Research Article

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Modeling of the two shuttle box system within the internal logistics system using simulation software

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Abstract: The efficiency and effectiveness of the production system are influenced by the logistical arrangement of material flows. The smooth production, especially for assembly lines in the required quantity and at the required time (JIT or JIS systems), is currently ensured by automatically controlled towing sets (logistics trains), which consist of a tractor and several trucks. Another factor that affects the smooth production of assembly lines is the system of controlling the circulation of transport units. The number of transport units used in combination with the transport system significantly affects the efficiency of assembly workplaces. This article presents an analysis of the supply of assembly workplaces using a system of two shuttle boxes. The aim of this article is to investigate the influence of transport speed and capacity on the smoothness of the assembly process. Within the described analysis, the transport of 50,000 components is analyzed using a simulation model, while the length of the transport route is 32 km and 65 transport units per shift are used.

Keywords: material flow, smooth production, assembly workplace, AGV, analysis

1 Introduction

When dealing with horizontal material transport in a number of industries within internal logistics, it currently

seems to be the most advantageous to use towing sets with or without a driver [1]. Logistics trains, compared to originally used forklifts or hand trucks, offer a number of advantages, especially in the field of production logistics and shipping [2]. They work in a smaller space and thus provide more space for production [3]. The use of logistics trains has increased several times the quality and efficiency of supply not only by production lines but also by assembly lines [4].

Gazda and Osieczko [5] defined logistics trains as automatically guided handling equipment, which currently represents the highest degree of automation in the field of material handling. It is a technology that allows you to automatically pick up and transport cargo to its destination.

It deals in detail with automated Ullrich tractors [6]. It describes the development of tractors from the original demand of the carmaker in the mid-1950s of the 20th century for the delivery of an automatically controlled train, through the various development stages, which have always been influenced by the possibilities of automated technologies used, to the present. It also deals with their construction, safety elements and perspectives of their use.

Logistics trains are very often used in the automotive industry [7]. Hercko et al. dealt with the applications of automated tractors and logistics trains, especially in the automotive industry in the supply of production and assembly lines [8]. Yang and Pan [9] stated that the use of automated towing sets increases the efficiency of assembly line supply and reduces inventory. Neradilová described, in her work, automated horizontal transport in internal logistics with a focus mainly on the management and optimization of supply lines using simulations and modeling [10]. Using computer simulation, it is possible to verify the proposed logistics systems, including negative production, handling and transport effects, and thus, prevent possible unexpected problems [11].

The type and number of transport units used are also important for the efficient operation of autonomous

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logistics systems [12]. As part of the article, an analysis of the supply process will be performed using a simulation model in the Tecnomatix Plant Simulation program, which is based on the circulation of two transport units for one assembly workplace. The aim of the paper is to present the way in which it is possible to model the two shuttle box systems for the needs of logistics process analysis. This article describes the creation of the method using the SimTalk language that simulates the process regardless of the extent of transport routes and the number of transported items.

2 Methods

The Industry 4.0 concept has given rise to various applications of specific innovative solutions in all industries. Therefore, there is a relatively rapid improvement of common procedures and technologies, modernization of production means with the use of automation elements and the transition to robotic nodes and automatic lines. There is gradual digitization of all systems, including documentation.

Increased interest in automation is also due to the situation in the labor market in connection with labor shortages. Automation is thus not only focused on the production and technological systems but also, at the same time, the related logistics processes are also automated. The application of automated logistics systems is evident especially in the automotive industry, which is traditionally a pioneer of most innovative solutions that increase efficiency and effectiveness, especially in logistics activities.

One of the areas that is suitable for the automation of logistics activities is the area of material handling. It is mainly the warehouse management and supply of materials to both production and assembly lines with the use of automatic means of transport.

Automatic trucks advantageously replace the originally used conveyor lines or forklift trucks. They are more

flexible when the route needs to be changed and take up less space when handling (Figure 1).

They move according to marks, magnetic tapes, inductions from wires placed in the floor, laser or gyroscope. AGVs facilitate material handling and, through their independence from the operator, facilitate material handling, increase the efficiency and safety of operation in their area of use and significantly reduce logistics costs. These are the main reasons for the use of AGV vehicles in various industries, which usually require specific design solutions.

Automatically controlled handling equipment currently represents the highest level in the field of material handling together with robots. It is a technology that allows one to automatically pick up and transport material to its destination. AGV vehicles often replace commonly used vehicles such as forklifts or pallet trucks.

AGV forklifts and pallet trucks are preferably used in logistics centers and wherever higher capacities are required. Automatically controlled forklifts are designed as multi-purpose vehicles that work completely automatically with pallets or mesh box pallets. It automatically places the pallet or mesh box pallet on the fork and transports it to the destination, which is usually the racking system. It automatically searches for free space and stores the cargo. Automatically, the automatic forklifts are able to find the pallet or mesh box pallet in the racking system and transport it for further use.

The development is moving from the used automatic tractors (AGV) to a higher degree of automation. There are already automatic robotic trucks, which decide for themselves in front of an obstacle, whether they go around it on another route or stop, pick up an empty crate on the way back to the warehouse, recharge the battery themselves, etc. A higher degree of automation is also the ability to decide whether to continue back to the warehouse after loading to the assembly line or to return to the warehouse for further recall based on the received radio signal or to pass this received radio signal to another robotic truck that is closer to the warehouse. Robotic trucks with a higher degree of control and navigation form the category of autonomous intelligent vehicles.

Figure 1: Example of an automatic truck used in internal logistics [13,14].

2.1 Two shuttle box system

The two shuttle box system is based, as the name suggests, on the use of two transport units. One transport unit is used to remove components and the other transport unit is used to deliver other components. When the components from the first box are consumed, the second box with the other components must be transported by then. This one will then be further used. Otherwise, production will be interrupted, which is undesirable and unacceptable in many production systems. In the analysis of this system, we can effectively use computer modeling and simulation.

Modeling and computer simulation allow each other to predict the behavior of systems under various alternative

changes in conditions and specified criteria. The simulation model is used to analyze an existing or proposed system and its behavior in various situations. Using computer simulation, the internal transport system as a whole can be analyzed.

2.2 Methodology of the research

The research idea of the presented article was realized according to the block diagram (Figure 2). Its overall concept was chosen so that the obtained results could be used for the analysis not only for a specific process but also for the general application.

Figure 2: Block diagram of the research idea.

3 Results

The two shuttle box system can be implemented using automatically controlled handling equipment. However, for its proper functioning, the entire system must be set appropriately in terms of individual operating parameters. When searching for parameters for its setting, it is advisable to use analysis using the method of computer simulation.

The procedure of such an analysis can be demonstrated by the example of using computer simulation for the analysis of replenishment of semi-finished products by individual CNC machines of the production line, which takes place completely automatically by a robotic AGV forklift controlled by sensors using IoT technology. The AGV truck transports 65 crates per shift, which is approx. 50,000 parts. The truck moves at a speed of 1.38888 m/s and travels a distance of 32 km (Figure 2).

The Tecnomatix Plant Simulation program was used to analyze the activity of replenishing the required components with a robotic AGV truck based on the orders of individual CNC machines.

The basic concept of the simulation model is based on the block diagram, as shown in Figure 3. The simulation of two boxes starts in the initial phase (red box) when one box (1) and the corresponding number of components are generated (2). Subsequently, in point 3, a shuttle box is loaded with a load of components, which

operator 4 uses for production in process 5. The result is an empty crate 6 and a certain number of final products (7). Meanwhile, in the second phase (green box), a second shuttle box with components (9) is generated that must be transported by AGV (8) to the operator (4) until the first shuttle box is finished. With the help of this condition, the production will continue without interruption and AGV (8) then transports the empty shuttle box for completing to the position (9).

Based on this, a supply process was created for each assembly workplace, which is shown in Figure 4. This submodel consists of six basic areas that provide subprocesses within the simulation model.

1. The generation of handling units is provided by the “Source” block, which will create the necessary handling unit for further operations.
2. The buffer (“Buffer” block) serves as a parking space until a new task is assigned to the relevant entity.
3. The pallets are loaded onto the truck in the “Assembly-Station” block, where the lower-order handling units are stored on the higher-order handling unit, as long as the capacity of the handling unit on which the pallets are loaded is available or filled.
4. The “Station” block is the time utilization of the handling unit in performing the required activity (moving from one station to another).
5. Unloading of pallets from the truck is performed in the “DismantleStation” block, where lower-order handling

Figure 3: Block diagram of the two shuttle boxes mode when using a robotic trolley.

Figure 4: Demonstration of part of the supply process model.

units are taken from the higher-order handling unit and then taken in a different direction than the higher-order handling unit.

6. The end block in this block diagram is the “Drain” block, which terminates the request operation with the handling unit.

The Tecnomatix Plant Simulation program has the Transporter function for transporting entities along the transport route (Figure 5), which represents a third-order

handling unit. This unit can carry a number of second- or first-order handling units.

Using the Method function (Figure 6), various conditions and configurations can be set within the modeling. With this function, various changes can be made to selected routes or objects within the modeling and simulation, compared and evaluated.

The advantage of the software application of the simulation program Tecnomatix Plant Simulation is the

Figure 5: Manipulation unit in the simulation program Tecnomatix Plant Simulation.


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is
  Rear, Front : object;
  TractorSpeed : real;
do
  Rear := @;
  Front := @.frontMU;
  if Front.IsTractor then
    TractorSpeed := Front.Speed;
    Rear.hitchFront(Front);
  else
    Rear.hitchFront(Front);
  end;
end;
end;

```

Figure 6: Method function in the simulation program.

possibility of displaying the model in 3-D design, which allows easier orientation (Figure 7).

3.1 Evaluation of modeling and simulation results

The initial situation assumes the use of one robotic AGV truck with one crate to replenish the components of the assembly line equipped with CNC machines. The obtained histogram shows the percentage of work performed on individual workplaces of assembly lines (Figure 8).

The histogram shows relatively large differences in the performance of individual machines, the causes of which may be different and are not the subject of this study. Using modeling and simulation, we adjusted the input data using two robotic AGV trucks.

The use of individual workplaces of assembly lines resulted in an improvement, which improved the efficiency

of most workplaces but the workplaces remained almost unused (Figure 9).

We obtained the best efficiency in the use of production lines with CNC machines by increasing the transport speed of one robotic AGV truck (Figure 10).

This solution brought an improvement in the course of assembly processes, with the exception of three workplaces. This is a significant change from previous experiments. This finding points to the assumption that a possible further increase in speed can also eliminate this problem. However, local conditions must be taken into account in this consideration, in particular, whether it will allow the AGV vehicle to operate at a given speed. In the event that this is not possible, it is necessary to analyze the service processes and increase their efficiency by increasing the efficiency of the entire assembly process.

4 Conclusions

The effort to increase the efficiency of logistics processes, improve their productivity and replace the often missing workforce usually begins with their optimization, which currently continues with the digitization of production and logistics processes. In particular, repetitive strenuous activities with low added value are being replaced by AGV-type technologies and other technologies that facilitate and minimize human labor. Gradually, logistics takes place from data collection and analysis to its autonomous management.

Currently used autonomous systems use a combination of depth cameras and lasers, which capture the

Figure 7: The basic model in 3-D view.

Figure 8: Histogram when supplying the line with one robotic AGV truck.

Figure 9: Histogram when supplying the line with two robotic AGV trucks.

space around robotic trucks and create a spatial map in the control system for subsequent navigation.

Autonomous robotic vehicles are able not only to transport goods but also ensure their loading and unloading, which increases the efficiency of the whole process. Flexibility is

increased by intelligent management connected to the ordering system.

At the end of the article, a study of modeling and simulation is described when supplying an assembly line equipped with a CNC machine using one robotic AGV

Figure 10: Histogram when supplying the line with one robotic AGV truck but at a higher travel speed.

truck, then two trucks and the third simulation is one truck at an increased travel speed, which was the most efficient. It is clear from the results of the analysis that even a small change in one of the operating parameters can significantly affect the efficiency of the entire logistics process.

The results of the research pointed to the fact that the transport speed of the AGV system significantly affects the ability of a sufficient supply of workplaces so that they do not fail due to a lack of components. The results of the simulation experiments present the fact that by application of the system of “two shuttle boxes” not only the number of used vehicles is important but also the appropriately chosen speed of their operation. At the same time, the results of the research are the presented methodology, which will allow one to determine suitable operating conditions using a simulation model and also the design of the model “two shuttle box system” in combination with the appropriate sequence in the program SimTalk. The proposed methodology and a way of modeling for the system of “two shuttle boxes” have universal validity and according to the analytical models of supply logistics of various production processes can be created.

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