Heat Mass Exchange Process Efficiency Increase in Small-Size Cooling Machines of Circulating Water

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Abstract. This article is dedicated to the heat mass exchanger processes efficiency increase of circulating water cooling at chemical enterprises with development of a new design of a small-sized device of circulating water cooling with a swirling air stream. It is also proposed classification of constructions of small-sized towers on the main grounds. There is showed the relation for calculation of the time of phase interaction, from which it follows that the time of interaction of heat-exchanging phases more continuously in the device with swirling air stream, than in devices with contraflow. The indicator of the increase in the heat transfer coefficient, which shows how many times the difference of water temperature in inlet and in outlet of the swirling flow small-sized towers with is greater than the difference of water temperature in inlet and in outlet of mini cooling tower with contraflow.

1. Introduction

In the processes of chemical technology, various apparatuses and equipment are used: the compressor facilities, heat exchange devices, fracking fractionator, and reactors and etc.

To maintain a regulated temperature regime in technological processes, it is required to divert the resulting low-potential heat from apparatuses and equipment.

In general, the most available refrigerant is used to divert low-grade heat in industry - water, and cooling of the circulating water is carried out on the cooling towers.

The cooling towers are used for cooling the circulating water, that circulating on vicious loop of the system. Wherein the fan cooling tower recognized as one of the more efficiency and economic methods of water cooling in the water-turnaround systems of the enterprises [1-5].

There are the series of hard claims to fan cooling towers, are determined by its using specificities. In particular its must has the high reliability to ensure the continuous functioning of all system. Moreover it is necessary that they must be the maximal long-lived - in instance theirs replace may be conjugated with some complexities [6-9].

Also is important, that cooling towers was characterized by enough capacity – in otherwise the liquid circulation in the circuit will be less of necessary, and the temperature of the liquid will decrease very slowly, in result it the intensity and the efficiency of all system will decrease. The economy in energy consumption- one of the claims, which is important due to the fact that very often this devices are used continuously for very long time [10].
Figure 1. The closed loop of cooling system.

N and Q – the energy and heat flows from external sources; Q₁ – the heat flow, transferred to the water during the working process; Q₂ – the heat flow transferred to the atmosphere during the water cooling in cooling tower; t₁ – the temperature of heated water in inlet; t₂ – the temperature of cooled water in outlet.

Despite the efficiency of the fan-cooling towers, it has a series of flaws: the great spread of the pipeline systems, connected with the fan-cooling towers blocks remoteness from the technological equipment; the high energy consumption of the pump equipment; the presence of significant ejections to the atmosphere [11-13].

2. Materials and methods

Actual is the search of the scientific and technical and constructor solutions, allowing replace industrial enterprises to the local cooling systems of the circulating water (small-sized devices to cooling of circulating water) which more mobile, serve the specific technological facilities and devices of chemical productions, the less power-consuming, are effective, ecologically safe. The transition to local cooling systems excludes the necessity of exploitation the expensive extended pipelines, minimize the ejections to the atmosphere [14].

Currently uses the following designs of fan small-sized devices to cooling of circulating water, which proposed to be classified according the following main features:

1 **According the location of the fan**
   - The location of the fan to the right angle
   - The Tangentially fan location
   - The bottom fan location
   - The top fan location
   - The lateral fan location

2 **According the fans quantity**
   - Single fan
   - Double fan
   - Triple fan

3 **According to the phases motion:**
   - contraflow
   - cross flow
   - combined (mixed flow)

4 **According to the productivity:**
   - low (5-50 m³/h)
   - medium (50-100 m³/h),
   - high (от 100 m³/h and more).
The main cause of less efficiency of exploited small-size devices of cooling of the circulating water is non-continually contact time of cooling air flow and cooled water flow and the contra flow mode of interaction of heat exchange phases.

There is offered the design of small-size cooling tower with the twisted air flow to increase the efficiency of heat-mass exchange process.

3. Thesudy
The cooling tower contains a framework 1 with fan 2 installed in the lower part with tangential branch pipe 3, feeder 4, catchment container 5 with outlet branch pipe 6. There is the water distribution system 7 in the top part of the framework to proportional irrigation of water over the irrigation area, the water traps 8, as the layers of cylindrical polymer cellular pipes, bent with the fold radius equal to their diameter and boiled in the point contact of the faces ends with forming of the hardness membrane, the output tangential branches 9.

The cooling tower works so. The water from the circulation system heated in technological process fed to water-irrigation system 7 by means of which evenly distribute over sprinkler 4 on surface of which there is a heat-mass transfer of the water flow with the swirling air flow pumped by the fan 2. The water drips to the feeder 4, where is cools in the drop-membranous mode and then drips into the water catchment tank 5.

The increase of the efficiency of this cooling tower is conditioned by that the air flow “twisted” due which the contact time of air flow and water flow increase [15, 16].

There were obtained the follows relationships for calculate the interaction time of the heat-exchanging phases:

The length of twisted air flow determines by:

$$L_{gen} = N\sqrt{\frac{(\pi d)^2 + h^2}{2}}$$  (1)

where d – the diameter of one coil, m
h- step of one coil
N- the number of coils

The interaction time of phases in mini cooling tower with twisted air flow calculate so:

$$\tau = \frac{L_{gen}}{V}$$  (2)

$$\tau = \frac{N\sqrt{\frac{(\pi d)^2 + h^2}{2}}}{V}$$  (3)

where V- the rate of the air flow m/s
Thus:

$$\frac{N\sqrt{\frac{(\pi d)^2 + h^2}{2}}}{V} > \frac{H}{V}$$  (4)

where $H/V$ – the interaction time of phases in contra flow cooling tower

From the obtained, it can be seen, that the phases contact time in the mini cooling tower with swirling flow more continually, than the contact time of the phases in the mini cooling tower with countercurrent.

Suppose that the area of a work zone of the mini cooling tower with swirling flow more than the area of the contra flow mini cooling tower.

$$S > S_{dir}$$  (5)
where \( S_{exp} \), \( S_{dir} \) - the area of a work zone of the cooling towers with swirling flow and contraflow correspondingly, \( m^2 \)

\[
P D_{eq} z > PH.
\]  

(6)

where \( P \) - is the air flow channel perimeter, \( m \)
\( D_{eq} \) - equivalent diameter of air flow, \( m \)
\( z \) - the step of a coil of the spiral air flow, \( m \)
\( H \) - the height of the cooling tower, \( m \)

**Figure 2.** Small-size cooling tower with swirling air flow.
1. Framework, 2-fan, 3-tangential branch pipe, 4-feeder, 5-water catchment tank, 6-output branch pipe for a water, 7-water-irrigate system, 8-water trap, 9-output branch pipe for air.

\[ D_\varepsilon z > H, \]

\[ D_\varepsilon z = kH, \tag{7} \]

where \( k \) – the index of the increase of heat emission coefficient.

\[ k = \frac{D_\varepsilon z}{H}, \tag{8} \]

\[ k = \frac{\Delta T_i}{\Delta T_{dir}}, \tag{9} \]

where \( \Delta T_{exp} \) – the difference of a water temperature in outlet and inlet of the mini cooling tower with swirling flow, °C

\( \Delta T_{dir} \) – the difference of a water temperature in outlet and inlet of the contra flow mini cooling tower, °C

\[ \frac{\Delta T_i}{\Delta T_{dir}} = \frac{D_\varepsilon z}{H}, \tag{10} \]

\[ \Delta T = \Delta T_{dir}. \frac{D_\varepsilon z}{H}. \tag{11} \]

\[ \Delta T = \Delta T_{dir}. \frac{D_\varepsilon z}{H}. \tag{12} \]

4. Conclusion
The obtained dependence allow to determine the main parameter of the technological process of circulating water cooling in small-sized cooling towers with the twisted air flow, with the aim of its design and optimal using in water rotation systems for the petrochemical production process.

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