Aspen Plus Simulation Software – A Basic Course for Beginners
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Lecture - 35
Plant Dynamics and Control

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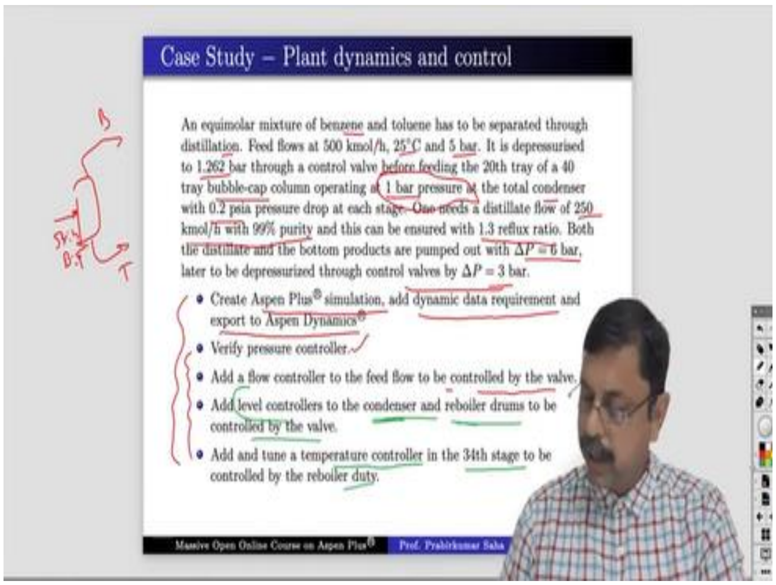

Welcome to the final lecture on the massive open online course on aspen plus. In this lecture we shall end this course with plant wide dynamics and control. Basically, this particular activity is a shift from aspen plus to aspen dynamics. Aspen dynamics is a separate software altogether. In aspen plus we perform everything on steady state basis. But in aspen dynamics we will see how the process behaviour changes with time.

So, we shall see the profile of pressure, profile of flow profile of other things changing with time. So, that we will see in aspen dynamics. And here in the very basic level we shall learn how to use the controller how to tune controller and how to use the controller in aspen dynamics. So, these are the things that we will learn today. Although it is a very preliminary thing as I said aspen dynamics is completely a different software and we can conduct a separate lecture series on aspen dynamics.

But here I just want to give a glimpse of what you can learn in aspen dynamics. So, to begin with we have to perform a case study on aspen plus and then only we can shift to aspen dynamics. So, the problem statement is something like this. An equivalent mixture of benzene and toluene has to be separated through distillation. So, we will have a distillation column where we will have a feed which is 50-50 mixture of benzene and toluene.

Here we will have benzene, here we will have toluene, benzene in the distillate and toluene as the bottom product. The speed flow its temperature pressure are given and it is depressurized to 1.262 bar through a control valve before feeding to.

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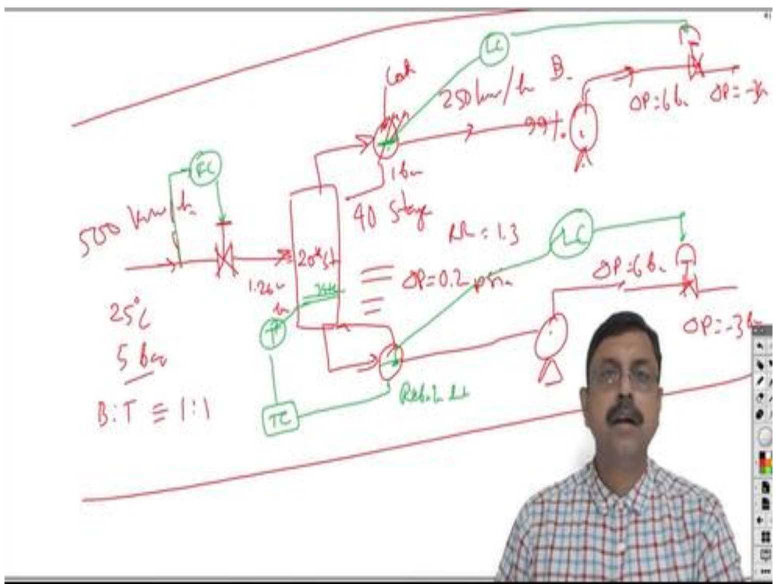

So, we will have a column. This is a distillation column and here we will have a control valve the speed is 500 kmol/hr, 25 degree centigrade and 5 bar pressure and benzene is 2 toluene = 1 is to 1, 50-50%. And this 5-bar pressure will be depressurized here as 1.262 bar before it enters the column. And here it enters at 20th stage of a 40-stage column that is what it is said.

A bubble cap column operating at one bar pressure at the total condenser with 0.2 PSI a pressure drop at each stage. So, here we will have condenser which will have a pressure of 1 bar and at each stage we will have ΔP of 0.2 PSI. And then one needs a distillate flow of 250 kmol/hr with 99% purity. So, here we will have 250 kmol/hr of benzene with 99% purity. This can be ensured with 1.3 reflux ratio.

So, we do not have to bother much we just have to set the reflux ratio as 1.3. Then both the distillate and bottom products are pumped out with ΔP of 6 bar. That means we will have a pump over here. And so here the ΔP will be 6 bar both end and later to be depressurized through control valves by ΔP of 3 bar. So, we will have a control valve over here where the ΔP will be 3 bar. There will be reduction of pressure over there.

So, this is the total process flow diagram. And we have to perform these five tasks. First, we have to create an aspen plus simulation which we all know how to do it. And add some dynamic data requirement and export to aspen dynamics. So, once we export to aspen dynamics then we have to do these four tasks. One is verifying pressure controller of this condenser, because the condenser pressure is 1 bar.

And then we have to add a flow controller to the feed flow to be controlled by valve. We will have a flow measurement over here and a controller over here flow controller which will take the measurement from here and pass the control signal to this valve. Then add a level controller to the condenser and reboiler drums to be controlled by valve. So, the of condenser and reboiler drum has to be controlled.

So, the level over here will be measured and there will be a liquid level controller which will control valve here and here as well. And finally add and tune a temperature controller in the 34th stage to be controlled by the reboiler duty. So, we will have the 34th stage over here whose temperature will be measured. And that temperature will be controlled by a temperature controller by manipulating the reboiler duty.

Now why the 34th stage has been chosen not 35th or 30th or why such an odd number, that explanation I cannot give. Because the process from where this problem has been chosen, they might have found that it is very crucial to control the temperature at 34 stage and that is why it is the process requirement. Anyway, so these are the tasks that we have to do one by one. So, let us begin with aspen plus simulation with this problem. So, let us go to the simulation.

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So, this one so we add benzene and toluene and we shall use Peng Robinson run it, then go to simulation. And then we have to bring one red frac column then we will have two pumps, one here, one here and then three valves one here, one here, one here and we have to connect the material stream. So, this is feed this is connected to the column. So, it is a red frac column so connect this with the pump, pump to valve and reboiler to pump and this pump to valve out.

So, let us rename the stream first let us, give the name feed then call in this is benzene. We ben 1 one this is toul 1 this is ben 2 this is toul 2 and this is ben 3 and toul 3. Let us rename it as column, this is pump 1 this is pump 2, this is valve 1, this is valve 2 and this is valve 3. So, just hide behind this. Now we have to give the specification of feed. Just refer it, feed flow equivalent 500 kmol/hr.

So, benzene and toluene both will be 250-250 pressure and temperature given. So, 25 degree centigrade 5 bar pressure this is 250 and 250. So, feed is done. Now the valve the outlet pressure is it is 1.262 bar. So, 1.262 and these two valves they will be depressurized to ΔP of 3 bar, so deep pressurized so it will be - 3. So, it will be pressure drop by 3 bar and this also pressure drop by 3 bar. And then let us fix the pumps pump one pressure increase by 6 bar so it is 6 bar.

And this also 6 bar. So, finally we come to the column we have to fix it, we have number of stage which is 40 and reflux ratio 1.3, distillate flow 250, 99% purity, 0.2 PSI of pressure drop and the pressure at the total condensate is one bar and it is a bubble cap column. So, this information we can feed in. So, it is 40 condenser is total distillate rate is 250 kmol/hr, reflux ratio 1.3. And the stream is feed stream at 20th stage.

The pressure at condenser 1 bar and the stage pressure drop is point 2 PSI. So, the column is fixed. So, we can run the process. So, just press run. So, the results are available just quickly let us see the results. Go to the column block stream results and we shall find over here molar flow, mole fraction, it is 99.2895% purity. So, we have reached the desired purity so we are happy and so this is done. Now let us go to the column internals add new.

So, press next and we will add a new. So, start with stage number 2, end with stage number 39 and the tray type is bubble cap. So, that is done, run it once again, so it is run. So, you can view the hydraulic plots almost all the stages are okay. Now the simulation with aspen plus is done. Now what you need to do is you need to go to the aspen dynamics. So, you have to export to expand dynamics. So, for that you need to go over here and press dynamic mode.

So, the moment you press dynamic mode some new information will be asked. So, what are that information? It will ask the column dynamics, the reflux drum type, sump type and hydraulics. So, let us give the vessel type reflux drum is horizontal with a length say 3.6-meter length and 1.8-meter diameter. And let us use a sump of height 4.8 meter and 2.4-meter diameter and then let us go to the hydraulics.

In the hydraulics we have to give some tray geometry. There start from stage 2 and end at stage 39. Why we are choosing stage 2 and stage 39? Because in a 40-tray column we always assume that first tray is the condenser and the 40th tray is the reboiler. So, anything in between column 2 to 39 that will be column internals. And let the diameter be 2.399 actually the sum we have given diameter of 2.4. So, we have given here it is 2.399 and rest of the things let us keep it as it is.

Because we do not want to disturb the default values and run the process. So, we have run it. Now let us go to the dynamics once again and you will find that these things are active. Now this is a pressure checker. So, check whether the simulation is configured correctly for creating a pressure driven dynamic simulation. So, basically there are two types of simulation one is pressure driven another is flow driven.

Now we will do pressure driven here because we have pressure changes at two or three places. The flow first comes at 5 bar pressure and then it depressurized at 1.262 bar. And then in the column it operates at 1 bar and then it goes out and through the pump it increases by 6 bar and then it is depressurized by the control valve by three bar. So, we shall use the pressure driven simulation. So, we have to press pressure driven simulation.

So, send pressure driven simulation to aspen plus dynamics and open in aspen plus dynamics. So, this is the last thing that we will do in aspen plus. So, after that anything that we do it will go to the aspen dynamics. So, at this moment let us first save this document. So, let us save the document. So, that in future if we lose the result or the system hangs in between then we can begin from where we have ended. So, now let us press pressure driven and we can save it as this.

So, your original file is simulation1dot apwz. So, that is the compound file of aspen plus simulation and the extension of files under aspen plus dynamic files is dynf, you can save it as dynf. So, just save it, it will give a few warning messages, you can just neglect them and press ok. And then you will find something clicking over here. Actually, this is the aspen class dynamics file that has opened over. So, as I said now everything will be on aspen dynamics.

So, we will not come back to aspen plus in near future, we have to do everything in aspen dynamics from now onwards. So, that is the strategy whenever you begin a new simulation. First you do it in aspen plus, converge the steady state simulation result and then export to aspen dynamics and now aspen dynamics window is open for you to work. Now this thing you can just okay. So, this is the aspen plus dynamics file and the window.

Here you will find some messages. You can see loaded this file with no errors preparing simulation for solution starting new snapshot file simulation, ready for solution. One equation was not eliminated because it has restore all these information's are there, an advanced user can understand each and everything. But what we will check over here it has number of equations 3006. So, we have 3006 equations and 4019 variables.

So, such a small simulation when it goes to dynamic mode it has so many variables and equations to handle. So, you can understand how many equations and variables aspen plus handles for a large plant, it has 128 number of steps. Here, you will find one controller, you can check over here it is said col underscore Cond pc, col means the column, Cond means that the condenser, pc means the pressure controller. So, this is a pressure controller set at the condenser.

So, you can refer the problem statement here. We have verify, the pressure controller and this is the one which you need to verify. So, just click the controller, you will find three things. One is SP that is the set point of a controller, PV is the process variable. In this case the process variable is the pressure and op are the output, output you can check it is mm kilo calorie per hour. So, it is actually the heat duty.

So, what it is doing? It is changing the heat duty of condenser to control its pressure and the pressure set point is at 1 bar. And this one is the configuration of controller. Now here it is tuning. These are the tuning parameters gain, integral time and derivative time. In the industrial lingo you will find it as gain as it is this is the reset time and this is the pre-act time. In terms of textbook, you will find it as a kc tau i and tau d and they are given.

The tuning parameters the aspen plus has designed itself. And here another, information is there the control action whether it is direct or reverse. Whether it is direct or reverse, direct means if the pressure increases then the condenser heat duty has to reduce to reduce the pressure. So, this is called reverse action. And for certain variables if the variable increases and the control action has to go in the same direction then we will call it a direct action.

So, that is the; difference between direct and reverse in this case. If the process variable increases control action has to go in the reverse direction. So, it is reverse control action. Now, ranges are given you can just keep it as it is filtering time constant. These things will learn later. This is the plot here. You can plot the data of process variable and controller output. So, you just run the dynamic simulation and you see it will integrate.

So, here you will find the set point and process variable they are merging, because they are both one. This is the manipulated variable. So, suppose we change the pressure from 1 bar to 1.1 bar. Let us see how it changes. So, set point we change to 1.1 bar. So, you see the set point has changed from 1 to 1.1 bar. And how beautifully the process variable it starts following it with very, very low time. I mean you can pause it and then you can zoom this portion.

So, if you say the time window between say 5 and 6, axis range from 5 and 6 or say 5.3 to 5.8 so at around 5.35. We have given a step change in the pressure and within 5.5 hours it has come to a steady state again. So, it hardly took around 0.2 hours to come to a new steady state. But it did not take 12 minutes even if it took less than that maybe 7 or 8 minutes within that time it has come to a steady state again. Anyway, so that is how we run the simulation.

Now let us bring it back to 1 bar and run it and again you can see within very reasonable time it has come down to 1 bar. So, let us stop it. And now we have to add a flow controller to the feed flow to be controlled by the valve. So, this is the feed flow and we have to control it by this valve. So, for that we shall place one controller over here. So, this is one controller and two more controllers we need, level controllers to the condenser and reboiler drums to be controlled by the valve.

So, the level controllers for these two things, one is condenser and there is reboiler which have to be controlled through these two valves. So, we put one controller over here and another controller over here. So, just place it over here and place it over here. Now we have to connect them through control signal. Here there are various connector connection material stream, polymer stream, heat stream, work stream and a control signal.

So, we have to press this one. The moment we press this one various option open up. So, these are the place where we can feed in our control signal. So, this is the output signal coming out from this, 17 variables are there. Now we have to take this total mole flow and feed it back to this input signal to the controller, which one? Process variable. So, this one is our process variable, the total molar flow is our process variable.

And output variable controller output that is the manipulated input should be this one which will manipulate the valve. This is the specified valve position. One controller connection is done. Similarly, we have to do the controller connection for other two controllers. First, let us check the condenser so condenser means the stage one. So, we have to look for the level of stage one so stage one level. So, this one should be connected to this as a process variable.

And output variable controller output rather that is the manipulated variable should be connected to this valve. Similarly, the reboiler means the stage number 40. So, go to stage number 40 level, where is the level? This is the stage 40 level that means the reboiler level. Connect this to this controller process variable and output of this controller which is a manipulated variable for this particular valve. So, the connections are complete.

Now we can tune them no problem. But for these three controllers we already have the controller tuning parameters. So, directly we will use, we will not tune them. So, for this controller we have the controller parameter over here. First you have to initialize because it is not at 50 kmol/hr. So, these are all default values. But actually, it is 500 kmol/hr so you have to initialize it. So, it has gone to 500, gain it is 0.5 and integral time is 0.3 so it is a PI controller.

And we will use the filter time constant as 0.1. Now we shall understand the filter time constant later. At this moment you may please check that the control action has to be reversed over here because when the feed flow increases then the valve should close down and vice versa. When the feed flow goes down valve should come up. So, it should be a reverse control action. The second controller again we have to initialize the default value is 0.78.

So, actual level at the condenser is 0.783 meter so that is the set point we have to follow here. The gain is 2 and integral time is very high it is 9999 and it is a direct control action. And the same thing will be given over here also. So, initialize in this case the initial value for the reboiler level is 2.48 meter. Here also we will use the gain 2 and integral time constant is 9999. It is a direct control action and the filtering parameter is 0.1.

And here we have forgot to give the filter time constant which is 0.1 again. Now we should see the plots. This is the plot for b 1, this is the plot for b 2 and this is the plot for b 3. So, we have all three plots with us now let us run the dynamics once again. And you can understand this will go like this till we change something. So, let us change the set point of the condenser level to 0.9 meters. Let us see what happens. So, we will change it to 0.9.

So, here we are not seeing any change in this line because the scale is very high it is - 20 to 55. I do not know why it should be like this. So, let us use it from if it is 0.7 and 0.9 let us say 0.521 that will do yes or we can say 0.7521. So, here you see already it has come to the steady state once again. If you run a few dynamic steps more so it began from 14.25 hours and within 15.75 hours. So, within 1.5 hours it has reached the steady state that is how the system works.

Similarly, if you change the set point of level of reboiler to say 2.422 and here also, we will change it from 1.9 to 2.5. So, we have given a step change let us see how the process variable follows the set point. So, from 16.25 hours at that point of time we have given the set point change within 18.25. So, within two hours the level has reached to the steady state. So, level of reboiler and level of condenser are controlled beautifully.

Similarly, we can check the flow also say flow let us check from say 400 to or 430 to 510. And we reduce the set point from 500 to 450 and let us check. So, fast within a few minutes it has reached to the new steady state. So, that is how we do the dynamic study. Now the last job that we will do. Add and tune a temperature controller in the 34th stage to be controlled by the reboiler duty. So, let us remove them and we will put another controller over here.

And this one we will check the column stage number 34; temperature will be fed to this particular controller as process variable. And this will be connected to the reboiler specified reboiler duty, done. So, now we have to tune this controller. Because we do not have any tuning parameters unlike the previous three controllers, we do not have any tuning parameters for this controller so we have to tune it.

So, for that first thing we have to do is we have to initialize the values. So, the set point is this. Once we initialize, we have to press this tune button. This tune button will open test and tuning parameter test means we can do some open loop test as we understand that we can give a step up or step down. Say, 1% step up change in the output we can start the test before that we can just run the dynamic simulation and start the test.

So, we have to wait until it reaches some value. So, just make it 1 2 0 2 1 3 0. So, it has come to a steady state. So, 1% change has been given. So, let us now stop it and let us say finish test. So, the moment I give finish test open loop gain, open loop time constant and open loop date time all the things are measured by itself. Now we have to go to the tuning parameter. Here we will find the controller type here we have PINPID.

So, we may or we may not like to add the derivative term. In this case let us not add derivative term let us go for a PI controller. And tuning rule there are many tuning rules here we have the options of Ziegler-Nichols, Cohen Coon, IMC, IAE, ISE, ITAE, ISE means integer square error, IAE means integral absolute error. Similarly, IMC is internal model control. Now many of you may know what is internal model control.

Those who do not know what is internal model control you can go and read the textbook. Unfortunately, it is not the forum that I can teach you internal model control. But it is possible to design a PID controller using IMC tuning rule. Only thing is that we have to feed in a parameter which is called IMC filtering parameter which is lambda value. So, that is the filter parameter few minutes back when we were using the other three controllers, we were giving filter parameter of 0.1.

This is the thing that we were feeding in. So, this filter parameter we have to give and IMC lambda value, in this case we shall use 42. Now this value has been found out by separate exercise. So, we will use this IMC lambda value which is a filter parameter for mc and then we will press calculate. The moment we press calculate the gain and the reset parameter of PI controller has been found and the action also it is suggesting it is reverse.

It is a reverse controller obviously because if the temperature of 34 stage increases then definitely, we have to decrease the reboiler duty in order to decrease the temperature. So, that control action has to be reverse. So, that is what it is being suggested over here. So, now if you press the configure button you will find the default tuning parameters over here 1, 20 and 0. Now the moment we say update controller all this information will be transferred to this point along with the action.

So, the direct will come to reverse, we do not have to do it. Just press update controller then you will find everything to get transferred to this. So, the controller is now updated. Now we are ready to run the simulation. So, let us run the simulation and set point we have changed to 118 because that was the original value of set point. We have done the step change because we had to get the step change data in order to tune the controller parameter.

That is the reason we have changed it from 118.58 to 125.70 that is 1% change. But right now, it is reverted to the original set point that is 118.5826. So, let us run the dynamic simulation and see the control action has started. So, let us change it between 110 to 127. So, record the time we have started it around 7.2 hours. So, let us see how long it takes to stabilize. So, almost it has stabilized over here.

You can see the numbers it is just one or two digits after the decimal point it is trying to fix. So, we can say that by 13.4 or 14 hours by 14 hours it has come to a steady state so from 7.2 hours to 14 hours. So, that means that temperature takes a lot of time to settle. It takes 7 hours to settle it is not like flow or it is not like level that within a very few minutes it will get settled. So, that is how we do the dynamic simulation.

Now as I said that aspen dynamics is completely a different ballgame and there could be a different lecture series on this. It is just a glimpse that I have given and one needs to do a lot of practice in order to master in the subject.

(Video Ends: 54:50)

So, we come to the end of this lecture series. And if you have any question anytime you can ask me my email address is p.saha@iitg.ac.in. You can write to me anytime with any doubts I can try to clear your doubts about this course and it will be a pleasure for me. So, hope you have enjoyed this lecture series. So, thank you and goodbye.