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CONTENTS

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Simulation approach to optimizing final product refining

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Abstract: Industrial enterprises have access to advanced technologies in production processes, as well as in logistics and transport, which have also been modernized. However, certain production processes, including those in polishing centers, still present opportunities for further optimization. With the help of current technological innovations, there is potential for improvements in these areas, moving closer to the fully realized Industry 4.0.

1 Introduction

Software simulation is a simplified representation of a real system through its simulation model. This model describes only the characteristics of the real system that are relevant for its study and simulation. The experimenter then conducts a series of simulation experiments with this model after verifying its logic and accuracy. During these experiments, different possibilities for improving the modeled system are proposed, and their effects on the system are examined. The results of these experiments are then applied back to the real system to improve its properties. It is clear that simulation is not a direct tool for obtaining an optimal solution. Instead, it serves as a supporting tool that allows the experimenter to test the effects of various decisions on the simulation model.

Modelling and simulation are important areas of the digital factory that allow businesses to answer questions about modelled processes. Modelling is the process of creating a simulation model based on available information about the real system. Based on the layout of the real system and its abstraction, we are creating a model on which experiments will be carried out later [1,2].

Simulation is a representation of the real system and its dynamic processes in the model. As has already been said at the outset, the simulation aims to obtain information for the real system, with its subsequent optimisation [3,4].

The advantage of this approach is the ability to predict the future behavior of the system and make necessary adjustments to the real system based on these insights. In digital enterprises, simulation has become a key tool for dynamic analysis of complex systems. The latest research results in the field of optimization are rapidly integrated into simulation software. Simulation is supported by techniques such as optimization, artificial intelligence, expert systems, and virtual reality.

Industrial enterprises today already possess relatively advanced technology in the field of production processes, but this is not limited to just this area. Logistics and transportation processes are also sufficiently modernized. However, there are still gaps in certain production processes that can be further optimized. Thanks to current technological innovations, there is potential for improving the production process and thus bringing it closer to a fully realized Industry 4.0.

In the submitted article, the Siemens Tecnomatix Plant Simulation software will be used to create a simulation of the polishing center. Tecnomatix Plant Simulation is a simulation tool from Siemens that allows simulation and optimisation of production and logistics systems and their processes. Through Tecnomatix Plant Simulation (TPS), it is possible to optimise material flow, resource utilisation and logistics at all levels of planning in the company. Tx Plant simulation as a discrete event controlled program takes points in time (events) into consideration that are of importance to the further course of the simulation. Such events may, for example, be a part entering a station or leaving it or moving on to another machine [5-7].

2 Description of the subject polishing center process

This article focuses on the polishing line, where the current production process, its parameters, and layout are described, followed by an analysis of the main issues affecting the process. The polishing station for ball studs currently operates at a capacity of up to 3,800 pieces per eight-hour shift, with a half-hour break. However, there are several drawbacks that hinder the overall efficiency of the line.

On Figure 1, the process of manufacturing stabilizer rods is schematically depicted.

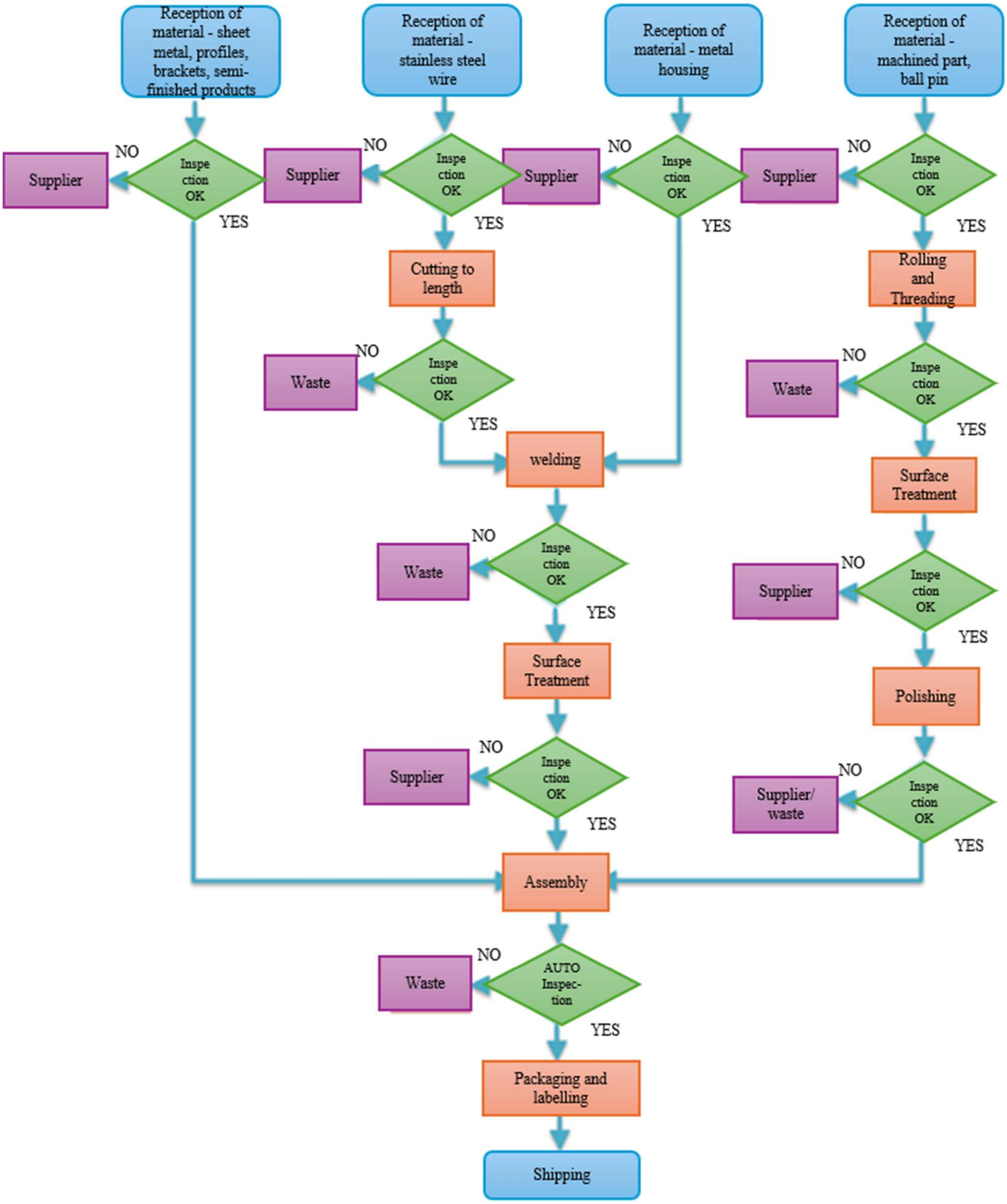

Figure 1 Simplified diagram of the analysed process

The following Table 1 provides an overview of the necessary activities in the complete polishing cycle for 232 ball studs and their corresponding time requirements. The polishing machine itself performs its task for only 1,375 seconds out of a total of 1,683 seconds in one complete cycle, which accounts for 81.7%. The remaining nearly 19%, or approximately 312 seconds, is spent by the worker on tasks such as loading, unloading, and other relatively unnecessary activities. The current cycle time for the polishing machine is between 7.25 and 7.37 seconds. The cycle time for the production worker is approximately 1.55 seconds, which makes up 21.38% of the total cycle time. This percentage is the target for reduction through the proposed automation of the polishing center. For the second and subsequent cycles, the cycle time decreases as the operator can perform certain tasks, such as loading pieces into the "nests," during the polishing process. Considering the entire 7.5-hour shift, 18.4 cycles can be completed, resulting in an average cycle time of 6.31 seconds.

The table provides an overview of the time required for various activities in the polishing process. It includes steps such as loading pieces into crates and "nests," operating the polisher, and handling materials before and after polishing. The polishing process itself takes 1,375 seconds, while the total cycle time per shift is 6.31 hours. The polisher remains inactive for 308–334 seconds during the first cycle and 78 seconds in subsequent cycles. Additionally, the total working time of a person ranges between 292 and 318 seconds.

Table 1 Time schedule of individual activities

Activity designation	Total time [s]
Loading pieces into a KLT crate (according to the reference)	26
Loading 232 pieces into "nests"	230
Loading "nests" and KLT crates into the polisher	17
Activating the cycle on the control panel and on the robots	13
Inserting the movable pallets of the polisher inwards	8
Polishing process (polishing time in active state)	1375
Extending the movable pallets of the polisher outwards	8
Moving KLT crates onto a pallet	29
Removing empty "nests"	3
Current cycle time of polishing pieces	5,7
Total cycle time for one 7.5 h shift	6,31
The time of the polisher in the inactive state during the first cycle	308 – 334
The time of the polisher in the inactive state during the second and subsequent cycles	78
The total time of a person at work	292 – 318

3 Proposal for the optimization of the polishing center

The main goal of this publication is to simulate the verification of the polishing center optimization design using Siemens Tecnomatix Plant Simulation software to address deficiencies in the process and increase its efficiency. The primary deficiencies in the polishing center process are considered to be three problems identified during the active state of the line. These include two manual tasks performed by the production worker: loading 232 unpolished ball pins into designated "nests" and subsequently placing them on the sliding pallet of the polishing center and then removing and placing the polished ball pins into the finished parts area and replacing the empty trays on the movable pallet of the polishing line, a process referred to as palletizing. These tasks also require the manual pressing of a button on the control panel and its subsequent confirmation on the robot control panels. The third problem with the line is the activity of the first pair of robots used for handling the ball pins, i.e., picking them up from the "nest," tilting them with a fixture, passing them to the second pair of robots for the polishing process, and placing the polished ball pins into trays for finished parts.

Based on a thorough analysis and monitoring of the line, it was considered that the first problem described, in particular, appears to be a critical issue that requires optimization or partial automation to potentially increase the line's output. From previous experiences in managing other production lines, it is possible to apply already established methods of supplying individual parts to the polishing line, ensuring standardization within the company in case of various errors and issues. This will save both time and money, while also minimizing unwanted complications. The most common and simplest solution would be the implementation of transport systems in various configurations. These systems will also provide solutions to other problems, such as the unnecessary stoppage of the polishing center approximately every 22 minutes, which is linked to the handling of empty KLT trays or "nests."

The presented article will describe the optimization design for the polishing center by applying a spiral vibratory conveyor, which would also include a reservoir for the ball pins. Based on sufficient vibrations, the movement of the ball pins would occur along the spiral, moving upwards toward the horizontal vibratory guide, as in the previous solution. This described assembly is shown in Figure 2. Since these conveyors are already used in the company for certain processes, the mentioned

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standardization would be achieved while optimizing another line.

Figure 2 Vibratory bowl feeder

4 Description of the proposed polishing center optimization

The design will implement new transport systems for loading the ball pins into the polishing center, including a magnetic 3-axis feeder, a staircase conveyor, and two vibratory rails on both sides. For the output section, two dual-level conveyors with elevators will be used for the overall movement of KLTs, i.e., both input and output. The design also includes the complete removal of the first pair of robots, which were previously required for rotating the ball pins and feeding them to the second pair of robots.

The overall layout representation for this proposal is shown in Figure 3. The required orientation of the ball pins will be ensured by the vibratory rails. The equipment also includes a camera with a sensor to monitor the flow of polishing paste. The optimization includes all necessary documentation and certification.

The function of this setup involves the production worker loading unpolished ball pins into the reservoir for the magnetic 3-axis feeder. This reservoir should be large enough to accommodate the necessary number of parts for the entire shift. The worker must also load empty KLT trays onto the conveyor system for later filling with finished ball pins. After these activities, the worker can activate the polishing cycle. The magnetic feeder will take a certain number of unpolished parts from the reservoir and move them into the hopper for the staircase feeder, from which the parts will be further transported to the robots via vibratory guides. A specific feature of these vibratory guides will be the ability to move the ball pins so that the robot can grasp them by the thread and immediately move them to the polishing station for polishing and subsequent air cleaning.

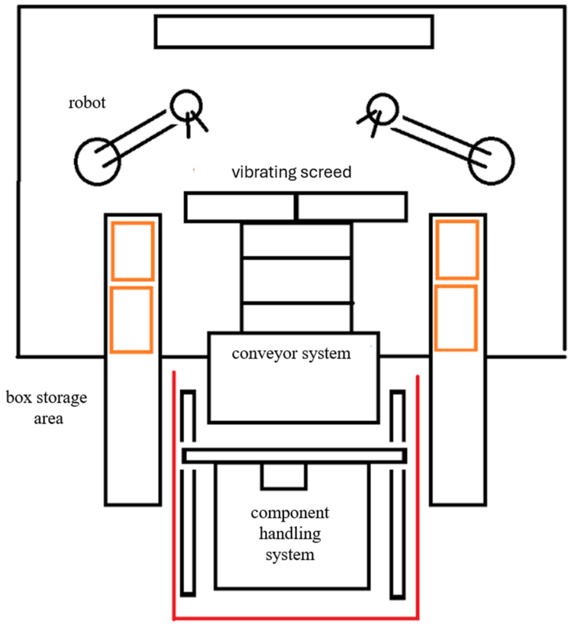

Figure 3 Simplified layout of the polishing center using a vibratory bowl feeder

In the absence of the first pair of “rotating” robots, it is necessary for this rail to deliver the ball pins with the ability to grasp them by the thread. After the polishing and air cleaning process, the robot will drop the finished ball pins into prepared KLT trays. Once a certain number is reached in the KLT tray, approximately 250 parts, the tray will be moved to the palletizing station, and a new, empty tray will be brought in by the elevator. This cycle repeats until the required number for a specific reference is polished.

5 Simulation of the proposed polishing center optimization in software Siemens Tecnomatix Plant Simulation

For the described proposed solution, a digital model of the final state of the line will be created. Since we have the necessary components and the required times and parameters, creating the digital form of this solution will be straightforward.

Initially, a source in the form of a Source will be required, represented by a reservoir with unpolished parts, MU Part, which will be placed under a manipulator designed with the *PickAndPlace* function. The manipulator will move the parts to the Buffer function, and then conveyors will follow, including the staircase conveyor and two linear vibratory conveyors to both sides in the Conveyor function. These parts will then be transported by a pair of robots, using the *PickAndPlace* function, to the polishing and air-blowing station in the form of a

ParallelStation. After these operations, the finished parts will be placed into KLT trays on a dual-level conveyor system. The lower part will contain empty KLTs, while the upper part will hold full trays. The loading and unloading of trays will be handled by the operator at the beginning of the shift, or when all five trays are filled. The conveyors are designed using the Conveyor function, and the KLT trays are represented as MU Container. The KLT trays have a capacity of 250 parts, and only five of these trays can be on the conveyors at any given time. This entire section is shown in Figure 27. For this case, all necessary parameters and speeds, as well as the total shift length (7.5 hours), were also configured.

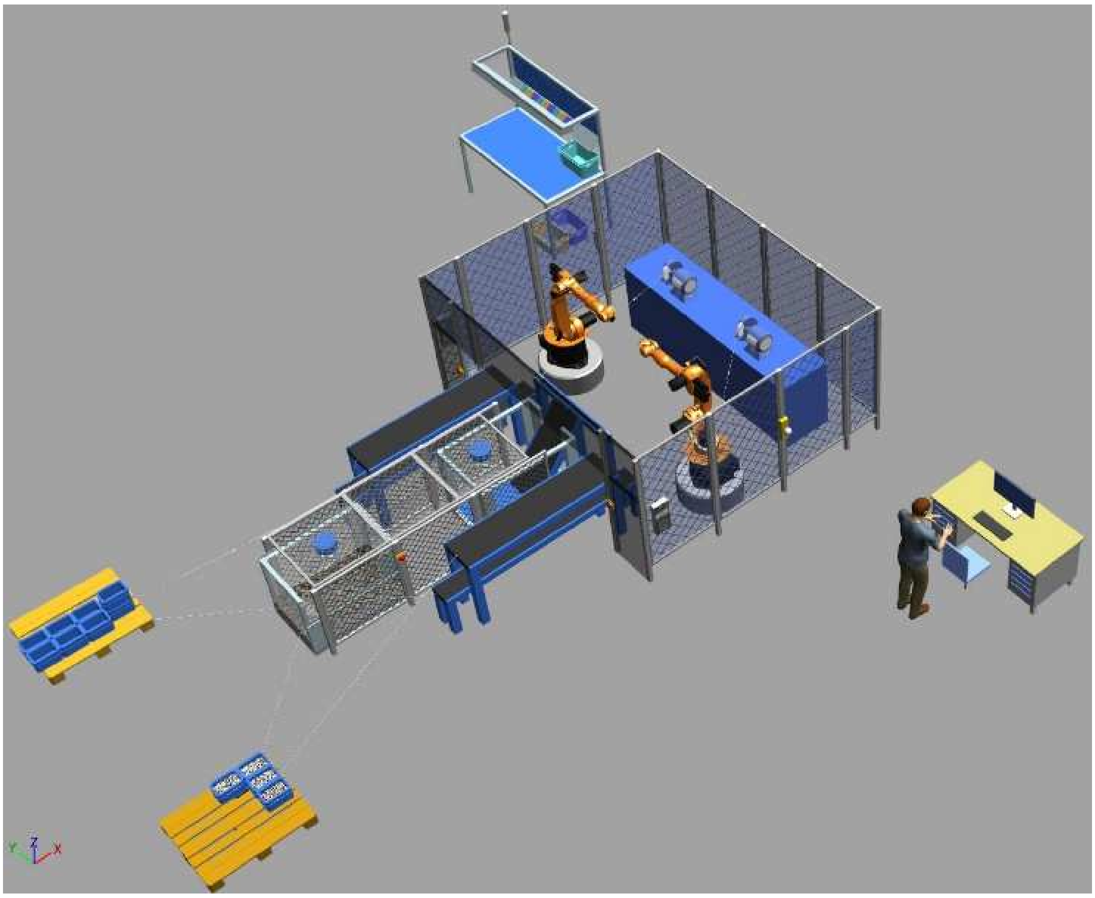

Figure 4 Simulation of the proposed polishing center

6 Conclusions

The automation of production processes plays a crucial role in today's industrial world, enabling higher production line efficiency while reducing costs. In this context, optimizing the polishing production process was also essential. With advancements in technology and the availability of various modelling software, it is now possible to predict the benefits of proposed changes in advance while simultaneously identifying and addressing potential shortcomings [8-11].

This article focuses on the simulation-based optimization of the polishing center using Siemens Tecnomatix Plant Simulation. By implementing process automation, we aimed to enhance overall efficiency and improve production performance. Through simulation, we analysed different optimization strategies to streamline operations and maximize productivity.

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