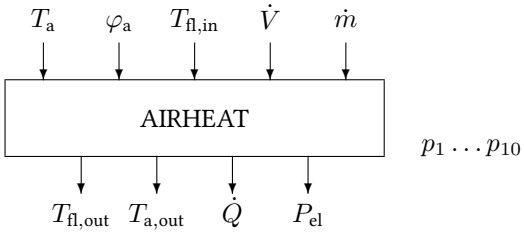
Block AIRHEAT

The AIRHEAT block simulates heating performance of a hot water to air heater as well as the cooling performance of a dry cooling tower in dependency of the perfromance data given on the data sheet for nominal operation conditions. Only valid for water volume flow rates of at least 30 percent of the nominal water flow rate.





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Inputs

1 Ambient air temperature / °C
2 Relative humidity air
3 Inlet water temperature / °C
4 Air flow rate in percent of nominal air flow rate (20 – 100 %)
5 Water mass flow rate / kg s^{-1}

Outputs

1 Water outlet temperature / °C
2 Air outlet temperature / °C
3 Recooling / heating power of the cooling tower / kW
4 Required electricity power of the ventilators / kW

Parameters

1 Nominal recooling/heating power of the air heater / dry cooling tower / kW
2 Heating fluid inlet temperature under design conditions / °C
3 Heating fluid mass flow rate under design conditions / kg s^{-1}

4	Density of heating fluid / $\mathrm{kg\,m^{-3}}$
5	Specific heat of heating fluid / $\mathrm{kJ\,kg^{-1}\,K^{-1}}$
6	(Ambient) air inlet temperature under design conditions / °C
7	Air volume flow under design conditions / $\mathrm{m^3\,h^{-1}}$
8	Electrical power consumption of the ventilator motor under design conditiones / kW
9	Total length of heat exchanger unit / m
10	Total width of heat exchanger unit / m

Strings

None

Description

The AIRHEAT block simulates the heating performance of a hot water to air heater as well as the cooling performance of a dry cooling tower in dependency of the performance data given on the data sheet for nominal operation conditions. In this model the outlet temperature of the air flow as well as the electrical power consumption of the fan are calculated in the dependency of the inlet parameters and the given nominal heating/cooling power. Because of the assumption made within the modeling, the model is only valid for water volume flow rates of at least 30 percent of the nominal water flow rate.

Fundamentals

The overall energy balance for the heating block is given by the following equation

$$\dot{m}_{\mathrm{fl}} \cdot c_{\mathrm{p,fl}} \cdot (T_{\mathrm{fl,in}} - T_{\mathrm{fl,out}}) = \dot{m}_{\mathrm{a}} \cdot c_{\mathrm{p,a}} \cdot (T_{\mathrm{a,out}} - T_{\mathrm{a,in}})$$

where

T_{in}	Air (a) and fluid (fl) inlet temperature / °C
T_{out}	Air (a) and fluid (fl) outlet temperature / °C
c_{p}	Specific heat capacity of air (a) and fluid (fl) / $\mathrm{kJ\,kg^{-1}\,K^{-1}}$
$\dot{m}$	Mass flows of air (a) and fluid (fl) / $\mathrm{kg\,s^{-1}}$

Assuming constant mass flow rates the heat exchanger efficiency is defined as follows

$$\phi = \frac{T_{\mathrm{a,out}} - T_{\mathrm{a,in}}}{T_{\mathrm{fl,in}} - T_{\mathrm{a,in}}}$$

If the specific heat capacity of the fluid is much higher then the one of the air, a middle temperature can be assumed resulting in the following equation

$$\phi = \frac{T_{\mathrm{a,out}} - T_{\mathrm{a,in}}}{T_{\mathrm{H}} - T_{\mathrm{a,in}}}$$

$$T_{\mathrm{H}} = \frac{T_{\mathrm{fl,in}} + T_{\mathrm{fl,out}}}{2}$$

For constant average fluid temperature, due to a larger heat capacity, the heat exchanger efficiency is also given by

$$\phi = 1 - \exp\left(\frac{U \cdot A}{\dot{m}_\mathrm{a} \cdot c_\mathrm{p,a}}\right)$$

where

U	Heat transfer coefficient of the heat exchanger / $\mathrm{W\,m^{-2}\,K^{-1}}$
A	Heat transfer area inside the heat exchanger / $\mathrm{m^2}$

The UA-value of the heat exchanger can be calculated at design conditions. For changing massflow rates the following law can be used

$$U \cdot A = C_\mathrm{HX} \cdot v_\mathrm{a}^n$$

with

v	Air velocity / $\mathrm{m\,s^{-1}}$
n	Parameter $n = 0.4 \ldots 0.6$
C_HX	Characteristic heat exchanger constant / $\mathrm{J\,m^{-3}\,K^{-1}}$

In order to calculate the air properties, empirical equations are used

$$\begin{aligned} p_\mathrm{s,a} = {} & 611 \cdot \exp(-1.91275 \cdot 10^{-4} + T_\mathrm{a} \cdot 7.258 \cdot 10^{-2} \\ & - T_\mathrm{a}^2 \cdot 2.939 \cdot 10^{-4} + T_\mathrm{a}^3 \cdot 9.843 \cdot 10^{-7} \\ & - T_\mathrm{a}^4 \cdot 1.92 \cdot 10^{-9}) \end{aligned}$$

$$\rho_\mathrm{a} = \frac{1}{T_\mathrm{a} + 273.15} \cdot \left(p - \frac{\varphi_\mathrm{a} \cdot p_\mathrm{s,a}}{R_\mathrm{a}} + \frac{\varphi_\mathrm{a} \cdot p_\mathrm{s,a}}{R_\mathrm{d}}\right)$$

with

$p_\mathrm{s,a}$	Air saturation pressure / Pa
ρ_a	Air density / $\mathrm{kg\,m^{-3}}$
R_a	Universal gas constant air (287 $\mathrm{J\,kg^{-1}\,K^{-1}}$)
R_d	Universal gas constant steam (462 $\mathrm{J\,kg^{-1}\,K^{-1}}$)

Before describing the algorithm which makes it possible to calculate the outlet temperatures, the proportional law for determining the electric power consumption of the ventilator is given.

$$P_\mathrm{el} = P_\mathrm{el,d} \cdot \left(\frac{\dot{V}}{\dot{V}_\mathrm{max}}\right)$$

with

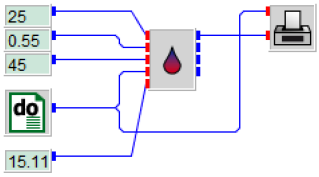
P_{el}	Electric power consumption / W
$P_{\text{el,d}}$	Electric power consumption at design conditions / W
$\dot{V}$	Air volume flow / $\text{m}^3\,\text{s}^{-1}$

Implementation

This subsection presents the algorithm used in order to describe the heat/ cooling block. In contrast to other heat exchanger models this block calculates the output via a given heat exchange capacity at nominal conditions.

1. Calculate air properties at design conditions
2. Determine air and water output temperatures with the input values as well as the air speed at design conditions in order to calculate the heat exchanger characteristic $U \cdot A$ and for C_{HX}
3. Calculate air properties at working conditions
4. Correct air flow at design $\dot{V}_{\text{a}} = n_{\text{rel}} \cdot \dot{V}_{\text{a,d}}$ conditions via the relative revolutions per second with $n_{\text{rel}} = \frac{n}{n_{\text{max}}}$ and calculate the air velocity at working conditions
5. Calculate the heat transfer $U \cdot A$ at working conditions
6. With $U \cdot A$ calculate ϕ
7. Now using the outlet temperatures of the air and the fluid can be calculated
8. Calculate the electric power consumption using the proportional law $\frac{\dot{V}}{\dot{V}_{\text{max}}} = \frac{n}{n_{\text{max}}}$

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A DO block varies the air flow rate of the heater between 20 and 100 percent of the nominal airflow. All other inputs are set constant.

A PLOT block shows the water outlet temperature as a function of the air flow rate.

