Aspen Plus Simulation Software – A Basic Course for Beginners

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Lecture - 34
Plant Economy and Utilities

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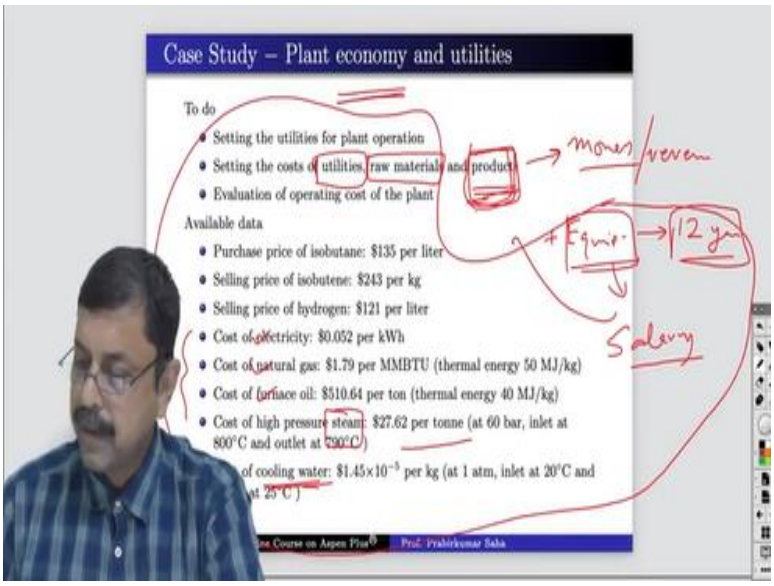

Welcome to the massive open online course on Aspen plus. Till now we have carried out quite a few case studies on various problems in Aspen plus. But in all those problems we have only gone through the operational aspects of those case studies. We have not touched upon a very important factor in the process plant that is economy. Now what are the things that the economy of a plant is dependent upon.

We have product of the plant which is syllable this should be syllable to the end user and from this only we get money or revenue. So, this is the only thing that we have which will generate the revenue for us after the plant operation. But in order to get this product we have to incur a lot of expenditure. What are they? We have to purchase raw materials from the market which will be used for plant operation.

And we have to purchase the utility like if we have to heat up some process stream or if we have to cool down the process stream, if we want to run a boiler to produce steam then we have to burn something to get the heat. It may be electricity which is very costly or it may be natural gas, it may be furnace oil and even if we want to purchase steam alone that is also possible from another source, we can purchase it.

And we may have to purchase the water also for cooling purpose. I am not taking care of the other cooling material like refrigerant and all and there are some other heating materials also like coal which we are not considering. And also, we have to incur some expenditure on equipment purchase which has a lifetime. Suppose equipment has a lifetime of 12 years then there will be a depreciation cost for the equipment that we have to take care of.

And also, the salary of the plant personnel. So, all this together summed up should be less than the selling price or the revenue generated from the product. Then only we can make a profit and there is a point in running the plant. Otherwise, there is no point in running the plant and there is no point in working on the Aspen plus simulation also. Now obviously in the aspen plus simulation we cannot take care of all of them.

But we can definitely take care of the raw material, utilities and product prices. So, that is exactly what we are going to do right now. Now for that we have to go back a couple of lectures back.

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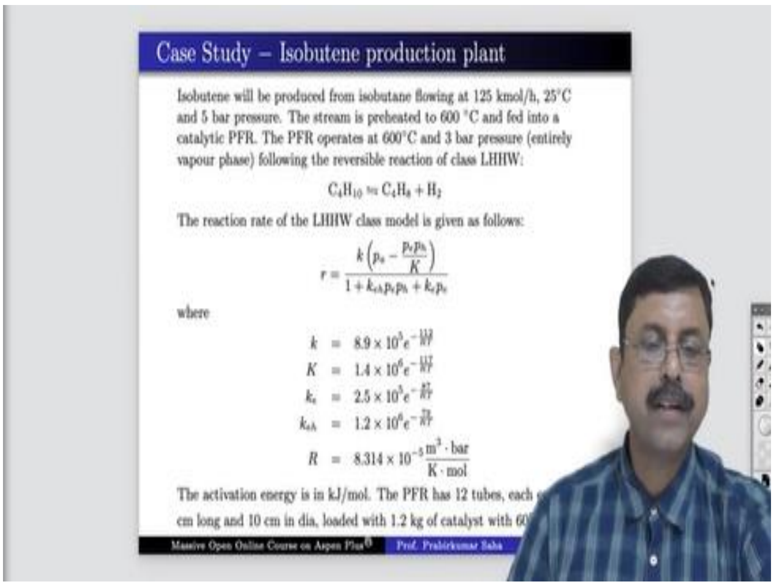

In the last week we have worked on a case study on isobutene production plant. So, just a short recapitulation what we did? Isobutene was produced from isobutane whose flow rate temperature and pressure were given. The stream preheated to 600 ^{0}C and fed into a catalytic

PFR which operates at 600 ^{0}C and 3 bar pressure and this is the reaction condition that has been given.

And then it is a catalytic reaction so all those catalyst and catalytic tube the dimension configurations are given.

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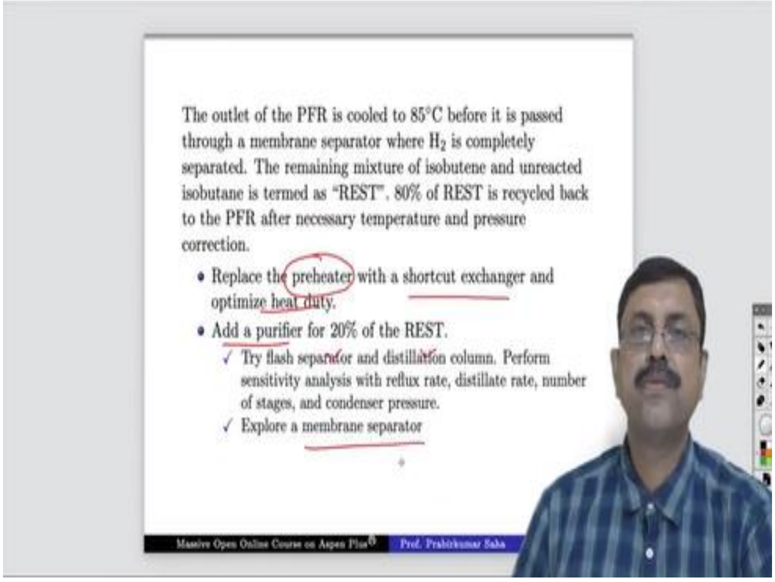

And first we have done with the preheater and then we have replaced it with the shortcut exchanger and optimize the heat duty and the last we have added a purifier. Now we have done a case study on which we found that flash separator and distillation column were of no use because the temperature of reboiler and temperature of condenser they were very close. It is not possible to maintain such close temperature at both ends.

So, we ultimately used a membrane separator for that purpose. So, that was something which we have done last week now we take the same example and add the utility condition in them. So, let us go back to the problem where we left.

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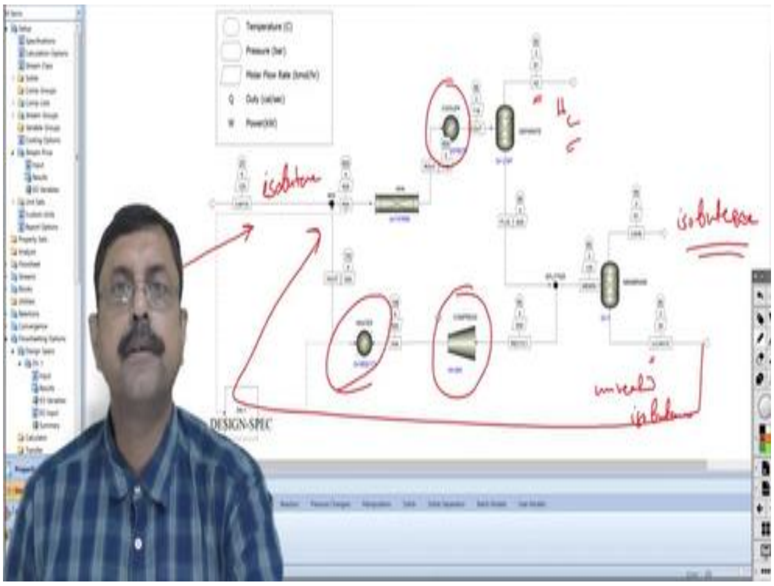

So, this is the plant that we were discussing about so this is the isobutane and this is isobutene and this is unreacted u isobutane that means unreacted isobutane. Obviously, you could recycle them also and here it is hydrogen. So, basically, we have only one raw material isobutane and two things that we could cell one is hydrogen another is isobutene. So, these are our syllable products and we have one heater over here one cooler over here and one compressor over here.

So, in the problem we have got the purchase price of isobutane and selling prices of isobutene and hydrogen. And we have got the cost of electricity, natural gas, furnace oil and high-pressure steam. So, these are used for heating and we have also the cost of cooling water which is relatively cheap, perhaps we are getting it from the nearby river or pond or something like that and we can directly use them for cooling purpose.

So, most of the data we have got from Indian perspective. So, if you search in the internet, you will get those prices at least very close to them I have converted from Indian rupee to dollar, so we have got the purchase price of isobutane as 135 $/lit, these dollars are USD, US dollar. Selling price of isobutane, it is 243 $/kg and selling price of hydrogen is 121 $/lit.

And this litre they are standard volume that is at standard temperature and pressure. Cost of electricity is 0.052 per KW this is industrial rate. Cost of natural gas it is 1.79 $/MMBTU with a thermal energy of 50 MJ/kg and this information is very well available everywhere you will get the same value 1.79. Then cost of furnace oil 510.64 $/ton with thermal energy of 40 MJ/kg.

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And steam pressure is 60 bar with inlet and outlet temperature as 800 ^{0}C and 790 ^{0}C respectively and finally we get the water which is relatively cheap. We have only one option for the cooler that is using water but we have several options for the heater, we have electricity, steam, furnace oil and the natural gas. So, we will try out various things and see which one is giving us a better result.

I mean by using what kind of heating element we can get the lowest expenditure on heating over here and obviously the compressor utility we have to run with electricity. So, compressor, separator, membrane separator, PFR everything will run on electricity only this will be running with water and this we will try with four things, let us see how. Now you need to go to the utilities block which are over here.

So, this is the utility block. So, press new, just name it as electricity, all of them will not come. So, electric that will do so you can copy from these things. So, if you copy from electricity then default value will come as a purchase price but you may not like this purchase price because this purchase price may be completely different from the data that you have. For instance, in our case the data is 0.052/kWhr.

So, you just change it from 0775 to 052 $/kWhr. Whereas if you want to say natural gas then you all find anything over here which remotely connects to natural gas. In such situation you have to keep it as blank, press ok and then it will open up a utility type for you and there you can say which type of utility that you want to add. So, here the option of gas is there, so just press gas and you want find anything over here.

So, you have to specify the value. So, what is the specification for gas? This is 1.79 /MMBTU with thermal energy 50 MJ/kg. So, here it is not given as dollars per kg but it is given as dollars per MMBTU which is 1.79 and thermal energy is 50 MJ/kg. So, this is 50 MJ/kg so we are burning it that is how we are using it. So, this is natural gas.

Similarly, if you say want to add steam then steam is 27.62 $/ton at 60 per pressure and inlet and outlet temperature has to be given so 27.62 so high-pressure steam 27.62 $/ton. Now the inlet and outlet condition, have to be given some default values have been given because you have picked up from some default value. So, here you have to press 800 and 790 because the inlet condition is 800 and outlet condition is 790, 800 and 790.

The pressure is 60 bar for both, so it is pressure add 60 bar and here also pressure and 60 bar. In case you want to use the latent heat of the steam then you can keep the inlet condition vapour fraction of 1 and outlet condition vapour fraction 0. Obviously at the same temperature that means you are using only the latent heat of the steam. So, then we can use say furnace oil, furnace oil is 510.64 per ton with thermal energy 40 MJ/kg so 510.64.

So, pick from here so this is 510.64 $/ton and its thermal energy is 40 MJ/kg and we will not give any inlet and outlet temperature because we are just burning it. Finally, we shall take cooling water. So, we just name it as water or cooling water and then take up from here and the price is very low value 1.45 10 to the power - 5 per kg, one atmosphere pressure inlet 20 outlet 25.

So, 1.45 10 to the power – 5, so, this is 1.45 e - 5 per kg. Inlet outlet condition it is 20 and 25 at one atmosphere actually it is a default value for cooling water. So, all those items are given over here. Now you have to fix the utility. So, let us begin from compressor, we have to click this utility id electric that is all. So, we have set the utility for compressor that means the compressor will be run by electricity.

Cooler definitely it will be run by the cooling water then membrane separator it will be run by electricity. This separator also will run by electricity and there is nothing to do with PFR heater. Let us use electricity only, so at this moment we are using electricity for running each and every unit operation except the cooler which is using cooling water as a utility. Now we have set the utility just run it, so it has run so you have to go to the operating costs.

So, here you can check we are not using any heating utility we are not using steam, we are not using furnace oil, we are not using gas, none of them we are using for heating. Obviously, we are using electricity for this but electricity the calculation is done completely in a separate manner not as a heating utility. So, heating is 0, cooling it says that those that much of calorie per second has been spent.

Now let us go and change the unit so that we can understand it better. So, let us use kilowatt or MW, so we have got 14.1257 MW of cooling duty required. For cooling the temperature from 600 ^{0}C to 85 ^{0}C. So, for that we need such an enormous amount of heat duty. Then the electricity cost we have so much of kilowatt of electric power for that we have 777 $/hr of electricity we need to run the plant.

So, total cost, total utility cost is 812 this is 777.211 plus the cooling cost that is 35 $/hr together it is 812 dollars per hour of cost. Now let us change the utility. For heater let us use steam in place of electricity. So, this is high pressure steam so run it once again. Now you can check now heating duty is 14 MW and cooling duty is 14 MW as well the electric power cost has reduced from 777 to 15.

Because the load on electric power has been reduced but we are using steam for heating and the utility cost for heating is 60510 dollars, so its steam is very costly. We really cannot use it, so steam is not at all usable in this case because it is increasing the heating cost. So, instead of steam let us use oil and check, go to the operation cost well, the heating duty is still 14 MW but the cost has come down to 792 $/hr.

Because oil is much cheaper than steam as a heating material. So, the heating cost is 742 not 60000. The cooling cost remains same and this is the electric power 290 kW and electric power also remains same because we are not changing it. Now finally we shall try the natural gas. So, for that go to the heater once again, go to utility and use natural gas and then run. So, here we are pleasantly surprised.

Because the utility cost is further reduced to 139 $/hr. So, among steam natural gas and oil definitely natural gas is the cheapest obviously electricity also. So, natural gas is the cheapest, so let us stick to natural gas for the time being we will not use electricity will not use steam we will not use oil for heating we will use only natural gas, because this is most economic.

Now can we reduce this cost? Definitely, because we; are unnecessarily using the cooler to cool down from 600 to 85 ^{0}C. But we can as well use a heat exchanger which can pre-heat this stream. So, the load on this heater is enormous, it has to take the temperature up to 743 ^{0}C in order to make the combined stream of this and this to maintain at 600 ^{0}C. So, if we use a preheater over here then the load will get reduced.

So, for that let us use an exchanger so let us reconnect destination over here and connect this thing over here and then this one we shall reconnect to hot liquid and the output we can connect to cooler. We need this particular temperature S1 should be 550 ^{0}C. So, we just make it a shortcut exchanger where cold stream outlet temperature is 550 ^{0}C, so press run.

So, we have got 491 ^{0}C over here and it has come to 150 and see 743 ^{0}C to 614 ^{0}C. So, by using a heat exchanger over here which has been used as a preheater we have increased the temperature of this stream to 550 ^{0}C and so, the load on this heater is reduced. So, the amount of q also has been reduced. So, do you want to see the proof how it has been reduced?

Just go to see the operating cost once again and check MW this MW, this MW. So, the total heating duty has been reduced from 14 MW to 11 MW and cooling duty also has been reduced from 14 MW to 10 MW because now cooler also has to cool down from 491 ^{0}C to 85 unlike 600 to 85 ^{0}C. So, the cooler also needs lower load.

And as a result, the total heating cost has been reduced to 67 total cooling cost has been reduced to 26 so compare these two figures with 89 and 35. So, this one without using any preheater we had to spend 89 $/hr for heating and 35 $/hr for cooling. But with preheating we have reduced from 89 to 67 and 35 to 26. As a result, the total utility cost also decreases to 109 from 139, so 30 savings over there.

Now let us further decrease it how remember that we still have it 7-digit heat duty for both cooler and heater. Now let us try whether we can reduce it down to 6-digit heat duty or less. Now here we find this particular stream is at 100 ^{0}C which has to be preheated to 614 ^{0}C whereas this particular stream is at 491 which has to be cooled down to 85 ^{0}C.

So, why not use this stream to preheat this particular stream, so that the load on this heater and cooler get reduced further. So, that is our aim for that we have to employ a second heat exchanger. So, let us take them and shift them over here so that we can get some extra room to manipulate the streams. So, bring it over here and put a heat exchanger over here. So, this exchanger flips horizontal and then cut this stream and reconnect to this end.

And connect this material stream to this end and then connect this stream reconnect rather to this end, this is a hot fluid entry and the hot fluid outlet should connect to the cooler. So, just put it over here now from 106 ^{0}C let us increase the temperature up to say 400 ^{0}C because it is entering at 491 or let us say 450 ^{0}C. So, the cold outlet temperature should be 450 ^{0}C.

So, here cold stream outlet temperature should be 450. Now run the process once again, so now the results are converged. So, we can find over here the heat duty has come down to 6 digits both here and here both the places it has come down to six digits. And you can check the operating cost. So, here you can see the heat duty and cooling duty both have come down to the range of 4 MW from 14 MW initially to 4 MW by using two heat exchangers.

One as a preheater to the feed and another as a preheater to the recycle stream. And what is the total cost? Heating cost is cooling cost is 9 together it is 34 only. So, electrical power cost 15 dollars and heating plus cooling is 34 together it is 49 dollars per hour, this is the utility cost of the plant. Now our job is not over we have to set the stream price as an input. So, what is the stream price for isobutene? This is 135 per litre.

So, it is standard volume basis and 135 dollars per litre, isobutene that is the product which will be 243 per kg so this is 243 per kg and hydrogen this is 121 $/lit. So, run this and check the operating cost. So, here we find the utility cost is unchanged but the cost of feed is this much, so this is the amount that you have to spend to purchase your isobutene but total cost of product is this much.

So, overall net cost flow is 73988.1, so this one is your revenue generation. So, this is the difference between this and this out of which your utility cost is very minimum 49 $/hr. So, this is a pretty good figure almost 74000 dollars per hour. So, you can argue that this is a very profitable business and some of the things that you can write over here. So, it has nothing to do with the simulation.

But you can use the format over here you can write that this is a plant economy study of isobutene production unit and you can give a timestamp also. So, this particular timestamp will tell you exactly when you have finished your simulation, you can do certain cosmetic changes. Certain something like you can use this one says this part is your, so if you use it with the yellow line which is not visible.

You can use a red line which is dotted in nature or dashed in nature and you can say that this is the place where you preheat and save heat you can use a different colour also just to note that this particular text is not related to your simulation. It is just a cosmetic change and then you can use this portion also and this line you can give a separate colour say magenta and also the weight may be different and the style may be like this.

And you can keep it over here and you can write add this extra preheater. So, these cosmetic changes are for your team members even during a presentation these kinds of notes will help you a lot. And to do more on that you can use some economic optimization, I mean here for an example in this case if you click on this splitter, you will find that you have used 0.8 split fraction as a recycle, so you can say that you have used 80% recycle.

Now if you change from 80% to 90% what happens if you change it from 80 to 70% what happens or you can do some kind of economic optimization that between 70 and 90 within this range at what condition of split fraction the profit will be maximum so, that is a good economic study. So, not only speed fraction you can change other variables also to find out the best operating condition for which your profit margin will be maximized.

Ultimately that is why we are doing the business in a process plant and obviously you can give certain constraints like although we are doing business but we cannot purge certain things beyond the limit allowed as per the government regulation. So, those kinds of constraint you can give in the optimization routine and I have taught you how to do it. So, these are the various things that you can do while doing plant economic study. So, with that we come to the end of this lecture. Thank you and goodbye.

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