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Deinkability Efficiency of Waste Office Paper Printed Using a Duplicating Machine

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Abstract: Flotation deinking of high-quality waste office paper printed using a Ricoh Priport duplicating machine based on screen printing system was examined. In order to analyse the efficiency of deinking, the printed and unprinted papers were tested for deinking by PTS (Papier Technische Stiftung) method based on three test procedures which are printed stock, unprinted stock and deinked stock. After deinking and preparation of handsheets, the optical and physical properties of samples were measured according to Tappi and ISO standards. Finally a comparison was made between three stocks as focusing on deinking performance, physical strength, yields and environmental concerns. Results showed that the value of average deinking coefficient for examined samples was 86.11% and pulp yield losses for all the runs were found around 30%. There were no significant differences in the quality and treatability of the process or waste water taken from the three runs. The deinked trial displayed improved brightness and whiteness properties and comparable strength compared to the printed stock trial.

Key words: Deinking, deinkability factor, flotation, waste paper, office paper, screen printing

INTRODUCTION

It is well known that recycled fibre is an important source of raw material for the paper and paperboard industry. Besides being a low-cost fibre source for paper and board manufacturing, it preserves forest resources, reduces environmental pollution and conserves water and energy (Bajpai and Bajpai, 1998). Papermakers are now focusing on recycling as economic necessity and raw material but it can be estimated that recycling will be the implicit fate of all paper producers in the future.

The recovery and utilization of waste papers is increasing all over the world. The major difficulty in recycling of paper is removal of inks (Vyas and Lachke, 2003). New deinking mills established in Turkey and world-wide in response to this projected need are already competing for the cleanest, most homogeneous and bright deinked pulp. When a printed paper is repulped, it usually gives a dark stock, or a stock which is specky. It is clear that the print on the paper is responsible for this behaviour. Some part of recycled wastepaper is treated to remove print particles, so the final stock is bright, speck free and can replace virgin fibre in newsprint, tissue and printing grades (Galland and Vernac, 1999). Deinking is a term describing a process for detaching and removing printing inks from recycled fibre to improve optical characteristic of pulp and paper using recovered printed material (Renner, 2000).

The efficiency of deinking process or ink/dirt removal is influenced by a wide range of factors (Ferguson, 1992;

Rao and Stenius, 1998; Dorris, 1999) Chemicals charge, process equipment and other factors such as retention time, temperature and pH for the waste paper deinking system depend firstly on the type of furnish (paper formulation, ink content, ink-printing system) and secondly on the final brightness requirements (Thoyer, 1995; Vincent *et al.* 1997; Carrasco *et al.*, 1999). Paper maker who produces paper from recycled fibre must know the degree of deinkability factor of waste paper and decide the brightness requirement of final stock.

The objective of the present study is to examine the deinkability efficiency or the degree of printing ink removal by the deinking process for high-quality office papers printed with Ricoh Priport duplicating machine and investigate differences in the quality and treatability of waste water discharged from washing process of deinked and printed stock.

MATERIALS AND METHODS

All tests were made on 80 g m⁻² white long grain office paper with A4 size and printed using a RICOH VT1760 model priport duplicating machine. Printed (POP) and Unprinted Office Papers (UOP) were placed in a warming cabinet for accelerated ageing (correspond to 3-12 month natural ageing) for 144±2 h at 60±3°C. It is well known that aging of paper affects on deinkability efficiency (Haynes, 2000). After being aged, samples were stored in a conditioned room at 24 h, 23±1°C and 50±2% relative humidity. Three 100 g oven-dry samples from a

representative part of the sheets (one of them taken from unprinted sheets for producing unprinted stock (US) and rest of them taken from printed sheets producing deinked (DS) and printed stock (PS)) were weighed out accurately and torn approximately 2×2 cm in size. Process conditions for laboratory evaluations are given in Table 1 and schematic of laboratory process stages is illustrated on Fig. 1.

To evaluate the pulp for all the runs, prepared sample of 100 g oven-dry was repulped with Hobart type pulper.

Table 1: Process conditions for laboratory evaluation

Re-Pulping	Sodium hydroxide	1.0%*
	Sodium silicate	1.5%*
	Hydrogen peroxide	1.0%*
	Temperature	40°C
	Consistency	10%
	Retention time	10 min
Reaction	Temperature	40°C
	Consistency	10%
	Retention time	20 min
Disintegration	Temperature	40°C
	Consistency	2.5%
	Retention time	2 min
Flotation	Olinor RS-4020 soap	0.8%
	Air flow	3 L min ⁻¹
	Temperature	40°C
	Consistency	1.0%
	Retention time	10 min
	Agitation speed	1450 rev min ⁻¹
Washing	Water flow	2.5 L min ⁻¹
	Temperature	40°C
	Consistency	1.0%
	Retention time	10 min
Other parameters	Water conductivity	148 µS cm ⁻¹
	Water pH	6.35
	Water hardness	4.5°dH

*All chemical charges are given as percentages based on oven-dried pulp

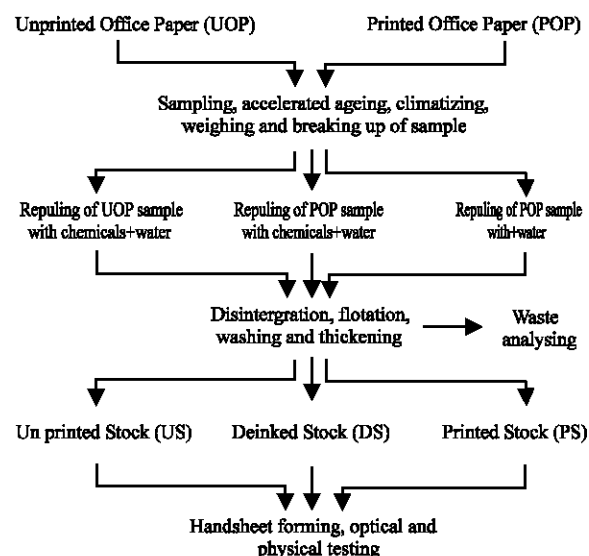


Fig. 1: Schematic laboratory process stages

Pulping time, temperature and consistency were fixed at 5 min, 40°C and 10% consistency. In order to swell fibres, break up of ink and bleach the stock required chemicals were added to US and DS pulp stocks. Stock sample was transferred into polyethylene (PE) bag and placed in a water bath of 40°C. Reaction was carried out at 10% stock consistency for 20 min.

Prior to flotation process repulped stocks were disintegrated in a laboratory disintegrator for 2 min at 40°C and 2.5% consistency. Flotation process was carried out in a 10 L capacity Degussa flotation cell. Disintegrated pulp stock was diluted to 1% consistency (o.d. wt.) and transferred into the flotation cell. The stirrer was set to 1450 rev min⁻¹ and airflow through the small hole in the bottom was controlled with the flow-meter to 3 L min⁻¹. 0.8% resin soap (Olinor-RS 4020) solution was added into suspension. Typically the flotation was continued for 10 min at 40°C.

Washing and/or thickening process was conducted with 105 µm sieves (150 mesh) on the inner box of the Degussa washing cell. This permits only fines, fillers and residual printing ink to pass. The deinked pulp with 1% consistency was transferred into the inner box and than washing cell was filled totally with water. Water flow into the inner sieve box was adjusted to 2.5 L min⁻¹ and simultaneously stirrer was switched on. The condition of the washing process was; 10 min retention time and 40°C flow water temperature. Waste water was kept in a bucket to be analysed further chemical tests such as Chemical Oxygen Demand (COD) (Taras, 1975), Total Dissolved Solid (TDS), conductivity, inorganic and organic material contents. Ten minutes later, water flow was cut off and pulp was thickened in the inner box to approximately 30% consistency. Stock was stored in a refrigerator at <+4°C before making handsheets and examination of other properties.

Freeness of the stocks was measured by Schopper Riegler instrument according to SCAN M3-65 method. To eliminate the influence of the pH on the brightness measurement pulp stock with 0.4% consistency was acidified to pH 5 before handsheet forming. Handsheets were prepared on the Rapid Köthen semi-automatic handsheet former. Optical and physical properties of handsheets were measured according to TAPPI and ISO standards. This laboratory study was conducted in the Department of Forest Product Chemistry and Technology, Forestry Faculty, Istanbul University, Turkey in 2005.

RESULTS AND DISCUSSION

Table 2 shows the results of the study conducted to measure the physical properties of office paper with

Machine Direction (MD) and Cross Direction (CD) and handsheets prepared by deinking of unprinted office paper (US), deinking of printed paper (DS) and recycling of Printed Paper (PS) under laboratory conditions. The handsheet strength character such as tensile and burst index of the DS was noticeably greater than the recycled stock PS and US.

The optical properties of the pads obtained from all the pulp stock can be seen on Table 3. Results show that opacity value of printed stock is distinguishably higher than deinked and unprinted stock. Dark colour and micro-particle of dispersing inks are attributed responsible for decreasing opacity value of the sheet. b^* value of base office paper is significantly higher than PS which confirms the removal of the optic whitener during flotation and washing process.

Traditionally the simplest and fastest way to evaluate deinkability is to characterise the difference between the brightness of the deinked pulp and the brightness of the pulp before deinking. Deinkability factor (Def) is calculated from the mean brightness values of the handsheets of Printed Stock (PS), Unprinted Stock (US) and Deinked Stock (DS) as follows,

$$\text{Def} = \frac{\text{Brightness(DS)} - \text{Brightness(PS)}}{\text{Brightness(US)} - \text{Brightness(PS)}} \times 100$$

Deinkability factor can be 0-100%. A deinking coefficient near 100% represents a perfectly deinkable sample, whereas a deinking coefficient near 0% means very poor deinkability. The value of average deinking coefficient in this study was calculated as 86.11%. This result shows a relative good deinkability of treated furnish. It is well known that deinkability efficiency is influenced by

number of factors such as paper type, ink formulation, ink set up, ageing and deinking techniques (Somasunduran and Zhang, 1998; Haynes, 2000; Costa and Rubio, 2005)

The CIELAB system was used to describe the colour of the paper after deinking. The three axes measure colour attributes as follows;

$$\begin{array}{lll} L^* = 0 & \text{Black,} & L^* = 100 \text{ White} \\ a^* < 0 & \text{Green,} & a^* > 0 \text{ Red} \\ b^* < 0 & \text{Blue,} & b^* > 0 \text{ Yellow} \end{array}$$

Thus the closer the value of L^* approaches 100 and the closer the values of a^* and b^* approach 0, the whiter colour appears. According to TAPPI official test method T-524 om-86 white or near white papers are those that have the following values;

$$L^* > 84 \text{ and } (a^{*2} + b^{*2})^{1/2} < 10$$

These parameters were used in detail on office paper for colour stripping characteristic (Hache *et al.*, 1994) The results found in this study for the L^* a^* b^* values of deinked stock were 92.15, 1.19 and -7.84, respectively. According to aforementioned formulations it can be easily concluded that handsheet evaluated from deinked stock was white or near white.

Materials losses with flotation and washing process are exhibited in Table 4. Yield figures show that total losses in the flotation and washing stage were found 30.07, 31.76 and 32.76% for unprinted stock, deinked stock and printed stock, respectively. Total solid material losses include; inorganic materials (filler, surface inorganic material and ink mineral), organic materials (broken up fibres and fines) and dissolved solid (any dissolved material in the pulp slurry).

Generally, waste or process water taken from the washing cell is a mixture of fibre, fines, mineral loadings, ink particles, colloidal inorganic and organic material, dissolved solid etc. Proportions of these vary according to the furnish of waste paper being recycled. In this study, Chemical Oxygen Demand (COD) values, contents of suspended and dissolved solids and conductivity of waste water taken from washing cell are measured and

Table 2: Physical strength results of base paper and handsheets

Physical properties	UOP-MD	UOP-CD	US	DS	PS
Grammage (g m ⁻²)	78	78	74	74	74
Thickness (µm)	101	101	146	142	140
Bulk (cm ³ g ⁻¹)	1.29	1.29	1.97	1.92	1.89
Breaking length (km)	5.319	3.321	2.393	3.435	3.004
Tensile index (N mg ⁻¹)	52.12	32.54	23.45	33.66	29.44
Stretch (%)	2.23	5.50	1.86	3.57	2.40
Tear index (mN m ² g ⁻¹)	7.30	7.35	8.34	9.34	8.18
Burst index (kPa m ² g ⁻¹)	2.09	2.09	1.47	1.86	1.39
Schopper number (°SR)	-	-	15	18	16
Ash content (%)	16.50	16.50	1.15	1.49	1.49

Table 3: Optical test results of base paper and handsheets

Optical properties	UOP	US	DS	PS
ISO Brightness (%)	103.26	92.57	91.32	83.57
CIE L*	94.65	94.80	92.15	89.71
CIE a*	2.71	1.98	1.99	2.06
CIE b*	-11.62	-7.07	-7.84	-6.48
(a ^{*2} +b ^{*2}) ^{1/2}	11.93	7.34	8.08	6.79
Whiteness (%)	139.24	117.58	116.42	106.31
Opacity (%)	87.53	86.45	87.84	94.94

Table 4: Yield analysis in the flotation and washing process stages

Process		US	DS	PS
Flotation losses	Quantity (g)	2.43	2.71	-
	Ash content (%)	51.45	54.05	-
Washing losses	Quantity (g)	29.64	30.05	32.57
	Ash content (%)	47.67	45.12	46.11
Total losses	Quantity (g)	32.07	32.76	32.57
	Ash content (%)	47.86	45.81	46.08

Table 5: pH of process stages and waste water analysis

		US	DS	PS
pH	Re-pulping	11.10	11.20	7.37
	Flotation	9.70	9.65	-
	Washing	8.70	8.80	7.00
	Prior to handsheet making	5.20	5.10	5.30
Waste water (37 L)	COD (mg L ⁻¹)	293.00	269.00	308.00
	Conductivity (μS cm ⁻¹)	66.00	57.00	30.00
	TDS (mg L ⁻¹)	78.00	83.00	56.00

results were given in Table 5. According to the results, there were no significant differences in the quality and treatability of the process water from the three runs.

CONCLUSIONS

The deinkability efficiency for high-quality photocopy papers printed by Ricoh Priport duplicating machine was studied using a laboratory flotation cell (Degussa) with a nominal capacity of 10 L. Process conditions for laboratory evaluations in this study were based on PTS methods.

According to the L^* and $(a^{*2}+b^{*2})^{1/2}$ values which were 92.15 and 8.08, handsheets made of deinked stock can be defined as white or near white paper. The value of average deinking factor was calculated as 86.11%. This figure gave an idea of relative good deinkability of furnish treated in this study. It means that office paper printed with duplicating machine studied in this study can be used in deinking facilities which produce high optic quality required final products. Total losses after flotation and washing process were found around 30%. This amount includes filler material, ink, fines and may be fibres. According to waste analysis such as chemical oxygen demand and solid content in the waste water there were no significant differences in the quality and treatability of the waste water for all the runs. As a conclusion, 80 g m⁻² white office paper printed using a RICOH VT1760 model priport duplicating machine based on screen printing system have a good deinkability character.

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