Rotary feeding system for metallic coating installation by electrodeposition

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Abstract. The paper aims to present an alternative feeding system for metallic coatings lines by electrodeposition which lends itself to the circular arrangement of the cuvettes used in such plants. The novelty lies both, in the arrangement of the electrodeposition installation components and mechanical feeding and transport system for parts to be electrodeposited. The control and actuation system of this type of installation simplifies. Nevertheless, all these increase the system reliability and run lower maintenance costs, without adversely affecting the quality of the end product. The paper presents the justification for reducing the total energy consumption in the electrodeposition process, too.

1. Introduction
Currently, worldwide, the mechanical parts transmission is linear. It is achieved with a crane in the case of cyclic processes, or with a conveyor in the case of continuous processes. In both cases cuvettes with solutions are arranged sequentially linear. This arrangement involves relatively large workspaces and mechanical transport systems of considerable size. Both metallic materials consumption and maintenance of such systems are a disadvantage [1,2].

2. The proposed system
The proposed mechanical feeding system differs from the conventional systems. The location of the electrolytic cuvettes is, in this case, radial. Mechanical system is located in the centre of the circle in which the electrolytic cells are arranged [3]. This transport system performs a vertical translation movement (descent - lift) and a horizontally rotating movement with a sequence of a specific angular pitch. The system is suitable for large series production and relatively small size parts[4].
2. Principle of operation

- The operation principle (analysis by total process time) is:

The parts to be electrodeposited are fixed on a support. This support is attached by sliding on one of the arms of the rotary system in position A (Fig. 2a) corresponding to the first cuvette from the electrodeposition process. The next phase involves descent the rotary system and thus immersing the parts undergo treatment in the solution of the first bath. After the time for keeping the parts in the bath runs out, they are removed by lifting the rotary system. When the system reaches the maximum superior point, it will execute the next phase: the rotation with a corresponding overlap angle over the second tank. Reached this position, the system will descend to the maximum inferior point corresponding to the complete immersion of the parts in the second solution bath.

This process is repeated until the pieces get to the last cuvette. After last solution bath, they are removed when the system is in position B (Fig. 2b), with the sliding support and sent to drying and packaging.

The system has a sequential rotary motion horizontally correlated with a translation movement vertically. During a sequence, we have simultaneously submerged parts in solutions in all stages of electrodeposition (degreasing, stripping, cleaning, electroplating, final wash).

For comparison, we will analyze the cyclograms for the transport processes for the classic system (Figure 3) and the proposed rotating system (Figure 4).

**Figure 2.** Rotary transport system of parts: a. side view; b. top view
1-vertical ax; 2-horizontal rotating arms; 3-fixing device for parts to be electrodeposited; 4-cuvette.

**Figure 3.** Cyclograms for the classic operation system (linear transport):
- \( t_c \) – time descent (parts immersion in solution);
- \( t_u \) – time lift (parts removing from the solution);
- \( t_d \) – motion time of the parts from one cuvette to another;

\([\text{level}]\)
\( t_{s1} \) – stationary time for parts in degreasing solution; \( t_{s2} \) – stationary time for parts in pickling solution; \( t_{s3} \) – stationary time washing parts; \( t_{s4} \) – stationary time parts in electrodeposition cuvette; \( t_{s5} \) – stationary time parts at final washing.

**Figure 4.** The operating cyclogram for the proposed system (rotary):

- \( t_c \) – time descent (parts immersion in solution);
- \( t_u \) – time lift (parts extraction from solution);
- \( t_s \) – stationary time parts in cuvettes;
- \( t_d \) – time parts motion from one cuvette to another.

Analyzing this cyclograms we obtain the total time of the entire process, as the sum of the process’ steps times.

For the classical linear system, with serial phases, we have a total time:

\[
 t_{ts} = n \cdot t_s + n \cdot t_u + (n-1) \cdot t_d + \sum t_{s} + t_r
\]

where:
- \( t_{ts} \) – total time of the linear process;
- \( n \) – number of process phases;
- \( t_s \) – time of keeping the parts in cuvettes;
- \( t_r \) – recovery time of travel mechanism to starting position.

For the proposed rotary system, with implementation phases in parallel, we have a total time:

\[
 t_{tr} = t_c + t_s = t_u + t_d
\]

where:
- \( t_{tr} \) – total time of the rotary process

Obvious:
\( t_{ts} > t_{tr} \)

So eliminating that starting and stopping stage of this ongoing process of electrodeposition, by comparing the results obtained, clearly show the superiority of the proposed method, the rotary feed system.

For the rotary system, parts will stay in the tanks appropriate for each stage, same time. It takes into account the largest time, the one that corresponds to the stage of immersion for electrodeposition.

This means, by default, that increasing the times corresponding to the other steps, lowers proportionally the concentration of the pickling and degreasing solutions. Here one more advantage for the proposed solution.

- The operating principal (mechanical analysis) is:

  The support with arms (position 2, fig.2) on which the parts to be electrodeposited are fixed makes a vertical sliding motion (descents) so that the parts can be immersed into cuvettes solution. The sliding is done with a single motor. After maintaining the necessary time \( (ts) \), the support with arms performs a translation movement vertically (lift). When it reaches the upper limit starts the motor that
does the system rotation where the parts are fixed, with the $\varphi$ angle. The size of this angle depends on the number of necessary vats for this process.

$$\varphi = \frac{360^0}{n}$$  

(3)

When the holder 2 was rotated by an angle $\varphi$, is triggered the motor of the vertical operating, descending parts in the solution. The descent can be achieved with energy recovery, which is another advantage.

This version requires having simultaneously parts in all stages of electrodeposition.

3. Advantages

The proposed version has the following advantages over conventional electrodeposition systems with successive longitudinal arrangement vats.

Transport system for the pieces to be subjected electrodeposition process in longitudinal layout version has a conveyor mechanism that slides on a runway located on both sides of the chain vats. Besides the considerable length of the runway, should be considered power cables and the control of the travel mechanism electric motors, they are also of considerable length. In addition, these cables are subjected to repeated bending requirements. The engines of the parts transport mechanism is moving just above the solution vats, being permanently in a corrosive atmosphere.

For the proposed version with radial arrangement of vats, the transport system disappears, it is replaced with a support with radial arms on which are attached the supports with parts to be subjected to electroplating. The vertical driving motor and the one that drives rotation are fixed and are mounted on a vertical axis. They have short and fixed links. The constructive dimensions of the mechanical system for components transport, in this case, are minimized.

Because the electrodeposition process is a continuous one and phases are cyclical, the process is suitable for automation. We have here an advantage of the system with radial arrangement of the vats towards the one with longitudinal arrangement [5]. For heating the solutions in the vats, we use in both cases the heating system with individual thermostats. For the movement control system differences occur. In Figure 5 is presented a complex command scheme for the electrodeposition process in the classical version, which has tanks arranged longitudinally. The movement control system involves sensors for each tank separately [6].

In case of the system with the radial arrangement of the vats, from operating analysis (2), the sensors should be installed only for one vat (preferably the one for electrodeposition), because the movement is cyclical with constant angular pitch, with angle $\varphi$. In this case the command scheme will be the scheme in Figure 6. We have two sensors to control the vertical movement (up and down) and a sensor for rotation.
Figure 5. Complex command scheme for the electrodeposition process (classic):
PLC – programmable logic controller; PC – computer; S – movement sensor;
ST – transport system; SC – current source; TS – turbo blower [7].

Figure 6. Complex control scheme for the electrodeposition process (rotary):
PC – computer; PLC – programmable logic controller; SC – current source;
Sx – position sensors (SR – rotation sensor, SS – upper position sensor,
SL – lower position sensor); ST – transport system.
So for the proposed version, the command and movement control system is greatly simplified compared to the classical version. Both sensors and electrical connections are in fixed mounting.

4. Conclusions
The radial arrangement of the vats requires less space than the longitudinal arrangement (linear). The mechanical system that serves the installation for metal electrodeposition is smaller than for the linear systems, meaning the total area of the site and its metal construction. The rotary system with arms replaces the transporting mechanism of the parts and the thereof runway system.

The system involves a single vertical translational mechanism and one sequential revolving mechanism horizontally.
- Short and fixed connections to power the drive motors (hydraulic or electric).
- Short and fixed links for the positioning sensors of the mechanical transport system.
- Increase productivity of metallic coating by electrodeposition line, because we have simultaneously pieces in all phases of the electrodeposition process.
- The use of pickling and degreasing solutions with lower concentration.
- The support with arms can be made of composite materials (carbon fiber-based or glass). This reduces the total load of the vertical drive motor, and thus obtain a saving of energy consumed in the process.

5. References
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