TECHNISCHE UNIVERSITÄT DRESDEN

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Maschinenwesen Verfahrenstechnik Institut für Holz- und Papiertechnik, Professur für Papiertechnik

Melting, Penetrating and Fixing of Laser Printing Toner on Fine Papers

Michael Barth (Stora Enso Uetersen)
Roland Zelm (TU Dresden)

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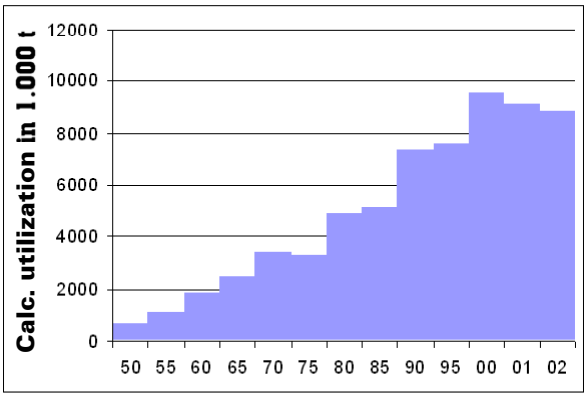
Content

Initial situation and problem formulation

Consumption of printing and writing papers / office and administration papers since 1950

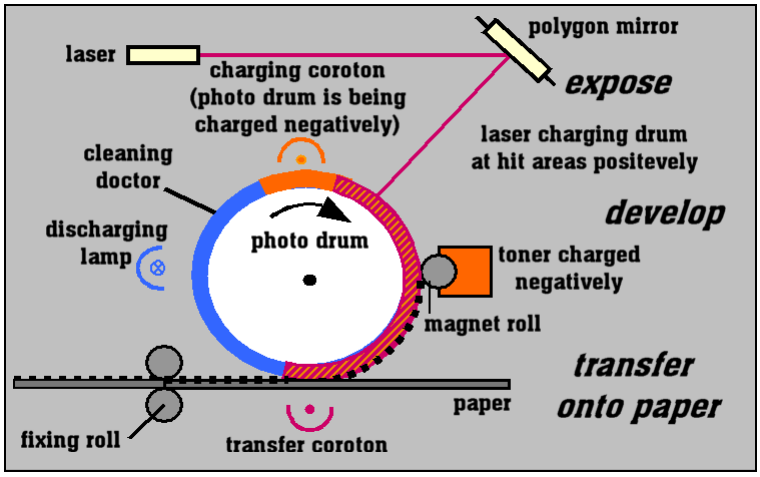


- Consumption of laser printing papers increases
- The laser printability of paper becomes an important issue for quality reasons
- Toner adhesiveness has been identified as a decisive factor

Initial situation and problem formulation

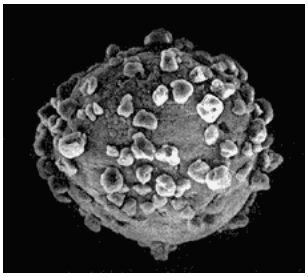
- Research in the field of laser toner adhesiveness is not yet enough developed.
- There is no universally applicable test method for the assessment of toner adhesiveness available.
- It is not yet possible to predict the influence of surface properties on toner adhesiveness clearly.
- There is a need to develop a measuring technique giving information on surface energy involving the effect of roughness as force in the unit “mN” (also for rougher papers).
- There is a need to define and develop a measuring procedure that assesses toner adhesiveness in a significant manner and with good comparability and reproducibility.
- The correlation of surface properties and other paper properties with toner adhesiveness needs to be examined.

Laser printing technology



Laser printing technology

Toner particles consist of:



Diameter 100 µm

- Resin particles which melt on the paper surface while they are exposed to high temperature
- Magnetisable metal oxides for electro static charging
- Colour pigments which give the right colour impression
- Supporting substances have special tasks, i.e. amorphous silicon dioxide as release agent

Surface energy: 30 mN/m
Diameter of modern toner particles: 5 µm -10 µm

Characterizing of the paper samples

Paper samples

sample code	substance weight g/m²	surface treatment
L01	80	uncoated
L02	80	uncoated
L03	100	uncoated calendered
L04	100	uncoated calendered
L05	100	uncoated
L06	160	uncoated
L07	100	uncoated calendered
L08	160	uncoated calendered
L09	135	matt coated
L10	135	glossy coated
L11	135	matt coated
L12	135	glossy coated

Characterizing of the paper samples

Thermal diffusion

$$\alpha = \frac{\lambda}{\rho \cdot c}$$

α – Thermal diffusion in m²/s

λ – Heat conductivity in kW/(m·K)

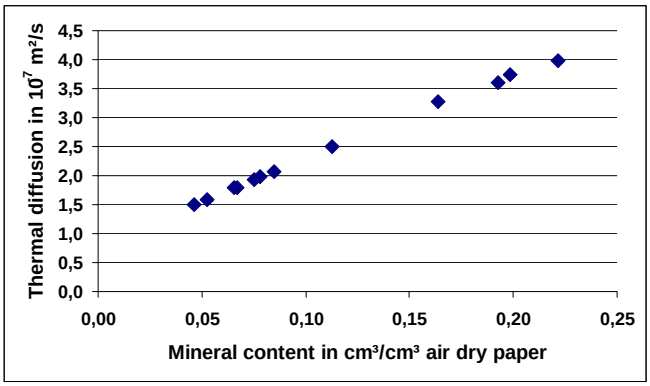
ρ – Apparent density of the paper in kg/m³

c – Specific heat capacity in kJ/(kg·K)

- Combines heat capacity and heat conductivity
- Includes dynamic changes of the temperature inside the papers
- Temperature propagation in z-direction depends on thermal diffusion

Characterizing of the paper samples

Correlation between mineral (ash) content and thermal diffusion



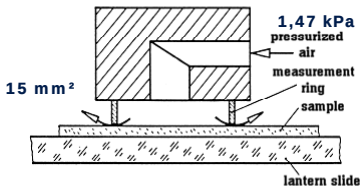
The higher the mineral content the higher the thermal diffusion

→ The higher the thermal diffusion the better is the toner adhesiveness

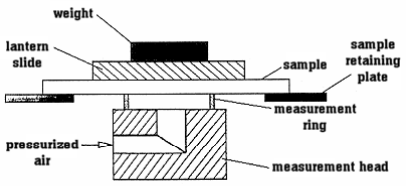
Characterizing of the paper samples

Modified roughness measurement Bendtsen method

Measuring head of the Bendtsen facility



Measuring head of the modified Bendtsen



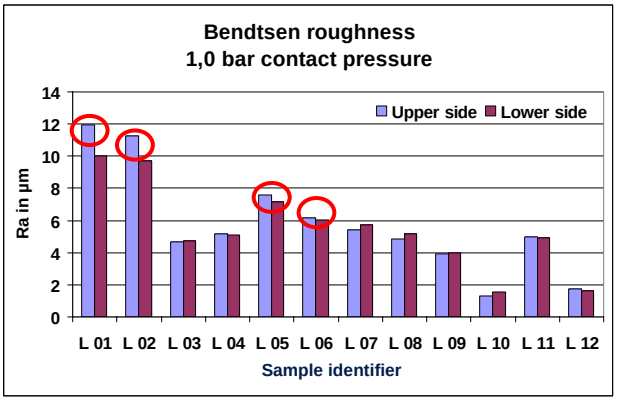
$$Ben - Ra = \quad 1{,}545 \cdot \sqrt[3]{BEN\text{-}RA} \quad \approx \quad 1{,}5 \cdot \sqrt[3]{BEN\text{-}RA}$$

BEN-Ra Rauheit Bendtsen (µm)

BEN-RA Messwert Rauheit Bendtsen (ml/min)

Characterizing of the paper samples

Bendtsen Roughness method using 1 bar (contact pressure over a hart pad)

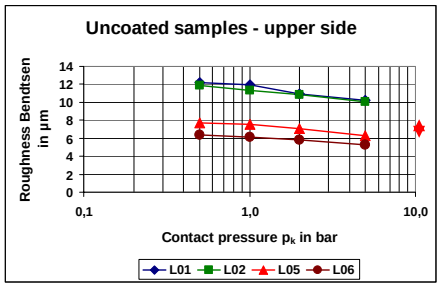


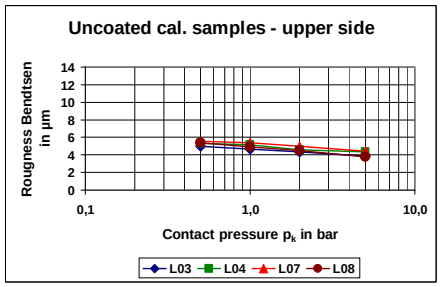
Untreated samples have the highest roughness

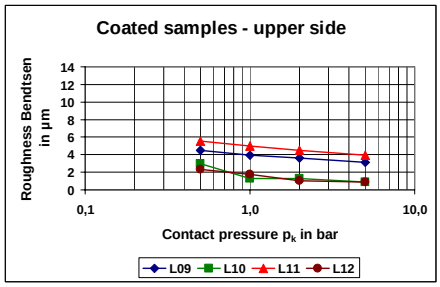
→ Lower toner adhesiveness

Characterization of the paper samples

Bendtsen roughness as a function of contact pressure (hard pad)

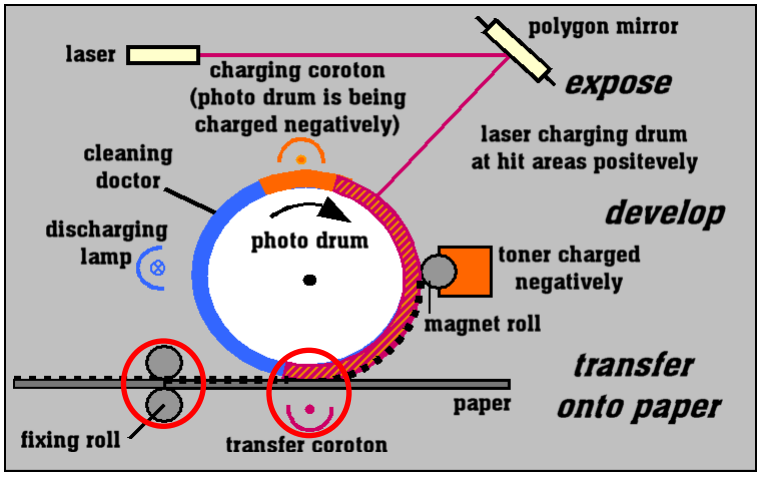






Between 0,5 bar and 5 bar Bendtsen roughness decreases approximately linearly with the logarithm of contact pressure

Laser printing technology



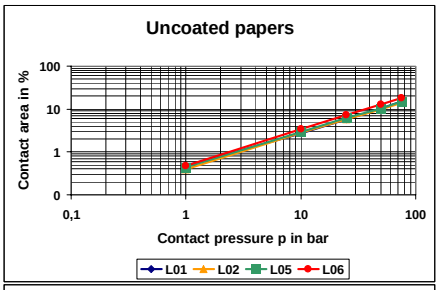
Characterizing of the paper samples

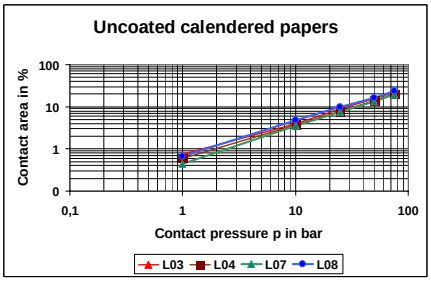
Relative contact area as a function of contact pressures

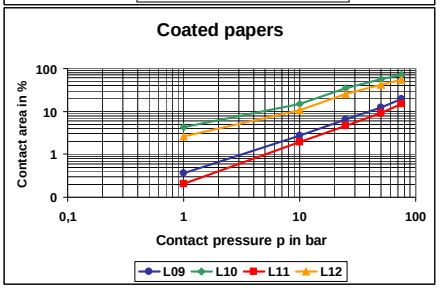
Relative contact area in %					
	Pressure p in bar				
	1	10	25	50	75
L01	0,47	2,77	5,75	10,06	14,85
L02	0,40	2,83	5,72	9,81	14,05
L03	0,75	4,02	8,88	15,34	21,65
L04	0,60	3,64	7,95	13,91	19,98
L05	0,44	2,99	6,19	10,15	14,87
L06	0,48	3,42	7,38	12,78	18,10
L07	0,45	3,50	7,61	13,29	19,27
L08	0,65	4,80	9,71	16,32	23,73
L09	0,37	2,77	6,62	12,60	19,92
L10	4,34	15,24	34,18	56,20	70,89
L11	0,21	1,89	4,60	9,17	15,17
L12	2,65	10,81	25,25	41,73	54,00

Characterizing of the paper samples

Relative contact area as a function of contact pressure (soft pad)





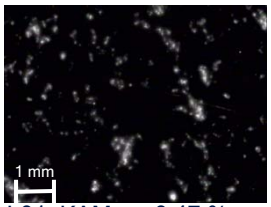


- Gradients of the functions for all paper grades are approximately linear

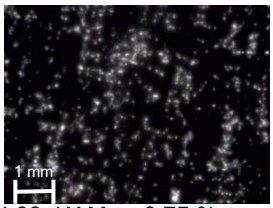
→ Higher contact area improves the toner adhesiveness

Characterization of the paper samples

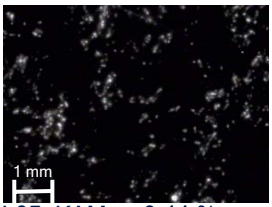
Relative contact area as a function of contact pressure (soft pad)



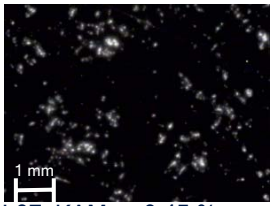
L01: $KAM_{1,0}$ =0,47 %



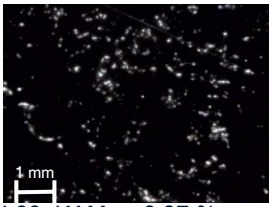
L03: $KAM_{1,0}$=0,75 %



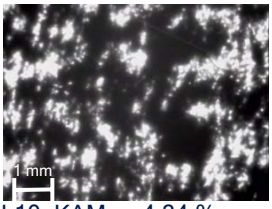
L05: $KAM_{1,0}$=0,44 %



L07: $KAM_{1,0}$=0,45 %



L09: $KAM_{1,0}$=0,37 %

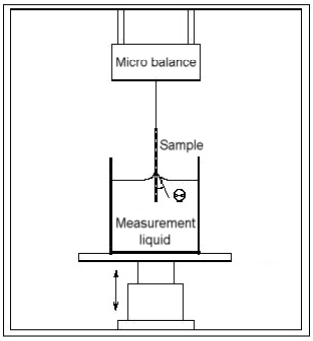


L10: $KAM_{1,0}$=4,34 %

Surface energy – Wilhelmy method

Measurement of the surface energy – according to the Wilhelmy method

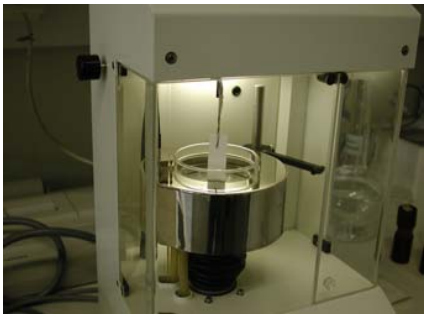
- Designed to measure the surface energy of liquids
- A platin plate is inserted in a jar containing the liquid
- The force necessary to pull the plate out of the liquid is recorded by a micro balance
- The higher the force, the higher the surface energy
- Platin plate – contact angle 0°
- Calculation of surface energy



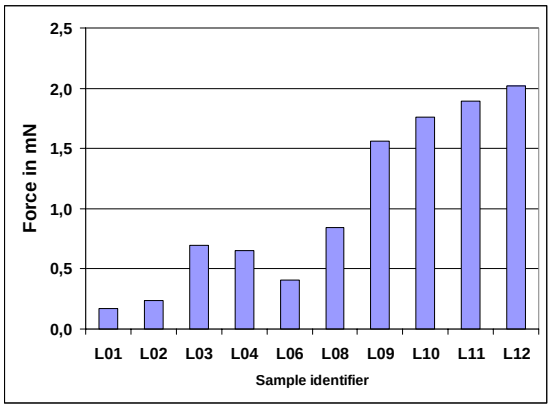
Surface energy – Wilhelmy method

Indirect measurement of the surface energy of paper

- Platin plate is replaced by a paper strip (15 mm width)
- Use of distilled water
- Gives only comparative, no absolute values
- Measurement results depend on both surface energy and roughness



Surface energy – Wilhelmy method



- Untreated paper grades need lower forces
- Highest values for coated papers

→ Higher surface energy improves toner adhesiveness

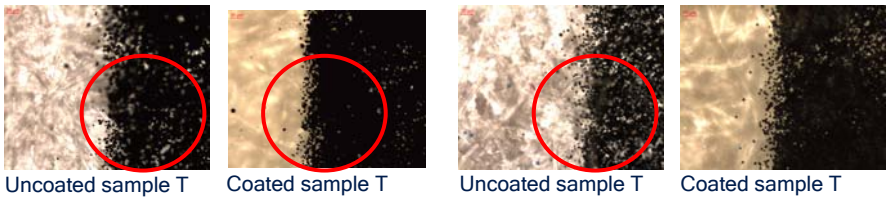
Toner adhesiveness

Sample of printed areas in x-y and x-z direction

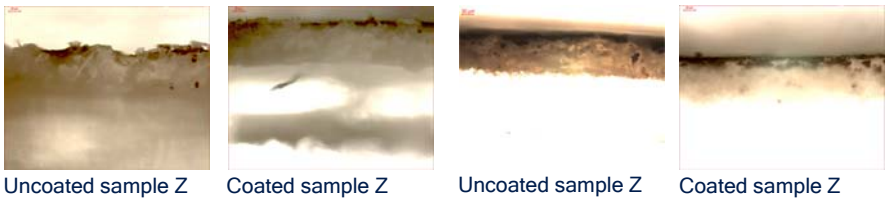
30 µ

Laser printer: black

Laser printer: colour



Uncoated sample T | Coated sample T | Uncoated sample T | Coated sample T

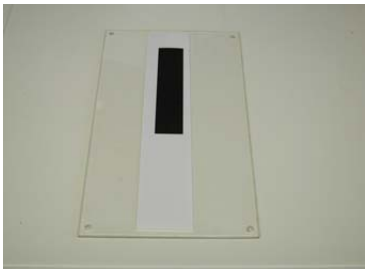


Uncoated sample Z | Coated sample Z | Uncoated sample Z | Coated sample Z

Toner adhesiveness

Printers investigated

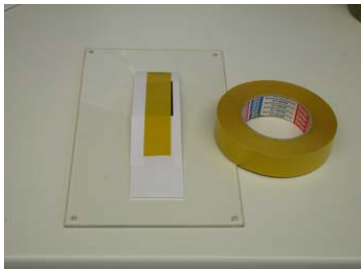
- Colour laser printer
- Black/white laser printer



Specimen for toner adhesiveness measurement

Cut sample

Toner adhesiveness

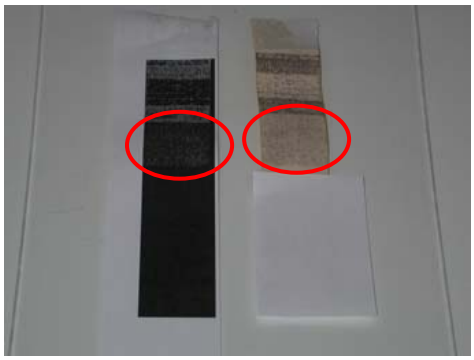


Sample with applied adhesive tape

Pressing of the adhesive tape

Tensile testing with clamped sample

Toner adhesiveness

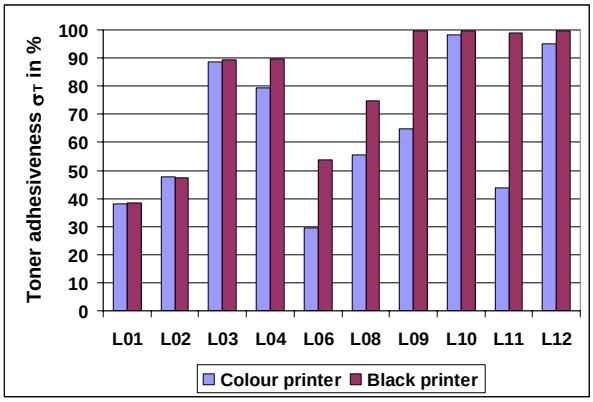


Toner adhesiveness σ_T :

$$\sigma_T = \frac{R457_2}{R457_1} \cdot 100\%$$

Toner adhesiveness

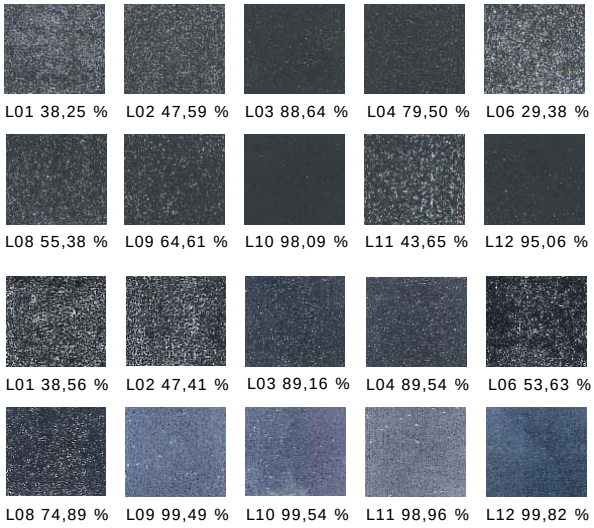
Comparison of the toner adhesiveness on the paper samples for both laser printers



- Toner adhesiveness is higher with coated papers
- Toner adhesiveness is lower for colour prints
- Printer type influences test results

Toner adhesiveness

Printing samples after removing the adhesive tape



L01 38,25 % L02 47,59 % L03 88,64 % L04 79,50 % L06 29,38 %

L08 55,38 % L09 64,61 % L10 98,09 % L11 43,65 % L12 95,06 %

Colour printer

L01 38,56 % L02 47,41 % L03 89,16 % L04 89,54 % L06 53,63 %

L08 74,89 % L09 99,49 % L10 99,54 % L11 98,96 % L12 99,82 %

Black printer

Toner adhesiveness

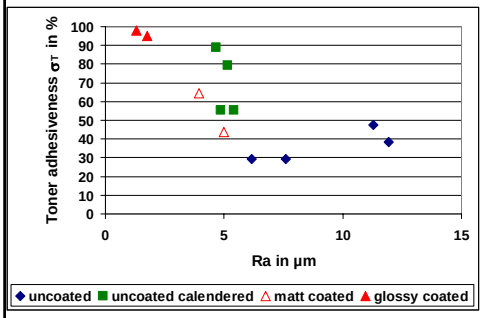
Correlation of various paper properties with toner adhesiveness

Grade	Grammage in g/m²	Apparent density in g/cm³	volumetric part in cm³/cm³ air dry paper				Bendtsen rougness (upper side) 1 bar in µm	Contac area 1 bar in %	TAPPI gloss (upper side), md in %	Surfase energy as force in mN	Spezific heat capacity in K.J/(Kg·K)	Wärmeleitfähigkeit in W/(m*K)	Thermal diffusion in 10^{-7} m²/s		Toner adhesiveness (colour printer) in %	Toner adhesiveness (black printer) in %
			Water	Fibre wall	Minerals	Air (gas)										
L01	81	0,81	0,036	0,400	0,067	0,497	11,9	0,47	5,4	0,1736	2,0	0,29	1,79		38,25	38,56
L02	80	0,85	0,036	0,398	0,085	0,481	11,3	0,40	5,2	0,2380	1,9	0,34	2,08		47,59	47,41
L03	101	1,07	0,054	0,563	0,066	0,317	4,7	0,75	14,9	0,6985	1,6	0,32	1,79		88,64	89,16
L04	99	1,12	0,047	0,517	0,113	0,323	5,1	0,60	12,0	0,6520	1,6	0,44	2,50		79,50	89,54
L05	99	0,85	0,032	0,411	0,075	0,481	7,6	0,44	4,2	0,4073	1,9	0,31	1,93		29,38	53,63
L06	160	0,93	0,045	0,458	0,078	0,420	6,2	0,48	7,7	0,4073	1,8	0,33	1,97		29,38	53,63
L07	101	0,97	0,042	0,536	0,046	0,375	5,4	0,45	9,4	0,8403	1,7	0,25	1,49		55,38	74,89
L08	161	1,01	0,049	0,553	0,052	0,346	4,9	0,65	13,9	0,8403	1,7	0,27	1,58		55,38	74,89
L09	100	1,20	0,046	0,428	0,199	0,328	3,9	0,37	30,5	1,5574	1,5	0,66	3,74		64,61	99,49
L10	100	1,41	0,053	0,518	0,222	0,207	1,3	4,34	78,7	1,7613	1,3	0,74	3,98		98,09	99,54
L11	133	1,09	0,036	0,419	0,164	0,381	5,0	0,21	20,4	1,8957	1,6	0,56	3,28		43,65	98,96
L12	133	1,33	0,047	0,519	0,192	0,241	1,8	2,65	65,7	2,0224	1,4	0,66	3,61		95,06	99,82

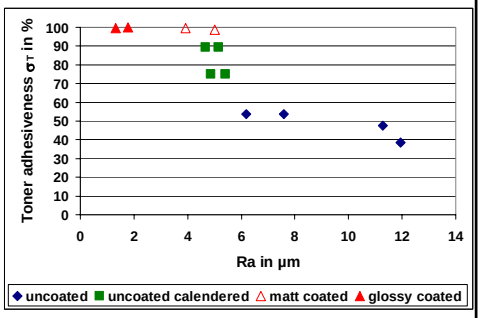
Toner adhesiveness

Toner adhesiveness as a function of Bendtsen roughness

Colour printer



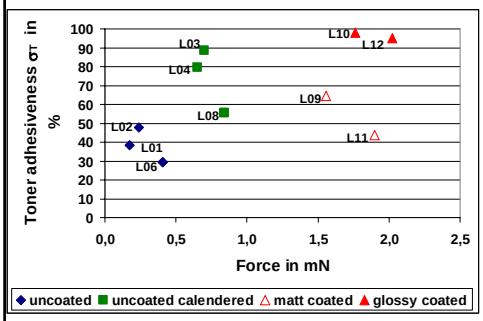
Black printer



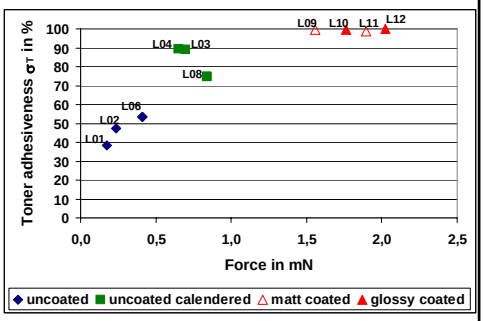
Toner adhesiveness

Toner adhesiveness vs. surface energy

Colour printer



Black printer



Toner adhesiveness

Test results

Property	Toner adhesiveness
Roughness ↑	-
Contact area ↑	+
Surface energy ↑	+
Specific heat capacity ↑	-
Heat conductivity ↑	+
Thermal diffusion ↑	+

- Low values of roughness and high values of surface energy improve the toner adhesiveness.
- The larger the contact area the better is the toner adhesiveness.
- Higher values of thermal diffusion improve the toner adhesiveness.
- Printer characteristics affect the toner adhesiveness significantly.

Summary and conclusions

- Roughness and surface energy have a pronounced influence on toner fixing.
- There is a good correlation between toner adhesiveness and thermal properties of the paper.
- The test results obtained provide only the basis for the assessment of the quality of toner adhesiveness.
- Printer characteristics affect adhesiveness of the toner significantly.
- In order to obtain more general conclusions the accomplished test should be extended to a broader variety of printers and toners.

Acknowledgement

The authors would like to express their acknowledgement to the German Pulp and Paper Association (VDP), all partners from industry for their valuable contributions and intensive support to this work.

Thank You for Your Attention