Problem of filling and transporting a tank with fluids inside

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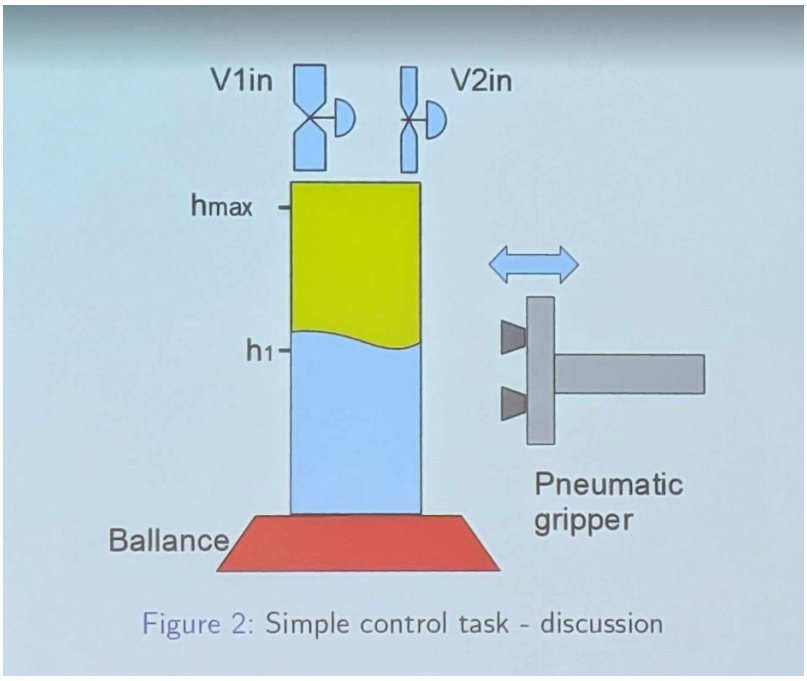
Introduction

The purpose of the exercise is to present the problems that occur while filling a tank with 2 different liquids and transporting this tank to a specific location. A diagram of the process can be seen below (Img.1).



Img.1 Diagram of the process

Two valves control the flow of liquids. It can be noted that pipes that provide fluids have different diameters. There are two sensors that measure the level of liquids after mixing. Then robotic arm must transport the tank from point A to point B.

Valves

In this process different types of valves can be used, such as: electrical pneumatic or mechanical. Each of these types has advantages and disadvantages (Table 1).

Table 1 Comparison of valves

Type	Pros	Cons	Is it suitable for the process?
Solenoid valve	Fast switching, easy control	May require a filter, operates in ON/OFF mode	Yes, if a simple control system is sufficient
Proportional	Allows precise flow regulation	Requires a more complex controller	Yes, if precise liquid flow is needed
Electric ball	Durable, resistant to contamination	Slower switching than solenoid	Yes, if high switching speed is not required
Pneumatic	Very fast operation, good for large flows	Requires compressed air supply	Yes, if a pneumatic system is available

Also, in this process there is a need for control of flow of liquid in both pipes so mixing would be accurate. For this reason, flow sensors could be used. Depending on the type of fluid contact or contactless sensor can be applied. For example, if liquid in pipe is conductive, electromagnetic sensor is a perfect fit.

There are a lot of problems that can occur while fluid flows within valves. One of them is that liquids are not mixed evenly which is caused by different speeds of flow for both valves. There are some solutions for this problem such as: appropriate steering of the process using flow sensors and sequential opening and closing valves. Another thing is that pipes can have poor ventilation so the air will affect the process. Air vents or air babble sensors can be applied for this problem.

Fluid level sensors

For this task a variety of different sensors could be used including contact (Table 2) and non-contact (Table 3).

Table 2 Contact level sensors

Sensor	Working principle	Advantage	Disadvantage	Suitable for the system?
Float Sensor	A mechanical float changes position depending on the liquid level	Simple, inexpensive, reliable	Sensitive to contamination and foam	Yes, if the liquid is not viscous and the tank is stable
Reed Switch (Magnetic)	A magnet in the float activates a reed switch	No electronic components in liquid, pressure-resistant	May jam with viscous liquids	Yes, if the tank is closed
Electrode (Conductive)	Works by detecting the electrical conductivity of the liquid	Cheap, effective for conductive liquids	Does not work for non-conductive liquids, requires calibration	Yes, if the liquids are conductive
Hydrostatic	Measures the pressure exerted by the liquid column	Works with foamy and viscous liquids	Requires immersion in liquid	Yes, if the sensor can be installed at the bottom

Table 3 Non-contact level sensors

Sensor	Working principle	Advantage	Disadvantage	Suitable for the system?
Capacitive	Detects changes in electrical capacitance near the liquid surface	Non-contact, works with conductive and non-conductive liquids	May require calibration, affected by tank wall thickness	Yes, if the tank is plastic or non-conductive
Ultrasonic	Emits sound waves and measures the reflection time from the liquid surface	Non-contact, high precision	Can have issues with foamy or turbulent liquids	Yes, if the liquid surface is stable (low foam, minimal vibrations)
Radar (FMCW)	Emits microwaves and measures reflection time	Highly accurate, works in harsh conditions	Expensive solution	Yes, if high precision is required
Optical (Infrared/LiDAR)	Detects the liquid level based on light reflection	Precise, works with various liquids	Can be affected by contamination	Yes, if the liquid is transparent and does not create deposits

These sensors should have an impact on valves so liquid won't overflow or there would not be enough fluid in the tank.

Robotic arm

There are several challenges in steering the robotic arm such as: incorrect tank handle, swaying and tilting of the tank, effect of liquid mass on the dynamics of motion and lack of control over grip strength. So to ensure tank transportation is safe and stable robotic arm should be equipped with sensors controlling handle, grip strength and stability.

To avoid spills, the movement of the robotic arm must be smooth and controlled. There are some options for that:

- Use of S-shaped trajectory - instead of sudden accelerations and stops, the arm should make smooth movements with controlled acceleration and deceleration.
- Monitoring tank tilt (IMU + PID Controller) - if the IMU detects too much tilt angle, the robot will automatically correct the movement.
- Reducing the ripple effect of the liquid (sloshing mitigation) - using slower accelerations and stops before the target point allows the liquid to stabilize before finally putting down the tank.

Summary

The system is designed to mix two different liquids in a container and then transport it using a robotic arm. The process involves precise control of liquid inflow, level monitoring, and stable movement of the container to prevent spillage.

Key Challenges and Solutions:

1. Controlling Liquid Flow and Mixing:
    - Two electromagnetic or proportional valves (V1in and V2in) regulate liquid inflow.
    - Flow sensors (turbine, electromagnetic, or ultrasonic) monitor the amount of liquid entering the tank.
    - Dynamic flow control using PID algorithms ensures proper mixing proportions and prevents overflow.
2. Monitoring Liquid Levels:
    - Low-level sensor (h1) (float, capacitive, or conductive) triggers liquid inflow.
    - High-level sensor (hmax) (ultrasonic, capacitive, or radar) stops the filling process when the container reaches full capacity.
    - Emergency shut-off mechanisms prevent overfilling.
3. Ensuring Proper Liquid Mixing:
    - Flow regulation and angled inflow create natural turbulence to enhance mixing.
    - Static mixers in the pipes ensure uniform blending before liquid enters the tank.

- Mechanical agitators (optional) improve mixing if liquids have different viscosities.

4. Safe Transportation of the Container:
    - A robotic arm with a pneumatic gripper moves the container from point A to B.
    - Force sensors (strain gauges) adjust gripping pressure to prevent slipping or damage.
    - IMU sensors detect tilting and help maintain stability during transport.
    - Smooth, S-shaped motion trajectory reduces acceleration shocks and minimizes liquid sloshing.