MBD

REPORT ON TANK PLANT MODEL IMPLEMENTATION

Stephen Power (20093364)

Model-Based Development

Tank Plant Model Implementation Report

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Project Title:	Tank Plant Model
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Start Date:	October 14, 2022

Description:	This document reports the implementation of the Tank Plant Model. The objective is to model a tank filling process and develop a control system to maintain the level of liquid in the tank. A plant model of the tank is developed in Simulink.

Contents

1. Introduction

1.1 Objectives

This document reports the implementation of the Tank Plant Model. A tank filling process is to be modelled and a control system developed to maintain the level of liquid in the tank. A liquid flows into the tank at a rate of Q_{in} litres/second. At the same time liquid flows out of the tank at the rate of Q_{out} litres/second. The liquid flows out of the tank through a valve that has a flow resistance of R. Increasing the resistance to flow R closes the valve, whereas decreasing the resistance R opens the valve. The height of liquid h in the tank at any time is proportional to the difference between Q_{in} and Q_{out} and the cross-sectional area A of the tank (A = πd metres^2). The plant model of the tank is to be developed in Simulink. The control variable of the model is the flow rate Q_{in} and the measured process variable is the liquid height h. The equation to be modelled is: $\frac{d}{dt}\ h(t) = \left(\frac{1}{A}\right) Qin(t) - (\frac{1}{RA})h(t).$

1.2 Acronyms

Qin:	input flow rate
Qout:	output flow rate
R:	resistance to flow of output valve
A:	cross-sectional area of the tank
t:	time period
h:	height of the liquid

2. Setup Procedure

Before setting up the model in Simulink, the inputs and outputs were clearly identified. The inputs used in the model were: Qin, R, and A. The single output of the model was: h. A subsystem block in Simulink was used to structure the inputs and outputs. The equation was modelled inside the subsystem block using mathematical operation blocks. Using the dashboard library in Simulink, sliders were selected to change the input values: Qin and R. The input value A was set using a constant block. The display tool from the dashboard library was chosen to display the value of the output h. A scope block was also used to display the output h, as a graph. Once the model was set up, verification and validation tests could be carried out in order to ensure that the model met the requirements of the specification and that it produced expected results.

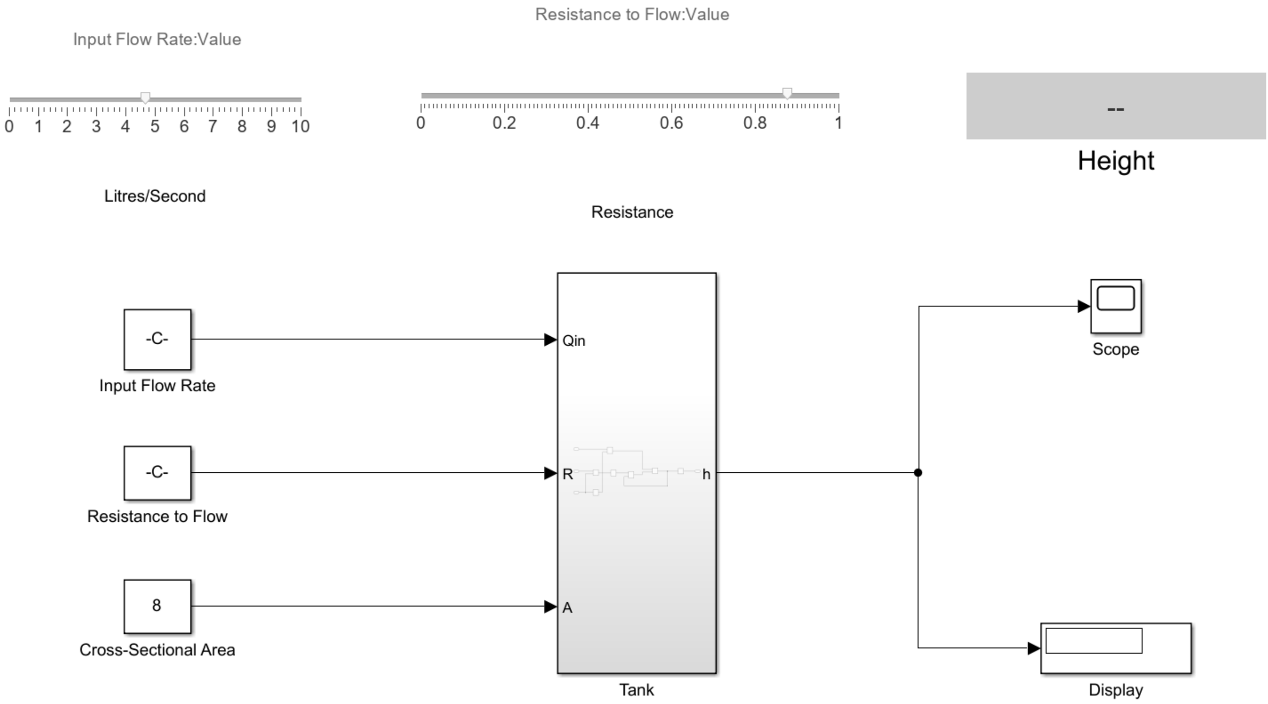


Figure 1: Tank Plant Model

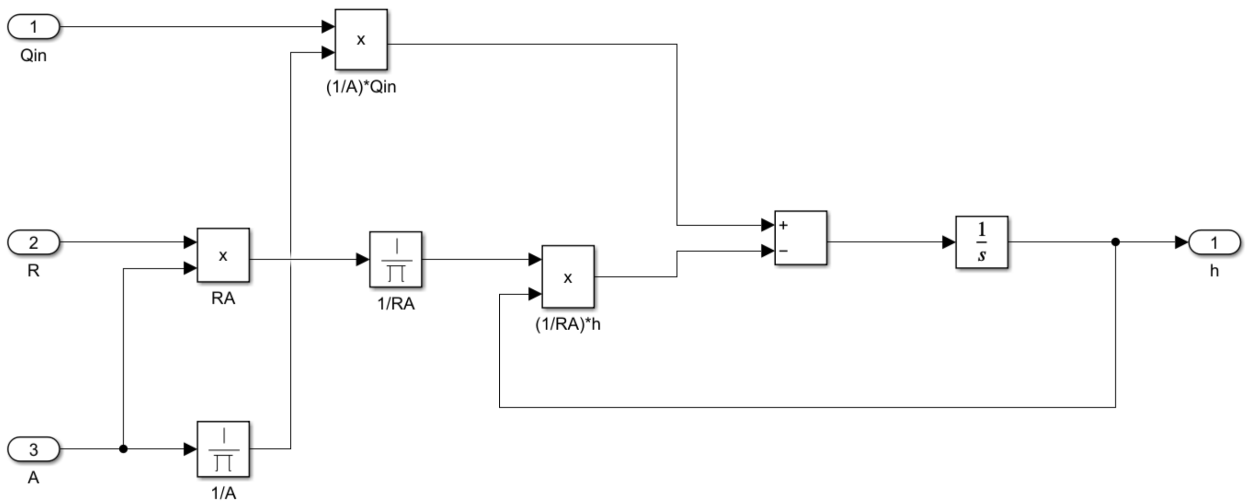
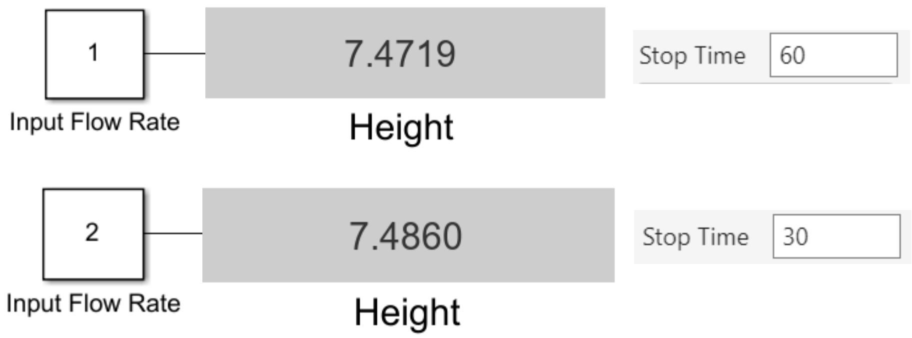


Figure 2: Tank Subsystem

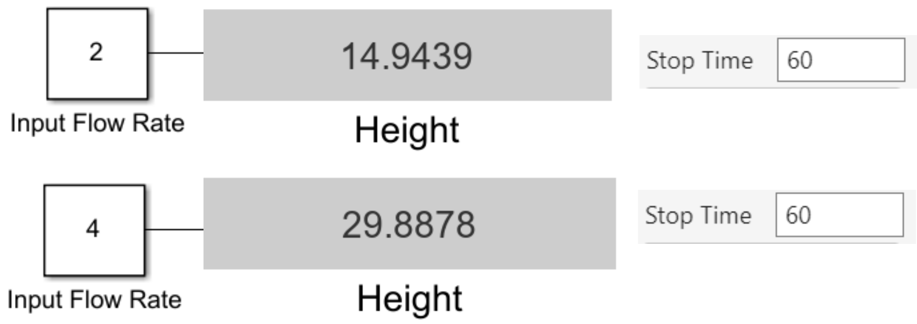
3. Testing Procedure

3.1 Verification

To verify that the height of the tank correlated with the flow rate, a simple test was carried out where the R value was set to 1000 (valve closed) and the CSA was set to 8 metres squared. Over a period of 60 seconds at a flow rate of 1 litre/second, the height of the liquid in the tank resulted in 7.4719 metres. The model was run again over a period of 30 seconds at a flow rate of 2 litres/second. As the time was halved and the flow rate was doubled, the same height as the first run is expected in the second run. The second run of the model produces a liquid height of 7.4860 metres which is roughly what was expected.



A similar test was carried out where both runs of the model were over a time period of 60 seconds, the CSA set to 8 metres squared and the R value was set to 1000. In the first run, the flow rate was 2 litres/second and it produced a liquid height of 14.94. For the second run, the flow rate was doubled to 4 litres/second meaning the liquid height would also be expected to double. The second run produced a liquid height value of 29.89 which is the result that what was expected.



The mathematical equation: Qin(t) / A = h, can be used to verify the model when the valve is fully closed. From the previous tests, an input flow rate of 1 litre/second over a period of 60 seconds with a CSA of 8 metres squares returned a height of 7.4719 metres. When these values were inputted into the equation: 1(60) / 8 = 15 metres. Both the model and the mathematical equation resulted in the output value of roughly 15 metres which is what was expected. Another test case had Qin set to 4 litres/second over a time period of 60 seconds with a CSA of 8 metres squared which returned a height value of 29.89 metres. The equation: 4(60) / 8 = 30 metres. The model and mathematical equation both returned the similar values of 30 metres.

3.2 Validation

Test 1: In the scenario where R was set to 0.001 (valve fully open) and the CSA was 8 metres squared, the tank needed to be filled to a height of 0.1 metres. A validation test was taken to find the flow rate that would meet those needs. Through running the model with different flow rates, it was found that a flow rate of 100 litres/second would fill the tank to 0.1 metres in height within the constraints issued. The height of 0.1 metres remains constant throughout any time period as the Q_{in} and Q_{out} rates are balanced.

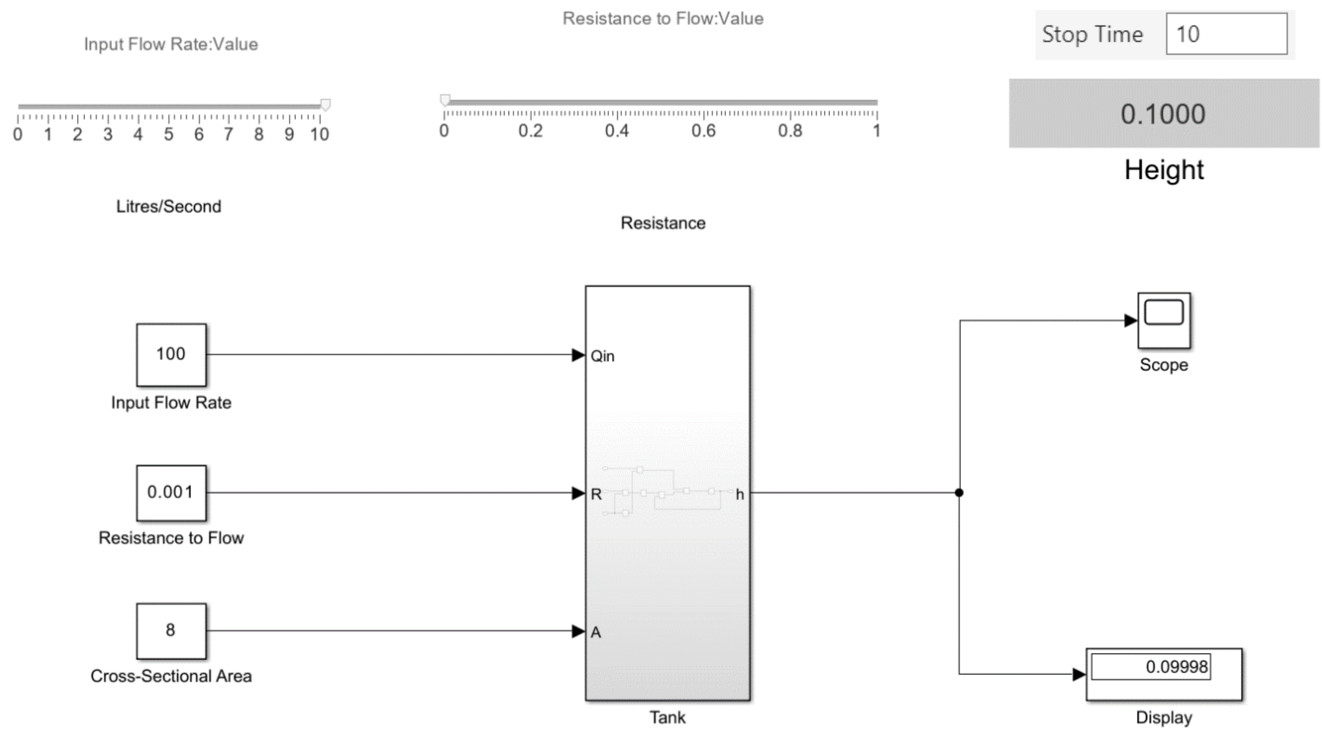


Figure 3: Test 1 - Display

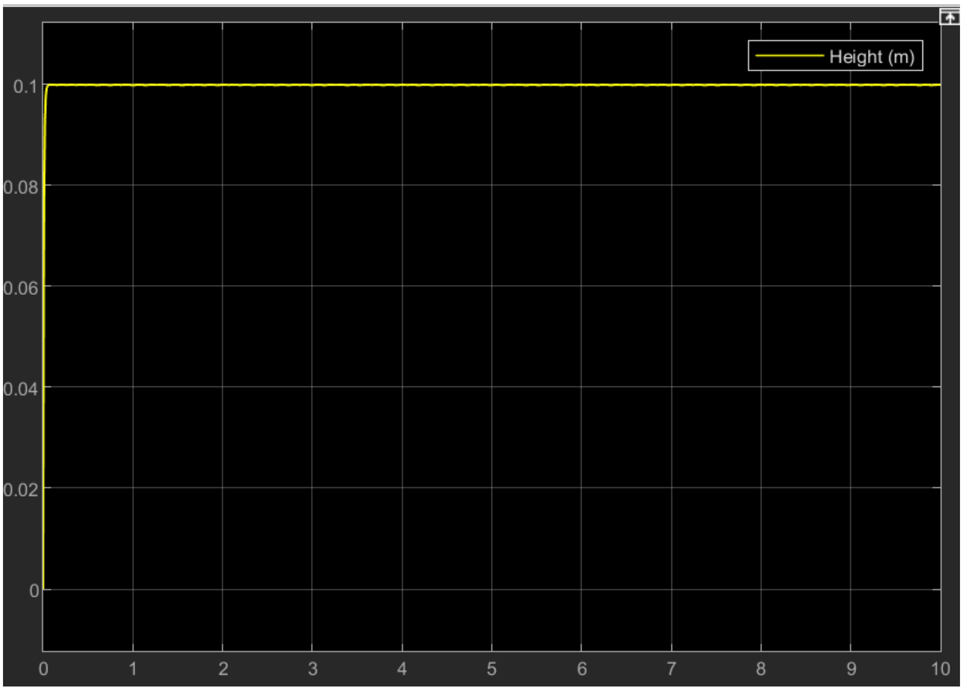


Figure 4: Test 1 - Graph

Test 2: In the event where the input flow rate is set to 5 litres/second and the height of the liquid needed to be 2.5 metres after 20 seconds, a validation test was taken to determine the required R value. Through altering the R value during multiple runs of the model it was found that when R was set to 0.5, the height of liquid resulted in roughly 2.5 metres after 20 seconds.

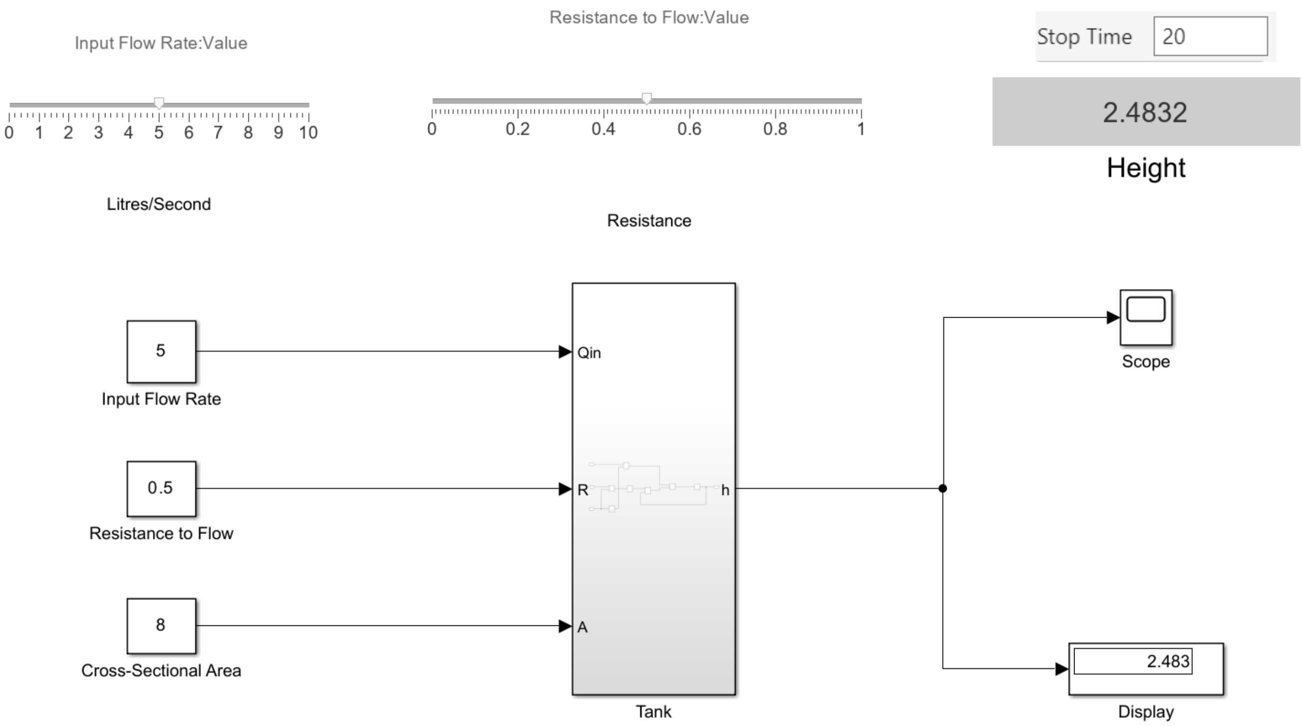


Figure 5: Test 2 - Display

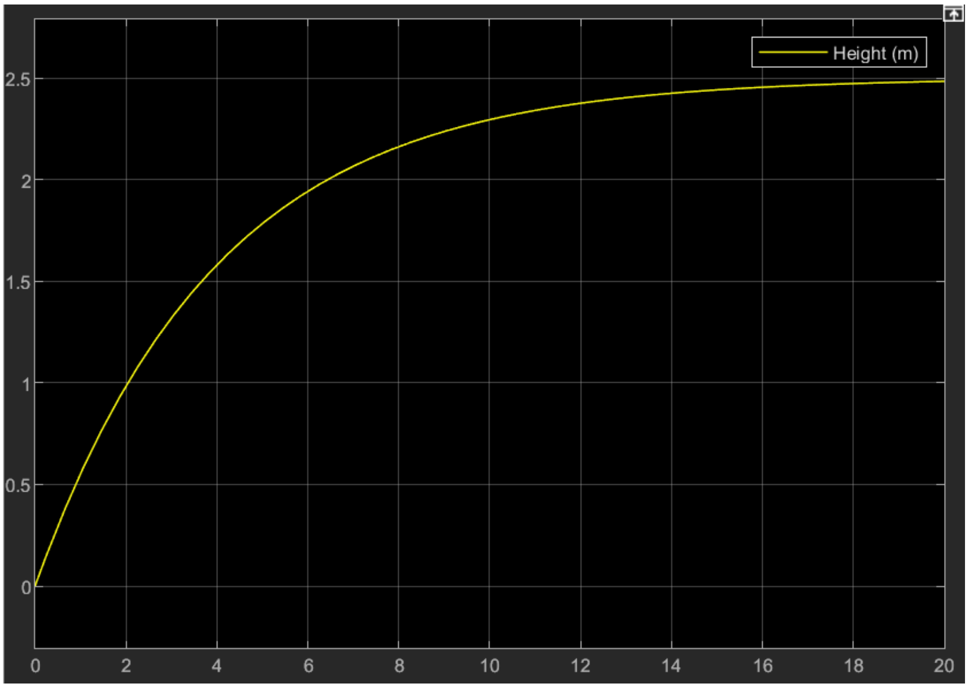


Figure 6: Test 2 - Graph

Test 3: A tank with a CSA of 5 metres squared with an R value of 10 requires filling to a liquid height of 30 metres. Through the use of a validation test, an input flow rate value is to be found to fill the tank to a liquid height of the desired 30 metres over a time period of 20 seconds. The test found that an input flow rate of 9.1 litres/second satisfied the need of an output value of 30.

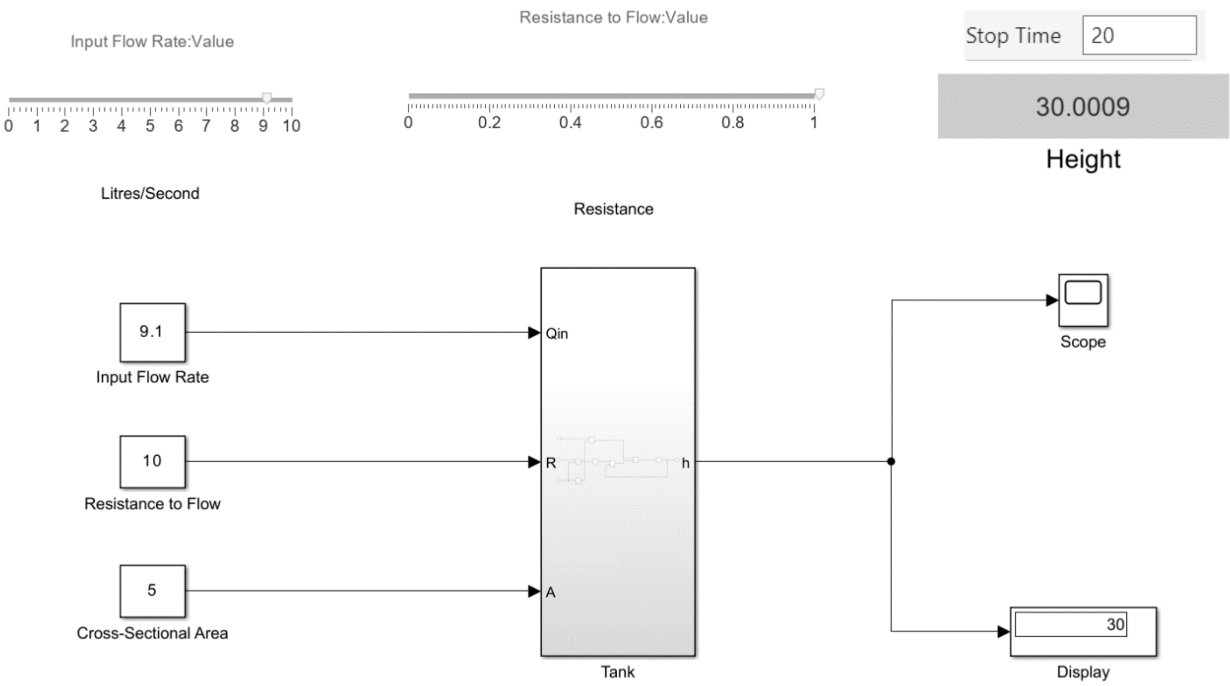


Figure 7: Test 3 - Display

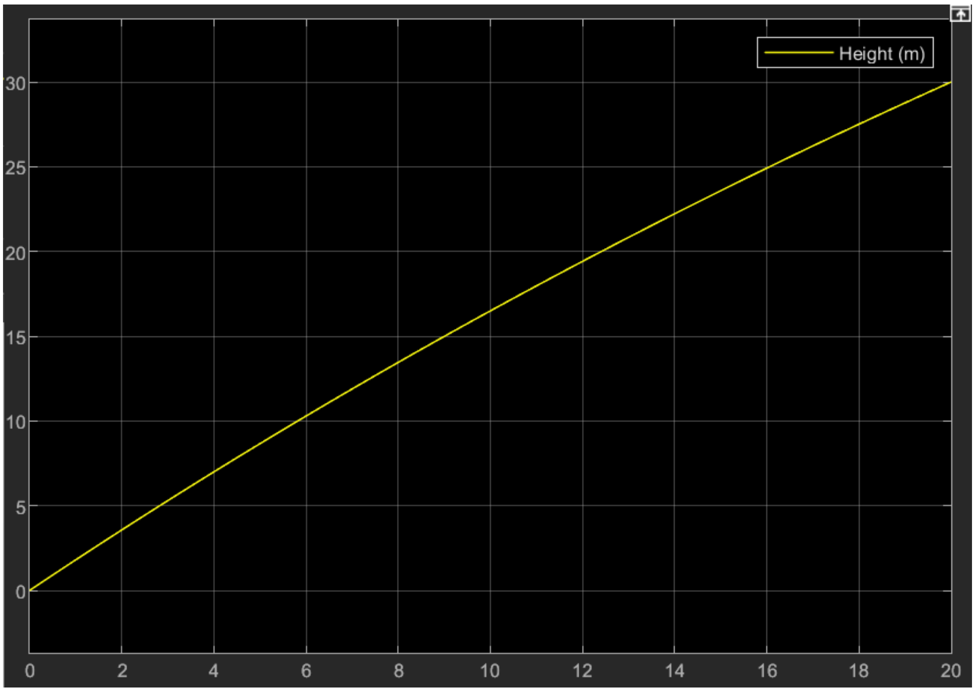


Figure 8: Test 3 - Graph

4. Conclusion

The objective of successfully setting up a Tank Plant Model was completed. The tank filling process was modelled using Simulink which allowed for control over the level of liquid in the tank. Once the model was set up, verification and validation tests were successfully undertaken on the model where the results were as expected. The verification tests showed that the model was built right and didn't contain any unexpected bugs. The validation tests put the model through possible situations where a user controlled the height of liquid using different input values.

It can be seen throughout the test cases that the liquid height is only linear if R is set to a very high value. When R is set to a high value this means that the valve is closed meaning liquid is only flowing into the tank and not flowing out which results in a linear graph as height increases as well as time. When the valve is open, the height of liquid will initially increase, but over time as the input and output flow rates balance out then the height will level off.

Using Simulink to set up the model was very straightforward. Simulink offers many libraries which were very useful in setting up the model such as the mathematical operation blocks which were used in modelling the core equation of the tank process. The dashboard library was convenient as sliders could be chosen for a more user friendly way of setting input values. The outputs could be displayed using a digital display which simply displayed the output value and also using a scope block which displayed the output through a graph.