Principle of Hydraulic Machines and System Design
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Lecture – 30
Hydraulic Turbine: Specific Speed

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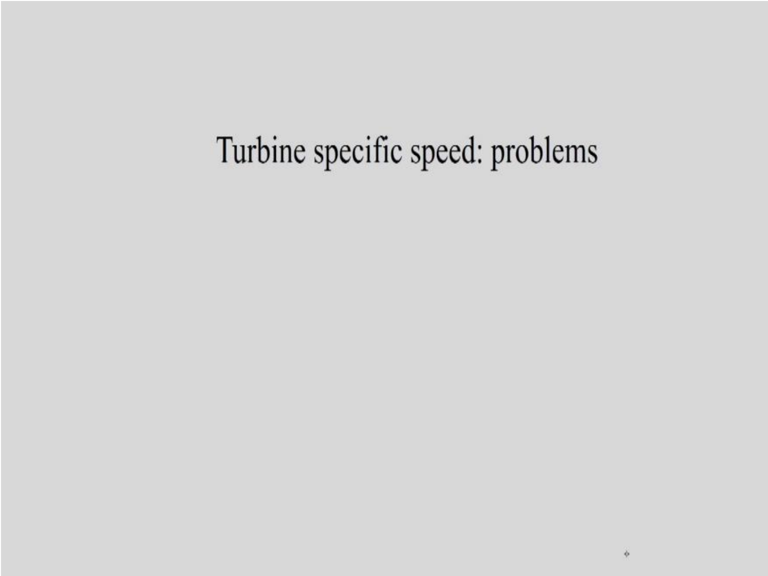

So, we will continue our discussion on Principle of Hydraulic Machines and System Design. And today we will discuss about turbine specific speed and we will work out few examples. So, we have discussed that specific speed, and we have derived the expression of specific speed for pumps. Similarly, today we are going to drive the in a specific speed of the turbine, because very this is very important.

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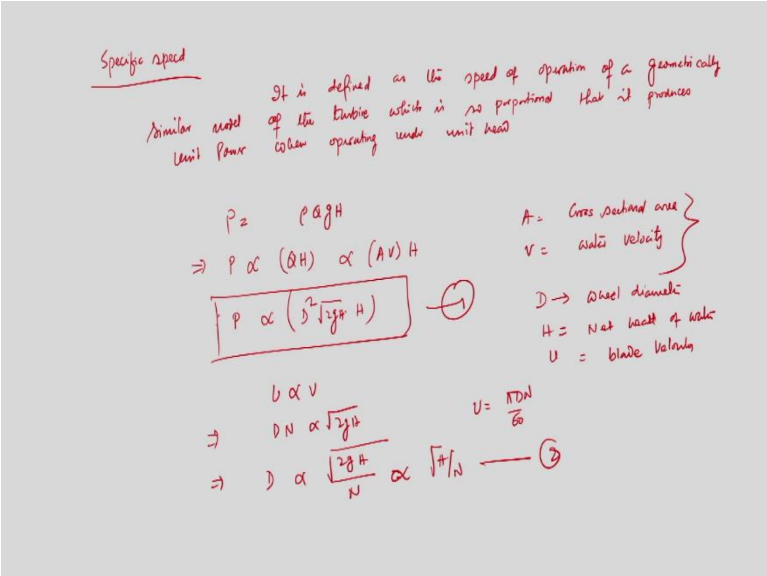

So, what is specific speed that is probably we have discussed that it is a speed of a geometrical similar machines. So, in the context of the discussion of pumps, we have discussed that speed of a geometrical similar machine which produces unit discharge when working under unit in case of a pump.

So, now we will see what is the definition of specific speed for the turbine? So, I am writing that it is defined as the speed of operation of a geometrically, similar model of the turbine which is so proportional that it produces unit power, when operating under unit head, or you know working under unit head, so when operating under unit head.

So similar to the definition of, similar to the definition of specific speed of pump it is defined as the speed of a geometrically, similar model I mean geometrically, similar that is we have discussed that it is identical in shape not in size nay differ, but shape will remain same of the turbine which is, so proportional that it will produce unit power when working under operating under unit head.

Now, let us try to drive the expression of specific speed so, what is power normally that is again I am repeating that based on the direction of energy conversion, have classified one turbine machines into pump and turbines. Pump, mechanical energy is converted to the increase the store energy of the fluid, while in case of a turbine it lies in the stored energy of the fluid to obtain the kinetic energy rotation of the rather kinetic energy and we are obtaining power .

$Power\ P = \rho QgH$

$P \propto QH \propto AVH$ A= cross section area, V = water velocity

$P \propto D^2\sqrt{2gH}\ H$ eq1 D = wheel diameter, H = net head available

$u \propto V$ $u = \frac{\pi DN}{60}$ u = blade velocity

$DN \propto \sqrt{2gH}$

$D \propto \frac{\sqrt{2gH}}{N} \propto \frac{\sqrt{H}}{N}$ eq2

$P \propto D^2\sqrt{H}\,H \propto \frac{H}{N^2}\,H^{\frac{3}{2}} \propto \frac{H^{\frac{5}{2}}}{N^2}$

$N \propto \frac{H^{\frac{5}{4}}}{P^{\frac{1}{2}}}$

$N = k\,\frac{H^{\frac{5}{4}}}{P^{\frac{1}{2}}}$

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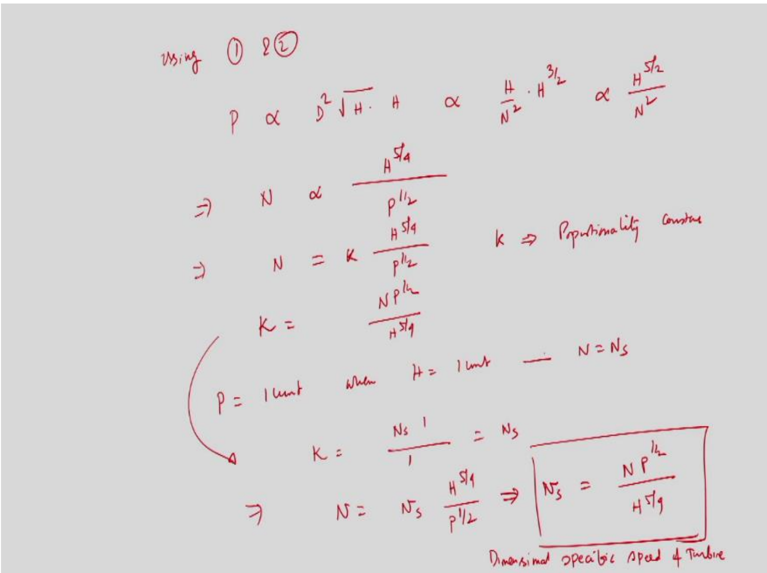

So, what is proportionality to obtain the magnitude of proportionality constant, we have to define the definition of the we have to use the definition of the turbine specific speed. So, what is definition specific speed? so that means P will be 1 unit when H is equal to 1 unit right and then N will be equal to N_S, so when working under or operating under unit head, it will develop unit power then it is specific speed .

$$k = N \frac{P^{\frac{1}{2}}}{H^{\frac{5}{4}}}$$

If P=1, H=1, N=Ns

Ns = k

$$Ns = N \frac{P^{\frac{1}{2}}}{H^{\frac{5}{4}}}$$

So, what drive the expression of dimensional specific speed of the turbine, similar to what we have derive in case of a pump or the definition was little bit difficult, because that was that will discharge unit under when working under the so, whenever specific speed of tur[bine]- pump was defined, because that was only Q 1 H. So, working under unit head it will deliver unit discharge so, but it will now you know produce unit power when working under unit head.

So, based on that we have derive the proportionality constant using the definition of you know specific speed. And we have obtained the expression of specific speed that is in power in P power half by 5 4. Now, so this is dimensional specific, dimensional specific speed, now to obtain the dimensionless specific speed again we have to divide it by g power g so, because it is not dimensionless.

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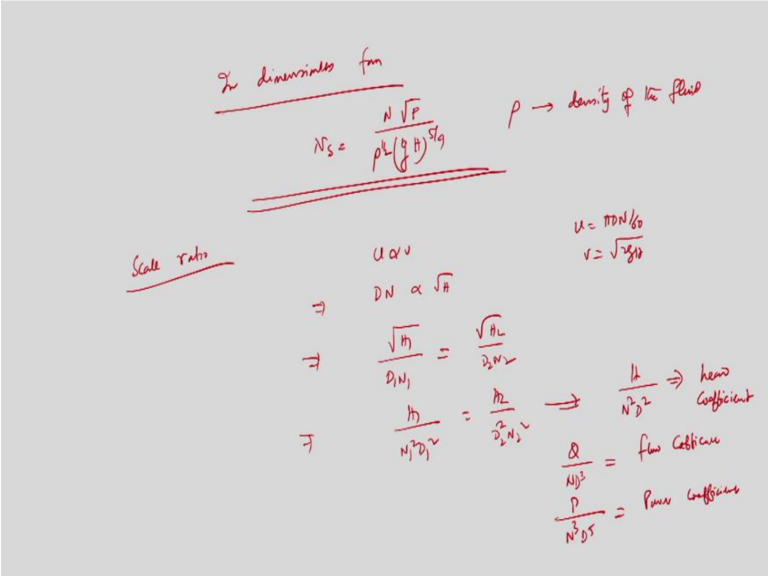

In dimensionless form

$$N_s = \frac{N\sqrt{P}}{\rho^{\frac{1}{2}}(gH)^{\frac{5}{4}}}$$

$u \propto V$ $\qquad u = \frac{\pi DN}{60}$ $\qquad$ u = blade velocity

$$DN \propto \sqrt{2gH}$$

$$\frac{\sqrt{H_1}}{D_1N_1} = \frac{\sqrt{H_2}}{D_2N_2}$$

$\frac{H}{D^2N^2} = Head\ coefficient$ $\qquad \frac{Q}{N\,D^3} = Flow\ coefficient$

$$\frac{P}{D^5N^3} = Flow\ coefficient$$

so rho is the density of the fluid. So, this is dimensional form of the dimensional, dimensionless specific speed, so this is dimensionless specific speed.

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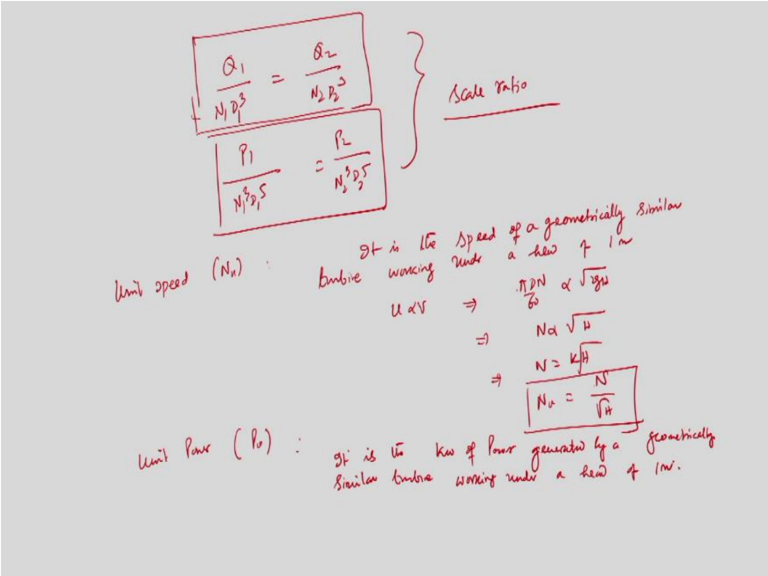

This is very important, because the pump of homologous series that the turbine of homologous series that is geometrically similar identical in shape, not in size. If we know the head discharge diameter at a particular speed, we can obtain the other things at when it is earning at different kind of speed.

$$\frac{Q_1}{N_1 {D_1}^3} = \frac{Q_2}{N_2 {D_2}^3}$$

$$\frac{P_1}{{N_1}^3 {D_1}^5} = \frac{P_2}{{N_2}^3 {D_2}^5}$$

Unit speed Nu - it is the speed of a geometrical similar turbine working under unit head so, it is a speed of a geometrically similar turbine working under a head of 1 meter.

$$N \propto \sqrt{H}$$

$$N = k\sqrt{H}$$

$$N_u = \frac{N}{\sqrt{H}}$$

Unit power Pu - it is the power of a geometrical similar turbine working under unit head so, it is a power of a geometrically similar turbine working under a head of 1 meter.

$$P = \rho Q g H = \rho\, A V g H = \rho\, A \sqrt{2gH} g H$$

$$P \propto H^{\frac{3}{2}}$$

$$P = k\,H^{\frac{3}{2}}$$

$$P_u = \frac{P}{H^{\frac{3}{2}}}$$

Similarly, unit power that is P u that is what again we can define that it is a it is the you know it is the (Refer Time: 13:58) generated by geometrically similar turbine working under head of 1 meter. So, P u, so it is the kilowatt of power generated by a geometrically similar turbine working under a head of 1 meter.

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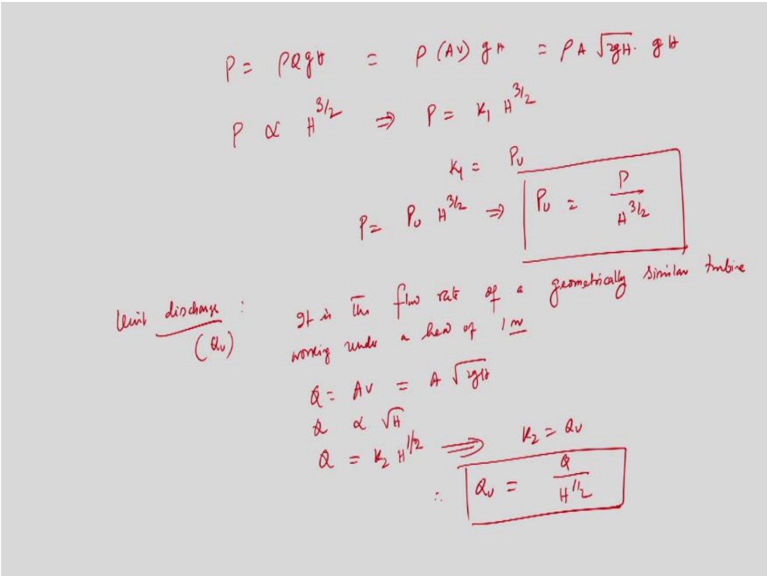

Unit discharge Qu - it is the flow rate of a geometrical similar turbine working under unit head.

$$Q \propto AV \propto A\sqrt{2gH}$$

$$Q \propto \sqrt{H}$$

$$Q = k\sqrt{H}$$

$$Q_u = \frac{Q}{H^{\frac{1}{2}}}$$

this is unit discharge. So, we have obtained unit discharge, unit power, and unit speed so, these three will be important, while will be a while will be we are solving a few problems. So, now with these, let us move to solve a few problems.

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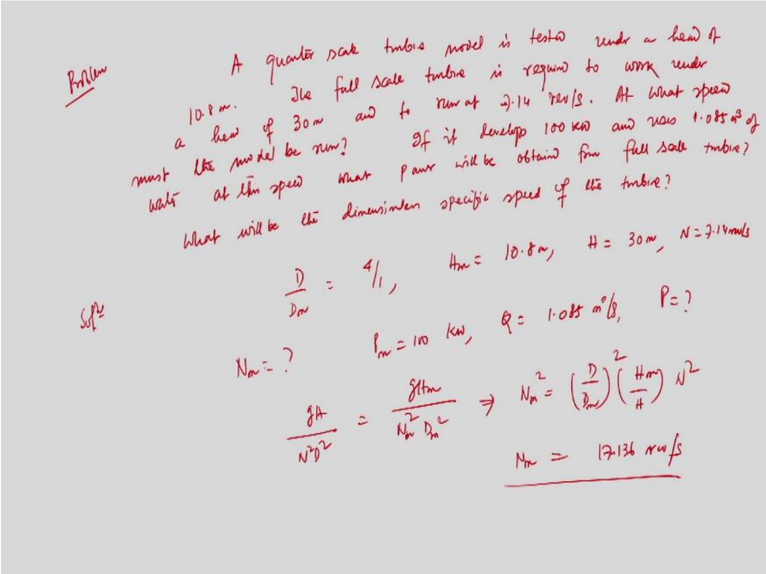

So, first problem I will be solving that the very important that question problem is a quarter scale turbine model is tested under a head of 10.8 meter. The full-scale turbine is required to work under head of 30 meter and to run at and to run at 7.14 revolution per second 7.14 revolution per second. At what speed the model be run at what speed the model at what speed the model will be run model be run? It if it develops 100 kilowatt if it develops 100 kilowatt and uses 1.085 meter cube of water at the speed you know.

Then what power will be what power will be obtained from the full-scale turbine so, and what will be the dimensionless specific speed of the full-scale turbine? So, we have to solve this problem, how we can solve, so, what is given D/D m model and full is equal to 4 by 1, H m is equal to 10.8 meter, H is equal to 30 meter, N is equal to 7.14 revolution per second that is given. So, we have to find out N m is equal to how much? P m is equal 100-kilowatt, Q m is equal to 1.085-meter cube per second, then P is equal to how much?

So, this is the problem; very easy, because you can use a scale you know you know similarity variable that has scale ratio.

$$\frac{gH}{N^2D^2} = \frac{gH_m}{{N_m}^2{D_m}^2}$$

Nm =17.36 rev/s

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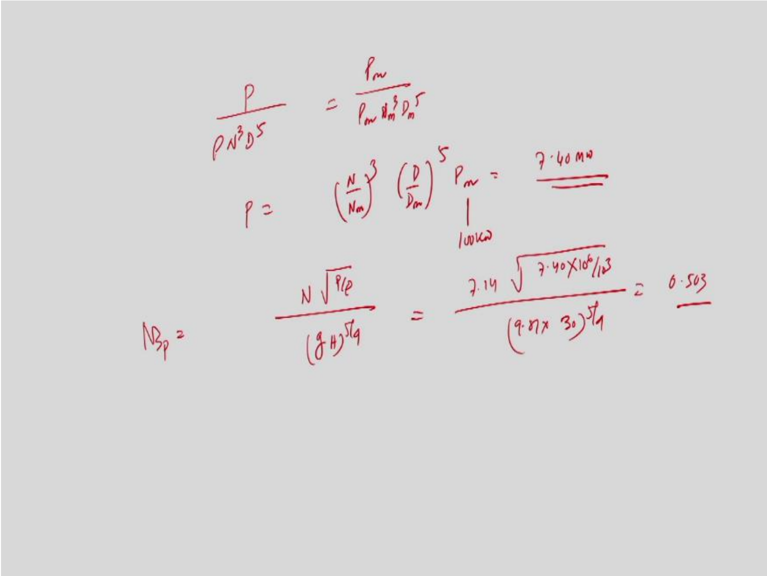

$$\frac{P}{\rho N^3 D^5} = \frac{Pm}{\rho Nm^3 Dm^5}$$

P = 7.4 MW

$$dimensionless\ specific\ speed = \frac{N\sqrt{\frac{P}{\rho}}}{(gH)^{\frac{5}{4}}} = 0.503$$

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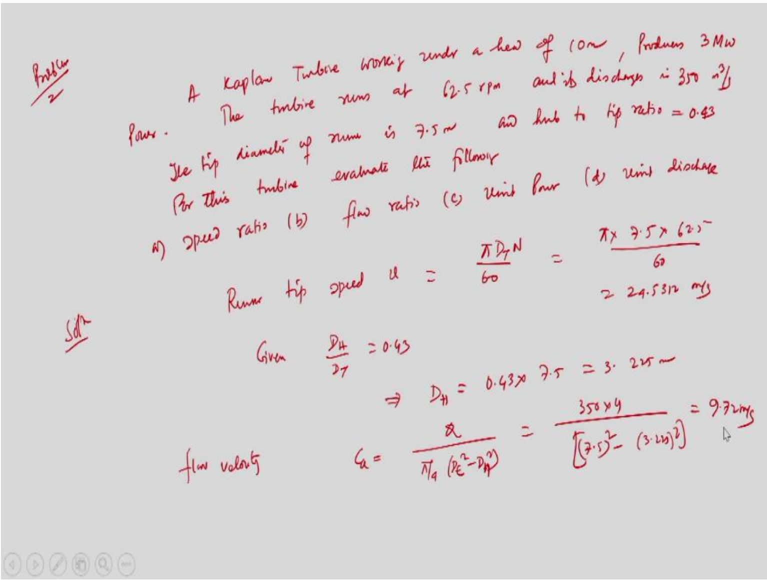

We can solve another problem very quickly problem 2 you know, a Kaplan Turbine working under head of 10 meter, produces 3 megawatt power right. The turbine runs at the 6 the turbine runs at 62.5 r p m, and it discharges each 350 meter cube per second, and discharge is 3. 350 meter cube per second and it is discharge is and it discharge and it is discharge is 350 meter cube per second.

The tip diameter of the runner is 7.5, tip diameter of runner is 7.5 meter, and hub to tip ratio is equal to 0.43. For this turbine evaluate the fluid following for this turbine for this turbine evaluate the following quantities number 1 speed ratio, flow ratio unit for unit discharge. Speed ratio; b, flow ratio c, unit power unit discharge unit power d unit discharge. How we can calculate? So, runner tip speed so, solution tip ratio diameter is given hub to tip ratio 0.43 is given.

Runner speed u = $\frac{\pi D_T N}{60} = 24.53\ m/s$

Dh/Dt= 0.43

Flow velocity Ca = $\frac{Q}{\frac{\pi}{4}({D_t}^2 - {D_h}^2)} = 9.72\ m/s$

Speed ratio = $\frac{u}{\sqrt{2gH}} = 1.75$

Flow ratio = $\frac{C_a}{\sqrt{2gH}} = 0.692$

Unit power = $\frac{P}{H^{\frac{3}{2}}} = 9.4\ x\ 10^4$

Unit discharge = $\frac{Q}{\sqrt{H}} = 110.679$

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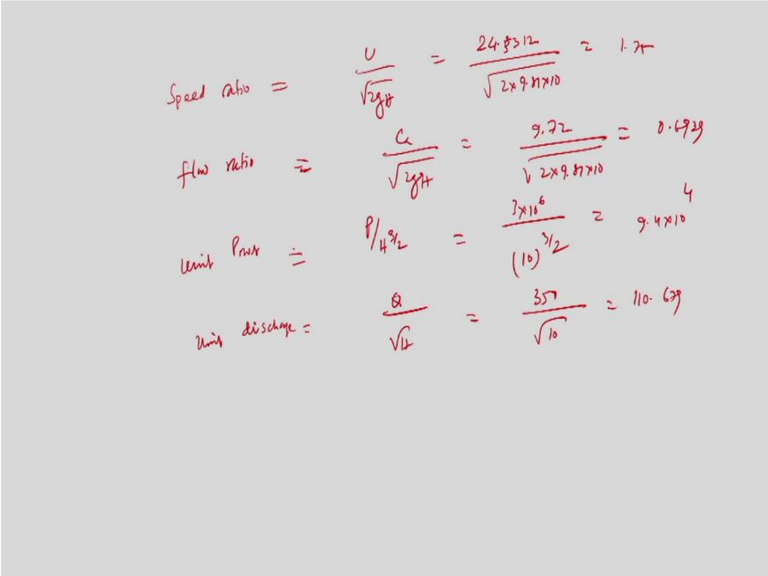

So, that are solved that these two problem and based on because how so in summary I can tell that we have we have drive the specific speed of turbine from there we have you know define scale ratio then from there we have define a few ratio like some power unit power unit discharge and unit head. And we have worked out two example how to solve the problems probably it will help you to work out a few examples I mean to and it will help you to get an insight about that how to solve a problem, and how to calculate different ratios based on the data available. .

So, with this I stop here today and I will continue in the next class, I mean about the you know some important points related cavitation of a turbine, and how we can prevent cavitation and the mathematical expression for the cavitation.

Thank you very much.