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CONTROL METHOD OF WINDING QUALITY IN SHRINK SLEEVE LABELS CONVERTING PROCESS

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Abstract

In manufacturing practices of most big printing companies there are collected data and records of process parameters. Gathering information from this data in form of developed models and rules such as data mining, which uses statistical methods or Artificial Intelligence, Artificial Neural Networks, Decision Trees, Expert Systems, and others are subjects of interdisciplinary fields of science. In shrink sleeve production, the effects of using data mining tools not only improve the quality of the shrink sleeve and winding process but also reduce manufacturing costs.

This paper describes developed models of Artificial Neural Networks (ANN) to be used for predicting initial tension parameters and winding speeds for each and every new design of shrink sleeve labels. Every individual design of shrink sleeve labels has a lot of factors. Some of them are more significant, some of them less. The aim of this paper is to choose the significant factors and build a model of ANN in the learning process by using the collected data. Finally, when the ANN model is computed, it can be used for predicting key winding parameters of new shrink sleeve label designs. For the company, this will result in saved time of experimental selection during converting winding parameters like tension and speed. It will also minimize the risk of defects occurrence with incorrect winding parameters.

Key words: shrink sleeve, converting, quality, data mining, artificial neural networks

1. INTRODUCTION

In many references and online resources different definitions of shrink sleeve labels exist (FTA, 1999; Forum Sleeve, 2015; AWA, 2014; Kiphan, 2001; Kit, 2009), but for the purposes of implementing this dissertation the following definition was established:

- Shrink sleeve labels are manufactured by printing the plastic film followed by seaming the printed film into a sleeve, which under the influence of a determined temperature for a given material, shrinks and clings onto the target surface.
- Shrink sleeve labels are produced using flexographic printing technology, more specifically it is a rotary printing method that uses a flexible printing form to compensate for the surface irregularities of the substrate. Ink is transferred from the inkpot onto the flexible printing form by aniloxy roller and from there directly onto the substrate. Labels printed with this technique are used to perform unstable mass production. The group includes, for example shrink sleeve labels (FTA,1999).

Main steps in the shrink sleeve label production process are divided into four stages which result in a finished product of a wound roll of shrink sleeves. These stages are: printing, slitting, seaming and inspection. The common feature of the steps mentioned in the production process is the winding from a roll to roll (R2R), which is typical for flexographic printing process (Kipphan, 2001; Kit, 2009). A schematic diagram of a roll to roll production is shown below (figure 1).

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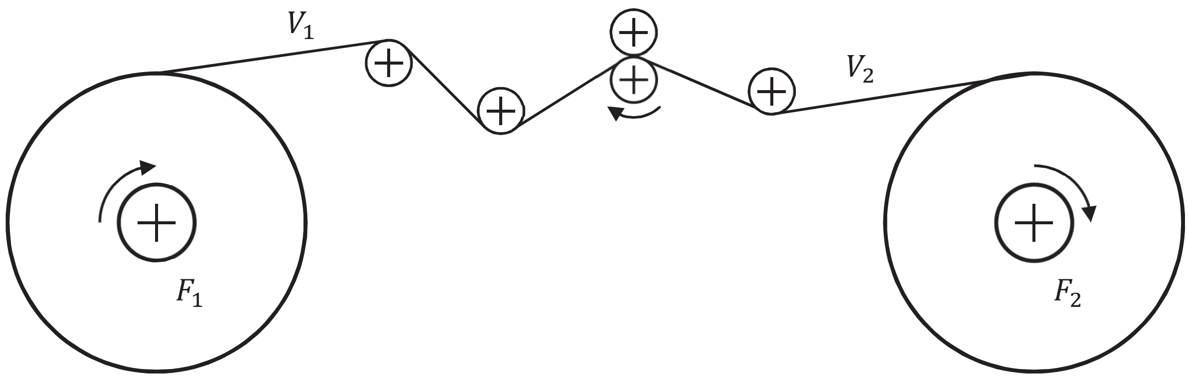

Fig. 1. *Schematic diagram of R2R production in converting process*

The winding and beam quality of the rolls at every stage of the process are essential to achieve the optimal quality of shrink sleeve labels and roll to roll winding process without problems. In reference to quality, it should be noted that significant factors which influence the winding quality are initial tension parameters and winding speed, which maintain appropriate web tension in the process. Winding quality issues indicate that incorrect tension parameters are setup on converting machines. There are two problems related to incorrect tension parameters: too high or too low tension, each of them causing different defects. The most important parameter which characterizes winding quality is lack of significant defects like glued sleeve layers, telescoping, film blocking, film web deformation (stretching), web wrinkling, damage of sleeve edge (U-fold), or finally wound damage, both – in manufacturing process and in final application process (Krystosiak & Werpachowski, 2014).

It is therefore expedient to collect, process and analyze information from the production process, and draw conclusions. It can be concluded that manufactured products speak to us through the data that we collect on them. Without these data, the enterprise doesn't have enough information related to the products which are produced. Identification of variables in the converting process will enable a better understanding of the phenomena occurring in the process and examine the possibility of adjusting such parameters as web tension setup.

2. WINDING QUALITY ISSUE

The winding quality issue is a topic of research at many universities and institutes, mainly abroad. It is worth mentioning, at this point, the research center at Oklahoma State University – the Web Handling Research Center, where issues concerning the processing of winding, packaging materials in the form of wounded rolls, are examined. One major question arises when speaking about the correct winding quality of converted product: what is the right tension? This issue is the subject of researches, and there are many different methods for determining the tension (Roisum, 1988; Walker, 2009; WH, 2015). However, this knowledge is based on experience and constant experimentation; and each organization should strive to improve their methods through this knowledge. The winding quality issue points to one fundamental problem of improperly adjusted tension values on the converting machines. The most common types of defects caused by too high or low tension setup on the converting machines are listed in the following table (table 1).

Table 1. *Typical problems related to wrong tension setup*

Too high tension	Too low tension
Glued sleeve inside	Telescoping
Film blocking	U-fold damages
Stretched film	Wrinkles
Web breaking	Beam damaged

3. PRELIMINARY RESEARCH RESULTS

Preliminary researches were conducted within the packaging industry where shrink sleeve labels are core product. The main reason for these researches was to determine which problems occurred during the converting processes. For this purpose Pareto-Lorentz analysis was used which is an excellent tool for indicating the factors responsible for a specific problem, also known as the Pareto principle 80/20 states that, for many events, roughly 80% of the effects come from 20% of the causes (Krystosiak & Werpachowski 2013).

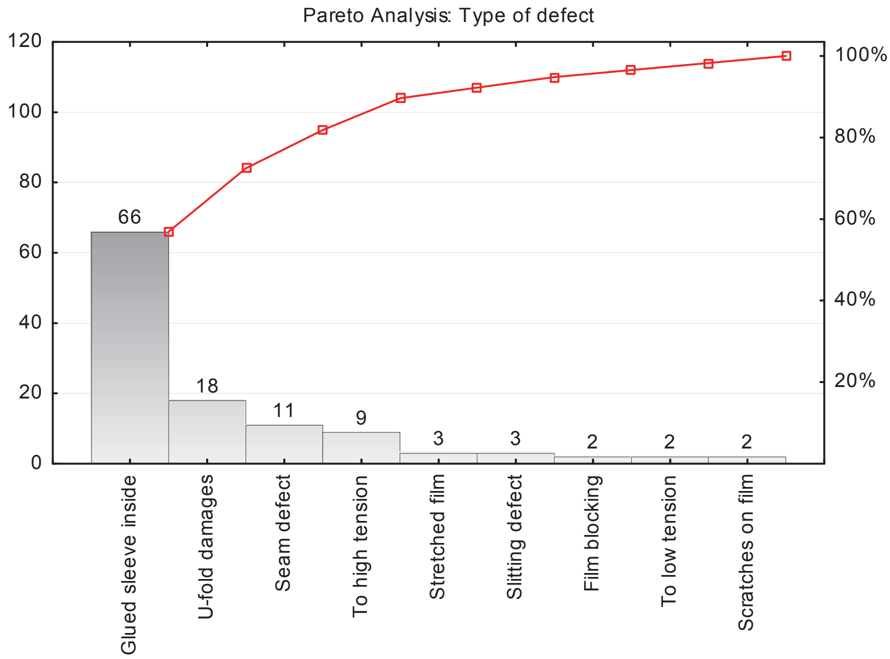

Fig. 2. *Pareto-Lorentz analysis of type of defects in converting process*

Table 2. *Summary of control variables in converting process*

Variable	Description	Unit	Data type
x_1	Web width	[mm]	Continous
x_2	Web thickness	[μm]	Continous
x_3	Material type	[X, Y, Z, …]	Discrete
x_4	Material manufacturer	[A, B, C, …]	Discrete
x_5	Converting machine	[S-1, S-2, S-3]	Discrete
x_6	Ink coverage	[1, 2, 3]	Discrete
x_7	Hot-melt	[0,1]	Discrete
x_8	Screen printing	[0,1]	Discrete

The present data states the quantity of non-conformities from the shrink sleeve label converting process which was registered in the packaging company from 2012 to 2013. The Pareto-Lorentz analysis of the various types of quality defects showed that the most common problem is glued sleeve inside (figure 2). This issue may arise as a result of incorrect web tension settings in the converting process. Among the many parameters which determine the quality level of the production process, based on personal experience, the carried out preliminary researches and conducted analyzes found that one of the main reasons for the use of improper tension setting was in fact due to missing or incorrect methods to effectively control the winding quality using web tension settings during the unwinding and rewinding of rolls in the converting process.

4. PREDICTING OF WINDING PARAMETERS WITH ARTIFICIAL NEURAL NETWORK

In order to develop an effective method to control winding quality, an Artificial Neural Network (ANN) was applied. Neural networks are usually used to solve problems of classification or regression. In this case it is typically a regressive problem. Pilot researches were conducted on the collected historical data of shrink sleeve labels during the seaming step of the converting process, which includes the following control variables listed below (table 2).

These variables are the input data to the ANN model. Unfortunately, some of the variables listed above in gray are not present; and the ANN model will be determined on the first six variables. At the network output there are three dependent variables - the initial settings of web tension on unwinding and rewinding roll in the converting process and winding speed which are listed in the table 3 below.

Table 3. *Summary of dependent variables in converting process*

Variable	Description	Unit	Data type
x_1	Unwind tension	[N]	Continous
x_2	Rewind tension	[N]	Continous
x_3	Winding speed	[m/min]	Continous

As shown, the input data presented both data types: continuous and discrete. This is not a problem due to the input of the ANN model because the ANN can compile different types of data. The mentioned input variables above apply only to certain parameters affecting the roll winding quality of shrink sleeve labels. Therefore, the developed model will not be perfect, as the process may include some interference. Also, the materials used may be of different quality; and certain characteristics can affect the winding quality, although this research needs to demonstrate a desirability of using this method. The target of the ANN model is to find the relationship between the input and output data.

Table 4. *Correlation matrix of input and output data for ANN model*

Variable	Mean	Standard deviation	Web width	Thickness	Winding speed	Unwinder tension	Rewinder tension
Web width	126,8962	38,61844	1,000000	0,065822	-0,187885	**0,637776**	**0,600814**
Thickness	47,1781	4,93726	0,065822	1,000000	-0,082456	0,108768	**0,209459**
Winding speed	348,0504	67,69137	-0,187885	-0,082456	1,000000	0,061095	-0,194684
Unwinder tension	35,4583	8,65569	**0,637776**	0,108768	0,061095	1,000000	0,500965
Rewinder tension	41,6955	12,34440	**0,600814**	**0,209459**	-0,194684	0,500965	1,000000

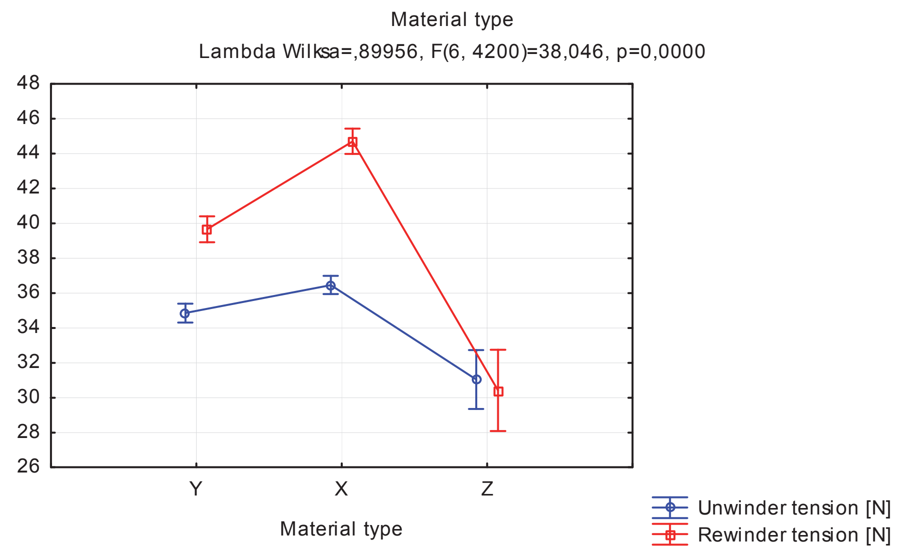

Fig. 3. *ANOVA analysis of material type*

The data records gathered come from October 2014 to March 2015 and include parameters from the seaming step of the manufacturing process. There were 2105 records. Records from work orders where any converting issues occurred were removed from this database. Next step in data mining process is to check correlations between control and dependent variables. A correlation table is presented below (table 4), and major coefficients have been highlighted.

An analysis of the variance was also conducted on the collected data, and it showed that there is a statistically significant variance in material type – material code “Z” was converted with a lower initial tension setup than material code “X” (figure 3).

5. RESULTS

In order to develop the ANN model, special software *Statistica Automated Neural Net-work* was used. Many variants of networks were tested; and finally, the model was selected: MLP 18-11-3, a multi-layer perceptron network with 18 neurons in the input layer (three discrete variables have been separated into individual neurons), 11 neurons in a hidden layer and 3 neurons in the output layer – as we have 3 dependent variables.

Developed in this way artificial neural network model has a correlation coefficient of input and output variables at the level of 0,78 for winding speed, 0,70 for the unwinder initial winding tension settings and 0,84 for the rewinder initial winding tension settings. These correlations were tested on a validation sample. Below the correlation graphs for each of the predicted variables (figure 4 – winding speed, figure 5 – unwinder tension, and figure 6 – rewinder tension) are presented.

Fig. 4. *ANN correlation graph for winding speed*

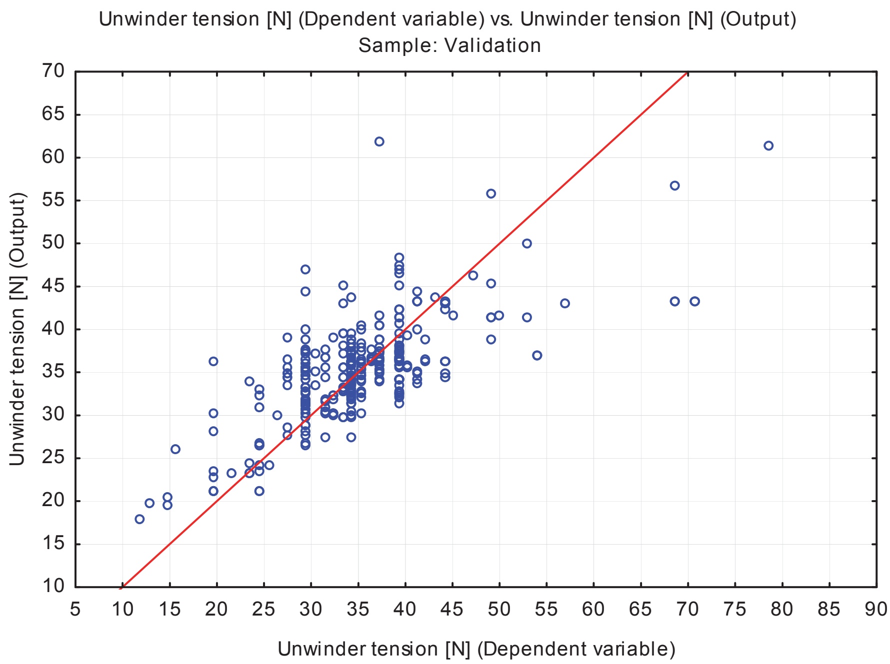

Fig. 5. *ANN correlation graph for unwinder tension*

Having analyzed the correlation graphs above, we can see a set of values substantially deviate from the correlation line, which can be explained in two ways: the data quality was not satisfactory enough or there are some variables or factors not included in the ANN model.

The obtained correlation of coefficients is oscillating in the range of 0,7 – 0,8 and as the industrial data are quite good the model may be useful – an Artificial Neural Network found dependences in the process.

The developed ANN model can be used for predicting the initial winding parameters of each new shrink sleeve label design. The variables of new designs will be set as the inputs, and the ANN model will compute the outputs such as the winding parameters – initial tension for the unwinder and rewinder and winding speed. This method can achieve saved time on the experimental way of setting of initial winding parameters during operation on work order, and a reduced risk of defect occurrence related to improper setup of winding parameters.

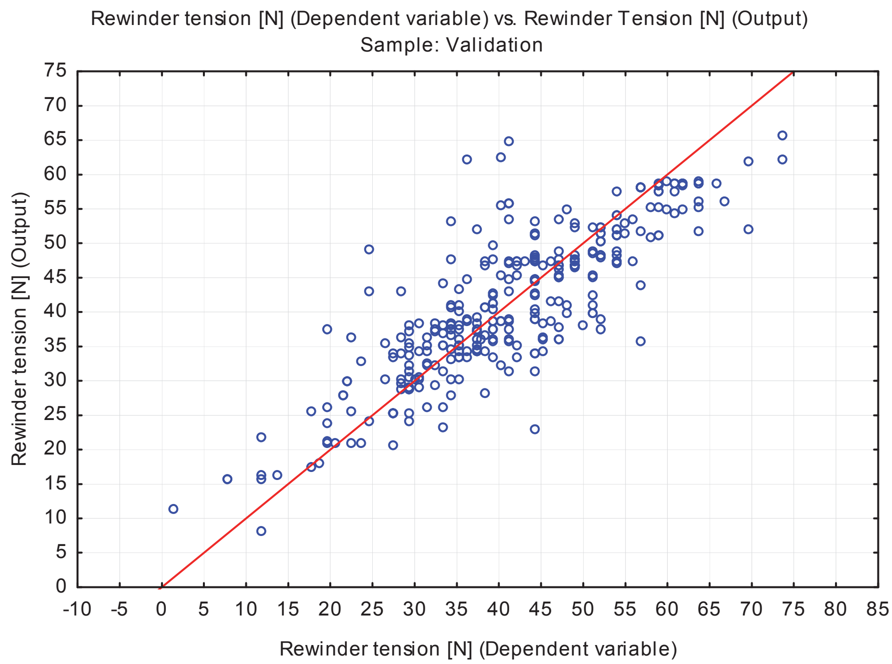

Fig. 6. *ANN correlation graph for rewinder tension*

6. CONCLUSIONS

The developed Artificial Neural Network model can be used for predicting the initial winding parameters such as the rewinder and unwinder tension and winding speed. The developed network can be used constantly to predict the winding parameters of each new production work order. Thus we need to bear in mind that in printing industry there are several new work orders every day, with different input parameters like web or sleeve width, type of material, ink amount or type, hot-melt layer etc., The Artificial Neural Network is able to perfectly find even complicated relationships and interactions in the process, and thus its use can be effective and measurable for the quality of the production process and the finished product.

The main rationale for the use of Artificial Neural Network in order to optimize shrink sleeve labels converting process is their main characteristics and advantages in their ability to reproduce very complicated relationships occurring in the processes, which also was confirmed in this study. Additionally, an important feature of Artificial Neural Networks is that variables don't need to represent the normal distribution and may belong to different data types: continuous and discrete.

The application of Artificial Neural Network in order to optimize the winding quality of the shrink sleeve labels has brought a positive effect. Pilot studies on historical data have shown that this method may be useful in order to determine the optimal initial winding parameters in the converting process based on several important factors determining the converting process. Research has shown that the Artificial Neural Network found dependences occurring in the process, but further research should focus on collecting data for all relevant factors, which are not included in current model of ANN, as well as limiting and less important factors.

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METODA STEROWANIA JAKOŚCIĄ NAWOJU W PROCESIĘ KONFEKCJONOWANIA ETYKIET TERMOKURCZLIWYCH

Streszczenie

W praktyce produkcyjnej w większości dużych przedsiębiorstw poligraficznych są gromadzone dane, zapisy dotyczące parametrów procesu. Wydobycie z nich informacji w postaci opracowanych modeli reguł i zasad postępowania jest przedmiotem interdyscyplinarnej dziedziny nauki jaką jest eksploracja danych, która wykorzystuje metody statystyczne, czy sztucznej inteligencji, jak np. sztuczne sieci neuronowe, drzewa decyzyjne, systemy ekspertowe, i inne. Efektem tych działań będzie poprawa jakości wyrobu i procesu oraz obniżenie kosztów wytwarzania.

Artykuł prezentuje opracowany model sztucznej sieci neuronowej (SSN), w celu wykorzystania do predykcji początkowych parametrów naciągów oraz prędkości nawijania dla każdego nowego wyrobu, czyli etykiet termokurczliwych. Każdy wzór etykiet termokurczliwych posiada wiele zmiennych. Niektóre z nich są bardziej istotne, inne mniej. Celem niniejszego artykułu jest wybór istotnych zmiennych i opracowanie modelu SSN w procesie uczenia sieci na zebranych danych. Model SSN obliczy wartości wyjściowe – w tym przypadku parametry początkowe naciągów dla odwijaka i nawijaka oraz prędkość nawijania. Uzyskany efekt, to zaoszczędzony czas na eksperymentalnym doborze naciągów w trakcie pracy przy danym zleceniu produkcyjnym, a także zmniejszone ryzyko wystąpienia wad związanych z niewłaściwie dobranymi wartościami naciągów.

Zastosowanie SSN w celu optymalizacji jakości nawijania przyniosło pozytywny efekt. Badania wstępne na danych historycznych z procesu konfekcjonowania udowodniły, że ta metoda może myć użyteczna do celu predykcji optymalnych wstępnych parametrów nawijania, takich jak naciągi czy prędkość, bazując na kilku najistotniejszych zmiennych opisujących proces konfekcjonowania. Niniejsze badania potwierdziły, że model Sztucznej Sieci Neuronowej odnalazł zależności występujące w procesie konfekcjonowania.

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