Research Results of the Process of Cooling the Gasoline Fraction with Dry and Wet Air

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Abstract. The article presents the results and conclusions of experiments on the effect of dry and wet air on the cooling efficiency in an air cooler in order to improve the processes of cooling gasoline fractions at oil and gas processing enterprises.

1 Introduction

Air cooling of raw materials, finished products and semi-finished products is important in oil and gas refineries. At the same time, several types of air cooling devices and their features are used [1, 2, 4]. The main parts of the air-cooled unit are the section and blade, and the vapors of the gasoline fraction move through the thin tubes of the section. The air flow through the blade passes through the gaps between the pipes and carries some heat. But the efficiency of these types of devices is less than that of others. One of the main reasons for this is the low heat capacity of air [3, 6].

According to the literature [1, 5], at a temperature of 20 ˚C the heat capacity of air is 1008 J/(kg ˚C), the heat capacity of water is 4200 J/(kg ˚C). This value fluctuates in the around of 3-5% when the temperature changes.

In order to improve the process of cooling the gasoline fraction in air-cooled apparatuses and increase the cooling efficiency, a number of experiments were conducted in the laboratory. The cooling process using dry and wet air was compared with each other (Fig. 1).

2 Methods

The gasoline fraction was used as a refrigerant during the experiment. Over time, the temperature of the gasoline fraction gradually increased. First of all, the gasoline fraction cooled by dry air was cooled to $\Delta T_{dry} = 25\ °C$ in the first *10* minutes, then to $\Delta T_{dry} = 35\ °C$ in the *20*th minute, and then to $\Delta T_{dry} = 36.5°C$ in the *30*th minute. We can see it from the Fig 1. The graph also shows that as the temperature of the gasoline fraction increases and over time, the cooling efficiency also increases rapidly, and towards the end of the experiment, the acceleration disappears and reaches equilibrium. At the next stage of the experiment, the properties of the refrigerant were changed by humidifying the air. To humidify the air, water droplets were sprayed using nozzles installed at an angle of 45° against the direction of the

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air flow transmitted by the fan. The scattered tiny water droplets quickly mixed together as a result of the turbulent air movement, forming a mist. In the same case, the experiment was repeated as before, and the results were recorded.

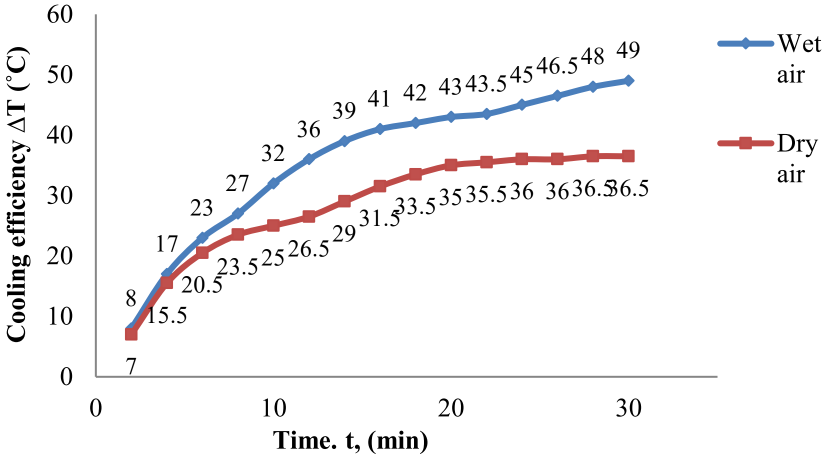

Fig. 1. Graph of changes in cooling efficiency when using dry and wet air per unit of time

The results showed that the process of cooling the gasoline fraction with wet air is more efficient than with dry air. The graph shows that the cooling efficiency of the gasoline fraction at 10, 20 and 30 minutes was 32˚C, 43˚Cand 49˚C. Although the above-mentioned changes in cooling efficiency using dry and wet air per unit time have been studied, it is also necessary to study the effect of changes in the volume flow rate and temperature at the inlet of the gasoline fraction on cooling efficiency. Accordingly, the volume flow rate of gasoline fraction during the experiments $V_1=3\cdot10^{-3}$ m^3/min, $V_2=7\cdot10^{-3}$ m^3/min and$V_3=11\cdot10^{-3}$ m^3/min the dependence of the cooling efficiency of dry and wet air from the change of the inlet temperature cooling device (Fig. 2, 3 and 4). In addition, it was assumed that the experiment was conducted at a constant air temperature, since the temperature of dry and wet air during the experiments ranged from 23 to 25˚C.

3 Results and discussion

In experiments, the difference between the cooling of the gasoline fraction by dry and wet air can be calculated by the expression $\Delta t=\Delta T_{wet} - \Delta T_{\mathrm{dry}}$ *(˚C)* In this case, the cooling efficiency with dry air $\Delta T_{\mathrm{dry}}$and the cooling efficiency with wet air $\Delta T_{wet}$are determined by the temperature difference of the gasoline fraction at the inlet and outlet of the refrigerator during the day.

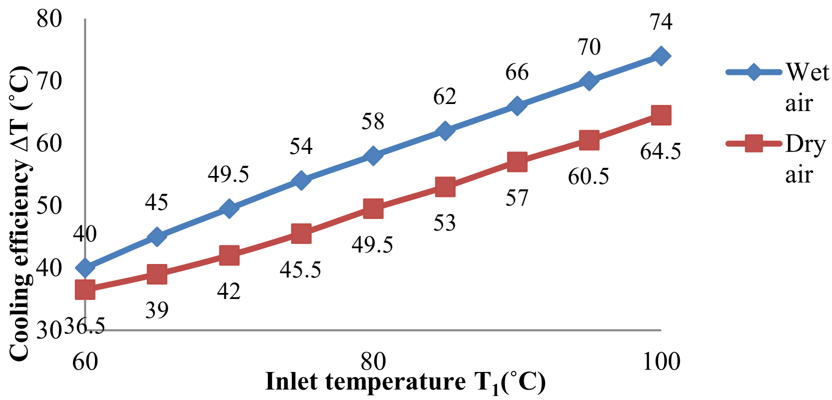

Fig. 2. Graph of the cooling efficiency of dry and wet air depending on the temperature change at the inlet of the cooling device. (At volume flow V1=3·10-3 m^3/min)

According to Fig. 2, the volume flow rate of the gasoline fraction $V_1 = 3\cdot10^{-3}$ m^3/min entering the apparatus and a temperature T_1=60 ˚C, the dry air cooling efficiency was ΔT_{dry}=36,5˚C and the wet air cooling efficiency ΔT_{wet}=40˚C. Then the difference between ΔT_{dry} and ΔT_{wet} turned out to be equal to Δt_1=3,5˚C. During the experiment, when the temperature of the gasoline fraction entering the apparatus increased to T_2=80˚C, the cooling efficiency in dry air was ΔT_{dry} =49,5˚C, and the cooling efficiency in wet air was ΔT_{wet} =58˚C. Then the difference between the two methods was Δt_2 = 8.5˚C. At the next stage of the experiment, when the temperature of the gasoline fraction reached T_3=100˚C, the cooling efficiency in dry air was ΔT_{dry} =64,5 ˚C, and the cooling efficiency in wet air was ΔT_{wet} =74 ˚C. Then the difference between the cooling efficiency using dry and wet air showed Δt_3=9,5 ˚C. In general, with a volume flow rate $V_1 = 3\cdot10^{-3}$m^3/min, the difference between the cooling efficiency using dry and wet air was 3.5 ˚C, 8,5 ˚C and 9.5 ˚C, respectively, at 60 ˚C, 80 ˚C and 100˚C.Thus, the difference between cooling with dry and wet air increases sharply with an increase in temperature at the inlet to the refrigerant and immediately goes into an equilibrium state. Therefore, the best option for the experimental process is to use wet air when the temperature of the incoming gasoline fraction at low volume flow is 80 ˚C.

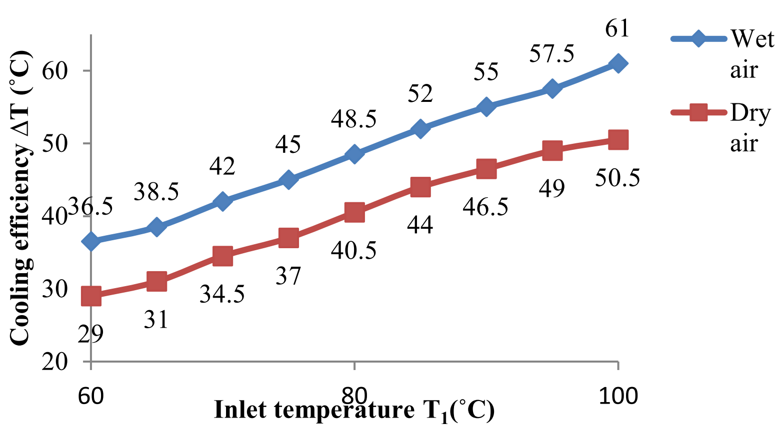

Fig. 3. Graph of the cooling efficiency of dry and wet air depending on the temperature change at the inlet of the cooling device
(At volume flow $V_1=7\cdot10^{-3}$ m^3/min*)*

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According to Fig. 3, the volume flow rate of the gasoline fraction $V_1 = 7 \cdot 10^{-3}$ m^3/min entering the apparatus and a temperature T_1=60 ˚C, the dry air cooling efficiency was ΔT_{dry}=29˚C and the wet air cooling efficiency ΔT_{wet}=36.5˚C. Then the difference between ΔT_{dry} and ΔT_{wet} turned out to be equal to Δt_1=7,5 ˚C. During the experiment, when the temperature of the gasoline fraction entering the apparatus increased to T_2=80˚C, the cooling efficiency in dry air was ΔT_{dry} =40,5˚C, and the cooling efficiency in wet air was ΔT_{wet} =48.5˚C. Then the difference between the two methods was Δt_2 = 8 ˚C. At the next stage of the experiment, when the temperature of the gasoline fraction reached T_3=100˚C, the cooling efficiency in dry air was ΔT_{dry} =50,5 ˚C, and the cooling efficiency in wet air was ΔT_{wet} =61 ˚C. Then the difference between the cooling efficiency using dry and wet air showed Δt_3=10,5 ˚C. In general, with a volume flow rate $V_1 = 7 \cdot 10^{-3}$ m^3/min, the difference between the cooling efficiency using dry and wet air was 7.5 ˚C, 8 ˚C and 10.5 ˚C, respectively, at 60 ˚C, 80 ˚C and 100 ˚C.

Thus, the difference between cooling with dry and wet air with an increase in temperature at the inlet to the refrigerant at first maintained an equilibrium state for some time, and then sharply increased. In this case, we can say that the best option for the experimental process is the use of wet air at a temperature of 100 ˚C or higher gasoline fraction entering the refrigerant.

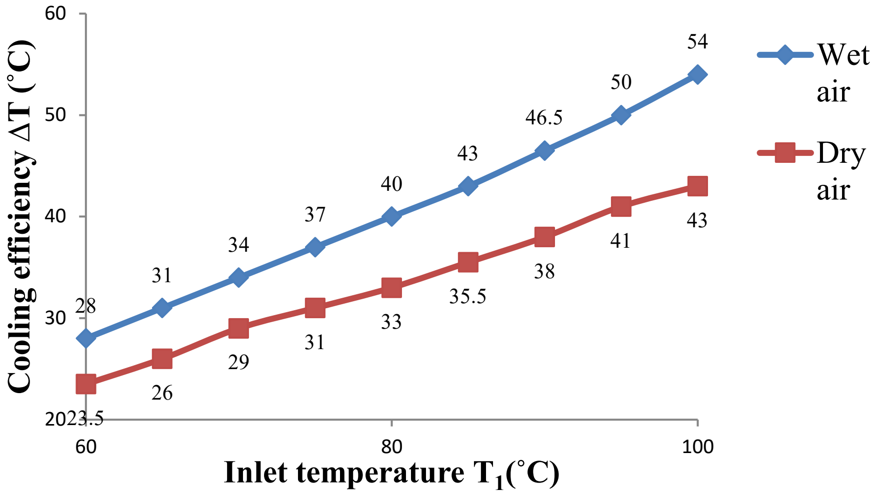

Fig. 4. Graph of the cooling efficiency of dry and wet air depending on the temperature change at the inlet of the cooling device. (At volume flow $V_3 = 11 \cdot 10^{-3}$ m^3/min)

According to figure 4, the volume flow rate of the gasoline fraction $V_1 = 11 \cdot 10^{-3}$ m^3/min entering the apparatus and a temperature T_1=60 ˚C, the dry air cooling efficiency was ΔT_{dry}=23.5˚C and the wet air cooling efficiency ΔT_{wet}=28˚C. Then the difference between ΔT_{dry} and ΔT_{wet} turned out to be equal to Δt_1=4,5 ˚C. During the experiment, when the temperature of the gasoline fraction entering the apparatus increased to T_2=80˚C, the cooling efficiency in dry air was ΔT_{dry} =33˚C, and the cooling efficiency in wet air was ΔT_{wet} =40˚C. Then the difference between the two methods was Δt_2 = 7 ˚C. At the next stage of the experiment, when the temperature of the gasoline fraction reached T_3=100˚C, the cooling efficiency in dry air was ΔT_{dry} =43 ˚C, and the cooling efficiency in wet air was ΔT_{wet} =54 ˚C. Then the difference between the cooling efficiency using dry and wet air showed Δt_3=11 ˚C. In general, with a volume flow rate $V_1 = 11 \cdot 10^{-3}$ m^3/min, the difference between the cooling efficiency using dry and wet air was 4.5˚C, 7˚C and 11˚C, respectively, at 60˚C, 80˚C and 100˚C. Thus, the difference between cooling with dry and wet air increases in parabolic dimensions with an increase in the temperature at the inlet to the refrigerant. Based on this, it can be concluded that the higher the temperature of the incoming gasoline fraction at high volume consumption in this case, the more productive the use of wet air will be for the experimental process.

The results of the experiment were carefully analyzed and proved that cooling with wet air is better than with dry air.

In the scientific explanation of the process, the difference in the efficiency of cooling the gasoline fraction with dry and wet air is due to the difference in the heat capacities of the two media, i.e., the heat capacity of air is 1008 J/(kg˚C), and the heat capacity of water is 4200 J/(kg˚C). Tiny droplets of water in wet air touch the heat exchange surface of the device, absorbing more heat than dry air and increasing heat transfer. The gasoline fraction transfers its heat to the wall of the device, and then through the wall to the external environment. The more heat the device emits through the heat exchanger, the higher the cooling efficiency.

In the course of experiments, it was studied that the efficiency of cooling using dry and wet air differs from each other even in cases of different volume flow of the gasoline fraction, and sufficient scientific knowledge was obtained.

4 Conclusion

Thus, the influence of dry and wet air on the cooling efficiency of an air cooling device used for cooling the gasoline fraction in oil and gas processing plants was studied. As a result, cooling the gasoline fraction with wet air proved to be more effective than with dry air. It is established that the key factor for changing the efficiency is the change in the heat capacity of the cooling medium.

In addition, the efficiency of cooling with dry and wet air was experimentally determined at the volume flow rate of the gasoline fraction $V_1=3\cdot10^{-3}$ m^3/min, $V_2=7\cdot10^{-3}$ m^3/minand $V_3=11\cdot10^{-3}$ m^3/min. Based on the results, graphs were constructed and indicators were compared with each other. For each value of the volume flow of the gasoline fraction, separate conclusions are given and it is recommended at which stage of the process dry or wet air can be used.

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