Hydrostatics and Stability

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Module No. # 01

Lecture No. # 33

Safety Regulations

We have come to the lecture 33. In the last lecture, I talked about the effects of flooding. Till now, we studied one major thing we did in the last 10 or 15 lectures. We have been studying the effects of trim. We are finding out - what are the effects of trim? -effects on trim due to different phenomenon, we studied how the trim of a ship changes.

So, first of all we studied - what is trim? and we talked about the different factors that affect trim mainly, how the draft forward and aft are different? and how it changes with respect to some phenomena, that occur the main reason for which is a change seems to be a change in the volume at any point.

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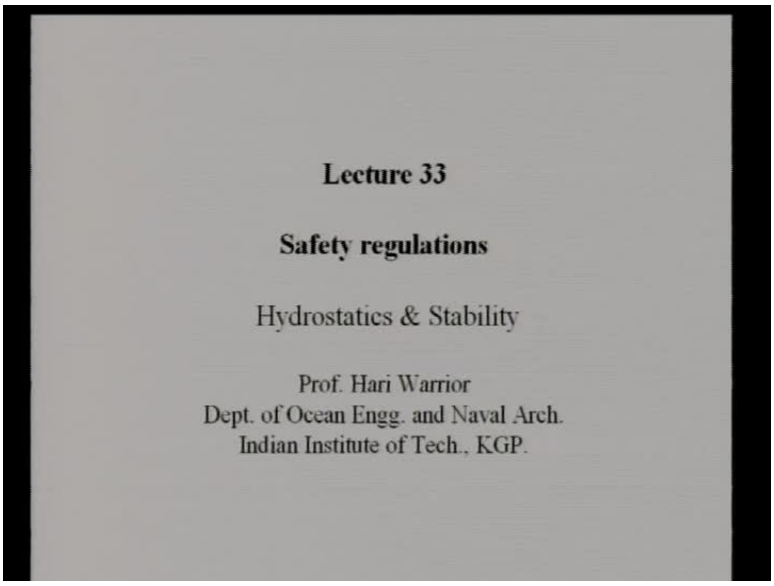

So, we talked about different conditions like change in the density of sea water that produces a change in the volume removing or what we call as discharging masses or the adding of masses to different points of the ship produces a change in the trim of the ship and similarly a shift in the mass of the ship anywhere in the ship. For instance if there is a shift in the ballast from let us say an aft tank to a forward tank, if there is a shift in the ballast or some fuel in some form, there also produces a change in the trim.

So, these all produces change in trim. We quantify these processes; We saw what are the different formulas and mathematical expressions for the different processes like provided you are given the initial trim, and some of the hydrostatic data or hydrostatic variables like MCTC or TPC displacement the initial drafts etcetera.

Once you are given the position of center of floatation, and once its distance from the aft perpendicular. So, once you are given all these parameters, you have been given the different formulas for calculating the trim, the change in trim. Once you find, we have already seen that we always talk. First of all, there is a parallel sinkage, which we assume it to occur at the center of floatation and then which is very straight forwardly measured by w by TPC; where w is a weight added.

Now, once you have that change in the mean draft, which we call as parallel sinkage. It is followed by the trim, which is a ship going like this or like this and this, we have seen what is the change in trim.

Once you calculate the total change in trim; how can we find the change in trim in the aft direction? In the aft point, how we can find the change in trim in the forward point just by taking the ratios of the concepts of similar triangles,

So, we find that change in trim forward aft, and once you find the change in trim forward you add from the initial draft, you add the change in trim forward and you add the parallel sinkage. You get the final draft forward, final draft aft. These are different things associated with trim and then in trim, we also saw after trim. We went into the concept of dry docking, how dry docking also affects trim, and then we came into the bilging process.

Now this bilging process is much more important in a way, than probably even the concepts of trim and dry docking, and so we talked about, how the flooding can be measured by using that methods of the method of loss buoyancy or the method of added weight. Both of these methods can be used for calculating the amount of the change in draft, and we also looked at how there can be a change in the heel or trim again of the ship due to the flooding.

Since, flooding is a phenomenon, that is unavoidable in nature. In real world, which means anytime you commission a ship you are certainly assuming that at some point or other in the future.

The ship is surely going to come across a situation, where it faces some kind of rupture, some kind of damage as a result of which there will be flooding in some compartment and so it is very important that you be able to properly quantify, what is the amount of flooding anywhere in the ship.

What happens when there is a flooding anywhere in the ship and how it will affect the general characteristics of the ship now once you have flooding. Occurring flooding which we also call as bilging, once you have this bilging occurring these are all damage stability conditions, damage stability scenarios.

So, once you have this damaged stability or when you have that we have seen using the method of bros buoyancy, how we can find the heeling? This will occur if the damage or the damaged compartment is not exactly center line, but it occurs probably towards one side of the ship or in the case when that damage is not in the mid ship section, but occurs towards one side whether it is a forward or the aft side

Then you end up with what we seen as trimming conditions. Now one possibility, the only formula that you have to know to do this trimming condition is that in this particular case, when one end of a compartment for instance gets damaged the only thing you need to know is you need to find.

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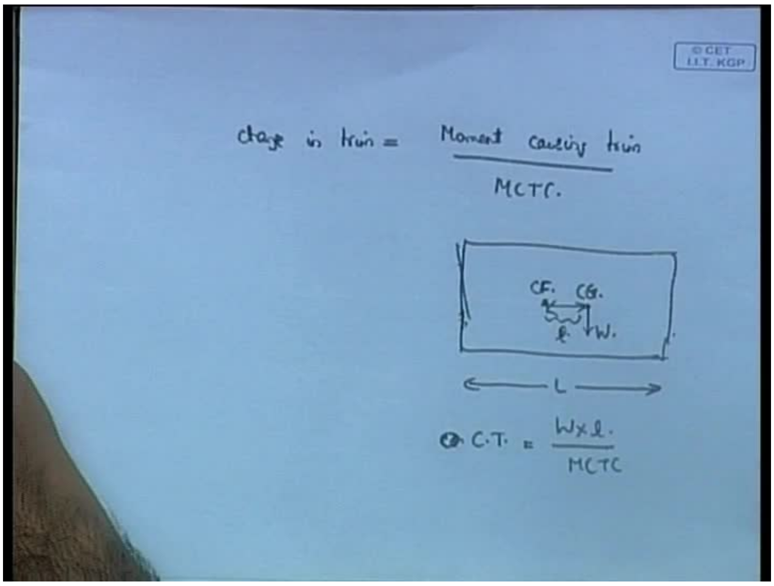

Finally, you are going to use the formula, the final change in trim. So we end up finally we are going to use the formula.

Change in trim is equal to the moment causing trim divided by MCTC. Now MCTC will be given the moment to change the trim by 1 centimeter that will be given and so the problem comes down to finding moment to moment that is causing the trim and in this case, if you remember the discussion in the last lecture, we have shown that it is important to remember that trimming always occurs about the center of floatation that is that center a line about which it pivots that pivoting point is actually the center of floatation.

So at that point, if you take the moments so the way to find out what is the rotation is obviously to find out what is the net unbalanced moment acting on it. So, we take the moments about this pivot, which is the center of floatation, so in this ship if you take the moments we have seen from the previous figure something like this you will have it was a box shape vessel. So if you assume that the center of floatation is somewhere here if this is the length of the vessel whole length of the vessel and if you have the center of floatation here then the net weight is going to act somewhere here, which is at the center of gravity, this weight is what is causing the moment.

So, the net moment is caused due to this weight; which is w and therefore the moment caused is W into the distance between the center of gravity and the center of floatation which in this case, we can write as something like this distance we are talking about this distance, so W into this distance. Let us call it small l, this small distance l divided by MCTC will give you the change in trim.

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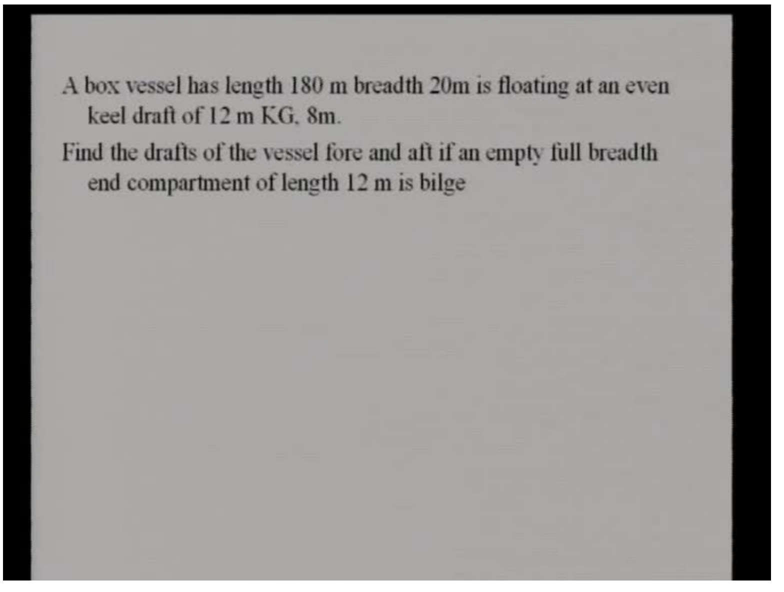

So, this change in trim will be given by, W into l by MCTC. So what we need to know is the weight of the ship and the distance between the center of gravity and the center of floatation. For instance, you might end up with the problem like this.

So this problem states that there is a box of length 180 meters and breadth floating at even keel, it is given as a draft. Now find the draft of the vessel forward and aft, if the empty full breadth compartment of bilge of length 12 meter is bilge.

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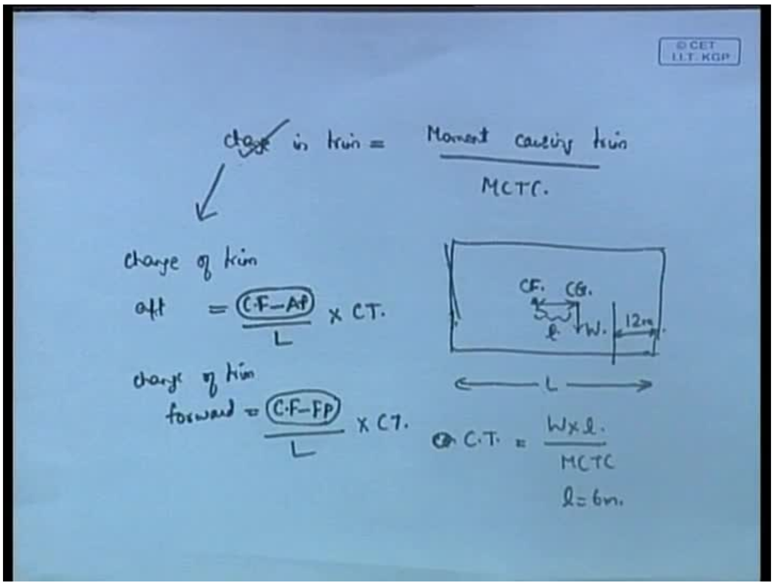

Now what this says is that in this problem, if you look here a compartment which is of length compartment of length 12 meters, what it says is that compartment of length 12 meters gets flooded here. Now if you remember the previous class we saw that this distance between the center of floatation and the center of gravity will be equal to this length divided by 2.

So it will be 6 meters. In this case, l will be 6 meters and now is very easy, the problem becomes very straight forward. All you need to do is so, l is given, W is the weight of the ship it is given, it is not written here but it is given the vessels displacement has to be given, otherwise you cannot do the problem.

Now once you have that and given the MCTC. You just find the change in trim, then you find the so once your given the change in trim. So once you find this you go and do the change of trim in the aft condition that also we have done; it is equal to the distance between the center of floatation and the aft perpendicular.

The distance between these two divided by L into the change in trim this will give you the change in trim aft and the change in trim forward. Change of trim forward is the distance between the center of floatation and the forward perpendicular divided by L into change of trim. So using this formula you can get the change of trim forward and the change of trim aft.

Now once you are given the change of trim, you add it to the initial trim you will get the final trim, but in add or subtract that is the only slightly confusing thing here. That is if you have the means in this case, you need to find out whether you need to add the initial trim or the change in trim to the initial draft or should you subtract the change in trim from the initial that you need to check.

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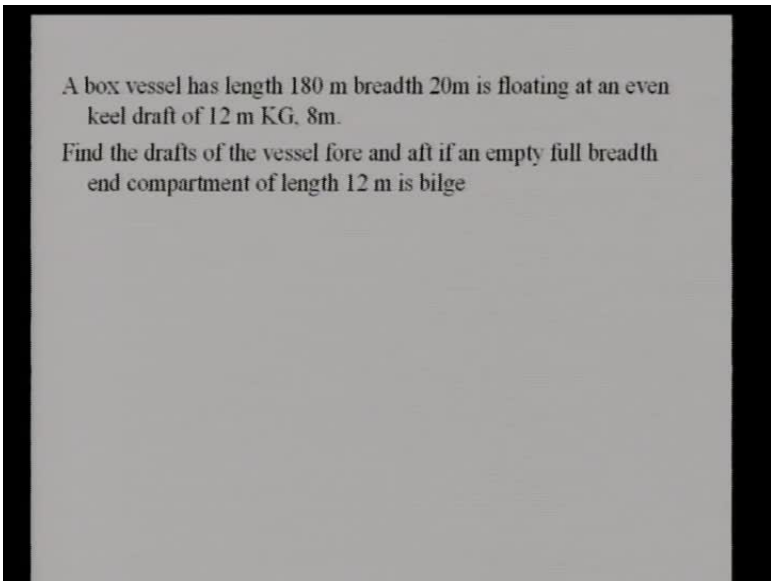

So, what is a easiest way to do this is you can see where the load is added for instance in this problem. You can see that the ship is bilged in the forward direction; it is given in the full forward. In this problem it is given though it is given here, but the problem is that the ship is bilged fully in the forward compartment.

So, if it is given that the ship is bilged in the forward compartment what it means is that this is fully bilged and therefore, if this is flooded, it comes with the automatic common sense that you can immediately deduce that this must be sinking like this the ship at that point, if this compartment is bilged. If this is filled with water, then it automatically follows that this ship should be sinking like this so what you do to get the final draft. So the forward draft at any point will become the initial forward draft plus the change in trim forward.

So once you add these two you will get the final draft forward. On the other hand how will you get the final draft aft you have the initial draft aft you have the change in trim.

Form the aft draft you subtract the final you subtract the change in trim aft you will get the final draft aft.

So, each problem instead of following just the mathematics if this concept is followed for instance, just check that is you see where the weight is added. If a weight is moved from the aft to the forward for instance this is not dealing with bilging

In case of the simple transfer of weight when the weight is transferred from aft to forward. It automatically means that the forward side will trim down its trim will increase that we usually say the ship trims forward trims by the forward direction. So, that is reverse if the weight is transferred back or if a weight is added in the aft then the ship will trim by aft, so it will go down at the backside.

So, the draft here at the trim; the back side will increase the draft there will decrease. Now the same thing actually can come in mathematics as plus and minus, if you are very careful that is definitely a good way of doing.

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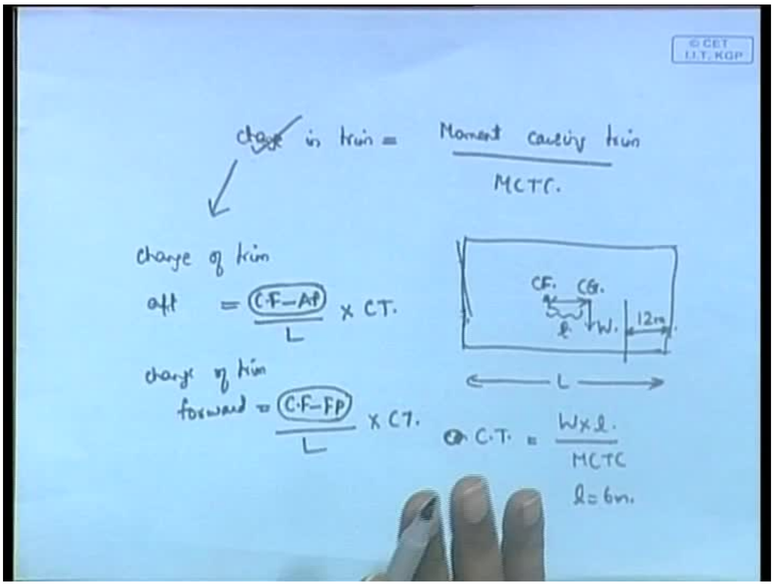

But each problem it is better to always like if you have the proper positive and negative. You will get it as the ship trim forward; it should increase or decrease the draft, but the best option is always to follow the logic and say that where is the weight being added. You just check that where is weight going, is it going in forward side or the backward side or in case of bilging you say which side is getting bilged, is it the forward side or the backward side is the forward side or the aft side and once you know that it is this or that end then you decide whether it should go down or go up and similarly, whether the change of trim should be added to the initial draft or subtract from the initial draft.

So, this is the way to calculate the bilging process, and we have done most of the problems related to bilging using the method of loss buoyancy. As I have said before, you have to know that the there is no difference in the final logic of the two methods.

Both are following a similar trend of logic except that in one case; weight is added to the center of gravity shifts and you assume that the total weight of the ship changes. Whereas in the second method, weight of the ship is not changed at all second method which means method of loss buoyancy.

The weight of the ship is not changed, the center of gravity of the ship does not change, but the volume is lost from the ship area is lost from the ship. As a result of which I is the moment of inertia of the water plane can vary, and the volume varies the area. So these calculations have to be born in mind so these assumptions that go into doing either of the method of loss buoyancy or the method of added weight. You have these basic assumptions should be clearly in the mind when you are doing the problems otherwise it is easy to make errors.

So, this is said as for as mostly bilging is concerned and so in this lecture, we are going into I think we are completely finished or raped up the section on trimming. Anything to do with the trimming, heeling also more or less and we are now going into a new final sections of dealing with regulations for instance. Today will going into the different safety regulations and maritime loss and maritime regulations which deal with the different concepts of stability parameters, which say whether the ship is stable or not and this different set of rules based on which different classification agencies like IRS that is a Indian register of shipping or the American bureau of shipping or the bureaus VERITAS any of them or law its register all of them, they all have their own set of rules adapted from a fix set of code.

Now, first of all there are some standard codes from which they have adapted their own rules and made it more detailed and more to find tune to their situations and to their countries for instance like Indian register of shipping has rules specifically made for ships in India its more tailor made towards that country.

So, like that we have, so what we will do today is we have completely rapped up the other sections in a way most of the real theory part on stability calculations, which we usually call as a statical stability curve. The dynamical stability and the different multipliers means Simpsons multiplier trapezoidal multiplier and then the different concepts of trim heeling and all that is more or less rapped up and we have come to an end of that and rest of it is more towards loss and regulations and of course some more parameters on waves and some resonance.

So, that is the rest of the lectures on today we will go into what we call as the safety regulations. Some of the important regulations that are followed in different parts of the world as I said before we have a fix set of rules there are given by the IMO lets go into that.

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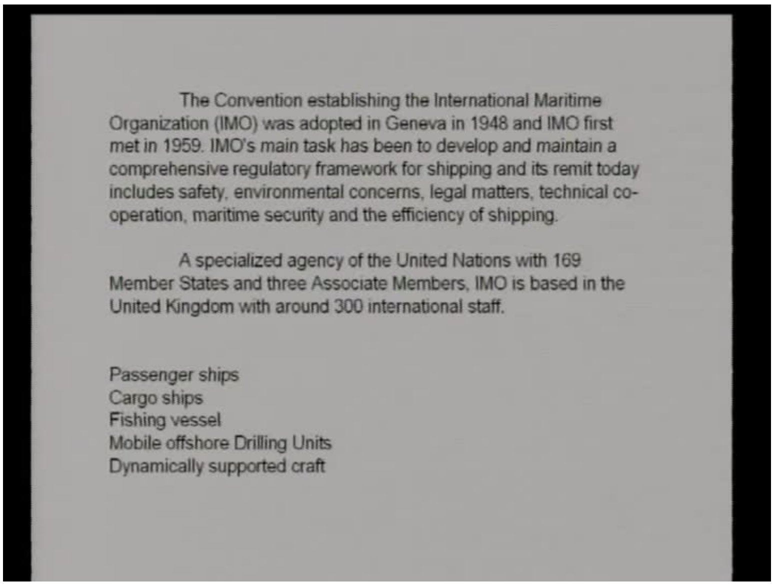

Now the main organization that deals with the law governing is known as the IMO which is known as the International Maritime Organization.

So, I will just read this the maritime organization was adopted in Geneva in 1948. Now these are the people who deal with the legal matters environmental concerns, technical maritime security, their deal with even that but their main work is to frame rules leading to the safety of ships. This one safety is their main thrust area of work, but they deal with all this environmental concerns what they mean by that is they call it as our purpose is to make a safe shipping in a clean world in a clean oceans they call it the clean oceans and the different things they are dealing with mainly they deal with IMO the International Maritime Organization so they deal with it is based in UK, somewhere in UK and it is a part of the united nations organization. It is a branch of the united nations; it is a council by itself and they have about 159 or 160 member states member countries and all of them come together and all these engineers and the scientist and the top research people come together with the law making people or the politicians they come together to frame the laws to make the shipping safer and more efficient.

So, we will be dealing with the set of frame work of rules there are fabricated by the IMO and mainly it is the rules are initially fabricated by IMO and they have been adopted by different navies mainly the US navy, the UK navy, or the German navy of course. These are one of the 3 most powerful countries, we will deal with some of the rules associated with them and we will see how the different criterion or the different problems that are faced by the shipping industry as such these people how do they tackle it as you will see most of the rules are very similar there are no differences. There are not much differences but slightly adopted for their country and for different slightly different situations and is that just some differences in the way of approach.

Now usually the ships are classified into many different types; you will see that in general naval architecture we call them as cargo ships container ships, tankers, passenger ferry then different types of fishing vessels or you will have tugs then you will have a mobile of shoot drilling units and you can have what we call as dynamically supported drafts DSE, that is one special class of crafts on its own they are some kind of unconventional crafts the others are all what we call as conventional crafts.

Now there are the rules we have already seen some of the rules associated with ships. we have already seen some of the basic rules that are followed in the few lectures in the middle. We talked about the different rules associated with the cargo or ore carriers we saw how the ore carriers have their own rules and what are the conditions that are important in dealing with these safety of these ore carriers.

We said grains and ores, it was actually grains so grains and ores follow the same principle, so for grains and ores they have a fixed set of rules on their own. We have seen what are rules associated, how the shipping industry deals with the concept of wind stability or the resistance to wind or how the industry adopts, how the industry meets this criteria, how it how the what are the condition that the ships have to satisfy in order to satisfy the wind criterion.

We have already seen how we took one distances if you remember as there was a heeling arm developed as lambda 0 and we do another healing arm at 1.5 lambda 0 and have we did some calculations similar to that and it is very important to remember that all these calculations. All the latest stability rules are based on the concepts of dynamic similarity and dynamic similarity; again as we have already discussed many times to do with the area under the GZ curve.

GZ curve we have already drawn it is very similar it familiar with that by now. GZ represents the righting arm and it is a curve between the GZ which is the righting arm and phi the heel angle, so GZ phi curve is what we call as a statical stability curve and if you do delta into GZ delta is the displacement of the ship so a curve between delta into GZ and phi the area under the curve is what we call as dynamic stability.

Now dynamic stability all the stability criterion or stability criterion dealing with dynamic stability, the importance of that was discussed many times. I will mention it again, importance is that dynamic stability actually represents the energy in that condition. Now delta is a weight and it is a force into GZ; there is a distance moved so it is like work done or energy content.

So, it is the energy content and so what are we assuming is when some form of energy is coming into the system some form of perturbation what we call as perturbation to the stability. Some kind of force or some kind of phenomenon that is acting to remove the stability of the system and some kind of energy is input into the system to remove the stability.

Now when that goes into the system how the ship reacts to it or if that much energy goes into how the ship reacts without capsizing or without any permanent damage to the ship, so this is the concept of stability, this is how we deal with stability. That is why this concept of dynamic stability is very important because it does not matter whether even if the wind is in a gust all we are concern about is the total energy in that gust and if that energy goes into the ship.

If the wind hits the ship and the energy goes into the ship or the wind does work on the ship again which is like energy going into the ship; what will the ship do so the ship heels will it go beyond some value such that it becomes unstable and capsize are will it stay in a or will it come back to its original position.

So whenever we are talking about dynamic stability we will be dealing with area under the righting arm and heeling arm curve between the righting arm heeling arm curve that area under that area is what provides the dynamic stability and that is what gives you the decides whether the ship is stable or not based on that background.

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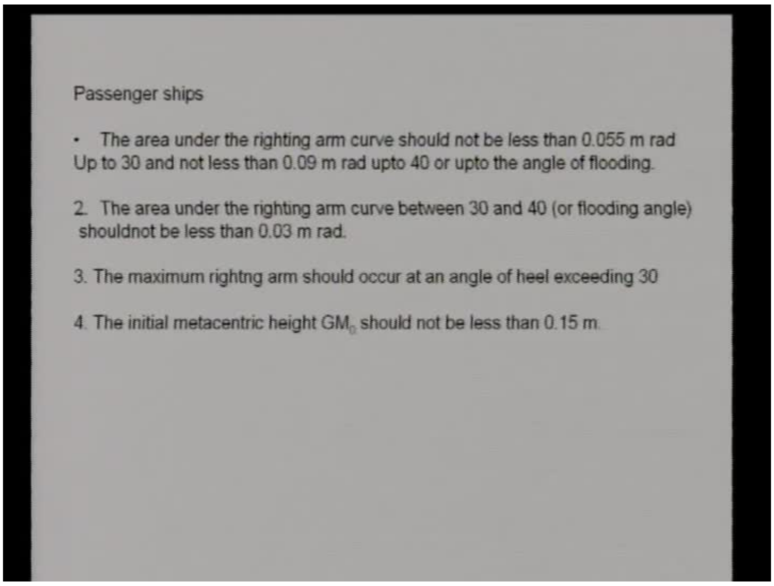

We will go into some rules that are very important, the first of which is the set of rules dealing with passenger ships; now some of as I have said before its always like this so you have the phi curve that is the heel.

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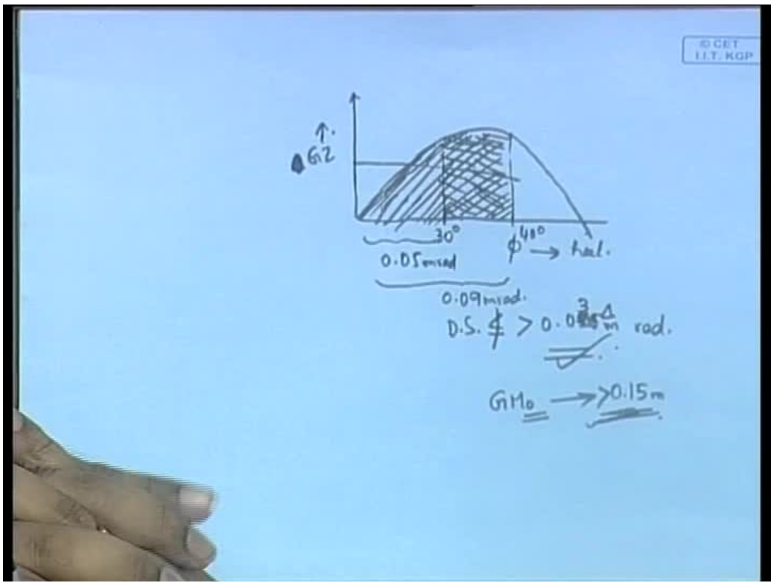

And you have the GZ curve and let us suppose that you have a curve like this so this is what we call as the and delta into GZ if it is instead of GZ if it is delta into GZ this curve becomes a the area under this curve becomes the dynamical stability.

Now always we draw the heeling arm as well now the first rule of passenger ships says that between 30 degrees and 40 degrees so this is 30 degrees 40 degrees the area under the righting arm curve this area should not be less than this is I will write it here it is called dynamic stability; it should never be less than that means it should be greater than 0.055 meter radians.

As you can see the unit of the dynamic stability is either meter radian or tonnes meter radians, so if you this is obviously in terms of GZ curve because its meter comes from GZ and radians comes from phi. It is the area under this curve so this is dynamic stability would be 0.055 delta, where delta is the weight of the ship. So this is general, it says that the dynamic stability per weight of the ship.

Dynamic stability is actually delta in to that so this says that the area so we cannot say exactly dynamic stability, but the area under the GZ curve this area which is between 30 degrees and 40 degrees should never be less than 0.055 meter radians.

That is the first rule associated with the passenger ships; it is not like that here the area up to 30 degrees should not be less than 0.055 meter radians and area up to 40 degrees should not be less than 0.09 radians meter radians and this is the rule, between 30 and 40 this area should not be less than 0.03 meter radians.

So, the rule says that clearly the rule for this is the IMO rule for passenger vessels so the rule is that between the angle of 0 degree and when its heels between 0 to 30 degrees within that angle of heel that righting arm curve should be such that the area under the righting arm area under the GZ phi curve should be greater than 0.03 meter radians upto 30 degrees and from 0 it heels up to 40 degrees between 0 to 40 degrees it should be at least 0.09 meter radians and also between 30 and 40 also it is important that there will be at least a margin of 0.03 meter radians.

So, this is very important as for as rules this fact is the back bone from which all the different rules associated with dynamically stability for different types of ships modify from this. This is where it starts from, so it is also important that the meta centric height GM 0 GM 0 is the meta centric height of the ship that it has nothing to do that angle heel it is 0 it is in the intact condition.

GM 0 should always be greater than 0.15 meter, so this is the Meta centric height. So the rule says that the meta centric height of the ship should always be greater than 0.15 meter.

Now as we have already discussed when you keep increasing the meta centric height because this is an important thing we have already discussed one thing that definitely should go home you should take home with you after the end of the all whole course that is that the stability of the ship is in general measured by its meta centric height and when you say that the meta centric height is large you are in generally saying that the ship is stable more stable and so we have said that the moment meta centric height becomes negative, that is a case when G or the Meta center M goes below G you say that the ship has become unstable and so GM keeps becoming more and more positive.

The ship in turn becomes more and more stable that is true, but we have already seen that we cannot make it too large because the ship becomes too stiff to its rolling so when the ship rolls it, rolls like this, if GM is too high.

we come to a situation of compromise between these two extremes of large GM and small GM somewhere in between you try to bring it so the optimal GM which IMO has come up with is says that the GM 0 of the ship which is the initial meta centric height which should not be less than 0.15 meter so 15 meter it is true for all kinds of passenger vessels regardless of their dimensions. So whatever be the dimension of the ship whether it is 100 meter long ship or whether it is a 50 meter long ship whatever its GM 0 should always be less than 0.15 meter.

This is the one important rule associated with the passenger vessels and it is in general recommended that maximum value of GZ which is your righting arm, the maximum value of GZ should occur at a value of heel angle, which exceeds 30 degrees; so they do not prefer you to have heel angle less than 30 degrees for their maximum GZ.

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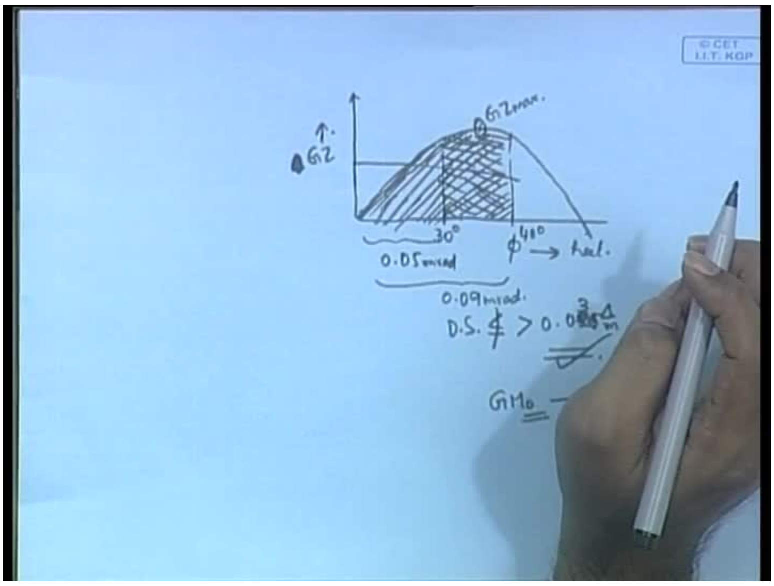

So, the position where you are get your maximum GZ in your curve like here this curve if you look at this this is where you are getting your maximum GZ this should always occur at an angle exceeding 30 degree, so somewhere here you should have the maximum.

So, these are the some of the basic rule from which all the series of regulations associated with the different kinds of vessel, cargo container, ore everything of course modify for that particular case, but this is the basic structure from which these rules I thing you should definitely keep it in memory and definitely keep it by hearted its something that is definitely important as the result of this course you should know this

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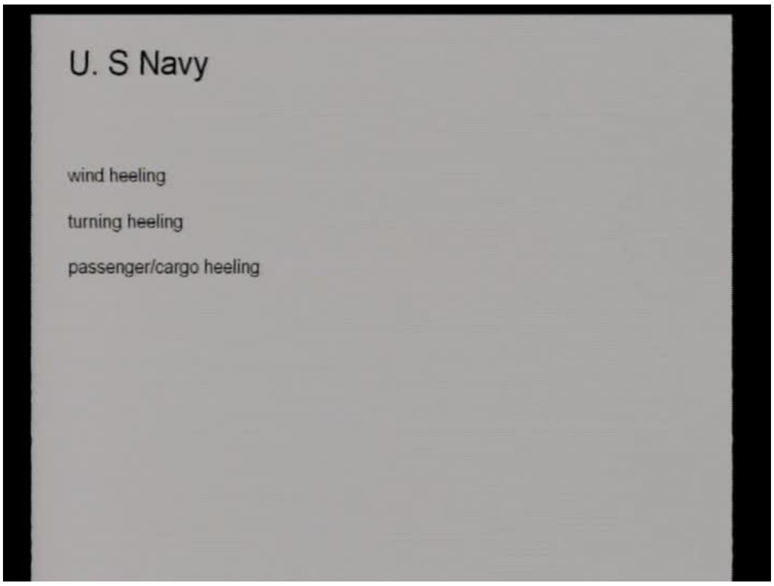

Now, once you have this basic set of rules, these are rule associated with the IMO that is a maritime organization; once you have this rules, there have been of course it is these rules are framed mostly by the 150 organizations, that go together to comprise the IMO in which it is the fact that the most of the work is done by US, UK, Germany, and a few of the western nations; they are mostly instrumental in developing all these codes.

Now, they have sometime slightly modified versions of this IMO codes. So, we will look at some of these important navy's which have their own set of codes; they have developed their own set of codes.

So, the US navy for instance have a couple of rules mainly, there are of course whole book dealing with these regulations. Maritime regulations is vast, there is many it deals with ballast, it deals with environmental concerns, it deals with passenger safety, it deals with fire- the lighting of possibilities of fire eruption, everything it deals with everything but since this course is devoted to stability concepts, hydrostatics and stability. so we will say that we will focus on those accepts of the code

Stability codes so like we did with the dynamic stability we showed the rules associated with that so we will deal with the stability concepts associated with wind heeling we have already told given in some previous lecture we have already described how the whole set of calculations is done

I will just mention here the different laws associated with it, so you have wind heeling is the possibility, and you can have a heeling due to turning; means when the ship tries to turn it can end up with the heeling.

That is a heeling possible and whenever you have cargo handling, means you shift a cargo from one point of the ship to another either from the port to the star board side or from the forward to the aft side, whatever kind of transfer it is, it will produce its own heeling. So, a heeling moment is generated due to the transfer of cargo does not have to be cargo; it can be the passenger as well; so the transfer of passenger also produces such a heeling. So, these are the different types of heeling moments possible and each of these navies infact has their own laws or rules associated with how to handle these kinds of problems.

And the basic rule for wind we have already given, I have already explained to you how the wind is done, how I explained that lambda 0 1.5 lambda 0, and how we assume that the whole energy has gone into the ship, and how long the ship will continue heeling with that energy input in to the ship.

How much further will it heel like that I have already discussed and turning I have mentioned the basic formula of turning heeling also and some passenger heeling will take and look at now.

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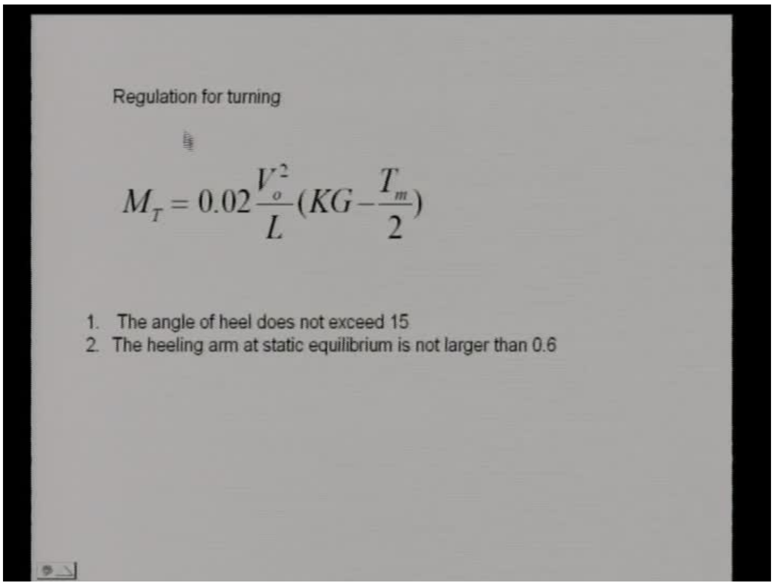

Now, for turning I mentioned this already, but what happens in the case of turning is so in case of turning what really happens is that, you have a force acting and you have a moment cause due to it; so what happens is that, when the ship tries to turn in its centroid exactly at the points of its KG, you will have a centrifugal force acting on it. The centrifugal force is given by M V square by r delta V square by r; where r is the radius of turning, so this will give you the moment that is acting to turn the ship; this gives you the force that is acting on the ship- that is the centrifugal force.

Now, how do you find the moment? So, once the ship is trying to turn, so this centrifugal force causes the ship to its acts on the center of gravity and causes the ship to shift infact.

So, the water in fact provides a reaction, it tends to cancel the effect of this centrifugal force; so the centrifugal force and the reaction from the water will cancel each other, out and the ship infact does not really slide or shift in that fashion

So, that vertical distance between the centrifugal force and the center of action of the reaction force from water is KG minus T by 2, where T is the draft; so T by 2 is the point where the water reaction can be assume to act and the centrifugal at KG, so KG minus T by 2 is the distances. So, centrifugal force the forces are the same so two forces acting and it produces the moment tending into heel.

So, the V 0 square by r into KG minus T by 2 roughly gives you the net moment acting to turn the ship. Now we can do something instead of putting the velocity of turning; you can convert it by some shipping, you have some shipping statistics, you can say how you can convert into V 0 which is the forward velocity of the ship; L is the length of the ship into point zero to its just some ships statistics so it as nothing to do with physics as such

So, this will give you the regulation; this gives the momentum, the moment produce moment trying to turn the ship this is M T

Now, of course this moment is provide by the rudder in turning the ship, so that rudder provides that moment and the ship turns; now the rule associated with this; is that this now it is very important that the angle of heel does not exceed 15 degrees.

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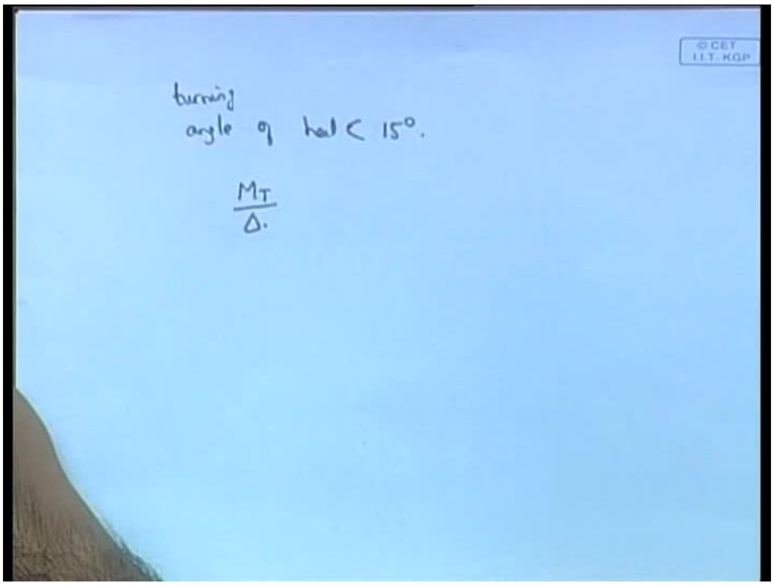

So, we say that, now it is very important that the ship does not heel beyond 15 degrees as a result of turning, whatever be the radius of turning you are not allowed to take a turn; that is more dangerous than producing angle of heel of 15 degrees then heeling arm; now note that the moment divided by the weight of the ship delta will give you actually.

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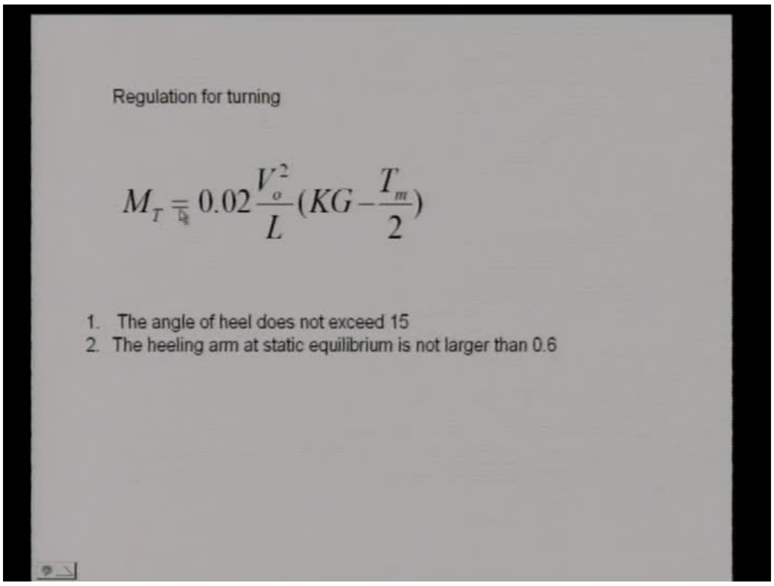

In this, I believe this is not empty as such in this actually represents the healing arm not the moment to turn moment, to turn should have a delta in it, that is your weight of the ship.

So, once you take that M T divided by delta, it becomes this quantity which is actually your heeling arm heeling arm.

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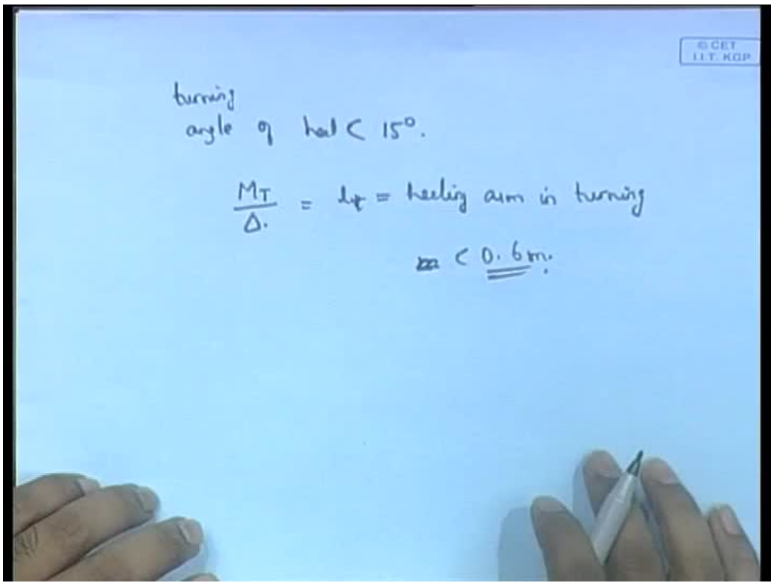

So, M T divided by delta, that is which we call as heeling arm in turning; so the heeling arm in turning should be less than 0.6, so the heeling arm in turning 0.6 meters so heeling arm in turning should be less than 0.6 meters so these are two important rules associated with the turning.

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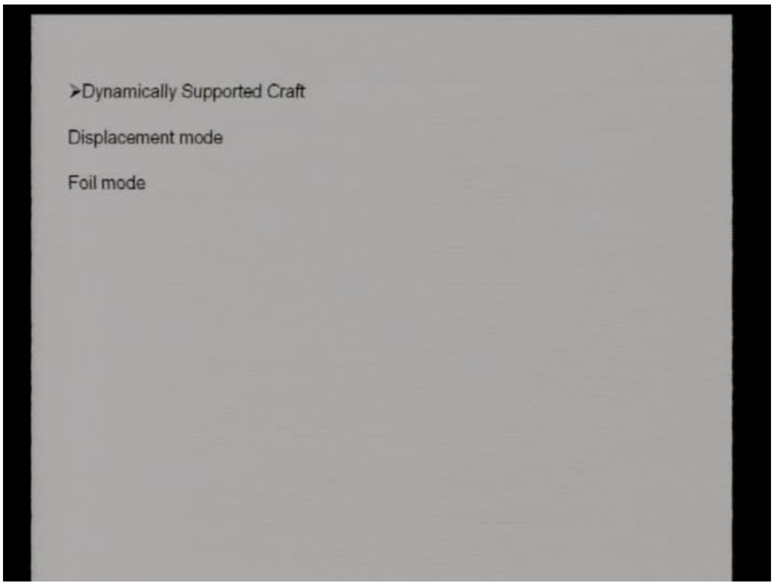

Then there are some forms of rules associated with, what we call as dynamically supported crafts.

Now, since most of you are not familiar or not very familiar with naval architecture, as such dynamically supported craft are crafts that have some other form of support rather than just the buoyancy force; you know that in case of ships, ordinary ships or conventional crafts which we talk about- like any kind of container ship or cargo ship tanker or any boat.

The weight of the ship, the weight of the boat or ship is balanced by the buoyancy force from the water, so this is the Archimedes principle; the weights balanced the weight of the ship is balanced by the buoyancy force, so this is the basis on which ships float ordinary, conventional ships float it is the Archimedes principle upon which it floats.

Now, it is possible that there are some other ways of actually balancing the weight of the ship rather than just the buoyancy force; for instance you can put different kinds of hydro foils infact, in the next lecture I will give you some pictures of hydro foil boats, these are kinds of boats which have hydro foil which is the hydro dynamic equivalent of an aero foil.

So, those who have familiarity with some aero foil concept or aero dynamic concepts, you will be familiar with what is known as an aero foil; especially for those of you have done some hydro dynamics or aero dynamics, you will know what is an aero foil; so there are flows over aero foils, it can produce lift it will if you deal with; if you study that a little bit, you will see that there are different ways in which flow over and aero foil can produce lift.

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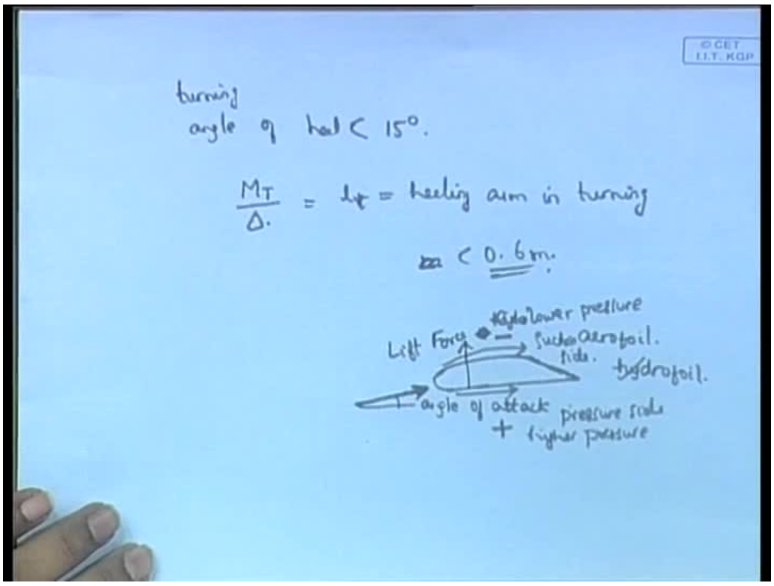

It is due to just quickly I will mention it that if this represents this is a basic structure of an aero foil, and a hydro foil is very similar and shape; so we can say that, this is the hydro foil so this is the shape; if you call this to be the shape of a hydro foil what will happen is that you bring an air like this if the air stream comes like this (Refer Slide Time: 44:53).

So, this is the structure which remains like this (Refer Slide Time: 44:53)and some air comes like this (Refer Slide Time: 44:53) or in our case we are talking about hydro foils, we deal with water when water comes like this (Refer Slide Time: 44:53); when it will come at some angle, which is known as an angle of attack and this will produce because of the air which flows over the hydro foil and below the ahead or water which flows above the hydro foil or below the hydro foil, this fluid because of the difference in velocity of a fluid, differential pressure is created here, and here so this region will end up with a lower pressure this is minus and this is plus.

Lower pressure and this region ends up with a higher pressure and so this is a negative pressure and this is a positive pressure; which we call as and this side we usually end up calling it as the pressure side and this is known as a suction side or the phrase and back whatever you call it and one side is at a higher pressure, one side is at a lower pressure; you know that when there is a when any system excess in a continuum, such that there is one side higher pressure and one side lower pressure.

There is a tendency for a force to act from the region of high pressure to a region of low pressure; so in this case there will be a tendency for a force to act like this (Refer Slide Time: 44:53);so from this high pressure to low pressure, force will act this, force we call it as a lift force.

So, this concept of lift force comes into play; in the case of a hydro foil craft so in the hydro foil crafts, because of the high speed in which it moves and the way in which it is designed because of the shape of the hydro foil and as such it will produce a lift on the hydro foil because of the circulation generated; it will produce a lift on the hydro foil.

Now, this lift infact tends to lift the let us call it a ship itself or a hydro foil craft that hydro foil craft is lifted up as a result of this hydro dynamically generated lift, so it is due to hydro dynamic forces and not exactly due to buoyancy forces; that is the difference between ordinary craft conventional craft and a unconventional craft which we call as hydro foil boats or hydro foil craft.

So, even a hydro foil craft or these kinds of vessels are what we call as dynamically supported craft; it is supported by dynamic forces rather than static force; buoyancy is a static force because it is just due to the volume underneath whatever is the volume and underneath and it is a static force, it is nothing to do with the velocity of the ship as such it as nothing to do with the dynamics or hydro dynamics its only hydro static; it is purely hydro static problem.

Now, therefore this is the this is what we mean by a dynamically supported craft; now even a dynamically supported craft can have two modes of operation, we say that it can operate into two modes; it can said to be operating in a displacement mode or it can be said to be operating in a foil born mode or a foil mode.

The difference is the two methods, I have already said if the DSC- that is the dynamically supported craft, if the DSC operates purely using the concept that its weight equals buoyancy Archimedes principle.

If it follows that concept, then we say that the ship is in or that craft DSC is in a displacement mode; if the ship operates such that its weight is now balanced by hydro dynamic forces ,which are coming due to the lift due to the hydro foil concepts; we say that ship is operating in a foil borne mode, so this is in general some basics about dynamically supported craft. Now, there are some specific rules for such- there are many set of rules associated with such crafts mainly because they travel at faster speeds and more likely to be and or they are more susceptible to

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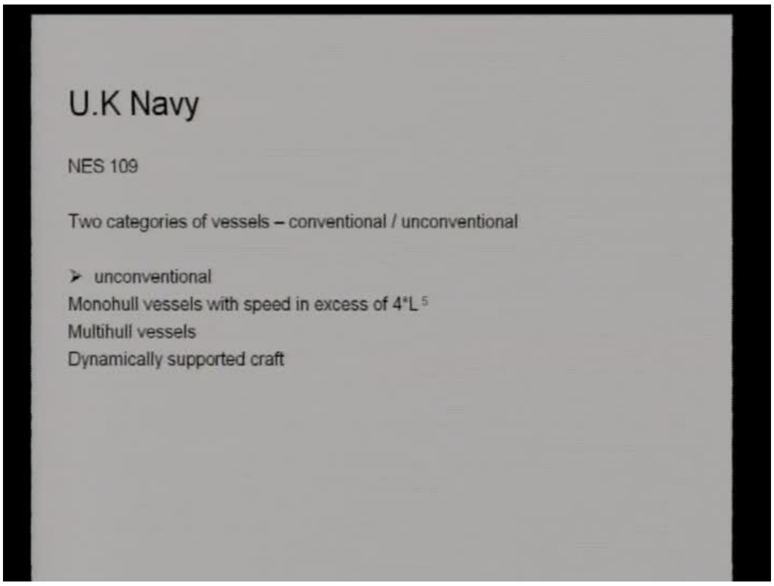

accidents or disasters; in fact there are lot of rules associated with that, some of those rules we are not giving, but please remember that these are some rules there are some special because we cannot mention all the rules in the short time that we have so we will broadly mention that, there are some similar rules that we have already specified for the other type of craft; that is the like we said the passenger vessel we have given a set of rules associated with the dynamical stability.

Now, the same set of rules can be there are adopted like that for dynamically supported craft as well and these are some of the rules associated with the US navy; now they have their own set of rules associated with wind heeling; for instance that is an important thing. Now I will go back to this.

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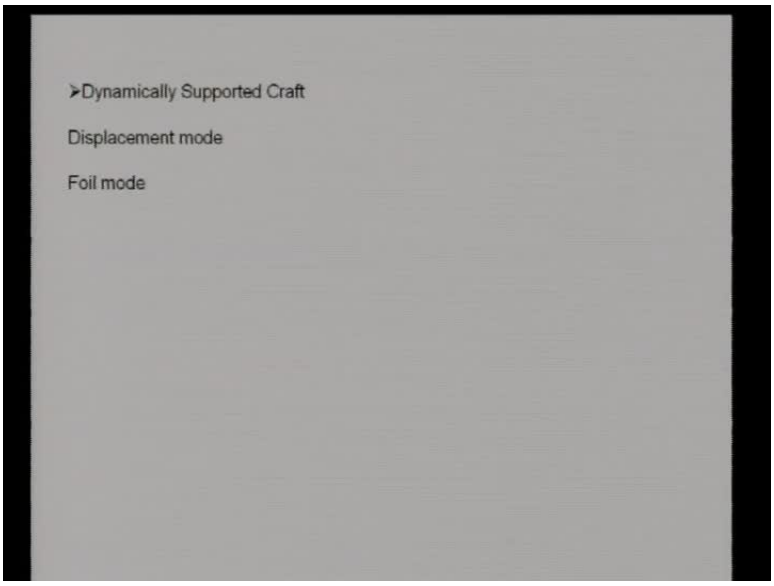

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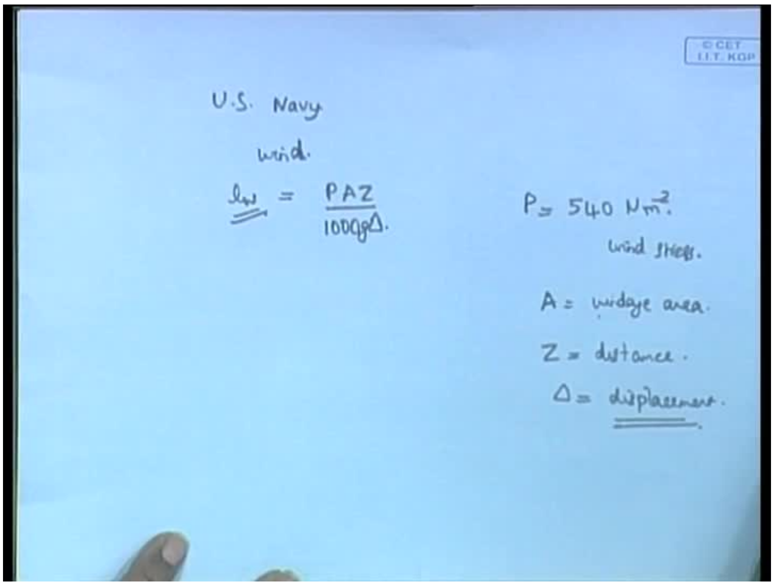

Now, the US navy also has their own set of rules associated with the wind; the US navy specifies that the wind lever which we call it as the heeling lever where the wind is associated, it is usually given as PAZ by 1000g delta.

So, in the previous definition sometime back when we did the wind heeling arms we talked about the general IMO rule, which is how the IMO generally states, which is the way in which IMO generally calculates how is the wind stability? Whether its stable or not. Now, the US navy has a slightly different way of dealing with the wind heeling arm;

US navy as a slightly different way of dealing with the wind heeling arm and what so we will go into that so first of all what they says is that, wind lever or the heeling lever is given by this formula PAZ by 100g delta; I will tell you what each term is- P is a is usually defined as a wind stress and it is given a constant value of 540 newton per meter the meaning of this is something like a very high value which is the maximum for instance that the ship can experience in the most violent weathers; usually the most violent weathers come in regions of north Atlantic and in the Baltic Sea somewhere in those regions.

You have the most fears winds and most powerful winds, which produce the most dangerous conditions. So, we say that in this P is assumed to be about 540 newton per meter square, this is the wind stress; then A is a particular characteristics of the ship it is the windage area it which means the area in the ship which is expose to wind that is it is not just that total area it is not important it is the projected area

So, if the ship is like this and let us assume that some region of it is above the water and if wind acts like this the wind acts from this direction, it comes here this area which is above which is projected onto this plane; so this area does not matter, it is only this area that matters project, this area into this plane you get the windage area, so that is known as a that is a windage area.

Then Z is the distance between the centroid; so if you have the windage area here, the centroid of that windage area to the T by 2- you know T by 2 means, again the concept is this the wind acts at the centroid of the windage area can be assume to act the centroid of the windage area.

The reaction from water here can be assume to act at the T by 2 half the draft- means the total force is acting over the whole draft and if the force is constant; that force can be assume to be acting at the centroid which is at T by 2, so the distance between this centroid of the windage area and the centroid and T by 2 that distance is Z.

So, Z is that distance, g is the acceleration due to gravity, and delta is the displacement of the ship; so once you have this you end up with the wind lever; so you get the wind lever and there are now a couple of formulas which give you what are the stability criterion, how the role of the ship is calculated as a function of this lever. since we are out of time now, we will continue with that in the next lecture, so we will stop with that today thank you.