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**Loop Heat Pipe Simulation - Condenser Development**

LOOP hEat pump ciRcuit (LOOPER)

CODE HANDBOOK

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*Legend*

*LOOPER (Main)*

|  |  |  |  |
| --- | --- | --- | --- |
| T\_amb | Ambient temperature | Pi | Starting pressure |
| Qext | External heat | Qleak | Heat leakage |
| h\_step | Integration time step | tmax | Simulated time |
| g | Gravity | hce\_ll | Liquid line external convection coefficient  |
| fr | Filling ratio | T\_hs | Heat sink temperature |
| hc | HTC at the condenser | M\_mol | Molar mass |
| R | Gas constant | P\_crit | Critic pressure |
| k\_g  | Adiabatic index | k\_90 | Concentrated loss factor due to 90 degrees turn |
| k\_in1,2,3  | Concentrated loss factor due to increase in pipe diameter | k\_out1,2,3  | Concentrated loss factor due to decrease in pipe diameter |
| ri\_cond | Condenser internal radius | re\_cond | Condenser external radius |
| L\_cond | Condenser length | ri\_ll | Liquid line internal radius |
| re\_ll | Liquid line external radius | z\_u | Height of the condenser from the heat pump |
| L\_ll | Liquid line length | nb\_ll | Liquid line number of bends |
| Lx\_ll | Length associated to a liquid line node | deltaz\_ll | Height associated to a liquid line node |
| ri\_vl | Internal radius vapour line | re\_vl | External radius vapour line |
| L\_vl | Vapour line length | nb\_vl | Vapour line number of bends |
| Lx\_vl | Length associated to a vapour line node | deltaz\_vl | Height associated to a liquid line node |
| rpw | Primary wick radius | Lpw | Primary wick length |
| rvg | Vapour groove radius | nvg | Number of vapour grooves |
| Lvg | Vapour grooves length | thickev | Evaporator shell thickness |
| rbi | Bayonet internal radius | rbe | Bayonet external radius |
| Lbay | Bayonet length | rsw | Secondary wick radius |
| Lsw | Secondary wick length | r\_vc | Vapour chamber radius |
| kn\_cond | Thermal conductivity condenser material | rho\_mcond | Density of the condenser material |
| cp\_cond | Specific heat of condenser material | rho\_mvl | Density of the vapour line material |
| rho\_mll | Density of the liquid line material | alpha1 | Porosity of the primary wick |
| kmpw | Thermal conductivity of primary wick material | r\_por\_pw | Primary wick medium pore size radius |
| rho\_pw | Density of primary wick material | cp\_pwm | Specific heat of primary wick material |
| alpha2 | Porosity of the secondary wick | kmsw | Thermal conductivity of secondary wick material |
| r\_por\_sw | Secondary wick medium pore size radius | rho\_sw | Density of secondary wick material |
| cp\_swm | Specific heat of secondary wick material | rho\_a | Compensation chamber material density |
| cp\_a | Specific heat of the compensation chamber material | kmb | Thermal conductivity bayonet material |
| rho\_bay | Density of bayonet material | cp\_bay | Specific heat of bayonet material |
| kwall | Thermal conductivity of the evaporator wall | rho\_we | Density of the evaporator wall  |
| cp\_wall | Specific heat of the evaporator wall | ra | Compensation chamber radius |
| La | Compensation chamber length | v\_sp | Initial specific volume  |
| u1 | Initial internal energy | m\_vo | Mass of the vapour inside the vapour grooves |
| m\_wall | Mass of the evaporator wall | m\_pw | Mass of the primary wick (liquid + solid) |
| m\_sw | Mass of the secondary wick (liquid + solid) | m\_bay | Mass of the bayonet (liquid + solid) |
| m\_evap | Total mass of the evaporator | cp\_pw | Average specific heat of the primary wick |
| cp\_sw | Average specific heat of the secondary wick | cp\_av | Average specific heat of the evaporator |
| Qdot | Resultant of the heat balance equation | u2 | New specific energy of the system after a time step |
| newP1 | Fictitious parameter to find the new pressure after the isochoric heating | toll | Tolerance |
| xi | Initial ratio between liquid specific volume and vapour specific volume | u | Fictitious specific energy of the system used to find the correct one after the isochoric heating |
| Tevap | Vaporization temperature corresponding to the pressure in node 1 | m\_cc | Mass of the compensation chamber (liquid + solid) |
| m\_vl | Mass of the vapour line (liquid + solid) | m\_ll | Mass of the liquid line (liquid + solid) |
| m\_cond | Mass of the condenser (liquid + solid) | mtot\_LHP | Total mass of the LHP system (liquid + solid) |
| V\_pw | Solid volume of the primary wick | V\_sw | Solid volume of the secondary wick |
| heat\_vap | Latent heat of vaporisation | mdot | Mass flow rate |
| n\_c | Number of condenser nodes | vu2 | Vector for the time evolution of the specific energy |
| vQsolid | Vector for the time evolution of the heat that goes into raising the temperature at the evaporator | vhci | Vector for the time evolution of the internal convection coefficient at the condenser |
| Rd12 | Distribute hydraulic resistance from node 1 to 2 | Rd23 | Distribute hydraulic resistance from node 2 to 3 |
| deltaPbay | Pressure drop associated to the bayonet | Pcapsw | Delta P due to capillarity in the secondary wick |
| Pcappw | Delta P due to capillarity in the primary wick | deltaP | Total hydraulic losses in the LHP |
| Rdvg | Distribute hydraulic resistance inside the vapour grooves | deltaPvo | Pressure drop associated to vapour grooves |
| cp\_cc | Average specif heat of the compensation chamber | hcvg | Convection coefficient inside the vapour grooves |
| kpw | Average thermal conductivity of the primary wick | Avg | Exchange surface of the vapour grooves |
| R\_pwvo | Thermal resistance between the wick and the vapour grooves | R\_vowall | Thermal resistance between the evaporator wall and the vapour grooves  |
| R\_wallpw | Thermal resistance between the wick and the evaporator wall | ksw | Average thermal conductivity of the secondary wick |
| hcbay | Convection coefficient inside the bayonet | Abay | Exchange surface of the bayonet |
| Rpw2 | Thermal resistance between the wick and node 2 | Tsat | Saturation temperature associate with the pressure in the liquid part of the wick |
| hLV | Latent heat of vaporisation of the wick | tempo\_evap | Integration time of the ODE for the evaporator system |
| Tstartcc | Integration starting point for the compensation chamber | y\_cc | Results vector of the ODE for the compensation chamber |
| T\_cc | Compensation chamber temperature | x0 | Initial conditions vector for the ODE for the evaporator |
| y\_evap | Results vector of the ODE for the evaporator | T\_vo | Vapour grooves temperature |
| T\_pw | Primary wick temperature | T\_wall | Evaporator wall temperature |
| P\_cc | Compensation chamber pressure | vT\_evaporator | Vector containing the temperatures of the nodes for the evaporator |
| vP\_evaporator | Vector containing the pressures of the nodes for the evaporator | P\_vg | Vapour grooves pressure |
| T\_vg | Vapour grooves temperature | rho\_vg | Density vapour grooves |
| v\_vg | Velocity of the vapour in the vapour grooves | Rc\_vc | Concentrated hydraulic resistance due to different sections between the vapour grooves and the vapour chamber |
| P\_vc | Vapour chamber pressure | T\_vc | Vapour chamber temperature |
| rho\_vc | Vapour chamber density | v\_vc | Velocity of the vapour in the vapour chamber |
| Rc\_vli | Concentrated hydraulic resistance due to different sections between the vapour line and the vapour chamber | P\_vli | Initial pressure of the vapour line |
| T\_vli | Initial temperature of the vapour line | rho\_vl | Density of the vapour line |
| v\_vl | Velocity of the vapour in the vapour line | P\_vl | Vpour line pressure |
| T\_vl | Vapour line temperature | deltaPvl | Total pressure drop due in the vapour line |
| Rd\_vl | Distributed hydraulic resistance for a single vapour line node | Rt\_vl | Thermal resistance of a single vapour line node |
| T\_vl | Temperature of vapour line single node | P\_vl | Pressure of vapour line single node |
| P\_c | Pressure of a single node of the condenser | T\_c | Pressure of a single node of the condenser |
| x | Vapour quality | sumQc | Sum of the heat dissipated at the condenser nodes |
| deltaPcond | Total pressure drop of the condenser | rho\_2p | Two phase mixture density |
| mu\_2p | Two phase mixture dynamic viscosity | v\_c | Velocity of the condenser |
| Rd\_cond | Distributed loss at condenser node | T\_c0 | Temperature at a condenser node at the previous time step |
| Ae\_cond | Condenser node external exchange surface | Ai\_cond | Condenser node internal exchange surface |
| Re | Reynold number | Pr | Prandtl number |
| P\_star | Reduced pressure | af | Dittus-Boelter coefficient |
| hce | External convection coefficient at the condenser | sh | Shah correlation coefficient |
| hc\_v | Vapour convective heat transfer coefficient | hci | Internal convection coefficient |
| mcond1 | Mass of the fluid part of the condenser | mcond2 | Mass of the solid part of the condenser |
| mcond | Mass of the single condenser node (liquid + solid) | hLV\_cond | Latent heat of vaporisation for the condenser |
| x0 | Vapour quality at the previous time step | tempo\_cond | Timestep for the integration for the condenser ODE |
| Rt\_cond | Total thermal resistance for the condenser  | y\_cond | Results vector of the ODE for the condenser |
| T\_ll | liquid line node temperature | P\_ll | liquid line node pressure |
| rho\_ll | liquid line density | h\_ll | liquid line specific entalphy |
| sumQ\_amb | total heat dissipated at the liquid line | deltaPll | total pressure drops at the liquid line |
| n\_dittus | exponent of the Dittus-Boelter equation | hci\_ll | internal convection coefficient liquid line |
| Rt\_ll | thermal resistance liquid line | Q\_amb | heat dissipated at single node of the liquid line |
| Rd\_ll | distributed hydraulic resistance of single node for the liquid line | v\_ll | velocity of liquid in the liquid line |
| Rc\_ll | concentrated hydraulic resistance in the liquid line | Rp\_ll | total hydraulic resistance for the liquid line node |
| T\_av | average temperature between the two nodes of the evaporator with solid mass | cp\_av | average specific heat between the two nodes of the evaporator with solid mass |
| gamma | fictitious parameter to chase the actual pressure value through the specific energy | dPisocor | increment in pressure due to the isochoric heating |
| R\_tot\_LHP | total thermal resistance of the LHP | Q\_c | heat dissipated at the single condenser node |

*Function: propisocor*

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| --- | --- | --- | --- |
| u\_v | vapour specific energy | u\_l | liquid specific energy |
| v\_v | vapour specific volume | v\_l | liquid specific volume |

*Function: phy\_prop\_water*

|  |  |  |  |
| --- | --- | --- | --- |
| kl | liquid thermal conductivity | mu\_l | liquid dynamic viscosity |
| cp\_l | liquid specific heat | kv | vapour thermal conductivity |
| sigma | surface tension | mu\_v | vapour dynamic viscosity |
| rho\_v | vapour density | h\_sv | saturated vapour specific enthalpy |
| h\_sl | saturated liquid specific enthalpy | rho\_l | liquid density |
| cp\_v | vapour specific heat |  |  |

*Function: v\_zero*

|  |  |  |  |
| --- | --- | --- | --- |
| vT\_cc | vector for the time evolution of the compensation chamber temperature | vT\_pw | vector for the time evolution of the primary wick temperature |
| vT\_wall | vector for the time evolution of the evaporator wall temperature | vT\_vo | vector for the time evolution of the vapour grooves temperature |
| vmdot | vector for the time evolution of the mass flow rate | vQext | vector for the time variation of the external heat |
| vP2 | vector for the time evolution of node 2 pressure | vP3 | vector for the time evolution of node 3 pressure |
| vPpw | vector for the time evolution of the primary wick pressure | vP\_cc | vector for the time evolution of the compensation chamber pressure |
| vPvo | vector for the time evolution of vpour grooves pressure | vP\_vl | vector for the time evolution of vapour line nodes pressure |
| vT\_vl | vector for the time evolution of vapour line nodes temperature | vP\_cond | vector for the time evolution of condenser nodes pressure |
| vT\_cond | vector for the time evolution of condenser nodes temperature | vQc | vector for the time evolution of heat dissipated at every node of the condenser |
| vx | vector for the time evolution of vapour quality at every node of the condenser | vT\_ll | vector for the time evolution of liquid line nodes temperature |
| vP\_ll | vector for the time evolution of liquid line nodes pressure | vQamb | vector for the time evolution of heat dissipated at every node of the vapour line |
| vP1 | vector for the time evolution of node 1 pressure | vT1 | vector for the time evolution of node 1 temperature |
| vT\_LHP | vector for the time evolution of temperature for every node of the LHP | vP\_LHP | vector for the time evolution of pressure for every node of the LHP |
| vQris | vector for the time evolution of the heat balance equation (in out only) | vR\_tot\_LHP | vector for the time evolution of the total thermal resistance of the LHP |
| vQdot | vector for the time evolution of the heat balance equation |  |  |

*Function: f\_cc*

|  |  |
| --- | --- |
| x  | compensation chamber temperature |

*Function: odeevaporator2*

|  |  |  |  |
| --- | --- | --- | --- |
| x(1) | temperature of the vapour grooves | x(2)  | temperature of the primary wick |
| x(3) | temperature of the evaporator wall |  |  |

*Function: f\_cond*

|  |  |  |  |
| --- | --- | --- | --- |
| A | vapour specific enthalpy at the previous time step | B | liquid specific enthalpy at the previous time step |
| C | vapour specific enthalpy at the actual time step | D | liquid specific enthalpy at the actual time step |
| h0\_cond | specific enthalpy at the previous time step | h\_cond | specific enthalpy at the actual time step |
| dxdt | subject of the ODE equation |  |  |

*Instructions*

The first section of the code is the one where to act, with the first part for boundary conditions like external heat (which is going to be your target) or the simulation time. The parameters already inserted in the code are constant.

Once you’ve put your boundary conditions, you have to describe your chosen working fluid. Please note that this is very important, since the original code is written for water, therefore you need to be extra cautious to change all the polynomials in the code using the different functions (i.e. *phy\_prop\_fluidname*). Moreover, please be aware that you’ll need to change also the polynomials in some functions like *propisocor* and *f\_cond*.

Then there are the two sections for the geometry and material to fill.

In the end, press run and on the command window are going to appear the time instants that the code is calculating and a window will open showing the real time progress of the Twall.