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Roughness of the Metal Sheet Edges – Problems of Measurement and Visualization

Abstract. *Many technical devices are built of metal sheets which are cut with the help of mechanical tools (guillotine or slicer). Usually the cutting process affects the properties of the mentioned metal sheets. In this paper this problem is considered on the basis of aluminium sheets used in printing industry for offset printing technique. The laboratory stand designed and constructed in the Department of Mechatronics at Silesian University of Technology is described, as well as the procedure of measurements.*

Streszczenie. *Wiele urządzeń technicznych jest wykonywanych z blach, które są wycinane za pomocą narzędzi mechanicznych (gilotyny). W każdym przypadku proces cięcia wpływa na właściwości tych blach. W artykule został przedstawiony problem pomiaru nierównomierności krawędzi i jej wizualizacji na podstawie badań blach aluminiowych stosowanych w poligrafii do druku techniką offsetową. Opisano również skaner laserowy zaprojektowany i wykonany w Katedrze Mechatroniki Politechniki Śląskiej, oraz procedurę pomiaru nierównomierności krawędzi.* ***Nierównomierność krawędzi blach – problem pomiaru i wizualizacji***

Keywords: cutting process, roughness of edge, laser measurement techniques, laser scanner.
Słowa kluczowe: proces cięcia, nierównomierność krawędzi, laserowe techniki pomiarowe, skaner laserowy

Introduction

Many technical devices are built of metal sheets which are cut with the help of mechanical tools (guillotine or slicer). Usually the cutting process affects the properties of the mentioned metal sheets and in consequence on the construction of the device. Sometimes the sheets are seriously impaired during their cutting process. The typical defect of the aluminium plate arising during the cutting process (Fig.1) is the deformation of the plate edge [1,2,3].

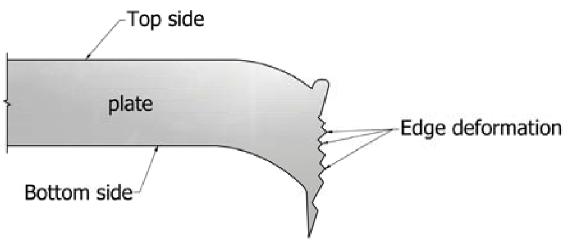

Fig.1. Deformation of the plate edge arising during cutting process

Because of that it is important to determine in the accurate and objective way the quality of cutting. The crucial problem is proper determining of the edge damage. In this paper this problem is considered on the basis of aluminum sheets used in printing industry for offset printing technique. The laboratory stand designed and constructed in the Department of Mechatronics at Silesian University of Technology is described, as well as the procedure of measurements.

Fig.2. Deformation General view of the Plate Edge Scanner (PES): 1 – control panel, 2 – laser heads, 3 – moving table, 4 – transportation linear module with stepper motor, 5 – PLC controller, 6 - power supply unit

One of the most essential problem is proper visualization of measuring results. To overcome the difficulties and to make this assessment process more objective, a special testing stand has been built and tested at the Silesian University of Technology by the Department of Mechatronics. The Plate Edge Scanner (scanner PES) allows assessment of the quality of the plate edge by non-contact and non-destructive measurements of the selected plate areas (Fig.2).

Functional Structure of Scanner PES

The general view of the PES (the prototype developed by the Department of Mechatronics in SUT) is presented in Fig.2. The PES consists of six main hardware components which are necessary for proper operation. Mutual relationships among the above-mentioned components and flow of signals are shown in Fig.3.

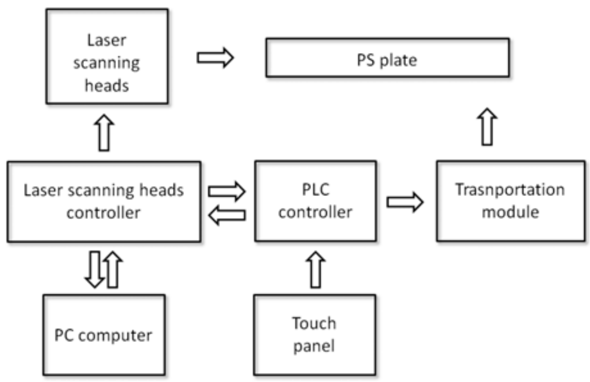

Fig.3. System block diagram and relationships between the hardware components

Two laser scanning heads Keyence LJ-G030 (Fig.4) which are appropriately located (Fig.5) work simultaneously and can scan top and bottom parts of the plate with the given resolution of 1 μm.

The main dimensions of the measured plate are described by: depth d_P and length l_P. The location of the scanning laser heads determines the scanning area which is determined by the intersection of two trapezoidal measuring regions. Its basic dimensions are shown in Fig.5 and in Fig.6. The scan depth is equal to s_D and is expressed in the number of scan depth points D. The number of measuring points N included in the range [0, N]. The single step (one measuring point) along the length s_L is equal to Δs_L. This means that the maximum sample length s_L is equal to $s_{Lmax}=N \times \Delta s_L$. The width of the laser measuring range m_R results from the scan depth s_D and is equal to: $m_R = 2 \times s_D$.

Fig.4. View of the Keyence LJ-G030 laser scanning head

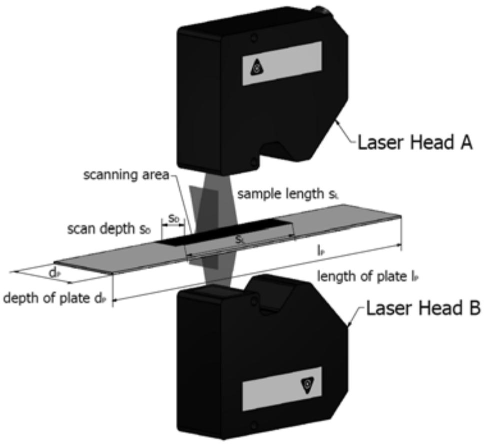

Fig.5. Location of laser heads over Top side and Bottom side of the plate

The reference distance from each side of the plate equals x_{REF} and is marked in Fig.6. The tested plate sample should be located in the scanning area symmetrically in reference to its central axis. The way to place the plate in the scanning area is explained in Fig.6. It ensures high accuracy of measurement.

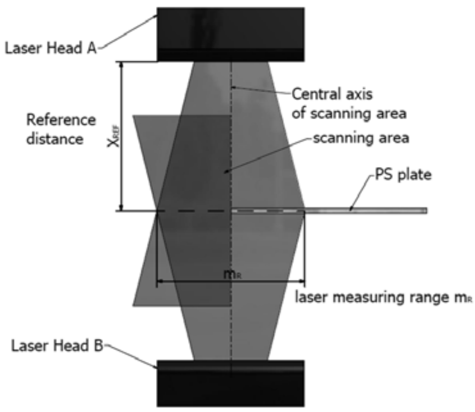

Fig.6. Basic dimensions of the scanning area of the Plate Edge Scanner (PES)

The controller for two scanning laser heads (Keyence LJ-G5001P) is device for controlling the heads and collecting temporary measurement data. The LJ-G5001P laser heads controller (Fig.7) is able to store in its internal memory the data of different scans taken along the scan length s_L.

The FESTO transportation linear module is composed of a toothed belt axis and a stepper motor (Fig.8). The toothed belt axis (FESTO series EGC) with the stepper motor (FESTO EMMS series) has many important advantages, such as proper dynamic response, high accuracy, sufficient rigidity and a large load capacity. This device is responsible for transporting the plate between the scanning heads in the direction of scan length s_L.

Fig.7. Scanning laser heads LJ-G5001P controller

Fig.8. Transportation linear module: 1-toothed belt axis, 2-stepper motor

The modular control system (FESTO CECX series) is based on a modular configuration and can be structured according to specific operator's requirements. It consists of the properly selected and integrated CPU and I/O modules (Fig.9). The modular control system is responsible for controlling plate movement and for keeping the plate sample in the given region.

Fig.9. The CECX modular control system consisting of CPU and I/O modules

Fig.10. Touch panel for controlling scan process

Touch panel (Fig.10) enables an operator to control the measurement (scanning) process. It allows the setting of the test conditions e.g. number of planned scans, the scan length s_L, etc. A Personal computer PC is necessary for collecting measurement data (imported from the LJ-G5001P laser heads controller) and storing it in a special folder (specified by the user). Plates Quality Evaluation software (installed on the PC) determines the quality of the plate (i.e. the “Roughness Factor” [1,2,3]) on the basis of the collected data.

Measuring Procedure and Graphical Visualization of the Measured Data PES

The touch panel enables proper position setting of the plate between the laser heads. In addition, it allows you to choose the number of planned scans and to adjust the scan length of the scanning region. In the next step information about all the mentioned settings are sent from the touch panel to the PLC controller. The PLC controller sets the transportation module in motion. After reaching a given desired position, a strobe signal is sent to the laser scanning head controller which starts a single scan of the plate. Results of this scan are sent to the personal computer.

The program for evaluating quality of the plates was created in the environment with the use of the GUI (Graphical User Interface) module. It offers a wide range of different display possibilities: 2D views (Fig.11) and 3D views (Fig.12). For 2D plots, one can choose the line plot or the bar plot (corresponding to Top side or Bottom side of the plate). For 3D plots, one can select top surface plot (Top side plot), bottom surface plot (Bottom side plot), two-side surface plot (Top side and Bottom side put together) and bar plot for edge roughness distribution. The software does not require re-entry of settings for performances of the next series because the measuring data are stored in the form of text files in a folder on the hard disk drive. If necessary, the old files can be analysed again and compared with the more recent ones.

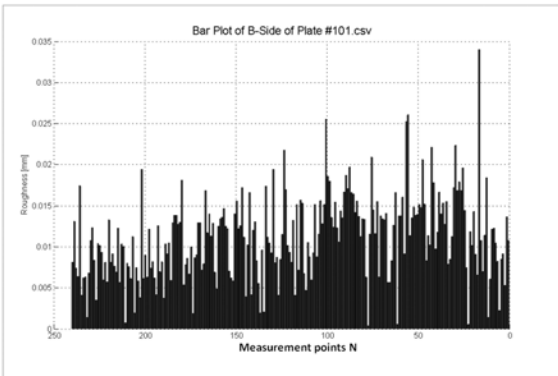

Fig.11. Exemplary result of measure 2D bar plot for Bottom side

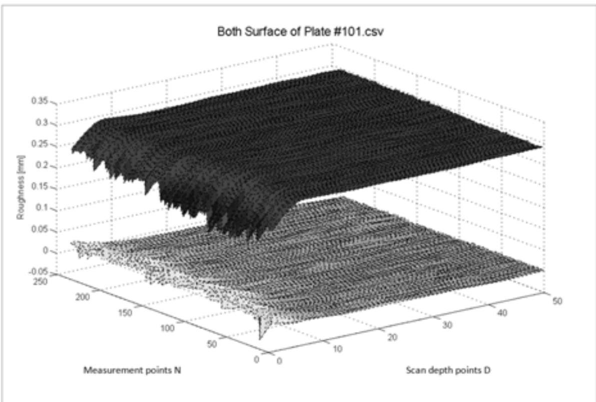

Fig.12. Exemplary result of measure 3D two-sides surface plot (Top side and Bottom side put together)

For the different types of plots, the data are calculated and compared to data from the reference line (Fig.13, Fig.14). The reference line is located in the middle way of scan depth s_D from the edge of plate (Fig.15).

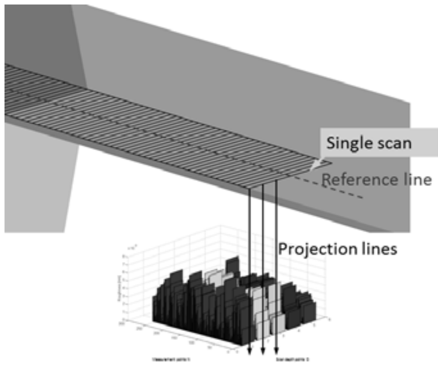

Fig.13. Methodology of calculating and representing the data

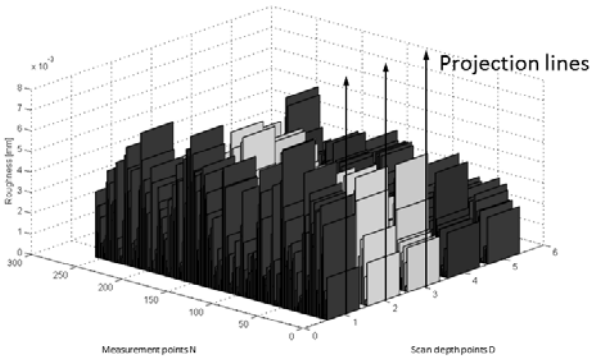

Fig.14. Exemplary of 5 measured points (in depth direction)

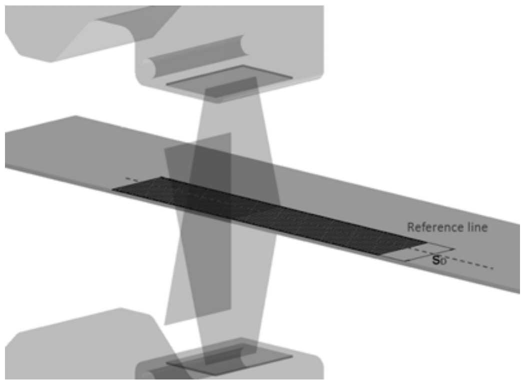

Fig.15. Location of the reference line (for representing the data and calculating Roughness Factor)

Procedure for calculating the Roughness Factor consists of the following stages [1, 2, 3]:

a) At the beginning all scanning data are stored in internal memory of the LJ-G5001P laser head controller. Then these data are put in a defined folder with "csv" extension. The "*.csv" file contains the data representing the shape of the top side and the bottom side of the plate surfaces.

b) The user uses the transportation linear module to adjust proper position of the scanning region (Fig.5). Additionally, the user determines a number of scanning points (sets them on the touch panel).

c) Presenting the measurement data in graphical way (to calculate “Roughness Factor” (RF), it is necessary to have

2D bar plot curves for Top side and Bottom side of the scanned plate for the total number of scans equal to N)

d) Based on the measured data, the "Roughness Factor" is calculated according to the following formula [1, 2, 3]:

$$RF = \frac{\sum_{k}^{K} S_{Ak} + \sum_{k}^{K} S_{Bk}}{N - K} K \cdot 100 \tag{1}$$

where: RF – "Roughness Factor"; K – number of measurements with roughness bars higher than 0,01mm; S_{Ak} – height of the k-th single roughness bar from the Top side; S_{Bk} – height of the k-th single roughness bar from the Bottom side; N – number of measurement points

Conclusions

The Plate Edge Scanner (scanner PES) allows assessment of the quality of the plate edge by non-contact and non-destructive measurements of the selected plate areas.

The all measurement data are collected in PC computer. The program for evaluating quality of the plates was created in the environment with the use of the GUI (Graphical User Interface) module in Matlab. In the program the factor of roughness is calculated and all data (from the Top side and Bottom side) can be represented as a 2D bar plot, 2D line plot, 3D surface plot or 3D bar plot. For the different types of plots, the data are calculated and compared to data from the reference line. Basing on the 2D bar plot curves for Top side and Bottom side of the scanned plate the "Roughness Factor" is calculated. The all measuring data are stored in the form of text files on the hard disk drive. If it's necessary, the old files can be analyzed again and compared with the more recent ones.

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