Improving the Dyehouse Production Process by QR Code Application as Poka Yoka

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Abstract

The dyeing process is one of the most sensitive phases in the manufacturing of textile products. Often the reason for the cost increase in this part of the production process lies in the mistakes that occur during the execution of dyeing operations, where a whole range of possible causes of errors (technologies, materials, chemicals, variability of the parameters of the mode of operation of machines, human factor ...) is present.

One of the reasons for their occurrence is the dosing of the paint that burdens the process as time-consuming as well as due to a constant possibility of decrease in concentration of workers, an error could be made in the procedure for measuring the quantity of different colors of the paint in order to obtain the appropriate shade.

As a result of the wrong dosage, there is a need to repeat parts of or complete dyeing operations. The aim of this paper is to present a solution that enables the process of measuring the color for obtaining a certain nuance, by using the QR code technology, corresponding software platforms and the principles of poka yoke. The above solution creates the conditions for the series of activities to be performed more efficiently and without the possibility of errors, while the traceability of the work activities in the production process rises to a high level.

Key words: *Poka Yoka, QR Code, Dyehouse*

1. INTRODUCTION

Textile manufacturing is a very dynamic area of industry and to remain competitive in this market is difficult and challenging. Nowadays, customers are becoming more demanding in terms of product quality, its originality and price.

Socks manufacturing is an important branch of textile industry, which also faces all of the stated challenges. For this reason, the analysis and the developed solution application proposal is given in this case study.

By analyzing the manufacturing process, it is concluded that the production of socks consists of five phases (Figure 1), which are:
1. Knitting,
2. Sewing,
3. Dyeing,
4. Pre-packaging,
5. Final packing-sorting.

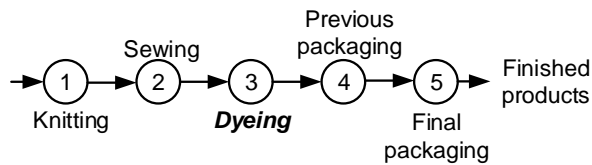**Process stages (Phases) of socks production**

Figure 1. Stages (Phases) of socks production

Each of the work phases has its own problems and specificities. The cost of performing certain phases of work is not the same, while the most severe consequences arise as a result of errors in work operations that occur in the dyeing phase. Precisely for this reason, in the revitalization of the production process it was necessary to make improvements first in the dyeing process.

Sock dyeing consists of several operations. It is done on machines that can be distinguished by their technological characteristics. The necessity of the technological diversity of machines used in the dyeing process stems from the specificity of the products to be dyed in them.

Sensitive materials (e.g. lycra) require to be handled with care, without rotation and manipulations that would jeopardize the structure of the product. Therefore, such materials are processed in machines that are constructed in such a way that the material is stationary during performance of certain operations while the fluid with chemicals and colors circulates around it.

On the other hand, less sensitive materials could be processed in machines where the material moves, while the fluid is stationary and mixing occurs due to the material rotation. Machines can accept the appropriate amount of material weight, which depends on the design dimensions. In addition, this quantity of material is called the batch.

The operations that need to be carried out in the dyeing process, regardless of whether the material moves or rests, are: washing, rinsing, painting, processing (not always only for certain types of items but mostly black and dark) and softening.

The operation of socks washing implies the addition of the washing agent at the appropriate temperature in order to remove impurities from the previous phases of the work (knitting and sewing) and handling semi-finished products (preparation for the dyeing process). Since materials often contain stronger impurities (e.g. grease that passes into materials in the knitting phase), this phase must be repeated frequently. This is the main cause for product returns, supported by the complaints initiated by quality sector from the fourth and fifth production stage. As the impurities separated from the materials and from detergents used for washing remain to a certain extent on the articles, it is necessary to perform a rinse operation.

Rinsing is carried out similar to washing, with the difference that only specific types of chemicals are added to this type of treatment. By its embodiment, the

washing and rinsing are performed in the same way, only the process parameters (time and temperature) are different. Bearing in mind that washing and rinsing remove all impurities from materials that can endanger the quality of the product, it is possible to continue to the next operation - dyeing.
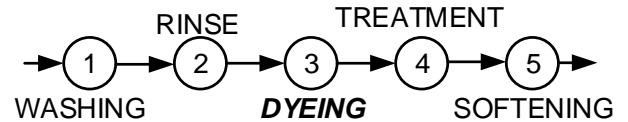
PROCESS of Dyeing

Figure 2. Structure of dyeing process

Dyeing operation (Fig. 2), carries the same name as the production phase (Fig. 1). It involves a number of interventions and therefore it is more complex for realization. The process starts by adding chemicals at the appropriate temperature and time, followed by the addition of colors mixture while keeping the final mixture on a certain temperature for a certain amount of time.

Then the mixture of chemicals and water colors is heated to a temperature t_2. Upon reaching this temperature, the heating stops and the products are kept for a certain amount of time at the so called "cooking" temperature.

Subsequently, it is necessary to the discharge the fleet from machines and the preparation for the next operation starts. Depending on whether the technology for the observed articles-products requires processing operation or not, the following operation is processing or softening. Since the operation in which the problem of losses is detected (which is also the subject of this research) precedes operations of processing and softening, these two last operations will not be peculiarly analyzed.

The aim of this paper is to provide an approach to improve the dyeing process by using an appropriate technological and conceptual approach with focus on the dyeing operation, based on QR code application, Poka Yoka LEAN tool and the corresponding software solution.

2. QR CODES

The concept of "Quick Response" (QR) codes began at a Japanese Toyota plant where QR codes were used to track inventory in order to improve production efficiency [1]. This concept provided necessary materials only when they were required, in the correct quantity and at the correct time. QR code defined by ISO/IEC18004 international standard [2], is now a popular scheme for embedding moderate amount of information in a 2D code pattern. QR code has numerous applications in manufacturing, sales, logistics, storage, transportation and consumer product industry [3]. A QR code pattern consists of black and white square dots as the basic binary information units. The number of dots, or the QR code size, varies with different QR code versions [2] and it is proportional to the amount of information stored

in the code. The minimum size can be 21×21 and maximum size can be 177×177.

According to the coding standard [2], a QR code generator/reader usually accepts four types of input data: numeric mode (0–9 integer numbers), alphanumeric mode (0–9 integer numbers, uppercase letters and some symbols), byte mode (for European characters) and Kanji (Kanji characters). It is evident that the four types of data are all designed for texts and characters and an image cannot be directly transformed to a QR code. In order to be compatible with common QR code generators and readers, it is feasible to convert an image into one of the text character modes first. In this paper, the simplest mode, numeric mode is adopted. A gray scale image is converted to a long binary sequence and the binary sequence is subsequently converted to a decimal integer sequence.

3. POKA YOKE

Poka Yoke represents another in a series of tools designed to prevent errors during the production process [4]. In translation from the Japanese language the word Poka means error, and Yoke prevention, while the overall meaning could be translated as protection against mistakes.

These are devices designed in a way to prevent the occurrence of human error. This tool was developed in the 1960s by Shingo Shingo of the Toyota Production System. He actually did a redesign of the process in which workers, during the assembly of the switch in the factory, keep forgeting to insert the necessary spring under one of the switch buttons. Here suggested the performance of this the task in two steps. At first, two springs are prepared and placed in the holder, and then inserted into the switch from the holder.

The moment the spring remains in the holder, the workers know that they have forgotten to insert it and there is a possibility to correct the error without effort. When determining the root of the problem, it is necessary to construct a Poka Yoke device. There is no system of how to make a device, but the construction rules of the simplest device should be followed [4].

4. PROBLEM DESCRIPTION

Each of the operations [5] identified in the dyeing process contains procedures that carry a lower or greater risk of making a mistake, which results in smaller or larger losses. However, the dyeing operation itself, consists of six sequences, which are:

1. the addition of chemicals,
2. maintaining the chemicals at temperature t_1
3. color adding at temperature t_1
4. color adjustment at temperature t_1 (the time is specified depending on product type)
5. heating of fleet to a temperature of t_2
6. maintaining the product at "cooking" temperature (t_2) in the mixture of water, chemicals and combination of different colors certain amount of time.

Special attention is paid to the sequence 3 (color adding at temperature t1). This consists of several actions that need to be carried out before adding the color to the washing machine (dyeing). The dyeing machine is in the same as the washing machine by design, while the only difference is found in the transition from one operation to another. Therefore, in some machines this transition is performed manually while others are automated or controlled by PLCs (Programmable Logic Controller) [6]. PLCs mainly manage the basic process parameters, and in this case, these are time and temperature.

However, what is common to all machines is that the addition of chemicals and mixtures of colors must be done manually. Addition of chemicals in the observed system must be done manually due to the physical limitations (the factory layout).

An unfavorable space available for holding chemicals greatly complicates the design and implementation of solutions with a certain degree of information and automated support.

Sequence 3 (color adding at temperature t1) includes the following activities which are executed sequentially:

- determining the type of article (determines the color) and the weight in the batch to be fished. Based on these two data, the color nuance and the amount of colors to be added are given to obtain the appropriate nuance,
- calculating the required amount of colors to get the proper nuance,
- delivery of colors from the warehouse,
- taking color from the shelf and measuring the appropriate quantity,
- adding water and vigorously mixing until the color mixture completely dissolves,
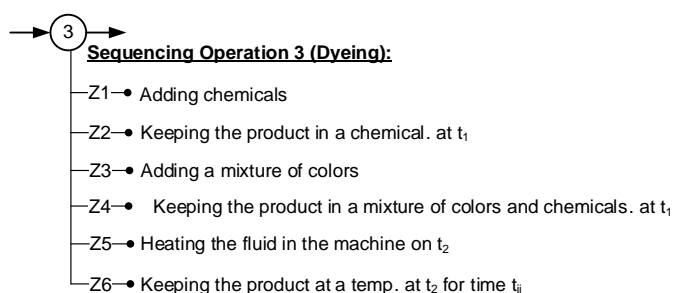- adding the mixture to the machine (Figure 3).

Sequencing Operation 3 (Dyeing):

- Z1 — Adding chemicals
- Z2 — Keeping the product in a chemical. at t_1
- Z3 — Adding a mixture of colors
- Z4 — Keeping the product in a mixture of colors and chemicals. at t_1
- Z5 — Heating the fluid in the machine on t_2
- Z6 — Keeping the product at a temp. at t_2 for time t_{ii}

Figure 3. Sequences in operation dyeing of products

The most sensitive activities of this sequence are:

- calculation of the required amount of color,
- exclusion of colors from the appropriate color-holding boxes, and
- weighing the required mass of the corresponding color nuance on the scale.

Sequence 3 (color adding at temperature t1) is performed according to algorithm given in the figure 4. According to the figure 4, it is necessary that worker calculates the masses needed for each of colors that fit

in the required nuance in the processed batch (position 1). Then he needs to pick the adequate color from the box (position 2) and for each of the colors determine the calculated amount on the scale (which is right next to the paint shelves - position 3). After measurements, color nuances should be poured in a bucket of water and stirred well to obtain the appropriate solution without granules and larger particles. Lastly, the prepared solution is poured into the machine (at appropriate temperature with already mixed chemicals).

Each activity is performed manually according to the given pattern. Due to the workers fatigue and the rhythmic repetition of these actions, it is possible to make a mistake. Color dosing, which often goes to the tenth of the gram accuracy, is very sensitive and requires movements that are compared to "shaking the ashes of cigarettes." For this reason, color dosing automation is very demanding and debatable as the varieties of colors differ considerably.

During exemption of boxes with color, it is possible to exclude a color that is not in accordance with the prescribed color recipe due to routine.
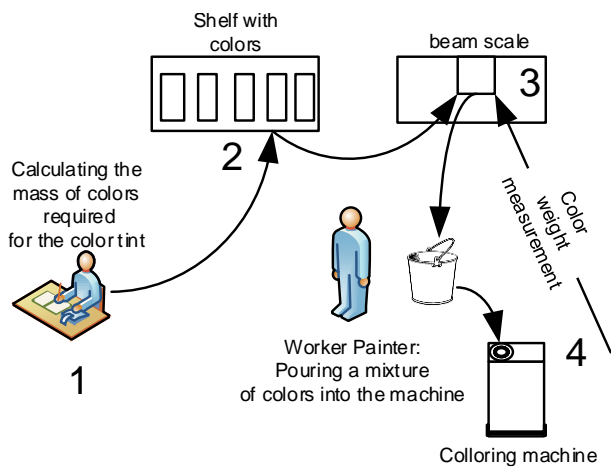

Figure 4. Working algorithm for dyeing

The calculation of necessary color mass for one production batch (the determination of the "recipe" - the combination of the necessary colors for dyeing the product batches), could be a source of possible mistakes also, where the time loss for this action could be significant. All of these problems significantly reduce the efficiency during execution of this sequence.

As a solution, a model for identifying sources of possible errors and a developed concept for overcoming these controversial activities as sources of errors is proposed. According to the developed model, the benefits of QR technology, software solution and the principle of poka-yoke LEAN thinking tools are applied based on integrated approach.

4.1 Proposed solution

Having in mind the previously described causes of errors, in order to eliminate and overcome them the poka-yoke way of thinking was applied in combination with advantages provided by QR technology utilization summarized in the corresponding software solution.

The first part of the software solution involves overcoming the need for calculations by workers. This means that, according to the developed solution, the worker will not deal with preparation of the corresponding nuance which needs to be dyed. By fitting the adequate mathematical equation, the appropriate part of the application was developed to perform this part of the work. Figure 5 shows the concept of the applied solution.

According to the activity algorithm required for established system, in the first step, the worker (1) should approach to computer (6). Afterwards, it is necessary to enter the parameters for its identification in the application that is displayed on the monitor (7) (Fig. 5), upon which all relevant information related to the product that is being dyed in a certain nuance should be entered. Upon the input of requested information, the color names and their specific masses are displayed.
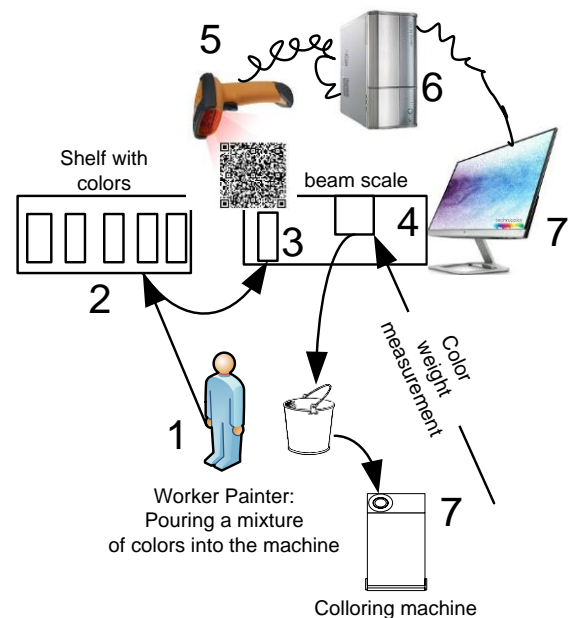

Figure 5. System for color measurement

According to the activity algorithm required for established system, in the first step, the worker (1) should approach to computer (6). Afterwards, it is necessary to enter the parameters for its identification in the application that is displayed on the monitor (7) (Fig. 5), upon which all relevant information related to the product that is being dyed in a certain nuance should be entered. Upon the input of requested information, the color names and their specific masses are displayed.

After excluding a colors box from the shelf, the worker transfers it on table (3) in front of the QR code reader (5). On the back of the box a QR code is placed and its role is to check that the correct color is taken, as well as is the selected color in accordance with the prescribed recipe. According to the displayed instructions, the

worker measures the color according to the required mass.

When the required mass coincides with the mass calculated by the application and the mass measured by the worker, the green field appears on the screen and the sound signal is recognizable for the correctly executed action. Provided signal also indicates that the transition to the next step is secured. On contrary, as long as the required color is not measured, a red signal and currently measured weight on the scale is visible on the screen. Each successive step repeats the same order of activity.

4.2 Software solution

The software solution can be divided into several parts. The main division is on two applications where each application is linked to a database, which is Firebase in this case. Applications are built in the Microsoft Visual Studio 2015 programming environment based on C# object-oriented programming language [8]. Firebase provides database services for real-time work. Unlike other databases that store data in a spreadsheet, the Firebase database provides the option of storing data in the form of a format such as JSON (Java Script Object Notation)[9]. JSON format is easy to process because it is presented in text format. JSON is based on two structures [10]:

- Collection of key / value pairs (e.g. object),
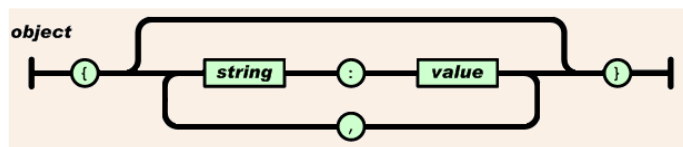- Edited list of values (e.g. array).

Figure 6. JSON object [11]

The object is an unregulated set of key / value pairs. Figure 6 shows the appearance of an object. Miscrosoft Visual Studio offers the ability to use libraries for ease of processing the JSON type. This project uses the Newtonsoft.Json 10.0.0.2 library. The libraries are embedded with NuGet Console, located in the Microsoft Visual Studio programming environment. By clicking the Tools section it is possible to select NuGet Package Manager and then NuGet Console. Then, Install-Package for Newtonsoft.Json is entered.

As noted above, for the purpose of research two applications have been developed. The first application is intended for generating a QR code, which will be used as the identifier of the colors used in the dyeing process, where each color has a unique identifier made up of color ID (color code) and color name. In addition, the second application consists of two parts: Administration and Processing. Part of the application is shown in the figure 7.
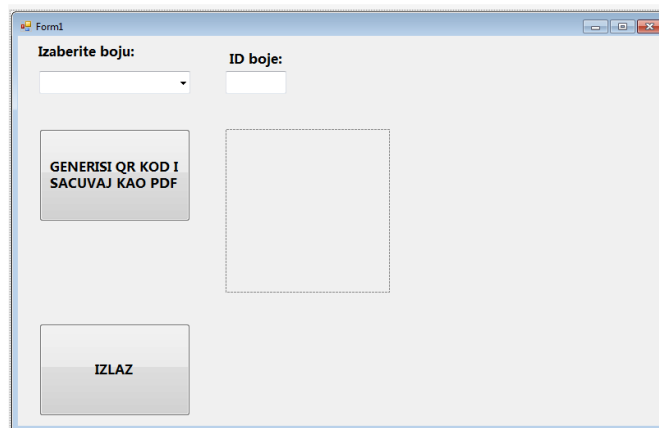

Figure 7. Partial view of the developed application

5. Conclusion

Observation of the workplace in the process of dyeing, led to the conclusion that the conditions and nature of work are such that they require psychological and physical readiness that is necessary to be at high level all the time. As the parameters of the work process (temperature and time), in terms of individual tasks, on most machines must be controlled manually, the consequences of any oscillations in the worker actions are generally recognized through high production costs. This results in significant reduction in both, product competitiveness (price) and quality.

Moreover, the application of the developed system for this production process reduces the "pressure" that previously burdened the workers. Apart from this, by carrying out activities related to the sub operation 3 (color adding at temperature t1) according to the above concept, the workers no longer have to worry about whether they have properly determined the required amount of colors. In addition, the accidental exclusion of color from the shelf is also completely prevented by the QR technology integration, while poka-yoke way of thinking in this case completely justified its application. Given the aforementioned, a small improvement in dyeing process has helped to eliminate a whole spectrum of possible consequences of identified errors, where the application of specific software solution enabled a much better traceability of the process. Lastly, worker performance analysis, material consumption (color), processing time, etc., are a number of advantages provided by implementation of software solution due to detailed data generation. Based on these analyses, it is possible to identify the sources of the problem and more importantly to develop a strategy for their overcoming.

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