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Original Research

AUTOMATED SYSTEM OF INTER-OPERATIONAL TRANSPORT WITH A PNEUMATIC DRIVE

ZAUTOMATYZOWANY SYSTEM TRANSPORTU MIĘDZYOPERACYJNEGO Z NAPĘDEM PNEUMATYCZNYM

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Abstract

This paper presents a design solution for a system used for the inter-operational transport of tanks. Thanks to its innovative design, this solution allows to carry out the processing and assembly of components on the tank without the need to change its orientation. The application of the solution allows for the reduction of line dimensions and its full automation. Thanks to the use of commercially available modular components for the construction of the system, the time and cost of its implementation has been significantly reduced. Pneumatic drives were used in the solution to reduce costs and optimise design. By using appropriately selected and configured actuators and controls, the expected efficiency and reliability of the system was achieved.

Keywords: automation, transport, assembly.

Streszczenie

W artykule przedstawiono rozwiązanie konstrukcyjne systemu służącego do międzyoperacyjnego transportu zbiorników. Rozwiązanie to dzięki swojej innowacyjnej konstrukcji pozwala na realizację procesu obróbki I montażu komponentów na zbiorniku bez potrzeby zmiany jego orientacji. Zastosowanie rozwiązania pozwala na ograniczenie wymiarów linii oraz pełną jej automatyzacja. Dzięki wykorzystaniu do budowy systemu dostępnych na rynku komponentów modułowych znacząco ograniczono czas oraz koszty jego wykonania.

Słowa kluczowe: automatyzacja, transport, montaż.

1. Introduction

Automation of a technological process is possible once the activities occurring in the process have been mechanised. Mechanisation involves replacing physical work of a human being with the machine work. To achieve this, it is necessary to use appropriate mechanical devices that will perform the work under human supervision. We can distinguish here four basic groups of driving elements: mechanical, pneumatic, electrical and hydraulic. Once the process has been mechanised, it is possible to automate it so that the machines can carry out the planned process without human involvement or with limited human involvement (Domińczuk, Kost, & Łebkowski, Automatyzacja i robotyzacja procesów produkcyjnych, 2022). It is possible thanks to the use of control systems including microprocessor-based programmable logic controllers (PLCs) (Kluz, 2012).

Companies manufacturing a variety of products tend to increase automation of basic, auxiliary as well as service processes. It also applies to assembly processes, although undoubtedly the advancement of the implementation of automated systems in assembly does not yet match the intensity of similar processes in other manufacturing techniques. This is due to a number of reasons with more important ones as follow (Łunarski, 2011):

- increasing complexity of the construction and operation of various electromechanical products, the possible automatic assembly of which would require special assembly equipment, expensive and often unreliable,
- limited serial nature of product manufacturing, which makes it not cost-effective to implement automatic technological devices for assembly,
- diversity of manufactured products into series of typically dimensioned, modular, functional, etc., which requires ensuring considerable flexibility of automatic assembly equipment,
- frequent cases of insufficient refinement of technological design due to the requirements of automatic assembly,
- lack of mass production of typical modules for the implementation of automatic assembly, allowing for easy configuration of automatic assembly devices due to the diversity of assembly needs,
- the need to manufacture specialised assembly units dedicated to a specific application (Salonitis, 2014).

Despite the above mentioned factors limiting the use of automated systems in machine assembly, the systems are gradually becoming more widespread, influencing the repeatability of the process and ensuring that it can be supervised automatically.

The most common reasons for assembly automation include:

- the need to increase productivity and to make optimal use of the technological possibilities of the mechanised and semi-automated manufacturing techniques present on the production line,
- the need to ensure process feasibility within a defined period of time (Domińczuk, Analiza możliwości budowy wysokowydajnych elastycznych linii pakowania w oparciu o konstrukcje modułowe, 2018),
- the need to offer competitive technical solutions limiting the probability of producing defective products,
- the need to reduce human involvement in monotonous, repetitive tasks often connected with high physical effort.

Such situations create opportunities for companies specialising in the design and manufacture of semi-automatic and automatic assembly machines and, indirectly, also for suppliers of components for such machines.

According to the author of the publication, (Łunarski, 2011) in order to take advantage of such opportunities, which increase in periods of economic prosperity and decrease in periods of crisis, it is necessary to:

- have an experienced, creative and innovative designers capable of solving complex problems quickly,
- have appropriate information systems to support the work of designers and the activities of planners implementing these projects (supplying, prioritising and scheduling tasks, utilising existing production capacities, resources, etc.),
- have appropriate technical infrastructure to enable projects to be carried out quickly and with a high standard of quality, and have links with suppliers, collaborators and subcontractors to facilitate execution of works.

The need for creativity results primarily from the fact that assembly automation should not always imitate manual procedures and operations. In such situations, there is a need to solve problems in an innovative way that guarantees high productivity, stable quality, safety of works and reliable operation of the automated assembly system.

Meeting these requirements often creates the necessity to develop basic, applied and developmental research (Kozioł, Samborski, & Zbrowski, Design of an innovative window-to-balcony building module, 2021) (Kozioł, Samborski, Siczek, & Zbrowski, 2018). The aim of these efforts is to develop and offer a variety of solutions, methods, tools, instrumentation and other elements necessary for efficient and reliable process automation.

2. Design requirements

The project task involved building a station for the automated process of machining and assembly of fuel tanks. The requirement was to base the tank at each station in a repeatable manner using dedicated surfaces and characteristic points. The design of the tank required completion of technological processes on all surfaces of the 1190 mm x 520 mm x 230 mm cube surrounding it (Fig. 1.). In order to ensure proper efficiency of process execution, the inter-operational transport time had to be within 5 s. The requirement for the process was to be run fully automatically both in the phase of supplying the container to the machining and assembly line and in the phase of product flow between the stations. The operator's task was to pick up the ready tank from the line and to deliver it to the feeding systems of components, which, due to their nature, cannot be fed by vibratory dispensing systems. According to requirements, if a process error was detected, the product separation (good/bad) was to take place automatically. Due to the existing transport solutions ergonomic conditions in the company, it was required that the transport height of the tank along the line was 1200 mm. It was assumed that the tank would not change its orientation during transport and that the transport would take place in a position consistent with the position of delivery of the tank to the line (Fig. 2).

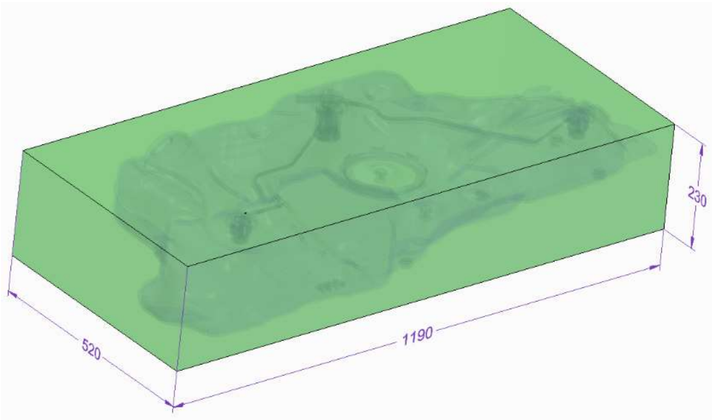

Fig. 1. View of the cube surrounding the tank

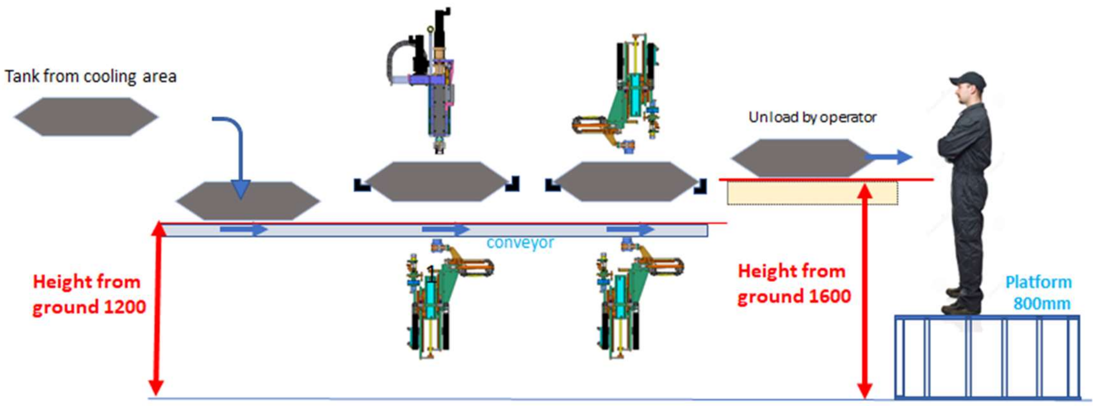

Fig. 2. Concept of tank transport through the production line

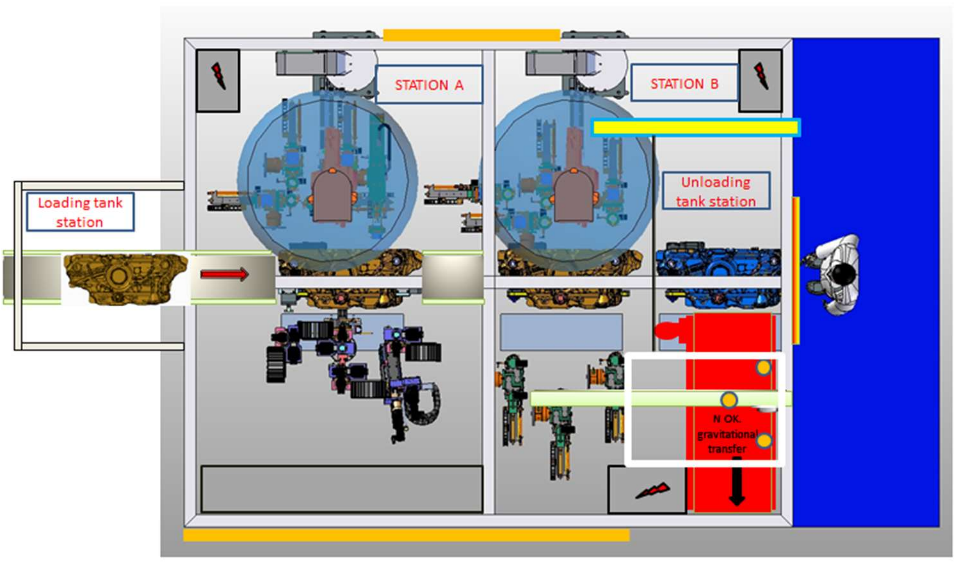

Fig. 3. Concept of tank transport through the production line – plan view

According to the developed concept, the machining and assembly line will consist of two automated machining stations. There will be a loading station in front of station A. The unloading station will be located directly behind station B. It will enable the separation of tanks into those correctly made and the faulty ones. The tanks classified as faulty ones will be removed from the line automatically with the use of the station dedicated for this purpose. Correct tanks will be directed to the unloading station, where they will be collected by the operator and placed in storage racks.

According to the concept adopted for the tank processing, its movement will be carried out using a feeder and the tank will move sequentially from the loading station through station A, station B to the unloading station. Due to the difference in height between the transport and unloading heights (Fig. 2.), it will be required to lift the tank by 400 mm. As it can be seen in the diagram (Fig. 2., Fig. 3.) the transport system must be designed in a way to enable each side of the tank to be processed according to specific technological requirements.

3. Technical solutions

The main problem in designing the line was determining the method of transporting the tank between the stations. The problem stems from the lack of free surface area of the tank that could provide a base surface for transport. As a result of the analyses carried out, the following transport system solution was proposed (Fig. 4.). It assumes moving the tank between stations in a sequential system after all technological operations at the machining and assembly stations have been performed. The task of the transport system would be to move the tank on slides along the track laid between the stations (from left to right, Fig. 4.). The tank would be initially based during movement. After moving to the work station, it would be based by being lifted to a defined position required for performing technological operations.

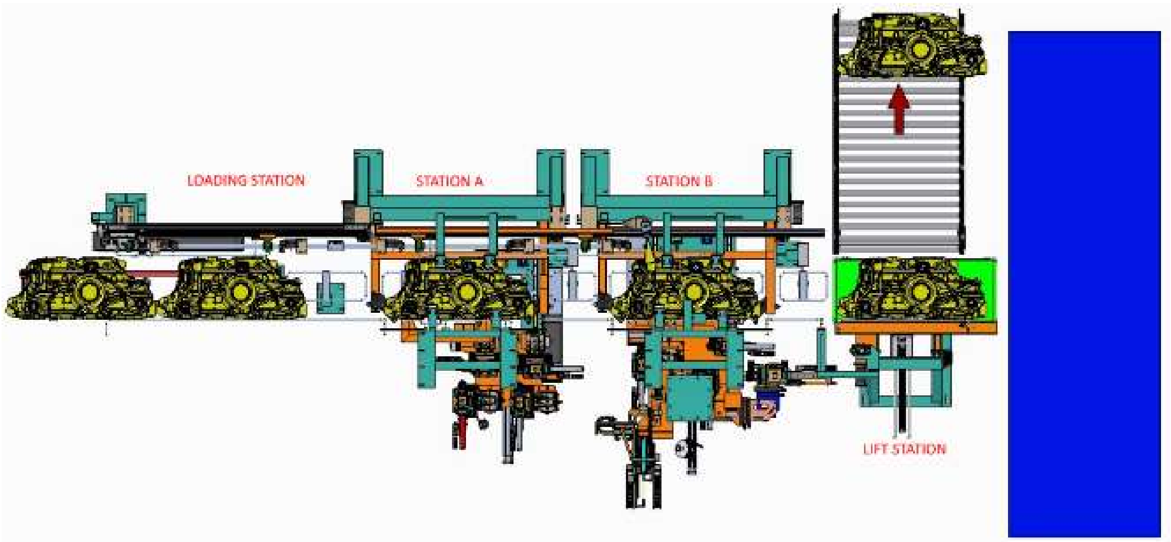

Fig. 4. Concept of transport system

This solution assumes that the drive elements of the transport system will be placed along one side of the tank. By using the tank lift system during basing, all tank surfaces will be exposed. Due to the necessity of removing the guiding elements used for tank transport from the bottom surface of the tank, the guiding system was integrated with the transfer of the work units, resulting in its removal from the work zone when the units occupy the working position (Fig. 5.).

The principle of operation of the feeder is illustrated in Fig. 6 and Fig. 7. The tank is transported to the loading station by the belt feeder (1) and its position is determined with the use of a stopper (2) (Fig. 6). The main feeder structure is based on an aluminium profile (3) to which a rail guide (4) is attached. On the guide, there are trolleys (5) with bearing units (6) attached. A sleeve guide (7) is fitted to the bearing units. This guide forms the base for the tank orientation and, thanks to its ability to move along the station line, it ensures that the tank is transported. This assembly is driven by a pistonless cylinder (8), which, thanks to its equipment, makes it possible to set precisely the drive stroke. The container is gripped during transport by movable arms (9), which are rotated by the cylinder (10). The tank between the arms is blocked in place with the use of clamping cylinders (11) (Fig. 7.). Once the displacement is complete, the arms are released and rotated into position and then moved to the parking position. Thanks to clamping units (12), the distance between the gripping units can be freely configured. This distance is determined by the mutual positioning of station B relative to station A (Fig. 8.).

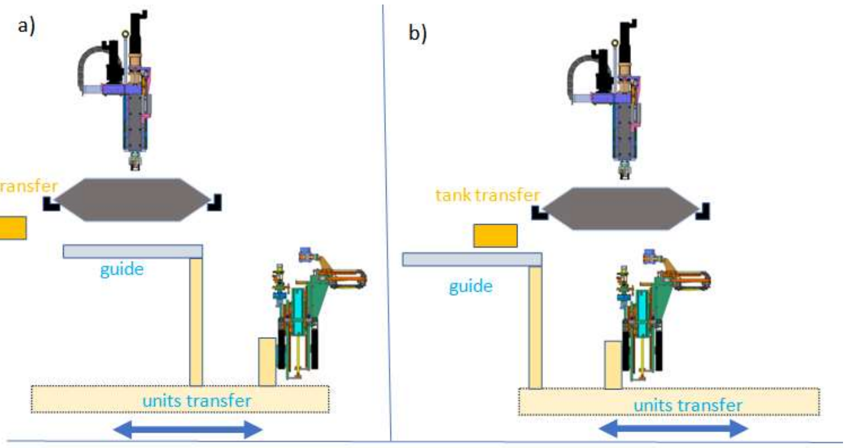

Fig. 5. Concept of the tank guiding system

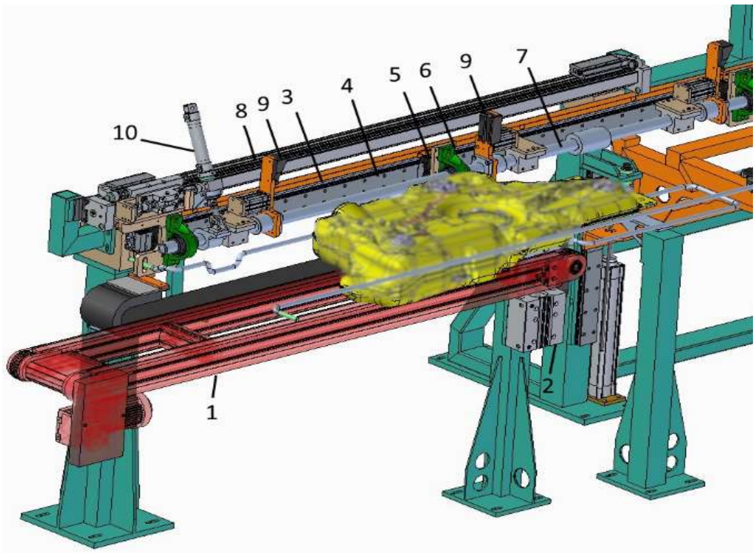

Fig. 6. Construction of the inter-operational feeder

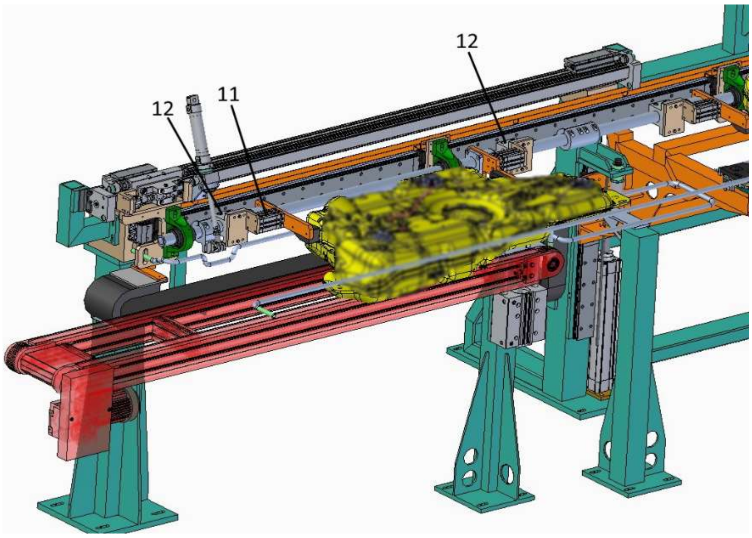

Fig. 7. Construction of the inter-operational feeder

Fig. 8. Position of the feeder during tank loading

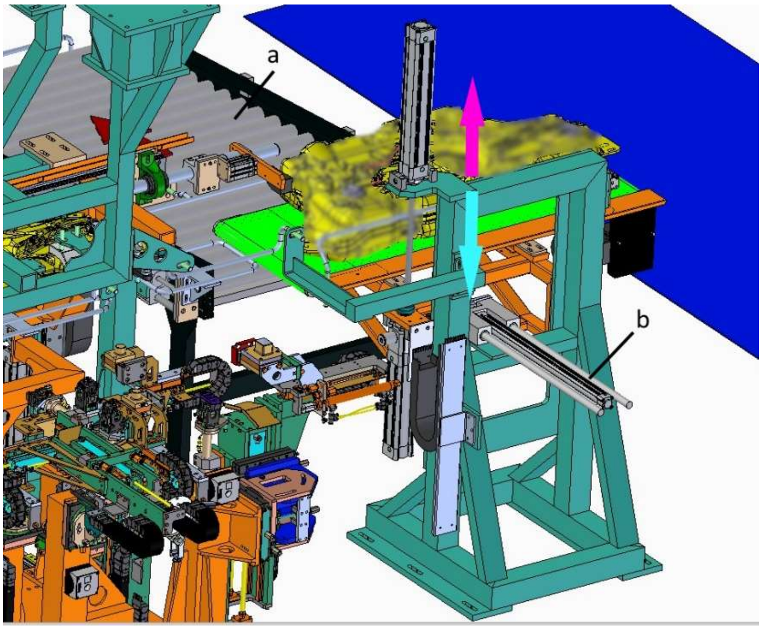

Fig. 9. Position of the feeder during tank loading

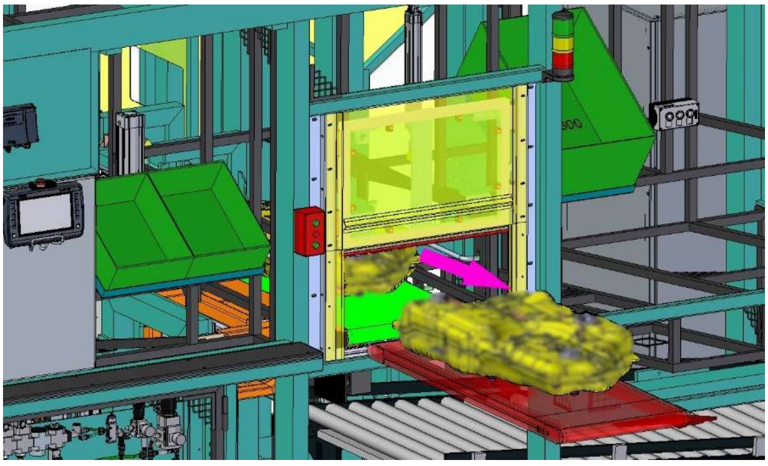

Fig. 10. Zone of collection of the tank by the operator

The unloading system is designed in the form of a lift equipped with a belt feeder. Loading of the tank onto the lift is carried out in the central position using a single ejector arm (Fig. 9.). The lift, thanks to the coupling of two pneumatic cylinders, can occupy three positions. The lower position allows tanks with NOK status to be unloaded onto the gravity feeder (a) using a transverse ejector (b). The upper position is used to safely transport the tank to the collection area by the operator (Fig. 10.).

4. Summary

The design solution presented in this paper, an automated inter-operational transport system with a pneumatic drive, allowed to perform the technological process without the need to change the tank orientation, which brought the following benefits:

- ensured the possibility of using an identical basing system at each station, which has a positive impact on the final quality of the product,
- reduced the cost of manufacturing basing systems due to their unification,
- provided the possibility to carry out the process on two work stations,
- ensured optimum use of production space,
- reduced costs of manufacturing the machine due to the relatively low manufacturing costs of the transport system built from modular systems.

The implemented innovative design solution of the transport system based on pneumatic drives is an example of the possibility to use simple and low-cost drives to perform important tasks in automated production lines operating within the framework of Industry 4.0 (Stadnicka, et al., 2022) (Kolberg & Zuhlke, 2015) (Brzozowska & Gola, 2021). The presented solution is the result of the search for optimal process execution conditions, which is one of the basic activities while designing robotic production systems. The presented system has a modular design, which allows it to be easily adapted to other industrial applications. It can be scaled and controlled using programmable flow control systems. By using this type of solution, it is possible to adapt its operating parameters to the requirements of the application at control program level. All these factors make the system concept versatile and universally applicable to a wide range of operating parameter variants.

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