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An Innovative Approach to Enameling Process Of Tanks' Interiors Dedicated to Domestic Hot Water and Central Heating

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Abstract

In the manuscript, an innovative approach of applying the enamel coating through the implementation of electrostatic method is presented. The new solution is strictly dedicated to tanks devoted to the domestic hot water and central heating tasks. In such a way, the technological line constructed in the Elektromet company is proposed, which can certainly be treated as the modern one, that has never been seen before. Two main parts of the industrial process are in relation with the respective units of preparing and enameling as well as burning by specialized furnace. The entire action presented in the manuscript confirms the usefulness of the new method conducted under the European Union programme called 'Fast track'. It should be emphasized, that the next stage of performing studies will be covered by the application of PLC-oriented layer into real infrastructure. This fact will be described in detail in the forthcoming paper. In the end, the conclusions with open problems related to the said patented approach, are indicated in the last part of the manuscript.

Keywords: Electrostatic method, enameling process, innovative approach, project profitability, technological line.

1. Introduction

Production technologies and methods of applying protective coatings for various types of tanks play an important role in durable and safe handling both domestic as well as broadly understood industrial applications (Gebril & Shuaeib, 2007), (Tator, 1984), (Reis et al., 2019). On the market we can find many competing producers of tanks for hot utility water and central heating (Winkelmann, 2020), (Elektromet, 2020). The parameters taken into account by end consumers include, in particular, the length of the warranty period for tanks, the corrosion protection methods used by the manufacturer and the price of the final products. In fact, in case

of tanks strictly derived from metals completely corrosion resistant, the warranty period could be very long. Unfortunately, such tanks would be significantly more expensive than other products and selling them, despite the definite advantage over quality, would be more difficult. In the practice, a plethora of solutions has been discussed, which certainly leads to selection the best one (Zwirner, 2018), (Hempel, 2020). Notwithstanding, choice of proper method is very difficult due to existence of different technological and financialoriented performance indices (Min'ko & Matveeva, 1999), (Schegel & Lips, 2008). Therefore, in order to meet the needed requirements, a new approach related to the electrostatic enamel coating method seems to be most reasonable. Its advantages over existing modern solutions can clearly be indicated, especially in terms of extending the warranty period. Thus, the new method gives a set of new possibilities directly improving the profitability of the entire tank manufacturing process (Ronald, 2020), (Activar, 2020).

In the manuscript, an innovative production methodology of said tanks covering their shape, and most importantly, preventive coating is given, which together with a new stamping technique, outperforms the classical solutions, especially the so-called wet method (Activar, 2020). The new approach can successively be implemented in reality, giving clear indications of overall success.

The paper is organized in the following manner. In Section 2, the porcelain enameling technique is effectively presented and its advantages over existing methods are clearly indicated. The new electrostatic-oriented proposal given in next section constitutes a main achievement of the manuscript. The profitability of the entire activity engaging the real process is touched in Section 4. In the end, the conclusions and open problems are summarized in the last section of the paper.

2. Porcelain enameling as the most commonly used protection method for HWTs

In the production of hot water tanks (HWTs), one of the important technological problems is their permanent protection against corrosion, both inside and outside their walls. The ideal solution would be production of tanks from corrosion-resistant materials, such as, e.g., stainless steel. Unfortunately, such tanks would be significantly more expensive than the typical, carbon steel ones and, consequently, the demand for them would be very limited. Therefore, in the products available currently on the market we usually deal with tanks made of carbon steel, painted with organic anti-corrosive coatings or covered with ceramic enamel porcelain (Gebril & Shuaeib, 2007).

Porcelain enameling technology, which is used for several decades for coating surfaces of different kinds of boilers, is considered to be the most durable corrosion protection for the hot water equipment. As numerous studies have shown, the expected durability of boilers protected

using this technology is longer than with alternative methods such as galvanizing or organic powder painting. Porcelain enamel is a coating with glass-like properties applied to a metal substrate in liquid or powder form, and then hardened at a temperature of about 800°C. Very good corrosion protection properties can be obtained in this way. According to the standard DIN 4753/3, the enamel layer should be at least 150 μm and should not exceed 500 μm. If local bumps are technically unavoidable, they should at least be limited to 1000 μm. The enamel layer should be even, smooth and shiny, with no visible pores or cracks; for instance, see: DIN 4753/3 –" Water heaters, water heating installations and storage water heaters for drinking water. Part 3: Corrosion protection on the water side by enamelling and cathodic protection – Requirements and testing".

To meet these requirements, the enamel layer may be applied by means of different methods, such as e.g.: flow coating, liquid spraying, electrostatic dry powder coating (Schegel & Lips, 2008).

In the previous years, tank enameling was only done using various liquid application methods such as above-mentioned flow coating or liquid spraying. However, these technologies have required large capital investments and a high level of knowledge as well as process skills to achieve good and consistent quality of the coatings. The following typical phases for the liquid application methods can be specified:

1. Stress relief annealing – thermal surface cleaning. During this phase the tanks are fired in an enamel oven at a temperature of 650-700°C.
2. Etching – chemical cleaning of the surface. It consists of a three-stage rinsing of tanks in special tubs.
3. Enameling – consists in distributing liquid enamel inside the tank, which is then thoroughly distributed on the inner surface of the tank and coils using turntables.
4. Burning – it takes place in a specialized enamel oven.

As a result, one obtains high quality corrosion protection which should ensure long and hygienic use of the tank. However, the main disadvantage of the liquid enamel application methods is the low repeatability and non-uniform structure and thickness of the coating enameling. During this process it is necessary to control many dynamically changing enamel parameters. Areas not covered with enamel are exposed to a rapid corrosion process which consequently shortens the life of the tank.

An effective solution to the above-mentioned problems was the introduction of electrostatic dry powder enamel application for HWTs. This technology simplifies the process of applying enamel coating and eliminates most of the waste emissions harmful to the environment. For this

reason, more and more boiler HWT enameling plants uses this technology worldwide at present. The following main phases of the electrostatic dry powder enamel application can be specified:

1. Blast room, where the cleaning material, shot at high speed, is thoroughly polished and prepares the surface for applying the enamel.
2. Enamel booth, where the computer-controlled varnishing lances electrostatically apply the enamel to the surface of the tank and coils.
3. Furnace, where at a temperature of over 800°C, the enamel tightly adheres to the ground, creating the highest quality corrosion protection.

The electrostatic application of dry powder enamels has many benefits versus traditional wet application methods, such as (according to the DET, Ditmer Enameling Technology – https://www.ditmer.nl/EN/Enameling):

1. Elimination of enamel preparation and drying stages which contributes to shorter lead times and fewer process steps.
2. Automatic recovery of over-spray powders which contributes to more efficient material utilization.
3. Benefits for the environment, because there are no air, waste water or solid waste emissions.
4. Simple systems with high level of automation helps to reduce labor costs and guarantee a good and constant finishing quality.
5. Powder enameling systems require less factory space than all wet enameling equipment.

Enamel coating applied by electrostatic method is characterized by higher quality and more uniform thickness throughout the entire area inside the tray. By using the electrostatic enameling method, the average tank life will increase by approximately 30% by increasing the corrosion resistance and defects in the material. However, dry enameling can be significantly less effective in covering hard-to-reach places inside the tank, especially when it has spiral coils. It is also particularly important here to properly prepare the surface of the tank before applying the dry enamel coating.

In order to overcome these and other problems, a new, significantly improved technology of the electrostatic dry powder enamel application for HWTs has been developed, which will be described in detail in the following section.

3. A new method of application of the enamel coating

As part of the project under Smart Growth Operational Programme 2014-2020, the firm Elektromet from Gołuszowice, Poland, obtained funds from the National Center for Research

and Development. The subject of co-financing is an innovative line for enameling the inner surface of the tanks, using a new innovative approach. Through the electrostatic phenomenon, the applied coating is characterized by high resistance to degradation during everyday use of tanks.

The postulated technological line consists of three sections guaranteeing adequate mechanical preparation of tanks, uniform application of enamel and permanent firing. Moving the tanks between such sections is to be carried out using the adjustable chain conveyors. A dedicated control system implementing the master PLC and various sensors, transducers, servo drives and conventional drives will operate in the system to ensure flexible movement of semi-finished products. The installed light curtain guarantees a lack of downtime in the whole process caused by the rearming of the technological line, especially when machining short series of various assortments. The tank preparation section consists of shot blasting units equipped with lances with nozzles and a cleaning segment covering the lance with blow-off nozzle. The lance positioning and centering manipulators along with the recovery and abrasive preparation system support the correct operations in this crucial section. On the other hand, the second section is dedicated to applying enamel. Like the tank preparation section, this part consists of enamel powder application units equipped with lances employing enamel nozzles. Manipulators for positioning and centering the spray lances together with the system of enamel powder conveyor as well as scheme of preparation of recovered enamel powder guarantee the correct course of the entire process.

In contrary to the existing solutions, the innovative method of application of the enamel coating can be characterized in the following manner. Sequentially, the tanks are delivered to the shot blasting segment by a light curtain. In the first and second units of the first section, the upper and bottom parts of the tank are cleaned, respectively, by using of the cast steel round shots. Thus, the upper-dedicated lance and the bottom-devoted inverted lance, having the nozzles with a shot blasting angle from the range of $45^{\circ}\pm5^{\circ}$, clean the insert of the tanks. In the next part of first section, the transported tanks are purged by compressed air of max. 6 bar pressure in order to remove the outstanding dust. Next, the tanks are transferred to the enamel powder application segment. In the first and second parts of second section, the enamel powder is applied by lances to the upper and bottom tank units, respectively, with a capacity of nozzles from 0.8 m^2 to 1.5 m^2 of surface per minute. At the end, in the final step of the entire process, the tanks are delivered by the second transporter to the sintering section, where the furnace temperature from the range of 820°C-850°C burns the raw enamel layer.

In such a way, after implementation of the proposed technology, a fully functional line will be created involving an innovative real time adapting mechanism to the size of enameled tanks. It should be emphasized, that the integration of all separate device's sections also covers a number of added values, never seen before. The application of new electrostatic enameling

approach using the beneficiary's technological solutions – under patent application No. P.418701, will allow to increase the production standards and result in obtaining the higher quality products than those offered by the competitors. At present, there are no solutions related to the activity indicated in the manuscript. In addition to the crucial technological advantages, the innovative method also increases the profitability of the services offered by the firm Elektromet, which will be shown in the next section. Pictures presented below clearly demonstrate the advanced construction prepared by beneficiary of the European Union programme - the Elektromet Company.

Figure 3.1: The installation view: front part

Source: author photograph

4. Profitability of the project

At the beginning, next to the project profitability, which is converted into financial proceeds, it is impossible not to mention an important aspect of the entire action impact on the natural

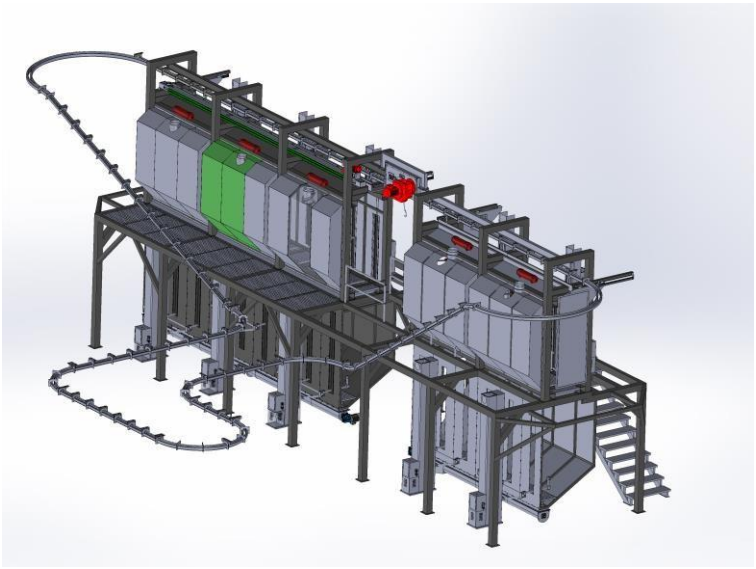
environment. The proposed new method through the optimal selection of the applied thickness of the enamel layer will allow the reduction of emission of waste and harmful substances to the environment. Moreover, this straight leads to the reduction of the enamel consumption, which is also a positive value here. Thus, in the ecological context, all of above possibilities give us an uncountable profit, which is the added value of a new methodology that falls under the trend of ’environment-friendly’ systems.

On the other hand, all activities related to the development and realization of the patented production line are associated with a cash expenditure of 1,19 million EUR (PLN/EUR exchange rate: 4,5962, 26.03.2020). In fact, this is a huge financial contribution in total, but from the point of view of the advantages of the new technology, this activity will allow the average saving in production of 2,97 EUR per item/tank. The planned net revenues during the five-year system operation should be at the level of 24,81 million EUR under average price of all types of tanks equal to 67,88 EUR.

Figure 3.2: The installation view: chain conveyor

Source: author photograph

Figure 3.3: The installation: CAD-oriented view



Source: author photograph

The employment of enamel coating by electrostatic method will increase revenues and, in particular, the quality of manufactured products. The optimal thickness of the applied layer,

provided here by a number of technological aspects, e.g., corresponding to the synthesis of thermal expansion processes between the different materials of crucial tank components with respect to such enamel coating, will allow to increase the product cycle life. Such solution will directly impact the possibility of extending the warranty protection period under reducing the warranty costs. Other properties associated with the used control system or the mechanism of rapid adaptive retooling of the production profile are invaluable.

5. Conclusions and open problems

The innovative method employing the patented method of enameling of tanks' interiors by the electrostatic phenomenon has been presented in this manuscript. Henceforth, the prototype of the production line prepared under European Union programme named 'Fast track', supervised by the National Centre for Research and Development of the Republic of Poland, can constitute an important solution from the practical and financial points of view. Thus, it would be very interesting to apply the control schemes supported by the Programmable Logic Controller(s) to the entire production process. Next intriguing aspect seems to be the broadly understood conducted research investigations, especially in context of optimization of investment outlays incurred by the beneficiary. The technique of applying the enamel can also constitute a real challenge, worth of further improvement. Notwithstanding, the open problems can be treated as the succeeding stages of the entire action planned by the Elektromet Company located in Gołuszowice, Poland.

References

[1] Gebril, M. and Shuaeib, F. (2007). Recent advances in protective coating of crude oil storage tanks. *Proceedings of the 6th Libyan Corrosion Conference*. Tripoli, Libya, pp. 460– 472.

[2] Tator, K.B. (1984). Selecting and applying protective coatings, *Journal (American Water Works Association)*, vol. 76, no. 1, pp. 60–63.

[3] Reis, S.T., Koenigstein, M., Fan, L., Chen, G., Pavić L. and Mogus-Milanković, A. (2019). The effects of silica on the properties of vitreous enamels, *Materials*, vol. 12, no. 2. pp. 248.

[4] Winkelmann Group. (2020) Producer of tanks for hot utility water. [Online]. Available: https://www.winkelmann-group.de/pl

[5] Elektromet. (2020) Producer of tanks for hot utility water. [Online]. Available: https://www.elektromet.com.pl/

[6] Zwirner Equipment Company. (2018) The truth about epoxy vs. enamel paint for your plant equipment. [Online]. Available: https://www.zwirnerequipment.com/blog/epoxy-vsenamel/

[7] Hempel. (2020) Guidelines for coating protection in accordance with ISO 12944. [Online]. Available: www.hempel.com/pdf/protective-brochures

[8] Min'ko, N.I. and Matveeva, T.A. (November 1999) Glass enamels for steel and cast-iron articles (review), *Glass and Ceramics*, vol. 56, pp. 358–363.

[9] Schegel, F.L.CH. and Lips, K. (2008). The pemcoat process: A new process that simplifies direct enamelling. *The 63rd Porcelain Enamel Institute Technical Forum: Ceramic Engineering and Science Proceedings*, vol. 22, no. 5, pp. 125–136.

[10] Ronald Ditmer. (2020). Main benefits of powder enamel. [Online]. Available: http://ronaldditmer.nl/home.html

[11] Activar Construction Products Group. (2020). Why use powder coat paint instead of baked enamel. [Online]. Available: https://www.activarcpg.com/activar-jl-industries-airlouvers/news/why-usepowder-coat-paint-instead-baked-enamel