Study of friction between the web and the air turning bar

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Abstract. In this paper, we will discuss a method used to reduce friction and ink set-off in web-fed machines through implementing an air cushion between the web and the air bar used to influence the web trajectory. In the available academic literature, there is no study of the friction force between said two surfaces. Our goal is to establish a correlation between air tension, tensile and the web's width. A specially designed experimental air bar was created; in a series of experiments, air was fed into the gap between the bar and the wrapping web. The results (friction force's dependence on air tension, tensile and web's width) are to be taken into account while designing web conductors for web-fed printing machines.

1. Introduction

To reduce friction between moving bodies, a gas (usually air) is fed under tension into the gap between them. In case the bodies are solid, gas lubricated bearings are created. The literature on the subject is quite extensive [1, 2]. There are also some new papers on the subject [3]. Nevertheless, there is not much information concerning the air stratum in case one of the bodies is a moving flexible web as we can see in machines using polymer film, belt-saws, and in web-fed machines. In the latter case, the air is supplied into the gap between the web turnovers (which are used to change the web guiding path) and the printing web which envelopes the web turnovers; this not only reduces friction but also ensures the preservation of the fresh paint layer on the web [4].

In the study of the air bars used in web-fed presses to reduce scuffing, the dependencies of the gap between the bar and enveloping paper web (of the air cushion) on parameters such as pressure of the supplied air, the diameter of the bar, the tension and the width of the paper web were identified, and also how configuration of holes and their diameters influence on it [5 - 8]. These studies were carried out in static conditions with a fixed paper web. Meanwhile, it is indicated in the patent literature that wall boundary layers of the air of a moving paper web can contribute to the formation of an air cushion between the web and the bar [9, 10]. In addition, the change in the friction force between the bar and the web (due to the air layer between their surfaces) can be used to adjust the thickness [11]. However, information about the value of the friction forces between the web and the bar (both with direct contact of their surfaces and in the presence of an air gap between them) are missing. Meanwhile, such information is necessary at the design stage of the printing equipment to select the rational parameters of the air system of angle bars and to regulate the web tension in different parts of the paper web track. It should be noted, that wall boundary air layers formed by moving paper web may contribute to formation of air cushion between the web and the air bar, as was described in patent literature [9, 10]. Also, changes in friction force between the air bar and the web created by the air stratum between them can be used to define its own width [11]. Nevertheless, no data concerning friction force between the web and the air bar could be found. Such data could be very helpful in the
printing machines design process; it could help to define the best parameters for turner bar air system and web's tensile at various points of the paper web's trajectory.

2. Purpose of the study

Friction between the web and the bar causes scuffing and damage to the paint layer on the paper web printed. The elimination of contact due to an air cushion requires the determination of a number of parameters, primarily the pressure of the supplied air, depending on the tension and the width of the web. The criterion for the effectiveness of an air cushion can be the friction force between the surfaces of the web and the bar.

The task of this work is to determine the effect on friction force (selected as a main parameter in a dynamic study) between surfaces of the paper web and the air blower bar of such parameters as air pressure, tension force of a paper web and its width.

3. Method of the study

The test was performed on a POG-60 web machine (Figure 1) as follows: webs of different width ($W = 250$ and 590 mm) were set on the drive roller bar ($D = 58$ mm). The tension was measured with the dynamometer 2. The force ($F = 20 - 350$ N/m) was applied to the floating roller 6. The pressure $P$ was measured with manometer 3. It ranged from 0.006 up to 0.028 MPa (depending on $W$). The pressure was generated by the compressor 4. Dial indicator 5 was mounted on a spring-loaded clamp around the bar (Figure 2). It measured deformation of the spring which was proportional to the friction between the surfaces of the web and the air bar.

To calibrate the friction sensor 5 (Figure 2b), a tangential force from 10 to 40 N was applied to thread 8.
Figure 3. Correlation between the friction sensor readings and the thread tension

Measurement errors can be estimated by estimating the standard deviation, which for the calibration process was 1.98 N/mm, with a student coefficient equal to 3.18 (with a confidence level of 90%). This gives a confidence interval of ±3.2 N/mm. The boundaries of the possible values of the estimated forces are shown in Fig. 3 by the dotted lines.

4. Test results

The results of the study of the relationship between the friction force and the belt tension force are shown in Fig. 4 and 5, from which it can be seen that when the compressed air is supplied with a pressure of 0.01 MPa (0.1 ATM), the friction force significantly decreases (in the investigated range of the web tension force) compared to the result that there was no air supply. With the increase in tension of the paper web, the friction force increases; this can be explained by the fact that the increase in tension leads to a decrease in the thickness of the air cushion [5].

Figure 4. The correlation between friction and tensile forces. The web's width is 260 mm. 1 - air – pressure of 0.01 MPa; 2 – no air pressure
Figure 5. The correlation between friction and tensile forces. The web's width is 590 mm: 1 – air pressure of 0.01 MPa; 2 – no air pressure

Figure 6. The correlation between friction and air pressure. 1 – the web's width is 260 mm; tensile is F= 250 N/m; 2 – web's width is 590 mm; tensile is F= 340 N/m; 3 – no air pressure

Figure 7. The correlation between friction and air pressure. Air is fed and tension is applied: 1 – 150 N/m; 2 – 230 N/m; 3 – 310 N/m
Compressed air is fed under pressure of 0.01 MPa (0.1 atm). In any case, tension lowers the friction force. At the same time, the width of the web slightly affects the friction force but with a larger width, the friction decreases slightly (Fig. 6). This can be explained by the fact that the pressure drop along the edges of the web (with increase of the web width) affects less the friction force.

At low web speeds, the air layer is stable, as indicated by an optical sensor. It was noted that with the web tension $F = 230$ N/m and reduced air pressure, the web literally adheres to the surface of the bar, which is highly undesirable from a technological point of view. The air cushion is stable at low speeds, as shown by the optical sensor 6 (Fig. 2), which was mounted on the center of the web, and also was confirmed by the static test [5–8]

5. Summary

At low speeds (up to 1 m/s) with air fed to the bars, the friction force increases when the web tension increases, and decreases when pressure increases. Numerical relationship between friction force and web's tensile and air tension are shown in our diagrams. The web's width has very little influence on the friction force. There was an “adhesion effect”: the web adhered to the air bar's surface. To avoid ink set-off, there are some special methods the authors are working on. Since the above data is purely experimental, there should be more experiments to establish the friction force for different material webs.

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