PACCMAN User/Developer Guide

(Python Analysis of Conformal Cooling Molds And/or desigNs)

This guide is meant to be used as a resource for using, adding to, or integrating the PACCMAN program. It is expected that users will have a package manager such as Anaconda or another program with Numpy, Scipy, Matplotlib, etc.

In order to install Pytest with Anaconda, open the Anaconda Powershell Prompt and run the command ”conda install -c anaconda pytest ”.

Feedback is welcome. Please report all bugs to hughfeehan353 on Github. Thanks.

Introduction:

This program is designed to aid in the optimization and design of conformal cooling molds. While sample variables are included, its main use is for user-provided data. From the chosen data file, PACCMAN performs functions and provides outputs of information about the mold that the inputted data describes. The outputs can then be compared to another design to determine which is the most efficent or saved as estimations of a particular mold’s characteristics. A NumPy array can also be used as an input variable to see how different values of a variable affect the mold’s performance. Multiple arrays can be used to compare things like the mold material that have multiple material property variables. However, it is important to consider that each variable for a specific material must be put in the same position in the arrays.

Basic Use:

When run, if the input variables are for a mold with straight cooling geometry, the program first presents two options.

Selecting ”N” asks the user to choose a single heat transfer coefficient correlation.

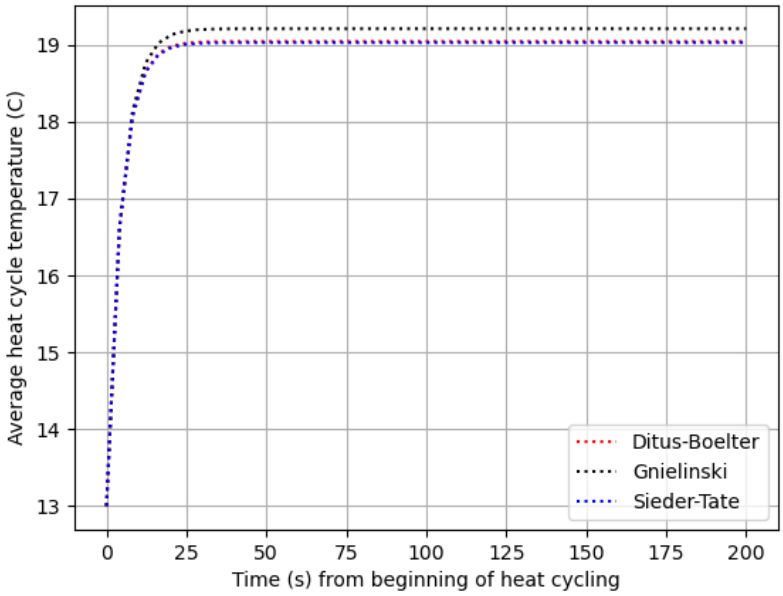
Selecting ”H” compares the three heat transfer coefficient correlations.

If the mold being analyzed has helical geometry, this option does not appear as there is only one heat transfer coefficient correlation.

For all choices, the program asks the user if they would like to save graphs of the average heat cycle temperature over time.

Choosing ”Y”, downloads the graph in .png and .eps formats.

Choosing ”N” will not download the graphs



An example graph of the PACCMAN results.

The program is written so that by changing the variables, it can analyze any desired conformal cooling design and will report the following data:

flow velocity, kinematic viscosity, Reynolds number, Prandl number, Darcy friction factor, heat transfer coefficient, average heat cycle temperature of the mold, time constant, and coolant pressure drop.

Multiple Variables / Arrays

Arrays can be used in this program to compare either multiple values for a single variable or multiple values for multiple values.

When comparing multiple values for a single variable, use a NumPy array and the program will compare the efficacy of the values entered.

When inputting multiple values for multiple variables, the number of values in each array must be the same. The values in array position 1 will always do arithmetic from the other values in position 1, the values in position 2 work with the other values in position 2, etc.. The final results that the program give will be the same as the number of array variables, which must be the same for every array. A recommended use of this is comparing different materials for the mold, coolant, or part and putting all the material properties of the same material in the same array slot.

Application Fundamentals for Advanced Use:

At the beginning, the program initializes and assigns all the basic variables. By default, these are imported from the ”basedata.py” file.

In order to change the values, the data in this file can either be edited directly or the import location can be changed. In order to do this, locate the import statement on line 12 of ”paccman.py” and change ”basedata” to the desired new file. All of the variables in ”basedata.py” are necessary for the program to function properly so none should not be completely omitted if a new file is used.

Afterwards, all the necessary functions are defined. These cannot be removed as they are necessary for the program’s function but could be added to.

At this point there is an “if” statement to check for the user’s desired function for the program. This “if” statement contains all of the program’s calculation functions in order to ensure that nothing will break if the user chooses an invalid letter.

The first thing inside the “if” statement are some calculations that must be completed no matter the chosen choice of the program’s function.

The rest of the calculations contain nested “if” and “elif” statements so that the correct variables are used for the chosen program function.

Once the calculations are completed, the program creates a plot of the average heat cycle temperature over time that the user has the choice of downloading.

The program can be tested using Pytest by running the following command in the program’s directory: ”python -m pytest”.

Variables Used:

Part Thickness: L_P

Coolant Line Diameter: D

Average Height of Coolant Line Surface Irregularties: ε

Coolant Line Length: L

Coolant Thermal Conductivity: K_C

Coolant Density: ρ_C

Mold Specific Heat Capacity: C_C

Coolant Temperature: T_C

Part Density: ρ_P

Part Specific Heat Capacity: C_P

Thermal Conductivity of Mold: K_M

Coolant Line Pitch Distance: W

Distance from Coolant Line to Mold Wall: L_M

Difference in Part Temperature Between Inserted Into Mold and Released: T

Cycle Time: T_{Cycle}

Mold Density: ρ_M

Mold Specific Heat Capacity: C_M

Initial Mold Temperature: T_{MO}

Coolant Flow Rate: $\dot{V}$

Coolant Dynamic Viscosity: μ

Coolant Dynamic Viscosity When Near Wall: μ_W

Coil Diameter: CD

Equations Used:

Flow Velocity of Coolant (U): $\frac{\dot{V}}{\pi \cdot (\frac{D}{2})^2}$

Coolant Kinematic Viscosity (KV): $\frac{\mu}{\rho_C}$

Reynolds Number (Re): $\frac{U \cdot D}{KV}$

Prandtl Number (Pr): $\frac{\mu \cdot C_C}{K_C}$

Darcy Friction Factor (straight cooling, Haaland Equation) (f): $(\frac{1}{-1.8log[(\frac{\varepsilon}{3.7 \cdot D})^{1.11} + (\frac{6.9}{Re})]})^2$

Darcy Friction Factor (helical cooling, laminar flow) (f): $\frac{64}{Re}$

Darcy Friction Factor (helical cooling, laminar flow, big vortex) (f): $\frac{64}{Re} * (1 + 0.15 * Re^{0.75} * (\frac{D}{CD})^{0.4}$

Darcy Friction Factor (helical cooling, turbulent flow) (f): $(0.1 * (1.46 * \varepsilon + (\frac{100}{Re})^{0.25}) * (1 + 0.11 * Re^{0.23} * (\frac{D}{CD})^{0.14})$

Dean Number (used for helical cooling only) (De): $Re * (\frac{D}{CD})^{0.5}$

There are three Nusselt Number equations for a straight cooling geometry mold (Nu):

1. Dittus-Boelter: $0.023 \cdot Re^{\frac{4}{5}} \cdot Pr^{0.4}$

2. Gnielinski: $\frac{\frac{f}{8} \cdot (Re - 1000) \cdot Pr}{1 + [12.7 \cdot (\frac{f}{8})^{0.5} \cdot (Pr^{\frac{2}{3}} - 1)]}$

3. Sieder-Tate: $0.027 \cdot Re^{\frac{4}{5}} \cdot Pr^{\frac{1}{3}} \cdot (\frac{\mu}{\mu_W})^{0.14}$

Nusselt Number (helical cooled mold) (Nu): $(2.153 + 0.318 * De^{0.643}) * Pr^{0.177}$

Nusselt Number (helical cooled mold, Reynolds number between 5,000 and 100,000) (Nu): $0.00619 * Re^{0.92} * Pr^{0.4} * (1 + 3.455 * \frac{D}{CD})$

Heat Transfer Coefficient (h): $\frac{K_C}{D} \cdot Nu$

Average Temperature of the Mold (ATM): $T_C + \frac{\rho_P \cdot C_P \cdot L_P \cdot T \cdot [(2 \cdot K_M \cdot W) + (h \cdot \pi \cdot D \cdot L_M)]}{h \cdot \pi \cdot D \cdot K_M \cdot T_{Cycle}}$

Time Constant ($T_{Constant}$): $\frac{\rho_M \cdot C_M \cdot L_M^2}{K_M} \cdot (1 + \frac{2 \cdot W \cdot K_M}{h \cdot \pi \cdot D \cdot L_M})$

Pressure Drop: $\frac{Df \cdot L}{D} \cdot \frac{\rho_C}{2} \cdot \dot{V}^2$

Equation for Graphs: $y = ATM + (T_{MO} - ATM) \cdot e^{\frac{-x}{T_{Constant}}}$

Validation Cases:

This folder contains two samples of data for use in the PACCMAN program. The data contained by the ”xucomparison” file contains values from pulled from [7], while ”xucomparison.csv” is a table produced through WebPlotDigitizer of Figure 4 in this paper. The data contained by the ”guilongcomparison” file is from [3] and ”guilongcomparison.csv” contains the data from Figure 6 pulled with WebPlotDigitizer.

As seen in the .png files for each validation case, the data from both papers is extremely close to what the PACCMAN program calculates. This provides some affirmation that the program works both correctly and accurately.

References

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