1988

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AN ANALYSIS RELATION AMONG THE MAIN PARAMETERS IN THE SPRAYING WATER ROOM OF AIR CONDITIONING SYSTEMS

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ABSTRACT

The way in conducting air with spraying water is now in common use in air conditioning systems of textile mills, but the relation among some parameters to be designed is not clear. This paper analyses the process and gives out the calculating formula of the main parameters in the spraying water room dependent on the heat and mass transfer, two-phase flow and energy equations.

In the formula, each parameter to be selected in designing shows evidently its effect to the efficiency of heat and mass transfer. Through contrasting with experiments, the calculating results are satisfactory. Using the formula, the structure of the spraying water room is also rationally improved if the quantity of air flow to be conducted is enlarged.

L'ANALYSE DES RELATIONS ENTRE LES PRINCIPAUX PARAMETRES DANS LA CHAMBRE DE JET D'EAU DU SYSTEME DE L'AIR CONDITIONNE

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RESUME

Le conditionnement d'air au moyen d'un jet d'eau s'emploie largement dans les usines textiles, pourtant, les relations entre les principaux paramètres dans la chambre de jet d'eau ne sont pas manifestes au cours des études. Le texte présente l'analyse du processus de l'air traité par le jet d'eau et, suivant la nature de la transmission de chaleur et l'équation de l'énergie, donne la formule des relations des principaux paramètres dans la chambre à jet d'eau.

Dans la formule, chaque caractère se révèle clairement influent sur l'efficacité de la chaleur pendant le traitement par le jet d'eau. La comparaison des résultats des calculs avec ceux des essais donne les résultats satisfaisants. Si on veut augmenter le volume d'air à traiter dans la chambre à jet d'eau, on peut employer cette formule qui contribuera à améliorer d'une façon rationnelle la structure de la chambre et les paramètres initiaux.
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SYMBOLS

- \( Q \) heat transfer
- \( C_p \) constant-pressure specific heat of air temperature
- \( \rho \) latent heat per unit mass of water containing water vapour in per unit mass of dry air time
- \( F \) total surface area of drops
- \( \mathcal{A} \) heat transfer coefficient
- \( \xi \) moisture-transfer coefficient
- \( L \) length of spraying water room
- \( D \) average diameter of drops containing water in per unit mass of air
- \( M \) number of drops
- \( N \) number of drops
- \( \rho \) density
- \( S \) cross section area
- \( \gamma \) velocity
- \( P \) pressure
- \( H \) specific enthalpy
- \( W \) mass flow
- \( R_0 \) thermal conductivity of air
- \( P_s \) pressure of spraying water in spraying head
- \( U \) ratio between water and air, \( W_w/W_g \)
- \( \text{INTRODUCTION} \)

The process of conducting air with spraying water is in common use in air conditioning systems of textile mills to keep certain temperature and relative humidity in shops, but the parameters: quantity of spraying water, water temperature, air flow velocity, average diameter of drops, structure sizes of spraying water rooms and so on, are chosen through tests and experience formula. The optimum condition is not easy to be reached in motion, design and adjusting, which consume more energy. This paper analyses the process and gives out the calculating formula of main parameters in the spraying water room. In the formula, each parameter shows evidently its effect to the efficiency of the heat and mass transfer. Through contrasting with experiments, the calculating results are satisfactory.

INFERERENCE OF THE CALCULATING FORMULA

According to heat and mass transfer equation, air flow in a differential length of the spraying water room, shown in Fig. 1, gives out the heat transfer
\[
dQ = \left[ \frac{C_p(T-T_b) + R(D-Db)}{\frac{\partial}{\partial t}} \right] \cdot \frac{dF}{dt}
\]
(1)

where
\[
\frac{dF}{dt} = \frac{dx}{V_g}
\]

If the average diameter of drops is \( L \), the number of drops is \( N \), the containing water is \( dM_w \) and the mass of air is \( dM_g \) in \( dx \), the ratio between the mass of water and the mass of air is
\[
Y = \frac{dM_w}{dM_g}
\]
(2)

where
\[
dM_w = \frac{\pi}{6} \cdot L^3 \cdot Zw \cdot N
\]
\[
dM_g = Sg \cdot S \cdot dx
\]
The surface area of drops
\[
dF = N \cdot X \cdot L
\]
(3)

Substituting (3) into (1), we obtain
\[
dQ = \frac{6 \cdot \pi \cdot S \cdot Y \cdot Zg}{C_p \cdot L \cdot Zw} \left[ \frac{C_p(T-T_b) + R(D-Db)}{\frac{\partial}{\partial t}} \right] \cdot dx \cdot dt
\]
(4)

Because the process of the heat and mass transfer between water and air in the spraying water room is isobaric, the quantity of heat, is absorbed by the air crossing the differential length, is the enthalpy increase of air, or the energy equation
\[
-dQ = dH \cdot dM_g
\]
\[
= W_g (C_p \cdot dT + R \cdot dD) \cdot dt
\]
(5)

Put (4) and (5) together, we obtain
\[
dx = \frac{6 \cdot \pi \cdot S \cdot Y \cdot Zg \cdot W_g}{C_p \cdot L \cdot Zw} \cdot \frac{C_p \cdot dT + R \cdot dD}{C_p(T-T_b) + R(D-Db)}
\]
(6)

where
\[
\alpha = \frac{R_o}{J} \cdot Nu
\]
\[
W_g = S \cdot V_g \cdot Zg
\]

If the \( T_b \) and the \( D_b \) are mean values, or the mean value of the specific enthalpy of water, we integrate (6)
\[
X_o = \frac{6 \cdot \pi \cdot V_g \cdot Zw}{6 \cdot Nu \cdot Y \cdot R_o} \cdot \ln \frac{H_{g1} - H_{wa}}{H_{ga} - H_{wa}}
\]
(7)

The formula will become the limit, \( o/o \), when the process is isenthalpy because of \( H_{g1} = H_{ga} = H_{wa} \). In order to infer the formula of the iso-enthalpy process, the condition of the iso-enthalpy is in use and the infering process is same as above. The only difference is that the heat transfer of the heat transfer equation is the quantity of heat absorbed by the dry air, not air. The heat transfer and energy equations become
\[
dQ = \alpha (T-T_b) \cdot dF \cdot dt
\]
\[
-dQ = W_g \cdot C_p \cdot dT \cdot dt
\]

According to the infering process as above
\[
X_o = \frac{6 \cdot \pi \cdot V_g \cdot Zw}{6 \cdot Nu \cdot Y \cdot R_o} \cdot \ln \frac{T_{g1} - T_b}{T_{ga} - T_b}
\]
(8)
Contrasting (7) with (8), it is well known that \( \frac{(Hg_1 - Hwa)}{(Hg_2 - Hwa)} \) and \( \frac{(T_{g1} - Tb)}{(T_{g2} - Tb)} \) are similarly the efficiency of the heat and mass exchange, which is decided by the difference ratio between the starting and final states in the designing process of air conditioning on the H-D chart, then (8) and (7) merge into a general formula

\[
Xo = \frac{Cp \cdot \Gamma^2 \cdot Vg \cdot Zm}{6 \cdot Nu \cdot Y \cdot Re} \cdot InA
\]

This is the calculating formula of the heat and mass transfer in spraying water rooms, which shows evidently the relation among the efficiency of heat and mass transfer \( A \), the length of spraying water rooms \( Xo \), the velocity of air flow \( Vg \), the average diameter of drops \( L \), the Nusselt number \( Nu \), and the containing water in per unit mass of air \( Y \).

The average diameter of drops, the Nusselt number and the containing water in per unit mass of air must be known when calculating. The average diameter is dependent on your way in spraying water and conditions. The Nusselt number is dependent on

\[
Nu = 2 + 0.386(Pr \cdot Re)^{0.8}
\]

The containing water in per unit mass of air is dependent on the distribution of drops in the spraying water room, which is calculated by the two-phase flow.

**CALCULATING EXAMPLE**

The data measured in Second Cotton Mill, Beijing, China

<table>
<thead>
<tr>
<th></th>
<th>Vs (m/s)</th>
<th>Ps (Pa)</th>
<th>Kg/cm²</th>
<th>U</th>
<th>Tw1</th>
<th>Tw2</th>
<th>Hwa</th>
<th>Hg1</th>
<th>Hg2</th>
<th>Xo</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ja: China</td>
<td>6.00</td>
<td>2.50</td>
<td>0.60</td>
<td>18.1</td>
<td>20.8</td>
<td>13.3</td>
<td>17.7</td>
<td>15.0</td>
<td>1.84</td>
<td></td>
</tr>
<tr>
<td>Luwa:Swiss</td>
<td>5.99</td>
<td>2.60</td>
<td>0.66</td>
<td>14.9</td>
<td>18.9</td>
<td>11.1</td>
<td>17.5</td>
<td>13.2</td>
<td>1.80</td>
<td></td>
</tr>
<tr>
<td>Luwa:Swiss</td>
<td>6.56</td>
<td>2.60</td>
<td>0.51</td>
<td>14.6</td>
<td>18.8</td>
<td>11.0</td>
<td>18.9</td>
<td>14.6</td>
<td>1.90</td>
<td></td>
</tr>
</tbody>
</table>

The average diameter is 0.25mm when the \( Ps=2.5Kg/cm^2 \) because the drops collide with one another that we measured. Through calculating with computer, the moving locus of drops is on Fig.2 and the velocity difference between the drops and the air flow is less than 1 m/s when the \( X \) is greater than 0.2m, then \( Nu=2.1 \). The \( Y \) is calculated by

\[
Y = U \cdot \frac{Vg}{Vw}
\]

The results is

\[
Xo_1 = 1.883m ; Xo_2 = 1.7963m ; Xo_3 = 1.945m
\]

The \( Xo \) is the effective distance between the bafflers of water and the centre of the spray head. It is satisfactory to real conditions.

**CONCLUSION**

The formula (9) is suitable for the designing process in the spraying water room of air conditioning and the calculating results is satisfactory with experiments, in which the relation among the main parameters can be found.

If we want to increase the quantity of air flow in a air conditioning system but the structure of the system and the parameters of air flow are not changed, the formula (9) is changed
\[ L \cdot \frac{V_g}{Y} = L' \cdot \frac{V_{g'}}{Y'} \]

The purpose can be reached by increasing the quantity of spraying water and decreasing the average diameter of drops, or increasing \( Y \) to \( Y' \) and decreasing \( L \) to \( L' \). The formula above provides also the way in improving old system of air conditioning and the relation among parameters adjusted in motion.

Improving the spraying efficiency, or decreasing \( L \), is the best way to save energy and increase the efficiency of heat and mass transfer in spraying water rooms through the formula (9). And the efficiency of removing dust is not reduced.

REFERENCES


Fig. 1 The differential length in the spraying water room.

Fig. 2 The moving locus of the water drop.

\[ V_g = 7 \text{ m/s} \quad V_{wo} = 0 \quad L = 0.25\text{mm} \]