Surface Facilities for Oil and Gas Handling

Prof. Abdus Samad

Department of Ocean Engineering

IIT Madras

Pressure Vessel-02

So, every time we say strength, stress, ductility, already I have explained these things in previous some lectures, but again just to recap I have drawn one figure like stress versus strain ok. And let us say I have taken a mild steel ok, now pull it from top to bottom ok, you say mild steel or ductile material. Ductile material means you if it pull it, it will not break suddenly rather it will create very thin long section then after that it will break, this is your ductile material ok? So, if I pull it, it will be getting elongated, so that part is called proportionality limit, proportionality limit will be coming here. So, just say you, you take one elastic band, you enlarge little bit, again leave it, again will come back to its original position, so that is called elastic limit within that there is no deformation, plastic deformation not happening. Plastic deformation means you enlarge it, you leave it, it will not come back to the original position ok, so it is called plastic deformation, so elas ok.

So, if you design one pressure vessel and it is getting plastically deformed that means after high pressure if you release pressure, it will not come back to its original position that means material is getting deforming permanently, when permanent deformation is there, it can be more dangerous ok. So, plastic deformation is permanent deformation ok, but elastic deformation means it will be coming back to its original position. So, normally our whatever material or whatever thing you design, you have to work within that your proportional limit, if you are going towards ultimate strength of fracture side, then your system will not sustain, it will break ok. So, if you give some more pressure, more tensile stress, initially you worked up to proportional limit, then you enlarge more, so then yielding will be starting, yielding is starting means permanent deformation will start ok.

Then you enlarge further ultimate strength will be coming, then if you enlarge further it will be it will give fracture ok. So, whenever you are designing anything, it will be within your proportionality limit. So, material property maximum amount of tensile strength, pulling or stretching, that is called tensile strength ok. So, material maximum amount of tensile strength you are applying, so if you apply more than that, then it will be permanent deformation ok. So, material will stand without breaking or undergoing deformation ok, so that is called tensile strength.

If it is deforming, then plastic deformation happening, then your system may not work, so your system must be within this range ok. And whenever talking about stress strain stress strain or stress or pressure, so in that case unit will be Pascal, Mega Pascal, psi, Newton per meter square ok. So, you have to sometime you have to use conversion factor also, but units are Pascal, kilo Pascal, Mega Pascal, kilo Pascal also possible,only Pascal, Giga Pascal also possible in certain situation, psi,Newton or kilo Newton per meter square, those are unit for pressure or stress design formula. So, whenever you are designing a pressure vessel, so what will be the water thickness, wall thickness? So, this formula will tell ok this much of wall thickness you have to use. So, if your maximum allowable working pressure P, maximum allowable working pressure PSIG in unitand R inside radius of the system, so S is maximum allowable pressure allowable stress ok, E is your joint efficiency ok, then wall thickness will be for cylindrical cell.

So, here I actually I have to tell something else ok. Whenever you are designing a pressure vessel, it will have different heads heads means like you have pressure vessel and previously in all separate design actually we had drawn figure like this right. Now, actually every time you may not have that much figure, sometime it may have only shell like this rectangular vessel, sometime it will be hemispherical end, end will be hemispherical this head, sometime it will be having parabolic ellipse not parabolic ellipsoidal head, 2 is to 1 ellipsoidal head, sometime conical section will be there ok. And sometime there will be internal cone, external cone will be like looking like this, internal cone is like this, it is completely like this and you are creating cone inside. So, outside one metal will be there, inside also there will be metal.

So, inside will be collecting your sand and other particle, outside will be as normal pressure vessel ok. So, cone bottom vessel use for solids, if solids are problem and maximum cone angle 90 degree ok, 90 degree cone angle possible apex, so alpha is 45 degree normally it will be there. And if you are using 45 degree or 60 degree cone angle, then it will be referred as 60 degree 60 degree cone or 45 degree cone like this. Vertical vessel normally it will have standard elliptical ellipsoidal head, ellipsoidal head contains pressure, the cone can be the steel made ok. This is steel made and will be thin sheet also thin ok, because outside also it is holding pressure, this is just guiding the sand.

Now, we will go to this design formula, if you have wall thickness, if you have 2 is to 1 ellipsoidal head, then wall thickness formula is like this, T equals P D, T this is T, T equals P D 2 A C 0.2 P and wall thickness for hemispherical head T equals P R 2 A C 0.2 P, this is P D, this is P R. Wall thickness cone T equals P D 2 cos alpha A C 0.6 P ok, this using this formula later we will solve some problem.

And your thickness now from thickness we have to calculate our shell weight, shell weight, because weight is in one important factor for design and use ok. So, shell weight W equals 11 D T L, W equals 11 D T L, W equals 11 D T L, W equals 11 D T L. What is D? D is I D of shell ok, so this is I D and T is the wall thickness. Normally, this shell will be thin wall shell, thin wall means D by T will be 20 the ratio, because our diameter is higher and thickness is lower, so the D by T will be normally more than 20 ok. Weight of 1 1 twist 1 ellipsoidal head, so if I have 1 ellipsoidal head, so weight of that one W W equals 0.

34 T D square plus 1.9 T D. And weight of cone, if I have cone then W equals 0.23 T D square sin alpha. If I have skirt length L equals 0.

25 D by 12 plus 2. If I have conical head, then length will be like 0.5 D 12 tan alpha plus 2. Now, what is skirt I will explain later. Now, so maximum allowable working pressure you can get from this table.

So, if you have less than operating pressure, then minimum differential between operating pressure and M A W P or allowable working pressure is 10 psi. So, similarly if you are changing pressure, so your this difference also changing. So, maximum allowable stress this table shows like you have carbon steel, carbon steel this one plates and plates and shells carbon steel. So, for that you have different grade, grade 55, grade 60, grade 65, grade 70 and grade A B C different grades are there for that for different temperature range 20 degree Fahrenheit to 60 degree 650 degree Fahrenheit. You have from ASME section 8, you have allowable stress 13,800, 15,000.

So, in mathematical problem if I do not give you the value for allowable stress, so you can get the allowable stress from the table ASME section 8 that from the table actually. This table I have taken from book Arnold and Morris surface production operation, this one also from Arnold Morris surface production operation. Estimating vessel weight most cost estimating process starts with W, W means vessel weight. Both empty and full with water may be needed to design foundation lifting erecting construction. So, when lifting erecting because weak separator system or weak vessels transportation, erection also one issue.

You fix it then again you have to fix all the heads, pipes and nozzles, so that will be big challenge. So, you have to reduce weight as much as possible. So, weight formula is that weight of shell, shell means this one shell, then head this one head and this one head, internals, internals

may be wave breaker and other things will be there. Nozzle may be there somewhere, nozzle may be entry exit, pedestal or this one scart actually where it is getting fixed bottom part. It should not be touching on the bottom, rather it will be hosted by some metal structure called scart or pedestal, pedestal like this.

So, whenever calculating pressure vessel weight you have to include all the parts. Now problem, using those formula already we have seen some formula, so using that formula we will try to calculate pressure vessel weight. A free water knockout is fabricated with butt weld and built as per division one of the ASME pressure vessel code. The bottom of the vessel has conical head, bottom of the vessel is, sorry bottom of the vessel that means this is conical head. So, design pressure is giving 125, maximum operating temperature is given 200 degree Fahrenheit, corrosion allowance given 1 by 4 inch, material is given AC 516.

So, if some value is required then we have to go back to table. Diameter is given 120 feet, seam to seam length is given 12 feet, cone apex angle is 60 degrees, alpha equals 30, joint efficiency E equals 0.85 and maximum allowable stress 17500. So, here already 17500 is given, so you do not have to go back to your table actually, so material may not be required then. Scart plate thickness, a scart plate means this bottom scart is here, so this plate thickness is given 0.

5 inch. Determine weight of the vessel, weight of the vessel means you have to add all the part, whatever information given based on that you have to add all the part. Compare this weight to that of vessel without the conical section and that to vessel with 1 by 4 inch plate internal cone. So, let us try to solve this problem. So, first start with shell, shell formula you can remember T equals P R, T equals P S E minus 0.

6 P. So, S value is given 17500, E value given 0.8. So, this gives 125 into P 125, R is D is 1, D is 60, D is 120, so R is 60 and S E S 17500, E 0.85 minus 0.6 into P value, P value is given 125.

So, this value is given 0.507 inch, but you have to give allowance first corrosion, corrosion allowance I think it is given, corrosion allowance 1 by 4 inch given. So, 0.25 we have to add.

So, T c given 0.25 inch. So, thickness total thickness equals 0.25 plus 0.507. So, it is coming 757, 757, 757. So, this is the total weight of the shell, weight is equals 11 D T L equals 11 into D 120 already given, D 0.

757 into 12 equals 8027 into 0.027 L b or pound. Now, you have calculated shell, now calculate head. So, you want to calculate head, then again T formula you have to use equals P D 2 S E minus 0.2 P. So, that will be giving 125 D 120 2 into S value 17500 into E value 0.

85 minus 0.2 into 125. So, this is giving 0.505 and so T total 0.505 plus 0.25 because corrosion allowance is given, so this is given so it is coming 0.

755 inch. Now, weight, weight equals 0.34, 0.34, weight equals 0.34 T D square plus 1.

9 T D. So, this will be giving 0.34 into 0.755 inch. So, this is 0.

57 into 120 equals 3866.702 pound. Now, we will go to next slide because I just filled it up. Now, cone, cone, so cone will be giving T equals P D 2 cos alpha H S E minus 0.6 P. So, the value if I put it will be coming like this 125 into 120 divided by 2 cos 30, then 17500 0.

85 minus 0.6 into 125. So, this will be giving 0.5 into 0.

5 0.585 inch. Now, thickness T total equals 0.585 plus 0.25 equals 0.835 inch. So, weight of the cone is 0.

23 into T D square by sin alpha as per formula. So, this will be 0.23, 0.23 into 835 T into D 120 square divided by sin 30.

So, it is giving 5532.49 pound. Now, skirt, skirt conical shape, so this is the weight of the cone. So, this is the weight of the cone. So, this is the weight of the cone. Now, the weight of the cone is 0.

25 into 10 to the power of 10. So, this is the weight of the cone. Now, L equals 0.5 D by 12 tan alpha plus 2. So, this value will be like this 0.

5 into 120 divided by 12 into tan 30 degree plus 2. This is coming H equals height, because this is like this. So, you have to calculate height also. So, A, B, C, this is alpha. So, A, B equals height, this is actually 60, this is 60, this is 60, this is 80, A, B.

So, this value will be coming 10.66 feet. Now, H, now W equals, it is coming L D T into 11 equals 11 into 120 into 0.

5 into 10.66 is given 70.735.77 pound. So, total weight, so shell head is equal to 10.66. So, this is the weight of the cone. Head because it will have shell, then head, then cone, then skirt. This is shell, this is head, this is cone, then skirt, all weight we have to add.

Head, then cone, skirt, shell weight is 11987.03, head weight is 3866.97, head weight is 3866.97, head weight is 3866.

97, head weight is 3866.70, cone weight is 5532.05 and skirt weight is 7075.77. So, total weight coming, total of the system, total whole pressure vessel weight is 2866.

97. So, total weight is 48421.55 L B. Now, case 2, that was case 1. So, case 2, skirt is changing. So, skirt length equals 0.

25 D by 12 plus 2 is coming 0.25 into 10.66. So, this is the weight, 120 by 12 plus 2. So, it is coming 4.

50 feet. Now, weight is coming 11 into 120 into 0.5 into 4.5, so 2970 pound. So, now summary. So, weight is 11 into 120 into 0.5 and summary is coming like this, shell, head, 2 heads are there.

So, skirt, so shell weight is 11987.03, head weight is 3866.70, so same head, 3873.97, head weight is 3866.97, head weight is 3866.70 and skirt weight 2970, we got just, altogether it is coming 22690.

43, total weight pound. Now, another case is there. Case 3 shows like internal cone, internal cone is 0.25 into 10.

66, internal cone is 0.23 into 10.66, internal cone weight is 0.23 3 D square by sin alpha equals 0.23 into 0.

25 into 120 divided by sin 30 degree. So, this will give 120 by 10.66. So, this is the weight of the cone, 1656 pound. Now, shell, this internal cone shell, height of the cone, height of the cone equals 10 by 2 radius divided by 10, 30. So, it is like this. So, this is A B C, this is 5 actually, 10, this is 5 and this is 30 degree.

So, BC by AB equals tan 30. So, AC equals BC by AC, not AB, BC by AC. So, AC is 5 by tan 30. So, AC equals BC by AC, not AB, BC by AC.

So, AC is 5 by tan 30. Now, from there we get height. So, height is 0.25 into 10.66. So, this is the height of the cone.

So, height equals 10 by 2 by tan 30 equals 8.7 feet. Now, we go to next slide. So, length of the shell, length of the shell, length of the shell is 12, already given plus 20. So, how it is like this? So, first it is there and your skirt is coming here. So, 12 is there and 8.7, your cone height, cone height is there and previously it was 12 and this is cone, 8.

7, this is 12. So, it is coming 20.7 feet. Now, weight of shell W is equals 11 dt L. So, 11 into 120 square into 0.

7 feet. So, this is the weight of the shell. So, this is 0.757 actually. We got it from previous slide, we got 0.

757 into length 20.7. So, it is coming 2, 2, 2. So, this value is coming 20637. So, this is the height of the shell. So, this is 20637.9. Now, summary shell height, shell weight, shell weight then head, head, skirt, cone.

So, shell weight is 20637.9 and head weight 30.

7. So, this is the height. So, this is 3866.7, 3866.7 and skirt weight is 2970.0 and 1656.0. So, all together it is coming 32997.3. So, you can see the difference if we change design, the weight is changing. Thank you very much for this lecture.