USE OF UNIT LOAD AGVS FOR FULLY AUTOMATED PART HANDLING IN THE WELDING SHOP

[1]Jiří ZÁRUBA, [2]Radim LENORT

[1]VŠB - Technical University of Ostrava, Faculty of Materials Science and Technology, Ostrava, Czech Republic, EU, jiri.zaruba.st@vsb.cz

[2]ŠKODA AUTO University, Mladá Boleslav, Czech Republic, EU, radim.lenort@savs.cz

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Abstract

The paper presents the possibilities of using unit load AGVs for handling parts in a welding shop. One of the key success factors of this technology implementation is the full automation of handling operations in front of welding lines and workplaces. Pallets with parts usually have a rectangular floor plan. Due to the high passability of the isles, it is advisable to transport these pallets to the welding lines with a narrower dimension (in width). This is done today with the help of forklift or tugger trains. Before the welding lines, however, the pallets are oriented lengthwise. This results in the necessity of turning them, which is carried out using forklifts. The effective deployment of unit load AGVs requires the replacement of forklifts and tugger trains. In that case, however, it is necessary to find such a solution, during which the pallet will be rotated in front of the welding line fully automatically. The aim of the paper is to propose and evaluate such solutions. For this purpose, a case study from the welding shop of a passenger car manufacturer and multi-criteria decision-making methods are used. A total of five possible solutions are evaluated. Each solution is analyzed in detail and evaluated from the point of view of seven criteria.

Keywords: Unit load AGV, welding shop, case study, MDCM methods, automotive industry

1. INTRODUCTION

The automotive industry is a leader in implementing automated logistics systems that use Automated Guided Vehicles (AGVs). Towing AGVs (automated tugger trains) have already become the standard in the internal logistics of this industry. To further increase the productivity of transport and handling operations, towing AGVs are increasingly being replaced by unit load AGVs. The unit load AGV is a type of AGV that is designed to transport unit loads such as pallets, racks, and carts (see **Figure 1**).

Figure 1 Example of the unit load AGV designed by Asseco CEIT [1]

However, the introduction of unit load AGVs is associated with new challenges. One of them is the full automation of handling operations in front of production lines and workplaces [2]. The aim of the paper is to analyze this issue in the welding shop and propose and evaluate possible solutions. The real-life case study in a passenger car manufacturer is used for the analysis and identification of possible solutions. The evaluation of the identified solutions is carried out using multi-criteria decision-making methods.

2. LITERATURE REVIEW

Automated Guided Vehicle (AGV) can be defined as a device for moving unit loads of materials from one place to another, within a facility, with no accompanying human operator [3]. AGVs are battery-powered driverless vehicles, centrally computer-controlled and independently addressable [4].

Hercko et al. [5] stated that AGVs create competitive advantage by means of the full automation of material handling operations especially in companies in the automotive industry. This claim can be confirmed by research studies that examine different aspects of AGV applications in that industry. Saffar et al. [6] used computer simulation to research AGV system as the automated transportation in handling material through warehouse to the automotive assembly line. They have demonstrated a significant reduction in idle and waiting times in warehouse and transportation operations. Correia et al. [7] showed that AGVs can be used for transport of heavy loads in the internal logistics of automotive industry. They underlined benefits such as better ergonomics, an enhance of safety and higher productivity.

On the other hand, the introduction of AGVs faces a number of limitations and problems. Based on two case studies from automotive industry, Hrusecka et al. [8] recognized set of 18 critical success factors that includes necessary conditions, which must be fulfilled before AGV implementation to avoid future problems. These factors are divided into three areas: technological, organizational, and safety. Similarly, Zaruba et al. [2] identified nine critical success factors for successful implementation of unit load AGVs for supplying automotive assembly lines by means of picking carts. Based on a multi-case study, Zuin et al. [9] demonstrates the need to develop a multidisciplinary approach to AGV fleet design and lays the groundwork for future design procedures capable of proactively engaging the designer, worker, and safety experts from the very beginning of the AGV introduction phase.

3. CASE STUDY

The case study is focused on the use of unit load AGVs for the transport of parts in the welding shop of a passenger car manufacturer. Front rails transport was chosen in this particular case. Front rails are parts of a vehicle underbody structure. Front rail is a typical thin-walled structure, which is the most critical force transmission and energy absorption structure for the frontal impact of a vehicle [10]. Front rails are transported from the warehouse to the welding line (see **Figure 2**). Transport is carried out by automated tugger train (towing AGV with a trailer). Front rails are transported in special pallets shown in **Figure 3**. Loading and unloading of pallets to/from trailers is carried out by manual forklifts. Full pallets are transported to the line and empty pallets are transported back to the warehouse. The aim of the case study is to replace the tugger train and manual forklifts operated before the welding line with unit load AGVs.

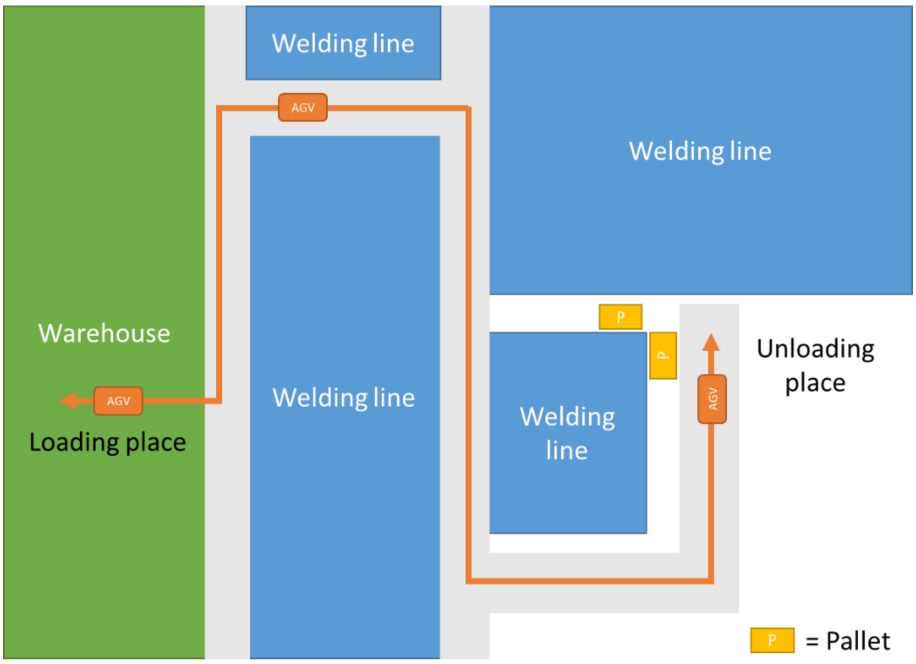

Figure 2 Transport system of the front rails

Figure 3 Pallet for front rails transport

4. PROBLEM DEFINITION

Because pallets have a rectangular floor plan, they are transported with a narrower dimension (in width) due to the higher throughput of isles. Before the welding line, however, the pallets are oriented lengthwise (see **Figure 4**). It is possible if the manual forklift is used. However, if a standard unit load AGV was used to transport the pallets, it would place the pallet at the line widthwise (see **Figure 5**). In that case it is necessary to find such a solution, during which the pallet will be rotated in front of the welding line automatically.

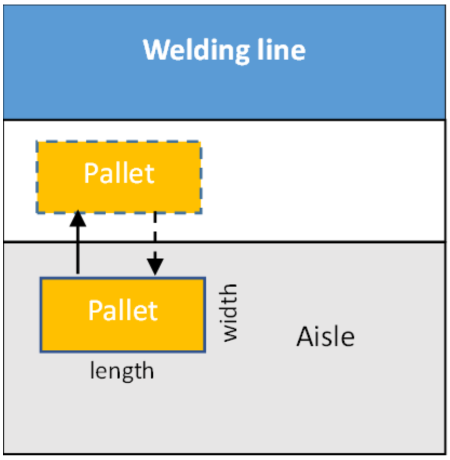

Figure 4 Method of handling pallets on the welding line

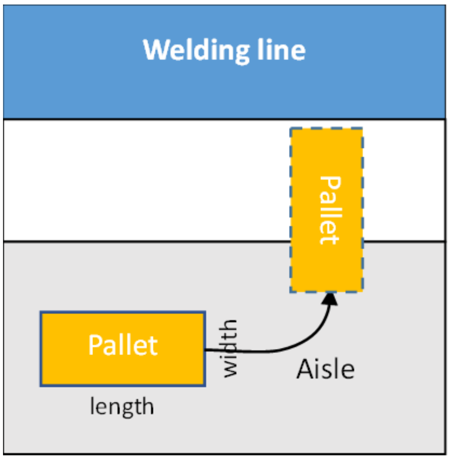

Figure 5 The method of placing a pallet carried by a standard unit load AGV

5. POSSIBLE SOLUTIONS AND THEIR EVALUATION

We found a total of five solutions that could be used for automation of handling operations in front of the welding line:

- Two-stage handling in front of the line (S1) – the AGV places the pallet in front of the line, drives out, picks up the pallet from the other side and drives it to the line.
- Turning the AGV under the pallet (S2) – the AGV places the pallet in front of the line, turns 90° under the pallet, lifts the pallet and drives it to the line.

- AGV rotating lifting module (S3) – the AGV module turns the pallet lengthwise in front of the line and thus the AGV drives it to the line.
- AGV with omni chassis (S4) – the AGV drives the pallet to the line lengthwise without the need to turn.
- Automatic carousel at the line (S5) – the pallet is placed on the carousel and turned lengthwise.

We chose seven criteria to evaluate the mentioned solutions:

- Market availability (C1) – expresses the necessity of developing the given solution.
- Safety (C2) – expresses the level of safety risks associated with the given solution.
- Investment costs (C3) – expresses the investment requirement of the given solution.
- Operating costs (C4) – expresses the amount of costs associated with operating the given solution.
- Handling time (C5) – expresses the time of handling operations for the given solution and thus the degree of effective use of the AGV.
- Space requirements (C6) – expresses the needs of the given solution on the space at the assembly line (including short-term blocking of the aisle in front of the line).
- Implementation time (C7) – expresses the time required for the implementation of the given solution.

Since the mentioned criteria have different importance, a weight was determined for each of them using the AHP (Analytic Hierarchy Process) method (for more, see [11]). **Table 1** shows the individual pairwise comparisons and the calculated weights.

Table 1 Pairwise comparisons of the AHP method and criteria weights

	C1	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**Weight (%)**
C1	1	2	2	2	3	3	3	26.92
C2	1/2	1	2	2	3	3	3	22.01
C3	1/2	1/2	1	2	3	2	3	17.19
C4	1/2	1/2	1/2	1	2	2	2	12.24
C5	1/3	1/3	1/3	1/2	1	2	2	8.68
C6	1/3	1/3	1/2	1/2	1/2	1	1	6.68
C7	1/3	1/3	1/3	1/2	1/2	1	1	6.28

Table 2 summarizes the criteria values for individual solutions. A Likert scale was used to determine them: 1 = the worst value, and 5 the best value of the given criterion. The TOPSIS (Technique for Order of Preference by Similarity to Ideal Solution) method was used to preferentially arrange the considered solutions (for more, see [12]). **Table 2** also shows the resulting order of solutions.

Table 2 Criteria values for individual solutions, TOPSIS score and solution order

	C1	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**Score**	**Order**
S1	5	3	5	4	2	3	5	0.58	2
S2	5	2	5	5	4	5	4	0.52	4
S3	4	4	3	4	5	4	5	0.56	3
S4	4	5	3	4	5	5	5	0.66	1
S5	3	3	2	3	5	2	2	0.26	5

The use of AGV with omni chassis appears to be the most advantageous. It is a relatively new solution that is only now being used in practice. Therefore, it belongs to the more investment-intensive solutions. In second place was two-stage handling in front of the line. The biggest disadvantage of this solution is the too long time required for handling and the associated temporary occupation of the space in front of the line and blocking of the traffic. The third solution is the AGV rotating lifting module, which increases the investment costs of AGVs. In fourth place is turning the AGV under the pallet. Its biggest disadvantage is the need to readjust the AGV safety zones to allow the AGV to rotate directly under the pallet, which reduces the safety of such a system. Automatic carousel at the line was identified as the worst solution. The disadvantage is the need to develop the carousel (financial and time-consuming) and the occupation of space at the assembly line. At the same time, increased safety risks of the rotating carousel and additional costs for its operation can be assumed.

6. CONCLUSION

This study proposes five possible solutions for automatic handling of pallets in front of welding lines as a replacement for manual forklifts. Based on a detailed analysis using multi-criteria decision-making methods, AGV with omni chassis can be recommended as the best solution. Thanks to this research, the passenger car manufacturer decided on a pilot deployment of this AGV type for the analyzed logistics process. A feasibility study has already been carried out and the technology will be implemented in 2023.

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