Process Integration
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Module - 7
Tutorial & Case Studies
Lecture - 3
Problem solving using HNT Software- part 03
Heat Exchanger Network Design (contd.)
HEN Optimization (Loop breaking)

This lecture deals with the design of a hen where stream splitting is not require we have all ready seen m e r design of hen where stream splitting is required. So, we have completed that part now I will take up this problem which is given a in table number six this stream problem will be consider for MER design, and then the same problem will be extended for non m e r design in the non m e r design, we will identify the loops and then will break this groups.

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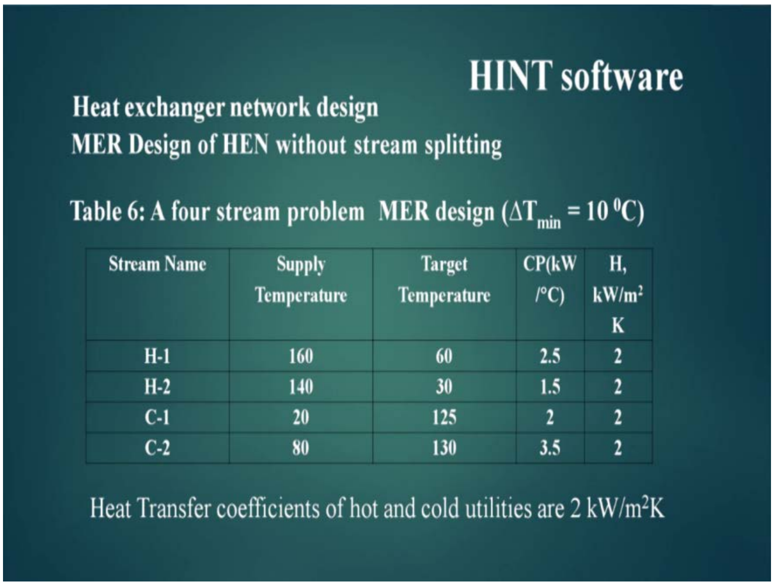

Now, let us start by taking the problem now open up the hint software now will go for the feeding of the streams streamed h 1 the supply temperature is 160 the target temperature is 60 and the value of m c p is 2.5.

Stream number 2 this is h 2 supply temperature is 140 target temperature is 30 and this value of m c p is 1.5 then we go to c 1 the supply temperature is 20 target temperature is

125 m c p value is 2 and the fourth stream c 2 supply temperature is 80 target temperature is 130 and the m c p value is 3.5. Now the h values for the streams have been taken as 2 kilowatt per meter square Kelvin which is a default value in the hen program.

So, I say ok. So, my stream table appears here 160, 60; 140, 30; 20, 125; 80 130 and m c p values are 2.5 1.5 2 and 3.5. Now I will directly go for the design if you want to see the different diagrams this is the composite curve this is the grand composite curve, and this is the great diagram which is needed for the design.

So; obviously, as I have done in the earlier case will try to see the feasibility and the feasible matches. So, these are the feasible matches above and below pinch number 3 can be joined with number 2 for a match placement number 4 can be matched with 1 and 2 in the below pinch the 1 can be only matched with 3.

So, let us start design we go for feasibility above the pinch now a match can be placed from this stable by entering data in to the this table or the match can be placed by heat exchanger and add option this also allows you to fix up the match. Here if you see that I can select the streams and the utilities cold utilities c 1 and c ! C 2 there are two options a three options I can select and the hot stream there are 2 hot streams and 1 utility. So, we will have three options here.

So, I can select the options and then specification type user supplied enthalpy and other specification types are also available user supply temperatures enthalpy to complete the course streams and enthalpy to complete the hot streams. So, these are four options which can be energized which can be taken up for the heat exchanger design.

Here it keeps you the inlet temperature like click this is inlet temperature, here I can fix up the temperature, here I can mention that it is a pinch temperature, here I can say that is an outlet temperature of heat exchanger number. Such in search like the change the heat exchanger number from here this drop down menu or I can specify code stream supply temperature. Now this is cold stream outlet temperature, if I click then I can provide the temperature I can say that cold stream outlet temperature is the pinch temperature or inlet temperature of a certain heat exchanger or cold stream target temperature.

Similarly, here for the hot streams I can say the hot stream inlet temperature to the heat exchanger is this I can mention here or I can say that, this is from the pinch or I can say this is outlet temperature of such in search heat exchanger or hot stream supply temperature similarly outlet temperature if I click. So, this options are available.

Now, by selecting this options I can plays a match or a easier option for at least placing a match is to go to this table and start placing the pinch matches. So, we will do the take up the easier option and now what will do will match the streams. So, above the pinch the rules are number of hot streams should be less or equal to number of cold streams and above the pinch I find there are two hot streams and two cold streams. So, this criteria is fulfilled.

The second criteria is m c p of hot streams should be less than m c p of cold streams; that means, a higher value here will match with a lower value; that means, 2 can be match with 1.5 3.5 can be match with 2.5 as well 1.5 ok. Now, let start placing the heat exchangers I can match this 160 to 60 stream that is stream number 1 with this stream because here this is 3.5 this is 2.5. So, 2.5 and 3.5 a press. So, the color changes it shows that it is a feasible match.

Now, place the heat exchanger I can click it again and I can say it places a match and this match can the place as well using this heat exchanger add option, but I am taking shorter root to place the at least pinch matches. So, it is entry temperature is 90 and its capacity is 175; that means, this stream has been take out because it reaches 130 degree centigrade.

And if I see here which is 175 and 160 minus 90 multiply by 2.5 will give me the capacity of this heat exchanger. Now I place a second heat exchanger between 140 to 30 and this is 20 to 125 between this two streams. So, again go to the stream go to the feasibility go to the above the pinch and these two can be match because 2 is greater than 1.5. So, I click here I click here, heat changes and then I click here and say ok.

So, it putts a heat exchanger here, now if I see I can drag down it to here drag down it to here now I see that the outlet temperature of this heat exchanger is 117.5 where it has to go to 125; that means, we need to put a heater here, but before putting this heater we will first place the pinch heat exchanger in both part; that means, above the pinch and below the pinch here and then we will put the heaters and coolers. So, let us try to put our pinch heat exchanger here.

I go to stream and feasibility go to the below the pinch. Now the rules are number of hot streams should be greater than number of cold streams. So, this is satisfied we have 2 hot streams 1 cold streams you do not have to bother about this group and m c p of hot streams should be greater than m c p of the cold streams.

Now, if I see this then I find that I can match this with this, but I cannot match this with this. So, let us first match this with this, now I can click this then next a. So, it places in match here they 75 kilowatt is a size of this exchanger; that means, capacity of this exchanger I can place it here now; obviously, if I see this then its outlet temperature is around 42.5 degree centigrade. So, from 42.5 degree centigrade to it has to be cool down to 20 degree centigrade. So, there is a possibility of putting the match from here to here

(( )) if I see this now rules does not permit. Now we have to little bit generalize this rules this rules are for pinch heat exchangers; that means, for the pinch heat exchangers these rules are cyclosent; that means, has to be followed very rigidly for pinch heat exchangers, but it is away from the pinch this rules can be slag; that means, some what we can slag this rule and put the heat exchanger only criteria is that it should not violet tell thirty minimum criteria.

So, let us try to put heat exchanger. So, we do not go here we take up this heat exchanger add option. So, we put a add. So, my heat exchanger number four this will be place between 3 and 2 3 and 2. So, my code stream is 3 3 and my hot stream is 2 and the enthalpy here available is 45, what this can be computed from the outlet temperature of this heat exchanger to 20 degree centigrade, and the outlet temperature of this heat exchanger which I will be put sorry the inlet temperature to this heat exchanger will be 20.

So, I go to 20 degree centigrade here, and the for the hot the inlet temperature will be the pinch temperature. So, put it 80. So, I now place this heat exchanger. So, I find that this inlet temperature is 42.5, and the outlet temperature is 20 thing somewhere (( )) format if I call then hot stream outlet temperature, hot stream inlet temperature and cold stream inlet temperature also if I click it then if I say I will get all temperatures.

So, here it is 80 it is entering and 50 it is going out. So, you need cooler here here it is entering at 20 degree centigrade going out at 20 42.5 degree centigrade. So, this stream is picked up.

So, this stream now requires a cooler. So, if I go to here and place a heat exchanger the number of the heat exchanger will be 5 this is the fifth one and the using cold utility; because it is a cooler and the hot stream is number 2 because this stream has to be cool down now the enthalpy of this is 45, what I can calculate it out because it has to cold down from 50 to 30 and the hot outlet temperature has to match to 30 or I can say that the hot stream target temperature. So, I put 30 here I say ok.

So, I put a 50 this is a 45 45 this shows why the hot inlet temperature is 16. Now the hot inlet temperature is 50 or I can say the outlet temperature of heat exchange number for if I say.

So, this matches now. Now, this shows you the feasible hen design which is a m e r design. So, we finish 2 hen designs one in which splitting was required another in which splitting was not required. Now this heat exchanger design will be further improved and we will identify the weaknesses of this design, we from the units targeting we know that if there is a loop then it consumes one extra heat exchanger per 2, and if the number of heat exchangers are more then; obviously, the cost will be more.

So, we have to do a trade up between the heat exchanger number of heat exchanger and the tag. So, we will identify the loops we will break the loops and once we break the loop we will find that causes delta t minimum violation and to eliminate that delta t minimum violation, we have to pass the heat from heater to cooler and rectify it. I have forgotten to putt the heat exchanger the heater here. So, heater has to put here.

So, tets put the heater here this is add heat exchanger hiko for the sixth number of heat exchanger because; four heat exchangers are there one collar is that five. So, next is this sixth one. So, it is put on third stream that is c 1 and this is the utilities and the enthalpy required is 15 kilowatt that we can calculate form this 125 and this and its inlet temperature hot inlet temperature is the outlet temperature of heat exchanger number 2.

It is not given. So, it do not go to this between this and this m putting. So, what the inlet temperature is 175 and the outlet temperature is 125 outlet temperature let us fix 125. So, I say some problem it has created 90 it has change this all these this is I have to delete some mistake I have done.

And this all these temperature has changed 50 50 no no no this has changed I want to correct this. Now this is a proper place. So, we again try this heat exchanger at this is sixth number heat exchanger this is between hot utility and cold stream is number no no hot utilities cold stream is number three stream enthalpy is 15 hund, no this is cold stream. So, the inlet temperature is outlet temperature of the hot stream outlet temperature is not giving. We can say the cold outlet temperature outlet temperature is colds 125 if I say yes let see what happens again some has taken has been done he is taking this to be heat exchanger and between this I delete this.

Cold stream is third these are the utilities enthalpy this is selected in just supplied enthalpy this is 15 kilowatt the inlet temperature is outlet we just applied enthalpy oh this is number six this is three this is utility enthalpy is 15 inlet temperature 175. It is 117.5 outlet temperature is 125 let us put it, This is getting problem this is number one this is getting problem delete yes ok.

That’s why! There was a problem! This has been gone let us put again there is ahead this is stream number three this is sixth number this is stream number 3 and this hot stream is utility enthalpy is 15 outlet temperature is 125 and should work, what is happened again and it is 60 to 60 all this 90 to 60 this is 50 this temperature has same somehow 250 all the suffix between one and three.

In order to eliminate the delta t minimum violation we have to pass the heat from heater to the cooler. In this case I have forgotten to put the heater. So, now, I will put the heater in stream number three. So, we go to the heat exchanger. So, add. So, this is cold stream is stream number three hot stream is the utility and the enthalpy is 15 and the inlet temperature this cold inlet temperature is 117.5.

Let’s see again as I start this heat exchanger at at committed of all tire not given a new number to the heater. So, I put the new number that is 6 now cold stream is 3 and the hot stream is the utility enthalpy is 15 and the inlet temperature is 117.5. So, now, is correct. So, we have a heater here. So, this finishes the design of a heat exchanger when stream splitting is not required.

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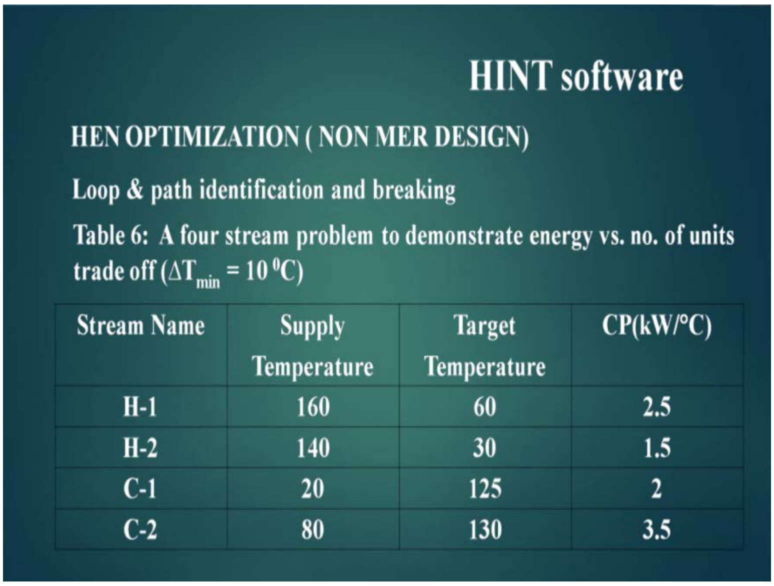

Now, we will touch a new topic which is loops and path and will. So, that this heat exchanger which is a m e r design can be improved by breaking the loops inside the heat exchanger network to decrease the number of heat exchangers. So, the same problem we take that is the four stream problem 2 hot and 2 cold to demonstrate the loop and path identification and breaking, which will improve this heat exchanger network, but the design will convert from m e r design to a non m e r design.

So, we have to first identify the loops. So, we go to the loops and path and then press the search. So, it identifies a loop here 2 2 4 and, then if I press this next it identifies a path from the heater to the cooler and the path is this if I again press next heat identifies another path from s six to two to c five and if I press next it identifies the loop.

Once we have identify the loop then our job is to break this loop this loop will be broken if I eliminate one of the heat exchangers of the loop either 2 or 4. It is beta to eliminate four because its heat duty is less. So, next will be to go for add. So, we see here this is the loop 4 2 4 and, if I press this button then yes button, it tells that my loop has been broken because the heat duty of forth number heat exchanger has become zero, but there is a delta t minimum violation here because my delta t is 10 degree.

This temperature which is 60 here should have been 67.5 to maintain the delta t minimum which is 10 degree. Now there is a clear cut violation of delta t minimum and hens this design is not correct to make it correct I have to restore the delta t minimum criteria; that means, I have to increase this temperature to 60 degree centigrade.

Now, this can be done by passing heat from h six through heat exchanger two to this cooler c 5.

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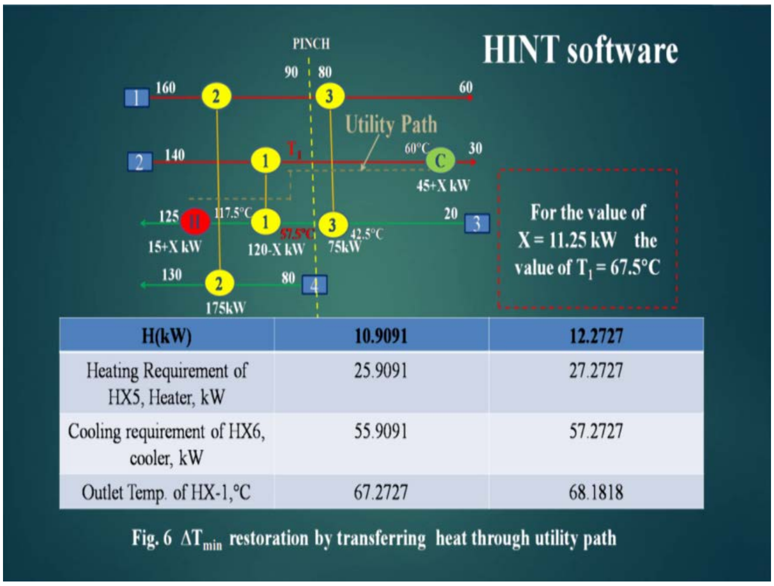

H(kW)	10.9091	12.2727
Heating Requirement of HX5, Heater, kW	25.9091	27.2727
Cooling requirement of HX6, cooler, kW	55.9091	57.2727
Outlet Temp. of HX-1,°C	67.2727	68.1818

Fig. 6 ΔT_{min} restoration by transferring heat through utility path

Now this can be shown by this p p p what does happened here there is a delta t minimum violation I have made this 0 to eliminate this heat exchanger. So, the capacity of this heat exchanger or the hate load of the heat exchanger increases to 75 plus 45 to take care of it, but once it takes care there is a delta t minimum violation. So, this heat has to flow from here to here.

Now, in this I show that I have to add x amount of heat to the heater, which will decrease the load of this heat exchanger by x amount. And increase the load of the condenser or the cooling cooler by x amount and to restore this delta t minimum here, I have written t one. So, the value of t 1 should be 67.5 to maintain a delta t minimum of 10 degree centigrade. So, the question is to find out the value of x when t 1 is 67.5 degree centigrade this is the job now.

So, we see how this can be computed using hint. So, we go to the loops and path again we press add and we now press the path, so h 6 then 2 and then c 5. So, this is the path heat will move from h 6 to 2 and 5 I have to cancel this we go for analysis here, this is it is moving from this six h ! And the h 6 and then to 2 and then 2 to 5.

Now, the important things, which I have to analyze is that this temperature this is the exit temperature, hot exit temperature form heat exchanger 2. I have to also see the enthalpy of heat exchanger 2. I have to also check the enthalpy of heat exchanger 6, I have to also check the enthalpy of heat exchanger 5 by this, which add I will select those. So, I go to the heat exchanger go to heat exchanger number 2. I had take hot stream target temperature place hot stream target temperature and then say ok.

And then again go to heat exchanger exchanger number 2 then enthalpy then then again, I go to the heat exchanger take heat exchanger number 6 say enthalpy press enthalpy, and then again I go to the heat exchanger heat exchanger number 5, which is cooler then enthalpy, and then now once I selected my require parameters to find out the amount of heat we should move from h 6 via heat exchanger 2 to this cooler to maintain this delta t minimum, which is now being violated then rest is to run this analysis.

So, we have run this analyses it says that if minus 2.7 to 727 kilowatt is added to the already the load of h 6 then the load of h 6 becomes 12.2727 and, if it is 12.2727 then this temperature, which is 60 is 68.1818. So, it is not going to solve our purpose because the cap between 57.5 and here to maintain a 10 degree centigrade cap this should be 67.55 degree centigrade.

So, now we search for the value. So, we see this is 60 this is 61 I have to go up to 67. So, this is 67.2727, which will not do because it should be 67.5. So, I find here if I add 10.9091 kilowatt do this h 6 then my temperature becomes 67.2727, if I add 12.2727 heat to this deduct from this and then add to this then this temperature becomes 68.1818.

The 68.1811 is because it provides me a delta t of 10 degree centigrade, which is required, now my value of heat which should be added will fall between this and this and this can be calculated using a linear interpolation. Now, we see here if I use interpolation the value of x comes out to be 11.2 5 kilowatt these values are available from hint. We can go for a linear interpolation and find out what should be the value of an x and it comes out to the 11.25 then I can put the value of x here. So, it is 15 plus 11.25 15 plus 11.25 which comes out to the 46.25. So, my heater load becomes 22.65.

Now, the loading of this heat exchanger becomes 120 minus 11.25, which comes out to the 108.75 and the load of the cooler is 45 plus 11.25, which comes out to the 56.25. Now if this loads are changed now this heater and this heat exchanger and this cooler then t 1 becomes 67.5 enhance the delta t minimum violation is removed.

So, this way we can calculate the amount of heat which should be added to this heat exchangers and then maintain the or eliminate the delta t minimum violation. Now you can also see through this add diagram, what is the cost change in cost you can also see that area and cost how the area and cost of the heat exchangers. Once their loads are changed are varying and by doing. So, we can find out whether, I am coming something by breaking this loop and passing heat through the heat path or we can go to the heat exchanger, and we can go to the results, and then we can one by one we can see this specifications or area and cost here the cost is given and the here the area is given.

So, by knowing this cost we can find out whether it is beneficial to break the loop and pass heat through the heat path from heater to the cooler. If we do not get any benefit by breaking the loop, it is better not to go for it and keep the hen as it is. So, this finishes loops and path loop and path identification and breaking can be done using software hint.