Assessment of printing cylinder deformation effect on nature of load distribution

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Abstract. Various loads have a significant effect on the operation of different equipment components. Modern national and international studies show high efficiency of applying finite element methods to research into the loading nature of various parts and systems as a whole. Unevenly distributed loads can reduce the performance of the equipment, as well as lead to the failure of components. This paper examines the effect of the position of the substrate gripper system on the deformations in the printing cylinder. The findings prove that the misalignment of the shaft and gripper bridge placement doubles the resulting deformations.

Keywords: modeling, printing cylinder, deformation, finite element method.

1. Introduction

One of the most important aspects in modern mechanical engineering is the application of the latest methods in the design and operation of equipment. Some frequently used methods at present are modeling, computer diagnostics and automation of calculation processes and performance evaluation. These methods increase the efficiency of the conducted scientific research. Moreover, virtual experiments are of greater accuracy compared to those done by a human. The use of computer methods reduce the time spent on the experiment, including the correction of the resulting data.

Various fields of mechanical engineering apply such methods, including printing industry [1-6], since computer modeling is an effective method to conduct experiments aimed at examining the deformation properties of a printing cylinder. These properties depend on the nature of the cylinder loading. Such studies will result in minimizing errors in the machine design stage and considering the possibility to use the machine in real conditions.

2. Problem statement

In general, the modeling process can be represented as follows:

1. Problem statement, research into the properties of the investigated object.
2. Selection of possible boundary conditions.
3. Development of the model, taking into account points 1 and 2.
4. Application of loads and conducting a virtual experiment.
5. Analysis of the obtained data.
6. In case of data inaccuracy, the calculation is corrected, starting from point 1.
The most common method of computer modeling is the use of software with the finite element method (FEM) [7] (Fig. 1).

![Finite element method](image1)

**Figure 1.** Finite element method

The main advantage of this method is that it can be used to study objects of different shapes and materials, as well as the ability to conduct different studies on the same model. This method has some disadvantages. For example, when studying a model with a complex shape, it is difficult to take into account all the boundary conditions. Besides, the correctness of the calculation largely depends on the finite element mesh and, consequently, on the shape of the finite element itself. The final elements used in various software products can be divided into three types:

1. One-dimensional final elements in the form of a segment; they can have from 2 to 4 nodes.
2. Two-dimensional final elements, based on a triangle or quadrilateral; they have a constant thickness or are a function of coordinates.
3. Three-dimensional final elements; the most common three-dimensional form of a finite element is a tetrahedron or parallelepiped.

Three-dimensional finite elements are used to partition the mesh of the 3D model, and the most common element is the tetrahedron (Figure 2) [8].

![A tetrahedron-shaped finite element](image2)

**Figure 2.** A tetrahedron-shaped finite element
In previous studies [9-10], the loading process of the printing cylinder was modeled. However, they only consider the shaft load from the printing pressure.

The aim of this work is to investigate the nature of the printing cylinder loading subject to the influence of various factors.

3. Results and discussion

One factor in skewing the gripper system and, consequently, changing the loading characteristics of the shaft can be caused by failure of the support bearings. A more detailed study of bearings, in order to expand the examined factors, is also possible by means of the finite element method and computer analysis.

The strength analysis system APM FEM for KOMPAS-3D was used to study the model in question. This software is based on the finite elements discussed above, in the form of a tetrahedron, which has four nodes in the vertices of the figure. The characteristics of FE can be adjusted depending on the need for a larger or finer mesh, and the number of nodes can be changed up to 10.

Based on the main known dimensions, a three-dimensional model of a jacketed printing cylinder was developed. The assembly has two parts mated with each other (figure 3).

![A) Printing cylinder design; B) Jacket design; Figure 3. Design details](image)

The material of the cylinder and jacket is the same. It is Steel 30. The characteristics of the material are shown in Table 1.

**Table 1. Material characteristics**

| Indicator                                      | Value  |
|------------------------------------------------|--------|
| Flow stress [MPa]                              | 460    |
| Normal modulus of elasticity [MPa]             | 210000 |
| Poisson's ratio                                | 0.3    |
| Density [kg / m³]                              | 7850   |
| Temperature coefficient of linear expansion [1/C]| 0.000012|
| Thermal conductivity [W/(m²*C)]                | 49     |
| Compression tensile strength [MPa]             | 600    |
| Tensile fatigue strength [MPa]                 | 294    |
| Torsional fatigue strength [MPa]               | 150    |
Two situations were considered:

Model #1. Applying a load along the rim of the printing cylinder at a distance of 10 mm from the edge.

Model #2. Modeling a skewed gripper system situation: distance from the rim on one edge is 10 mm, and 8 mm on the other edge.

The assumption is made that the load is applied as a continuous line, without separating the area of each gripper, since there are many grippers with the same spacing between them (Fig. 4 and Fig. 5).

The pressure equal to 40-60 N is accepted as the load from the grippers (60N is taken in this work).

The works [9-10] show that the deformations arising in the structure should not exceed 0.01 - 0.02 mm.

Table 2 shows the characteristics of the model partitioning into finite elements.

| Name                              | Model 1. | Model 2 |
|-----------------------------------|----------|---------|
| Maximum element side length [mm]  | 5        | 5       |
| Maximum thickening factor on the surface | 1        | 1       |
| Volume rarefaction coefficient    | 1.5      | 1.5     |
| Number of finite elements         | 410009   | 410162  |
| Number of nodes                   | 128091   | 128120  |
Figure 6 shows the results of the calculation for the first model.

![Figure 6. Total linear displacements. Model 1.](image)

If to apply the load equally along the entire length of the part, the maximum stresses occur in the center. The maximum total displacements are 0.0003252 mm, which is within the permissible range with a large margin (Fig. 6).

Figure 7 shows the loading results of the second model. In this case, the maximum loads are off-center and the maximum total displacements are 0.0007594 mm.

![Figure 7. Total linear displacements. Model 2.](image)
Conclusion
The following conclusions can be drawn from the results of the research.
For each of the models, the maximum total displacements are within the permissible limits.
With an even load distribution, the displacement is at least 2 times less than when the gripper system is skewed.
Thus, displacement of the maximum loads results in the greatest loading of one of the supports.
This, in turn, adversely affects the operation of the unit, and can lead to a printing process breakdown.
A more detailed study of the factors influencing the uneven distribution of loads on the cylinder is planned as further work.

References
[1] Lundström J, Verikas A 2013 Assessing print quality by machine in offset colour printing Knowledge-Based Systems. 37 70–79
[2] Verikas A, Lundström J, Bacauskiene M, Gelzinis A 2011 Advances in computational intelligence-based print quality assessment and control in offset colour printing Expert Systems with Applications 38 13441–13447
[3] Serkova L B, Varepo L G, Panichkin A V, Kolozova O A, Glukhov V I, Belyaev P S. 2020 Geometric modeling of sheet trans-fer process from grippers to grippers Journal of Physics : Conference Series 1546 012043-1 – 012043-7 DOI: 10.1088/1742-6596/1546/1/012043
[4] Serkova L B, Varepo L G 2020 Investigation of the deformation characteristics in the printing cylinder structure Proceedings of Tula State University: technical Sciences 5 498–504 (in Russian)
[5] Kulikov G B, Bykov A V 2002 Use of computer diagnostics methods for determining the technical condition of rolling bearings of printing machines Proceedings of Higher Education Institutions. Problems of printing and publishing 2 30–35 (in Russian)
[6] Lohith Reddy S, Rajanikanth K, Praveen Kumar A, Ponraj sankar L 2020 Finite element investigations on the transverse crashworthiness performance of stiffened cylindrical tubular elements Materials Today: proceedings 27(2)1934–1938
[7] Makovkin G A, Likhacheva S Yu 2012 Using FEM for the solution of problems on deformable solids mechanics. Tutorial. Part 1. N. Novgorod: NNSASU Publishing House 71 p (in Russian)
[8] Yu Hou, Xi Wang 2021 Measurement of load distribution in a cylindrical roller bearing with an instrumented housing: Finite element validation and experimental study Tribology International 155 106785
[9] Semenov A A 2012 Modeling deformations of the printing cylinder of an A1-format machine Bulletin of the Moscow State University of Printing 4 94–96 (in Russian)
[10] Gulyaev S A, Herzenstein I Sh., Suslov M V 2010 Range of permissible deformations in cylinders of printing apparatus Proceedings of Higher Education Institutions. Problems of printing and publishing 4 41–47 (in Russian)