Friction Properties of Laser and Inkjet Prints

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Abstract

Friction between different papers, inkjet and laser prints were investigated experimentally. Static (SCOF) and kinetic (KCOF) friction coefficients between paper and paper, paper and prints, prints and prints were determined. The highest friction is between prints and prints and lowest is between paper and paper. The dependence of the SCOF and KCOF on pressure (both decrease) together with the roughness measurements enables to conclude that friction of prints is governed mainly by the adhesion forces.

Introduction

The application fields of the digital printing (inkjet, laser) permanently enlarges. Digital printing is more and more used in the paper or board package production [1]. Packages must answer more requirements as compared with the single prints. Among them becomes more prominent the friction between paper and prints. Friction parameters are also important for the run ability of printing devices and also influence the durability of the printed products.

Paper friction properties are reported in many publication [2-10]. Many investigations were made with uncoated paper. It was determined, that paper pulping and bleaching doesn't change friction properties, despite differences in surface energy [7]. In some publications it was determined that friction decreases with the amount of LLC (low molecular mass lopofilic compounds), fatty acids, fatty alcohols and tristerins. Contrary common fillers like calcium carbonate, synthetic precipitated silicas and silicates increased friction [8-10]. Filler size and shape were considered to be dominant factors [8]. High friction coefficients between coated papers are related to the amount of different fillers in its structure.

But the friction properties of prints are almost not investigated. Only in [11] was made an attempt to investigate the friction of flexographic and laser prints. In this work were investigated the friction properties of inkjet and laser prints made with the different papers. Friction of prints was important from the practical viewpoint and the friction between prints and prints and prints and paper was investigated in this work relating friction characteristics to the surface roughness.

Experimental

For the investigation were chosen widely used papers: uncoated "4CC" and "Maxi offset" and photopaper "Lomond". Digital laser prints (electrophotographic laser) were made with widely used printing machine "Xerox 8000". Inkjet prints were made with an inkjet printer "Epson L800". In both cases full coverage background was printed with black ink (single toner layer, 100% K).

Paper and prints roughness was determined with "L&W SE 165 PPS Tester". This method gives the results of roughness in micrometers calculated from the air penetration speed between contacting paper at metal strip surfaces at pressure 0.5 Mpa [12]. Every paper and print sheet was tested in 10 places and the value of roughness is the arithmetical average 10 measurements.

Static and kinetic coefficients of friction between paper and paper, paper and prints, prints and prints were measured with "Thwing – Albert" FPDAS 1.0.0.1 horizontal plane friction measurement device (schema in Fig. 1). Specimen is placed on the table and other is wrapped on the sled. The coefficients of friction are determined from the change of sled pulling force (further friction force) as is shown in Fig. 2: static coefficient of friction (SCOF) is calculated by the computer of device from the friction force maximum value, and the kinetic coefficient of friction (KCOF) is calculated from the friction force relatively stable value. Sliding speed 100 mm/min was set for measurements and the different loads were used to change the pressure between sliding surfaces. As the real contact area between surfaces is unknown, the results are mainly presented referring only to the load (the mass of the sled, sled dimensions 40x40 mm).

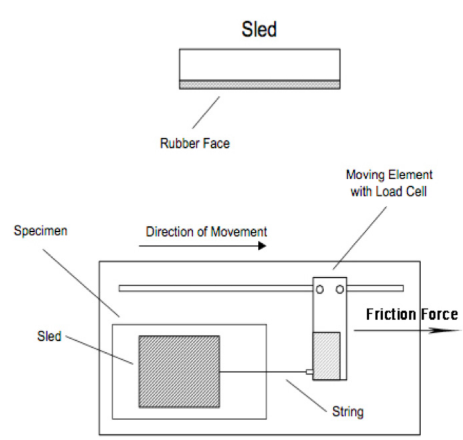

***Fig. 1**. The scheme of horizontal plane friction measurement device*

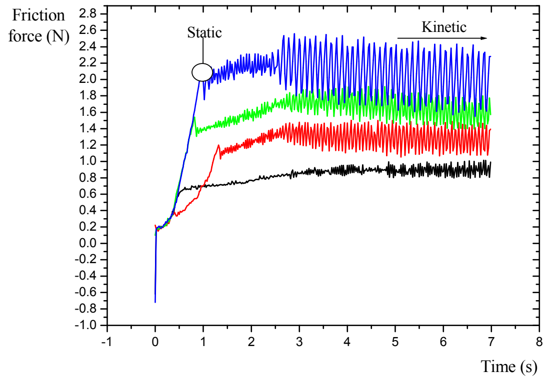

Fig.2. *The change of sled pulling force (friction force) during sliding and the determination of static and kinetic coefficients of friction*

Results and discussion

Inkjet and laser (electrophotographic) printing changes the friction properties of the paper. The changes are different for inkjet and laser printing and depends on the paper grade. Some results of the investigation of the static (SCOF) and kinetic (KCOF) friction coefficients are presented on Fig. 3-8.

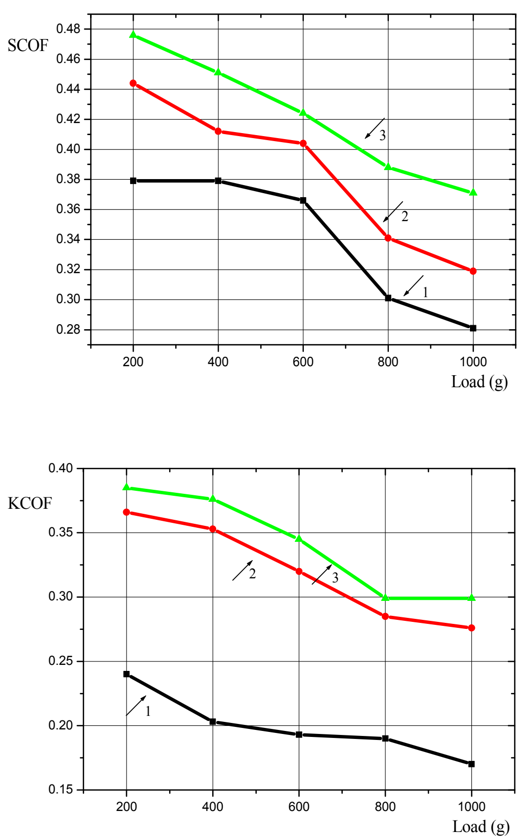

Fig.3. *Inkjet prints, paper “4CC”. Dependence of static (SCOF) and kinetic (KCOF) coefficients of friction on load: 1 – paper to paper, 2 – paper to print, 3 – print to print.*

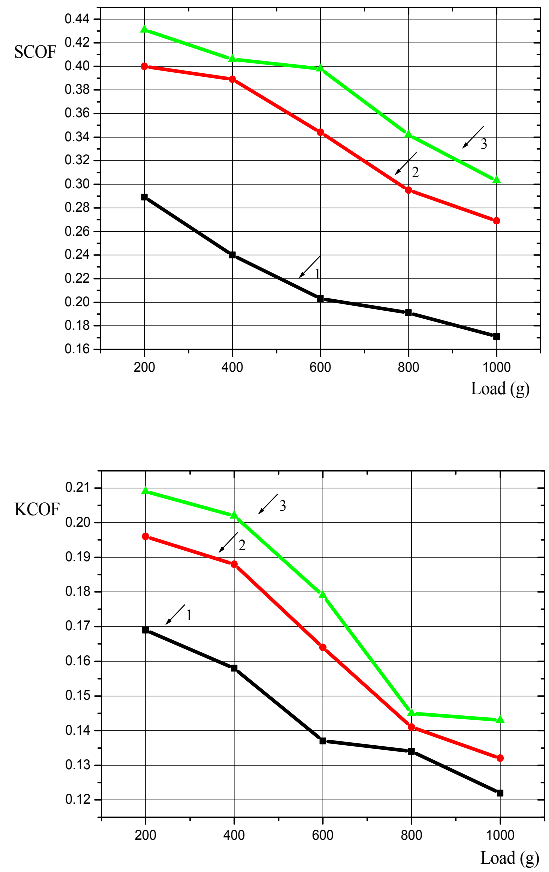

Fig.4. *Inkjet prints, paper “Maxi offset”. Dependence of static (SCOF) and kinetic (KCOF) coefficients of friction on load: 1 – paper to paper, 2 – paper to print, 3 – print to print.*

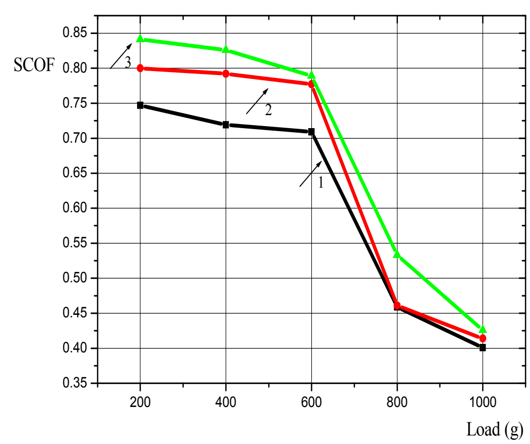

Fig.5. *Inkjet prints, photopaper “Lomond”. Dependence of static (SCOF) coefficients of friction on load: 1 – paper to paper, 2 – paper to print, 3 – print to print.*

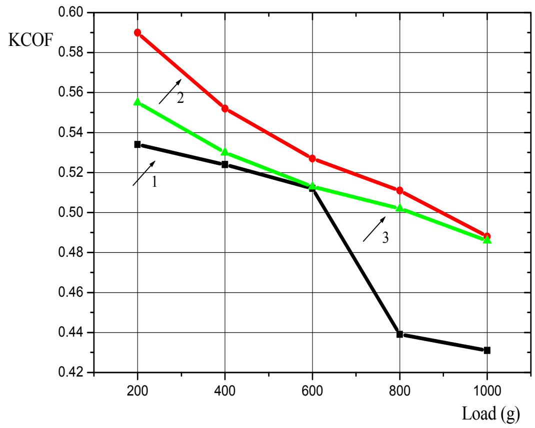

Fig.6. *Inkjet prints, photopaper "Lomond". Dependence of kinetic (KCOF) coefficients of friction on load: 1 – paper to paper, 2 – paper to print, 3 – print to print.*

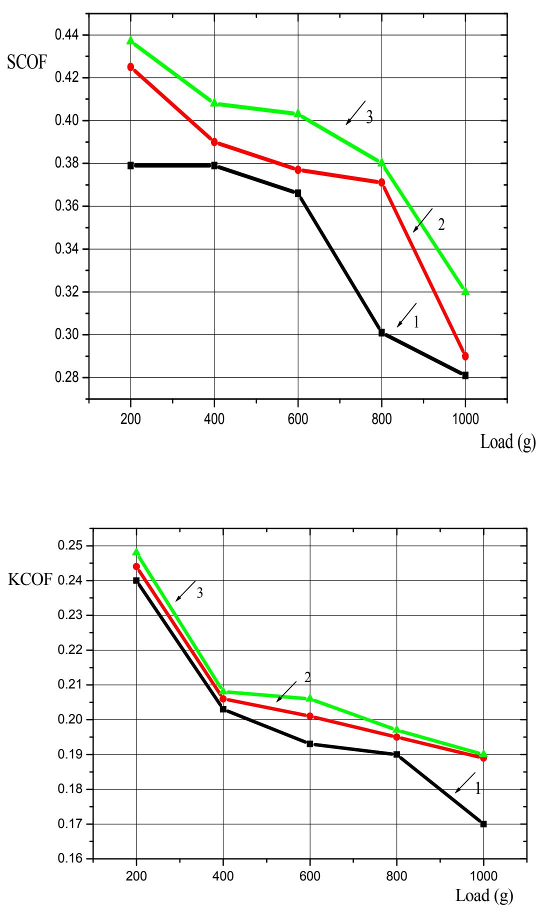

Fig.7. *Laser prints, paper "4CC". Dependence of static (SCOF) and kinetic (KCOF) coefficients of friction on load: 1 – paper to paper, 2 – paper to print, 3 – print to print.*

SCOF values decrease with load (pressure) in all cases (Fig. 3-8) and ink on the paper does not change this dependence essentially (some differences can be caused by the experimental inaccuracies).

The SCOF value decrease can be explained considering the role of adhesion and deformation factors. The possible reason of SCOF decrease with load is that the coefficient of friction is dependent on roughness and adhesion takes a small part in it. Surface real roughness decreases with the pressure so the friction force should be lower because number of asperities becomes smaller. On the other hand contact area with pressure becomes bigger and the input of adhesion forces increases but this increase is less than the increase of the pressure. So the overall result is that friction coefficient decreases with the load (pressure). The pressure affects KCOF values less and relatively smaller its decrease was observed (Fig. 3-8). In this case the situation is a little different: sled has to overcome not pressed surface and therefore pressure influence becomes smaller.

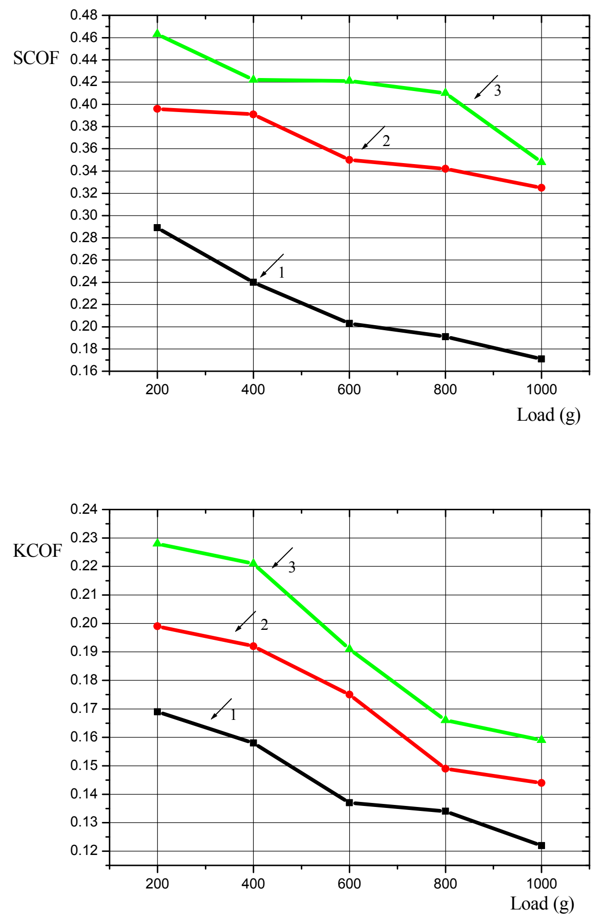

Fig.8. *Laser prints, paper "Maxi offset". Dependence of static (SCOF) and kinetic (KCOF) coefficients of friction on load: 1 – paper to paper, 2 – paper to print, 3 – print to print.*

Comparison of inkjet and laser prints on different papers and at different loads (pressure) shows that static friction coefficients of paper to paper, paper to print and print to print are higher than kinetic friction coefficients as it was expected. Although it was observed one exception: in the case of inkjet prints on photopaper SCOF becomes lower at higher pressures (Fig.5). Similar effect in some coated papers is refered in [6]. Photopaper „Lomond“ is coated paper and it can be assumed that this coating is responsble for the unusual behaviour but the reasons require more detailed investigation.

SCOF and KCOF values depend also on the sliding surfaces. The highest static and kinetic friction is between prints and prints (Fig. 3-8), and the lowest friction is between paper and paper. One possible causes of the increase of friction can be the higher than paper print‘s surface roughness. Analysis of surface roughness (Fig. 9) does not confirm this assumption. Only inkjet prints on the 4CC and uncoated offset paper are of higher roughness while roughness of prints on photopaper is the same as paper roughness and laser prints are even of lower roughness (Fig.9, 4CC paper). This means that the role of the deformation forces does not play significant role and the main factor determining the prints friction properties is the adhesion forces between paper and toner and between toner layers. This is in line with the conclusions made in [6] for the plane papers.

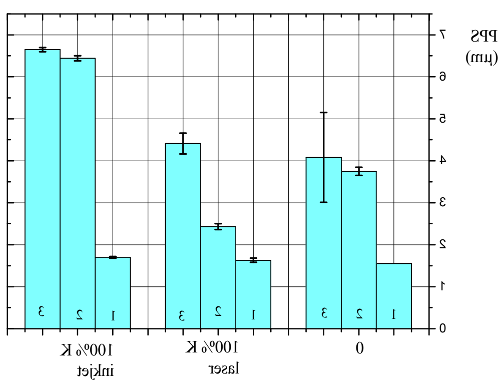

Fig.9. *PPS roughness of paper and inkjet prints. Papers: 1- photo paper “Lomond”, 2 – uncoated “4CC” 100 gsm, 7 – uncoated “Maxi offset” 100 gsm*

Comparison of the absolute values of the static and kinetic friction coefficients on the same paper shows that generally friction of inkjet prints is higher than laser prints.This not big difference can be attributed to the influence of the water based inkjet ink on the uncoated paper. Ink loosens paper surface fibers and causes the increase of the roughness. Roughness takes part in turnin the friction increase. In both cases (inkjet and laser) the friction coefficients of prints (print to paper and print to print) is influenced by the friction coefficients of paper itself: the higher friction paper to paper determines paper to print and print to print friction.

Conclusions

The friction of the inkjet and laser prints is higher than the friction of the paper itself. Paper coating with inkjet ink or fused toner increases both static and kinetic coefficients of friction paper to print and print to print as compared with paper itself. During printing surface roughness which is one of factors influencing the friction changes also. But prints’ friction increase cannot be caused only by the observed changes of the surface roughness although some input of the roughness in the friction of inkjet prints increase is observed. SCOF and KCOF decreases with the pressure. Paper and prints friction dependencies on pressure are similar. This observation together with the roughness changes enable to conclude that the friction of prints depends mainly on the adhesion forces.

SCOF is almost always higher than KCOF with the exception of coated paper at higher pressures. The causes of such behaviour although known in paper physics are not clear and require more detailed investigation on the other coated paper grades.

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