Numerical Ship and Offshore Hydrodynamics
Prof. Ranadev Datta
Department of Ocean Engineering and Naval Architecture
Indian Institute of Technology, Kharagpur

Lecture - 01
Introduction

Welcome to Numerical Ship and Offshore Hydrodynamics.

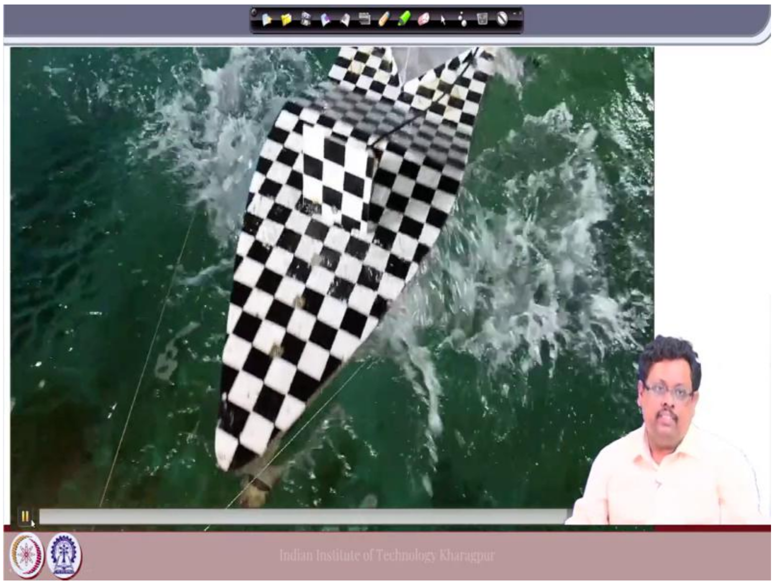
(Refer Slide Time: 00:17)

So, today we are going to cover this following concept, we start with the basic introduction of the course followed by the discussion on different problem statement and then we are going to discuss some different solution approach of course, there are lot of solution for this type of problem and finally, I just outline the overall course structure ok.

(Refer Slide Time: 00:41)

And these are the keywords that you are going to use while searching this video. Well, let us start let us start with the video.

(Refer Slide Time: 00:50)



Now you see the ship is moving in a calm water and you can see that there are waves actually created by the ship because the ship is advancingly forwarding and then in the back side you can see there are some waves right this is typical problem wave resistance.

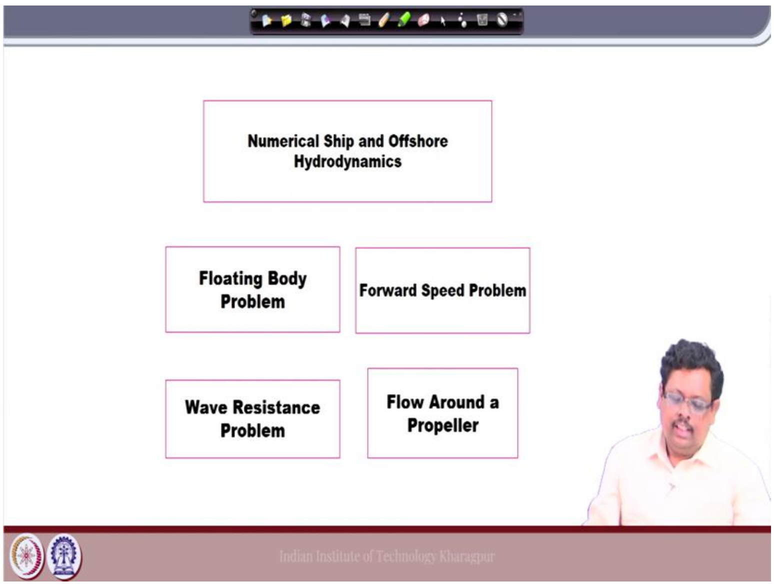
Now, you can see the ship start oscillating and then there are another type of waves is coming which is called the radiation waves which is coming because the ship is oscillating inside the water. Now you see now what happening the waves hit the structure and because of that you can see there is a large motions of the body.

Now, you see now this phenomenon is very complicated why? Because this phenomenon let us see again let us see again in the last part of this video you can see here this is a very complex phenomenon why it is complex? Because it is combination of so, many different types of waves one is when the ship is coming forward in backside you can see the waves ship is oscillating because of that some wave got created and then finally, the wave is the instant wave is hitting the body and because of that you have a large motion.

Now, in this complex scenario what is seeing in this video at this particular time what is happening all sort of waves are acting on the ship and then because of that I mean the ship experience large amount of forces, but then how to compute these forces is not a very easy task because you really do not know what type of force is coming because the ship is moving forward, what type of wave is coming because the ship is oscillating, what type of wave force is coming because the wave is hitting the structure right.

So, you know it’s very interesting of course, but pretty complicated as well right.

(Refer Slide Time: 02:58)



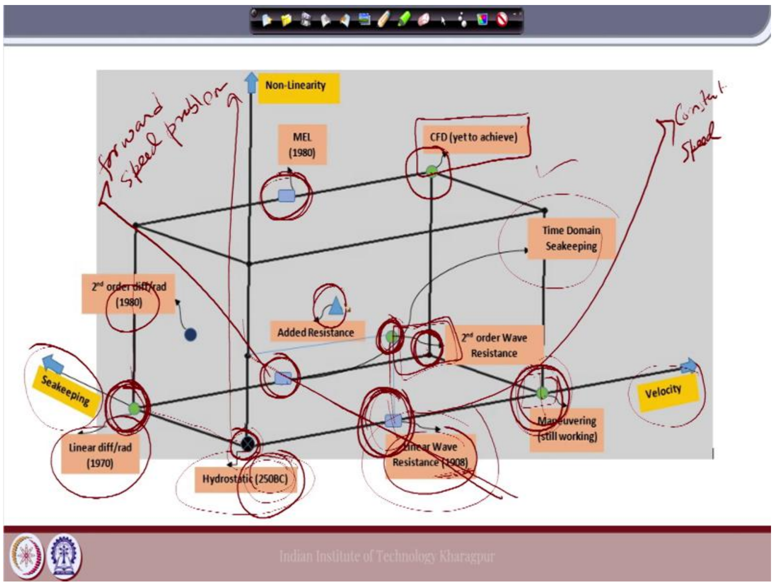
Now this course is not possible to cover everything, but certain amount of things we are going to cover, but let us see that what different type of things we can do.

First on this we can find out the floating body problem. It means that ship or offshore structure is floating on ocean and then wave is hitting then wave is the interaction right it is very important for the offshore structure problem it is very important like for semi submersible structure extracting the oil from the ocean that time this problem become very important.

Now, second one is that when the ship is moving forward right at that time also there are in floating body problem you have the waves that that, but the body is not moving, but because the body is moving, then you have another type of forces coming into the picture. So, therefore, it becomes a forward speed problem which is more complex than the floating body problem.

Now, these two major thing that actually we are going to cover in this course; however, there are very classic two problems also and also very popular which is wave resistance problem and then flow around a propeller; however, you need little bit of viscosity comes into play in these two problem and this is now not the scope of this particular course. Here we mostly concentrate on the floating body problems and then forward speed problem ok.

(Refer Slide Time: 04:32)



Now, this is a very interesting picture. Now you see that why this is so, complicated now if you look at here you can see this is the first time actually when actually you are going to start this process right and its started with the hydrostatic; that means, in calm water in calm water nothing is moving there is no waves and we try to find out what is the forces.

Now, it you can see that the time is 2500 BC. Now you see it is not a continuous graph ok this is basically some points actually they are extracting like you can see here this axis is called the velocity, but it is not a continuous axis. I just pick some point here and just there is some meaning of this particular point.

Now, here this is velocity; that means, if I advance from here actually I am in getting the velocity the ship is moving forward now this side this axis is basically the seakeeping or we can call it's a waves ok. So, now, and if you look at this top axis this one this basically our complexity or non-linearity.

Now, let us see where we are. Now this particular point is basically it is in this axis. Now here at this point there is no velocity, there is no waves because this axis also 000 there is no velocity, there is no waves and there is no non-linearity and it calls the hydrostatic and this is how it started in 2500 BC.

Now, this point particularly it has no waves of course, because it is in this this axis where wave is 0. So, here you have no waves and then it is basically the ship is moving in a constant speed. So, this is basically when the ship is moving in a constant speed and we call this as a typical wave resistance problem.

Now, let us go this side. Now this side basically there is no velocity therefore, ship or structure is not moving, but you have waves. So, typically this is called the floating body problem that I discussed in the last slide ok. Now let us move little bit up in non-linear side. Now you can see here from 2500 BC actually it is this take that much of time to solve this problem 1980.

So, you can see that we need almost 2000 year to come from hydrostatic for this second order diffracted problem; that means, even we do not introduce the speed. The floating body and then the floating body problem even the linear problem where actually we solved in 1970.

Now, you can understand how much complex it is when you started from the hydrostatic to this particular level right. Now let us see this point now after this point actually till this point we did not consider any acceleration of the body. Now you know that if you do not consider acceleration then the ship is moving in linearly right you the ship cannot take a turn. So, for that you need acceleration.

So, here ship can take a turn and we can call this classical maneuvering problem right; however, still we do not consider any wave right. So, now, we can standardize even you can see the linear wave resistance where we really do not consider the waves only you consider the forward speed it takes 1908.

So, we understand like that how much effort is required right anyway. Now let us take this part what is this point? This point is basically you have waves and you can have also a velocity right because till this point we consider the ship is moving with a constant velocity. Now this point ship is moving with a constant velocity and this we called the forward seakeeping problem.

So, this point also it is important I am writing because this is the major focus of this particular course, we can call this forward speed problem ok. Now there are so, many non-linear side let us go little bit now here it is linear wave resistance problem if you go up, this point if still we do not consider the waves we can call the non-linear wave resistance.

Now, here actually we can call the added resistance which is nothing, but the which is nothing but the you know because a non-linear part of the wave resistance problem we can move little bit of non-linear side. Now here let me see that we are going to achieve actually our goal is to achieve this point right.

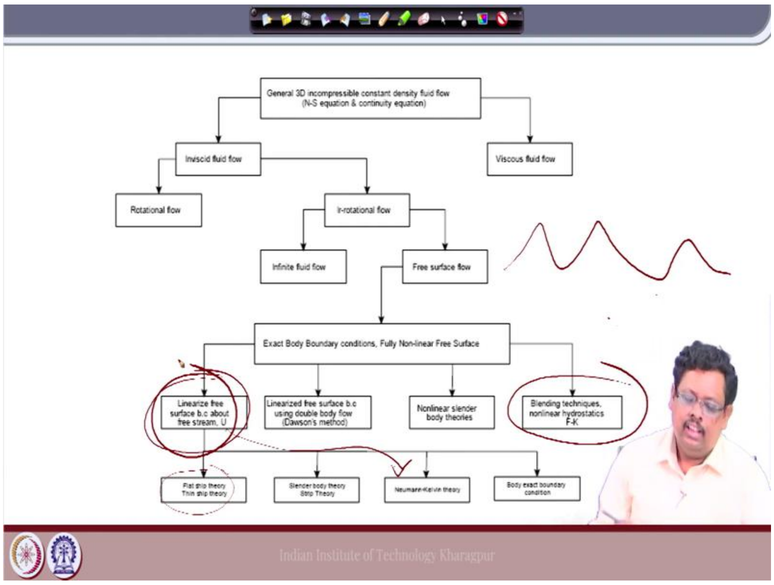
Here we have no wave, no velocity, no non-linearity the waves are and here the point where we have everything we have the velocity, we have the non-linearity, we have the non-linear waves right and this point actually you know yet to achieve. So, we can understand we started in 2500 BC and still we are not getting into the complete solution.

The closest solution you can see although it is this one which is called the MEL method we are going to discussing this all later stage of this course. In this particular situation what we did basically we are considering we do not consider the acceleration of course, we consider only the without acceleration then body is moving forward without acceleration and you can incorporate the non-linearity in the seakeeping problem ok.

And then very interestingly you know we do not even achieve this point we have not even achieved this point what is this point? Here ship has an acceleration under the waves so; that means, you can see the maneuvering where that there is no wave. So, it is the acceleration without considering there is a wave.

Now, here we have considered the acceleration and also we have considered the linear wave you know even now this is become a huge problem for us we do not have very consistent solution for this. However, our course mainly focusing on this green to green circle this is one and another one is this one ok.

(Refer Slide Time: 12:14)



Now, let us see that you know what level of assumptions we are making to come to this particular stage. Now here we have general 3d incompressible I mean this is the general problem like we considered the viscosity and we solve the Navier stoke equation. So, this is the most general situation now what we did is, from here we actually come here let we are do not consider the viscous term we only consider the inviscid fluid flow right.

So, we consider the inviscid fluid flow and also we do not consider the rotational flow right and only we consider the irrotational flow. See you have two level of approximation from here the starting we are started with the Navier stoke solution with has viscosity and then we do not consider the viscosity and then we do not consider the rotational also rotational flow we consider the irrotational flow.

And also there also again you can see here further making the approximation we do not consider the infinite fluid flow we consider the free surface flow; that means, we consider the ship not inside the ocean not the middle of the ocean or its not submarine right it is basically ship which is floating on ocean surface.

Now, under this also you can see there are hell lot of solutions. First is linearized free surface, then linearized free surface boundary Dawson type solution we have non-linear and we have blending techniques right under that we have four solutions; however, we are mostly interest on the first one which is the linearize body conditions right and from that even that also we can have the four solution. We have first orders thin ship theory, we have slender body theory, we have Neumann Kelvin problem, we have body exact conditions.

Now, from there actually most popular one is basically the Neumann Kelvin approximation; however, still in this course we try to you know address this problem as well where we can do some kind of non-linearity into the solution ok. Now from this actually we can understand that you know how what level of approximation we need to do to address this particular problem.

This problem is appearing to be very simple it is the ship floating on a water and then there is a waves and wave is hitting to the structure because of the structure start oscillating because the structure start oscillating, then you can you can have some kind of waves right.

And this all this mechanism we try to address it appears you know when you see from offshore you can see some ship and wave is hitting and even you know when we go like oceans and we can just go for bathing and all inside the ocean we really do not understand like what complex phenomena is going on right; however, if you want to solve this problem numerically, then we cannot solve as it is we have to make lot of lot of approximation.

So, particularly we need to understand what level of approximation we are making and because of this approximation it is not possible to address all sort of problems right sometimes now nowadays what happened that let a lot of your somebody we work in some kind of industry right. And then you have lot of software's available with you and therefore, somebody asking you to run the software and try to figure out like what is the response of the vessel to give a proper design of the vessel what is the design load you need to calculate all these things and therefore, you run the software.

However, you do not have enough knowledge or enough understanding on the approximations then what happen? After some point of time you can find some results of course, if you run a software definitely you are going to get some kind of results and then really you do not really understand whether this results are actually realistic, this result is meaningful you really do not know why because you do not have the background knowledge and you do not have the knowledge of the approximation.

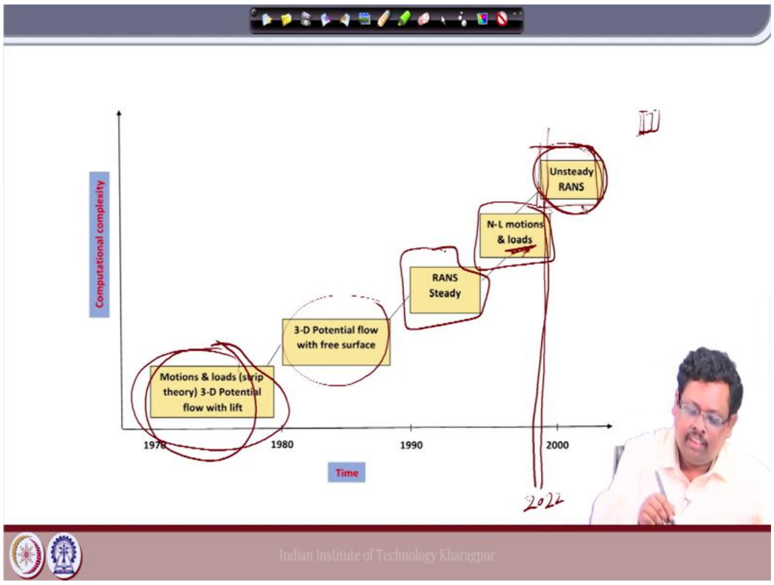
So, what happens? Sometimes, your software gives some erroneous results and that might represent kind of weird physics and, but since you do not have the knowledge of the limitations of the software's and when the software may go wrong you really do not have an idea, you keep on insisting the wrong physics and what is the outcome of that your design is faulty and then that actually very dangerous because the load you are calculating based on that particular physics that again fail right.

So, therefore, we have to understand like you can see over here how much approximation we are making and really if you go into the ship and in a ocean nobody we going to tell you that it's basically a linear waves or that mean how many of you go to the ocean and find the waves are basically you know harmonic nobody right.

You know even if a kid if you ask a kid to draw a waves you know any cartoon also mostly they draw like this type of waves kind of this irregular it is always there right; however, under this linear assumption we are approximating the waves are harmonic the response is harmonic right and then we are ignoring some kind of non-linearity in the process. So, we are making approximation of course.

But; however, even if you make such approximation still our theory holds and then you know this all this calculation all this numerical method is still meaningful ok.

(Refer Slide Time: 18:48)



Now, it's very interesting slide actually here year wise actually I am trying to find out that you know where we are standing. Now, you see that you know in 1970 onwards you know that first time it the strip theory actually and 3D potential theory is developed and this is the first time actually we really try to attack the problem and still now it is 2022 still this method is valid and very popular in industry level particularly the strip theory.

However, during eighties and nineteens normally in in before the seventeens only the two dimensional methods are very popular like strip theory slender body theory and other type of theory now during 80 to 90 the 3 dimensional potential theory become very popular and people started using it ok and this is of course, based on some assumptions of the irrotational and then you have to find out some velocity potential all these things we are going to discuss later on.

However, from 19s people are try to address this problem with the help of CFD and we are having the rans based solution, but it is you can see that rans steady; that means, their solution is not particularly for the seakeeping problem, mostly the solution is for wave resistance problem that mean ship is moving in calm water then what type of force is acting on the ship.

So, such problem actually they started addressing in during 1990s and then in from 2000 onwards actually we try to address little bit of non-linearity into the solutions ok. So, what kind of non-linearity? We introduce we introduce the wave nonlinearity then we consider the wave is not harmonic ok. So, wave is non-linear waves you can approximate with lot of theories are available you can approximate complete non-linearity you can approximate second order non-linearity fifth order non-linearity wave so, many things we have started.

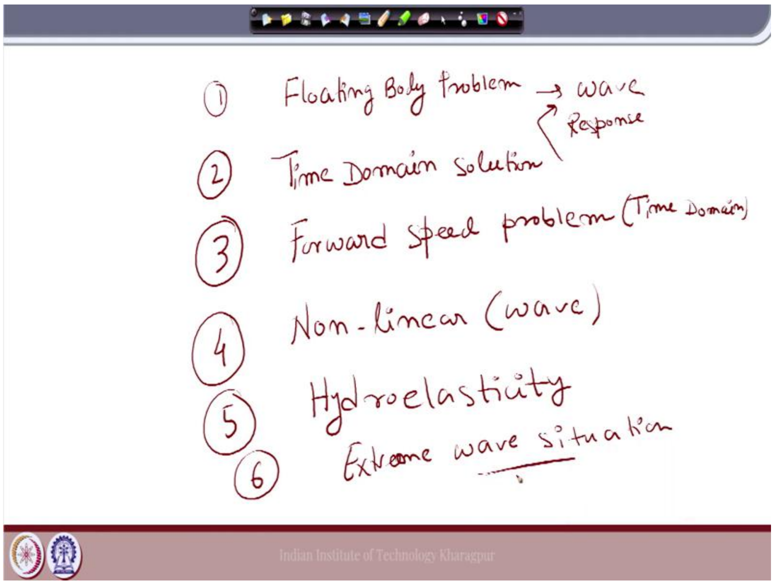
However most of the time that response of the vessel always assumed to be linear. So, what they do is, they assume the waves is hitting to the structure that waves is a non-linear waves; however, the response of the body is still linear; that means, you know if you look at that video where we can see that body is moving. So, the body is moving we should consider that also be a non-linear, but we do not do that.

So, the wave created because of the body is oscillating that wave should be non-linear, but we do not consider that to be non-linear only we consider that wave which is hitting to the structure that is non-linear. So, these things again you know still we are working on this particular problem and still we do not have you know very satisfactory solution for that also, but we are going to discuss this also.

And finally, as I said that our ultimate aim to achieve the unsteady rans solution; that means, we consider everything we consider our ship is moving with acceleration we consider that waves is non-linear and we consider the all other all other waves created by the ship that also non-linear, we can take a turn, we can do maneuvering, we can do seakeeping we can do everything. So, this we need to you know achieve ok.

So, now as you can see here we are here I mean this point still it is in a 2022 some over here and I hope that after this course we are some people will try to solve this problem as well ok now let us see that what actually we can address for this particular course.

(Refer Slide Time: 23:27)



So, first we started with floating body problem. Now here we consider everything is linear the wave is linear and also the response also linear and then after that actually what we are going to discuss is basically a time domain solution. Now in time domain solution this again everything is linear ok.

In third we are going to address the forward speed problem. So, what is happening that this also in time domain ok and then number 4 we are going to discuss some kind of non-linearity at least we can consider the wave is non-linear maybe not the responses and finally, we are going to discuss something called hydroelasticity.

Now, what is hydroelasticity? We are going to discuss in the next slide we have that some video of the hydroelasticity and then finally, if you know we get some time of course, I wanted to of course, do something you know something extreme waves extreme wave situation. So, here actually we can address something called the green water and sometimes we can have the slamming ok.

So, what is the green water and what is the slamming definitely we are going to discuss in the in coming days and at the end of this of course, the course.

(Refer Slide Time: 26:06)

Now, let us see our ultimate aim to develop a software which address the fluid structure interaction problem at least you know let us take a linear wave and then let us take the response also linear and also let us take the structure is not rigid the structure is elastic.

Let us see if you assume the structure is elastic or flexible what happened? Now here you can see that the waves is hitting to the structure and then structure oscillating. Now if you look at carefully this structure is not behaving like a rigid body and what is happening for the large floating structure the structure is no longer behave as a rigid body and structure behave as a flexible body and actually this becomes more complex to solve, but this phenomenon is very interesting and very important also.

Sometime we really do not realize we are carrying some 400-meter-long vessel and we are going in a middle of the ship and suddenly you know that all the responses are small we are very happy the wave is wave condition is absolutely normal there is no extreme waves ok and suddenly what happen the ship breaks due to some high bending moment or whatever the cause.

And that time actually it happened in 2013 right when this hydroelasticity started you know become very popular, this is some very large ship just going inside the ocean and suddenly it breaks and we will find out because we really do not consider that at 400-meter-long ship is no longer behave like a rigid body. So, in this particular course also we are going to address this ok. So, this is that our final aim we are going to you know model a numerical method and this is our final aim ok. So, with this let us stop today.

Thank you.