Coursework Requirement 1: Sawdust Tank Process

Industrial Automation (IA3112)

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1 Introduction

The purpose of this coursework is to write a script using a high-level programming language such as Python to simulate the behavior of a tank as it is gradually filled with sawdust and reaches its maximum capacity.

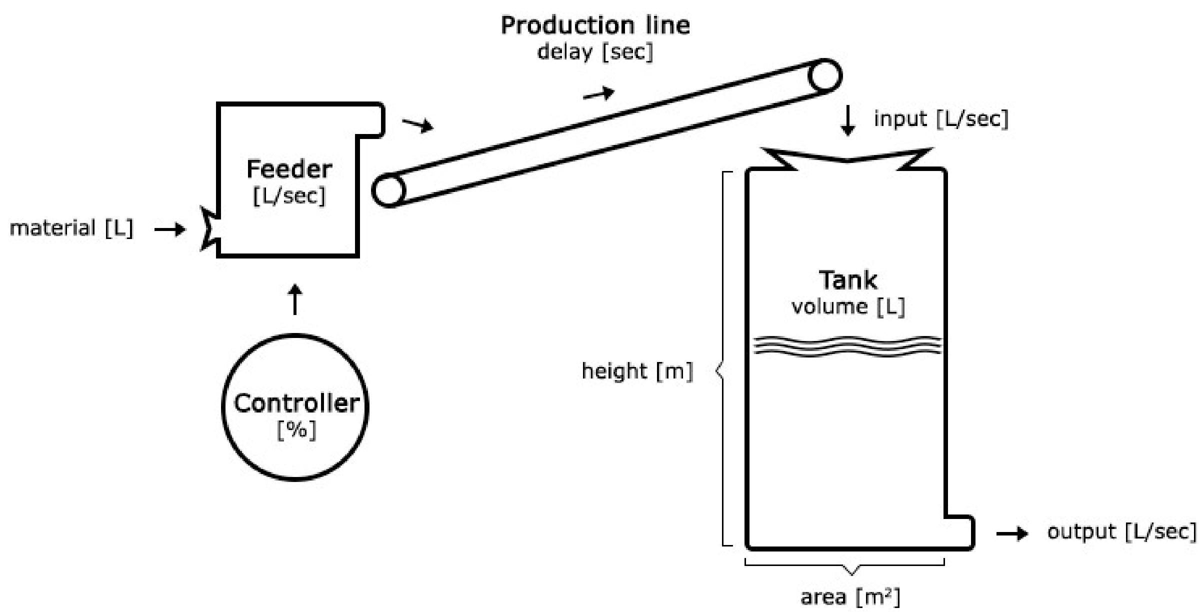

Figure 1-1: A minimalistic diagram of the Sawdust Simulator.

The script will be tasked with simulating the content of the tank as it is gradually filled over the course of a preconfigured time, with a delay, and a set of constant values that will control the flow of sawdust that goes into the tank and as sawdust is simultaneously withdrawn from the tank. This general behavior is illustrated in Figure 1-1 above.

The script must be written in Python so that it may be readable by any potential participants and supervisors of the coursework, and the script must use a set of constant values that have been used in a previous design by Finn Haugen, PhD. Constants are found in table 2.2-1.

2 SimTank.py

The SimTank.py script consist of class objects, constants, and a mathematical model.

2.1 Class Objects

The script takes advantage of a class object to describe the tank. This class object is simply named Tank, and can be found with the rest of the simulator in SimTank.py. It is instantiated with height, area, output, and current volume filled as parameters.

2.2 Constants

2.2.1 Simulator

The simulator is set to run once every 0.1 second over the course of 4000 seconds.

Table 2.2.1-1: The simulator constants used in this simulator.

Constants	Value
DeltaTime	0.1 [sec]
Start	0 [sec]
End	500 [sec]

2.2.2 Mathematical

The mathematical constants are given with the coursework, and are originally written with kg/min units. These units are rewritten as kg/sec, since that is the unit of time that the script operates in. The original percentage value between 0-100 is also reduced to 0-1. A full list of constants can be read in the table below.

Table 2.2.2-1: Mathematical constants and their modified equivalent.

Constants	Original value	Modified value
Feed max rate	(1500 [kg/min] / 45) * 100	25 [kg/sec] / 0.45
Feed delay	250 [sec]	
Feed density	145 [kg^3]	
Tank height	15 [m]	
Tank area	13.4 [m^2]	
Tank output	1500 [kg/min]	25 [kg/sec]

2.3 Mathematical Model

The mathematical model used to fill the tank is relatively simplistic. If there is no output value from the tank, the input is multiplied by DeltaTime over density, and added to the current content of the tank. If the tank has an output value, then the output value is subtracted from the input value prior to multiplying DeltaTime over density.

```
tank.Fill += ((maxFeedRate * u) - tank.Output) * dt / density
```

Figure 2.3-1: Mathematical model where the tank's input is determined by a max feed rate multiplied by ratio.

The model is however not complete without the delay caused by the production line, a delay predetermined to be 250 [sec].

```
u = 0.45
if isDelayReached and isTankNotFull:
    u = 0.5

tank.Fill += ((maxFeedRate * u) - tank.Output) * dt / density
```

Figure 2.3-2: Complete mathematical model.

3 Result

The result is a straight line from (250.0, 0.0) to (3747.5, 15.0), illustrating that the tank gets filled after a 250 second delay until it reaches the tank's maximum capacity at 201 liters (15 meters).

```
Fill (  0 s):   134.0000 / 201.0 [L]
Fill (250 s):   134.0000 / 201.0 [L]
Fill (251 s):   134.0192 / 201.0 [L]
Fill (500 s):   201.0019 / 201.0 [L]
```

Figure 3-1: Output values.

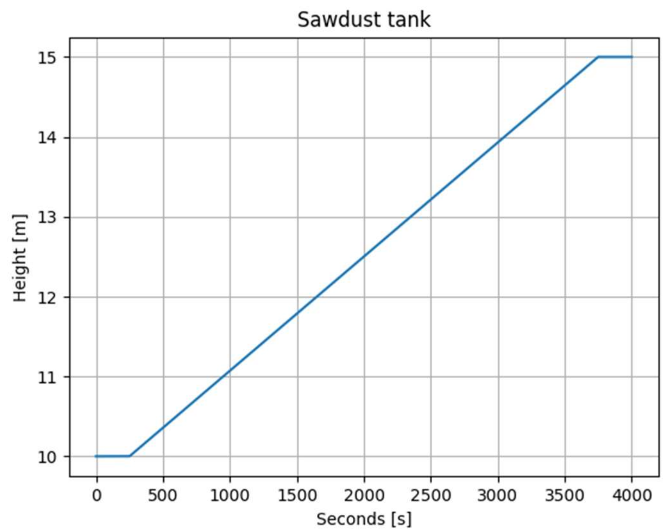

Figure 3-2: Graph illustrating the mathematical model being simulated.

The tank's content is printed in Figure 3-1, showing that there is an increase in 0.0192 [L] after one second. Since DeltaTime is 0.1, we can go ahead and multiply that in to get the slope. Another route is to take the integral of 27.77 [L/sec] - 25 [L/sec], and multiply it by DeltaTime over rho. The result will again be around 0.00192 [L].

$$\int_0^1 \frac{\left(0.50\left(\frac{25\ L/sec}{0.45}\right) - 0.45\left(\frac{25\ L/sec}{0.45}\right)\right)0.1}{145} = 0.00192\ L$$

Figure 3-3: The theoretical value of the slope.