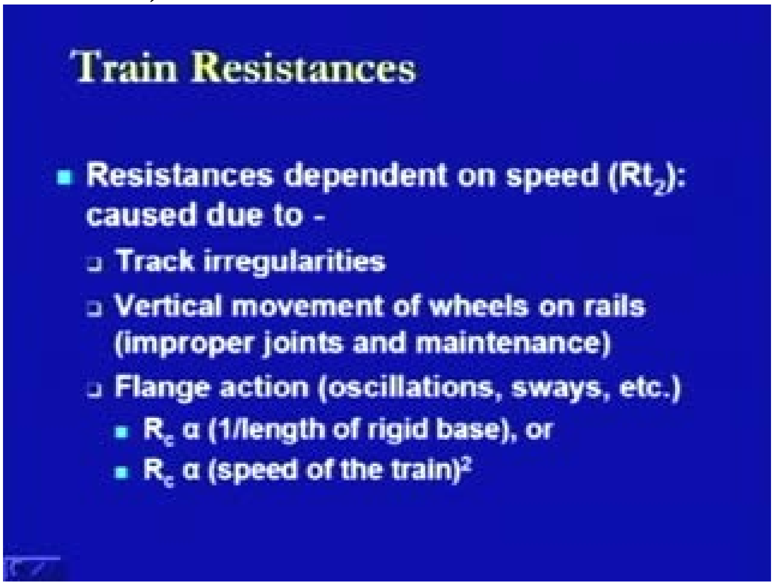

Now, another case of resistances is the dependent on its speed. They are also the part of the rolling stock resistances. Here we talk about the track irregularities, then the effect of the track irregularities as soon as the speed of the vehicle increases. As far as the vehicle is standing there is no problem, as far as the track of irregularities are concerned but when there is a movement then these track of irregularities creates certain sort of resistances to the movement and therefore we have to look at these track irregularities. As far as the passenger movement is concerned we assume these track irregularities in terms of the discomfort being caused to the passenger or the riding effort which will be there in that case.

Now another condition which is happening is the vertical movement of the wheels. Now this vertical movement of the wheels is a phenomenon which is causing due to the track irregularities only and these track irregularities here are related with the maintenance aspects, like if we talk about the joint. The joint of the rail at that point, both the rail should be at same level. If they are not at the same level, then if there is any movement of the wheel from one rail to the another rail and the second rail is at a higher level there is going to be a vertical movement at that point and this is termed as jerk. So, this is a proper technological word which is used for us to have this movement.

Another aspect is related to flanges. As we have discussed previously while we talked about the coning of the wheels there is some distance between the flange and the head of the rail because of this distance the flanges or the access have the flexibility of moving in the lateral direction and that is what is termed as the oscillation or the sway.

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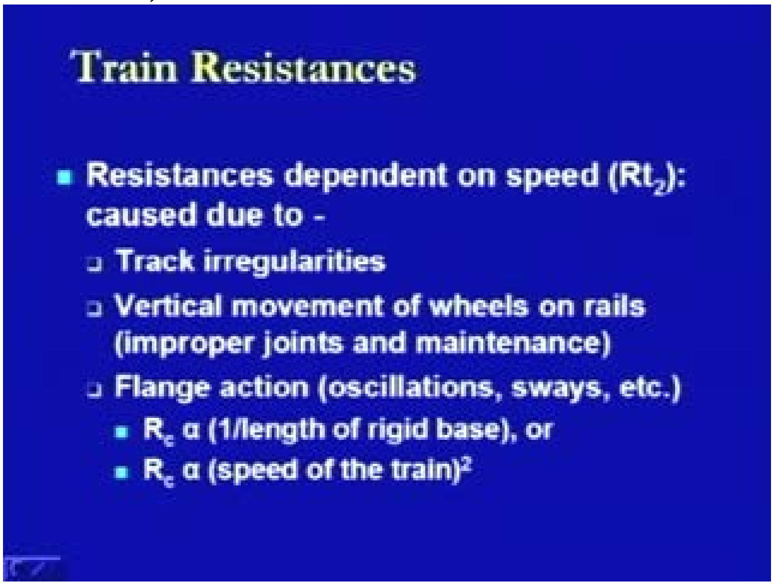

And this oscillation or the sway and the resistance being offered due to the section is inversely proportional to the length of the rigid base or it is proportional to the square of the speed of the train. So, what we can find out that if the speed of the train is very high then this type of action may create derailments or overturning of the vehicles, if not taken properly contained with. Now this value of resistance which is dependent on speed is taken as Rt 2 and this Rt 2 is given by

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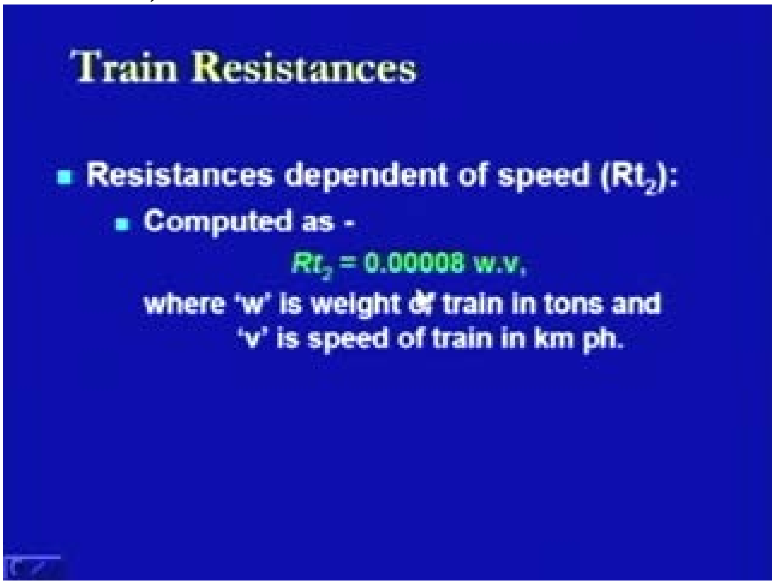

point 00008 w into v, where w is the weight of the train in tons and here what we found is from the previous formula now we are incorporating this vector v which is the speed of the train and that is how this is dependent on the speed.

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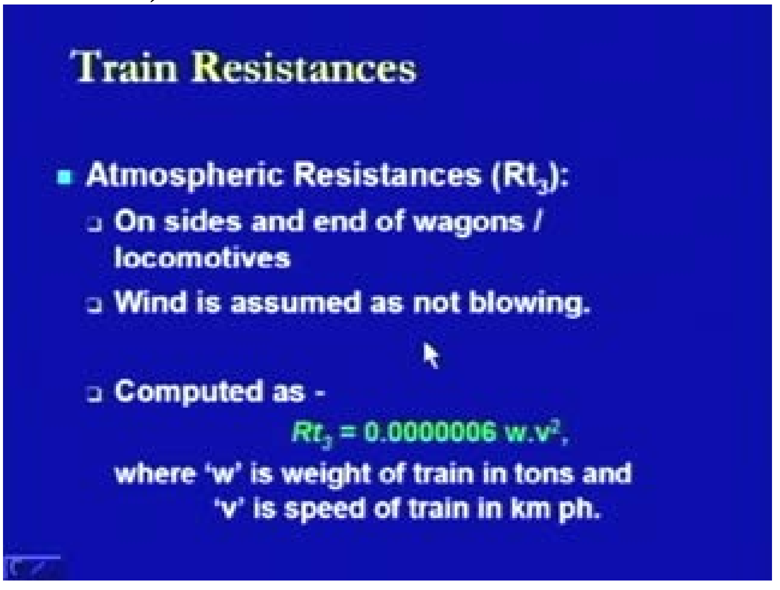

The other case is the atmospheric resistance now how this resistance atmospheric resistance is going to be different and the wind resistance has been taken in the first level of the categorization of different resistance is that here we are assuming that the wind is not blowing. Now, when the wind is not blowing therefore there is no relative motion of the vehicle with respect to the wind. So, whatever is the total weight of the air, it is going to create some effect on the movement on the train and therefore this is to be taken into consideration and this effect is going to be there on the sides of the wagons or the locomotives or at the ends of the wagons or the locomotives and this value is computed as point 0000006 w into square of v, that is, the speed of the train in kilometers per hour. So once we have all these three values then the total train resistance due to the rolling stock will be nothing but it is a combination of all the three values that is Rt 1 plus Rt 2 plus Rt 3 and in that case it will be given by this equation point 0016 w plus point 00008 w into v plus point 0000006 w into v square. Now, we come to the resistances which are offered due to the track profile. As we have seen these resistances are because of the physical features of any track

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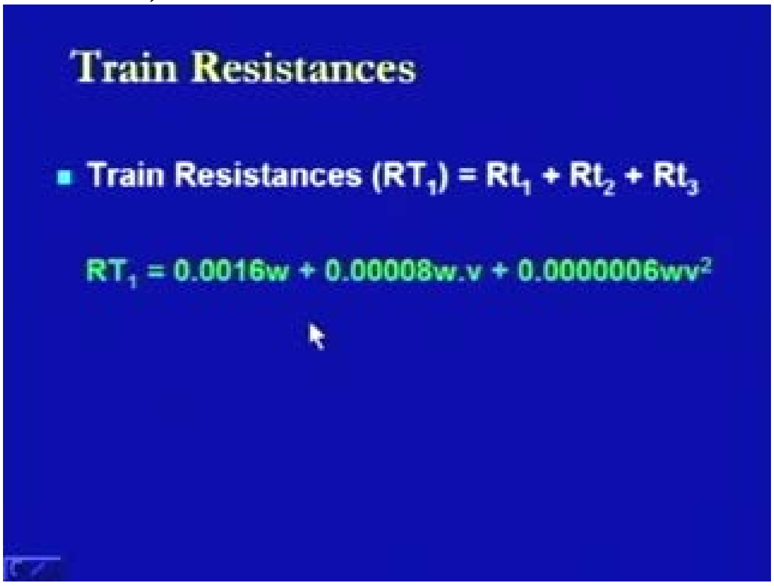

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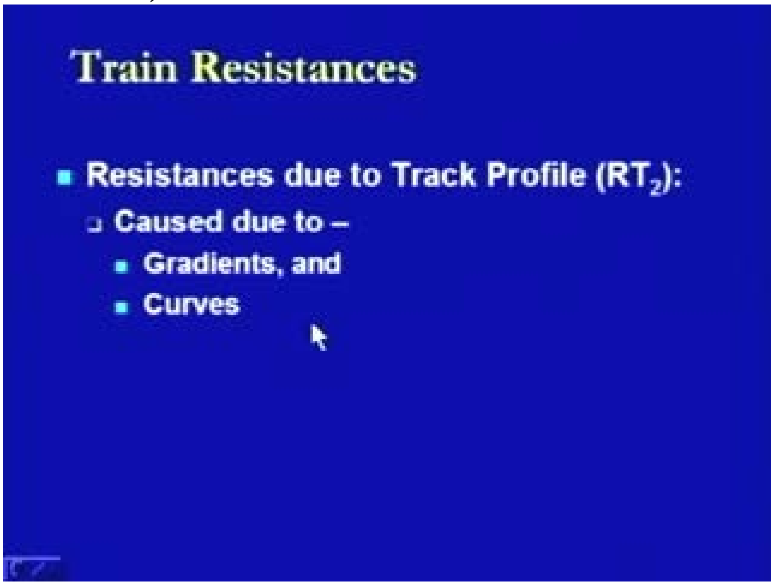

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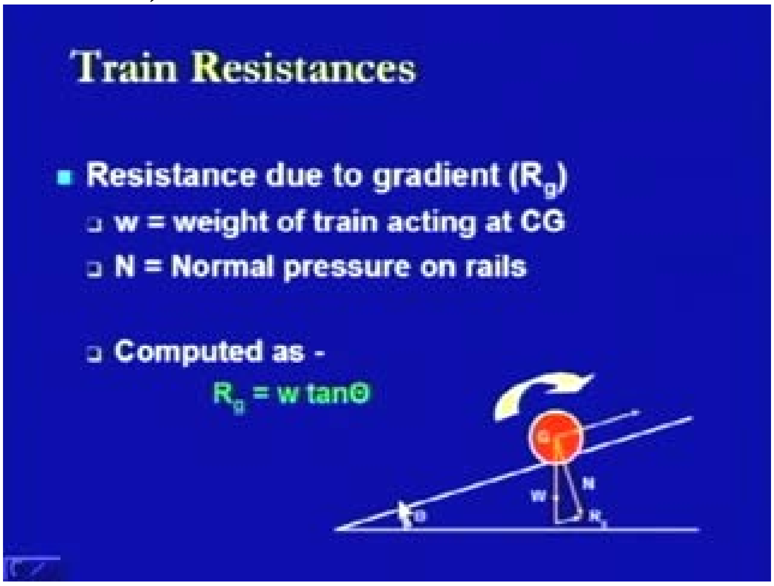

and the two main physical features of any track are the gradients and the curves.
So, we will be looking at these two conditions. Here the first condition is being defined that is for the gradients. What is being shown here is a wheel which is moving on some gradient which is defined by this angle theta. There is a movement in this direction towards the right hand side. The weight of this wheel is working vertically downwards. There is a normal component which is working perpendicular to the level of the rails, that is defined by N and then there is a resistance being offered in this case which is defined by Rg which is being shown in the vector notation here, g is the C G of this wheel through which this weight is acting.

In this case, there is resistance to the gradient is computed as nothing but w multiplied with tangent of this angle theta, that is, angle of inclination. Here the assumption is being made that this angle theta is quite small and therefore the values can be taken as sine theta is equal to tan theta whereas in this equation, in this form of a triangle where we are looking at this 'w' and N Rg, we have this angle as theta and therefore Rg can be defined as, this is 90 degree and therefore Rg can be defined as w tan theta in this case. So, this is how we can compute the value of the resistance which is offered by the gradient.

There is another case where the resistance is being offered by the curves. In the previous case when we were discussing about the coning of the wheels, what we have seen is that there is a requirement of the higher movement on the outer side of the curve as compared to the inner side of the curve and that is how the vehicle can remain in the equilibrium condition. In that case, in that sense what we found is there are certain factors which control this type of phenomena, is the rigidity of the wheel base.

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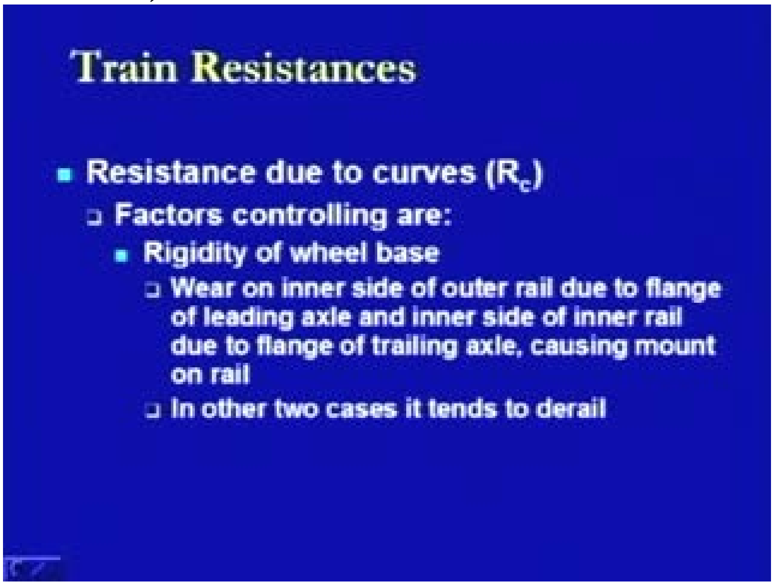

In the case of the rigidity of the wheel base because the two axles have been added to that one, what happens is that there is not a circular movement in this case. It remains a linear sort of a movement and when there is a linear sort of a movement there will be a differential movement of the axis in the outward or the inner side depending on the front or the rear axle condition which are combined to the rigid wheel base, and therefore what happens is that there is more wear on the inner side of the outer rail due to flange of leading axle, and similarly there is more wear on the inner side of the inner rail due to flange of the trailing axle, and some of the cases if there is more of the centrifugal force and the centrifugal force is not been counter acted clearly, then in that case what may happen is that there may be a mounting of on the rails of those wheels.

Similarly, if we talk about the other two conditions, that is, outer side of the outer rail and we talk about the outer side of inner rail in this case, then there are chances that it may tend to the derailment of the rails or trains. So, we have to take care of the mounting or the derailment of the rails in this case.

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Further, in the same case there are some more factors which can create any factors in terms of the slippage of the wheel and this slippage of the wheel may be there because of the longitudinal movement of the train or because of the oscillations or sways in the lateral direction, that is, the transverse direction. There is insufficient super elevation or extra super elevation being provided in both of the cases it is going to be harmful for the movement of the train. It may create depending on the type of the condition either on the inner rail or the outer rail more pressure will be created, and the next point here is that the maintenance aspect. What is the level of maintenance of the track or its components? If it is poor, then obviously the resistances will be offered by that also.

Here we are looking at this diagram, where in this diagram we are trying to check out with the right hand curve.

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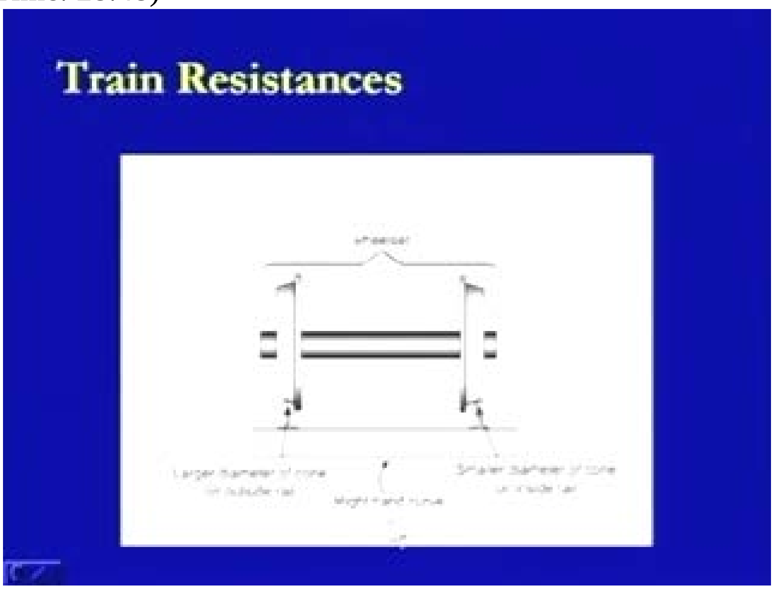

Now, when there is right hand curves like this, in that case there will be a centrifugal force which will be acting in the lateral direction towards left hand side. When there is a centrifugal force which is acting in this direction then what will happen is that this axle will move in this direction laterally and because the wings have been coned, now there will be a larger diameter at this side and there will be a smaller diameter on this side. Of course, it is going to create a help as far as the movement is concerned because we require a larger movement on the outer side of the wheel as compared to outer side of the curve as compared to inner side of the curve. So, because of this larger diameter this circumstantial movement will also be moved, whereas in this case of this lower diameter the circumstantial movement will be lower and that is how this differential value will come into picture, and we are going to use this differential values as to find out the resistance in the case of the curves.

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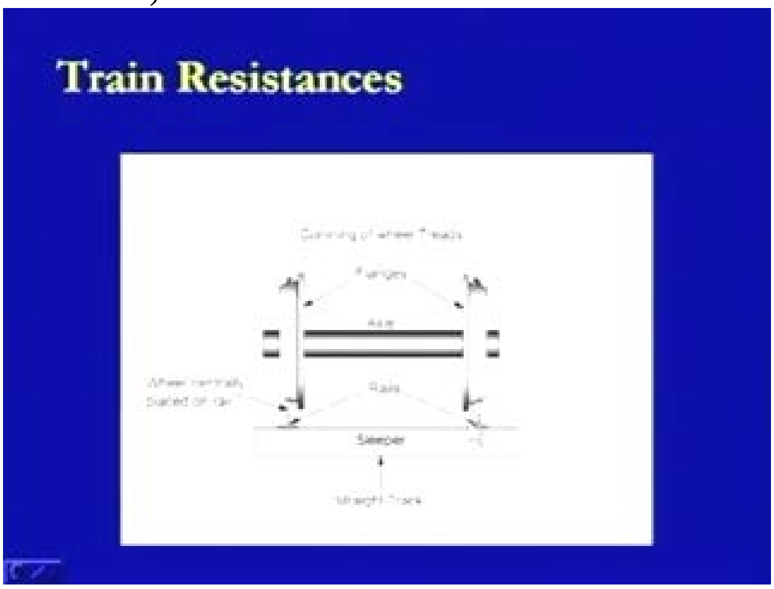

Here, in this diagram, we are looking at a straight track condition where this axle is being placed along with these wheels in the equilibrium condition on these rail systems. Here, what we see is that in these both the cases the average diameter is coming on the rails and when the average diameter is coming on the rails it means the total distance travelled by the outer wheel or the inner wheel is same because this is related to the circumstantial movement that is pi into d. So, that is why the distance moved by this wheel as well as by this wheel is going to be the same if we are talking about a straight track and this type of differentiation between the straight track and the curve track is going to be used for computation of the resistance.

The same thing here is being depicted in form of the movements or the distances which needs to be covered here.

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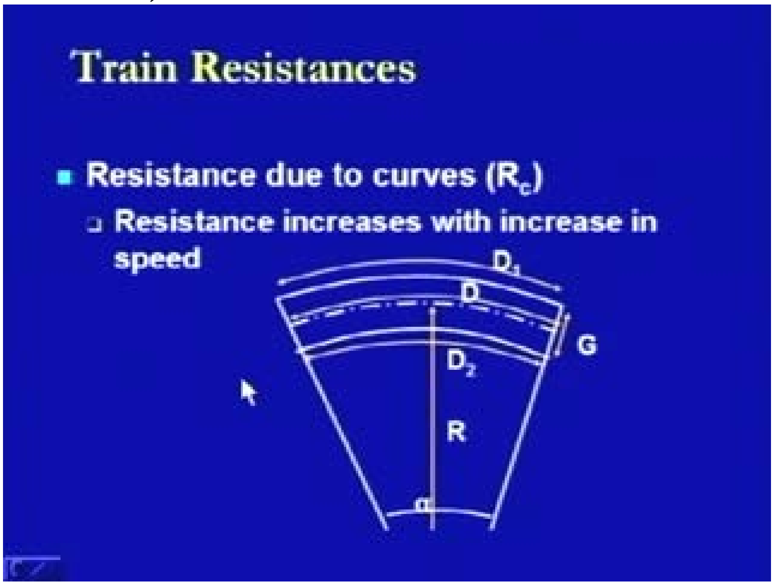

Here, this is a curve which is being shown in this direction. There is, this is outer rail and this is the inner rail. This is an angle alpha of this curve and radius R, that is, the radius R corresponds to the central point of this curve and it is being at any gauge G. Now here if you look at the distance which needs to be moved in the case of the average condition, that is, related to the radius R what we found is the distance moved here is defined as D but if we go towards the outer side, that is, we are moving to a distance R plus G by two, that is G is the gauge and that is why this distance will become G by 2. So, if we have moved the distance of R plus G by 2 that is coming to this point then we are moving a distance here as D 1 whereas if we come to the inner side of this curve, that is, we are moving to a distance R minus G by 2, then we are moving a distance equals to D2. From this pictorial diagram itself we can easily see that this distance moved D2 is going to be smaller than the distance which is moved at D1 and this is what is to be taken into consideration as a curve resistance being offered by this curve and this resistance increases with the increase in the speed. So, therefore on the basis of what we discussed previously what we found is that

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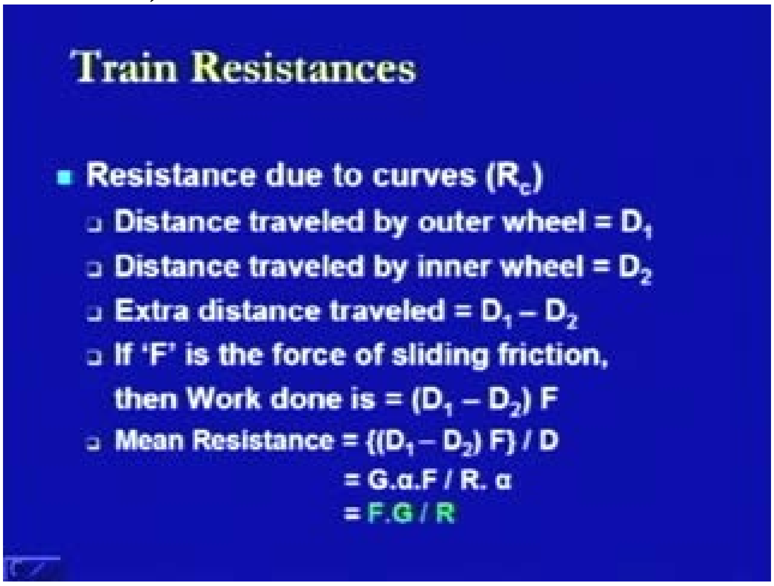

if we are having the force F which is the force of the sliding friction, then the work done can be given here as the difference between the movement on the outer rail and inner rail multiplied with this force of the sliding friction and the mean resistance in that case will be nothing but it will be defined as D1 minus D2 multiplied with F divided by the average diameter D and if we convert this diameters with respect to the angle and the grade and this gauge which is used, what we found as a final value as F multiplied with G divided by R. So, this mean resistance F divided by G divided by R, it says that the resistance gets affected by the force of the sliding friction, the gauge of the track and degree of curvature.

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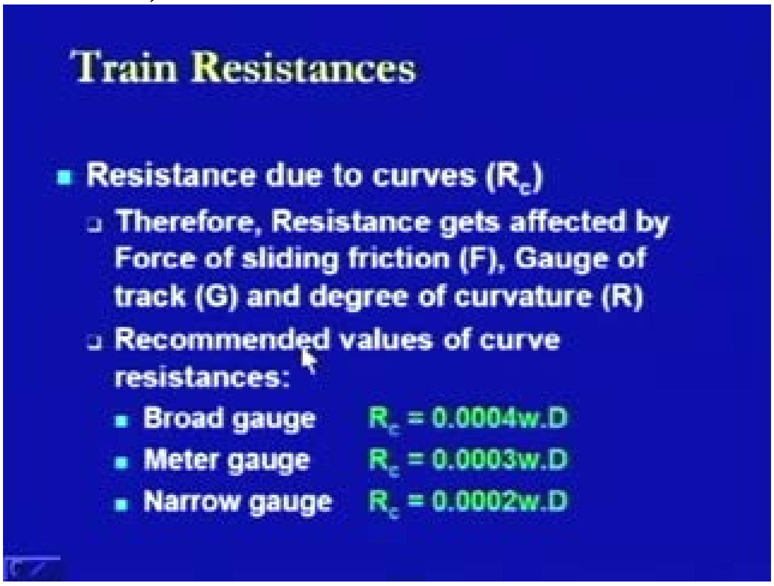

On the basis of the different competitions then the recommended values of the curve resistances have been given as such for the different gauges. For the board gauge, this value is 0.0004w into D, where D is the degree of the curve and w is the weight of the train. Similarly, in the case of meter gauge this factor changes from 4 to 3 and here in the narrow gauge this factor is changing from 3 to 2. Now, we are coming to another condition that the resistances being offered by the tractive effort.

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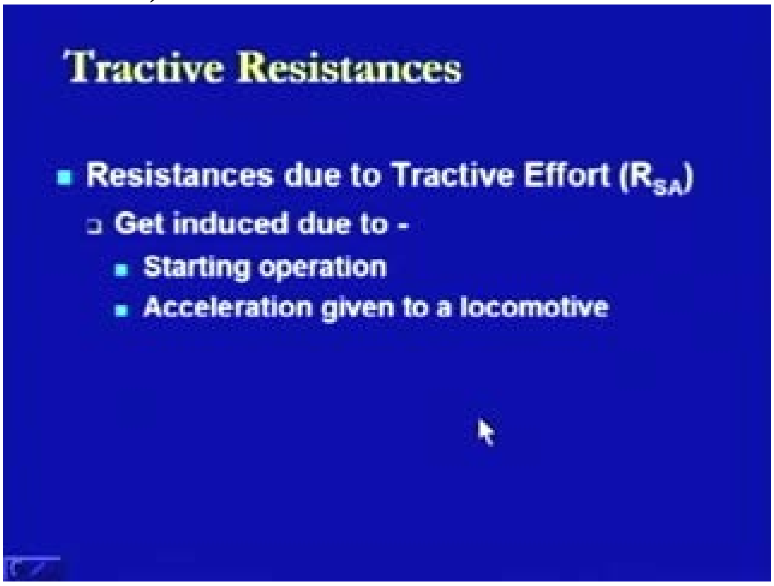

Here we will be looking at two conditions; one is because of the starting and other is because of the acceleration. In the case of the starting, the value is being defined for locomotives and for the vehicles, that is, the wagons differently and this is defined as point 15 w1 where w1 is the weight of the locomotive and in the case of the wagons or the vehicles it is defined as point 005 w2 where w2 is the weight of the vehicles.

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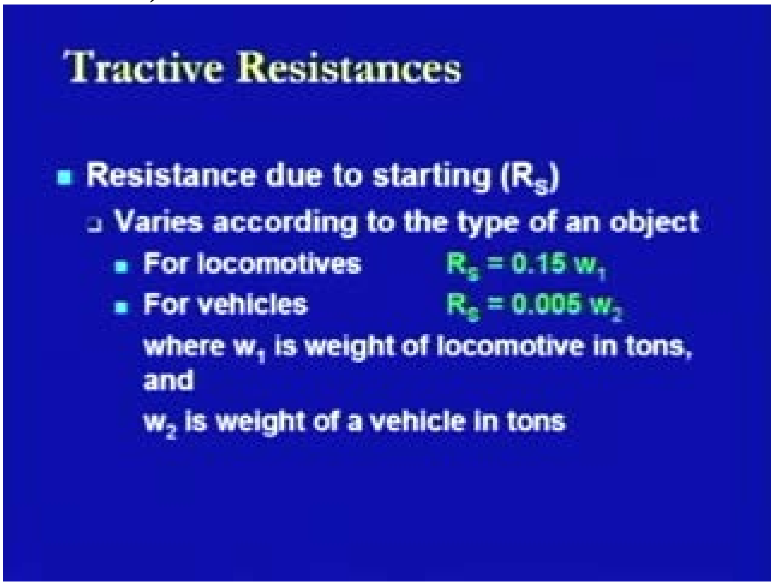

This is related to the starting, that is, the initial efforts which will be there. In the case of the acceleration, it is with respect to the change in speed ,that is, from v1 to v2 within a timeframe of time t. In that case this resistance is defined as point 028w into v 2 minus v1 divided by t.

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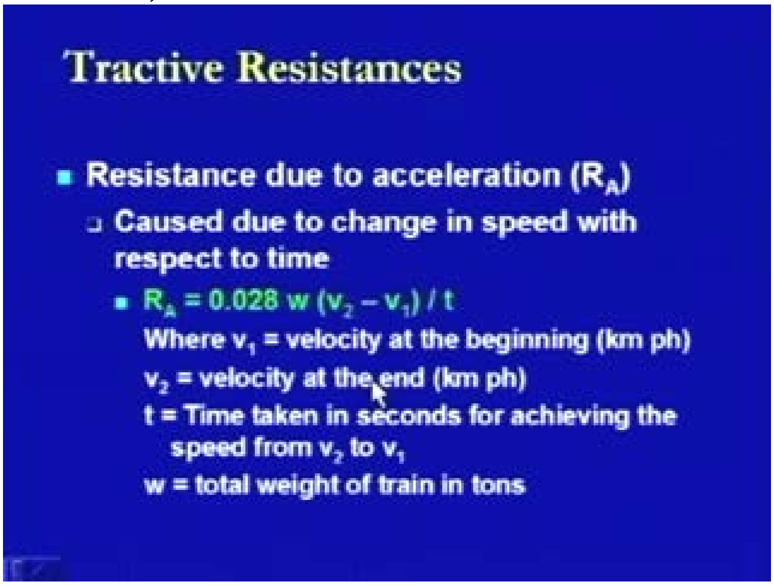

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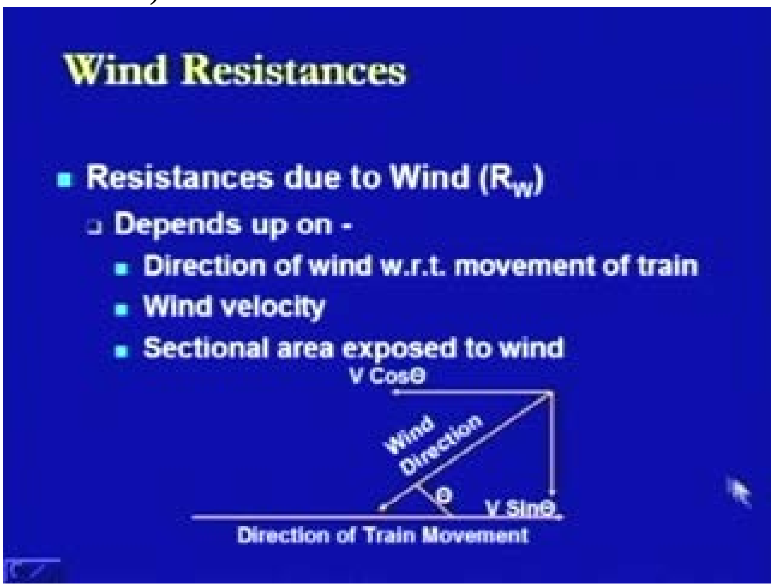

Now, there is another case of the wind resistance. In the case of the wind resistance it is going to be defined by certain factors like what is the wind velocity, what is the direction of the wind and what type of movement of the train is there with respect to that.

In that sense, what we can find out here is that if the train is moving like this and there is a wind which is coming in this direction at an angle of theta with the movement of the train, then in that case there will be two components; one is V cos theta, another is V sine theta. The V cos theta is going to be directly creating an effect as a resistance from the longitudinal direction in the opposite direction of the movement of the train and V sine theta is a push which comes from the transverse direction on the vehicle and this resistance here is defined as point 000017 A multiplied with square of V, where A is the exposed area of the vehicle in square meters and V is the speed or the velocity of wind in kilometers per hour. Just remember that this velocity is not the velocity of the train in kilometers per hour.

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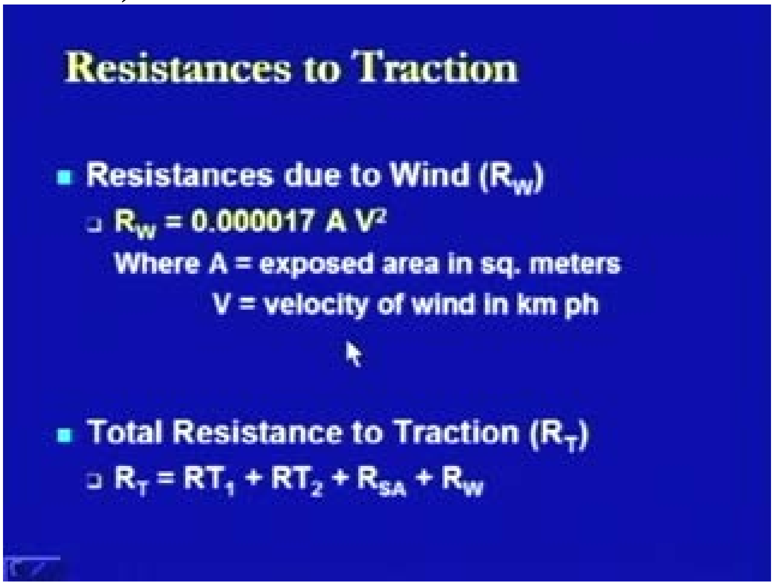

Therefore, the total resistance to traction will be defined as nothing but the combinations of all the resistances which we have seen so far ,that is, RT1, RT 2, RSA ,that is, starting an acceleration and RW, that is the wind effect.

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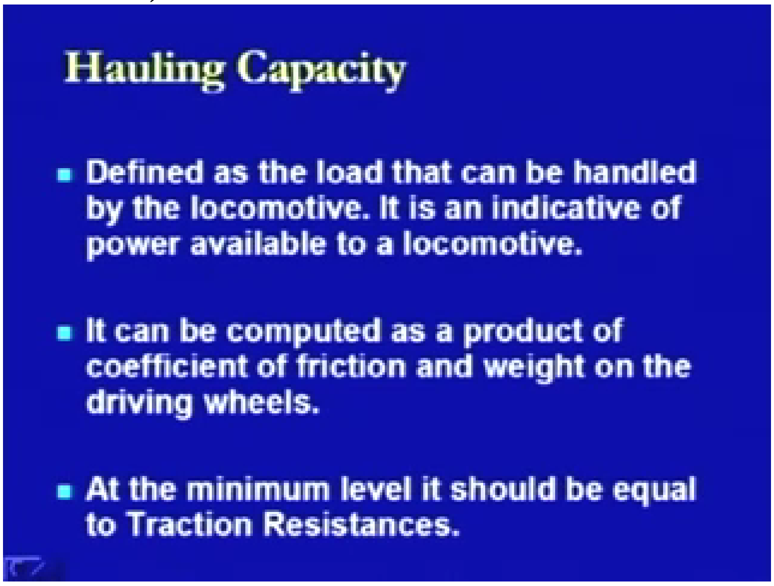

Now, once we have the idea of the different resistances which are being caused, the another aspect here is on the basis of these resistances we can find out the hauling capacity and this hauling capacity is defined as the load that can be handled by the locomotive. It is an indicative of the power which is available to the locomotives and this can be computed as a product of the coefficient of friction and the weight on the driving wheels. Another thing is at the minimum level; it has to be equal to the tractive resistances which have been offered to the movement, that is, what we have seen previously as RT 1 plus RT 2 plus RSA plus RW.

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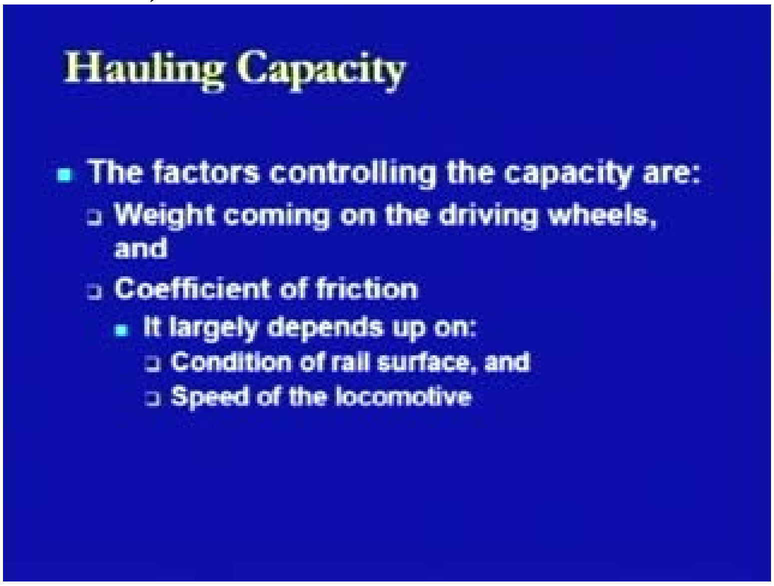

The factors which are controlling the capacity are the weight which is coming on the driving wheels and the coefficient of friction. Now, this coefficient of friction is going to be governed by the movement of the train and the interaction of the wheels with the flanges with the rail. So, there are two things which are there; one is the condition of the rail surface another is the speed of the locomotive. On the basis of this or on the basis of different conditions, certain values of the coefficient of frictions have been suggested.

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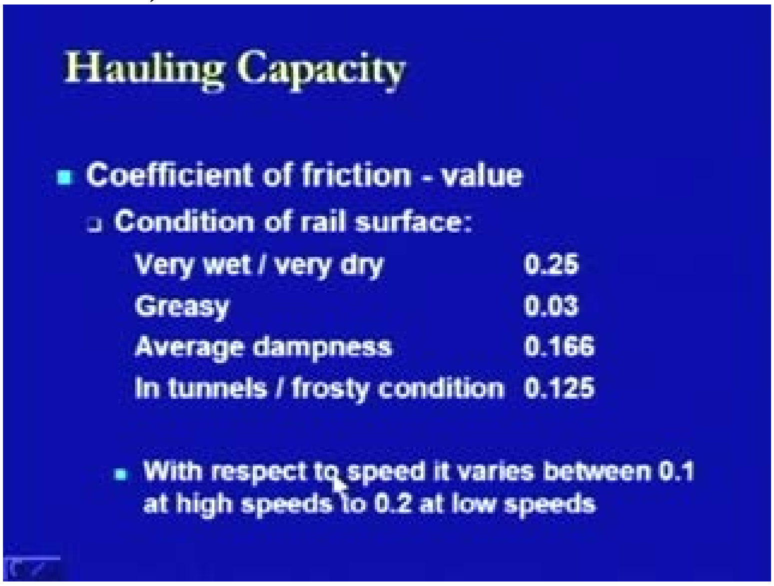

In the case of the condition of the rail surface, if it is very wet or very dry it is taken as point 25. It is greasy then it is taken as point 03. If it is average dampness condition then it is taken as point 166 and in the case of frosty or thermal conditions it is taken as point 125. Similarly, there is an effect of the speed and the case of the speed it varies between point 1 to point 2, that is from high speed to the lower speed conditions respectively.

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In that sense, the hauling capacity will be defined as moue multiplied with w multiplied with n, where moue is the coefficient of friction as defined previously. The values have also been defined there, w is the weight on the driving wheel or axle and n is the number of pairs of driving axles or wheels. If you take these together, then this will transform into nothing but capital W which is total load on the driving wheels. In our Indian conditions, the maximum axle loads which are being used on the different gauges are 28 point 56 tonnes for broad gauge, 17 point 34 tonnes for meter gauge and 13 point 26 tonnes for narrow gauge movements.

Now, once we have the hauling capacity of the locomotive available to us, next aspect here is the tractive effort.

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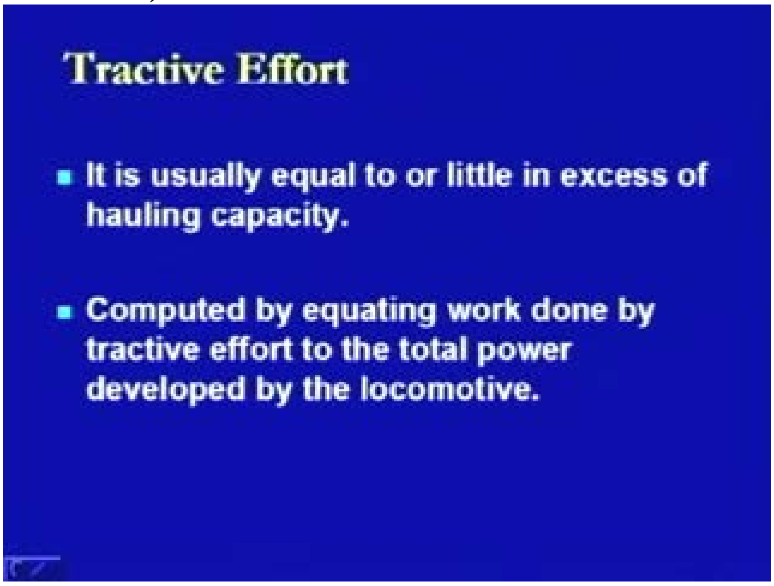

The tractive effort is usually taken as equal to or little in excess of the hauling capacity and this is computed by equating the work done by the tractive effort to the total power developed by the locomotive. So, this is the basis of the computation of the tractive effort for whatever the type of locomotive we are using, whether the steam locomotive or the diesel locomotive or the electric locomotive.

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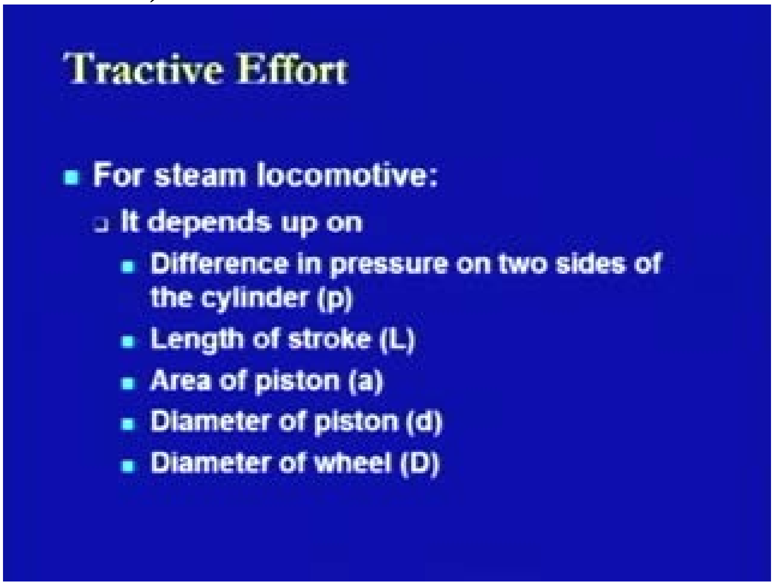

Now in the case of the steam locomotive, what we can see is that it is going to depend on the difference in pressure on the two sides of the cylinder. Here in the steam locomotive what happens is there is a steam pressure and there is a cylinder in which because of this steam pressure we will be having a piston which moves, that is, what is termed as the stroke of the piston and the length of the stroke is taken into consideration. This length of the stroke, this stroke will be coming back and that is how that one cycle will be completed and because this is a cylinder so we have to take into consideration the area of the piston, the diameter of the piston and similarly diameter of the wheel. Taking up all these factors together, then we can compute the value of the tractive effort in this case.

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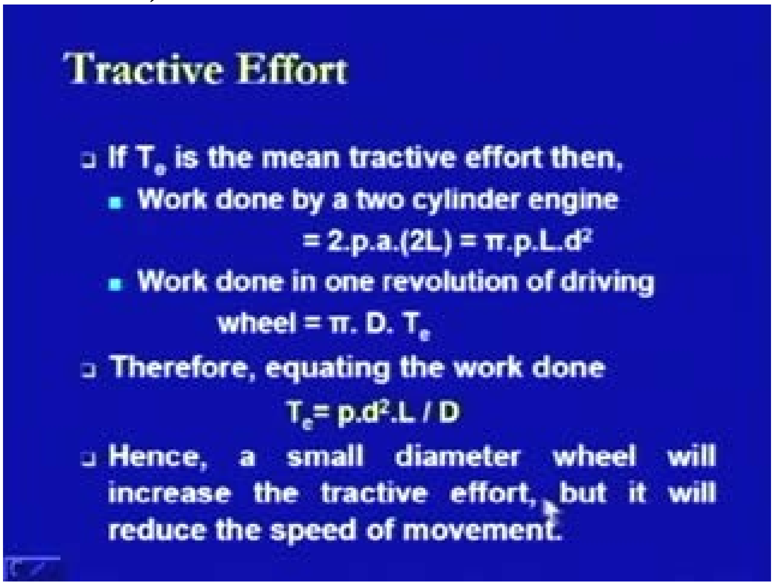

Here the work done by a 2 cylinder engine will be this 2, 2 is for the 2 cylinder condition, p is the pressure which is being applied on the area of that cylinder on the piston, a is the area of the piston and again we are taking twice of length L which is L is the length of the stroke because in one cycle the stroke goes in one direction and comes back ,that is why the total length governed here is two L and this is how we compute the value and this is transformed into another value like pi p.L.d square, where d is diameter in the cylinder or the piston.

The work done in one revolution of driving wheel, here we are talking in terms of the tractive effort which is being given to that driving wheel as T and because of this the wheel is moving. Therefore, there will be a movement equals to the circumference of the wheel that is pi D and the work done will be nothing but pi D multiplied with T. So, once we combine these two together and we create them, then what we get Te has p into d square into L divided by capital D, where capital D is the diameter of the wheel, but we found here is that if the diameter of the wheel is small then we are going to have more of the tractive effort but the problem here is that if diameter is smaller then it reduces the speed of the movement. Therefore, we have to look at this tradeoff between the diameter verses the tractive effort and accordingly the diameter of the wheels have to be decided. Similarly, in the case of the diesel locomotive the equation has been given for the tractive effort as 308 multiplied with the rated horse power of the engine HPr and divided by the velocity in kilometers per hour. So, this is the equation by which we can find out the tractive effort.

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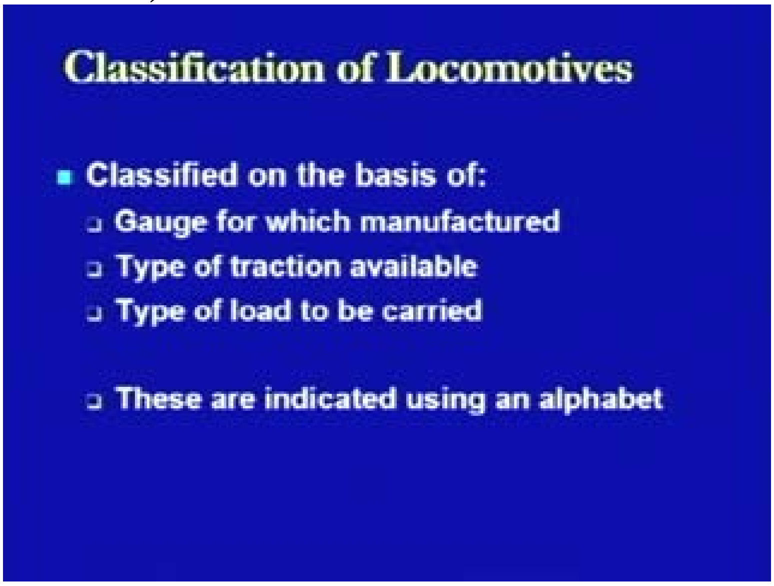

Now we come to the last thing in this case, that is the classification of the locomotives. The classification of the locomotives is done on the basis of gauges for which they are manufactured. The type of the traction available, the type of the load to be carried and based on all these conditions for which it is to be defined, they are indicated using an alphabet.

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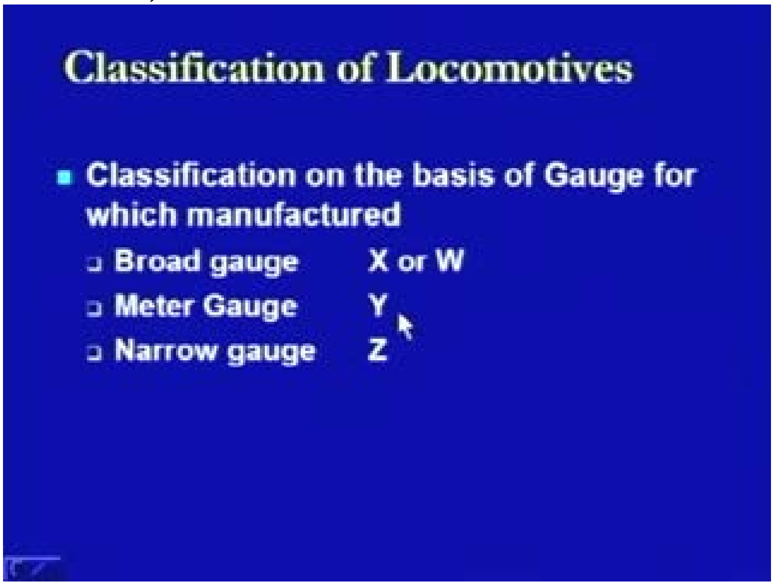

How this is being done? In the case of the classification on the basis of the gauge; if it is a broad gauge condition then we will find that in the name of the locomotive the word X or W will be there. Similarly, if it is a meter gauge condition then Y will be there in the name of that locomotive and if it is a narrow gauge condition then Z will be there in the name of the locomotive.

The next aspect is the tractive or traction available or the source of the traction. If it is diesel then in the name of the locomotive we will find capital D, if it is AC electric vehicle, then it is going to be A and if it is DC traction, then it is going to be capital C. So these are the alphabets we will be using when we have to define any locomotive.

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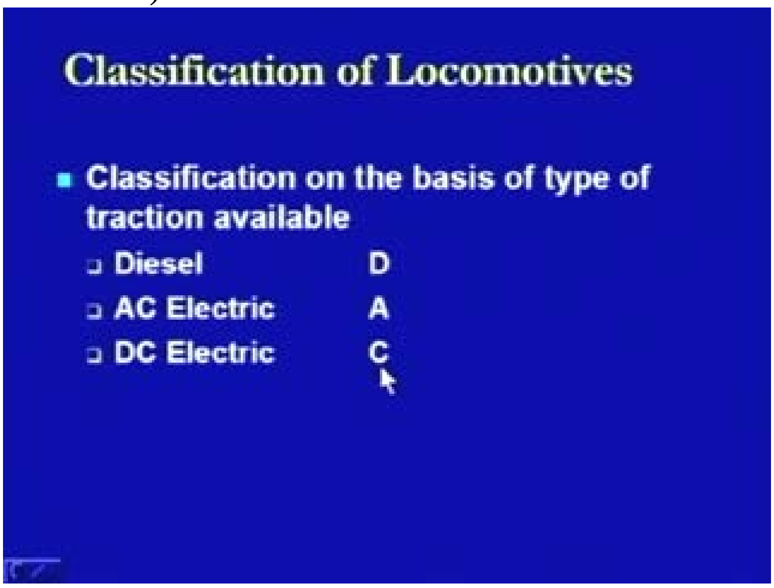

Further, on the basis of the type of the load which will be carried, we have A or L in case the light passenger, B or P in case standard passenger, capital C in case of heavy passengers, D or G for the standard goods, E for the heavy goods, M for the mixed conditions where the goods and passengers both are being transported and U, T or W in the case the shuttle or shunting conditions are there.

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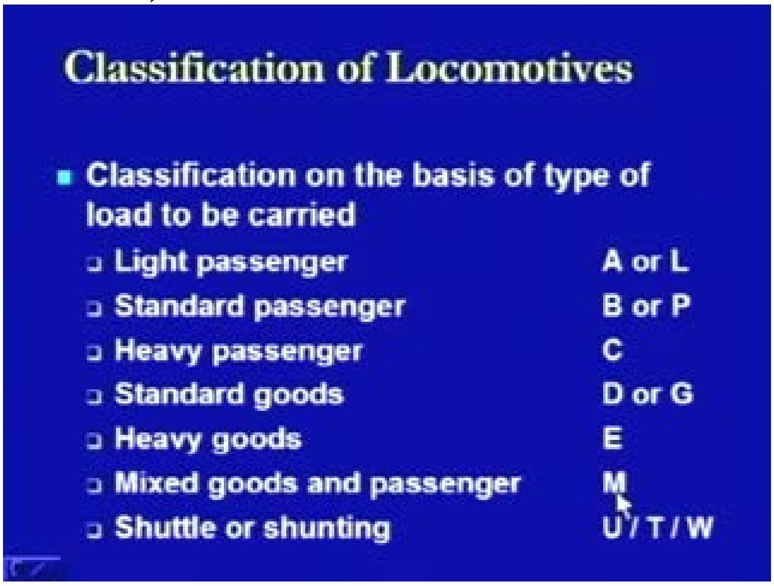

Therefore, when we take all these combinations, we will be having certain types of the locomotives. We are going to look at some on the certain salient features of some type of locomotives which are defined in terms of the type of the locomotive where the axle or the wheel conditions have been defined for the trailing or the front or the driving wheels the axle loads are being defined and the length of the locomotives are also defined.

If we took this XA, then how this XA is going to be defined? This XA as we go back and look at the condition, that is, if you do this one what we found is this X is for broad gauge and then we come further then A is for the AC electric condition. So, that is how, it comes to this XA and this XA is having the body type condition of 4-6-2 where 4 are the front wheel, 6 are the driving wheel conditions and 2 are the trailing wheel conditions. The axle load is 13 point 2 tonnes and the length of this locomotive is 19 point 2 meters. Similarly, we have another for XB, that is, now we are talking about the standard load condition for the passengers where what we see is that the axle load is increasing and similarly the length is also increasing though the type remains the same.

Then we go to the heavy load condition for the same board gauge category. Then, still the type is the same but the axle load is increasing and the length of the locomotive is still further increasing to 23 point 2 meters. This is for the goods condition, the goods traffic is there, therefore what we are increasing is the driving wheels here and the trailing or the front wheels are reduced. Here it is comparable to XB condition as far as the axle load or the length is concerned. Then this is extreme condition where much heavier loads are there, so therefore, the axle load needs to be increased and because of this the length of the vehicle is also increasing. Similarly, now as Y as come this is for the meter gauge condition for the standard loading of the passengers, so we have the vehicle type as 4-6-2 but now in this case, the load is lesser and the length is also lesser. Similarly, is the case for YC, where 4-6-2 is still being used with a lower value of axle load or YD where a further value of the axle load is being used. Z pertains to the narrow gauge condition where what we found is that the vehicle is reducing further and the length of the vehicle now is 12 point 8 meters and around where the axle loads are much lower and they are somewhere around 6 point 1 tones. This is 8 point 1 tonnes in the case of ZE condition where the heavy loading is there.

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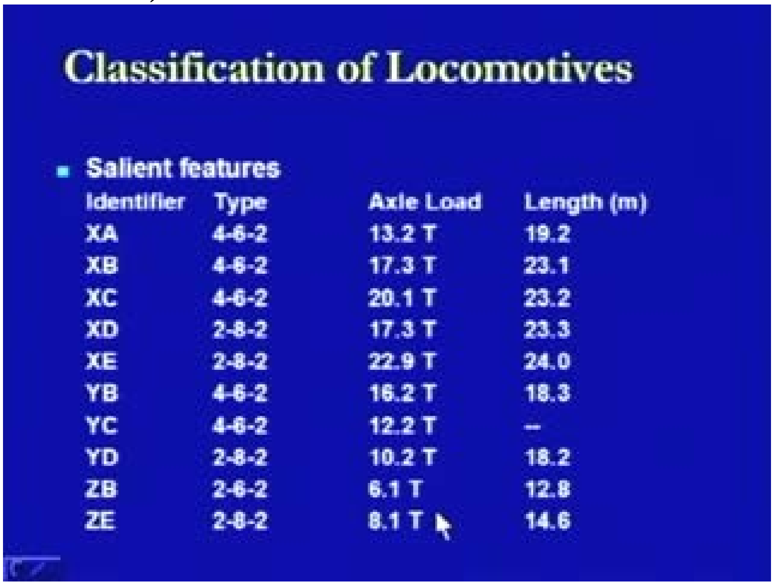

So on the basis of all these things what we found is there are certain common identifiers for different types of the tractions; in the case of the diesel we have for the broad gauge WDM or WDM 1, 2, 3 or likewise. What it is says is W is for broad gauge, D is for diesel traction and M is for the mixed condition of the passengers and the freight. 1, 2, 4 this type of numerals which are being defined along with the name they say the level of modification which is being there or the change over which is being there from one sort of locomotive to the other condition of the locomotive. In the case of the electric locomotive, similarly if we look at the broad gauge condition we have WAM, we have WAP, we have WAG or we have WCM or WCG, likewise different type of locomotives are there and for meter gauge we have YAM and likewise. I am not taking all the different types of the combinations which can be there in this case.

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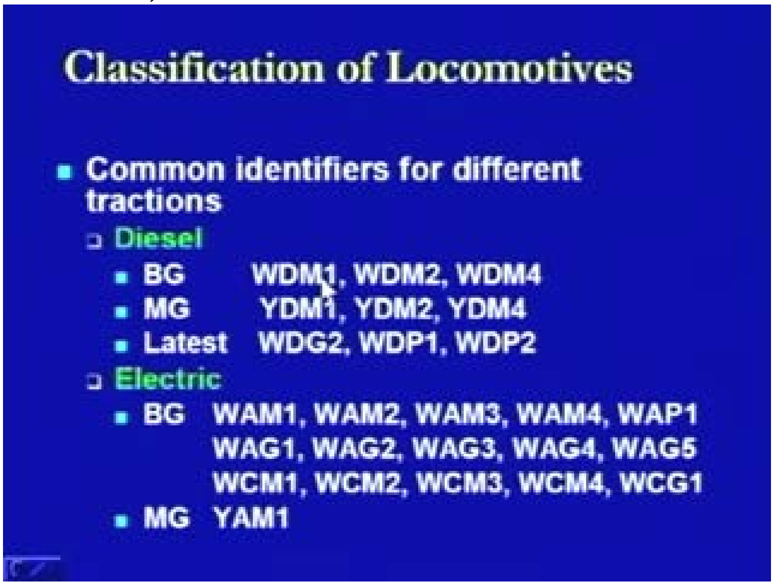

Just look at this locomotive, in this locomotive it is already written here as WDM 2. Now this WDM 2 means it is going to be used for a broad gauge because W, it is a diesel traction because of D, and this is M it means it can be used both for mixed conditions ,that is, for passengers as well as for the goods and 2 is the category means there has been the previous case also where WDM1 was also there.

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Similarly, there is a number being defined here is as 18527. 18527, the first three letters 185 they defines the series. It means it is 185 series locomotive and 27 means the production number. So, it in the 185 series it is 27 number of production of this type of locomotive of WDM2, that is how these numbers are defined and they are categorized.

This is another case where this is a WAP5 condition, that is again for broad gauge, for AC traction and for a passenger traffic fifth category of this type of vehicle and here the code number is 30006; it means the first three letters are 300 that is it's series is three hundred and then it is a sixth vehicle being produced in that one.

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Similarly, we look at this another type of a locomotive. This locomotive is WAG 9.
This WAG 9 means it is for the goods traffic now. G is for the goads traffic and here again there is one number being given; this is 31014, that mean it is 300 ton series in which this is a fourteenth locomotive which is being produced in this case. So, this is what all is about the different types of the locomotives for the different tractions or resistances being offered on the track or whatever are the tractive efforts which can be computed the hauling capacities or the tractive resistances which can be computed.

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So today, we have tried to look at certain resistances which are offered in this case. Now these resistances which have been offered in this case are going to be transferred back to the rails, sleepers or the ballast sections and we will try to look at the different resistances or the stresses being induced on the different components of the permanent way in the coming lectures. So, we are stopping at this point today and I hope you have gone through and you have now found out that how you can classify the locomotives as soon as you go to a station and found some locomotive coming to you. Thank you.