Analysis of Waste Paper Processing through Disc Screen

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Short Summary

The main raw material for papermaking is fiber - wood fiber and wastepaper. After wood, the second largest share of pulp produced worldwide is pulp made from recovered paper. Today, waste paper is not considered a general waste, but it is mainly treated as a secondary raw material that is cost-effective and energy-saving for the paper industries. In the year 2014, about 17 million metric ton recovered paper applied in paper manufacturing in Germany; in the same time the whole German paper and board production was about 23 million metric ton. This means that their need to raw material (only recovered paper) is in the scale of 70%.

Effective recycling relies on effective sorting. The collected waste papers need to be sorted into different fractions with closely defined material properties according to the standard grades of paper and board for recycling (DIN EN 643) and undesirable materials (metal, string, glass, textiles, sand, plastics, etc.) must be removed from the collected paper as completely as possible.

Since the role of disc screen as the first sorting unit in waste paper processing plants is critical, enhancing the performance of these screens to segregate valuable stocks from unwanted materials and impurities will improve the overall purification of final products and its market price. The objective of this research is to find the best sorting trend of waste paper on disc screen (qualitative and quantitative) relative to feed material characteristic and influencing variables via various practical experiments, then modeling the role of studied variables on sorting process and finding the most applicable forecasting model (with the least error) that best fits to the obtained practical test results. Online analysis of feed material properties and automatically adjusting of sorting device will be a potential process idea of this research's findings.

Achieving 90% or above mass recovery and value yield (deinking material) simultaneously in the underflow of applied disc screen and designing a forecasting disc screen-based model with ≤ 3 predicting error for waste paper sorting through studied influencing variables are the hypothesis of this research.

Two kinds of material are applied in this study: mixed and single object material. The amount of applied mixed material in this study was three 57 kg samples including 83% deinking papers (print paper, magazines, newspapers and flyers that are suitable for ink detachment) and 17% boards (cardboard and corrugated board). The reason for choosing three samples was studying on three different settings of applied disc screen and the reason for choosing higher share of deinking material to board (83% to 17%) was due to the fact that Germans use more deinking papers in daily life (about

108 kg from 249 kg per capita paper consumption in year 2012) and the importance of deinking papers for paper manufacturers. Selecting mixture of materials was because of simulation of a real waste paper processing condition. Usually in Germany, the post-consumer papers from household and commercial sectors will be stored in a separate blue container that will be regularly collected and transported to the sorting stations (bring and pick-up system).

The applied single object samples were waste packaging material (cardboard and corrugated board) in three different sizes (A3, A4 and A5). The reason for choosing these material was their special characteristics (such as rigidity and volume) and also studying of their behavior during sorting on disc screen. The target of this experiment was studying the behavior of boards on the disc screen under different material-process properties. However, defining the influential parameters on the sorting of waste packaging is critical to get the most optimal disc screen setting through sorting the material with high stiffness.

This research falls into two main phases: practical and theoretical. The practical phase was screening mixed and single object material via different settings of disc screen such as four applied sorting speeds (60, 72, 84, 96 rpm), length between discs (180 and 240 mm) and shafts (180 and 230 mm) and also various moisture contents of feed material (5 and 10%). The determination of particle size distribution (PSD) of mixed material (>50% was bigger than 240 mm) and the open screening area (A0) of disc screen were critically important, while pieces of material that are smaller than the spacing between the discs and shaft assemblies or the flexible material such as deinking material fall through the screen. Thereby the probability that a particle with definite area passes through a sieve opening will be calculated. To measure the opening area of disc screen with twisting sorting compartments and screen plate, the upper profile (bird's eye view) of discs in an idle mode of disc screen is considered. After calculation of the average area of discs and shafts, the result was subtracted from the inner area of disc screen and the minimum and maximum range of the opening area is being calculated (31% and 34%) as well.

By calculating the opening of disc screen (A0), mass and value yields (R_m and R_w) and the aforementioned influencing variables on the sorting process, the mathematical modeling (theoretical phase) of waste paper sorting via disc screen was possible. The model is based on the obtained data from nine influencing variables on sorting process. The studied variables are material codes, weight and moisture of materials, rotation speed of disc screen, number of discs, length between discs, number of shafts, length between shafts and open area. Afterwards the 120×10 data matrix is built

from collected input-variable-output data of 120 implemented experiments for this research. Since the experiments outputs are affected by many different variables (as stated earlier), two of the most advanced statistical forecasting methods including multiple linear regression (MLR) and multi-layer feedforward (MLF) neural network model were developed through MATLAB software for predicting the behavior of waste paper sorting on the disc screen.

Based on the results and findings of this research, although the highest achieved simultaneous R_m (89%) and R_w (100%) happened through 3rd setting of disc screen, the 2nd setting (distance between discs: 180 mm, distance between shafts: 230 mm and opening area: 31%) met better the ideal sorting requirements. Since its open area is neither too narrow as the first setting, nor too wide as the third setting. When the size of feed material (deinking and packaging) is in the range of 240 mm and their moisture is ≥ 10%, by applying 1st or 3rd setting of disc screen, an efficient sorting in both disc screen's products (underflow and overflow) cannot be happened at the same time. Also via 2nd setting, the best sorting of mixed material (with both moisture contents) occurred with the first applied sorting speed (60 rpm) but the best sorting for packaging material (with both moisture contents) occurred by last applied sorting speed (96 rpm). This condition of 2nd setting makes it compatible with potential process idea of this research (online control of feed and sorting devices). Through this idea, when the share of packaging material in feed is high, the sorting speed of disc screen will be automatically changed to 96 rpm, otherwise it will bring the sorting speed down to 60 rpm.

From comparing results, precision, pros and cons of both applied models in this research, it was shown that the MLF model produced more reliable results for single object experiments (packaging materials) compared to MLR model. Although the obtained error value of MLR (3%) was lower than MLF (4%) particularly for mix materials, one should be cautious about the accuracy of coefficients estimation by using the MLR. For further improvement of MLF model, having more observations in associate with defining more given values to variables is necessary. Also the collaboration of waste paper sorting industries for developing the model will be very supportive.

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