Geometric modeling of sheet transfer process from grippers to grippers

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Abstract. One of the important processes in operation of a printing machine is the transfer of a sheet of printed material from one cylinder to another. The transfer of the sheet is carried out using special grippers attached to the printing cylinder, and quality of printing depends on their accuracy. At the stage of printing process preparation, an important step in setting up the equipment is the correct installation of the grippers. The paper presents the results of developing a geometric model of the sheet transfer process from grippers to grippers. This process is visualized using a computer simulation. The presented model makes it possible to define the trajectory of the paper movement in the transfer zone, and track the untimely opening or closing of grippers. This may lead to printing process abnormality.

1. Introduction
One of the most important components of the printing machine is known to be the sheet conductor. Among the existing solutions, the method of transferring sheets by grippers hold of the leading edge is common. The sheet is assumed to follow the trajectory of the grippers, which grasp this sheet from the grippers of the previous cylinders, and then move it at the leading edge along the circumference of the cylinder, and pass it to the grippers of the next cylinder.

These grippers can have different modifications, but their operation principle is as follows:
1. The front edge of the printed sheet is clamped between the support surface (cylinder surface) and the gripper; in this case, the friction forces firmly press it against the cylinder surface and provide movement with the cylinder surface;
2. These grippers are placed on the shaft (clamshell bracket), which is fixed in the rollers; the entire system is located in the non-operating zone, that is in the cylinder body;
3. These rollers are rolled onto the elevation area when the cylinder rotates, and at this time the grippers are opened and closed (receiving or transferring the leading edge of the sheet);
4. This process is performed at the same speed of grippers displacement.

Also there is a method of transferring the sheet [1] which is essentially different as the sheet is transferred at different speed of receiving and transferring grippers, both in magnitude and direction. The sheet is carried by the transfer grippers along the cylinder movement trajectory, then at speed the leading edge of the sheet is transferred to the receiving grippers. The grippers of the transfer cylinder open, and the sheet slows down the movement in the receiving grippers under the friction force.

There are also ways of sheet transfer at the tail edge by the grippers. This method can be used when transferring a sheet in a sheet turning device.
In this case modeling allows visualizing the process before prepress makeready and studying the most relevant arrangement of parts. Currently, modeling is widely used in graphic arts [2].

2. Problem statement
The disadvantage of these methods is that there is no procedure to determine the sheet trajectory. Also cases where errors may occur during the transfer of the sheet have not been taken into consideration. If not to address to the issue of sheet trajectory in a prining machine setting, the grippers will not probably provide adequate reliability during the printing process. It is possible that the grippers will open or close at the wrong time and the sheet is likely to be not grasped or jammed, or the printed blanket to be torn.

The proposed method to determine the trajectory and error of the sheet movement in the printing machine when it is transferring from the grippers to the grippers can be used for setting up a printing machine, namely the device for sheet conveying. This method is realized using the geometric modeling.

3. Theoretical basis
Computer process modeling makes it possible to significantly computerize data processing. This issue is relevant in printing industry, and computer-aided systems allows us to evaluate both the process itself and the quality of printing [3, 4].

Geometric modeling is a method that includes forming a geometric model of the object under study for its further transforming and obtaining the necessary properties of the object, as well as for determining its geometric properties for further research.

A geometric model is usually understood as the form of an object realized in specialized software, indicating the configuration and dimensions of the object components.

The advantages of this method are visualization of the object under study, the possibility to construct computational models, and determination of the geometric arrangement of components in order to ensure smooth operation of the full-scale press.

Using geometric modeling, the problem of representing the process of transferring a sheet of paper from grippers to grippers from one cylinder to another can be solved.

The objective of the research is the system for transferring a sheet of paper (Fig.1) [5], and the study subject is the transfer process.

![Figure 1. Process of transferring a sheet of paper](image)

1, 6 are sheet transfer.
2, 3 are turn of the gripper shaft.
4 is counter-movement of the grippers.
5 is sheet clamping.

To determine the trajectory of paper movement and possible displacement of its position in the point of impression, a geometric model is proposed and a software product is developed [6]. The basic source data for modeling the process are presented in table 1.
Table 1. Source data for process modelling

| №  | Notation         | Explanation                                                                 | №  | Notation         | Explanation                                                                 |
|----|------------------|-----------------------------------------------------------------------------|----|------------------|-----------------------------------------------------------------------------|
| 1  | t0, tk, tau, dtvyv | start and stop time of calculation at intervals                              | 13 | F0, Fk           | movement angle of the paper edge on cylinder                                  |
| 2  | Nk, Nvyvk        | number of data outputs                                                       | 14 | R11, dR11, R12,  | radii of cylinder 1 and fixed cylinder under the roller and their deviations |
|    |                  |                                                                             |     | dR12             |                                                                             |
| 3  | R13, dR13, H13, F13 | slide radius and deviation, its height, the slide center angle of cyl.1, indication from left to right through the center | 15 | R14, dR141, dR142 | the radius of the roller                                                      |
| 4  | DL15, R15, dR15, DL16, DL17, dR17 | dimensions of roller and levers to the stop and the hook point | 16 | Om1             | angular velocity of the upper cyl.1 (opposite of cyl. 2)                   |
| 5  | F1cr, dF1        | angle of the gripper stop position of cyl.1 and paper edge                   | 17 | DDR             | cylinder clearance                                                           |
| 6  | TL0              | paper thickness                                                              | 18 | R21, dR21, dR22, | radius and oscillation amplitude of the axes of lower cylinder 2             |
|     |                  |                                                                             |     | dR22             | angular velocity of the lower cyl.2                                           |
| 7  | H23, F23         | height and slide center angle of cyl.2, indication from left to right through the center | 19 | Om2             |                                                                              |
| 8  | F2cr, dF2        | angle of the gripper stop position of cyl. 2                                | 20 | dC21             | beat frequencies of the axes of cyl.2 (do not exist for cyl.1)              |
| 9  | deLT10, deLT20, deLT1, deLT2 | initial values of indicators and their intervals for cylinders 1 and 2   | 21 | zadev1y0, zadev2y0 | neutral positions of ordinates for space indicators (Y values) when there are no intersections of hook edges with the paper. |

4. Experimental results and discussion
Building a geometric model for the process of transferring a sheet of paper from cylinder 1 to cylinder 2 with the radii R1 and R2 that are located at a distance of the paper thickness with a gap dDR is carried out as follows:
- Input of source data for modeling; initial and final calculation time with calculation steps and printing with initial rollover to data arrays is set: t0, tk, tau, dtvyv.
- Input the Cartesian coordinate system Oxy with the origin at the bottom of cylinder 1 (see Fig. 2) to determine the coordinates of the paper movement and the edges of the grippers.
- Determination of coordinates in the Cartesian system; initially, we consider the change of angles for the basic nodes in time by the formulas (1)-(3), as well as the angular values of the grippers edges and stops for paper by the formulas (4)-(7).

\[
\begin{align*}
\varphi_1 &= \varphi_{10} - \omega t, \\
\varphi_2 &= \varphi_{20} - \omega t, \\
\varphi_0 &= \varphi_{00} - \omega t, \\
\varphi_{17} &= \varphi_1 + (L_{16} + L_{17})/R_1, \\
\varphi_{27} &= \varphi_2 + (L_{26} + L_{27})/R_2, \\
\varphi_{16} &= \varphi_1 + L_{16}/R_1, \\
\varphi_{26} &= \varphi_2 + L_{26}/R_2.
\end{align*}
\]

- Definition of coordinates for the gripper edges and a sheet of paper. The Cartesian coordinates for the gripper edges \((x_1, y_1), (x_2, y_2)\), and the sheet of paper \((x_0, y_0)\) are evaluated by the following expressions:

\[
\begin{align*}
x_0 &= R_1 \sin(\varphi_0), \\
y_0 &= d_{DR} + R_1 (1 - \cos(\varphi_0)), \\
(x_0 < 0) &\rightarrow x_0 = R_2 \sin(\varphi_0), y_0 = -R_2 (1 - \cos(\varphi_0)), \\
x_1 &= R_1 \sin(\varphi_{17}), \\
y_1 &= d_{DR} + R_1 (1 - \cos(\varphi_{17})), \\
x_2 &= R_2 \sin(\varphi_{27}), \\
y_2 &= -R_2 (1 - \cos(\varphi_{27})).
\end{align*}
\]

- Finding the coordinates of the gripper edges and the leading edge of the sheet on impact with the cam. When the rollers and the slides clash, the grippers raise is carried out taking into account the distances between the slides axes and roller axes. These distances should not exceed the values \(L_1 = (R_{13} + R_{14})\) and \(L_2 = (R_{23} + R_{24})\), respectively, for cylinder 1 and cylinder 2, and are equal when rollers and slides clash.

- Identifying possible intersections between the gripper edges and assigning indicators.

- Output of an array of data on the sheet movement.

\[\text{Figure 2. Determination of motion coordinates}\]
Visualization of the trajectory is implemented in Microsoft Excel, dependance diagrams being build based on the obtained coordinate arrays. Figures 3 and 4 show the graphs according to the performed calculations.

Figure 3. Trajectory of paper and cylinders

Figure 3 shows the trajectory of a sheet of paper (namely, its leading edge - line 2) between the cylinders. Lines 3 and 4 represent the trajectories of the gripper edges movement of cylinders 1 and 2, respectively. Line 1 presents the specified indent being equal to 6 mm in this case. When the sheet moves from right to left, errors in the mechanisms of cylinder 2 are taken into account, they are shown in the graph by a large number of peaks on line 4. The rises on lines 5 and 6 indicate that the gripper edges for cylinders 1 and 2 touch the paper.
Figure 4. Distance (meters) of the paper edge to the gripper edge and its stop

Figure 4 clearly shows the distance between the leading edge of the paper sheet and the gripper edge (lines 3, 5), as well as the distance to its stop (lines 4, 6), which was assumed to be 6 mm. Lines 1 and 2 represent the first and second cylinder, the gripper edges height (hooks) from the cylinders surface in time t (seconds), respectively. Line 7 (grippers and hooks of cylinder 1) shows the indicator response to the intersection of the edges and paper hooks in time, and line 8 represents the same for cylinder 2.

5. Conclusion
The proposed model and the developed software product allow:
- visualizing the process of transferring a sheet from one cylinder to another,
- forecasting the process of transferring a sheet depending on changes in the input source data,
- tracking the trajectory of the sheet in automated mode,
- and selecting the most rational arrangement of parts for the design and operation of printing machines.

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