Equipment Design: Mechanical Aspects
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Lecture 13
Design of Flanges

Welcome to the third lecture of week 3 and here we are discussing design of flanges. Now design of flanges we have started in lecture 2 and where we have defined the flanges and discussed different types of flanges. Now we are continuing the discussion on design of flanges in this lecture. So let us start.

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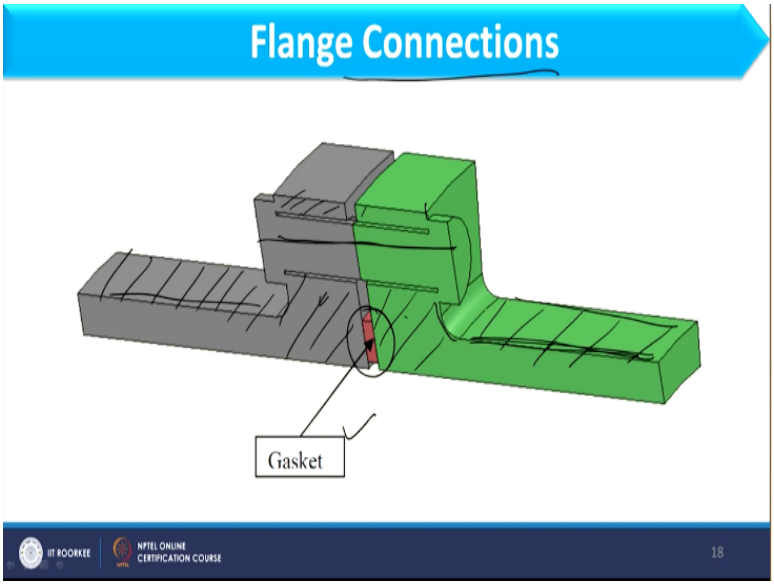

Now, if you focus on this particular figure it is basically speaking about flange connection. Now, here you see this section, what is this section if you are able to understand you can identify that this is the part of shell or the head or wherever that flange is connected, okay. So let us assume that this is the part of shell, okay. In the similar line this will be the part of shell. As we have discussed in the previous lecture that usually flanges are available in pairs, okay.

So at one side one flange appear and in second side second flange appears. So in the similar line in this figure also we have two flanges which are basically paired to each other and they are connected to two different sections of shells, okay. So here as we have discussed that this is the

shell and this is the shell, now what is this section, okay. If you see what is this section. This is nothing but the flange, okay. So this is one pair and this is another pair.

This two pair of flange is connected through the bolt, okay. This is one bolt only, okay. So that entirely crosses the two flanges and then they are connected. Now, the main point to focus over here is this section. Now what is this section, this is nothing but the gasket. So why this gasket we are using. If you imagine the flanges, these are usually made of metal and whatever force are applied, for example, if I am having this is one flange, this is second flange, both these flanges are made of metal.

So whatever force I am applying to this I cannot ensure leak proof connection. So to offer leak proof connection I need some material which is soft enough and which should fill the irregularity between two metal surfaces that I need to provide and that substance or that assembly we can call as gasket. So usually flange connection when we are discussing it is discussed or it is defined in terms of where I am placing the gasket, whether it is placed between the bolt or outside the bolt area.

So in that way we can define different connections of flanges.

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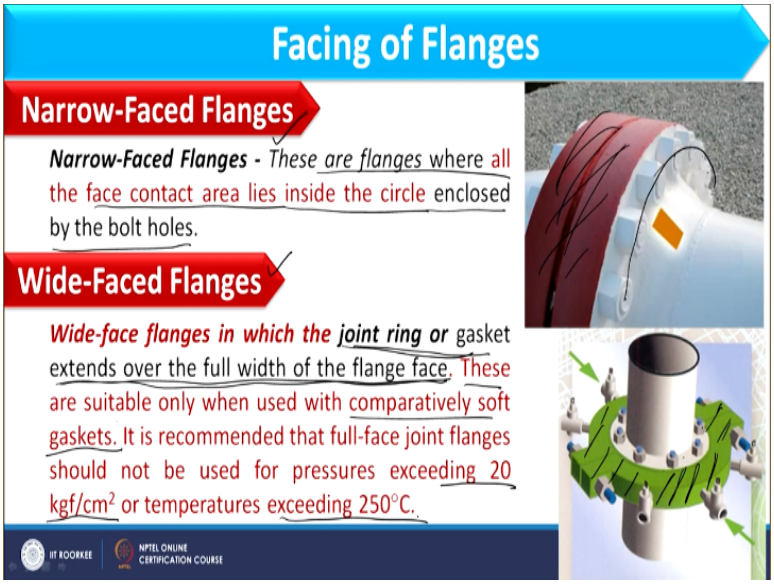

And that different connection of flanges are basically called facing of flanges, how flange face to each other that is defined by placing the gasket. Wherever I am placing the gasket accordingly

face of flange is defined. So considering that point I have two broad classification of facing of flanges. One classification is narrowed-faced flange, okay, as you can see here. Now what is that narrowed-face flange. These are flanges where all the face contact area lies inside the circle and closed by bolt holes.

What is the meaning of this, that we can better understand by this image. Now if you see if we connect this centre of these bolts what it gives. If I connect centre of these bolts, it basically gives bolt circle, okay. So if gasket is placed within the bolt circle we call this as narrow-faced flange. And in such type of connection when you see from outside you cannot see the flange. For example, if you consider this section which is outside the bolt circle area, this is the bolt circle, okay, and this is the outer area in the bolt circle.

So here you cannot see any gasket. Whatever gasket I am placing in narrow-faced that will be inside this bolt circle diameter. And in the similar line I am having another facing, which is called as wide-faced flange, okay. So this wide-faced flange, it means that in this case gasket is basically available at wider part than the bolt circle diameter. So let us discuss that. Wide-faced flanges in which joint ring or gasket extends over the full width of the flange face.

So in these case gaskets are basically available over the bolt circle diameter and how it looks like that you can imagine or that you can see in this image. Now in this image, if you consider these are basically bolt and when we connect the centre point of this bolt, it is basically bolt circle diameter, and then whatever gasket I am placing that gasket is placed above this bolt circle diameter.

So in this case this part is basically you can imagine as gasket. So in this particular connection you can visualize you can see gasket from outside; however, that is not possible in narrow-faced, okay. So these are suitable, these means wide-faced flanges are suitable only when used with comparatively soft gasket. It is recommended that full face joint flanges should not be used for pressure exceeding 20 kg force per centimeter square or temperature exceeding 250 degree Celsius.

So here basically gasket material is soft, we can see that from outside because it is soft it cannot be used for extreme condition. So these type of gaskets are not lined within the flange face, okay or between the flanges these are not lined. So this cannot be used for extreme condition, okay. However, when I am speaking about narrow-faced flange there gasket is lined between the flanges, okay, in between the flanges. So it provides better connection in comparison to wide-faced flange.

And therefore narrow-faced flange can be used for extreme operation or extreme service. Therefore, here onwards we will discuss different type of facing related to narrow-faced flange. So let us start the discussion.

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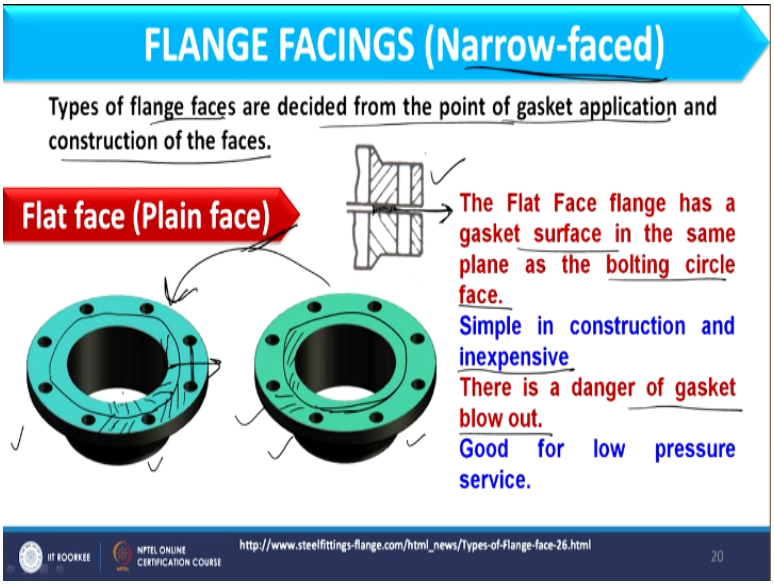

Flange face we are considering and here I am considering only narrow-faced. These flange faces are decided from the point of gasket application and construction of the faces. So here we are basically discussing different types of facing related to narrow-faced and narrow-faced you have understood that whatever gasket I am placing that gasket is lined within the bolt circle and that you cannot see from outside.

Now, within the bolt circle itself we have different type of connection or different type of assembly where we can place the gasket, and therefore these types are there. So let us start the types of flange faces related to narrow-faced flange. Now, first face in that category is called as flat face or plain face. So flat face flange has a gasket surface in the same plane as the bolting

circle face, so that you can better understand from this image. Now if you see this, this is the flange and this is the flange, both pair of flanges are there.

Now what happens, narrow-faced if I am speaking it means I have to place the gasket in this section. That is below the bolt circle and similarly in this flange also, okay. Now in this case, flat face or plain face has gasket surface in the same plane as the bolting surface. It means if you consider this particular section where I have to place the gasket and this particular section which is available in bolt circle and outside that.

These two surfaces are at same plane in this image also or you can visualize this image also that this section as well as this section both are available at same surface or same plane. So this is simplest and inexpensive type of flange as you can see this is simply the flange where I do not have any extra construction for placing the gasket. Gasket will lie here as well as here and then this flange will lie over this and then we can connect that with bolts. So that is simple as well as inexpensive.

There is a danger of gasket blowout. Now what is the meaning of this, when I am considering this image as well as this image and when both are connected to each other, it means when this section is above this flange, so what happens this gasket is basically in between these two and here I have to place the bolts. So what happens this section is basically open for this gasket to come out, okay. So this is basically called gasket blowout.

So this is the disadvantage of plain face or simple face and therefore we cannot use these type of faces for severe condition. On the other hand these type of faces are very good for low pressure or low operating condition. So if you consider the schematic view, it is looking like this and this is basically the side view of the connection where gasket is available in between two, from here it has the chance to come out or blowout.

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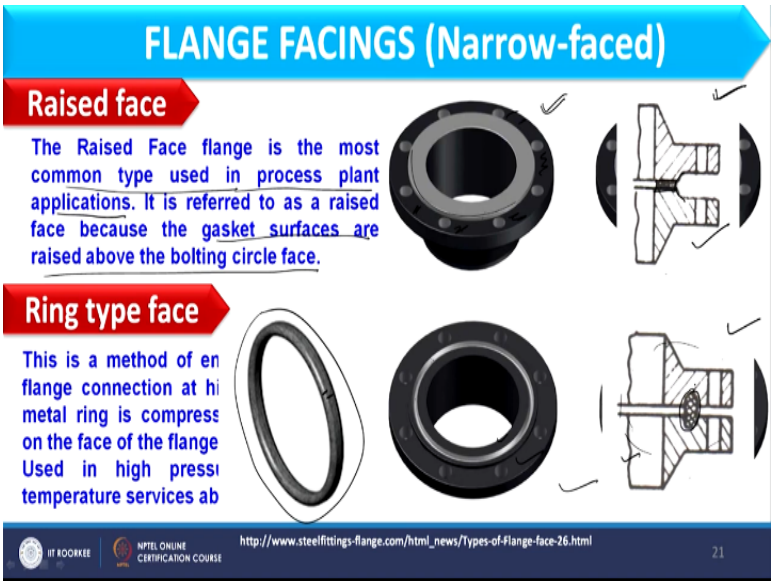

Second face in this category is the raised face and which can be considered or which can be defined as raised face flange is most common type used in the process plant application. So this is most common type. It is referred to as a raised face because the gasket surfaces are raised above the bolting circle face. Now what is the meaning of this that you can better understand from this image. Here we have two flanges or that is the pair of flange.

Now what happens over here that if you consider this section, grey section, and this grey section these are basically raised faces. It means these are slightly above than this bolt circle or bolt section, okay. Bolting we are doing and that bolt holes are available at slightly lower surface than the raised face or than the face where I am placing the gasket. So what happens over here that because of this raised face gasket will sit over the material more tightly in comparison to plain face if I am putting same bolting load, okay.

So in that case further I cannot ensure that blowout of the gasket will not happen, but obviously it will not happen as regularly as happen in plain face. So these type of faces are basically used more in comparison to plain face in process industry. Now if you remember the previous lecture, where we have discussed different types of flanges, there we have in the schematic of all those flanges we have discussed the raised face and at that time I asked you to keep it as it is and then we will discuss that later on.

So here it is the detailed discussion on that that raised face or those faces which are slightly above than the area where I have prepared or we have prepared the bolt holes, okay.

And if you see the schematic this is basically the schematic or side view of the connection where this is the raised face available and in between this two raised face we have the gasket. So here blowout opportunity for the gasket is significantly less in comparison to plain face. Next type of face I am having is the ring type of face and in this type we can ensure leak proof flange connection at high pressures, okay. So first of all discuss how it looks like.

So if you consider these images, here we have the raised face in both flanges. In this flange also we have raised face, here also. Now in between these raised face we have the deep section and that deep section is prepared to fit or to sit the ring, okay. So that connection is made in this pair as well as in this pair, okay. So here you see we have the deep circle in the raised face and similarly we have the deep circle in this flange, okay.

So what happens here in the ring, the gasket ring either made with that soft material or it can be prepared with the metal wool, so that can be set properly between the gasket and there we have least chances to blowout or we can say that blowout is totally avoided in that case as the connection is very well made, okay. So this type of connection is used for severe condition. So a metal ring is compressed into the groove on the face of flange to make the seal and these are used at high pressure as well as high temperature that is above 427 degree Celsius.

So in that way this ring type face will work for severe conditions. So if you see this image, this is basically the ring gasket, half portion of this ring gasket will sit on this flange, however, second half will be fitted in this circle, okay. So in this way this ring gasket works and when you see the side view of the schematic, it will look like this. Because it is a ring and some sections of this will lie above flange and some section will lie below flange.

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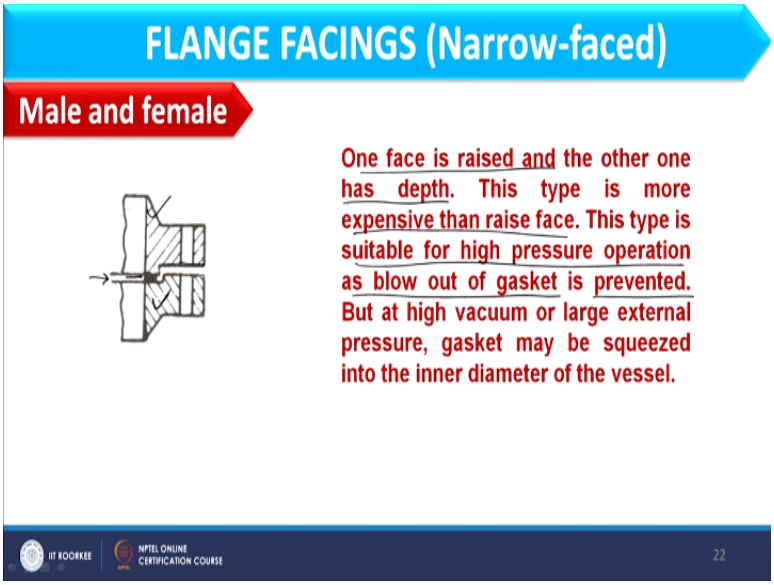

Next flange I am having is male and female type, how it is working and how it looks like, let us discuss that. So in this case one face is raised and other face has depth, okay. So basically this has different type of assembly where one has the raised surface another has deep construction or deep section, okay. So that raised face will lie within the deep section and therefore gasket is placed between the two faces.

So this type is more expensive than the raised face and this type is suitable for high pressure operation as blowout of gasket is totally prevented, okay. Now what happens, if you see the side view here, this flange has the raised face because this section is slightly above than the bolt circle section and when we consider second flange here I am having this deep section, okay. So gasket will lie in between these two.

Now the main problem is here blow down will be totally prevented. Gasket cannot move in this and then blowout, no. Gasket blowout will be totally prevented, but what happens when high pressure operation will be done, this gasket will stick to this wall. Now what happens when very high pressure operation is carried out, this high pressure pushes this gasket and it accumulated over here at this section. Though it do not blowout, but it will not serve the purpose of gasket as it is totally collected at one section. So that is the disadvantage of this type of facing.

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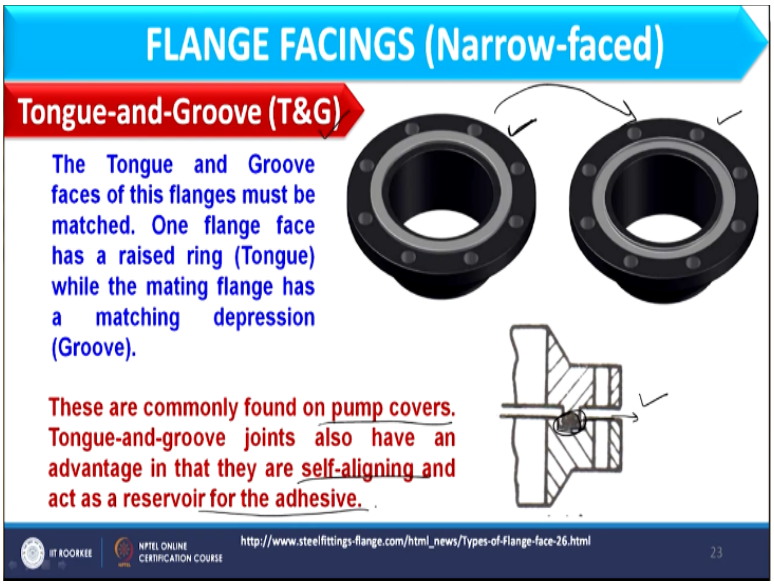

Now next facing I am having is tongue-and-groove type. So this tongue-and-groove type is more advanced than male and female type. In this case, what happens, here I am having tongue-and-groove. So in one flange I have the raised face, in another flange I have the deep face like we have discussed in male and female type connection, but here we have this assembly or this construction is slightly different.

Now what is the difference that you can see from this image. That in one flange we have this raised face, okay. So that raised face is basically called as tongue and when we are considering the second flange this particular section is basically deep section or that we can call as groove or depression. So what happens when this flange lie over here, it automatically takes its place that is the most important point to consider that such type of flanges have very good alignment tendency.

So if you see the schematic the side view is available in this image, where it has this section that is depression section or deep section, we call this groove and this raised section we call as tongue. So this type of flanges are automatically fitted or assembled or aligned to each other and gasket is basically lying over here. So it will prevent blowout totally as well as the shifting of gasket to one side. This type of connection will be used for severe condition because here gasket will be properly fitted.

So these are commonly used for pump services. Tongue and groove joints also have an advantage that they are self-aligning and act as a reservoir for the adhesive or gasket. So this is the basic advantage of tongue and groove type that it is self-aligned.

So in this way we have discussed different type of facing related to narrow-faced and we also have discussed in what condition which type of face can be used. So that is all about types of facing. Now we will start design part and in design part though gasket is a part of flange, we will first discuss what is gasket and what are the design parameter associated to the gasket, okay, and then we will continue to design part. So let us start it.

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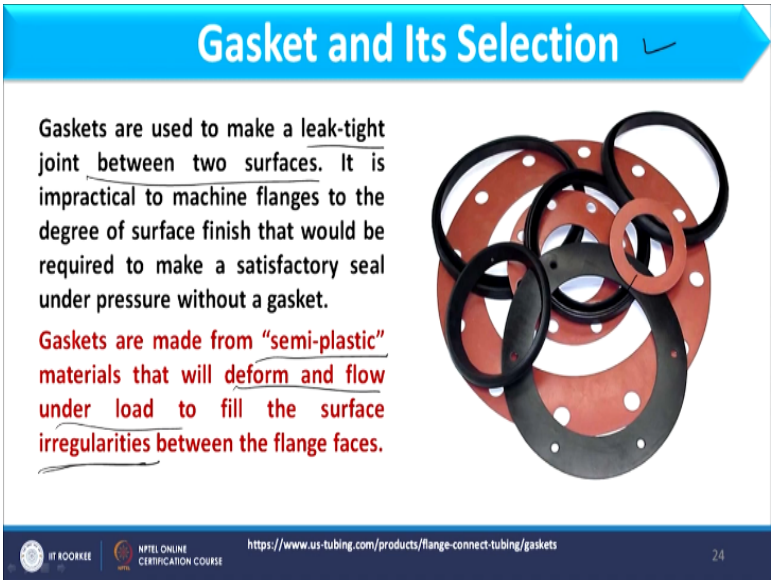

Now we have gasket and its selection. Gaskets are used to make leak-tight joint between two surfaces. So that we have discussed earlier also that whatever force I apply, whatever load we apply on two faces of metal, leak proof connection cannot be made, some irregularity or some opening may be there, which can be completely avoided by placing the gasket. So what is the basic role of gasket.

When we are applying the gasket between two faces and we put the load there what happens gasket material is spread and it covers the irregularity between two surfaces. So that is the basic function of gasket and as it fills the irregularity it will provide leak proof connection. So these are usually made of semi-plastic material that will deform and flow under the load to fill the surface irregularity as we have already discussed.

So in this image we have different gaskets, like here we have, this is flat type and this is basically ring type. Even you have seen gasket in our household thing, which is very commonly available in pressure cooker, you must have seen the ring of pressure cooker and that is nothing but the gasket that fills between two metal surfaces between the cover as well as the body part of the pressure cooker.

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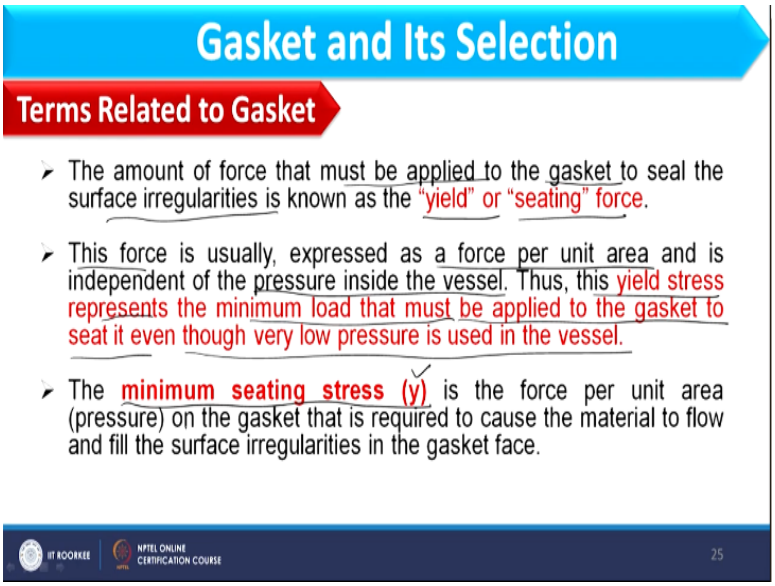

Now here we will discuss some of the terms related to gasket and these terms we will use in design also, so let us define these terms. Now first is the yield or seating force okay and that is defined as the amount of force that must be applied to the gasket to seal the surface irregularity is known as yield or seating force. So what you can understand by seating force that is the amount of force we apply on a gasket, so that it deforms and fulfill the irregularity.

So that force we basically called as seating force or yield force, okay. Now if you can understand that seating force or yield force will be used whether the system is being operated or not, okay. Because whether system is not operated then also that connection should be tight enough, okay. It is not like when system is being operated then it will become tight, no. It has to remain tight during resting condition or during operating condition.

So this seating force is usually expressed as force per unit area and is independent of pressure inside the vessel and therefore I am telling whether process is going on or not going on this force

must be applicable to the connection, to the gasket. Thus, this yield is stress represents the minimum load that must be applied to the gasket to seat it even though very low pressure is used in the vessel or even if it is not in use then also this force will be applicable. So it is independent to operating pressure. It basically depends on how much tight I want to make the joint.

So the term basically called as minimum seating stress and that will be represented by y is the force per unit area or we can have that as pressure unit on the gasket that is required to cause material to flow and fill the surface irregularity in the gasket face. So this y is basically the minimum seating stress and that will be defined for each type of gasket separately because how much force will be applied to each type of gasket so that it deforms and melt it depends on the characteristic of that gasket.

So it will be dependent only on the material of the gasket, but it does not depend on the pressure or operating condition.

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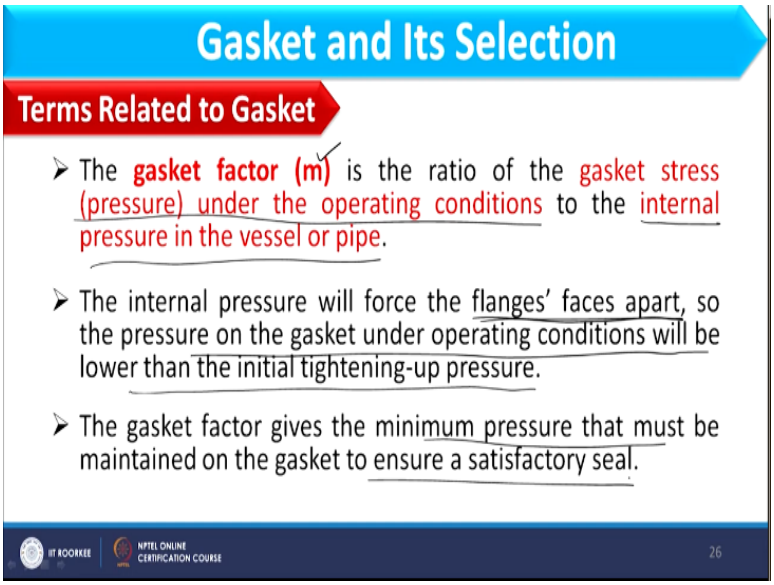

So one term I have considered as minimum seating stress, next term I am having is the gasket factor, and that gasket factor is denoted by m and it is the ratio of gasket stress under operating condition, okay. Two the internal pressure in the vessel or pipe. So this gasket factor is basically the ratio of gasket stress under operating condition. What is the meaning of this, that when operation is going on the joint should be tight enough, okay.

So when operation will be going on what are the forces which are applicable to the gasket. First force would be the seating force, which is applicable all the time whether it is operated or not operated, so that y will at and another force will act as whatever pressure is inside during the operating condition. So that pressure when I am considering internal pressure it will try to depart that joint, okay. So that gasket stress is basically the stress which is applicable on the gasket to make it tight connection during operation.

It means that will consider seating force as well as internal pressure of the vessel. And when gasket stress is divided by internal pressure, it gives me a factor that is gasket factor, which is denoted by m. So the internal pressure will force the flanges faces apart, so pressure on gasket under operating condition will be lower than the initial tightening-up condition, okay. So tightening-up condition means when only seating stress will be applicable, okay. So seating stress will try to compress the gasket.

However, operating pressure or internal pressure will try to apart the two flanges, okay. So what happens when I am considering total pressure on the gasket during operating condition, this will be lower than the minimum seating stress, which is applicable on the gasket. So the gasket factor gives minimum pressure that must be maintained on gasket to ensure a satisfactory sealing. So in this way we have defined two parameters, two factors y as well as m. When operation will be going on then m will be applicable along with y.

Y will compress the connection, internal pressure will apart the connection, so difference between these two will call as gasket stress. I hope it is clear to you and the second term I am having is minimum seating stress.

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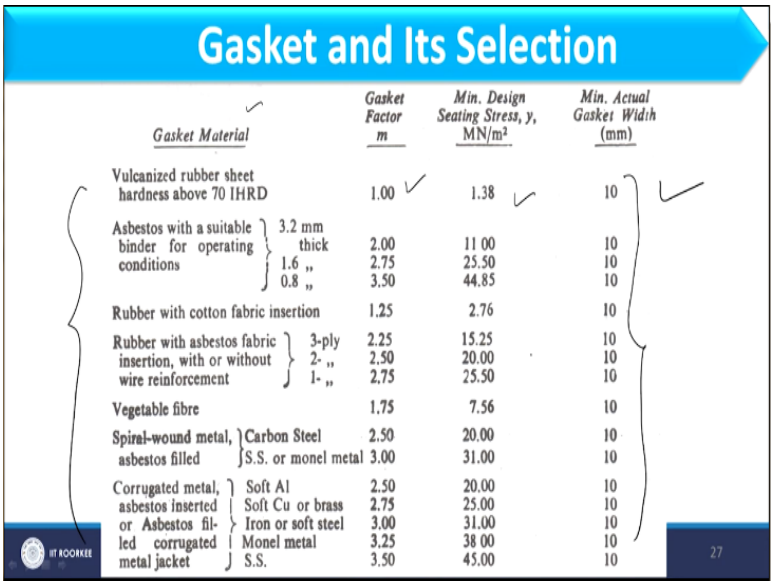

If you see this table, this table basically comprises the gasket material and related gasket factor as well as seating stress according to these material, okay. So for each material you can have different value of m as well as y because it depends on the material. And here I am having another term which is called as minimum actual gasket width. So all these three parameters we will consider in design and this table continues in this slide also for different material.

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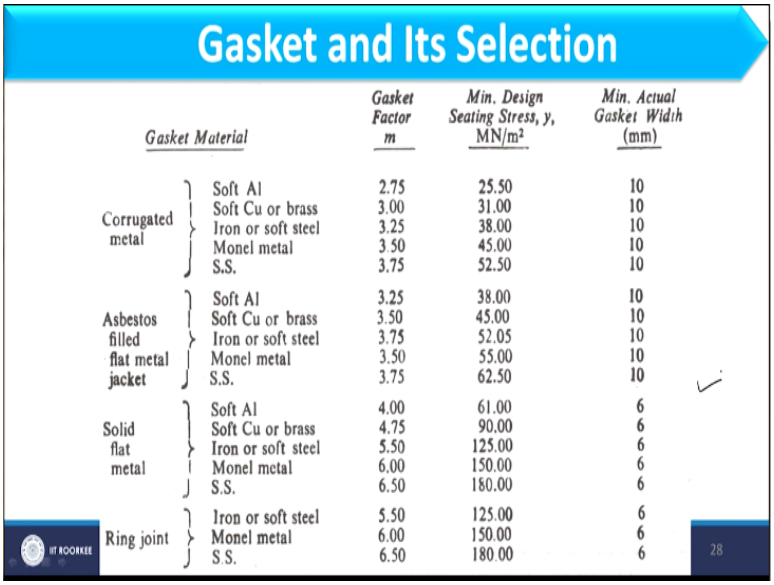

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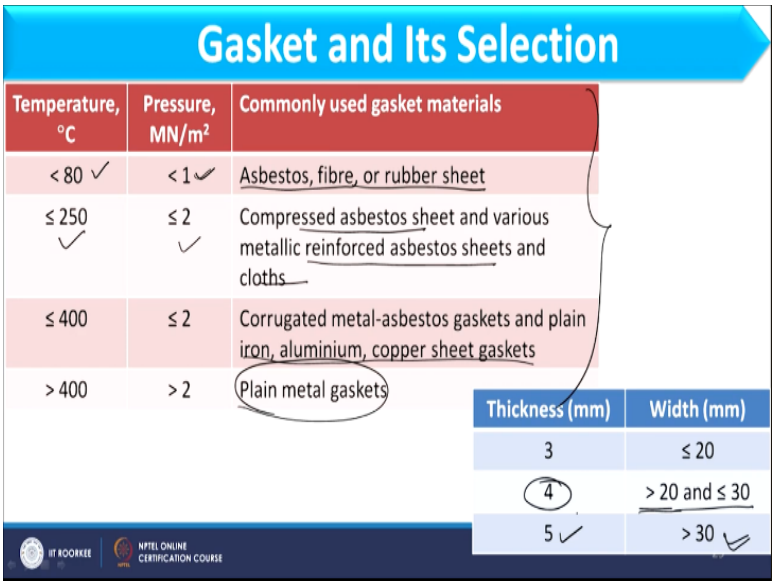

Now here I am having a table which summarizes that which type of gasket material will be used under which condition. So if you see when temperature is less than 80 degrees Celsius and pressure is less than 1 meganewton per meter square we can use asbestos, fibre or rubber sheet as gasket material.

If temperature is less than 250 degrees Celsius and pressure is less than 2 meganewton per meter square, we can use compressed asbestos sheet and various metallic reinforced asbestos sheets and cloths. If temperature lies below 400 degrees Celsius and pressure 2 meganewton per meter square we can use corrugated metal-asbestos gasket and plain iron aluminium copper sheet gasket. Now if I am having temperature more than 400 degrees Celsius and pressure more than 2 meganewton per meter square I can use plain metal gaskets as a gasket material.

So here we can choose the gasket material according to the operating condition. And in this table I have thickness as well as width. If width is less than 20 mm, so what is that width. The width of gasket is basically that dimension which is lying from inner of the flange to the bolt circle, okay. I hope I am clear. And when it is less than 20 mm, the thickness should be 3 mm, thickness of the gasket sheet should be 3 mm.

When the width exceeds 20 mm and it is less than or equal to 30 mm, we have the thickness of 4 mm and when width exceeds 30 mm we can use thickness up to 5 mm. So in this way we choose the dimension, however, the exact width of the gasket can be decided, can be computed

considering the actual flange and the type of gasket I am choosing because it depends on m and y parameter, okay, so that we will continue in next lecture. That is all for now, thank you.