INSTITUT FÜR SOLARTECHNIK

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TRNSYS Type 861

Ice Storage Model with ice-on-heat exchangers

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Abstract

This TRNSYS Type simulates a ice storage with ice-on-coil, ice-on-plates and ice-on-capillary mat heat exchangers. This storage typer does not allow two types in the same deck and direct ports (wihout heat exchangers) are not implemented. This Type is compatible for TRNSYS 17 and 18

Contents

1. Introduction

The mathematical formulation of this model has been presented in Carbonell et al. (2018) for capillary mats and coils and in Carbonell et al. (2017) for flat plate heat exchangers.

2. Revison history

Date	Version	Changes
Sep 16, 2021	v1.1	update on documentation only
Jul 14, 2020	v1.1	Small clarificatons in the documentation
Oct 31, 2018	v1.0	First version released

3. Notes

- The model does not allow to freeze completely one control volume of the storage tank. The energy balance is applied to the water of each control volume. Thus, if there is none or too little volume of water available, the model suffers from instability
- For stability of the complete system it is recommended to bypass the ice storage once completely iced
- The model has never been tested for other PCM, but probably with minor modifications it should work

4. List of parameters

Nr.	Description	Name	Units
1	information level	0: no messages, 1: only important, 3: all, 4: debug mode	-
2	Storage Volume	V_{tes}	m^3
3	Storage height	H_{tes}	m
4	Storage width	W_{tes}	m
5	Storage geometry 0: box 1:cylinder (W_{tes} not used)	s_{type}	-
6	Distance between pipes if hx_{type} = 1 Distance between hx if hx_{type} = 2	x_1	m
7	Distance between hx if hx_{type} = 1	x_2	-
8	Effective thermal conductivity of store	k_{wat}	W/(mK)
9	Density of storage fluid (water)	ρ_{wat}	kg/m^3
10	Specific heat storage fluid (water)	$c_{p,wat}$	J/(kgK)
11	not used		
12	Thermal conductivity of ice	k_{ice}	W/(mk)
13	Water$\leftrightarrow$ice enthalpy	ΔH_{ice}	J/kg
14	Supercooling temp	$T_{supercool}$	°C
15	Freezing temperature	T_{freeze}	°C
16	Initial amount of ice in store	kg_{ice}	kg
17	not used		
18	Maximum storage ice volume fraction	$V_{ice,max}$	-
19	Parameter check control	1 : breaks if pars out of range	
20	not used		
21	hx height respect to the total	hx_{height} [0-1]	-
22	maximum ice floating ratio in layers were ice is produced (only relevant when deicing is used)		
23	Use of T_{wall} from previous time step (improves convergence)		m
24	Number of used hx	only used for hx_{type} =1	
25	use constant physical properties in the water from the storage		
26	use corrugated configuration for flat plates	only used when hx_{type}=0	

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	Heat Exchanger i:		
27 + 19(i-1)	Hx geometry	hx_{type}	
	0=flat plates, 1=capillary mats or coils		
28 + 19(i-1)	Number of hx	N_{hx}	
29 + 19(i-1)	hx_{type}=1 inner tube diameter	$d_{in,hx}$	
	hx_{type}=0 height flat plate	H_{hx}	
30 + 19(i-1)	hx_{type}=1 outer tube diameter	$d_{out,hx}$	
	hx_{type}=0 width of flat plate	W_{hx}	
31 + 19(i-1)	Length of hx	L_{hx}	
32 + 19(i-1)	hx_{type}=0 additional heat capacity hx		J/m^3
	hx_{type}=1 wall thickness flat plate	$dx_{wall,hx}$	m
33+19(i-1)	Order of hx from 1 to 4. Used only if seriesMode is active	not implemented	
34+19(i-1)	Hx thermal conductivity	$\lambda_{hx,i}$	W/(mK)
35+19(i-1)	Relative height of inlet on the hx	[0-1]	
36+19(i-1)	Relative height of outlet on the hx	[0-1]	
37+19(i-1)	Fluid density	ρ_{fluid}	$kg/(m^3)$
38+19(i-1)	Fluid specific heat	$c_{p,fluid}$	J/(kgK)
39+19(i-1)	Glycol concentration		%
40+19(i-1)	Number of Cv in the Hx	$N_{cv,hx}$	
41+19(i-1)	C Factor for Nusselt correlation (heating)	$C_{hx,i}$	
42+19(i-1)	n Factor for Nusselt correlation (heating)	$n_{hx,i}$	
43+19(i-1)	C Factor for Nusselt correlation (cooling)	$C_{hx,i}$	
44+19(i-1)	n Factor for Nusselt correlation (cooling)	$n_{hx,i}$	
45+19(i-1)	Enhanced Nusselt number for laminar flow ($Nu = Nu \cdot Nu_{en}$)	Nu_{en}	-
	End of Heat Exchanger		
103	U lower lateral side	$U_{low,lat}$	$W/(m^2K)$
104	U upper lateral side	$U_{up,lat}$	$W/(m^2K)$
105	U bottom side	U_{bot}	$W/(m^2K)$
106	U upper side	U_{top}	$W/(m^2K)$
107	1^{th} relative sensor height position	y_{s1} [0-1]	
108	2^{th} relative sensor height position	y_{s2} [0-1]	
109	3^{th} relative sensor height position	y_{s3} [0-1]	
110	4^{th} relative sensor height position	y_{s4} [0-1]	
111	5^{th} relative sensor height position	y_{s5} [0-1]	

5. List of inputs

Nr.	Description	Name	Units
1+3(i-1)	Inlet fluid temperature of the hx i	$T_{in,hx,i}$	°C
2+3(i-1)	Inlet mass flow rate of the hx i	$\dot{m}_{in,hx,i}$	kg/h
3+3(i-1)	Reverted temperature of the hx i	$T_{rev,hx,i}$	°C
	Temperature used when $\dot{m}_{in,hx,i}$¡0		
⋮	for i=1 i $\leq$4 i=i+1	⋮	⋮
13	0 : mechanical de-ice off ; 1 : on		
14+(n-1)	Surrounding temperature around the TES (for heat loss calculation)	$T_{amb,n}$	°C
⋮	for n=1 n $\leq$nCv n=n+1	⋮	⋮
14+(nCv)	Surrounding temperature below TES (for heat loss calculation)		°C
14+(nCv+1)	Surrounding temperature above TES (for heat loss calculation)		°C

6. List of derivatives

The definition of derivatives is used to calculate the number of control volumes in the storage nCv

Nr.	Description	Name	Units
n	Initial storage temperature for each Cv n	$T_{ini,n}$	°C
⋮	for n=1 n $\leq$ nCv n=n+1	⋮	⋮

7. List of outputs

Nr.	Description	Name	Units
1	Average temperature of the store	$\dot{T}_{s,av}$	°C
2	Total heat provided by the Hx to the storage tank	$\dot{Q}_{hx}$	W
3	Total heat accumulated of the storage tank	$\dot{Q}_{acum}$	W
4	Total heat losses of the storage tank	$\dot{Q}_{loss}$	W
5	Total heat used to melt the ice from the storage tank water	$\dot{Q}_{melt}$	W

6	Total heat used to form the ice. This includes icing and melting with the heat exchangers	$\dot{Q}_{\text{ice}}$	W
7	Total imbalance heat	$\dot{Q}_{\text{imb}}$	W
8	Mass of floating ice	$\dot{M}_{\text{ice,f}}$	kg
9	Total ice thickness in the heat exchangers	ds_{ice}	m
10	Total mass of ice (floating + hx,ice)	$\dot{M}_{\text{ice,T}}$	kg
11	1: Upper part of the storage is full of ice (no ice can be released); 0: not full		
12 + 7(i-1)	Inlet temperature of heat exchanger i	$T_{\text{in,hx,i}}$	°C
13 + 7(i-1)	Outlet temperature of heat exchanger i	$T_{\text{out,hx,i}}$	°C
14 + 7(i-1)	Wall temperature of heat exchanger i	$T_{\text{wall,hx,i}}$	°C
15 + 7(i-1)	Power provided for all parallel heat exchangers i	$\dot{Q}_{\text{hx,i}}$	W
16 + 7(i-1)	Ice thickness in the heat exchangers i	$ds_{\text{form,i}}$	m
17 + 7(i-1)	Ice melted in the heat exchangers i	$ds_{\text{melt,i}}$	m
18 + 7(i-1)	Total heat transfer coefficient for all parallel heat exchangers i	$UA_{\text{hx,i}}$	W/K
$\vdots$	for i=1 i $\leq$4 i=i+1	$\vdots$	$\vdots$
40	1: Heat exchangers are full of ice (collapse of ice storage); 0: not full		
41 +(n-1)	Temperature of sensor n		°C
46 +(n-1)	Temperature of the storage for the Cv n	T_n	°C
$\vdots$	for n=1 n $\leq$ nCv n=n+1	$\vdots$	$\vdots$
56	Losses at the bottom	$q_{\text{loss,bottom}}$	W
57 +(n-1)	Losses for the Cv n	$q_{\text{loss,n}}$	W
$\vdots$	for n=1 n $\leq$ nCv n=n+1	$\vdots$	$\vdots$
67	Losses at the top	$q_{\text{loss,top}}$	W
68	Temperature of the storage at the bottom	T_{bottom}	°C
69	Temperature of the storage at the top	T_{top}	°C
70	Heat transfer coefficient at the bottom	U_{bottom}	W/(m^{2}K)
71	Average heat transfer coefficient at the side of the storage	U_{bottom}	W/(m^{2}K)
72	Heat transfer coefficient at the top	U_{zop}	W/(m^{2}K)

i=1 to 4 which is the maximum number of heat exchangers

References

Carbonell, D., Battaglia, M., Philippen, D., and Haller, M. Y. (2017). *Ice-Ex - Heat Exchanger Analyses for Ice Storages in Solar and Heat Pump Applications*. Institut für Solartechnik SPF for Swiss Federal Office of Energy (SFOE), Research Programme Solar Heat and Heat Storage, CH-3003 Bern.

Carbonell, D., Battaglia, M., Philippen, D., and Haller, M. Y. (2018). Numerical and experimental evaluation of ice storages with ice on capillary mat heat exchangers for solar-ice systems. *International Journal of Refrigeration*, 88:383–401.