Optimizing nozzle position on an evaporator of absorption system cooling machine

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Abstract. This study examines the refrigerant jet spraying system that has been mounted on the absorption system cooling machine and is optimized using a CFD (Computer Fluid Dynamic). The study was conducted on an absorption system cooling machine that had been built using an absorber system in the form of a LiBr-H2O solution. As an refrigerant, water circulated in the tube bundle is used. Refrigerant spray patterns greatly affect the performance of the cooling machine. The more evenly distributed refrigerant beam in the space between the tube bundle lattice, the more effective the process of water cooling in the tube. The adjustment of the position of the nozzles and the evaporator grille is very influential in this refrigeration cycle. From the results of the initial conditions simulation of the placement of the nozzles with the arrangement of the tube bundle that there is fluid flow in the space between the lattice is not spread evenly. After being modified using the CFD software, an effective formation of tube bundle arrangement, evaporator lattice, and nozzle position is expected so that the refrigeration cycle is expected to go well.

1. Introduction
The history of absorption refrigeration machines began in the 19th century before there was a type of steam compression refrigeration engine and had experienced its own greatness. Commercially there are currently two absorption engine cooling configurations, the first is for applications above 0°C or used as air conditioning machines. For this air conditioning it uses the Lithium Bromide cycle as an absorber and water as a refrigerant. For applications below 0°C, use ammonia as a refrigerant and water as an absorber. The absorption cooling cycle is similar to the steam compression cooling cycle. The main difference between the two cycles is the force that causes the pressure difference between the evaporation pressure and the condensation pressure and the way the steam moves from the low pressure region to the high pressure region.

The compressed vapor cooling system uses a compressor, while the absorption cooling system uses an absorber and a generator. Low pressure steam is absorbed in the absorber, the pressure is increased by the pump and applying heat to the generator so that the absorber and generator can replace the compressor function absolutely. To perform the compression process, the steam compression cooling system requires mechanical work input while the absorption cooling system requires heat energy input. Therefore, the steam compression cycle is often referred as a work-operated cycle and the absorption cycle is referred as heat-operated cycle.
Steam absorption refrigeration systems using LiBr solution, water is extensively used in large capacity air conditioning systems. Water is used as refrigerant and lithium bromide solution in water is used as an absorber. Because water is used as refrigerant, this system is not possible to provide cooling at sub-zero temperatures. Therefore it is only used in applications that require cooling at temperatures above 0°C, so this system is used for air conditioning applications.

This study reviewed the spraying system of LiBr-H2O solution in the absorber in the absorption cooling system in the Engine Thermodynamics Technology & Propulsion Center (BT2MP). Water refrigerant is circulated to be sprayed on the evaporator tube bundle at 872 Pa. Under these conditions, water will evaporate at a temperature of 5°C. The heat for the evaporation process is taken from the chilled water flowing in the tube so that the temperature drops from 13°C to 8°C. The refrigerant vapor is absorbed by the LiBr solution that is sprayed on the absorber. Because the absorption of refrigerant vapor is an exothermic process, it needs to be cooled by cooling water. LiBr solution that has absorbed refrigerant will become more runny. To form a closed cycle, the refrigerant must be separated again from the LiBr solution. For this reason, the LiBr solution from the absorber is pumped to a higher pressure generator, which is 9,472 kPa, to be heated so that the water refrigerant will evaporate and the solution becomes more concentrated. The more concentrated solution is then returned to the absorber, while the refrigerant vapor is then condensed in the condenser by cooling it with cooling water. Condensate is flowed as make up refrigerant in the evaporator. Thus the cycle will repeat itself.

The process of diluting the LiBr solution to the absorber is due to mixing with water vapor from the evaporator that flows through the lattice between the absorber and evaporator chambers. When the absorber solution is sprayed through the nozzles in the spray header, water vapor simultaneously flows through the lattice space between the evaporator and the arbiter, resulting in a mixture of the two to the solution dilution process. The more water vapor flowing into the absorber, the more effective the process of diluting the solution.

The spraying pattern of the absorber solution is a characteristic function of the nozzle used, in this case using a solid cone type nozzle with a beam angle of 120°. The magnitude of the beam angle is expected to be able to reach optimally the area of the tube bundle underneath, while also optimizing the mixing of the absorber solution with the refrigerant. The placement of the nozzles in the absorber chamber also affects the absorption process of the refrigerant solution that enters through the lattice of the evaporator. This research will examine the position of the nozzles in the absorber through the fluid flow simulation method using CFD (Computer Fluid Dynamic), so that the optimal position is obtained.

2. Methodology
To start the simulation, the absorber system modeling is done on the absorption refrigeration device. There are a number of nozzle placement positions in the absorber to see which flow pattern is most optimal to produce a mixing effect between the absorber fluid and the water vapor from the evaporator. The nozzle placement system is in the following position:

2.1. The nozzle is placed in the center of the top of the absorber (position 1)
This position is the initial condition of the placement of the nozzles on the absorption refrigeration device in BT2MP. For this reason, the nozzle placement performance will be reviewed based on the results of the CFD simulation. From the simulation results an analysis will be taken to modify the nozzles placement.
2.2. Modification of the absorber model 1 (position 2)
The nozzle is placed in the upper right corner of the absorber with the angle of the spray nozzle 45° towards the vertical axis. The nozzle placement system at this position uses the analogy of the ejector theory. The number of tubes is 136 units, arranged in 14 columns, 9 rows, and lattice space is removed.

3. Results and discussion
In the CFD results display it will be difficult to distinguish the interference pattern of the nozzle output from the absorber output fluid flow. For this reason it is necessary to simulate the condition of one of the lattice inlets at a speed of 0 m/s.
3.1. Simulation results on the lattice inlet condition $v = 0$ m/s, seen in the following figure

![Figure 3](image_url)

Figure 3. The simulation results modeling of the absorber, position 1.

Figure 3 shows the direction of the fluid vector from the nozzle is emitted in the direction of the tube bundle, a portion reflected by the tube leads to the lattice at a slower speed. The amount of fluid flow velocity that leads to the lattice inlet is between 0.65-1.31 m/s. This speed is classified as slow, resulting in the inhibition of refrigerant vapor flow into the absorber chamber.

3.2. The nozzle is located between the two refrigerant fluid inlet lattices

![Figure 4](image_url)

Figure 4. The simulation results modification of the absorber model 1 (position 2) $V_{in}$ nozzle = 12.9 m/s, $V_{in}$ lattice = 0 m/s (vector scale = 25).

Shown in the figure 4 above, the absorber fluid sprayed by the nozzle leads to the closest column tube to the position of the nozzle i.e. in rows 3-5 from the right. Tube lines on the far side are not reached by the nozzle beam. Fluid in the tube turns in the direction of the absorber chamber, while another part can flow between the affected tubes and continue to descend toward the outlet.

The arrangement of the tube in the tube bundle needs to be modified to anticipate deflection of the flow towards the top of the absorber chamber by adding to the tube line up. The most possible form of arrangement of the tube is to form a hexagonal pole or circle. To form the pattern can be used by adding back the tube which was originally reduced by 24 pieces and move some tubes in the bottom row. With a reduction in the number of tubes, it is quite effective in giving a gap for fluid flow between the tubes.
In order to reach the farthest tube from the spray nozzle position, the spray nozzle angle needs to be raised. Increasing the nozzle angle results in the lattice angle also having to be raised. The nozzle's current angle is 45° from the vertical axis. Based on the tube geometry, assuming the beam direction follows the direction of the lattice, the farthest side of the tube can be reached by rotating the lattice and nozzles at an angle of 60° to the normal axis.

3.3. *Modification of the arbsorber model 2*

By placing the nozzle in upper right corner, following the analogy of the ejector theory, lattice changes and tube arrangement. Nozzle angle varies 55° (position 3) and 65° (position 4).

![Figure 5. Modification of nozzle position and tube bundle arrangement.](image)

3.3.1. *Simulation result of modification arbsorber model 2*

![Figure 6. The simulation results modification of the arbsorber model 2 position 3 V_in nozzle = 12.9 m/s, V_a lattice = 0 m/s (vector scale = 25).](image)

Figure 6 show a nozzle beam fluid flow pattern, where the vector flows enter between the tubes and then exit through the outlet. Figure 7 show the absorber fluid flow in the direction of the refrigerant vapor fluid flow. The velocity of the fluid in front of the grating reaches 4.59-8.04 m/s, greater than the speed of the fluid flow in front of the grating simulation results as shown in Figure 6 in the amount of 3.07-4.09 m/s. An acceleration of flow in front of the grating between the absorber chamber and the evaporator allows the absorber and water vapor to mix optimally.
Figure 7. The simulation results modification of the absorber model 2, position 4. $V_{in}$ nozzle = 12.9 m/s, $V_{in}$ lattice = 0 m/s (vector scale = 25).

4. Conclusions
The simulation results by placing the nozzles in position 1 (top center) show a fluid flow interference pattern between the absorber solution and the refrigerant vapor. This interference pattern tends to result in the mixing / mixing of the two fluids, because the direction of the fluid absorber vector flow towards the direction of the refrigerant vapor flow is opposite to each other. This is shown by the acceleration of fluid flow under the nozzle beam and slowing down the fluid in front of the grid. The simulation results by placing the nozzles in position 3, show the fluid flow pattern with the same vector direction between the two inlets. So the higher flow velocity of the nozzle output fluid will accelerate the speed of the refrigerant vapor flow from the lattice inlet. This condition also indicates the effect of refrigerant suctioning fluid by the absorber fluid due to the flow pattern by placing the nozzle in position upper right corner. The placement of the nozzle in position 4 is the most optimal position in the mixing process of the absorber solution with refrigerant vapor and the effect of refrigerant vapor absorption into the absorber chamber.

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