TemperatureTube

Real time temperature simulator for the tube, when the liquid flow moves in it.

v1.0

1. Introducing

TemperatureTube can be used to visualize the temperature of the outer surface of the tube in models of industrial rooms, machines and units, laboratory equipment. The length, diameter and wall thickness of the tube may vary.

The physics of heat transfer processes is calculated based on the solution of the differential equation of the temperature field in the flow.

The calculation of the temperature field is performed every 0.2 seconds, those 5 times per second. Simulators flow rate, flow temperature at the inlet to the tube, ambient temperature are non-stationary and change in time.

Flow rate $g(\tau)$, flow temperature at the inlet to the tube $t(\tau)$ and ambient temperature $a(\tau)$ independently change over time according to dependence:

$$g(\tau)=a_1+b_1\times\sin(c_1\times\tau) \quad , \quad t(\tau)=a_2+b_2\times\sin(c_2\times\tau) \quad , \quad a(\tau)=a_3+b_3\times\sin(c_3\times\tau)$$

a_1, b_1, c_1, a_2, b_2, c_2, a_3, b_3, c_3 – user configurable parameters.

Such the dependence is universal, it can establish constant and variables values of parameters with a wide or narrow range of variation.

Now the tube is made from Steel, and Water flows inside it. Other materials that can be used to make the pipe (for example, Plastic,...), as well as other substances that flow in the pipe (for example, Air,...) can be added.

2. Installation

Just copy the TemperatureTube.dll to your project's assets folder.

3. TemperatureTube creation as GameObject.

The TemperatureTube is easy to create. Create an empty GameObject, add a new script component to the created empty GameObject and select TemperatureTube from the list of available scripts.

At the same time, in the editor mode, the created TemperatureTube is not displayed on the scene. This is due to the fact that in the Mesh Renderer component, no materials have been set for the tube surfaces. They can be set manually to see tube in the editor. It is designed so, that the first surface is on top. So, by installing only one material, as shown in the figure, you will be able to see the outer dimensions of the tube.

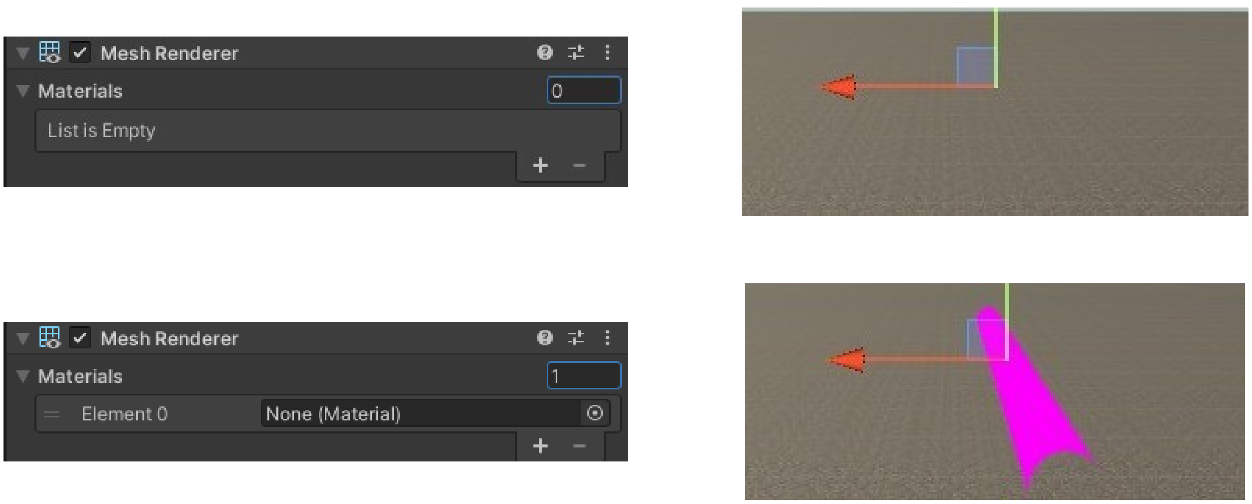

Figure 3.1 — Material definition for tube in editor mode

If there are errors in the initial data for the tube, it is marked in window where the scene hierarchy is shown, as erroneous and it excluded from the scene, that is started.

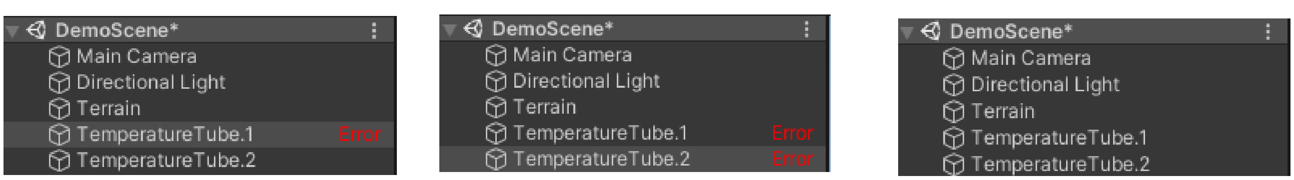

Figure 3.2 — Mark tube with errors in hierarchy window

4 Configuration options, restrictions imposed on them and possible errors.

The initial data for the tube are divided into 4 groups:

- tube parameters,
- substance parameters,
- ambient parameters,
- simulation parameters.

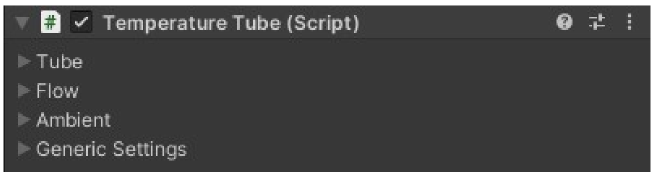

Figure 4.1 — Simulator initial data groups in inspector

4.1 Tube parameters

Tube parameters are the material, from which it is made, and its geometrical parameters. The material is selected in the drop–down list. Geometrical parameters – length, inner and outer radius. Wall thickness is defined as the difference between the outer and inner radiuses.

The geometric parameters of the tube are determined in meters.

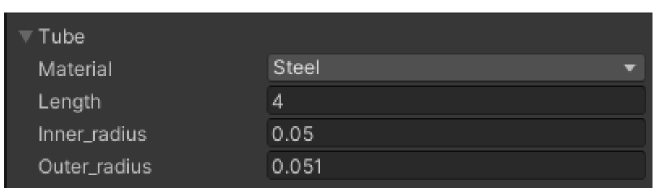

Figure 4.2 — Tube Parameters

The wall thickness of the tube should not be less than one millimeter. In the event, that the radiuses are determined so, that the wall thickness of the tube is less than one millimeter, an error warning appears. In this case, it is necessary to correct the radiuses so, that their difference is greater than 0.001 meters, i.e. one millimeter.

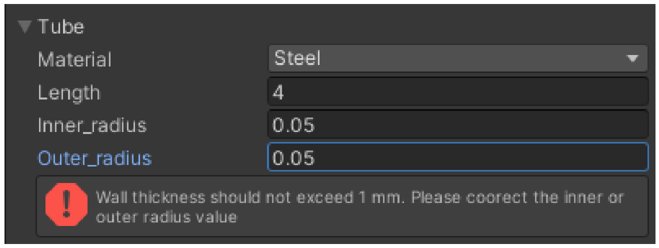

Figure 4.3 — Error, when the wall thickness is less than one millimeter

4.2 Flow parameters

Flow parameters are the substance, that flows in the tube and the dependencies of changes its flow rate and temperature at the inlet to the tube. The substance is also selected from the drop– down list. Dependencies of flow rate and temperature are represented by triplets of values. In the inspector, the values are shown as in the expression $f(\tau)=a+b\times\sin(c\times\tau)$.

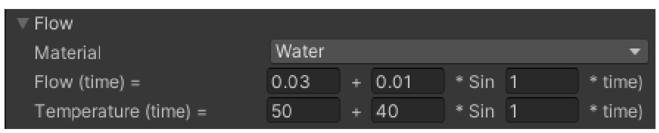

Figure 4.4 — Flow parameters

The flow rate is measured in cubic meters per second.

It can vary from 0, when the coefficients a_1 and b_1 are equal, and up to the maximum value, determined by the sum of the coefficients a_1 and b_1. Changing the direction of the flow in the tube is not provided, so by the determining the flow variation at current time, a_1 must always be greater than or equal to and b_1.

The maximum value of the flow rate should be such, that its velocity in the pipe does not exceed 6 meters per second. In the case, that the flow rate is determined so, that the speed of the substance exceeds 6 meters per second, an error message appears. It appears in two places – where the dependence for the flow rate is determined and where the inner radius of the tube is determined.

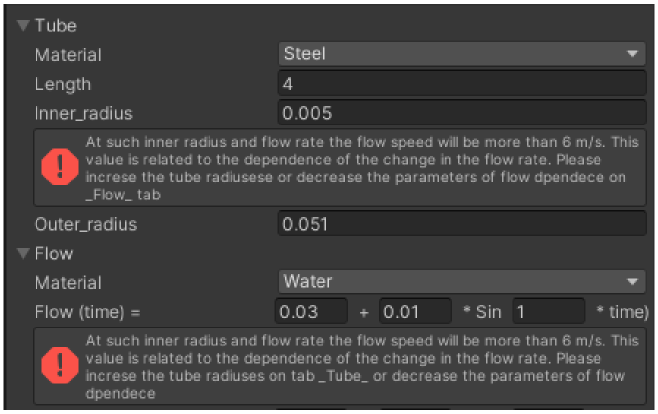

Figure 4.5 — Errors, when flow speed exceeds 6 meters per second

The error can be corrected by increasing the radiuses of the tube or decreasing the flow rate of the substance through it. By reducing coefficients a_1 and b_1, we reduce the flow rate.

Since water freezes at 0 degrees and can no longer flow, when setting the dependence of the change its temperature, the coefficient a_2, as well as for the flow, must be greater than or equal to b_2. This case was considered in the process of entering the initial data for simulation, and if the temperature of the substance goes beyond the boundaries in which it retains a liquid state, an error message appears. The maximum temperature value is determined as the sum of a_2 and b_2, and the minimum as their difference.

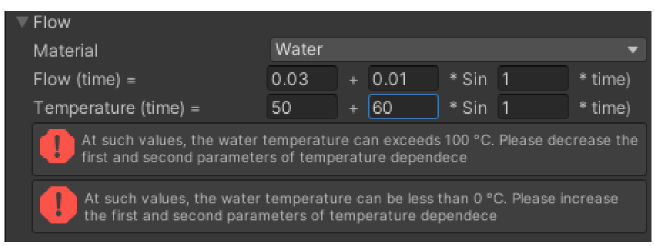

Figure 4.6 — Errors, when temperature is outside the bounds 0 – 100 °C

4.3 Ambient parameters

Ambient temperature is set in the same way as flow rate and substance temperature. Here, there is no restriction on the temperature, and it can be negative. So, the requirement that the coefficient *a3* must be greater than or equal to *b3* is excluded here.

Figure 4.7 — Ambient parameters

4.4 Simulation parameters

Simulation parameters are gradient that visualizes the calculated non stationary temperature field, and the time period after which simulation starts on scene. Under the gradient are shown the minimum and maximum temperature values that corresponed as the maximum possible temperature of the substance at the inlet to the tube.

Figure 2.8 — Simulation parameters

5 Input data example

The figure below shows the settings for a steel tube 4 meter long with an inner radius of 5 centimeters and an outer radius of 6 centimeters. The inner diameter is 10 centimeters and the outer diameter is 12 centimeters, and the tube wall thickness is 1 centimeter.

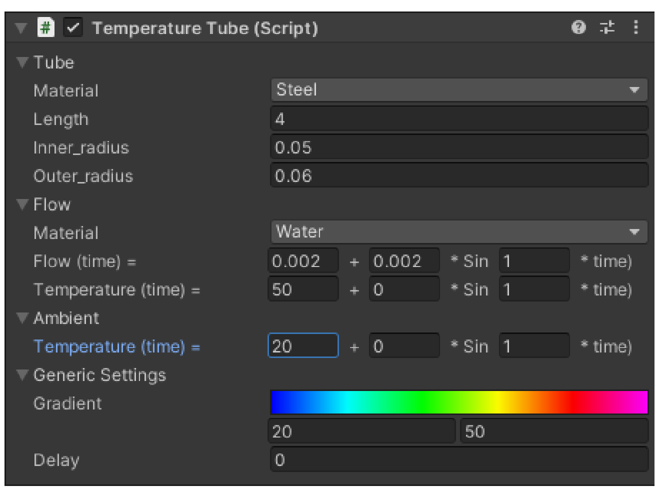

Figure 2.9 — Input data example

A stream of water flows through the tube with an almost constant temperature of 50 degrees and a flow rate that varies in time within the range of 0 to 0.002 cubic meters per second. The ambient temperature is constant at 20 degrees. The temperature field is represented by a gradient ranging from blue to red. The blue color corresponds to the minimum temperature that is reached at the pipe surface. In this case, it is the ambient temperature. The red color corresponds to the maximum temperature. In this case, it is 50 degrees.

6 Camera

A small and simple script for controlling the camera has been added to the package. It is not part of the simulator and was only used during the development process. The main camera movements are listed below:

1 Up arrow on keyboard – move forward

2 Down arrow on keyboard – move back

3 Move the mouse with the left button pressed – rotation

4 Moving the mouse with the wheel pressed – moving along the X axis (parallel to the plane of the screen).