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Management the Quality Control of Application the Adhesive on a Flat Material

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ABSTRACT

Control of accuracy in quality of the products is essential. However, when the products move on the production line in a high speed it might be a problem. During production the paper boxes for packaging purposes the adhesive is applied on corrugated paper as a flat material. The accuracy in application of adhesive on corrugated paper has a direct influence on quality of boxes as final products. The problem of adhesive application is that the production line moves so fast that the physical checking is not possible. Therefore, the automated control is necessary. The designed equipment uses the principle of transmitted signal and its subsequent scanning while eliminating the external influences. The property of the dispersion adhesive, which necessarily contains water, is used when scanning, especially immediately after the application. The adhesive has a different reflection than its surroundings. The reflectivity depends on the wavelength of the test light being emitted. Experimentally, it was verified that the most suitable UV light would be below 400 nm. The external influences may be caused, in particular, by illuminating the hall where oscillation of the light intensity caused by the 50Hz supply voltage can appear. Fluctuation of component parameters, such as temperature changes and possible aging, must also be corrected. The program for the controlling the signals is written in ASSEMBLER and C programming language.

Keywords: Production, control, management, program, adhesive.

Mathematics Subject Classification: 94-04

Computing Classification System: J.7

1. INTRODUCTION

The quality control is an important part of the production processes. When quality control is automated, it can achieve both faster verification speeds and greater accuracy. The paper focuses on control the accuracy in application the adhesives in the factory for the box production. The boxes,

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which are produced, are used for packaging purposes and therefore the accuracy in the adhesive application can directly influence the qualitative properties of the produced packaging. With regard to the amount and speed of production, it is not possible to control the application of the adhesive physically individually, but automated control of the adhesive control is required.

Antonyová and Antony wrote several scientific works, which are based on the experimental activities and are devoted to the control processes. Management the control of recycling process for a waste paper resulted in the construction of the sensor to prevent clogging the paper pieces flowing through the chamber in the pressing apparatus (Antonyová and Antony, 2016). They also work on management the electro flotation process together with their colleague Benfano Soewito (Antonyová et al., 2015). The control system was made as authomatic with possibility of setting the parameters also through the Ethernet connection in the collaboration with E. Joelianto (Antonyová et al., 2017). The flotation process was used especially for reduction of the wather pollution. The water treatment with the use of the electro-flotation process has been shown to be particularly effective for contamination with dispersing colorants included in the reverse logistics chain. Efforts to maintain a clean and safe environment are the driving force behind the scientific research of many scientists. Zachary Moran Leffakis proposes the future research to increase the production of manufacturers with respect to the environment (Leffakis, 2016).

Another driving force of research activities is the effort to increase work productivity, precision of machined products as well as automation of the management in the control the individual phases of production processes. Joelianto et al. (2013) worked on improvement of the transient response performances standard PID controller has performance limitations. Their research results were checked using the generated training data set (Joelianto et al., 2013). Another scientific work of Joelianto with Williamson is devoted to improvement of transient response of feedback control systems using the hybrid reference control (HRC) system (Joelianto and Williamson, 2009). Paulo Leitão and Nelson Rodrigues devoted their research to designing the multi-agent system according to the current requirements of re-configurability, flexibility and modularity. The system adresses processes of integration the production and quality controling in washing machines production (Leitão and Rodrigues, 2011). William I. Norton Jr. and Lyle Sussman introduce how quality control is subject to team performance. The team plays an important role, especially when introducing new products into production (Norton and Sussman, 2009).

The proposed article focuses on management the quality control of the applied adhesives. Adhesives are usually characterised with their strength and releasability. Daniel R. King and Alfred J. Cosby modeled prediction to calculate compliance of adhesive properties with respect to geometric properties as well as the sort of the bonded materials (King and Crosby, 2015). The demonstrated optimization has wide applications especially in industrial settings.

Marcos Ricardo Rosa Georges aims his research into control of self-adhesive production. The production requires for its specificity a unique system with the continuous flow of the data as well as the decisions. The control system (Georges, 2010) was implemented after six months of development. The system is able to model the production processes and provide the necessary flow

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of the data. Moreover, the scientific work of Ellen Haustein, Robert Luther and Peter Schuster is devoted to control systems. Their theoretical work (Haustein et al., 2014) focuses on innovative activities of companies involved in designing management control systems to prove that the control system is not a hindrance of creativity. Construction of analysis algorithm using asymptotic stability analysis of fuzzy control systems can be applied to control nonlinear process (Tomescu et. al., 2007).

Modern technologies enable deeper research and optimization of manufacturing processes. Such technologies include in particular: genetic programming, evolutionary programming, genetic algorithm, evolution strategies etc. (Oduguwa et al., 2005). For instance Masumeh Shams, Esmat Rashedi, Seyed Mokhtar Dashti and Ahmad Hakimi present novel optimization algorithm that is inspired by the first law of thermodynamics and kinetic theory (Shams et al., 2017). Alejandro Garcia, Alberto Luviano-Juarez, Isaac Chairez, Alexander Poznyak and Tatyana Poznyak propose projectional dynamic neural network while using second Lyapunov's method to prove the practical stability of the identification error (Garcia et al., 2011).

Barbosa et al. tested the mechanical properties of structural adhesives (Barbosa et al., 2017), especially epoxy resins as one of new, modern bonding methods. Epoxy resins are of greater applicability, mainly due to their good chemical, thermal and mechanical resistance as well as modulus of elasticity. Many research results are mainly associated with tensile and ductility tests. According to the testing, the mechanical properties were influenced for instance using of plasma surface treatment. Jaeho Lee, Jayendra Maharjan, Muyang He and Chang-Dong Yeo investigate dynamic surface interaction in relation to adhesion. The horizontal motion of the samples was tested with the systematic experiments (Lee et al., 2015). Evandro Piva, Eduardo C. Azevedo, Aline O. Ogliari, Katerine J. Pilownic, Marcia B. Pinto, Guilherme B. Camacho, Cesar L. Petzhold and Fabrício A. Ogliari stress the importance of use the proper adhesive in the bonding protocol of NiCr alloys (Piva et al., 2015).

2. METHODOLOGY

The equipment to control the accuracy of the applied adhesives was constructed, tested and implemented into practical use. The adhesive is applied on both white and brown corrugated paper. Control the quality of application should be automated as pieces of the corrugated papers that are cut according to the shape of the packaging box move on the line at a speed about 2000 pieces per second. It means that physical control with individual is not possible. However, the accuracy of application the adhesive directly influences the quality of the packaging boxes.

Figure 1 shows the main principle in management the control process. The shape of the glue surface applied to corrugated paper is controlled by the transmitting and receiving diodes. The diodes transmit both red and UV light. The red light serves as a reference light, which is necessary for correction the evaluation of the overall measurement to ensure the independence of the measurement from the corrugated paper distance fluctuations when moving on the line by the pre-bending process of the bending in the shape of the box.

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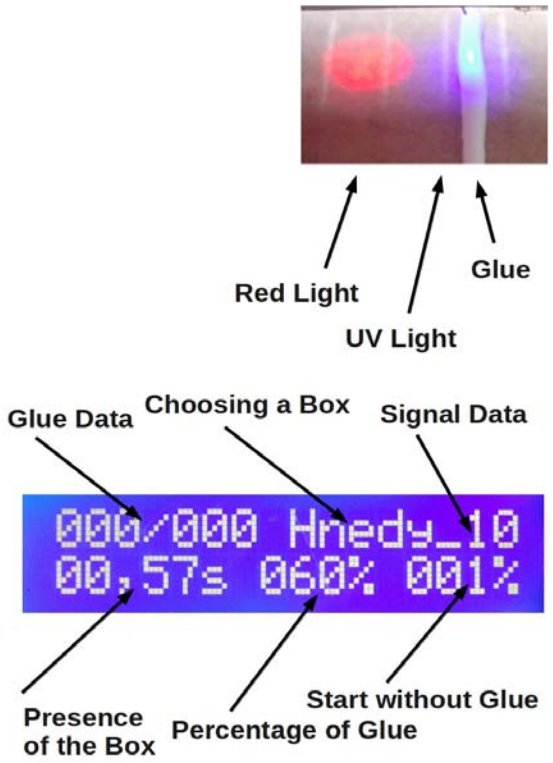

Figure 1. Schematic representation of the sensing principle for checking the accuracy in application of adhesive.

Figure 2 shows the process as it appears at the production belt, where:

A … Gap (value expressed on the display as: Start without glue),

B … Length of adhesive,

C ... Gap (part without applied adhesive).

$$A + B + C = 100\% \tag{1}$$

The values *A* and *B* are evaluated through comparison with the pre-set input parameters. The error is reported if: *A* > value of the input parameter, *B* < value of the input parameter. The input parameters depend on the size of the glued area. Parameters must be set so that the applied adhesive ensures the strength of the joint. At the same time, the adhesive-coated surface must be as optimal as to prevent the glue from overflowing during compression of the interlocking parts.

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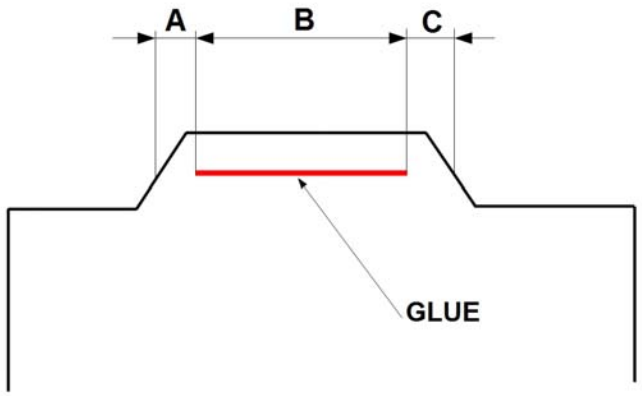

Figure 2. Material with glue as adhesive application on the flat material of corrugated paper.

Figure 3 uses the flow chart to express the process of control the accuracy in application of adhesive. The whole process is repeated in a high speed of 2500 times per second. “Test of Red PIN diode” means testing the reflection of the environment (surrounding interference environment) captured by the appropriate PIN photodiode. Similarly, it is regarding UV PIN diode.
In the algorithm, the detection uses conditions:

$$red - bred < \varepsilon_1$$

$$ultra - bultra < \varepsilon_2$$

Expression: ”red – bred” means the difference of signals detected by PIN diodes with red light on (red) minus without red light on (bred). Similarly,”ultra – bultra” means the difference of signals detected by PIN diodes with UV light on (ultra) minus without UV light on (bultra). The "idle" signal is never stronger than the signal obtained from a reflection of some material. The "idle" signal is given by the surrounding light, and the reflection is always greater than zero ($\varepsilon_1, \varepsilon_2 > 0$). So $\varepsilon_i > 0$, $i = 1,2$) are not set, but it can be obtained directly by measurement.

As the paper moves on the belt, it does it constantly in a horizontal direction, so its distance from the detector changes. This way, the signal values are constantly changing. However, the relative ratio expressed as the value γ is not influenced by this movement. Therefore, the value of γ can be used to indicate the presence of a glue.

$$\frac{red - bred}{ultra - bultra} < \gamma \tag{2}$$

The range for the value of γ regarding the absence (presence) of the glue is determined experimentally.

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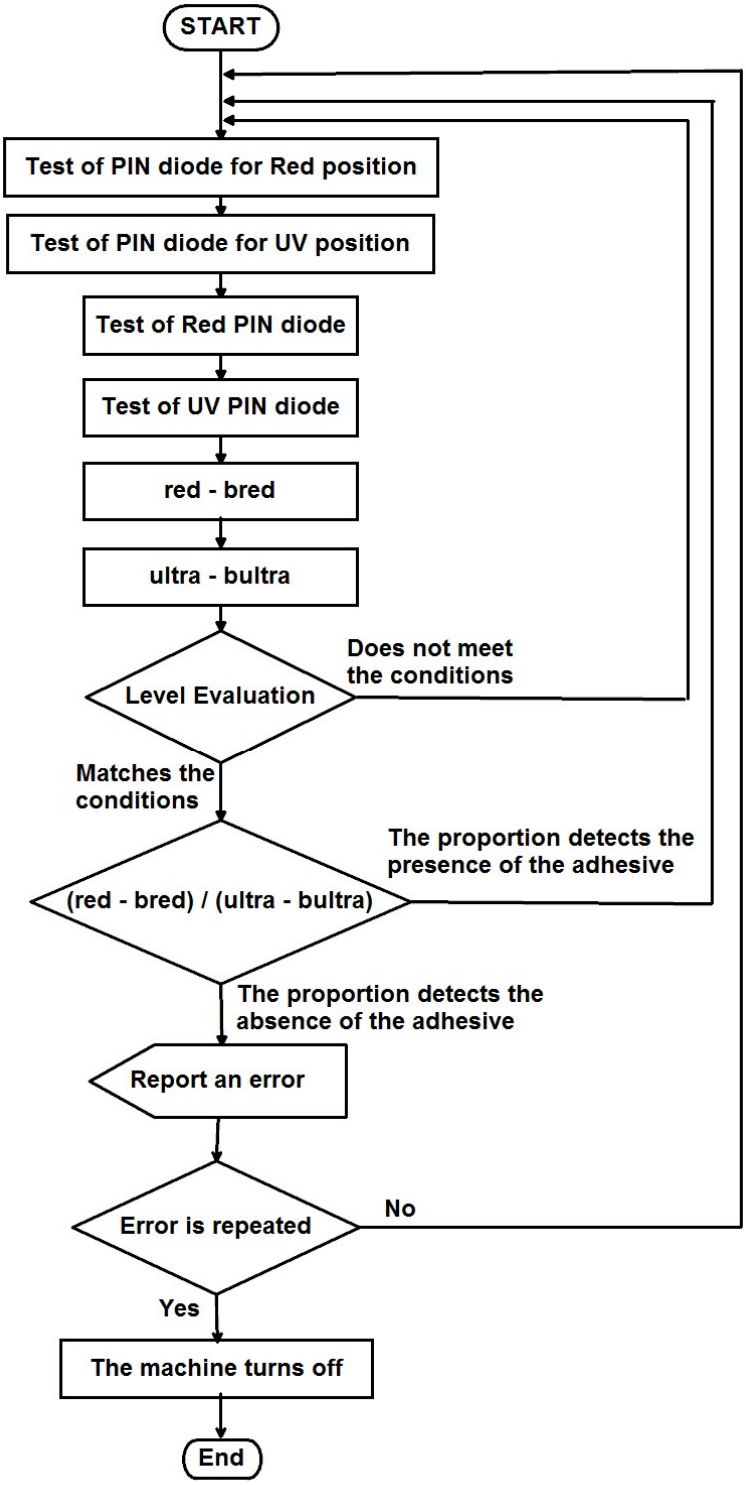

Figure 3. Flow chart to express the process of checking the accuracy in application of adhesive.

The transmitting diodes (for red and UV light) are set so that the PINs of the readings, after reflection from the paper, have the same values. The relative spectral sensitivity of both SFH 203 diodes

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actually determines the values of the drive current flowing through a resistor in the value of 100kΩ. Relative spectral sensitivity of silicon PIN photodiode with very short switching time SFH 203 is expressed in Figure 4 according to parameters given by the producer: OSRAM Opto Semiconductors GmbH & Co. OH.

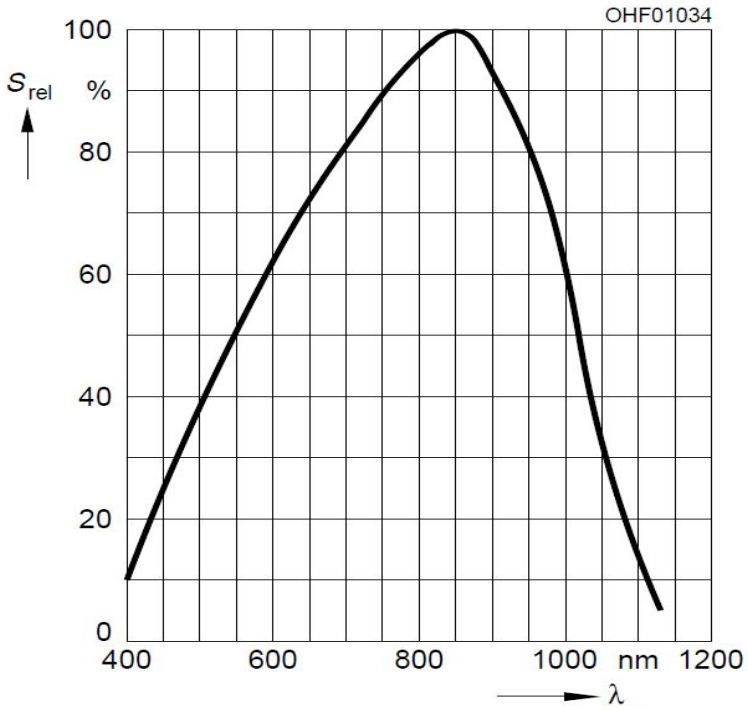

Figure 4. Relative Spectral Sensitivity of Silicon PIN Photodiode with Very Short Switching Time SFH 203 according to parameters given by the producer: OSRAM Opto Semiconductors GmbH & Co. OH.

Signal value at 660nm is about 73%, at 395nm about 10%. Therefore, the mutual signal level must be adjusted to approximately the same level at the level of analogue processing. Thereafter, the signal is digitized and sent in the communication. The equation (3) directly corresponds with the graphic representation in figure 4.

$$S_{rel} = f(\lambda) \tag{3}$$

where

S_{rel} ... *Relative spectral sensitivity,*

$f(\lambda)$ ... is a function of wavelength.

Two wavelengths are transmitted; for UV: 395nm (approximately as for 400nm) and for red (reference): 660 nm. PIN diodes were chosen because of fast response, which fulfills the execution requirement of about 2500 measurements per second. Thus, four boxes per second means approximately 600 measurements per box.

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3. DESCRIPTION THE EQUIPMENT

The device was positioned so that the operator could simultaneously monitor the glue readings as well as the display values. This applies in particular to setting parameters according to the type of corrugated paper. If the setting is incorrect, the device signals an error. Figure 5 shows the positioning of the device for checking the accuracy of application of adhesive on the line in the production hall.

The device itself was preceded by a set of experimental testing. The equipment for the testing is illustrated in Figure 6. The equipment consists of the following parts: 1 LCD display, 2 Switch: choice of paper brown or white, 3 The outer box of the device, 4 Minus (when editing parameters), 5 Plus (when editing parameters), 6 Allows adjustment mode, 7 UV light (measuring), 8 Red (reference) light, 9 Protective cover, 10 Metal cover of the measuring part itself, 11 Connecting connector, 12 Duralural supporting (fastening) body.

Figure 7 illustrates detecting the presence of adhesive on corrugated paper in practice directly on the production line, while Figure 9 shows the detail of the sensing process for checking the presence of adhesive.

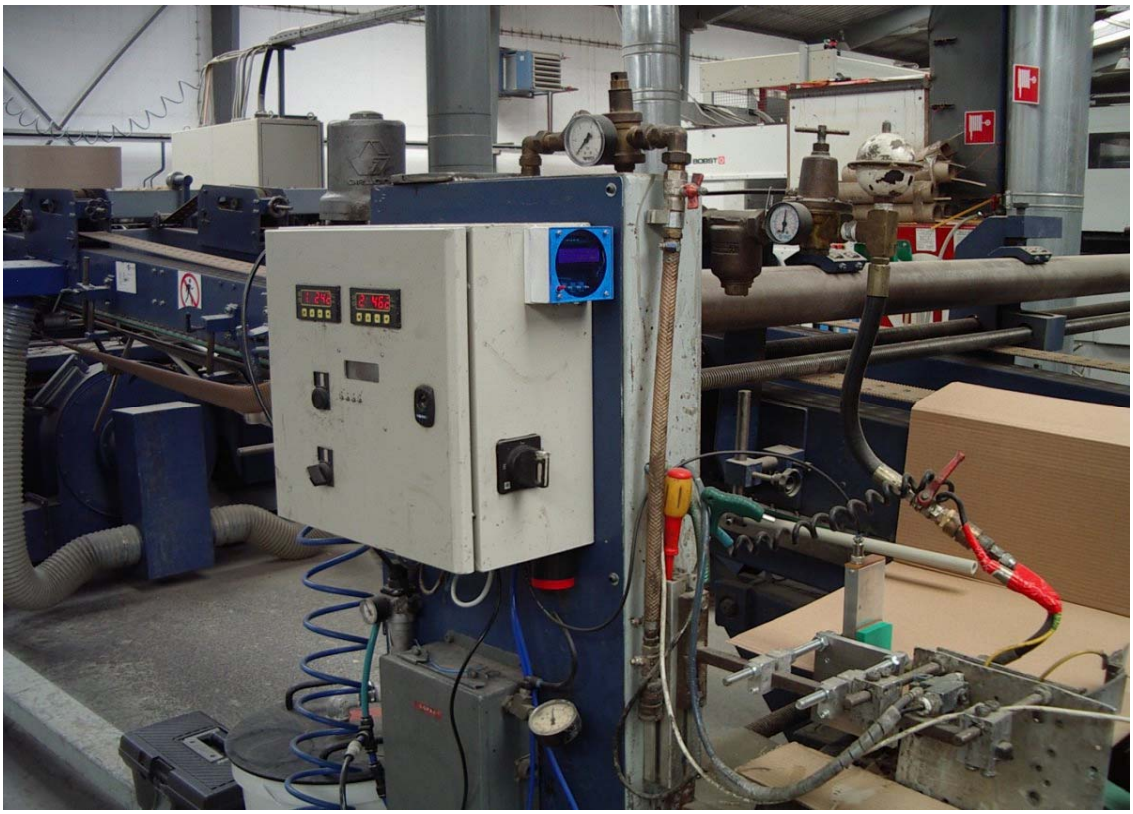

Figure 5. Practical realization of the device for checking the accuracy of application of the adhesive.

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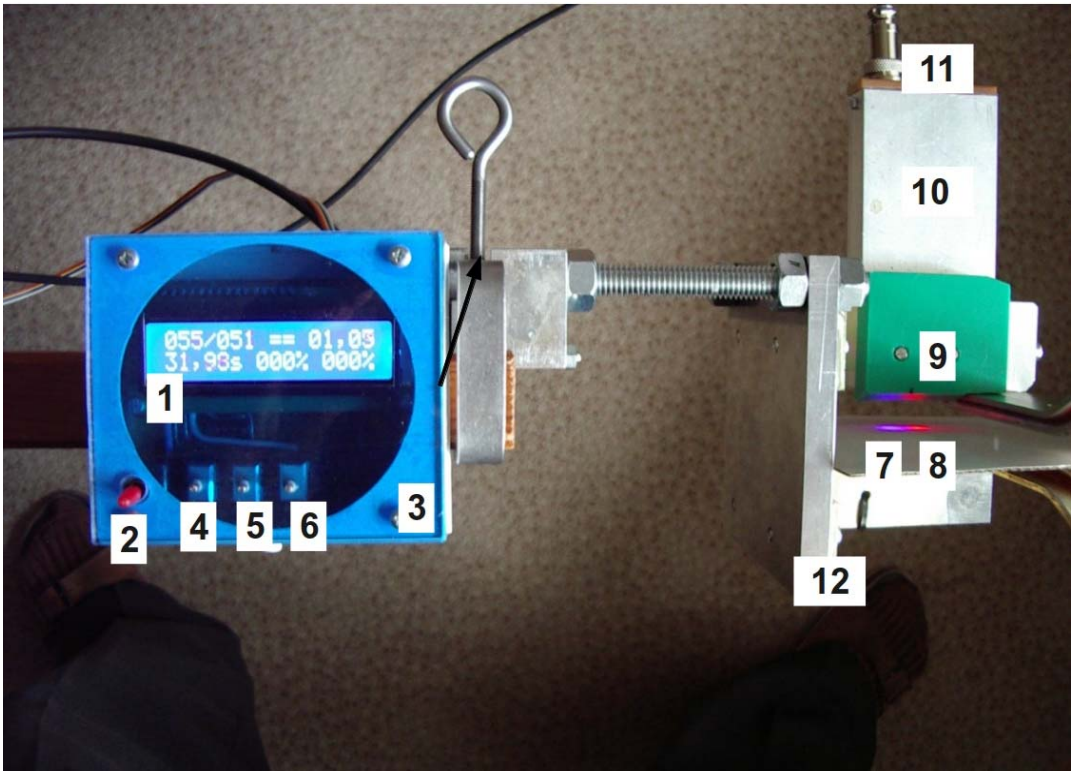

Figure 6. Experimental device for testing and pre-setting the device to check the accuracy of the adhesive application.

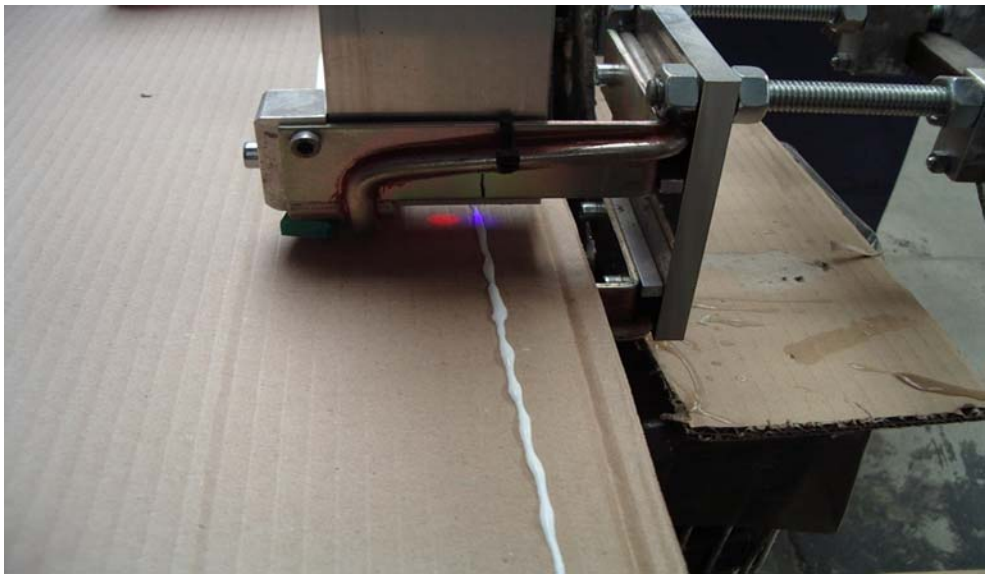

Figure 7. Detecting the presence of adhesive on corrugated paper.

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Figure 8 shows the view of the sensor part of the device. Four cavities are visible on the body of the device. The diodes are located in the cavities of the duralumin body for reasons that exclude their mutual influence and electro-optical shading occurs. In the upper cavities, the receiving PINs are SFH 203. Below the receiving LEDs are situated the transmitting LEDs this way that the red LED is on the left and the UV light on the right.

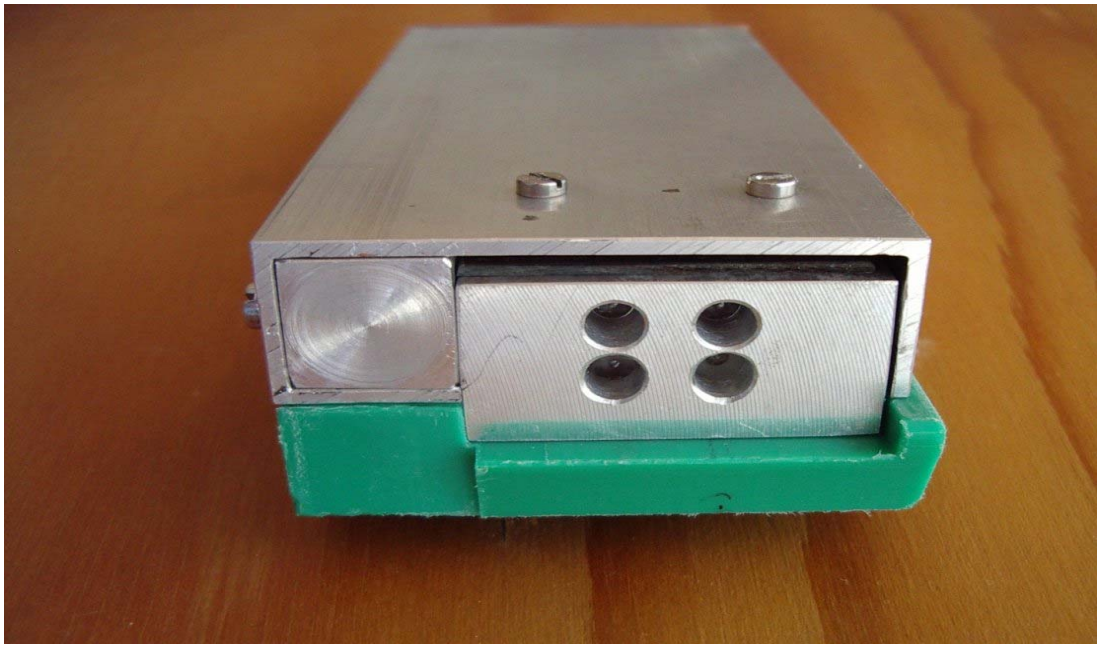

Figure 8. View of the sensor part of the device.

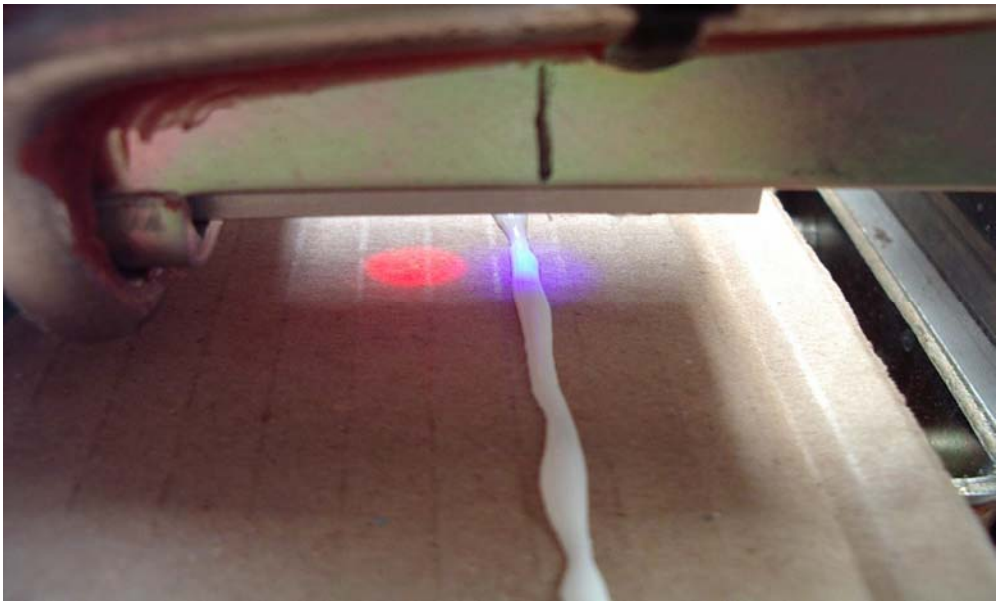

Figure 9. Detail of the sensing process for checking the presence of adhesive.

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4. ALGORITHMING WITH THE PROGRAM

The program was written partly in ASSEMBLER and partly in C programming language. The program, which ensures the scanning of ambient light reflected from corrugated paper, then measures the reflected light from corrugated paper: red and UV. The program processes the obtained results by subtracting the initial ambient light from the values obtained with the red and UV light measurements. Both results are sent through the serial line for further processing. For this stage, ASSEMBLER proved to be a fast processor because the process is 2500 times per second.

Part of the program in ASSEMBLER:

```
;*********************************************************************
;                              I N I T I A L I Z I N G
;*********************************************************************
;Setting the serial line
                mov SCON,#11010000b    ; mod3, 9.bit, receiving allowed
                mov TMOD,#00100001b    ; counters (internal,mod2,mod1)
                mov PCON,#80h            ; SMOD=1, normal
                mov TH1,#255        ;115200(22,118MHz/12/(256-255)/16)
;for 24MHz ... 125000
                setb TR1            ;Start the timer1
                setb re485
                setb de485          ;transfer from Tx
                clr ti
                clr ri
;*********************************************************************
;                            M A I N    P R O G R A M
;*********************************************************************
start:
                call red_light
                call UV_light       ;Measure without lighting
                mov bred,red
                mov bultra,ultra   ;Write values
                clr rrled    ;Shine red LED
                call pauza          ;cca 25us
                call cervene        ;Measurement of red light
                setb rrled          ;put lights off LED
                clr uuled           ;put lights on UV LED
                call pauza          ;cca 25us
                call fialove        ;measurement of UV light
                setb uuled          ;go off LED
;Calculate the difference
                mov a,red
                clr c
                subb a,bred
                jnc for1
                clr a
for1:
                mov red,a
                mov a,ultra
                clr c
                subb a,bultra
                jnc for2
                clr a
for2:
                mov ultra,a
```

```
;Sending values over Tx
                setb TB8
                mov sbuf,red
                jnb ti,$
                clr ti
                clr TB8
                mov sbuf,ultra
                jnb ti,$
                clr ti
                ajmp again

;*******************************************
;                    B R E A K
;*******************************************

;reading the value from A/D converter ADC0831 /55us/
;Reader readings are done for both red and purple light. Since both procedures are more or less
;equivalent, we give an example of possible program just for red light:
red_light:
        clr rrclk
        nop
        clr rrcs
        nop
        setb rrclk
        nop
        clr rrclk           ;Start conversion
        nop
        setb rrclk
        mov b,#8
ume2:
        nop
        clr rrclk
        nop
        mov c,rrdo
        rlc a
        setb rrclk
        djnz b,ume2
        setb rrclk
        nop
        clr rrclk
        mov red,a           ;Measured voltage
        setb rrclk
        nop
        setb rrcs
        ret
```

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Program language C processes the calculation of the values obtained by the serial line. It also displays the required values on the display. In this way, an error message is also provided via an acoustic signal when an alarm is triggered if necessary.

5. RESULTS AND DISCUSSION

The result of (1), according to expression in Figure 2, is dependent on the presence of the adhesive and not on the distance of the corrugated paper from the sensor. It is very important as paper moving on a running production belt is also characterized by constant random irregular vibrations.

$$red - light / UV - light \tag{4}$$

As ”red light” means the difference of signals detected by PIN diodes with red light on minus without red light on. Similarly, regarding UV light, the system only evaluates the reflection of the light alone, excluding the influence of the environment. This can be ensured through the expression of proportion in equation (4). The program ensures the correct operation of the procedure even in the event of a possible problem of zero division.

Experimentally, it was confirmed that correct detection occurred even though the adhesive was not applied uniformly. So even under such circumstances, light has been reflected and a value is shown by showing the proportional value. One important step is also the correct setting of the parameters for the proportion in equation (4) between which the resulting values should be moved depending on the presence or absence of the adhesive. Parameters also have characteristic values depending on the color of the paper or other flat material.

Glue checking reports an error with three consecutive cartons with incorrectly applied adhesive. The system also allows other specific settings (4, 5 or more boxes). In the event of an error, the alarm is activated and the relevant information is displayed on the display. The correct operation of the instrument, which was designed on both theoretical and experimental basis, was verified primarily experimentally at low production belt speeds. The device has been tested for corrugated paper of both white as well as brown color.

6. CONCLUSION

The paper presented management the quality control of the adhesives, which were applied on a flat material that is placed on a production belt, which moves in a high speed. The designed equipment has proven the accuracy in scanning as well as the correct display of the results on the display. The equipment uses the principle of transmission and subsequent scanning the signal produced with PIN diode. The equipment works while eliminating external influences. The external influences may be caused, in particular, by illuminating the hall where oscillation of the light intensity caused by the 50Hz supply voltage can appear. Fluctuation of component parameters, such as temperature changes and possible aging, must also be corrected.

The equipment has been tested not only experimentally but also in practice. The equipment was implemented in the factory where corrugated paper is used for production of boxes for packaging purposes. Nevertheless, the equipment is also suitable for use in testing the accuracy of adhesive application on other flat materials that are placed on the moving production belt during processing. We will try to apply this principle also to applications for other possible phases of the production process through our future scientific research work.

7. ACKNOWLEDGMENT

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