Aspen Plus Simulation Software – A Basic Course For Beginners

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Lecture-30
Absorption and Distillation - Part 2

(Video Starts: 00:29)

So, in the stripping column again we will choose a Rad Flac column this time. Let us choose this type of icon let us increase the size a bit let us rename it as stripper str. Now for stripper we have some information. Go to the relevant chapter, yes, model validation of stripper. Here it says in the stripping section case study we have two different pilot plant facilities considered one is CO_2 capture facility from synthetic material chemistry described in Tobiesen et al and it is available in this reference.

And the other one is a pilot plant from university of Texas at Austin described by Dougas found at this reference. What is the difference? Difference between the two cases found in the configuration of the water stream exiting from the condenser. In the first case in SINT F water is mixed with the liquid exiting from the bottom of the stripper and then sent to the reboiler. So, that MEA if we have a condenser over here in the column this is the condenser and this is the reboiler.

So, this liquid stream is added with the reboiler it is sent to the reboiler and in UTA case the same stream is sent back to the top of the column as reflux. So, in UTA case it is given like this and for the first case it is sent like this. Now we will choose this one Tobiesen et al. Now, again why we are choosing it? Just for the sake of it. When you do the practice problem you can choose Dugas reference also go back to simulation.

Now as we have to do such, such type of changes in the condenser and reboiler output we cannot use the condenser and reboiler integrated with the column because the condenser and reboiler which are integrated with the column has its own configuration which we cannot change. So, we shall use two flashes one at the top another at the bottom. The top flash will be regarded as the condenser and the bottom flash will be regarded as the reboiler and we will do the configuration at our choice. So, for that we choose one flash at the top which will be our condenser at the bottom which will be our reboiler.

So, we name it accordingly this is our condenser and this is our reboiler. So, as it is said water stream exiting the condenser it is mixed with the liquid exiting the bottom of the stripper and then sent to the reboiler. So, basically this stream is sent to the reboiler and this stream also is sent to the reboiler. Mixing MEA you can use a mixer but even otherwise you can just throw in inside the reboiler either way it will work.

And then this is the stream in this is the stripper outlet to the condenser and this stream should be pure CO_2 if not pure it is mostly CO_2 all other things have been knocked off. So, we shall rename them accordingly we will rename it as str in this is str vapour this is str liquid this is condenser liquid and this is CO_2 and one more output is left this one actually two outputs one is reboiler output which is going inside the stripper back.

So, this one is reboiler recycle and this one is reboiler vapour that is going inside the column again. First, we have to check what is the feed in the stream line? For that let us choose the Tobians in case its temperature is 389.91 Kelvin. So, 389.91 Kelvin, pressure 196.96. So, 196.96 of kPa, molar flow rate it is 10.71 kilo mole, mole fraction 0.0348 CO_2, MEA0.1102 and water 0.8549. So, total it is coming 0.9999. So, let us add one somewhere let us add here that makes one.

So, everything has been given. Now streaming has been given stripper again it is rate-based number of stages let us say 20 stages again there is no condenser no reboiler because both of them we are using externally. The stream, now stream in will send from the top of the column and reboiler vapour it will be added from the bottom at the 20th stage so, on 20th stage. And then go to the pressure.

Now stage one pressure has not been said but as the liquid stream str in is inserted at the top of the column and its pressure is 196.96 kPa. So, let us keep the stage one pressure also at 196.9

kPa and there is a pressure drop somewhere yeah this is a pressure drop 1 kPa. So, condenser pressure drop one kPa what about the flash? Flash it says that it operates at 196.96 kPa the pressure is 196.96 kPa and the temperature condenser temperature has been given 288.15 Kelvin and already we have entered 196.96 kPa at the stage one.

Let us say pressure drop is zero rather than fixing the pressure once again. We will say pressure drop is zero. So, there is no pressure drop in the condenser the reboiler we have the information of reboiler duty which is 11.6. So, it is 11.6 kW of heat duty with zero pressure drop there is no pressure drop in the reboiler as well. So, reboiler is done. So, condenser reboiler, as it is a red based column.

So, we have to fix the column internals add new there add a new section and extend the section from 1 to 20. So, that is a single section column its mode of calculation again its rating and type is packed packing type I think it is different here it is Mellapac 250Y cells. So, it is Mellapac cells dimension 250Y height and diameter 3.89 and 0.1 3.89 and 0.1. Now go to the rate-based modelling setup the old stuff we just repeat them it is 0.9 reaction condition factor.

Film discretization ratio of 10 and in this section, we will have a rate-based calculation and then it will be discretized the liquid film with five discretization point we will consider the vapour phase film it is done and, in the rate, based report we can include the mass transfer rate as well. So, the reactions it occurs from stage 1 to stage 20 and the reaction id is MEA reaction. So, it is done. So, there is a problem with condenser and stripper.

Let us check what. So, here I have given condenser pressure drop of 1 kPa instead of condenser pressure drop we have to say stage 2 pressure drop because there is no condenser in the system and again. So, there is an error perhaps the reboiler duty is not enough. So, we shall increase the reboiler duty to 21 21.6 and try it once again. So, again there is an error in the in the stripper. So, we have to look somewhat carefully what could be the error twentieth stage pressure is one and two.

There lies the problem we are operating at 196.96 bar. So, I always say that you have to be very careful about your units with the wrong unit all your simulation will go down the drain. So, again you have to do the simulation and hopefully it will converge. Now, so, it has converged without further problem. So, let us save this simulation. Now here again we have to check a few profiles the stripper liquid temperature profile variation it should look like this. So, we go to the stripper block this time.

So, this is the stripper block profile is the liquid temperature convert into Kelvin and then copy and go to the; yes, this one. So, we will check only this up to this point, yes, so 390 to 394 I think we have shifted it to chart one will delete this one yes. So, from 395 to 390.5, so, it has come from 395 to 390.5. So, with 20 it is neither 10 nor 16 or 70. So, we have taken n is equal to 20. So, it should be somewhere in between and I believe that the trend is correct and if you want to see the CO_2 vapour composition that also is possible you have to go to the composition vapour and mole CO_2 copy go to sheet2 press over here, yes.

So, this is the chart. So, in this case the height is not 6.55 the height is 3.89 meter. So, we have to change the data. So, from 6.55 to 3.89 and here also 3.89 now it has, yeah from 1 to 3.89 the trend is definitely same. So, we can argue that our trend as well as the numbers they are matching we have verified the absorption column and the stripper columns separately with separate input information.

Now we shall add them up first we should see what is the temperature and pressure at various ends. So, the temperature and pressure at various ends are given over here before that let us refer to the chapter 5 where the design analysis has been integrated. So, this is the industrial CO_2 post combustion capture by reactive absorption stripping plant flowsheet. Now here we have to use a heat exchanger and a pump while sending the rich solvent from here to the stripper.

So, obviously we need a pump because here the pressure is 1 bar and here the pressure is 2 bar. So, we need a pump to increase the pressure and we need a heat exchanger because here it is at 28 ^{0}C and here it is 117 ^{0}C. The reboiler output it is 119 ^{0}C. So, it is expected to transfer the heat from this end to this string through this kind of heat exchanger arrangement. So, let us first use a pump.

So, the pump is over here and for the time being let us use a simple heater later we can change the heater to heat exchanger no problem. So, the pump will pump it out with a discharge pressure of 196.96 kPa which is actually the pressure at entry point at the stop stage of stripper column. So, we write it as pump and we connect this to the outlet of the absorber. And then the outlet of this pump will go to this heater and another material out from this end to this end and we will have one mixer over here.

So, let us use a mixer let us connect this one to this mixer and let us connect the water outlet of the condenser to the mixer instead of the reboiler here the configuration has changed. So, we have to reconnect this stream with a new destination which is over here. So, we will keep it over here and this one will keep it over here and outlet of this stream out of the mixer is over here. And obviously we have to fix the heater let us say the heater will go up to 110 ^{0}C with zero pressure drop.

So, it is 117 ^{0}C with zero pressure. So, let us run it, it should not take much time because already it had converged a few minutes back let us check yeah. So, it has converged again. Now the system is ready to connect these two strings. So, what we will do we will knock off this str in and add this s13 to str. So, for that let us cut this and reconnect this one to str and now we can safely rename it as str in.

Now obviously the composition of the new string will be different earlier the composition was 3.48 of CO_2 11.02% of MEA and 85.49% of water. But right now, the condition will be of the rich amine which is actually almost no carbon dioxide instead of 3.58 we are entering with no carbon dioxide and 95% of water we are entering and MEA is merely 3.75% instead of 11. So, there will be lot of changes and lot of ions will come in earlier there was no ions in it.

Now there will be lot of ions. Now we have to fix in the connection point of strm because earlier we deleted the previous stream. So, we have to re state that string is at or above stage one and.

Now we have to re-run the system. So, again it has converged we are happy it did not take much time. So, we save the result. Now you see the temperature has increased to 121 ^{0}C. Now let us take a strategy. Now time has come to replace this heater with this heat exchanger but will not completely discard this heater I will tell you why we feel that it is not possible for this stream to pass on enough heat to make it 117 without experiencing the temperature crossover.

First, we will place the heat exchanger over here and then we shall reconnect this line to this destination and reconnect this line with this source and we shall rotate this icon take this stream reconnect with this destination take this material stream out connect with this take this out and connect with this. Now we shall increase it up to 150 ^{0}C, I will tell you why I am doing it. Fix the heat exchanger let us say shortcut heat exchanger will fix the cold stream outlet temperature at 117 ^{0}C.

Rename it as hx rename it as h out. Now run it once again. So, all other things were already converged. So, they should not take much time yeah. So, it has converged again. Now we will look at the condition, here if you say vapour fraction. So, this is vapour fraction completely one and here the heat exchanger output we have vapour fraction 0.85 that MEA gradually the vapour has started condensing and lot of latent heat is being spent in heating this stream at 28 ^{0}C to 117 ^{0}C.

Now here you can check the vapour fraction is 1 over here and here the vapour fraction is 0 that MEA here it is entirely liquid here it is entirely liquid here it is entirely liquid if you check the heat duty you will find 22 kW that MEA 22 kW of duty is required to take this temperature from 28 ^{0}s C to 117 ^{0}C. Now the temperatures are so close that it is my apprehension that it is not possible for the heat exchanger to take up enough heat from here to bring the temperature from 28 ^{0}C to 117 ^{0}C.

So, what we can do we can decrease the temperature a bit. So, instead of 117 let us take 110 ^{0}C. So, that the temperature difference from this end and this end are a bit higher and run the simulation once again. So, in the bargain we have got even lesser amount of heat duty that is being carried over here. By decreasing the temperature, we have got a fair estimate that perhaps. Now we have enough amount of heat duty that we can transfer from this stream to the stream.

Now let us decrease it from 150 to say 130 and check what happens. So, you can see that it has come to 70% of vapour fraction. So, we can still decrease the temperature say to 125 ^{0}C and run it once again. So, now it has almost come to the level let us make it 121. It is very close though. So, it has almost no latent heat at all. So, let us save it and then change it make it 120 now and see whether it can converge.

So, it has safely converged. Now you can see that it is showing heat duty zero that MEA this heater is not at all working its temperature is same 120 and a stream of temperature 120 ^{0}C is able to offer enough heat duty for this heat exchanger to work. So, now what we can do we can simply delete this one and we can delete this stream as well and we can reconnect with this destination and we run it once again, yes.

So, it has converged. So, we can save it. So, now you can see how small this temperature is it is only 33 ^{0}C. So, almost we are able to exchange entire amount of heat. Now the purpose of vapour fraction is over. Now we can just untick it to reduce the clutter. Now the recycle stream is having the temperature of 32 ^{0}C and it is at two atmosphere pressures. Now it has to come to one atmosphere pressure or to be very specific it should be one zero three point one five kPa pressure and the temperature has to be 19 ^{0}C in order to make it usable over here.

Now for that refer to this here they have asked us to use a pump and a cooler but pump is not necessary because it is already at two atmosphere pressure there is no need to pump it to a higher pressure rather we have to use a valve over here. So, that we can reduce the pressure to 103.15 kPa and obviously we need a cooler to cool down the temperature from 32 ^{0}C to 90 ^{0}C.

So, we need a valve over here and one cooler in series. So, rotate this icon and this icon also this one is cooler and this one is valve. So, that is how we rename it and we connect this and this material connection from this to this and this is the outlet. Now rename it as mixer rename it as

M out rename it as V out rename is as recycle and then we have to specify the outlet pressure of the valve or discharge pressure of the valve and that is 103.15 kPa.

Because that is the pressure at which lean amine enters the column and the cooler output it should be 19 ^{0}C or we can refer to this one once again. So, it is 292.15 Kelvin. So, it is 292.15 Kelvin and zero bar pressure drop. Now you can run it once again. So, it has run and it has converged also. So, save it, and we have come to the last portion of our task that we have to recycle it before that let us see the results of recycle and compare with the original lean stream.

Now the temperature and pressure are same the molar enthalpy mass enthalpy molar entropy mass entropy the densities everything are comparable the molar flow rates are also comparable but the mole fraction is somewhat different MEA the lean phase it was 5.48% whereas in the recycle stream it is 3.97% water it was 94.48% in the lean stream it is almost comparable in recycle stream. There was no CO_2 in either stream there is CO_2 obviously in recycle stream but there in the form of CO 3 minus MEACO minus etcetera.

Now the question is whether we can directly remove the lean stream and add the recycle stream in its place. In other words, whether we can do like this if it is possible then our job will be much simpler. We will just open the absorber and we will tell that we are feeding the recycle stream at stage number one and then we can run it let us see whether this thing works. So, let us open the control panel there will be lot of changes in between we will just keep on observing.

Observer converges stripper also getting converged yeah it is good sign but iteration one it says 18 variables are not converged. So, we are at iteration number two the stripper and observer they are not creating any problem but again 19 variables are not converged. Here iteration number 3, 18 variables are not converged iteration number 4, 16 variables not converged then 16 variables becomes 17 variables. Instead of going down it is going up iteration number 16 it says 15 variables not converged and so on.

Let us see how long it goes. So, we have waited up to 35 iterations and there is no sign that it will come to a convergence very soon still we are hovering around 17 variables which are not converged. So, what we will do we will stop over here and take some other strategy. Now it is a known fact that converging a recycle stream is a tricky thing it is not always possible to converge a stream very easily.

There are various techniques one of them is steering a stream. So, in this method you have to tear a stream in two parts one is inlet the other one is outlet. So, you have to set in the inlet to such a condition that the outlet at the other end also is same for instance suppose you delete this stream and recycle it back and then you can tear this particular stream that MEA this is an inlet stream and this is an outlet stream this is in this is how there is no connection between them.

And you can manipulate the inlet stream and its condition in such a way that the condition of the outlet stream is same I MEA after the simulation it comes to be the same. So, once this inlet stream and outlet stream conditions are exactly same or somewhat similar very close then you can just delete one of them and connect the other end in such situation it will be very easy to converge your solution.

Now there are many other ways of converging recycle stream if you study various literature and study material or video on Aspen Tech you will find various other techniques. But one technique that I am going to teach you will not find it in any other study material or other video because that technique I have found myself while working with aspen tech which I am going to teach you. Now for that you need two splitters and one mixer.

So, suppose you have a splitter over here and one splitter over here and you will get one mixer. So, this is splitter one; this is splitter two and rotate this icon just flip vertically this is mixer. Now we shall reconnect the stream to this destination reconnect this stream to this destination then connect this to this destination and connect this to this destination and the mixer output we connect to this one and then one output will be in this one and here the output will be like this.

Now rename it as Arlene and rename it as R recycle this is M in. The M in will go into the first stage. Now we have two blocks to fix first one is the sp1 that is the block over here and second block is sp 2, sp 1 we will say that Arlene is 0.99 sp 2, R recycle is 0.01. Now look at this what we have done we have used a splitter where the lean amine has been splitted into two parts 99% is going over here one% is being rejected.

And the recycle stream only 1% is added over here 99% is rejected these two are mixed and the mixed flow is being sent into this particular absorber. So, run this. Now although we have done some changes but the lean, I MEA it is still 99% and recycle only one percent. So, only 1% change I have introduced into the system and the recycle loop is connected in most of the cases this thing will converge because the amount of recycle is very, very small it is just 1% yes it has converged.

So, we save it first. So, we have saved it. Now in this case you can add in the molar flow rate and let us not bother about the temperature and pressure at this moment because these information's are not of that much of relevance. And heat information is also not needed instead we are watching the mass flow rate and molar flow rate. So, here we find the mass flow rate is 223 and molar flow rate is 11.

Now we decrease the lean I MEA portion to 95 and increase the recycle portion to 5% then run. So, gradually we will decrease the fresh amine and increase the recycle. So, it has converged again. Now you decrease it further make it 90% and this one you make it 10% run it again it has converged. Now every time you can see the mass flow rate is gradually increasing earlier it was 223. Now it is 224 kg/hr and next time you can change it to 80% and this thing to 20% run it again it has converged.

Now we have become a little bit adventurous. So, we reduce down from 80% to 60% a big jump and there we increase it to 20% to 40% and run it well it has converged again. So, it gives us more confidence in decreasing the line amine further to say 60 to 40% another 20% jump and lift the other one from 40y% to 60% run once again. So, it has converged again. Now you can see 138 kg/hr of recycled stream is being entered over here only 89 kg/hr of fresh amines.

So, we reduce it down further less 0.2 and increase it to 0.8. So, it has converged again and you can see 185 kg/hr recycle stream we are entering while 45 kg/hr is the fresh amine. So, we will do one more just reduce it to 10% and increase it to 90% this is the last thing that we are going to do. So, it has converged once again. Now you can see out of 235 kg/hr of recycle stream we are using 212 kg/hr only 22 kg/hr of fresh amine we are using and 24 kg/hr of the recycle we are just throwing it back.

Here you will notice although we have got some result but we are having some warning of convergence streams crossing the loop converse by solver are not in mass balance. There is a problem of the mass balance mainly because earlier when we were sending lean amine it was only 223 kg/hr but we have increased it to 234. So, 11 kg/hr we have increased as the mass flow rate has increased perhaps 0.1-meter diameter column is not enough there may be the problem of flooding over here.

What we may argue that well this splitter we do not need instead we will give 10% of the lien amine over here. So, this one also we can delete cut and we can cut this as well and we can reconnect and we can change its value. So, instead of 3.04 we can give 10%. So, it is 0.304 in that case we do not have to use any splitter directly we can enter this lean amine to the mixer which will get mixed with the 90% of this recycle 10% anyway it is going out as in west.

So, this gives us an idea that although recycle stream is having all the amines but we cannot use them entirely we have to throw some amine out and replenish with some fresh amine and that is exactly what is done in real life scenario. In the industrial usage you really cannot use the total amount of amine in the recycle mode you have to add in some fresh amine always. And finally, if you want to store your simulation results in proper format you can do it by exporting the result into microsoft excel file.

For that you have to go to the result summary go to streams and here you will find the send to excel ASW. So, just click it, it will give the option and you can add the table to existing workbook or you can take it to a new one. So, it says export tables to excel and suppose you want to send it to CO_2 MEA dot xls save then you will find the progress over here this is the material stream that is going to the stream and export to excel file completed successfully.

Now you can open the excel file. So, this CO_2 MEA dot xls has been opened. So, you can check all the result in a single sheet and if you want to generate a report then you can do it by pressing this report over here suppose you want to get a report of the absorption column. So, just click on the report and say generate report and it will generate a report like this. So, it is hydraulic analysis report of the absorption column. So, this is the contents this is the column internal summary number of stages total height 6.55 meter the head loss pressure drops.

So, it is packed bed with bald saddles then it will give you the feed summary packing geometry and here column diameter and other things are given and very importantly the column internals that is the operating point at each and every stage. So, it is stage 1 then it will be stage 2, stage 3, stage 4, stage 5 up to stage 30 it has generated all the reports will be generated like this. So, with this we come to the end of this lecture of this week. In the next week we will come back with yet another interesting case study till then thank you and goodbye.

(Video Ends: 01:04:32)