Fluid Dynamics And Turbo Machines.
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Part B.
Module-2.
Tutorial-1.
Tutorial: Week 6.

Good afternoon, so we come to the end of this week 6 and today we will take up some tutorial problems and we will do it step-by-step so that we have the familiarity with the concepts that are discussed. And which will also help you in doing the tutorials in this week. So let us look at the first problem.

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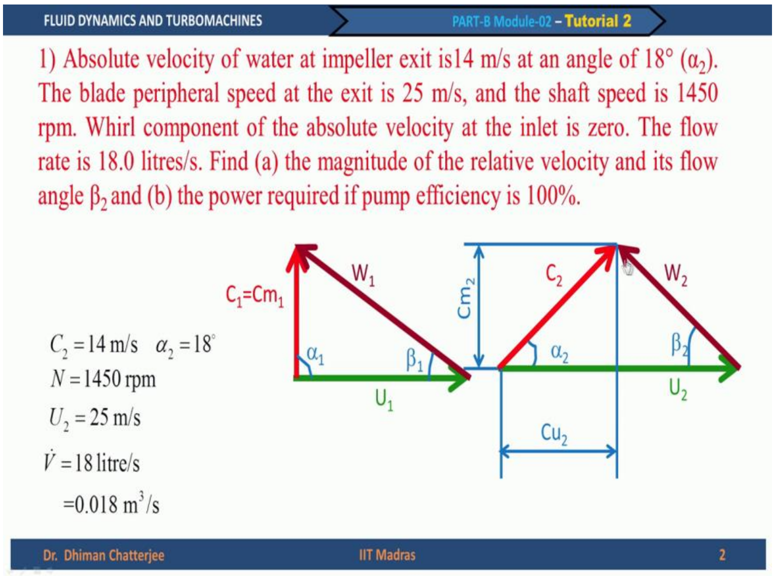

The first problem says that an absolute velocity of water at the impeller exit is 14 metres per second at an angle of 18 degrees. So when we talk about absolute velocities, the angle, corresponding angle is Alpha 2. In the problem that we will be giving you in the tutorial set we will not mention it as alpha 2. In the worked out example today I am talking about alpha 2 so that you can connect and remember that alpha is the angle which the absolute velocity makes.

The blade peripheral speed U at the exit is 25 metres per seconds, shaft speed is 1450 rpm, whirl component of the absolute velocity at inlet is zero. The flow rate is 18 metre per seconds, please take care of the units, you have to be consistent, so convert this into metres cube per seconds and find the magnitude of the relative velocity and its flow angle beta 2, also find out the power required assuming that the pump of efficiency is 100 percent. We will solve this problem for pump efficiency of 100 percent.

If the pump efficiency is different from 100 percent, you should be able to take it into consideration by the suitable factor of the efficiency. So in this sort of problems, my suggestion is always draw the velocity triangle and write down what all are given. So this is the exit velocity triangle with C2 is absolute velocities, W2 is the relative velocity and U 2 use the blade peripheral velocity on the pressure side or the exit. Alpha 2 and beta 2 are the corresponding angles, CU 2 is a whirl component and CM2 is the meridional component.

And at the inlet, since it is given that the whirl component of the absolute velocity is zero, so we can write C1 equals CM1 and the corresponding other velocities are U1 and W1. What is given as C2 equal to 14 metre per seconds and alpha 2 equal to 18 degrees. We also know that the RPM is given 1450 as N, we have written, U 2 as 25 metres per seconds, CU 1 is zero. Volume flow rate is 18 litres per seconds as I said convert it into metres cube per seconds. We need to find out the relative velocity, means we need to look at the triangle at the pressure side.

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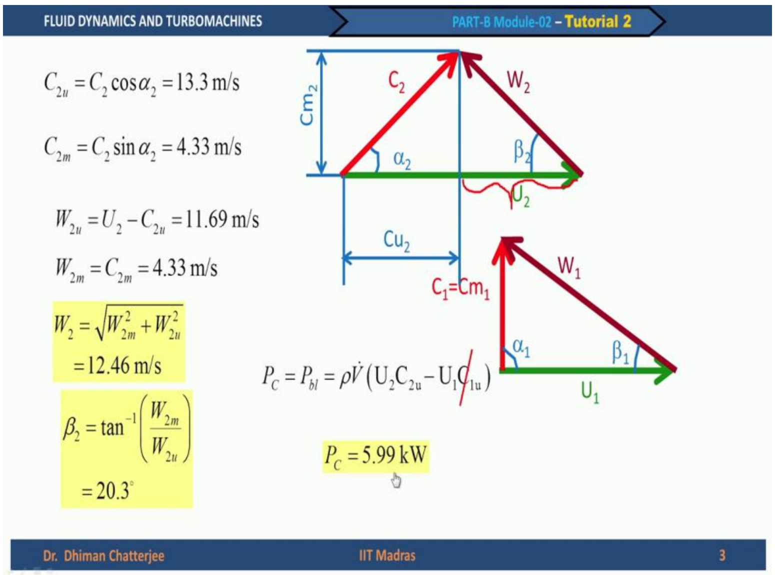

So let us look at the triangles again okay. So we are talking about C 2U or CU 2, the notations can be used in different ways but both are consistent. So CU 2 or C2U are the same quantity is C to cos Alpha 2 which is 13.3 metres per second, you can work it out, the values you can get from the relationship. And C2M is related with the sin alpha, so C2 multiplied by sin Alpha 2 is 4.33 metres per second, thus we know this is 4.33 metres per second and CU 2 is 13.33 13.3 metres per second. So what is W U 2, W U2 is the corresponding projection of W-2 along U2, so this distance.

This distance is what we are talking about. This distance is W U2. And here when we are talking about it, we can find out the W U2 or W2 U is U2 minus V 2U is 11.69 metres per second and we know that C2M or CM2 equal to W2 M and it is equal to 4.33 metres per seconds. So now to get W2 is nothing, we know W2 M and W2 U, so we can find out W2 to be 12.46 metres per seconds and beta 2 can be found out by the tan of beta 2 we know is W2 M by W2 U and hence beta 2 is tan inverse of W2 M by W2 which is 20.3 degrees.

And coupling power, in this case is a blade specific power because there are no losses, we have talked about hundred percent efficiency, so we can see coupling power equal to PBL is equal to rho V dot U2 C U2 minus U1 C1. But CU1 is zero and hence we get the coupling power is 5.99 kilowatt. We can continue with this problem and add some more complexities.

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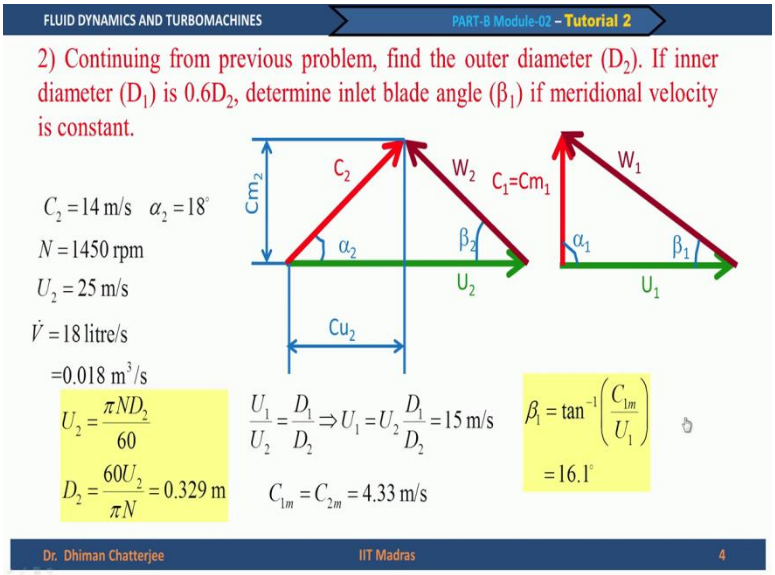

We can say that the outer diameter of the same pump which we have talked about, we need to find out. And if the inner diameter is 60 percent of the outer diameter, can we find the inlet blade angle beta 1? It is given that the meridional velocity is constant, which means C1M equal to C 2 M. So as before we will draw the velocity triangles and taking the data which we have already obtained in the first problem and along with what is given, let us write down. It is already given that C2 is 14 metres per second and alpha 2 is 18 degrees.

The blade rotational speed was also given along with the blade peripheral speed, volume flow rate was also given. We know the relationship that U 2 is equal to pie N D2 by 60 and hence D2 can be obtained as 0.329 metres. We know that U1 by U2 is equal to D1 by D2. Basically U2 is pie N D2 by 60 and U1 is pie N D1 by 60, hence U1 by U2 will be D1 by D2. And we can get U1 as 15 metres per second. Now look at the velocity triangle at the inlet or the suction side. We know U1 and since it is given that CM1 equal to CM2, we can say that both are 4.33 metres per second and hence we can find out beta 1.

Beta 1 is tan inverse C1M by U1 which is 16.1 degree. Okay. So what did we do, we have found out the velocity triangle information given in the outlet or the pressure surface and then obtained the corresponding relationships which we required for the inlet or the suction surface, suction side.

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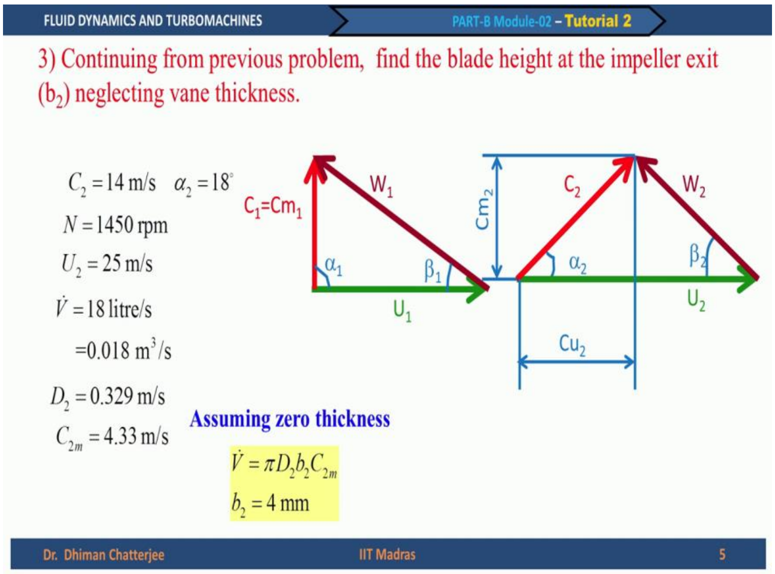

And we can continue with this same problem, we want to find out the blade height at the impeller exit which is B2 neglecting the vane thickness. That is we know the volume flow rate and you you know from the classes that we have done in the last class, we talked about the volume flow rate in case of a radial flow machine is nothing but pie times D times B times the corresponding meridional velocity. So we will use that relationship here.

As before we are talking about the velocity triangles, we write down whatever are given, the C2, alpha2, U2, volume flow rate and diameter, we have also obtained diameter D2. So we can write, and we know the C2M, we have calculated and obtained it in the first problem, now assuming that zero thickness of the vanes we can write that V dot is nothing but pie D 2 B 2 C2M which will give me B2 to be 4 millimetres. Now you can do this problem yourself by assuming that the blades occupy let us say 5 percent of the vane passage.

Or blade thickness is accounting for 5 percent. So then you can write a factor with 5 here which is equal to 0.95 and you can find out B2. I leave that as an exercise for you and a similar problem where the blade height has to be obtained in case of a finite vane thickness is given for your practice.

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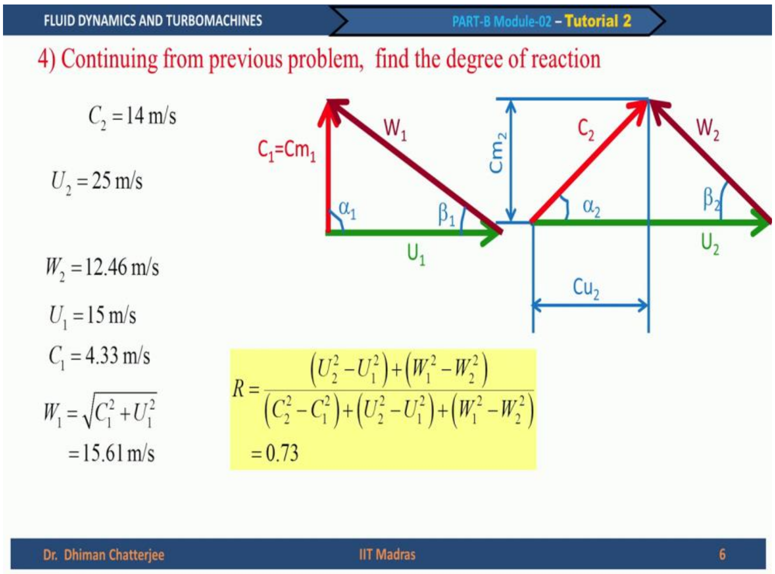

Finally I come to the last problem that we want to find out the degree of reaction. We know from the previous 3 problems that C2 is equal to 14 metres per second, we know U2 is 25 metres per second, we know W2 is equal to 12.46 metres per second. All these were either given or obtained in problem 1. Now we also know from the 2nd problem that U 1 is 15 metres per second and C1 is nothing but CM1 as I have written here and CM1 equal to CM2, it was also given.

So we can say it is 4.33 metres per second and we can find out now W1 here in this velocity triangles, right angle velocity triangle and hence W1 is nothing but square root of C1 square plus U1 square and we get 15.61 metres per second. So now we have obtained or it was given to us C2 U2 W2 and U1 C1 W1, so we can find out the degree of reaction as U2 square minus U1 square plus W1 square minus W 2 square divided by C2 square minus C1 square plus U2 square minus U1 square plus W1 square minus W2 square and that will give me our or the degree of reaction as 0.73.

So these are the some of the problems, while solving these problems on pumps, turbines or any Turbo machine, please keep in mind that you should draw a neat picture of the velocity triangles and try to draw the angles, not, you do not have to make it exact but try to make it looking close. For example if beta 2 is given as some value which is acute, try to draw it acute because then you will have a proper idea of how CU 2 is working, is it more or less and then try to work out the triangles properly and get what are the informations which are missing.

And rest of the problem is actually application of suitable formulae. The crux or the most important part of Turbo machine that we will be covering here, we have covered so far and we will be covering in the coming lectures is understanding a problem, translating that problem into suitable velocity triangles and determining different components and then plugging these components into the relationships as we have done here. I hope that if you do the tutorials, these portions will become clearer.

In the next week we will start the pumps and we will revisit some of the problems that we did today in more details. We will talk about the pump performance and the related problems and some of the concepts that we did here will also become more relevant and more meaningful with the practical example of pump. Thank you.