Seakeeping and Manoeuvring

Prof. Dr. DebabrataSen

Department of Ocean Engineering and Naval Architecture.

Indian Institute of Technology, Kharagpur

Lecture No. # 34

Captive Model Tests and Experimental Determination of Hydrod Ynamic Derivatives

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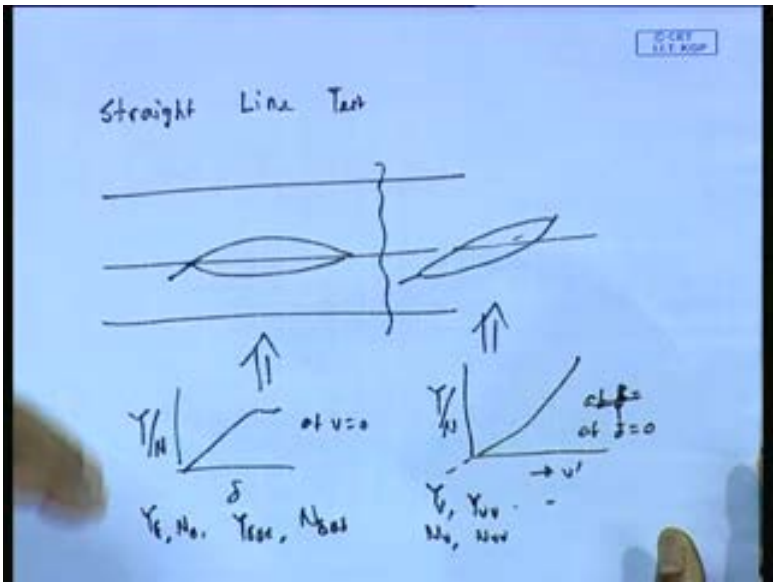

Ok, see we were talking about experimentally finding out hydrod Ynamic derivatives using captive model test ok. So, what we talked just last lecture is straight line test what we call. So of course, I will have to keep drawing this always; so if I do this way this or let me put it this way otherwise make this. See, what we said in the last class I could find out Y versus v that is Y v Y v v etcetera and N v N v v etcetera because they are nothing but, slope of that if everything else is 0 that is at delta 0. So, I am doing this test keeping this rudder fixed at delta 0 and towing it right.

Here I want I can find out Y delta, n delta, Y delta delta delta N delta deltadelta etcetera. Doing the test at v equal to 0 means, no angle of attack. This what I said last class, but now I want to tell you how I can find out Y delta v the couple terms from the same test ok. How do I do that? Now, remember that this this this part.

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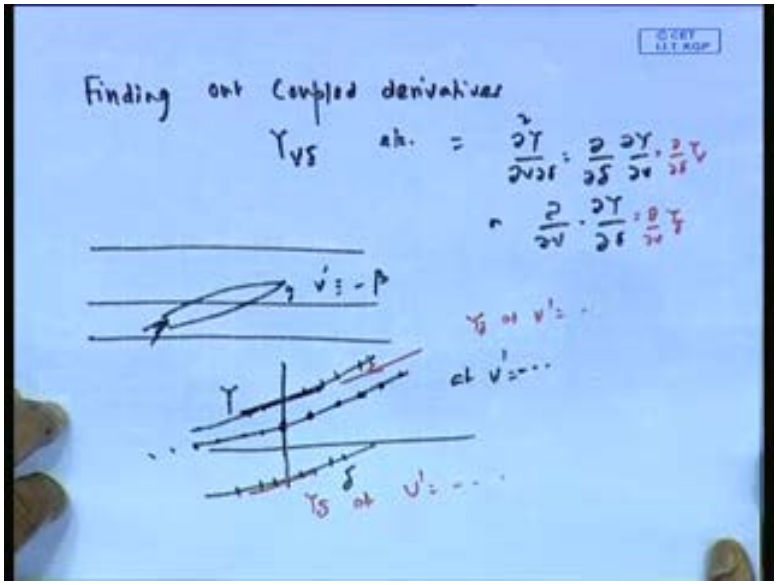

How to find out, how do I do that remember what is Y v delta, this is nothing but, d Y by dv d delta or you can say it is d by d delta of d Y by dv or we can say d by dv of d Y by d delta whichever way you call, essentially that is what it is right. The Y v delta is basically proportional to d square Y by dv d delta. That is a second derivative with v and delta, that is either it is rate of change against rudder angle of Y v or rate of change in other words you know this first term is d by d delta of Y v and this term is d Y dv of Y delta, whichever way you call the same thing how do I do the test see it is very simple now. What we will do we are going to the test now keep a non zero v and then rotate this that means for a given v or beta, I do the test and find Y, so what I am doing I am going to do here Y versus delta, at v equal to some value. What I will get a point it will look like that may be something like that. I am going to tow this model with a value of drift angle beta that is v dot and keep it fixed keep it towed and also give a angle delta.

So, now for let us say I keep it 1 degree, so for 1 degree I will now keep varying delta from right from 0 if I get 0 I get this point, then I get one degree etcetera, I keep on varying this delta. So, I will end up getting this point, so this graph that point I measure will be for v dash equal to some value. Now I will repeat the same thing for V dash equal to another value. Now you must get this in your mind see, what we are doing is we are fixing one variable beta, in this case I showed and for that given beta I change keep on changing delta and doing the test. So, then when I measure Y versus delta then the graph I get will be for a given beta, one line will be that for particular beta that I kept say I kept

at 3 2 degree the beta angle so I kept the beta angle 2 degree but, I keep on varying this and keep towing it. So, what would happen I will find Y versus delta for a given v dash or I can do the other way round Y versus v for a given delta.

What then what happen, what is this slope now I got these points, what is this slope this slope is see Y delta at that v that so this one. So, I have got different Y delta versus v then I what I do I have to make a cross plot, Y delta against v dash if I plot. So, what I will do next step is I'll plot, so it might be very small may be whatever you expect it to be small.

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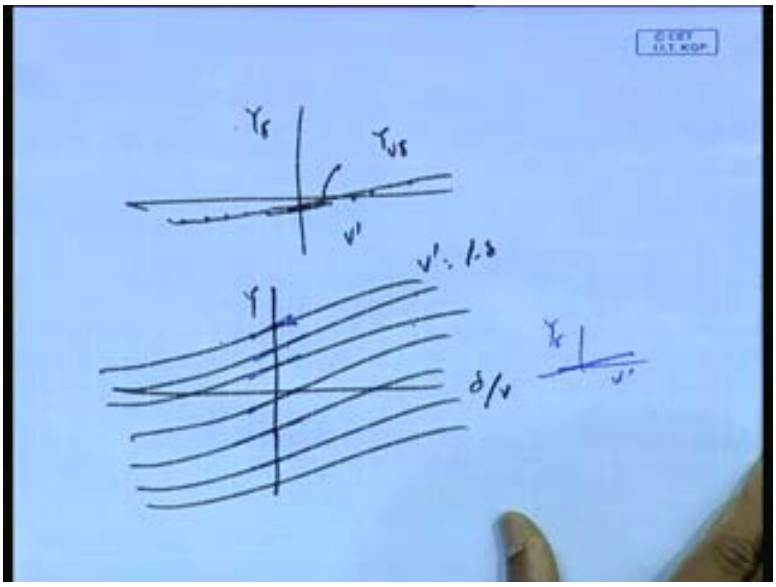

This slope then I will take this slope is going to be Y v delta. So, you know what is happening is essentially the question is that see, if you look carefully there is a slope here, there is a slope here there is a slope here, it is the change of the slope against this. That is what you are looking see there is a slope here, say this slope is some value 3 degree let me just give an example, for v dash something this is also going to be close to 3 degree may be 2.5 degree this going to be 1.5 degree. Now rate of change of this rate of the change of the slope, against this parameter for which you have taken, is my second second order rate of change which is of course, always very small. You know you can think you will expect them to be parallel, if they are actually perfectly parallel then in fact it become 0 it will show 0. They are not parallel it will not be 0 in fact, what will

happen you will end up getting a series of graph, for different values of v v dash delta versus Y you can do the other way round also I can also do v and against delta.

Then I will take these slopes; remember I am not measuring this point. I am normally measuring the other points, then I will again replot it this slope versus v dash because, I know that this slope is for this v dash, this for this v dash this for this v dash, get a line which is very small, then this particular slope is going to be my Y v delta so you understand that. Now what normally people do you know, it is all the question of curve fittings. I just showed you the principle that yes, in a straight line test it is very interesting since the parameters I can I can vary are v and delta, I can always find out derivative against v, derivatives in delta, and derivatives couple derivatives of v and delta it is always the case. If I could vary x and Y a f z as a function of x and Y, then I can find out from the measurements slope against x, slope against Y, slope against x and Y is essentially a surface we are looking at this is the principle the principle is this.

In practice what we would do, you will be getting this points and doing the test. And it is all automated now a days because, there will be a computer program written which you would have actually found out by least square fit because, you will never find the points in real life to be falling on a straight line you are going to always find in experiment point will fall, then you have to actually assume a curve and then you have to fit it.

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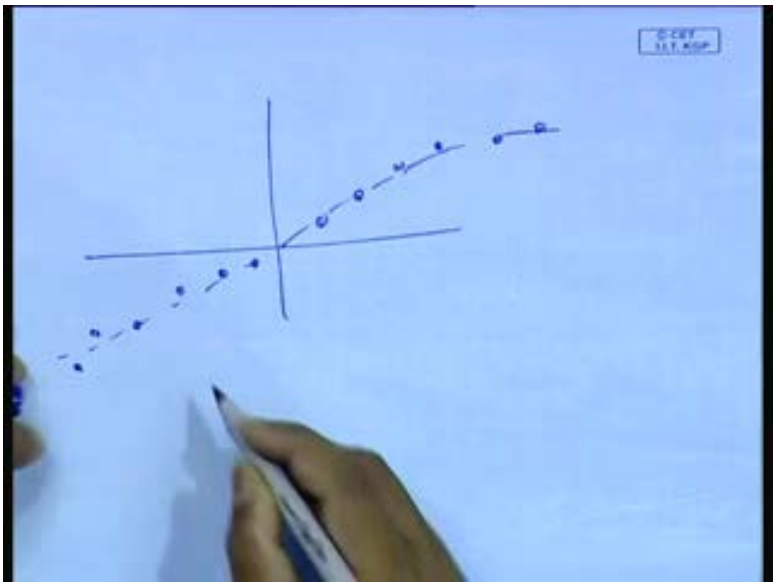

What I am saying, that it will always happen that experimental point will always lie something like that. It may not be lying exactly on a straight line, you have to simply use the least square fit, typically it is coded within the program like when you are doing a test here you are going to basically sit on a carriage. You know there will be carriage there on which you tow it you finish towing, the carriage will have its own in built computer processing is done, you end up getting this coefficients. That is what you end up doing it remember this coefficients will always like no experiments will be a perfect fit you have to actually determine this.

So, a so this cross plots etcetera what I said, can is also coded in a computer depending on the model you feed the data will be processed. Remember again the data that measurements are only this points, this set of points these are the one that you are measuring. Let us say you are doing over 10 delta and different v ranging from 1 degree to say 10 degree both sides. So, 20 20 experimental point for let us say 20 degree so 400 or so whatever depending on your run you can analyze that.

So, this is the question of how we can find out experimental fit. Now this is my what is called the straight line test. So, I will just summarize the straight line test before, I go to the next level of test.

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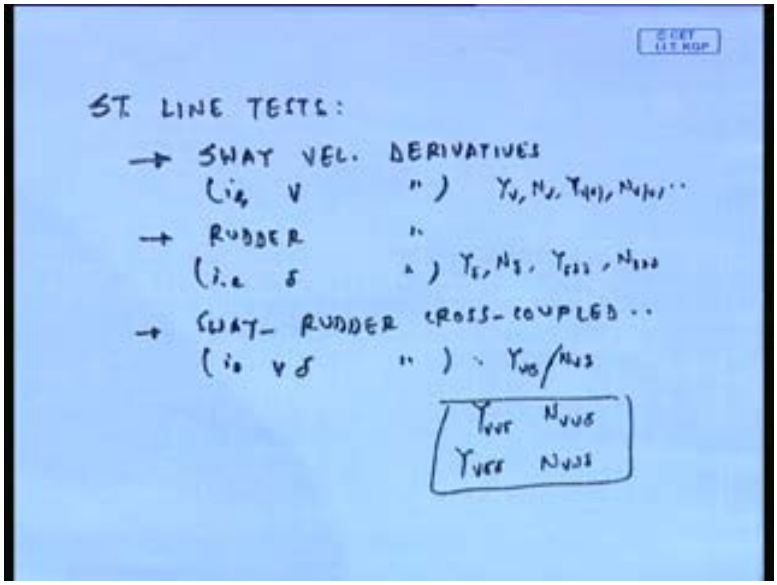

So, you see I can therefore, find out the straight line test. We can find out ((no audio 11:09 to 11:43)) you can find v derivatives which would be Y v N v Y v v N v v etcetera

you can find out here Y delta N delta, Y delta delta delta N delta delta delta. You can find Y v v d N v d and I leave it to you if you do not like that you can also find out Y v v d and N v v d, Y v delta delta N v delta delta even this can be found out. It is just one more level, you remember when you varying some parameter you can also find out by fitting I am going to leave that to you to think and tell me, how you can from the data how you processes it to find out say Y v v delta and Y v delta delta Y and N are same thing.

This is also possible because, remember that I am varying v and delta. So, it is a question of varying you know x and Y and therefore, taking higher and higher derivatives. Normally obviously you expect slope of slope, and slope of slope of slope will be a small number always so. You know so they are very small numbers usually, but why it is retained because, it has been found out that for certain extreme maneuver when you are going at a very tide turn and all they may have an influence. This one has a very strong influence Y v v and N v v or Y v cube, you should not in any trajectory simulation or any studies neglect them because reality has shown that this is actually fairly quadratic.

So, this is now what is I will just go to the p a next test. What is the advantage of this straight line test, simplest to carry out because, you do not need a facility towing tank serves the purpose, still you do need in d Ynamometer a 3 component or whatever 5 component depending on the type of test you do. You find out you need a d Ynamometer what is the limitation, you can only find out this derivatives not all, It will remember that only this derivative did not solve me because, I needed minimum Y r N r also at least to assess my straight line stability. So, this is a simple case, but we call straight line test, now we will go to the test that has been devised called rotating arm technique which is specially devised for finding out rotary derivatives. This is type 2 test type 2 I am calling it here; see this is mainly devised for rotary derivatives, that is r rotary velocity derivative.

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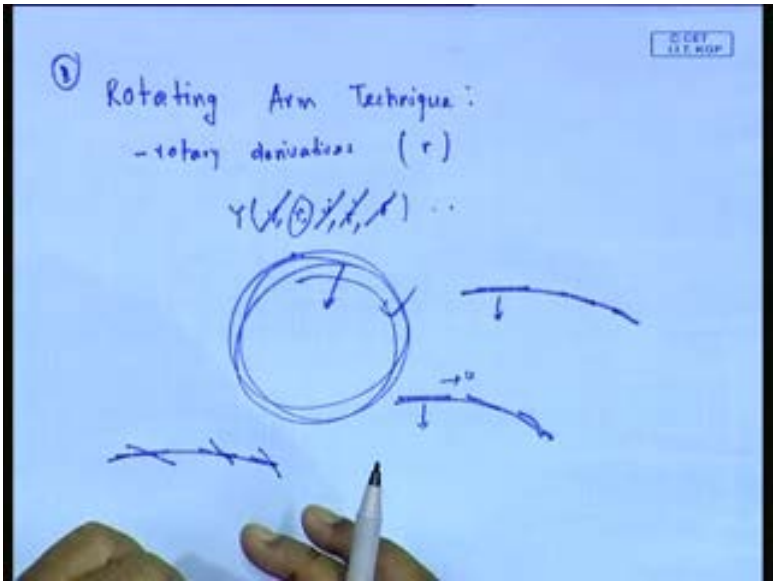

Now you see what I will need now here interestingly as I said in last the beginning of last class I therefore, want to make sure that everything is 0 only this is non 0 means, I must have a set where I am able to achieve only r. How do I achieve r you know that when you rotate it, see when you rotate something like this way, you take a string and you rotate it you end up getting r, but no v because remember v is this side and you are actually if you if you make it always tangential this side v is always 0. You see here I am just before, I tell supposing I take a object and I just rotate it this way and object is always tangential to that, what would happen I have a u here, but my v is 0 but, I have r here. So, this what you have to do, but remember in isolation the ship cannot do I told you that the ship can never go exactly like that it has to have a drift angle, it has to have a v and r together it can never have only v only r in fact, it cannot have also only v in free running crest.

That is why, that is why the word captive tested. I now want to hold it in such a way that I can give only r and no v, how it can be done obviously by rotating.

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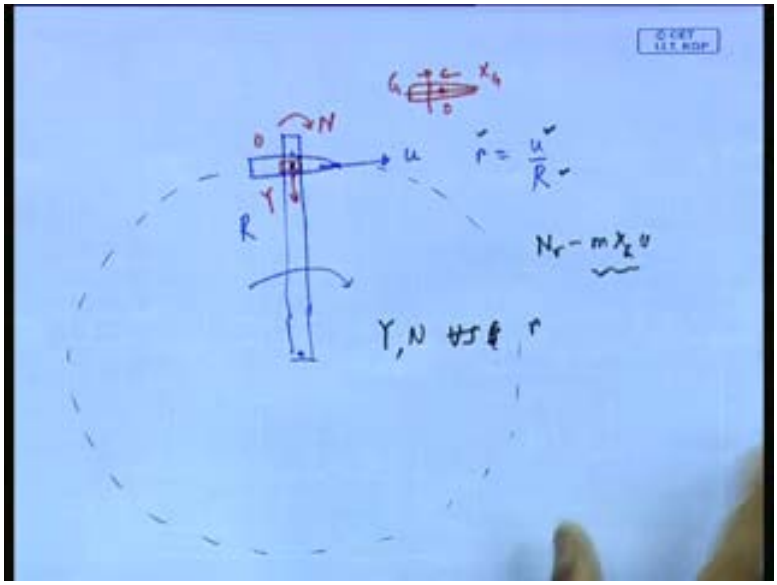

So, the device came the device will look like that, I have a tank I have an arm like that long longish arm like that. This is a set up if you see there will be a carriage long arm. So, this point somewhere I can fix my model and this full thing can be rotated this full thing can be rotated.

So therefore, number 1 number 1 is that, you need a special tank a device because, it is a square tank square tank square type of basin call maneuvering basin anyhow I will first let me talk about the derivatives how we do that and then we will talk about the limitations what do you need you know etcetera. You see here I go it with a value u, I rotate it what is my this is R. Let us see this radius is R, what is the formula R is u by R. Isn't it is that is the formula for rotational velocity rotational velocity into R is u linear velocity is isn't it. So, what we are doing very simple again I rotate this bod Y I have a d Ynamometer measure Y and N this always of course, be there because I must have a d Ynamometer at that point of a action it, you know I am not going to the detail it can be C G it can also be at another point sometime it is advantageous to put it another point o and there are corrections they are small inertial connection.

What I mean, the point of action sometime it is convenient not to be at center of gravity G because, center of gravity may center of gravity may change depending on loading condition. So, it is sometime easier to put a point o and if you do the point o, what you measure will have some correction terms what you will measure will be actually say in

terms of N r you will measure N r minus m X G into U. You know this extra time will come. What I'm trying to say is a that part is trivial part because, the what you measure will have inertial component you can take it out. Suppose I put at point o which is a distance X G from center of gravity, then additional momentum comes m X G into U. m u into X G that part the instrument will measure force which will be the hydrod Ynamic force plus this force. So, the hydrod Ynamic force is going to be measurement minus that etcetera, it will actually measure plus. So, what you what you will measure is this value so from there you take it out this so you get this.

I do not know I let me again explain to you, see what is what I'm saying here, I am measuring by towing rotating it by this at a speed which means, what I am giving an R no v my v is 0 because it is fixed like that my v is 0 but, I have got only R. so I am able to vary R what do I measure I have a d Ynamometer at this point. So, I measure Y force and N moment. Now my point was saying is that supposing where I connect it this connection point is not C G but, a point o say the connection point is o. And o differ from C G by X G then what happen what you measure, will be the term N r minus m X G U. My objective is to measure N r so that is very simple my instrument will say for example, give a moment of 50 kilo Newton meter. What I have to do I have to simply take this much added minus you know like correct for m X G U to find out N r. Because I am trying to find out N r so these are very trivial point, what you measure will always embed some other constant quantity that is what I am trying to say. What you measure will always have some other constant quantity because; the inertia equipment cannot take that inertial part. So, that is a trivial point forget it we know.

So, what we are measuring here Y and N versus r, everything else is 0. So, I can easily plot again Y versus N for r. How do I change r, tell me how do I change r this r because, I have to do at over number of r of course, I can change u, but I can also change r remember u is a forward speed. Normally what happen now this is a point I want to tell you and you keep in your mind this one. Here we are presuming that the derivatives remain constant whether the ship's speed is 10 knots or 15 knots or 20 knots. That is what we are saying because you are dividing by and assuming to be constant because, you are telling that I will do a test at u and it is not important because, I divide by half rho u square.

But in real life what happen you do not know for sure. So, it may depend on u so that is why the test should be done as close as possible to the service speed of the ship u. That means supposing I am doing this test for a ship which is designed for 16 knots, then I should try to take a take a scale speed u of 16 knots and try to keep it close to that instead of varying u I should try to vary r that is my point. Because varying u you do not really know because you know at 14 supposing I vary u and do it at a very low speed of say 3 knots or so equivalent 3 knots I will come to the scaling in a minute. What would happen you make you well you get a non dimensional derivative all right, but you would may not well you are doing experiment you are not very sure, it may be very close good enough very good. So, you would try to keep the u to be rather close to the surface speed and change r. How do you tell scale u normally you scale by foot scaling normally so you know foot scaling you know 1 by root lambda.

Same thing applied to the straight line test, the speed you are doing normally you keep the foot scaling speed. And then you basically vary the angle of attack beta there. So, here you should vary r, mostly now you know now here comes the questions, see many questions will come here, number 1 is that I will ask this question, how do I make well see.

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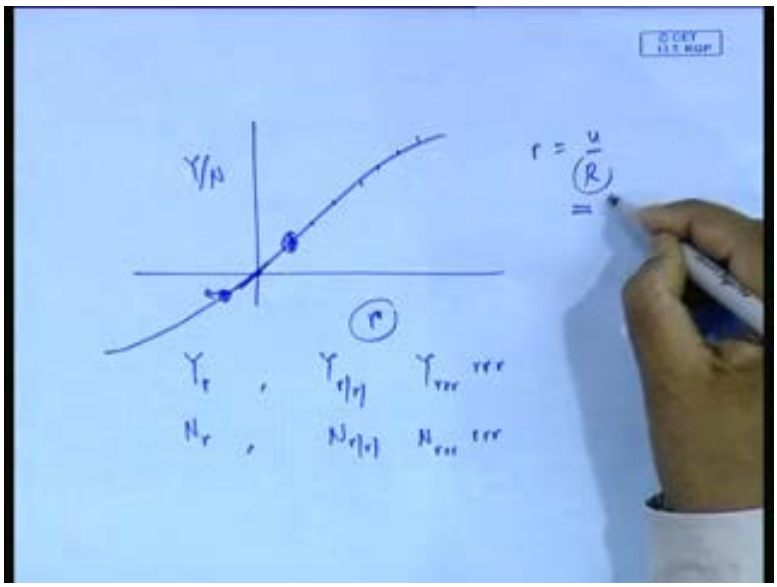

So, what is happening I am having r versus Y and N. so, I got these points so as I said r equal to u by R and you are changing this r you are getting this thing. How do I get

minus r, how do I get this side I need to do both sides know, how do I do it you tell me it is very simple, see here this one see this point if you see this point, you know turning this way. I basically want to turn this side for the other r isn't it both. See this if this is plus r, then this is going to be minus r. That means this side is entering see this this point is entering to the curve if it is plus r then I of course, want to do also this way. So of course, what I should do you simply turn it and tow this way turn it and tow it the other way round see basically, rather turn the other way round like I bring this here and turn this way exactly. So, I basically will change this see I'll change this way and turn this side see here, if I turn this way this empty edges entering if I turn this way so r can be changed.

So, you have to do that I mean, I am why I say sometime it is not explicit in the mind you know. You do not turn this side you have to turn the model upside down and then see you have to change the model and then turn you get it opposite r. Now we have got this let us look. So, we know that we can find out Y therefore, it is very simple that I can find out what do I can find out. Y r Y r r Y r r r r r r r N r; that means Y versus basically the derivatives against r that means I am able to determine in this experiment the derivatives against your velocity linear and non-linear, remember this. See I'm going to ask you this, what derivatives you can find out by doing a test? In our maneuvering there is not much of numerical example or questions you really cannot do it, you know you have to have a hang off various kinds of small numbers of derivatives the main purpose is to understand this concept of derivatives the forces how the hull turns etcetera etcetera

So therefore, what I am saying this test you'll know I can find out Y and N forget Y and N this is the force output against r that means, derivatives against yaw velocity linear and non-linear. This is known as rotating arm techniques before, I go to what else we can do what are the other parameters we can do let us look at this some of this you know like. Let me rather I will get back to this may be little later, let us find out before that the technique part only. Remember that r is r can be changed so let us presume for now that I can vary r by this thing, but I cannot make r as 0 remember I always wanted this therefore, I want to do the point as close as possible isn't it. See I want to get measurement as close to this point as possible that means, I want to make r as small as possible. How do I make r as small as possible, making u as small as possible, but I said u should not bring it small.

Then making are as large as possible, but I r there is a limit in any case we will see that larger the r, better the experiment to this point larger r means, I need a larger r larger r means larger facility. But, I will come to the facility part in a minute, but I let me first talk what else we can find out tell me, what else we can find out from here. Can we find out Y v N v and and and and the and the Y against v. Now here is the interesting point and then Y delta N delta and etcetera. Now one thing you know, let me put this way whether I can find out this part, can I do a test where I have both r and v the answer is yes because, I can always tow the model now with this orientation. So, I can have a fixed v and fixed r, so I can always do the test at a fixed v and fixed r, get this point again clearly that if I were to tow the model or rather let me go to this diagram.

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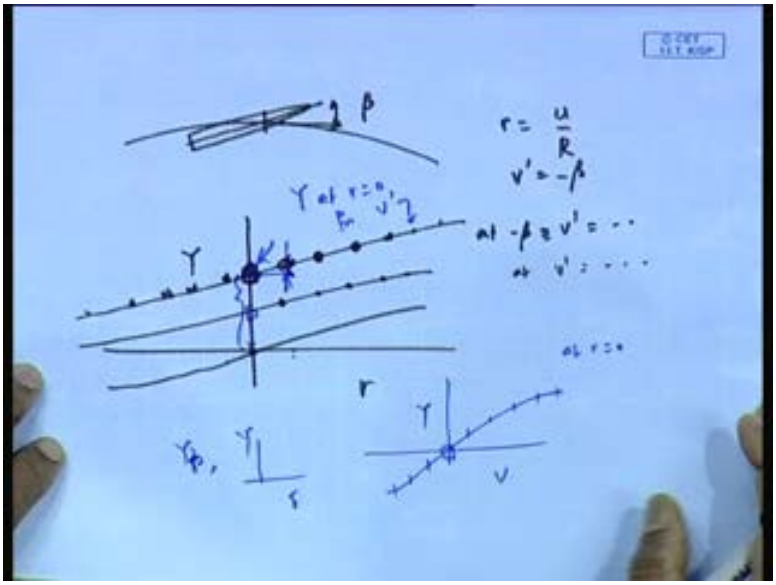

If I were towing the model with an orientation like that what do I have I have r but, I have also P dash. In fact, I can rotate plus minus like for a any r I can have different beta or I can do the test for a given v. Now r versus Y I just you show one so I do a test measurement, what is this is at beta or rather some value now do another one you understand what I am saying. I can do the test now for different beta, see I do a rotating arm test with beta equal to 0 that would have been going through this point, but then I do the test with beta equal to 2 degree that means, I am having a v and r and I measure the Y force but, remember I measure this forces because, r is never 0. I have not got remember this is very important I have not got this point because, I cannot measure it because this point is r is 0 r 0 means, I had not really rotating it or rather I have to have infinite radius

means I make it as see r 0 means, r infinity means making this circle infinitely large radius means a straight line test by default making r 0 is making a straight line test I'm not doing it after all.

So I am getting only this point this point, but what I could do indirectly is that I plot this value and I can get this point from the graph therefore, I can measure Y from the experimental at r equal to 0. See here I have got then Y value what is this point, Y value at r equal to 0 for this v. Now I take this points Y versus v at r equal to 0 get Y v indirectly so you see I could get Y v here indirectly although it is not recommended because you are not measuring the force here, but it is supposing you're stuck in a facility which has only this many Russian labs have this you would be able to find out.

But you see we must understand, you know experiments are very expensive you may take one week time to make a model make fix up etcetera know make the fixtures etcetera you know take a facility the cost is very high. So, when you measure data you must make sure that you are using the data to the fullest extent, whatever possible to derive from that data you should use it. Otherwise it is a waste of effort you know you would have paid in our term may be lakhs of rupees and some facility in fact, I can tell you for real project for naval project it goes to corers of rupees in with facilities facility charge are very high. So, you would like to get maximum things so always took the raw data and find out everything possible. So, I will just show therefore, even Y v is possible to find out.

What about Y delta same thing because, I can just give the v 0 and change delta. So, I can also find out Y delta indirectly. So, I can also find out Y delta and obviously when I say Y delta I can basically measure Y versus delta. Because I can measure this Y versus delta the r equal to 0 by extra potation again instead of v I will turn this model with different rudder angle.

Rudder angle.

That is so I will get Y versus r, for different delta then take at r r 0 point by extra potation so I would know that value of force is basically at Y coming only for delta because, r is 0 at that point. Like this value this force this force must be the one this much extra is coming for Y as r, but this much must be coming because of Y at v because here r is 0.

See at this distance because, here my r is 0. This one is my Y for v and r of it is this must may be for Y for v and this small one is the extra r part this part. So, you know that you see so what I am trying to say therefore, you can find it out anything more what about crossed coupled terms you can also find out.

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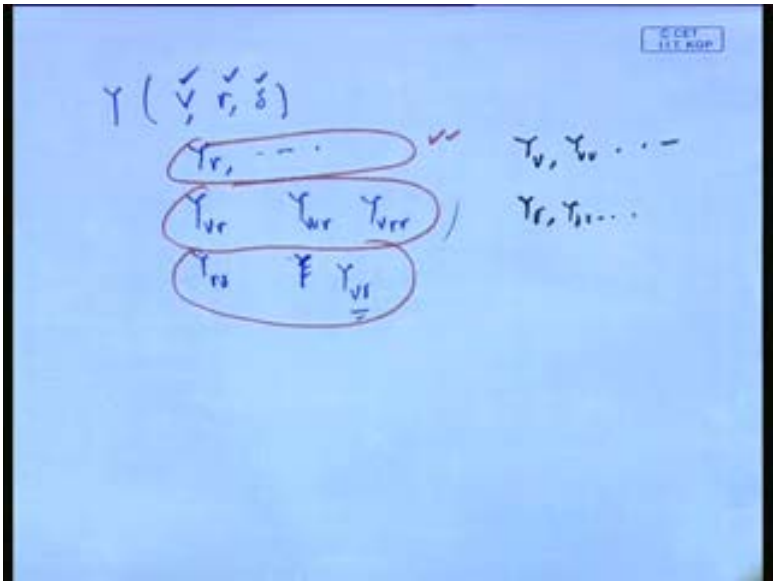

Obviously now I have I have an interesting point, see I find out that I can v r delta. I am giving r fine, but I can also do the test with giving some v with giving some delta right, because, you see I could do the test here, I am giving an r but, I can also give a v by giving an angle of attack I can also give a delta. So, obviously I told you that I will not elaborate you have to figure it out. How I can find out Y v r Y v v r etcetera. Obviously, this means I will be able to cross plot and find out Y v r or Y v v r Y v r r, I can find out Y r delta which I already said. I can find out here from well, normally we do not want to do Y v delta, this is a bit far stretching because r is not there but, I can find out this cross couple coefficients specially v and r coefficients.

In fact, anything that r couples with I can find out, see because you are the difference is therefore, you can understand this becomes a step higher than the straight line case. In straight line I could only give beta and my r mathematically speaking must only infinity this capital R. Because it is straight line straight line means cycle of infinite radius. Here I have r therefore, I have r but, also beta and that is v dash and delta is also possible therefore, I can do one step ahead of whatever I have done there, but of course, the

primary purpose of this test is rotating arm derivative which is difficult to do which is not easy.

Regarding the angle very simple I can always change it see this make it this way my beta is the opposite so I can always do for a given r plus beta and minus beta delta same thing I can keep it this way I can keep it this way. So, I can basically find out this derivatives rotating arm technique by the very term it implies therefore, I can find out primarily Y r etcetera. That is a that is a most primary part primarily rotating arm technique therefore, I can find out this that is a purpose main purpose of this but, I can also find out indirectly Y v Y vv etcetera. In fact, I can also find out Y delta Y delta etcetera.

Although we do not do that, or even if you do I will tell you what is done, but other thing important is this and this for this you cannot do it by remember these I could do by straight line test. Although I can do from here also, but I can also do in straight line test. In fact, straight line test I only do this and of course, v delta couple here I am getting Y r values, but what I said is that I can also find out this indirectly. What typically therefore, you would do you know tell me any facility that you have, first thing that a marine research facility will have the towing tank. Agreed because towing tank is the first level of test I mean you would not get a maneuvering basin, but not a towing tank normally you would not expect that so towing tank will be the fundamental facility available all you need is a d Ynamometer to measure those straight line test. So, you would normally do always straight line test available.

Then some facility will have rotating arm technique was straight line test is not good enough you see it is not giving my Y r values which is important without the Y r I cannot find out even the basic level of maneuvering. In fact, this two would give me somewhat but, I still haven't answered the added mass derivative v dot r dot. Remember but, at least with this I can find out stability index you know that c coefficient. What you would do logically you do a straight line test and get this numbers, you would do a rotating arm test and get this number but and also as I told you having spend so much of money you would also get this number. So, then you'll have this number coming from two sources one is straight line test, one is rotating arm test the act as a reinforcement to each other the act as a verification. Which one would you trust more if I would to if you are to put your money you trust the straight line test because, that is more captive you know more controllable, but normally you would find out this and compare with that say.

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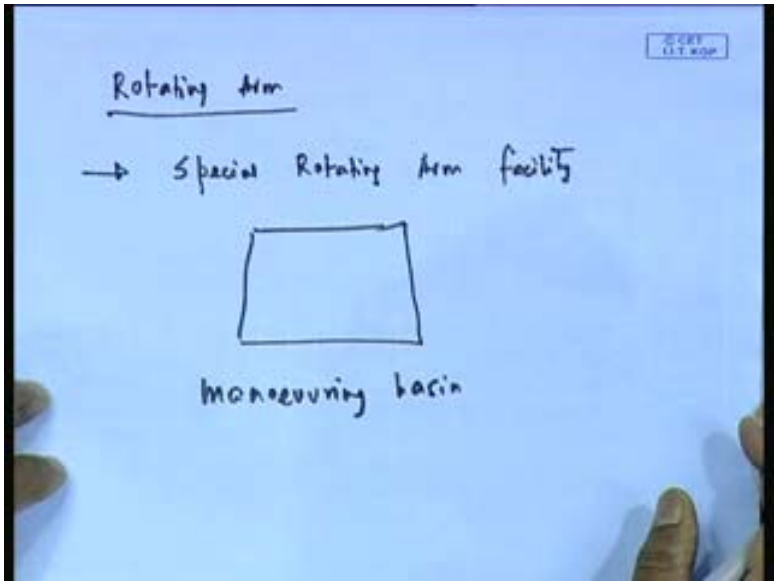

Now, I will tell you what are the problems with a you know these are the issues what are thing of rotating arm technique. You need number one, a special facility let me just write it down from here, you need a you tell me this involves what this facility when I said is it the equipment of the making it rotating arm. See this itself is an equipment you know this is going to be a carriage type thing this long arm going below that there will be some kind of connection where you can put a module etcetera. Obviously this thing if you look at that is cross section point of view it will look on a tank water surface is here, this will be this thing you will be able to take the model and this full thing has to be rotated something like this thing model is here, water surface is here, you will be able to rotate it you sit here this is the carriage you rotate the model.

So, you need a rotating arm facility itself, but more than that I why I brought it you all think a special tank remember that I need to make as big as possible. I said that because if I make it as big as possible I have r as small as possible what is a typical value used is about 30 meter 40 meter 25 meter you know for typical that means, I need 30 meter or 25 meter range about 50 meter 60 meter square tank. So, that means I cannot do in a towing tank I need a large basin, I will need a large basin manoevuring basin. In fact, in our country we do not have any rotating arm facility, there is a basin there in IIT madras but, there is no rotating arm for you need the basin on which rotating arm equipments which would obviously be as I said a long arm which is turn. So, this is a special facility you need.

Other problems suppose I turn it one, can I keep going down and down and measure how long I should make the measurement force after all the force will be transient and then it has to see when I start from there it'll accelerate. So, the force is not yet at stead Y r you accelerating you are starting then when it becomes stead Y only then you have to take the measurement. How long can you take the measurement can I keep on going number of rotation? The question is why no the waves will get created fluid will grow is not then more issue, but the surface will get see. I am supposed to the test in a in a calm water but, moment I come here it has alread Y got it is you know like surface wake. So, the wake comes out therefore, I need to actually come back and more or less measure it within that time otherwise it will go to travel its own wake.

So, that means I should be able to accelerate quite fast this full thing. So, you know it basically amounts to requiring specialized equipment etcetera. And that essentially means I need a large and large tanker as I said once again I therefore, need a large extent I need this large and also accelerate fast therefore, I need a larger tank, I need a capacity to accelerate this full thing very quickly, it obviously it is not a very small thing know this full rotating arm has to quickly turn. This is if you are thinking of this 20 meter bar with a model here and of course, a facility to change this r because, the model it should be a long arm where I can the extreme extent and you can change the model at various locations then only I you can change the r. So, all these facilities are required in order to do this rotating term arm technique and this the one that I can find out.

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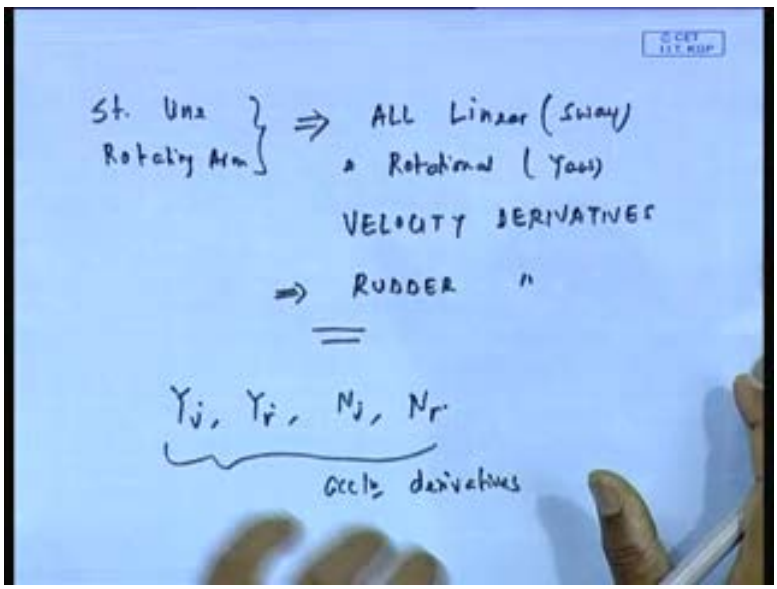

Now I am going to talk about, well so this two test let me just now compliment this two take straight line, all linear that is way and rotational velocity derivatives. This is what I can find out by some means, linear non-linear I am not talking but, I wanted to talk once again I emphasize the what non-linearity I wanted to introduce because, if I did not do that and I did this first you would not know that the test can also determine non-linear derivatives. As I said when you do a test you should try to find out maximum available no point of doing a spending a money and find out and that I could find Y v and then you do not know what is Y v v. See is it the end of the story, remember that I need now also that is acceleration derivatives or I may call added mass forces. So, I also need to measure this now this we will discuss later on but, for this there are lot of you know by itself there are equipments to measure only added masses but, should not it very nice to have an equipment which can measure, this as well as this all together you know you would basically you are looking at this and this all together.

This particular there is equipment that has been devised or well I can say invented in about 1960s by an American it is known as planer motion mechanism, it is a mechanism which fortunately can be applied and implemented on a towing tank. So, on a towing tank it is an equipment therefore, see rotating arm is a facility and an equipment because, I need a facility of a strong long tank a square tank basin straight line is a facility in a sense equipment because I need in a towing tank just a force d Ynamometer.

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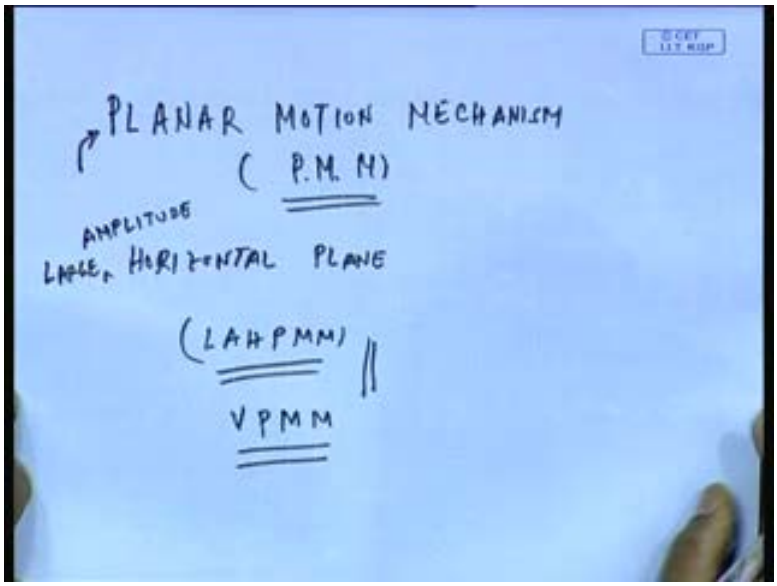

The planar motion mechanism, this I this I will discuss that later on next class this which call planar known as P M M is an equipment or instrument that has been devised which can be used in a towing tank. But, it can find out all the derivatives that is acceleration as well as velocity derivatives. Obviously the technique is going to be slightly complex but, this is very important this equipment P M M it can find out acceleration and velocity derivatives linear as well as rotational means, everything that we want to know can be found out from that equipment and instrument system. And you could understand that obviously the equipment the system the even the experimental technique will be slightly more different nature because, otherwise it would be simple this we will discuss you know eventually.

In that also there are basically prefixes there this is called horizontal plane. What I mean you can call horizontal plane planner motion mechanism in fact; some people call it large amplitude horizontal plane. I am just adding these words large amplitude horizontal plane planar motion mechanism that is L A H you can call L A H P M M this is a system that is used for ships, when it comes to submarines torpedo's submerge bodies remember we have been talking about ships only but, maneuvering is equally important if not more in fact, I my opinion is that is even more important for submarines torpedo's submerge bodies because submerge bodies are able to move in fixed freedom up down side all directions forces are also different nature this a neutrally point even in up and down etcetera.

For that the same equipment not same a similar, concept can be used with what is known is V P M M vertical planner motion mechanism. So, this mechanism we will be discussing in the next class at length but, since we have few minutes time let me tell you the principle behind that, I just want to rather give you this thought, see just let me tell you this.

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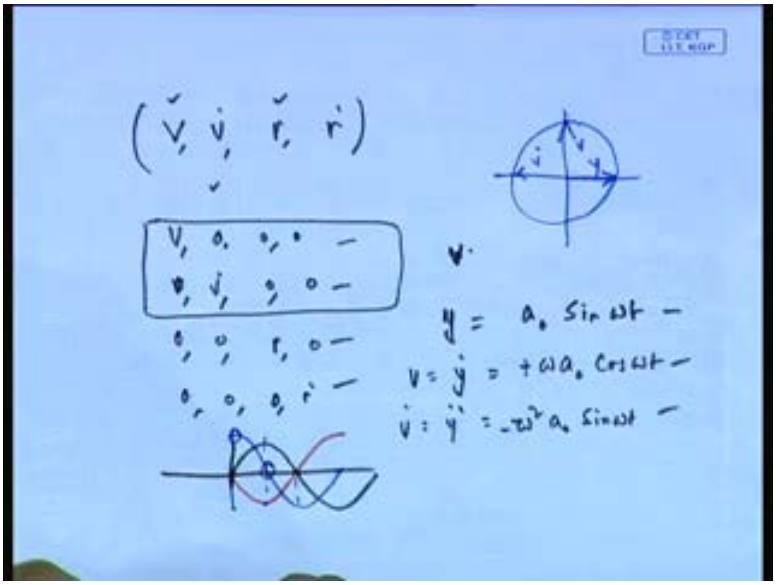

See I have got this V v dot r r dot, just let me take this. Now I want an equipment that can give me only V if I want but, only v dot if I want it should give only r if I want see that means I want V 0 0 0 or V 0 v dot 0 0 0 0 r 0 0 0 0 r dot I mean, I should be able to create all that tell me what kind of motion let us take just this two what kind of motion can possibly give me only v and only v dot. Why I'm asking you know is interesting specially from sea keeping point of view. See just take an example of sinusoidal motion I have some motion say velocity V or say Y displacement given by a 0 sin omega t. Something is moving up in Y direction in oscillating form. Now when you oscillate something it is sinusoidal motion what happen to V it is d Y by dt, what happen to this becomes minus omega a 0 you agree with that what happen to v dot.

Omega square.

Omega square a 0.

Now tell me this is a very interesting observation, what is the phase between the three if this is sine curve Y how does V looks like minus cos curve minus cos means, no this is this is plus sorry sorry sorry this plus and this is minus so plus cos curves plus cos means, it will look like that agreed how does v dot look like v dot will look like minus sine curve that is now tell me this is what we are looking at the blue one and the red one is there any way to isolate V and v dot because, I need to isolate V and v dot remember I need have a only V at sometime only v dot at sometime you can find it out here.

What you will find that see here at this point when I have got v dot v v my v dot is 0 and at this point when I have got V equal to 0 I have got certain v dot. So, what happen the this is the what is exploited you know when you take a sinusoid because, the sinusoid means it is like if there is a velocity displacement here it is here Y here V here v dot here they are by 90 degree phase difference there are instances where my V is 0 but, only v dot exists and there are instances when my v dot is 0 and only V exists

So, if I oscillate that a model then what happened there will be some fixed times at this time that time I have only v and v dot is 0 and some other set of times I have only v dot and v is 0. Only points yes but, we will find out that how that can be improved much more, but this is the principle concept that is used that in a sinusoid you are able to use exploit the fact of the phase gap between the motions, you have oscillation uh therefore, velocity and acceleration both are there but, there are fixed times where only velocity exists no acceleration and other fixed time only acceleration no velocity.

So, if I measured Y Y v Y will be time when my Y is only because of V. In some other time Y is only for V dot. So, this therefore, I can find out both Y versus V and Y versus v dot this is what is exploited in P M M which we will discuss at length in the next class we you'll find out there is only very simplistic way of looking at just to the be the concept over property of sinusoid phase gap but, of course, the actual experiment will be much more detailed processing is much more because, if you do any you know experiment you will never get a exact sin output graph that we will discuss in the in a next class.

So, next class we will spend on the final test of our this series of lectures on P M M technique with that I end today.