

Technical Process Description: Coating Line Simulation

1 About

Detailed description of the coating line simulation process, including data structure, manipulator movement, line setup, and speed constraints. The goal is to accurately simulate the takt time of the line and test different manipulator strategies and recipe sequences.

2 Takt Definition

Takt is the final algorithmic cycle that will be programmed into all manipulators. It defines the full set of synchronized movements and timings that each manipulator follows to process rams through the coating line. The takt ensures coordination and efficiency across the entire system and is the primary unit for measuring throughput and process synchronization.

3 Data Description

The simulation relies on three main data sources: the layout of the line (**linka**), the technological process recipes (**recept**), and the manipulator movement characteristics.

3.1 Linka (Bath Layout)

- **typ_vany** – Name/type of bath (e.g., "Oplach I").
- **id_vany** – Unique numeric ID of each bath.
- **pozice_x_rel** – Distance in mm from the previous bath.
- **pozice_x_cum** – Cumulative X position in mm from vstop.

These define the physical layout of the coating line. Even baths not used in a recipe remain in place; manipulators pass over them without interacting unless required.

3.2 Recept (Technology Process Recipes)

Each recipe represents a specific technology and defines the sequence of baths a ram must pass through, with timing constraints.

- **tech** – Identifier of the technology (e.g., tech1, tech2).
- **id_vany** – Bath ID where this operation is performed.
- **poradi_operace** – The step number of this operation in the recipe.
- **cas_min** – Minimum allowable time in bath (s).
- **cas_opt** – Optimal target time (s).
- **cas_max** – Maximum allowable time (s).
- **okap** – Whether drip-off is required after this bath (1=yes).
- **okap_cas** – Time in seconds to wait during drip-off.

3.3 Manipulator Characteristics

Manipulators are robotic gantries that move along the line, performing vertical and horizontal motion with the following characteristics:

- **Range** – Each manipulator can cover a defined number of baths.
- **No simultaneous axes** – Movement is only in one axis at a time (either X or Z).
- **Idle behavior** – If not immediately needed, manipulators move to a neutral waiting position.
- **Acceleration/Deceleration** – Horizontal movements include a 3-second slowdown ramp.
- **Collision avoidance** – No two manipulators may enter the same bath simultaneously.
- **Okap positioning** – If required, the manipulator stops at 2000 mm height for okap.
- **Lifting/Lowering range** – Full vertical path is 2750 mm.
- **Speed (horizontal)** – 35 m/min.
- **Speed (lift)** – 15 m/min.
- **Speed (descent)** – 12 m/min before final slowdown.
- **Speed (final 500 mm)** – 8 m/min for precision placement.

4 Main Processes and Logic

4.1 Vstup (Entry)

- Always contains a ram ready to be picked up.
- The closest idle manipulator is assigned to move it into the first bath.
- The manipulator performs:
 1. Horizontal movement to position 0.
 2. Controlled descent to place the ram.
 3. Returns to idle.

4.2 Bath Movement

- A manipulator lifts the ram from its current bath when its bath time reaches at least `cas_min`.
- It waits if the next bath is occupied.
- If `okap` is required, it stops at 2000 mm and waits for `okap_cas` seconds.
- After `okap` or direct lift, the manipulator moves to the next bath and lowers the ram.

4.3 Vystup (Exit)

- A manipulator collects the ram from its last bath.
- Performs drip-off at 2000 mm if required.
- Moves to position 100 (exit).
- Releases the ram.

4.4 Queue and Scheduling

- All tasks are placed in a dynamic task queue.
- Each task includes timestamp, origin, destination, ram ID, and operation type.
- Manipulators pull from the queue in priority order.
- Manipulators do not have to wait at a bath; they can service other rams while another finishes.
- Movement priority and collision avoidance must be managed.
- **Queue is checked:**
 - Immediately after completing a movement.
 - After finishing a lift or drop.
 - When reaching idle state.
 - When a bath signals readiness (e.g., time $t = \text{cas_min}$).

4.5 Movement Types

- **Vertical descent** – with two phases: fast, then slow for final 500 mm.
- **Vertical lift** – constant at 15 m/min.
- **Drip-off (Okap)** – stop at 2000 mm for a defined time.
- **Horizontal transfer** – constant at 35 m/min.