Created in COMSOL Multiphysics 5.2

Cooling Finned Pipe Designer

About the Cooling Finned Pipe Designer Application

Finned pipes are used for coolers, heaters, or heat exchangers to increase thermal performance. These fins come in different sizes and designs depending on the application and requirements. When placed outside the pipe, they increase the heat exchange surface of the pipe so that a cooling or heating external fluid can exchange heat more efficiently. When placed inside the pipe, it is the inner fluid that benefits from an increased heat exchange surface. Instead of fins, grooves can also enlarge the heat exchange surface, particularly inside the pipe where space is limited.

In the application, you can customize a long cylindrical pipe with predefined inner and outer fins or grooves to observe and evaluate their cooling effects. Figure 1 shows three examples of fins and grooves among those provided by the user interface.

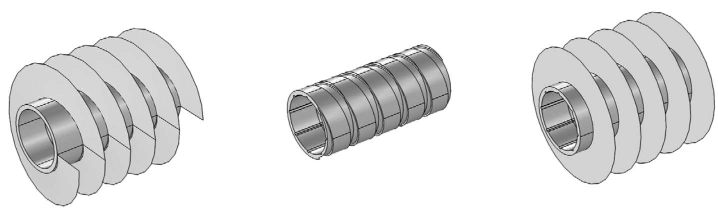
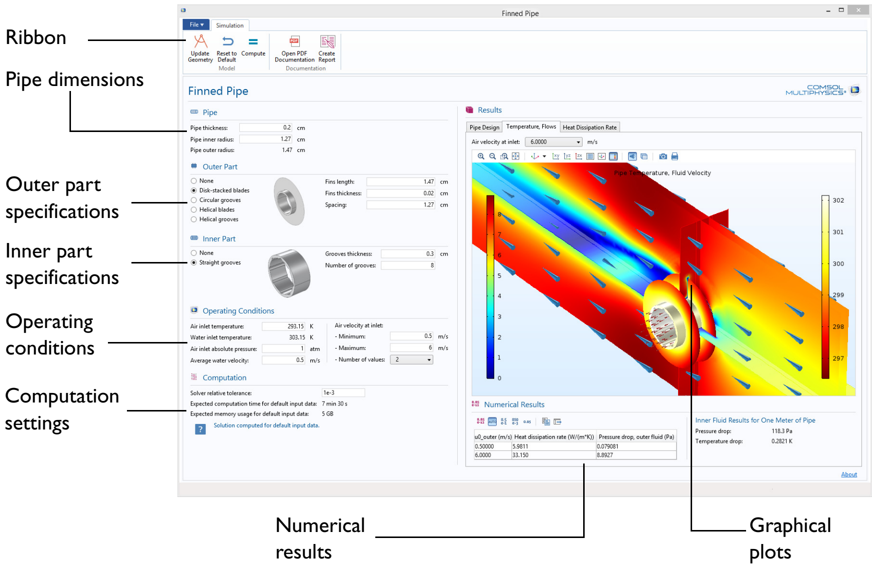


Figure 1: Inner and outer fins and grooves of a cylindrical pipe.

The inner fluid is water, the outer cooling fluid is air, and the pipe is made of copper. However, it is still possible to alter the app to set different materials. After specifying the geometry and operating conditions, the app provides a characterization of the pipe through the following quantities:

- Pipe mass
- Inner volume of the pipe
- Inner and outer heat exchange surfaces
- Heat dissipation rate
- Pressure drop for the inner and outer fluid
- Temperature drop for the inner fluid

The figure below shows the user interface of the app.



The different sections for setting the design of the pipe are detailed below.

PIPE

Use this section to specify the dimensions of the pipe itself. The available parameters to manipulate are the **Pipe thickness** and the **Pipe inner radius**. The **Pipe outer radius** is then deduced automatically.

OUTER PART

Select between **Disk-stacked blades**, **Circular grooves**, **Helical blade**, **Helical grooves**, or **None** for the outer part. According to the selection, size parameters for the fins or grooves can be specified.

INNER PART

For the inner part, select between **None** or **Straight grooves**.

OPERATING CONDITIONS

In this section, define the **Air inlet temperature** and **Air inlet absolute pressure** for the air flow around the pipe. The **Water inlet temperature** is automatically updated when the **Air inlet temperature** is changed. Define the **Average water velocity** for the water flow inside the pipe. The app solves the model for different possible values of velocity for the air flow to analyze its effect on the cooling. Set the **Minimum** and **Maximum** values for the air velocity range at the inlet, and choose the **Number of values** to solve for, between **2** and **10**.

COMPUTATION

Set the **Solver relative tolerance**. The default value provides a good solution at moderate computational costs. This section also displays useful information about computation time and memory consumption.

RESULTS

This section shows several graphical plots and numerical results after computation. The **Pipe Design** tab displays the geometry according to your custom inputs. At the bottom, information on the mass and dimension of the pipe are provided.

The **Temperature, Flows** tab shows the graphical plot of the temperature in the pipe domains, and velocity in water and air domains. Change the values of **Air velocity at inlet**, defined beforehand in the **Operating Conditions** section, to display the corresponding plot. At the bottom, the **Numerical Results** section shows the heat dissipation rate, pressure drops for inner and outer fluids, and temperature drop for the inner fluid.

The **Heat Dissipation Rate** tab draws the curve of the heat dissipation rate with respect to air inlet velocity, in the range specified in the **Operating Conditions** section.

The Embedded Model

The model consists of a finned and grooved pipe filled with water, which is cooled by the surrounding air. The model makes use of pseudoperiodicity conditions to be able to compute only a small section of the pipe. This provides reliable results if the temperature field along the whole pipe is periodic up to a constant offset and following the geometrical periodicity.

MODEL DEFINITION

The model solves for a turbulent flow inside and around the pipe. Indeed, the cooling air flow at the exterior of the pipe often reaches high speeds, bringing the problem to the turbulent validity range. Inside the pipe, the water flow already reaches a Reynolds number in the turbulent range from 0.5 m/s.

For heat transfer, the water inlet temperature is 10 K warmer than the air inlet. This ensures that the overall temperature gradient is not too large and material properties in the pipe section remain constant.

To avoid modeling any specific length of pipe, you only solve for a sample of the pipe of 0.5 inch (1.27 cm) that is geometrically periodic. For that sample, pseudoperiodic heat conditions are applied to the opposite extremities. This way, the heat flux is the same at these boundaries but the temperature field has an offset determined by the operating conditions.

RESULTS

The default input data solves for two values of air velocity: 0.5 m/s and 6 m/s. The numerical results for these parameter values are shown in Table 1. These results are given for one meter of pipe.

TABLE 1: NUMERICAL RESULTS

AIR INLET VELOCITY	HEAT DISSIPATION RATE	PRESSURE DROP (AIR)	PRESSURE DROP (WATER)	TEMPERATURE DROP BETWEEN PIPE EXTREMITIES
0.5 m/s	5.9811 W/(m·K)	0.079081 Pa	118.3 Pa	0.2821 K
6 m/s	33.150 W/(m·K)	8.8927 Pa		

The default geometry is characterized by the following data.

TABLE 2: MASS AND DIMENSIONS OF THE PIPE

QUANTITY	VALUE
Pipe mass	1.371 kg
Inner fluid volume (water)	0.5235 dm^3
Inner heat exchange surface	8.758 dm^2
Outer heat exchange surface	41.19 dm^2

Figure 2 shows the plot of temperature in the pipe domain and velocity magnitude in the air domain.

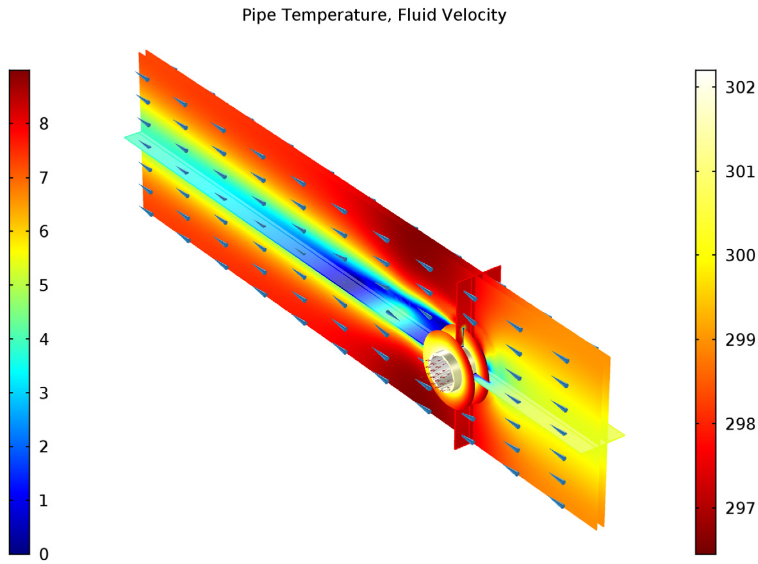


Figure 2: Temperature plot in the pipe domain and velocity magnitude plot in the air domain.

Figure 3 shows the heat dissipation rate curve with respect to air velocity. The curve is obtained with only two values. For a more significant trend, the model should be solved for more values of air velocity.

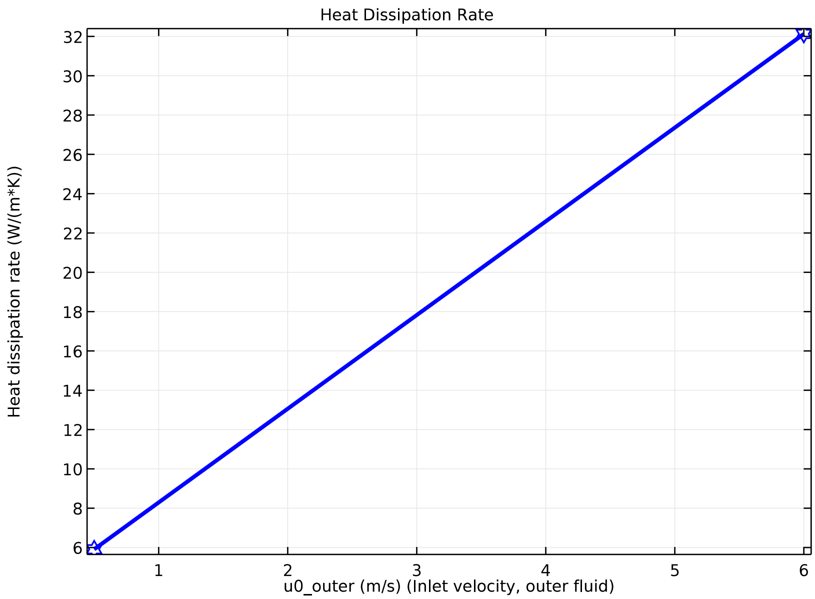


Figure 3: Heat dissipation rate versus air velocity.

Application Library path: `Heat_Transfer_Module/Applications/finned_pipe`
