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# INCREASING THE EFFICIENCY LINE OF SURFACE TREATMENT PROCESSES OF THERMO-CHEMICAL REACTIONS BY USING

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***Abstract:*** The paper is oriented to the field of engineering production. Specifically, it focuses on the field of surface finishing on parts made of different grades of steel. These are surface treatments, using thermo-chemical reactions. In particular, alkaline blackening, or else burning and phosphating of zinc, also called bonderization. The paper deals with increasing efficiency and production possibilities on the line, which provides just these two metal surface treatments. With the help of simulation, a digital model of this line was created, where possible improvements of its production possibilities were tested. The task was to increase the flexibility and elasticity of production and ensure the fulfilment of orders in the greatest possible satisfaction of customers and in the shortest possible time.

## 1 Introduction

It is often not enough to produce products manufactured in the machine industry according to the present drawing documentation by means of chip machining. In many cases there is also a requirement for the visual and surface treatment of these parts. This coating is often required, either for aesthetic reasons or to improve the surface properties of the parts. Alkaline blackening and phosphate of zinc coatings are also suitable for these conditions. These coatings are characterized by the following properties [1].

Alkaline blackening of steel materials is a proven process between steel surface treatments. It is a way of colouring steel products to ensure the appearance, abrasion resistance and corrosion resistance of the parts so treated in combination with adequate preservatives that support this treatment and extend its service life. Technically, a conversion iron oxide layer is achieved by means of hot alkaline blackening. The process consists in depositing thin oxide layers consisting of mixed oxides ($FeO$ a $Fe_3O_4$) by immersion in a solution of acids, hydroxides or hot alkaline melt, for example a mixture of sodium hydroxide and sodium nitrite. This production process is also called noble rust. In contrast to conventional ($Fe_2O_3$), which peels from the parent metal, the oxides formed on the metal remain alkaline by blackening and prevent further oxidation. The treated surface is treated with a layer of preservative oil or varnish. This refined surface is achieved by a series of basic steps: Degreasing products, pickling, preheating and the blackening process itself. In the production process, it is necessary to maintain the necessary fluid temperatures, which range from 55 to about 142°C, depending on the operation.

Advantages of alkaline blackening (Figure 1):

- improves the appearance of components,
- increases abrasion resistance and improves corrosion resistance in combination with suitable impregnating oils,
- the dimensions of the parts to be treated remain unchanged, the coating being applied has a thickness of 0.5 to 2.5 µm,

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- long-term durability of the treated surface with suitable treatment.

Practical application of alkaline blackening:
- manufacture of weapons,
- manufacture of measuring instruments,
- production of binoculars,
- Engineering industry,
- etc.

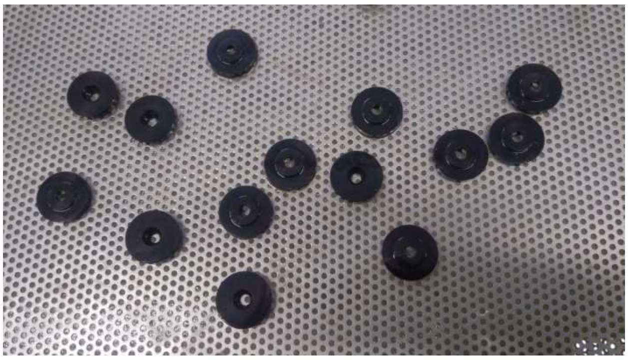

*Figure 1 Components after alkaline blackening and conservation*

Zinc phosphating is a chemical treatment of metal surfaces that creates corrosion-resistant coatings, minimizes surface friction and improves abrasion resistance (Figure 2). These coatings are electrically nonconductive, resulting in a reduction in the corrosion current. In this chemical process, an insoluble crystalline layer of phosphates and zinc is formed, which are neither soluble in water nor in organic solvents, thus having very good adhesion to the parent metal and thus providing a better adhesion of different kinds of paints. It is also possible to preserve the phosphate layer itself by means of a preservative oil, but this surface gives the possibility of good bonding of paints, waxes, lubricants, which reduces friction, varnish and the like.

Advantages of zinc phosphate layer:
- corrosion protection of metals,
- improvement of sliding properties,
- serves as an insulator,
- ability to bind another layer of adhesives,
- suitable for subsequent mechanical treatment (pressing, cutting, pulling, etc.),
- a protective layer of approx. 2 μm thickness.

Practical application of phosphating:
- surface protection layer of brake components,
- protection of the gear surface when running in gear systems,
- more durable alternative of primer for further dyeing process.

*Figure 2 Brake disc with surface treatment phosphate of zinc*

## 2 Original condition of surface treatment line and its properties

The production line on which both surface treatments are carried out consists of:
- 13 tubs of 180 l volume with chemical solutions and water rinses (Figure 3),
- gantry crane for material handling,
- an exhaust system to eliminate chemical vapours,
- material preparation workplaces,
- the final material inspection workplaces and packing workplaces.

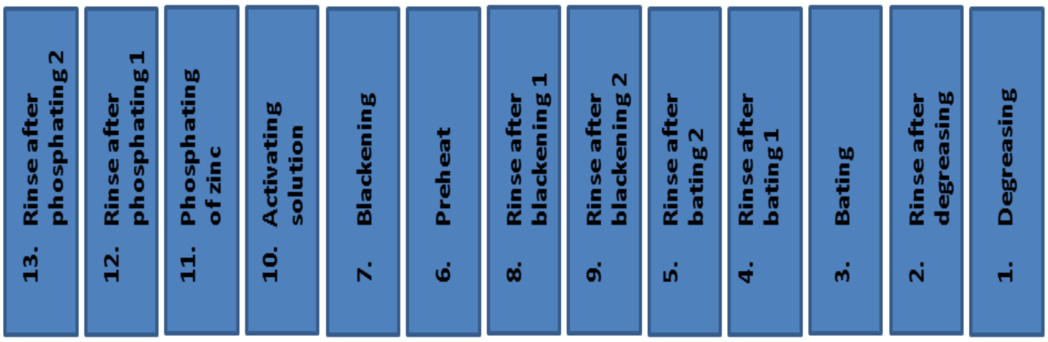


*Figure 3 Schematic representation of tubs on the surface treatment line*

***Comparison of the surface treatments in question***

The technological process and its sequence in the alkaline blackening process can be seen in Table 1. In the whole process it is necessary to observe the prescribed temperature and time ranges for individual operations [2].

A process similar to alkaline blackening is a phosphating of zinc process. The technological procedure of this surface treatment is shown in Table 2. It is also necessary to observe the prescribed temperatures, the sequence of operations and the time frame of individual operations in order to achieve the necessary surface quality.

*Table 1 Technological process of alkaline blackening*

| Odred | Temperature | Time | Production description |
|---|---|---|---|
| | | 10 min. | Input and preparation of input material |
| **Tubs no. 1** | 55-99 $^0$C | 1-6 min. | Degreasing of parts |
| **Tubs no. 2** | ambient temp | 30 sec. | Rinse after degreasing |
| **Tubs no. 3** | 15-30 $^0$C | 5-15 min. | Bating of the solution 15% HCl, removal of corrosion residues |
| **Tubs no. 4** | ambient temp | 30 sec. | Rinse after bating no.1 |
| **Tubs no. 5** | ambient temp | 30 sec. | Rinse after bating no.2 |
| **Tubs no. 6** | 60-70 $^0$C | 3-5 min. | Preheat |
| **Tubs no. 7** | 135-142 $^0$C | 12-20 min | Blackening, time and temperature depends on the material composition of the parts |
| **Tubs no. 8** | ambient temp | 30 sec. | Rinse after blackening no. 1 |
| **Tubs no. 9** | ambient temp | 30 sec. | Rinse after blackening no. 2 |
| | | | Drying and subsequent applying of parts with preservative oil, subsequent packaging of finished products |

Both production processes of surface treatment are placed on one frame and form one common workplace for both technological processes. This is because the processes are very similar and, in many parts, identical. In this way, the space and personnel that both processes are saved (Figure 4) [3]. The disadvantage of the current line structure is its low flexibility. It is not possible to perform both processes without restrictions at the same time. Depending on the needs and orders for individual finishes, the production currently operates in alternating mode. This means that one process is always performed during one working day and not simultaneously. However, this solution means for the customer that it takes at least 2 business days to fulfil both the phosphating of zinc and alkaline blackening process. As there is currently a greater demand for alkaline blackening, it often happens that the line is doing this process for several consecutive days, and orders for the second phosphating of zinc process have to wait several working days. The production ratio is about 70:30, (alkaline blackening: phosphating of zinc). Therefore, the worker working on the line performs one technological process of one surface treatment during the whole production change. In this process, one more person is required to prepare the material before the process as well as to complete it after the process and also to package it for distribution [4].

*Table 2 Technological process of phosphating for zinc*

| Order | Temoperature | Time | Production description |
|---|---|---|---|
| | | 10 min. | Input and preparation of input material |
| **Tubs no. 1** | 55-99 $^0$C | 1-6 min. | Degreasing of parts |
| **Tubs no. 2** | ambient temp | 30 sec. | Rinse after degreasing |
| **Tubs no. 3** | 15-30 $^0$C | 5-15 min. | Bating of the solution 15% HCl, removal of corrosion residues |
| **Tubs no. 4** | ambient temp | 30 sec. | Rinse after bating no.1 |
| **Tubs no. 5** | ambient temp | 30 sec. | Rinse after bating no.2 |
| **Tubs no. 10** | 15-30 $^0$C | 3-5 min. | Activating solution |
| **Tubs no. 11** | 65-70 $^0$C | 3-5 min | Phosphating of zinc |
| **Tubs no. 12** | ambient temp | 30 sec. | Rinse after phosphating no. 1 |
| **Tubs no. 13** | ambient temp | 30 sec. | Rinse after phosphating no. 2 |
| | | | Drying and subsequent packaging of finished products |


*Figure 4 Production line of surface treatment*

As can be seen in Tables 1 and 2, which show the technological processes, and from Figure 3, which shows the schematic arrangement of the line in both cases, the processes are very similar. The main difference is the final process, which has the largest share in the type and quality of surface treatment. From the technological processes it is well visible that the process of alkaline blackening requires more time. The main operation takes 20 minutes. In the phosphating of zinc process, the main operation takes 5 minutes. Figures 5 and 6 show simulations of the initial state of both production processes in one working day, or

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two working shifts, as the workplace operates in a two-shift operation.

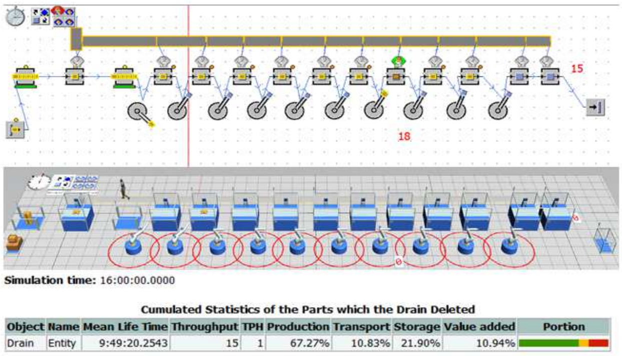


*Figure 5 Simulation model of alkaline blackening in its original state*

As can be seen in the simulation model in the alkaline blackening process, the line is able to process 15 batches in the current mode. One batch is considered to be a material that hangs on a special fixture to which parts of different shape and size can be hung. In the cumulative statistics generated by the program, we can see additional process data generated automatically by the Tecnomatix Plant Simulation software.

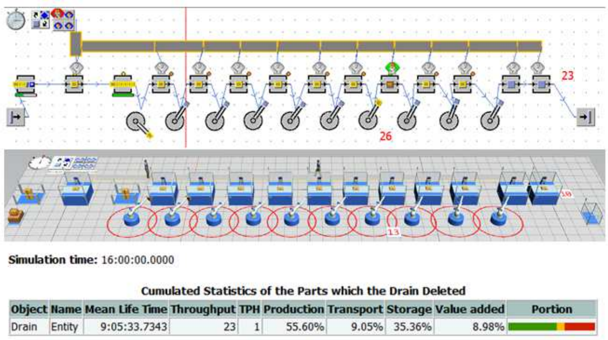


*Figure 6 Simulation model phosphating of zinc in the original state*

Also, from the simulation model phosphating of zinc (Figure 6) is evident, its less time consuming. During the working day the line is able to process 23 production batches. The company has determined as a unit of measure the weight of components it processes. The smallest production batch must be 30 kilograms and the line is capable of carrying 500 kg of material. However, weight does not play a role in software statistics; cumulative statistics are based only on the number of batches processed.

## 3 Linking both surface treatments into one concurrent production process and evaluating its properties

One customer often orders both types of surface treatment in one order and requests to process the order in the shortest possible time. As already mentioned, the line is not able to do two processes in one working day in the current production mode. This implies that processing of such an order takes at least 2 working days. However, it is optimal for the customer to wait for his order. Therefore, it is necessary to increase production flexibility. For this reason, the problem of how to increase production flexibility and ensure that both surface treatment processes can be done simultaneously within a single working day has been addressed. A simulation model was developed in the Tecnomatix Plant Simulation software module [5-7]. The design consists of an extension of the gantry crane and an additional track and hoist. Thus, it will be possible to perform two operations at the same time as the movement of the material along the line is conditioned by the movement of the hoist. The proposal will ensure that each surface treatment will have its own chain hoist and thus both alkaline blackening and phosphating of zinc can be performed simultaneously. However, it is necessary to employ second operator who will operate the new hoist, because one person would not be able to operate two hoists at the same time [8-15].

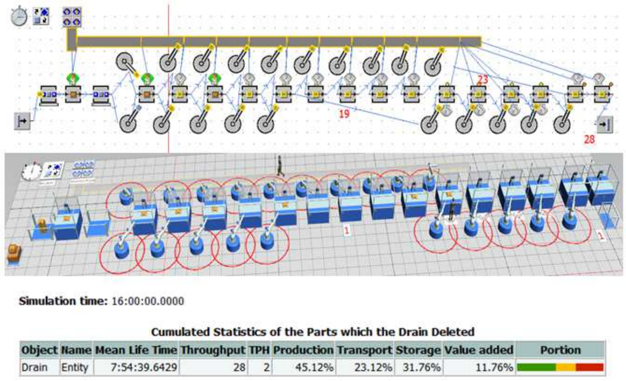


*Figure 7 Simulation model for the proposal of surface treatment unification into a parallel process*

The created simulation model of the design (Figure. 7) of the unification of production processes into a concurrent process shows that during two changes in one working day the line will simultaneously produce a total of 28 production hangers. The total added value of the parallel operation of the line is 11.76%.

## 4 Conclusions

Nowadays, when thinking about improving the efficiency or functionality of production lines and equipment, or making changes to entire production halls, companies do not have to make complicated and lengthy calculations about productivity and return on potential investment in technology improvement. The designs can be analysed in a relatively simple way with the help of simulation software, which, after setting several known parameters, will provide us with a lot of information on what production can look like after the change. It is possible to record various counters of individual devices, view graphical and statistical data and other necessary information that help management of the company to make the right decisions in the field of innovation and investment in interventions in production processes. In this way, time and money are currently saved in modernizing and improving production.

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