TRANSNAV
http://www.transnav.eu
the International Journal
on Marine Navigation
and Safety of Sea Transportation
Volume 12
Number 4
December 2018
DOI: 10.12716/1001.12.04.19

Technological Process of Spreading Coatings Over Structural Details of Automated Guided Vehicles Used for Relocation of the Containers

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ABSTRACT: The authors of this article presented technologies of spreading coatings over structural details of automated guided vehicles used in the handling terminals. Technological process of painting with the use of powder paints was presented, as well as innovative methods of surface preparation with the use of BONDERITE M-NT 2011 technology and OXILAN 9807 preparation. Modern methods of surface preparation with production of silane conversion coatings were presented and analysed. The authors of this article selected a system of guaranteed power supply of the processing lines. ABCUS software was applied to check the time of battery backup of UPS units in selected N+1 system.

1 INTRODUCTION

Globalization of business activity, which is a factor generating the growth of cross-border flow of good has led to the increase in the volume of the containers serviced in the seaports. The sea terminals, playing an important role in international transport TEU must be ready for the service of growing number of the containers [9], [15], and to achieve higher efficiency, they must follow the directions of *„4th Industrial Revolution"* and idea of *„Industry 4.0"*. One of the ways of increasing efficiency is the automation of the processes using energy from renewable sources [13], [1]. The handling terminals in the chains of intermodal transport use modern automated technologies in the process of unloading. One of them is automated guided vehicles (AGV) for relocation of the containers from or to the ship from storage places. The reliability of positioning and navigation of AGV vehicles can be achieved in many ways, and the factor responsible for choosing a method is working area (internal or external).

The most popular navigating methods include [3], [5], [6]:

- A method of induction loop using flow of current in the wire and generating magnetic field detected by trolley sensors.
- A method of magnetic loop, which is similar to induction loop, but the source of magnetic field is different. In this method, a band made of ferromagnetic material that allows quick change of the route of transport is usually applied.
- A method of reflective line using camera tracking the lines painted with reflective paint or lining the road with reflective band.
- A method of laser navigation determining location coordinates towards laser beam emitted by the scanner on the trolley and registering environment looking for the points reflecting laser beam and identifying location of a vehicle.
- Gyroscope method, which requires additional device – gyroscope, placed on the trolley in order to detect changes of driving direction and transponders placed in the crucial driving points – arcs, stops, etc.

– A method of a coordinate system based on the reference points placed on the floor of the object allowing to coordinate the location of a trolley in space.
– Ultrasound method emitting and „listening" of the return of signal reflected from vertical surfaces allowing to estimate distances from the object.
– GPS method using satellite system and GPS receiver placed on the vehicle.

2 AUTOMATED GUIDED VEHICLES USED FOR RELOCATION OF THE CONTAINERS

The application of automated guided vehicles largely affects optimization of flow of goods, improving general operational efficiency in the terminals and competitiveness of the seaports (Fig. 1) [14]. Due to various sizes of the containers, the dimensions of of AGV vehicles must provide transport in many configurations (Fig. 2). The sizes fluctuating around 15 meters long, 3 meters wide and 2 meters high of a loading platform provide load capacity up to 70 tonnes and loading of [7], [8], [9]:

1 One container of total weight fluctuating around 40 tonnes (20, 40, 45-foot containers).
2 Two containers of total weight up to 70 tonnes (two 20-foot containers).

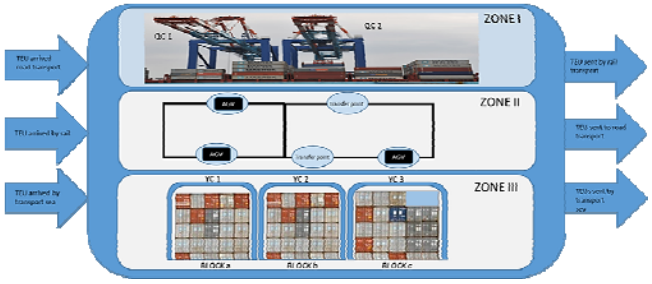

Figure 1. Maritime container handling terminal

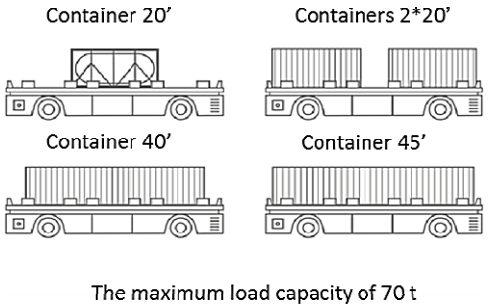

Figure 2. Automated guided vehicles

The collisions in road traffic are prevented through transhipment control system usually operating in the Just-In-Time mode (JIT) cooperating with other components of a terminal, for example, mobile transhipment cranes [8], [9].

The advantages of implementation of transhipment control system:
– Prevention of collisions by using the sensors.
– Traffic improvement by eliminating the need of slowing down, stopping or accelerating in the interchanges of high driving frequency (crossroads, narrow sections).
– Optimization of time needed for transhipment.
– 24-hour supervision of the process.
– Energy saving (there is no need to illuminate fully automated zones).

Proper operation of inspection system is based on the set of sensors, which is an additional equipment of the platforms selected individually to the needs of the process. The application of structural elements of AGV vehicles (engine, battery, sets of sensors and transmission antennas) sensitive to damages forced their protection with the shields resistant to damages and weather conditions. The metal sheets that they are made of must undergo the shaping processes on the automatic press brakes changing their initial shape. Formation process depends on the size and shape of automated guided vehicles. Basic set of shields consists of front, back and side shields, and their number and arrangement depend on the structure of a vehicle, location of a drive unit and other elements of its structural system. Then, processed shields are transferred to subsequent phases of the process – varnishing and assembly. The order of varnishing process was presented on figure 3.

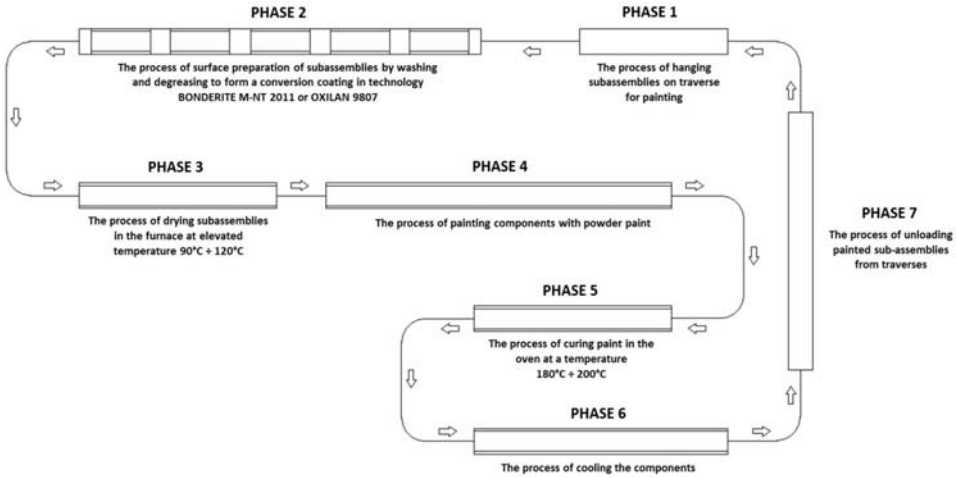

Figure 3. The phases of the process of varnishing the details of AGV vehicles in the automatic processing lines

3 TECHNOLOGICAL PROCESS OF SPREADING COATINGS OVER THE DETAILS OF AGV VEHICLES

Technological process of painting with the use of the powder paints takes place in modern automatic line in accordance with following phases [2]:

The process of washing and degreasing of the details on the crossbars (PHASE II) with production of silane conversion coatings takes place in five-zone automatic spray washer that includes the following stages (Fig. 4) [4]:

1 Washing and degreasing of the sub-assemblies.
2 Rinsing in tap water.
3 Rinsing in deionized water.
4 Passivation with production of BONDERITE M-NT 2011 conversion coating.
5 Rinsing in deionized water („demi").

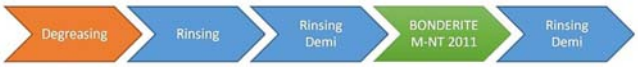

Figure 4. The stages of the process of washing and degreasing BONDERITE M-NT 2011

Alternative stages (Fig. 5) [10]:

1 Washing and initial degreasing of the sub-assemblies.
2 Fundamental washing and degreasing.
3 Rinsing in tap water.
4 Rinsing in deionized water („demi").
5 Passivation with production of silane conversion coating OXILAN 9807.

Figure 5. The stages of the process of washing and degreasing OXILAN 9807 depending on the type of the process

Rinsing in deionized water in this technology is very important because it removes all ionic pollutants from the surface and increases the level of anticorrosive protection of the sub-assemblies of AGV vehicles. After drying operation, the details are painted automatically and hard-to-reach places are manually dusted. In the process of painting, colour of powder paint can be quickly changed **without technological stoppages**. Painted details are put into the stove, where coatings are hardened. Final phases (VI, VII) of the process include cooling down and unloading from the crossbars of painted details with visual inspection. During technological process, the details are transported by automated overhead transport.

The following devices are necessary for controlling technological process of powder painting:

1 pH meter measuring pH of analysed chemical substances.
2 A device examining water conductivity.
3 A device examining adhesion of the paint coatings.
4 A device examining thickness of the paint coatings.
5 Time and temperature recorder in the stove with four measuring probes (3 on the details + 1 air).
6 Chemical fume hood for chemical analyses.

Technological process of painting with the use of powder paints with preceding process of preparing their surfaces make the products (structural elements of automatic AGV vehicles used in the handling terminals for relocation of the containers) properly protected against corrosion.

4 APPLIED TECHNOLOGIES IN THE PROCESS OF SPREADING COATINGS OVER STRUCTURAL DETAILS OF AUTOMATED GUIDED VEHICLES AND THEIR QUALITY

Technology of electrostatic painting with the use of powder paints and preceding process (phase II) of preparing the surface of the details based on innovative technical and technological solutions were applied for painting details of the vehicles.

– Technology of electrostatic painting with the use of the powder paints
  Technology of electrostatic painting with the use of the powder paints uses power of electric field in the process of spreading paint particles over the details [16]. Unlike electrostatic painting with liquid paints in powder technique, coating material, which is the so-called overspray, is

returned again through recovery system (cabin, cyclone and/or filter) to the application device. It is possible to use it completely – between 85% and 99% depending on the type and efficiency of recovery devices.

The powder paints and technology of electrostatic painting perfectly comply with recent **directives of the European Union, having all features of modern manufacturing technology.** Harmful components are not emitted to the atmosphere and working environment in the process of application. Whereas, the coatings made of powder paints belong to the group of „high performance" coatings – very durable and having unique protective and decorative properties. Technology of electrostatic painting with the use of the powder paints is called the best available technique (BAT).

– **Technology of preparing the surfaces of the details for painting**

In the process of anticorrosive protection of the products – production of protective layers, the fundamental element preceding painting is ground preparation [17]. The main goal of this processing is achievement of such surface features ensuring good adhesion and slowing down the corrosion processes. Even the best painting material spread on poorly prepared surface has poorer protective properties and worse adhesion to the ground manifesting in (after relatively short period of time of product exploitation) delamination (loosening) of the coating from the ground. The methods of surface preparation applied in practice can be divided into two fundamental groups:

– mechanical methods;
– chemical methods.

In practice, mechanical and chemical processing are usually combined. Knowledge and specialist literature of surface preparation show that popular technology of preparing metal grounds (steel, galvanized, aluminium) for varnish coatings (powder) is ferric (amorphous) or zinc (crystalline) phosphating – in the cases when better corrosion resistance is required. In the engineering and automotive industry, where better corrosion resistance is required, the so-called tri-cationic phosphating (zinc-manganic-nickel) is applied. It is an unstable process that forms large amounts of sludge (pollution) containing heavy metals (Zn, Mn i Ni) that are hard to utilize. Despite the defects of phosphating process described above (sludging, content of heavy metals, high temperatures of the process), due to very good anticorrosive properties of a conversion coating in combination with paint coatings, this process has been applied in the industry so far and it was difficult to find any substitute. The aspects of environmental protection and safety rules in the workplaces have become fundamental now. The actions of many specialists lead to development of agents for surface preparation, of which fundamental feature is elimination or reduction of pollutions to the environment (gas, liquid and solid pollution). In the implemented line of spreading coatings over structural details of automated guided vehicles, surface preparation is automatic processing with the use of innovative preparations developed by the companies: Henkel, Chemetall. Technology developed by Henkel is based on **newly-developed** zirconic preparation Bonderite M-NT 2011, whereas, technology developed by Chemetall is based on silane agent Oxilan 9807 [1].

4.1 *Technology - Henkel*

The processes of washing and degreasing with production of zirconic conversion coating take place in five-zone washer with the use of newly-developed BONDERITE M-NT 2011 preparation. Applying this technology allows to eliminate the process of universally applied standard ferric phosphating, which forms a lot of sludging, that is, large amount of waste that needs to be utilized (costs), which poses a threat to environment (in some countries, the plants applying ferric phosphating must get a license allowing to use it) (Fig. 6) (Fig. 7) [1].

The main advantages of this technology in comparison with ferric phosphating include:

– reduction of formed sludge – reduced environmental pollution;
– longer time of bath „life" (even 2 – 3 times);
– reduced use of rinsing water;
– the option of processing of steel, galvanized and aluminium products;
– energy demand lowered by about 30%;
– thinner protective layer improving quality of preparation of the surfaces before painting.

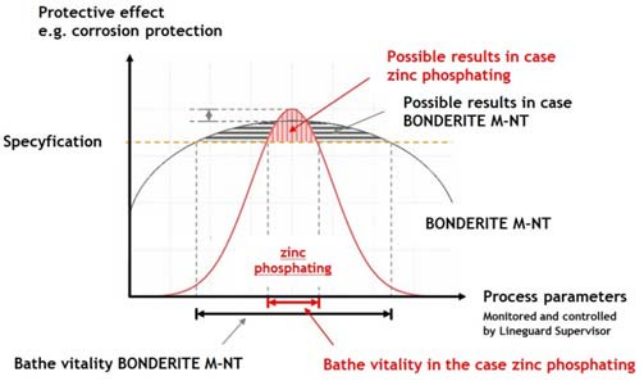

Figure 6. The comparison of the capabilities in the case of zinc phosphating with BONDERITE M-NT results [11]

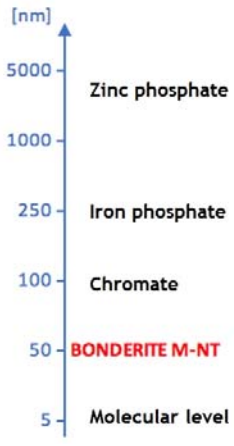

Figure 7. The comparison of thickness of the coatings [12]

Technology of preparing the surfaces of the products before painting based on BODERITE M-NT 2011 process is on the of the best available techniques (BAT) and it is of **innovative character**. It was developed in 2011 and launched to the Swiss market in 2012 [1]. It was implemented for the first time in Poland in 2013.

4.2 *Technology - Chemetall*

This technology is based on the end process with the use of OXILAN 9807 preparation. It belongs to the group of silane chemical agents, silicon compounds of general formula RSi (OX)3. It consists of polysiloxane and zirconium in the form of fluoride complex. These compounds react with surface of the metals forming thin, conversion coating permanently connected with the ground and varnish coating. The whole process of surface preparation takes place in four to six stages depending on the type of selected process. OXILAN 9807 does not contain heavy metals and phosphates [1].

The main features of OXILAN 9807 are the following:
- it does not contain heavy metals and phosphates;
- short processing time (a few seconds);
- no sludge (solid pollutants);
- final rising is not required – no use of water (significant problem and cost of processing of the grounds before painting).

Technology with the use of this preparation is an important step forward in comparison with standard processing of phosphating. The results of the research on corrosion properties (research in the aerosol chamber) of conversion coatings produced in Oxilan 9807 process are good enough to be comparable with coatings obtained as a result of cataphoresis, which are popular in the automotive industry (the highest requirements).

Just like the one above, technology of preparing the surfaces of the products before painting
based on OXILAN 9807 process is one of the best available techniques (BAT) and it is of **innovative character**.

Going through all phases of the process of technological powder painting **guarantees appropriate quality**, long-term operation and durability of the details. Quality acceptance of the details produced in technology of electrostatic painting with the use of powder paints includes checking specific values demanded by the clients. In order to meet expectations of the clients, painted parties are checked by controlling the values of microns of spread coating and adhesion of the paint coatings. The details come into use if they meet minimum assumed before technological process.

5 THE SELECTION OF GUARANTEED POWER SUPPLY OF PROCESSING LINE OF SPREADING COATINGS OF THE DETAILS OF AGV VEHICLES USED FOR RELOCATION OF THE CONTAINERS

N+1 system was accepted for technological process of spreading coatings over the details, in which the higher priority of acceptance, the higher necessity of using solutions that are not based on static workaround [18]. Parallel redundant configuration allows for failure of one of UPS units without transition to power supply directly from network. Two or more units of the same type work at the same time. This configuration requires for every UPS unit to have power higher or equal to power demanded by the receivers. Therefore, UPS units may work synchronously and parallel, that is, load must be divided. Every unit may be put away for the period of service in the uninterruptible way. Service workaround is still required in the event of service of a bus-bar [2]. Among many advantages of this solution is, above all, high degree of reliability of the system – higher than in the case of N configuration. One of the main defects is creation from single bus-bar a system point, which, in the event of a failure, causes faulty operation of the whole system. ABACUS software was applied in order to determine the time of battery backup for accepted UPS units in N+1 system. An outline of the system of guaranteed power supply N+1 and time charts of battery backup for designed system were presented on figure 8 a, b.

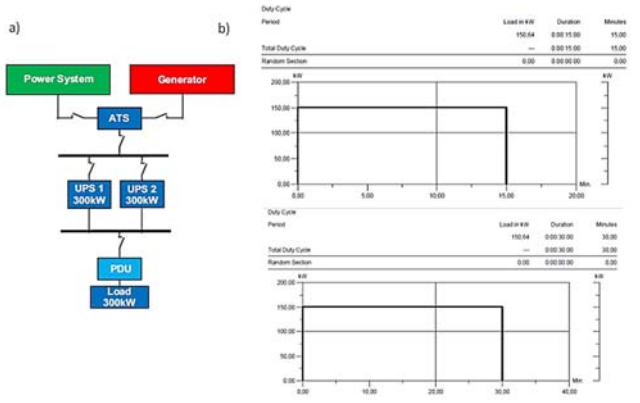

Figure 8. Guaranteed power supply of processing line of spreading coatings: a) an outline of N+1 system, b) time of battery backup of UPS 1 and UPS 2 units for the variants of 15 minutes and 30 minutes of supplying processing line obtained in ABACUS software, ATS - Automatic Transfer Switch, PDU - Power Distribution Unit

6 CONCLUSIONS

Systematization of operation of the handling terminal largely contributes to increasing the efficiency of logistic operations and improving transhipment works. The use of automated guided vehicles and automation of transport areas will lead to increasing the level of competitiveness and constant improvement of transport processes. Modern methods of spreading surfaces largely improve varnishing process and affect the quality of the coatings.

The basic advantage of technology of electrostatic painting with the use of powder paints used in the handling terminal for relocation of the containers is:

- No emission of solvents - 100% reduction of VOC (Volatile Organic Compounds).
- Reduction of solid pollutants through recycling of powder.

No emission of harmful substances during the processes of coating production (painting) is very important for the workers doing painting works (health and safety rules at work). The order of the Minister of Economy and Labour of October 20, 2005 Dz.U. [Journal of Laws] no. 216, item 1826 implementing recommendations of the Directive 2004/42/EC *on reduction of emission of volatile organic compounds as a result of application of organic solvents in some paints and varnishes and products for renovation of the vehicles* imposes high requirements concerning reduction of the content of volatile organic compounds (VOC) in the varnishing products. These compounds contribute to depletion of ozone layer in stratosphere and formation of summer smog in troposphere.

An important issue in the manufacturing technological processes is the aspect of guaranteed power supply. The main objective of selection of an appropriate system is the ability of selected system to increase the reliability of power supply in order to prevent stoppages during technological process. Battery system is supposed to guarantee, above all, uninterruptible power supply in specific time for failure removal. N+1 of UPS system selected and recommended by the authors guarantees completion of commenced operation of spreading coatings, which can be continued without losses after power restoration. However, it must be taken into account that accepted variant of guaranteed power supply for considered technological process for 15 and 30-minute backup, will considerably increase the costs of not only of UPS system with the batteries, but also of the whole electricity infrastructure.

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