Production Efficiency in Company with Small Series Production

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Abstract **– This paper elaborates the manufacturing process and efficiency in detail – what influenced the production systems in the past but also what they expect in the future. Also, the individual criteria according to which we can break down the production and the factors acting on it. The main efficiency calculation technique is the overall efficiency of the OEE (Overall Equipment Effectiveness) and its extension. There are clearly defined terms such as productivity, efficiency and effectiveness. The aim of this work is to make surface treatments more efficient, to increase savings and productivity.**

Keywords **– production process, efficiency, productivity, OEE, industrial revolution.**

1. Introduction

Developing trends in products, processes, materials and technologies are changing the manufacturing environment. The necessary transition to leaner, smarter and more flexible production will have a significant impact on the design, operation and control of factories, supply chains and the nature of work.

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Increased digitization and the use of data collection and analysis will allow for faster, more sensitive and interconnected production where products and production processes will be developed together to accommodate changing customer, market, or product requirements. conditions in factories and businesses. Production systems have evolved over many decades driven by advances in manufacturing technology and machine tools. The introduction of new materials and complex products requires new processing technologies and many organizational strategies that seek to minimize cost increases, quality and reliability and maximize profit. The greater the impact on the development of manufacturing systems is the proliferation of products that have motivated the transition from mass production to more flexible, configurable and variable manufacturing systems [23].

Nowadays, competitiveness is driven by differentiation, as the variety of products increases. Production is shifting from mass production, which produces more of the same products which is more cost effective, to more flexible systems and to production that is able to adapt and personalize economically to meet the growing demand for increased product diversity and to achieve maximum value for customers and manufacturing systems continue to evolve and adapt to these changes [2]. Production has seen many significant changes during the first, second and third industrial revolution. We are currently witnessing the Fourth Industrial Revolution which is characterized by more distributed, collaborative, networking and global production [4].

Sophisticated and powerful sensors and sensing techniques are being introduced to enable better communication between factory and enterprise manufacturers. Increasing computing power, speed and storage have made it possible to create new communication techniques, so-called a broadband information highway that makes use of the Internet of Things (IoT), the Industrial Internet of Things (IIoT) and the Internet of Production (IoP), allowing us to make better, real-time decisions. In turn, it creates a huge amount of data (Big Data) on all aspects of production and products and new products for smarter manufacturing systems for autonomous planning, operation and implementation.

2. Integrated Production Efficiency Approach

Many companies face new challenges due to the growing automation of production facilities and they continue with internationalization of their manufacturing facilities [3]. Automation and interconnection of production systems leads to complex production systems that must be global. The requirements for the development of global manufacturing networks are increasing, although the complexity of production costs, process quality and product quality is also increasing [1].

A commonly used value for assessing the efficiency of manufacturing systems is the overall equipment efficiency (OEE). OEE is a term that basically covers only one machine. However, there are widespread concepts, and they are mostly limited to individual production lines. There is no global extension of this efficiency concept that defines and summarizes the influencing parameters in the global production network [24]. The production process as a system is defined as the type of physical change. The architecture of the technological process, physical processes and their interactions is shown in Figure 1.

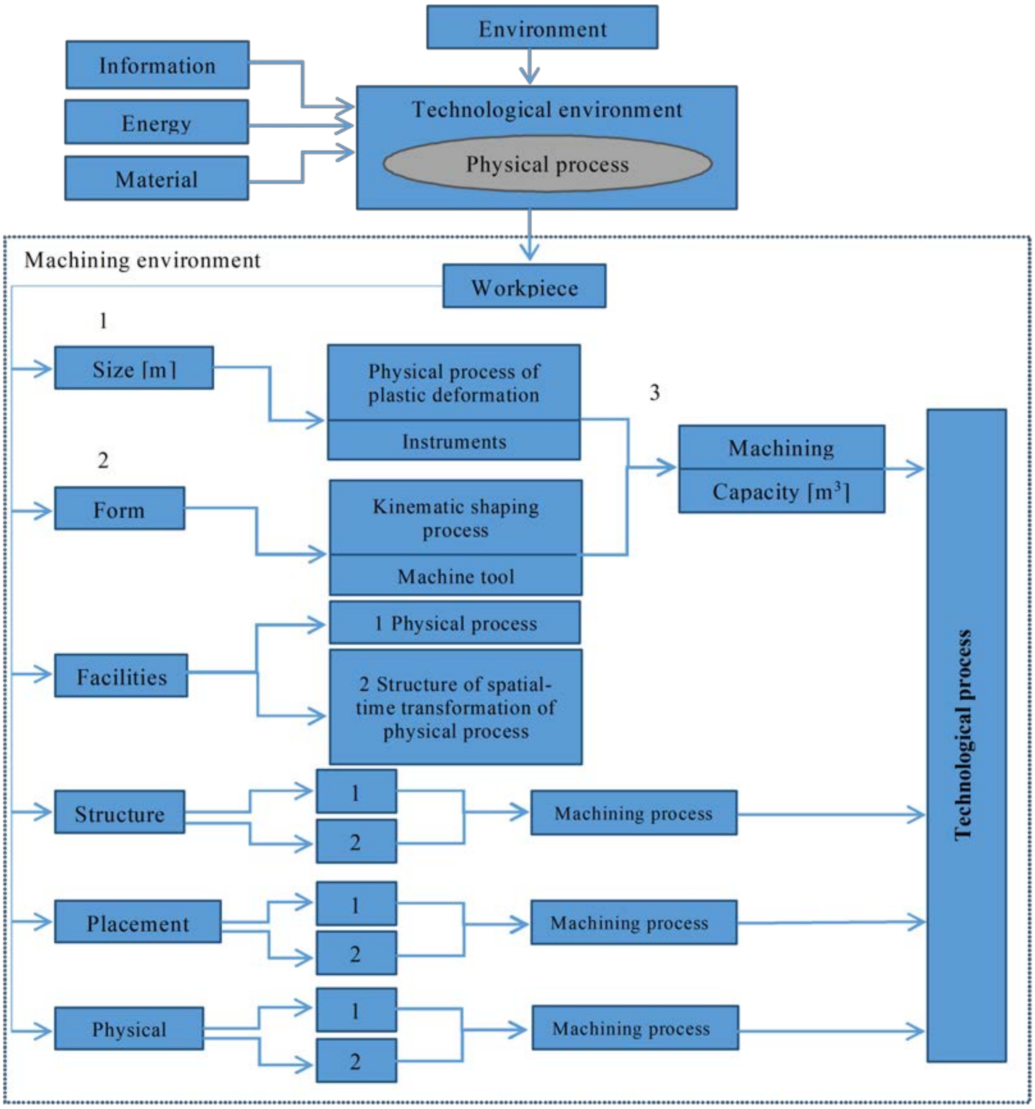

Figure 1. Integrated production efficiency approach

The technological process is carried out through a production facility using material, energy, information. The result of the technological process is a product that must meet the customer's expectations. Efficiency is the range of use of any source. Productivity is a measure of the change in properties, conditions, structure of matter [7], [8]. The accuracy of processes, equipment and production is determined by the level of compliance or degree of approximation of the amount of information about the actual properties, parameters and properties of the product (object, product or part) with the nominal amount of information or the ideal [25].

Therefore, the ratio (energy, information, time, etc.) of the E_{out} / E_{inp} is an estimate of E_e's efficiency. E_{inp} characterizes the resource used in the process of the technological machine, the production system. E_{out} is useful for the theoretical possible maximum resource value relative to the physical phenomena of a process, device or system [21], [22]. In all cases, using the value of the resources we have ideal use (nominal or theoretical) and real use (real). Then we can write an expression to evaluate performance indicators:

$$E_e = \frac{E_{out}}{E_{inp}} \; alebo \; E_e = \frac{E^f_{out}}{E^f_{out} + E^{ch}_{out}} \qquad (1)$$

Where:
E^f – physical processes using the resource,
E^{ch} – processes that ensure the use of the resource and its loss.

In general, when several types and forms of resources are used, we get:

$$E_e = \frac{\sum E^f_{out}}{\sum E^f_{out} + \sum E^{ch}_{out}} \qquad (2)$$

The comparison of processes, equipment and production based on their relationship is such:

$$U_e = \frac{E^1_e}{E^2_e} \qquad (3)$$

Overall Equipment Effectiveness (OEE) is a traditional Total Productive Maintenance (TPM) rating measure that needs to be maximized and compares the operational level with the ideal performance potential of the company [9]. The basic idea is based on the concept that this ideal operational potential is reduced by different losses.

Using this methodology identifies the reasons for these losses so that corrective action can be taken accordingly. The productivity value was developed by Seiichi Nakajima as part of the TPM. Initially, this term was only used in the TPM sector but OEE can now also be used as an independent tool to improve traffic, such as lean manufacturing and Six Sigma. OEE evaluates and improves the efficiency of machining and manufacturing processes for many companies and demonstrates the effectiveness of the TPM concept. OEE is increasingly used in many production and assembly lines for series production. Productivity and economic benefits can be well described with OEE. Based on recorded operational and mechanical data, OEE can be calculated very easily, for a defined production period. Figure 2. summarizes key elements and underlying affecting OEE parameters [5].

Global Production Efficiency (GPE) is based on OEE principles and describes all the essential determinants in a globally distributed production system. The development of GPE is first discussed by the factors that underlie the integrated key indicator [12]. Depending on the current network configuration, it is possible to identify and define individual determinants in a global context. Then, these parameters are individually compiled and then transferred to a global comprehensive survey [10].

The company's infrastructure provides a network in which the company operates and thus determines its geographical orientation. If the horizon is global, there must be a transnational supply, production and sales network that distributes structures and processes strategically to different locations [11].

The production network is particularly important to GPE, as GPE must be translated into several departments coming from production machines.

Manufacturing efficiency (ME) is the basic element of GPE. Using it, it is possible to measure the efficiency of individual sites and additionally indicate the link between GPE components [17].

The change still exists in joining the k value. This value indicates how many parts of the device are needed to join the plant [13].

The same goes for expansion. In addition, a variable factor (VAR) is introduced to be demonstrated by the flowchart shown in Figure 3. depending on available considered data and failures [20].

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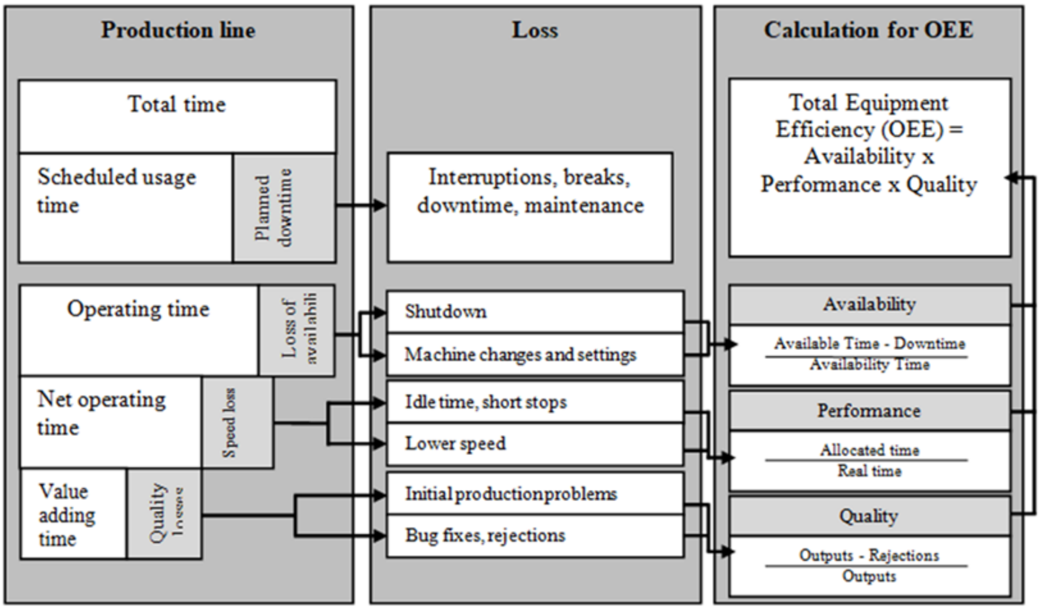

Figure 2. Basic elements and parameters OEE

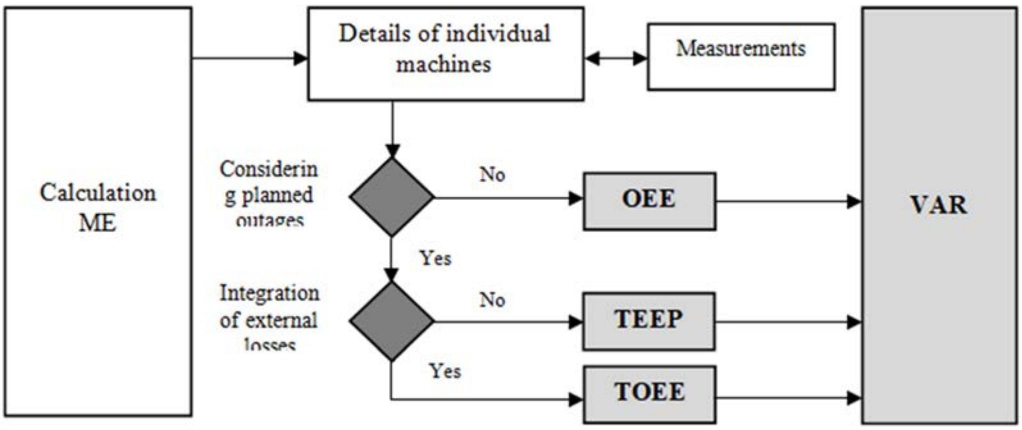

Figure 3. Production efficiency

$$ME_j = \left\{ min\left\{\frac{VAR_i * Q_a}{t_i * k_i^J}\right\}, \frac{VAR_a}{t_a}\right\} * min\left\{\min k_i^J * t_i, t_a\right\}, min \in \{1, \ldots\ldots, n\} \quad (4)$$

$$ME_S = min\left\{ min\left\{\frac{VAR_i}{t_i} * \prod_{j=i+1}^{n} Q_j\right\}, \frac{VAR_n}{t_n}\right\} * t_{BS}, min \in \{1, \ldots\ldots, n-1\} \quad (5)$$

$$ME_P = \frac{\sum_{i=1}^{n}\left(\frac{VAR_i}{t_i}\right)}{\sum_{i=1}^{n}\frac{1}{t_i}} \quad (6)$$

$$ME_E = \frac{\sum_{i=1}^{n} min\left\{\frac{VAR_i * k_i^E * Q_i}{t_i}, \frac{VAR_i}{t_i}\right\}}{\sum_{i=1}^{n} min\left\{\frac{k_i^E}{t_i}, \frac{1}{t_i}\right\}} \quad (7)$$

Where:

VAR – variable factor, Q – quality, n – last station index, a – station index after connection / expansion, t – cycle time, BS – obstacles.

For the ME calculation, the subsystems are modelled in accordance with equations (4) - (7), and the overall system is, on the contrary, considered as a subsystem serial system [16].

3. Production Efficiency Analysis in Small Batch Production

As we will be dealing with surface treatments in this part of the thesis, it is advisable to use the SIPOC diagram which shows the processes associated with this issue. SIPOC Diagram shows all surface treatment processes, their inputs and outputs [19].

The paint shop is a customer for suppliers. It contains all the necessary equipment for the paint shop which is necessary for the realization of painting and sanding [18].

Also included are activities such as protection of contact surfaces and panelling to the required requirements [15]. Furthermore, we can see the paint shop outputs, i.e. the painted part according to the protocol, followed by colour depreciation and stock update to make production ready for the following products. At the end is the installation for the paint shop [14].

Figure 4. illustrates the assembled water dam mechanism in the concrete casing and the water flow setting options, where:

A – Maximum regulated water flow,
B – Free water flow,
C – Regulated water flow,
D – Concrete skeleton.

The 3D model of the entire assembly in Figure 5. is modeled in SolidWorks. For better orientation and clarity, individual parts of the kit are distinguished by colour [6].

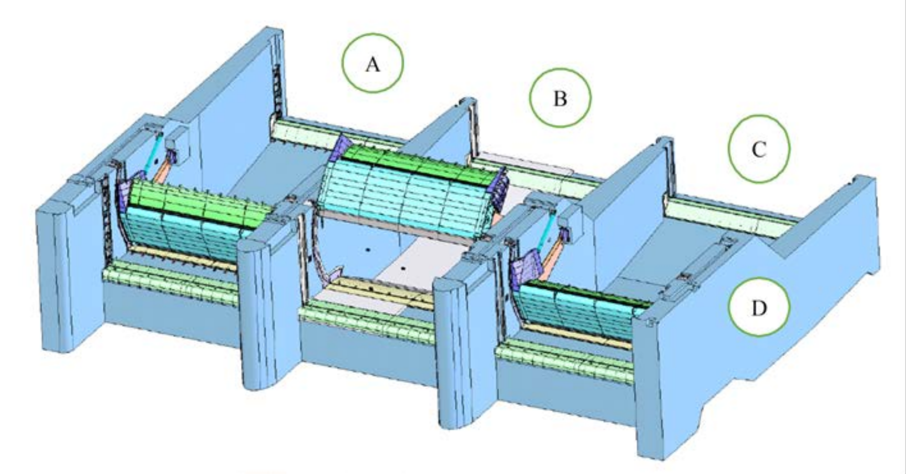

Figure 4. Assembled water dam mechanism

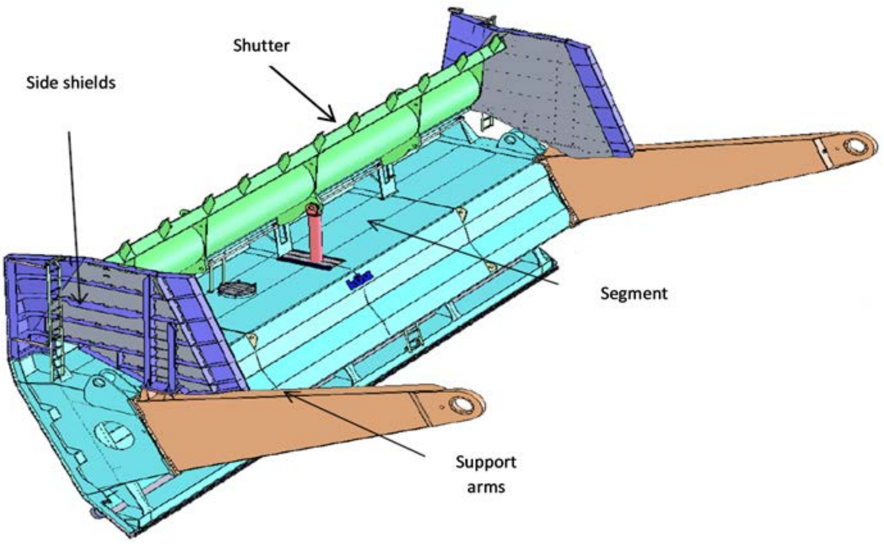

Figure 5. 3D assembly model

4. Analysis of the Initial State of Painting

From the Corrosion Sheet it is possible to determine the maximum required amount of colour. Based on the archiving of results (colour consumption and layer thickness measurements) to 3 pieces of the same water parts (segments) and then averaging, we found an initial state that represents a 36% excess of the total color thickness to the desired thickness.

On the water side, it is assumed that about + 30% of the colur thickness is added, while for the air side, about + 41% of the colour thickness is added over the nominal value, which on average causes a 36% colour overhang. Fig. 6. shows the applied paint thickness on the air side.

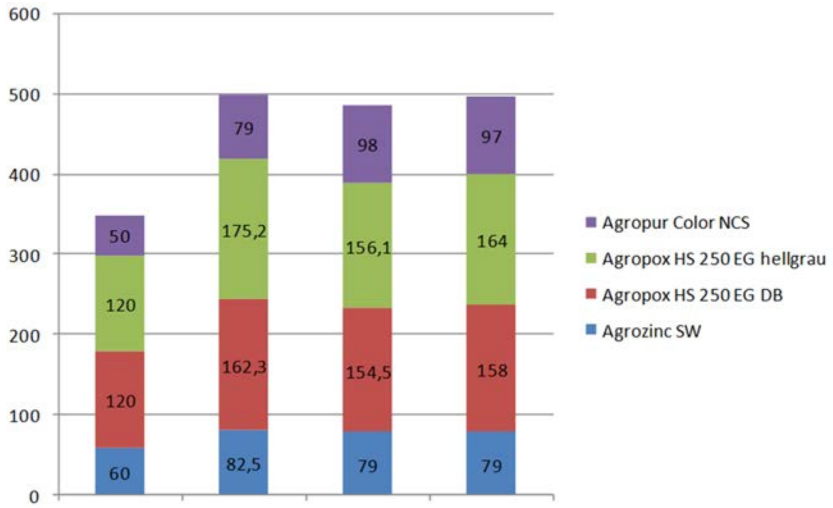

Figure 6. Applied paint thickness on the air side

The first column refers to the Corrosion Sheet from which the desired layer thicknesses are known. In the other columns, there are segments on which the measurement was made. On the right side of the graph is a legend that shows the individual colours used for painting.

The blue is the base, red and green are the 1st interlayer and the 2nd interlayer and the purple is the top marked. Figure 7. is similar to Figure 6., the difference is only in the painted part. And as can be seen, the thicknesses of the layers vary considerably from the air side.

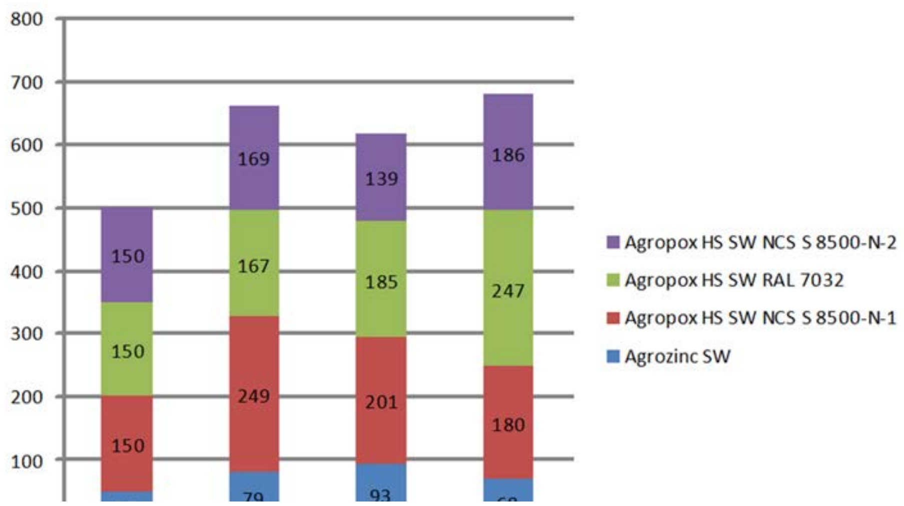

Figure 7. Colour Thickness - Water Side

5. Design Changes in Production Management with Regard to Production Efficiency

Time barriers and project meetings have identified obstacles to work towards to improve the quality:

- Wet self-inspection has not been performed at all.
- Drought control was only conducted by OTK employee (Technical Control Department) who considered the acceptability according to the acceptance criteria. Dry drought was the second important improvement.
- Marking of measured thicknesses by dry pencil directly on the part.
- Dirtying of parts - formation of tapes.
- Spraying parts - spray hose.
- Workplace lighting in enclosed parts.
- Monitoring of the quality results of painted parts during painting as well as monitoring the quality of each varnishes.
- Introducing the Paint Shop Leader - responsible for monitoring and painting quality.

Given the above issues, we suggest introducing the following corrective actions:

- Introduction of the wearing of the sleeves while walking on the parts, so as not to tread the part and to avoid coating defects. We propose to use the sleeves (see Figure 8.)
- Obligation to measure wet with record in protocol to improve painting (see Figure 9.).

Figure 8. Using of sleeves

Figure 9. Wet inspection

- Self-control for dry before painting next layer.

Pencil Marking After Dry Layer Measurement (see Figure 10.).

Figure 10. Marking of dry film thickness

- Implementation of workplace modification – hose holders with roller guidance. This is a part cleanliness.

Ensuring enough illumination for enclosed spaces (see Figure 11.).

Figure 11. Lighting and hose holders

The comparison of the results of the lacquered coating and the consumed colour evaluated in (kg, L) may vary by a non-part overset resulting from the technique of painting that painter. Therefore, the main criterion for assessing savings is the amount of colour used.

Based on the measures taken and based on the OEE calculations, we have adapted the following Segment 4 to these criteria. The results of the comparison can be seen in Figure 12. and Figure 13.

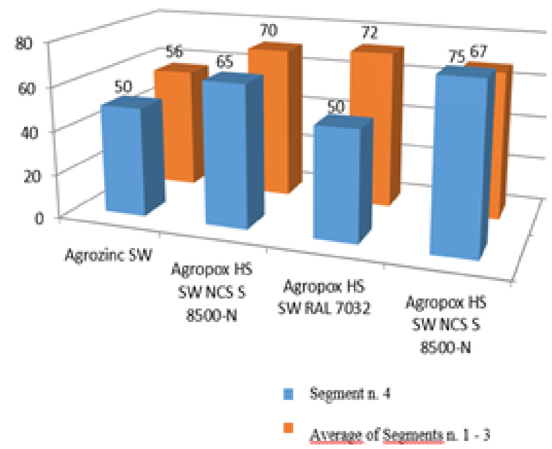

Figure 12. Colour comparison – water side

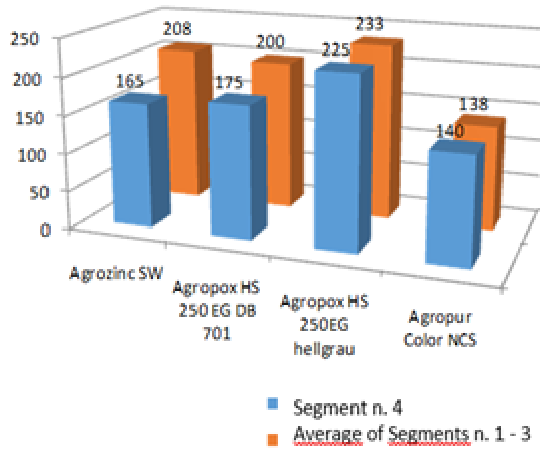

Figure 13. Colour comparison – air side

The new paint system is very similar to the original paint system. The only difference is that a wet check is performed after painting the part and it is decided whether the thickness is sufficient. If so, the part can dry and then the dry thickness is measured once more. If not, the part returns and must be sprayed again so that the colour thickness is sufficient.

At the second and subsequent layers, the runners are initially checked, and the dust is blown off. Again, parts of the part to be protected (if necessary) are glued. Subsequently, paint is prepared for overcoating and then the paint for coating the layer.

6. Conclusion

One of the main goals of manufacturing companies is to increase their market share, while it is important for every business to produce quality products at the lowest cost. An enterprise can only do this on condition that it follows the production process in detail and needs to be improved. Any waste can mean huge losses in the long run, so it is important to use all the company's resources effectively. The evolving trends in manufacturing systems have created a new way of thinking about production and are currently moving towards flexible and reconfigurable production systems. In the article, we focused on the coating system, and we mentioned that there is potential for improvement. Colours, whose thickness we tried to reduce and gain colour savings and basically streamline the surface treatment process, entered the analysis. We have succeeded in doing so because we have managed to avoid losses on the basis of the measures taken. The individual measures have put together a new system of problem prevention, as more frequent checks have been introduced that have led to improved results.

With remedial measures we have managed to improve, respectively making the surface finishing process more efficient. Surface finishes have dropped by almost 10% which can be seen as a very favourable result.

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