Surface Facilities for Oil and Gas Handling

Prof. Abdus Samad

Department of Ocean Engineering

IIT Madras

Introduction to Heat Exchanger-01

Now, we are trying to move towards the calculation LMTD heat exchanger ok. LMTD is actually very much famous for examiners I think I have seen many GATE papers in mechanical petroleum and chemistry or chemical also. They are using LMTD related formula because it is a very simple concept if you do not understand you will not get marks ok. So, especially GATE exam many many questions are there using LMTD. LMTD plus some other mix-up, but LMTD will be on part ok. In GATE also last few years petroleum trend also been seen, majority time 90 percent time they have used the LMTD thing ok, one problem using LMTD ok.

So, you should learn ok. So, multiple transfer mechanism. So, normally if you have on a single slab temperature let us say 100 degree and 200 degree and temperature heat is getting transferred solid body life is easier q equals k a minus k a delta T by L ok, q equals minus k a del T by L. So, this formula used.

Convective heat transfer also you can you have used h a delta T ok. So, length was not there, but if you have multiple issues like say you have convective heat transfer here fluid is heat less 100 degree centigrade here may be 200 degree centigrade and I have one layer or surface coating may be that h value will be different k value will be for this material is different may be there is another material L value oh sorry k 1 k 2 may be there will be air here. So, their h value will be different ok. So, many layers are there and heat is getting transferred let us say you have one tube ok. So, tube one will be upper layer may be some fouling fouling or extra deposition or metal or some dirt is there.

So, that will have some conductive heat transfer coefficient above that there will be convective heat transfer coefficient then solid metal may be copper conductive heat transfer coefficient ok. And inside also there may be some again deposition or layer or dirt again convective. So, if you have to calculate this one then the single formula k equals del T by L will not work. So, you have to make some combine or combination formula ok. So, that formula is like this u equals u A delta T ok, simplified formula.

So, what is u what is A what is delta T u actually universal constant universal how they are making universal not like gravitational constant or like this they are making using this k h some other parameters also ok. So, this is called universal constant or overall heat transfer coefficient overall h T coefficient overall h T coefficient C CoE ok. So, this unit is unit is B T u British thermal unit h r f T square degree f this is not minus this dash dash I have given ok. And Q value Q value is B T u per hour ok, because u is having hour term. So, that is why hour is coming if you want to convert to second or minute then you have to convert 1 ok.

And del T temperature difference ok A area ok. Now from here this del T del T also not simple del T inlet temperature outlet temperature let us say if I have 2 pipes ok wait ok,wait wait hm not looking good just let me draw properly ok. Let us say 1 inner pipe and 1 another outer pipe ok 1 pipe this 1 another pipe is here ok. So, 1 pipe flow direction let us say Q 1 another pipe flow Q 2 maybe same direction both fluid flowing inner temperature maybe T 1 outer temperature maybe T 2 2 fluid inner maybe gas out maybe water ok. And inner temperature maybe say 100 outer temperature maybe 200.

So, 200 to 100 heat will be transferred or opposite way I can make outer 200 inner maybe hm outer maybe 100 inner maybe 200. So, heat will be getting transferred from 1 pipe to another pipe 1 right. Now, so how to calculate this in this case ok it is not simple easy case for example, what happens ah this in inlet temperature the inlet for outer 1 maybe 30 degree ah 30 degree to 100 degree increased and inner 1 this is 300 degree ok. So, inner pipe has 300 degree temperature when it is exiting it is giving 200 ah outer pipe inlet temperature 30 degree exiting 100 degree ok. So, temperature changing for both fluid because heat is getting transferred.

So, both fluid temperature is changing. So, in that case what will be your del T this is very difficult. So, in that case you have to use logarithmic mean temperature difference ok. So, how to do it? So, let us say this is pipe length ok. So, inlet T outer pipe Ti increasing 30 to 100 ok 30 to 100 and inner pipe 300 to 200 this will not be straight rather it will be parabolic type 300 to 200 right.

So, temperature inner pipe initially it was 300 it will become 200 reduced outer pipe it was 30 it will becoming 100 ok. But if I have opposite case where opposite case let us say inner pipe flow same direction same temperature inlet 300 degree centigrade ok and 200 degrees 200 degree centigrade, but fluid direction this ok, but outer fluid direction opposite ok. So, outer fluid direction opposite. So, in that case inlet temperature can be let us say same temperature if I keep 30 degree and outer maybe 50 degree possible. So, outer increase temperature 30 to 50 inner reduce temperature 300 to 200.

So, how this figure will look like? So, first let us do inner one inner one is 300 to 200. So, 300 to 200 ok and outer one 30 to 50. So, 30 to 50, but direction opposite. So, my arrow direction should be opposite 30 ok. Now, because del T you have to find del T actually LMTD logarithm mean temperature difference.

So, LMTD when you are calculating. So, left side del T 1 equals you have to say T 1 this temperature difference left side T 1 maybe this is del T 2. So, does not matter which side you are writing del T 1 del T 1 side you can write del T 2 also there is no issue, but one side del T 1 another side del T 2. So, here also del T 1 del T 2 ok does not matter whether you are writing left side del T 1 right side del T 2 ok, but formula is most important. So, logarithmic mean temperature difference equals del T 1 minus del del T 2 logarithm a natural log not base time this log base T del T 1 by del T 2.

This is actually del T whatever you are giving in the equation 1 ok. Equation 1 you have written del T. So, that del T actually. So, LMTD equals del T 1 minus del T 2 divided by logarithmic del T 1 divided by del T 2. So, if you are writing del T 2 minus del T 1 log also will change.

So, symbol will be positive finally, ok. So, you should not mix up you are writing del T 1 first then logarithm also up del T 1 then del T 2 ok. So, then symbol will be positive if you are doing some mistake anyway then it will becoming negative negative means you have done something wrong ok. So, this is universal formula for both cases. So, only you have to remember del T 1 del T 2 how to write ok.

Then after that the formula is only one formula LMTD. LMTD is formula 1 for both parallel flow or counter flow. This is equal ah this is same directions with parallel flow ok and this is counter flow. Well therefore, sometime we write co-current flow also ok. So, for this one this figure and for this one this figure ok.

So, phase change also possible let us say water you are taking 0 degree high temperature hot fluid temperature 200 to 100 reducing, but water temperature is fixed that is also possible because as far as temperature difference you are creating this formula is unique ok LMTD this formula. And based on this formula I think mechanical chemical I already told petroleum they are using lots of problem tweaking here and there ok. So, so you should be having good comment about this one whatever I believe ok. So, let us see some simple problem. Hot fluid enters concentric pipe heat exchanger at temperature 300 degree Fahrenheit.

Hot fluid 300 degree Fahrenheit entering it is to be cooled to 200 degree Fahrenheit by cold fluid entering at 100 degree Fahrenheit and and heated to 150 degree. Calculate LMTD for counted current and co-current co-current means parallel flow ok. So, both are actually parallel, but co-current normally they say parallel. So, first you have to draw the figure ok before you handle any LMTD problem first draw the figure. So, your hot fluid co fluid you are saying counter current.

So, first you draw counter current ok and one co-current also co-current means like this first of all. Now you put the temperature what about data given ok you show that arrow also ok. So, you are saying hot fluid entering pipe heat exchanger 300 degree Fahrenheit. So, 300 degree Fahrenheit here also 300 degree Fahrenheit ok this is counter this is co right ok. Now and is to be cooled 200 degree by cold fluid and it is to be cooled 200 degrees.

So, 300 200 degree here also 200 degree ok by cold fluid entering 100 degree Fahrenheit cold fluid entering 100 degree Fahrenheit here also 100 degree Fahrenheit and heated 150 ok. Now, del T 1 del T 2 ok. So, del T 1 what is del T 1 300 minus 150 150 here counter current del T 1 del T 2 100 ok for co-current del T 1 200 del T 2 50 ok. Now LMTD LMTD for this one yes I will separate LMTD for this one. So, del T 1 minus del T 2 divided by logarithm of del T 1 by del T 2 ok.

So, del T 1 what is this 150 minus del T 2100 divided by logarithm of del T 1 150 divided by del T 2 100. So, 50 divided by logarithm of 1.5 and LMTD for this one same same formula I have to apply del T 1 by del T 2 ok. So, del T 1 how much 200 here del T 2 50 logarithm of 200 divided by 50. So, it is coming 150 logarithm of 4 ok.

So, what is the left side value? 150 ok. So, this is coming 123.3 degree Fahrenheit this is coming 108.2 degree Fahrenheit ok. So, two different values are coming, but this is the procedure.

So, in exam also similar or some twisted problem can be created and it will be given ok. Is it clear? So, this sort of problem you search Google lots of problem there in mechanical get paper also I have seen not only petroleum, petroleum also there every year. Last few years I see 2016 what I checked every year LMTD there almost ok. Overall heat transfer coefficient I told Q right.

Q equals U A del T. So, del T already we calculated LMTD, but not only LMTD if some other value also given like say already fixed temperature I will be giving use this formula this value. So, you can take that one ok. If there is not given maybe you have to calculate using LMTD or some other method that will be instructed in your question. And what is the U value all right? A means area you know, but U value you have to calculate. So, U value like yeah I have one pipe I have one pipe ok.

So, pipe actually it is like this ok. I cut this one I have cut it 50 percent. So, that is why it is looking like this ok I just split it ok. Now I will have inner diameter of the pipe I have this one inner diameter maybe R radius R I R O ok. So, it will have inner maybe some convective heat transfer coefficient, outer maybe heat transfer convective heat transfer coefficient, I can have fouling also fouling means extra metal deposit on the surface ok because of you have calcium water is not preferred and we are using for your boiling application. So, the salts will be deposited on the surface.

So, that will be dangerous sometime it will be problematic. Sometime water or fluid will have some dirt that will be getting deposited on the surface. So, metal conductivity is very high, but your scale or the dirt or fouling that part the heat conductivity will not be same it will be normally lower ok. When heat conductivity lower that means heat conductivity it is reducing ok. Your pure copper will be very high conductivity, but when dirty is there so conductivity will get reduced ok.

So, you have to remove actually or you have to make some arrangements so that that deposition will not be there. So, if it is deposition is there then what will be your heat transfer rate that you have to calculate. So, you to calculate that and actually you have to use this u value overall heat transfer coefficient. So, you may have one layer of scale we say scale ok fouling or dirt and you have one convective heat transfer here because from outer fluid one layer will be created then heat will be transferred to a solid body then again inside one layer will be there ok. So, then one convective layer, one conductive layer, one conductive layer then again conductive layer maybe then again conductive layer sometime there will be some multiple layer of pipe also one pipe can be like one solid softer material harder material.

So, pipe also will have many layers sometime ok especially in electrical conductivity system they will have many layers ok. So, formula is that 1 by u equals 1 h i A i plus 1 by k by L plus 1 by h o plus r i plus r o ok. This is the universal heat transfer heat transfer coefficient. So, h i inside film h i inside film coefficient film coefficient or heat transfer coefficient of a convective heat transfer coefficient. So, it will be creating thin film ok on the metal surface.

So, that is why sometimes they say film coefficient ok. So, you should be familiar with the term convective heat transfer coefficient or film coefficient all the same ok. Again unit you know Btu Hr ft square degree f ok. So, these are not minus this is just dash dash I put ok. So, do not be confused that minus I put h o outside heat transfer coefficient ok and k L 1 by k L k is conductivity transfer coefficient L means length ok.

A i pipe inside diameter and A o outside diameter A o r i r o. So, you have many other resistance also. So, you can add ok these are called resistance actually ok. So, if you have many other resistance then you can add one by one.

Process heat duty. So, using sensible latent heat process fluid temperature changes. So, sensible heat, sensible heat means you can measure using temperature. So, you can sense actually it is hot it is cold this is sensible heat like 0 degree to 100 degree centigrade water temperature increased. So, you can sense it you can feel it ok. So, this formula is u sensible heat equals W c T 2 minus T 1.

I think you already know, but just you should be recapping W means mass it is heat capacity temperature difference. So, this is sensible heat you are calculating, but if you have latent heat the formula will be W lambda. So, lambda is actually your latent heat

Btu per pound and mass L b per hour. So, this latent heat for value will be coming Btu per hour ok.

So, C value if you are putting in sensible heat unit. So, so W is mass flow rate in sensible heat. So, if it is having unit B mass flow rate L b per hour. So, Q sh also becoming Btu per hour ok. And C value C unit is Btu per L b per degree Fahrenheit. And heat duty from multiphase stream Q p equals Q g plus Q o plus Q w.

Q g gas heat Btu per hour Q o oil heat duty Btu per hour because all unit must be same ok Q water water heat duty water again same unit Btu per hour ok. If you have different if you have different unit then you have to convert and you have to make same unit then you can add only.