Statistical Analysis of the possibilities and limits of Flexographic Process Modelling.

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Abstract: Several research programmes are aiming at a standardisation of the flexographic printing process. To obtain viable results, it is necessary to distinguish between different steps in the scientific approach to the problem. The first one is to formulate a "useful" definition of printability in flexography. This definition will then, at a final stage, allow a statistical analysis based on parameters defined in advance. One of the intermediate steps of the work consists of a comparison of the different possibilities of modelling the flexographic process. The goal is less to pass a judgement than to find a correlation between the different methods for future investigations. In this study, we have compared 2 different industrial production presses, a laboratory press and 2 simulation systems. The results obtained are positive: the parameter printing press can, within certain limits, be fixed as a constant for future investigations.

1. Objectives of the investigation

The flexographic process is from the first approach based on a simple ink transfer concept but if you look at it in more detail you discover a multitude of variable parameters which influence this ink transfer and also the quality of the final printed result. Due to economic demands and ever decreasing delivery times, it is impossible to run a job on a production press for use as proof. Therefore the industry is looking to develop systems with the ability to refine the flexographic process or at least a part of the process. The goal of the project was to analyse the correlation between production printing presses and these modelling systems.

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2. Review of the modelling systems available in the market with short description

An inquiry has shown that the number of available systems is not as significant as expected. The reasons are once again the costs of the development of such devices which can not be sold in large series and the
lack of knowledge of modelling the flexographic process.

References to 6 companies have been found which deal with development and marketing of "modelling systems" for the flexographic process.

IGT Reprotest has developed the computerized F1 printability tester which consists of a combined inking unit with an engraved anilox roller, doctor blade and a printing unit with printing form and impression cylinder. The substrate is attached to a substrate carrier and placed on the substrate guide, between the printing form and the impression cylinder. With the aid of a pipette, a few drops of ink are applied to the nip between the doctor blade and the engraved anilox roller. The ink is transferred from the anilox roller to the printing form and from the printing form to the substrate.
Two prints are automatically made since this the anilox roller is filled as well as possible with ink. The second print will be used for the evaluation.

The MacMillan Bloedel Print Indicator & Sizing Tester was developed to provide a rapid indication of print quality and sizing characteristics. Using an analytical pumping system, the device dispenses microliter-sized drops of ink onto a mylar foil. The drops are then drawn onto the paper sample and down its length by a motorized blade at controlled speed and pressure. The resulting printing length is directly related to ink receptivity and surface topography.

The Pamarco Flexo Proofer is a simple hand-held device, using an anilox roller for dispensing a layer of ink on to the substrate. With the aid of a micropipette, 250µl of ink are applied to the nip between the anilox roller and the rubber roller. Then the proofer is drawn rapidly along the sample to make the print.

The RK company supplies laboratory reel to reel presses. Their RK Rotary Koater can be configured for flexography. The flexographic unit consists of a printing head with micrometer adjustable pressure settings, doctor blade assembly and an ink tray; also required are anilox rollers. With sufficient drying, speeds up to 90m/min can be reached which allow inks to be used at press viscosity.

The RNA-51 two shaft Printability Tester is a microprocessor controlled unit. When fitted with an anilox roller and steel doctor blade assembly, fast setting inks can be used. The motorized system keeps the anilox roller in constant motion, thereby continuously bathing the anilox in ink and subsequently doctoring it off.

The Flexo Proofer F.P. 100/300 is a reel to reel device which has been developed by the Saueressig company. The substrate is stocked from the top onto the presseur and stick on the roll for printed material. The plate cylinder and anilox roller move hydraulically to the arrested presseur. When the doctor blade comes into position, the ink will be provided with a pipette and the print operation is started.

3. The selected systems for the trials in order to look at correlation

a. the printing devices:
In the following study we will compare 2 of the mentioned devices (IGT and Saueressig), which represent the main families of modelling devices, to production presses. The RNA system can be assimilated to the IGT F1 and the RK Koater to the Saueressig Flexo Proofer. The 2 other systems reviewed, MacMillan Bloedel and Pamarco were not suitable for this study due to the only partial modelling of the flexographic process they offer. In the first case the system does not include any anilox roller nor any photopolymer plate; in the second case no control of the pressure at the nip and no constant speed are to be seen. Hence the choice not to integrate these devices in the study.

As far as the production presses were concerned, the investigations were carried out on 3 different presses.
The LEMO flexopress, located at the DFTA-TZ in Stuttgart (D) is a five-year-old six-colour CI-Press, with a width of 1300 mm and equipped with chambered doctor blades, CNC motors for the adjustment of the nip pressures and an automatic regulation of ink viscosity.
The second press is a Flexocompact seven-year-old, two-colour press with a 600 mm width. This press located at the IMT in Stockholm (S) is a modified production press used for research work. The capability and repeatability of the press have been tested in the past and show very good results.
A new Soloflex eight-colours CI-Press with a 850 mm width was the third flexopress in the programme. This press located at Windmöller & Hölscher in Lengerich (D) represents a standard product on the market in the middle-width range and is also equipped with chambered doctor blades and an ink viscosity regulation system.

b. the data acquisition:
A testform with different types of elements was elaborated for the series of trials. This testform should make it possible to establish the correlation between the different presses by measuring the density and the dot gain at different places and within the range of 1% to 100% by 18 steps. Circular dots. a resolution of

2540 dpi and a 34 l/cm screen were selected so as to reflect industrial reality. The testform is also quite particular in that it allows study of the influence of the printing direction. Moreover, it consists of other elements such as bar codes, a large solid area, a large 50% field and negative and positive text which will be used for further investigations and to look respectively at the edge sharpness, the uniform coverage and the cleanliness of the print.

The data acquisition was carried out using a Gretag D19C densitometer and using the KeyWizard data collection software to import the values into calculation tables.

4. Test methods and parameters

a. Description of the materials

a.1. the different paper qualities:
A discussion with experts from the SCA and StoraEnso paper industry companies led to the conclusion that to make the work credible it was necessary to print on five different paper qualities (Table I).

	Paper quality
SEC	Coated Liquid Packaging Board
SEU	Uncoated Liquid Packaging Board
SCAWT1	White Top
SCAWT2	White Top
SCAPK	Print Kraft

Table I: The different paper qualities

The chosen qualities represent 3 large product families. The characteristics of the different substrates are presented in table II. It is important to note the large amplitude of the paper characteristics: the surface roughness (PPS) shows values between 1.9 and 7.2 μm, the thickness between 157.0 and 269.0 μm and the weight between 138.7 and 193.0 g/m2. This dispersion will allow explanation of certain results and eliminate the risk of error in the interpretation regarding correlation.

	PPS	Bendtsen	Thickness	Weight
	(µm)	(ml/min)	(µm)	(g/m2)
SEC	1.90	93	267.50	193.00
SEU	7.20	493	269.00	172.00
SCAWT1	6.45	277	157.00	138.70
SCAWT2	6.59	297	161.00	139.30
SCAPK	6.90	330	170.00	141.80

Table II: The characteristics of the different substrates

a.2. the different printing plates:
With the same objective of eliminating the risk of erroneous conclusions due to coincidence, 4 types of photopolymer plates have been used for the trials (Table III).

Name:	Type:
DPS	Digital
	"universal plate"
HOF	Conventional
	"flexible plate" (exposure latitude and image resolution)
HOS	Conventional
	clean image relief / high quality process printing
TDR	Conventional
	the "corrugated board plate"

Table III: the different types of plates

Both the conventional and digital plate making workflow have been considered. 2 different thicknesses have been tested and all the plates presented different types of polymer, exposure time and hardness.

Name:	Hardness	Thickness (mm)	
	(Shore A)	min.	max.
DPS	49	2.80	2.84
HOF	55	2.85 / 2.80	2.89 / 2.84
HOS	71	1.70	1.73
TDR	37	2.85	2.87

Table IV: the characteristics of the different plates

The values in the table correspond to our measurements and could differ from the standard values given by the supplier. 2 plates have been used for the HOF type therefore 2 values for the min. and max. thickness. The plates were mounted using a 0.20 mm PVC tape for the 2.84 mm plates and a 0.38 mm PE foam for the 1.70 mm plate.

a.3. <u>the ink:</u>
The ink was the same for all the trials and was a cyan commercial water-based ink. The ink was printed with a 28-30s viscosity (Frikmar cup 4mm).

a.4. <u>the anilox rollers:</u>
The anilox roller is a very important component in the ink transfer process and is sometimes described as the "heart" of the process. The problem is that different suppliers have different methods to engrave the cylinders. This reality explains that the cells could have different forms, depths and surface finishing and consequently the ink transfer will not be the same! Moreover the anilox roller manufacturers use different ceramics and deliver protocols with volume indications measured with more or less accurate methods. In view of this problem and to moderate its influence, 2 different volumes have been selected for the trials: 8 and 12 cm3/m2. The screen ruling, the exact volume and the supplier are shown in Table V.

Press:	Screen ruling	Volume	Supplier
	(l/cm)	(cm3/m2)	
LEMO	160	7.0/7.5	Zecher
	100	13.0/11.6	Praxair
Saueressig	120	8.0	Saueressig
	80	12.7	Saueressig
Flexocompact	140	7.9	Praxair
	100	12.4	Praxair
IGT F1	180	8.0	IGT
	120	12.0	IGT
W+H Soloflex	140	8.0	Zecher
	120	11.0	Zecher

Table V: the anilox rollers characteristics

b. Description of the trials

The trials took place at different locations under external conditions (Table VI) varying within a range not affecting the substrates and the printing conditions. The procedure was the same for each trial, only the planing was different for practical reasons. Depending of the press it was easier to start by changing the plate, the paper or the anilox roller.

Press:	Place	Temp.	Rel. humidity
		(°C)	(%)
LEMO	DFTA-TZ	25-27	43
	Stuttgart (D)		
Saueressig	DFTA-TZ	23	40-43
	Stuttgart (D)		
Flexocompact	IMT	26	48
	Stockholm (S)		
IGT F1	StoraEnso	20	40-45
	Falun (S)		
W+H Soloflex	W+H	23	50-55
	Lengerich (D)		

Table VI: the printing conditions

The first step, after checking the ink viscosity, was to obtain the Kiss Print. The Kiss Print, first contact between the printing plate and the substrate, was important with regard to the rest of the trials because fixing the reference for the following different pressures at the plate-substrate nip. No standard method exists for obtaining the Kiss Print and it is still a subjective procedure. To minimise the fluctuation, elements have been tested but without success. Therefore it has been decided that one person, the same for all the trials, would be responsible for the "OK Kiss Print" with the help of a reference sample.

After realisation of the Kiss Print, it was printed at different plate-substrate nip pressures: 100, 150, 200, 250 µm over the Kiss Print. The printing speed was kept constant: 120 m/min. For each pressure 25 samples were cut for the evaluation after printing the complete series. These samples represent approximately 1/10 of the total running time: which, depending of the repeat length (Table VII), was about 45 to 60 s. It was sufficient to allow the establishment of a stable situation.

For the IGT F1, it was not possible to keep the same parameters. The speed was 0.3 m/s (18 m/min). This choice results from the study of anterior research, which have shown that by printing with speeds above 0.6 m/s, the print density decreases and the coefficient of variation increases. The pressures at the plate-substrate nip were 65 and 120 N which, once established after several tests, should correspond to 100 and 200 µm respectively over Kiss Print. Moreover, after checking the repeatability of the device, the decision was taken to print only 2 "good samples". The washing time was about 5 minutes between each sample, corresponding to 190 hours for 25 samples! Lindström, Dölling and Poustis looked at the repeatability in their work and came to the conclusion that the repeatability expressed as the coefficient of variation of print density was about 1%.

The Saueressig Flexoproofer was run at 50 m/min and the plates were mounted diagonally to avoid the significant vibrations observed in the normal configuration.

Press:	Repeat length	Width	Speed
	(mm)	(mm)	(m/min)
LEMO	480	1300	120
Saueressig	315	270	50
Flexocompact	600	600	120
IGT F1	530	50	18
W+H Soloflex	400	850	120

Table VII: Repeat length, width and speed

The particular features of the 3 production presses were that they were equipped with chambered doctor blades and 2 of them had an ink viscosity regulation system. In the case of the third one the viscosity was manually controlled regularly. Drying was necessary for the 2 presses with the short paper band before rewinding and the temperature was maintained at between 70 and 75°C.

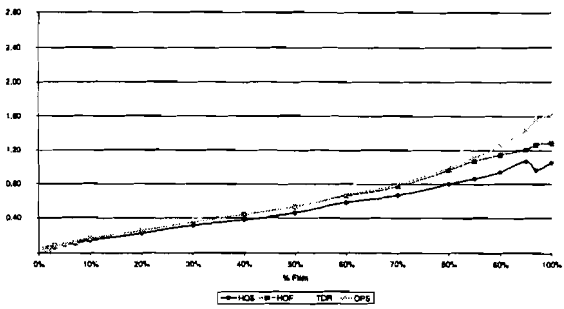
5. Results

The significant quantity of trials and measurements has produced a very large database. To be able to make a relevant interpretation and a comprehensible presentation of the main conclusions, it has been necessary to extract only a part of the values. The goal of the project was to analyse the correlation between production printing presses and modelling systems. Different combinations with different types of plates, anilox rollers, pressures at the nip and substrates have been tested and evaluated.

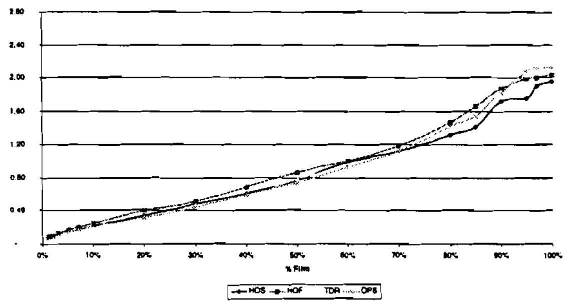
Figures 1 to 5 represent the density variations measured for each press with the 4 different plates. The pressure at the plate-substrate nip was 100 μm and the volume of the anilox roller 8 cm3/m2.

A study of the diagrams shows that all the curves have the same profile with the same ranking for the different presses regarding the ink transfer: the DPS plate transfers the least ink, then the HOS and TDR have almost the same comportment and finally the HOF is characterised by a higher ink transfer.

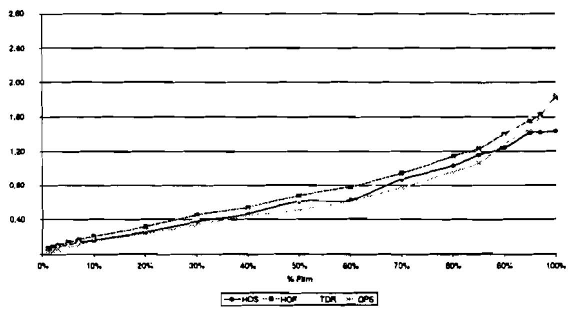
Density IGT-SEU-8-100



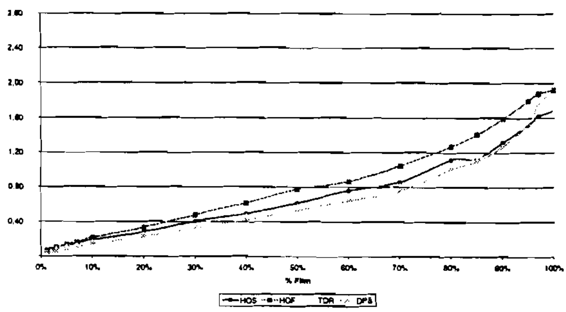
Density Saueressig-SEU-8-100



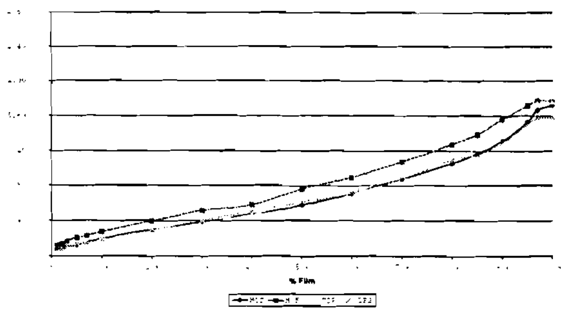
Density DFTA-SEU-8-100



Density IMT-SEU-8-100



Density WH-SEU-8-100



Only the IGT F1 presents an inversion of the ranking: the HOS and HOF plates show an ink transfer of about 35% less than expected. The reason should be the following: the HOF and HOS plates both have a higher degree of hardness and 65N represents in this case less than 100 µm due to the higher resistance of the polymer against the action.

The fact that all the curves have the same profile enables us to look closely at the influence of the presses for one type of plate and all the different substrates. The DPS plate has been chosen to purchase this study.

The next series of diagrams (figure 6-10) the represents the density variations measured for each substrate with the printing press as a variable parameter. The pressure at the plate-substrate nip was 100 µm and the volume of the anilox roller 8 cm3/m2. The influence of the anilox roller and of the pressure at the plate-substrate nip will be considered separately shortly.

The curves obtained show a large divergence between the comportment of the uncoated substrates and the SEC coated one. For this last quality, only the IGT F1 has a conventional density profile. This is probably due to the fact that it was running at the lowest speed and also a more uniform ink transfer. What is responsible for this abnormal result? The thickness of the SEC is almost the same as the thickness of the SEU quality - it is also possible to eliminate this parameter – and the study of the curves at the 200 µm pressure produced the same results. It seems also to be only the coating which affects the result. This is confirmed by figure 11, which shows the influence of the paper for the IMT press. In this diagram it is easier to see the special comportment of the SEC substrate.

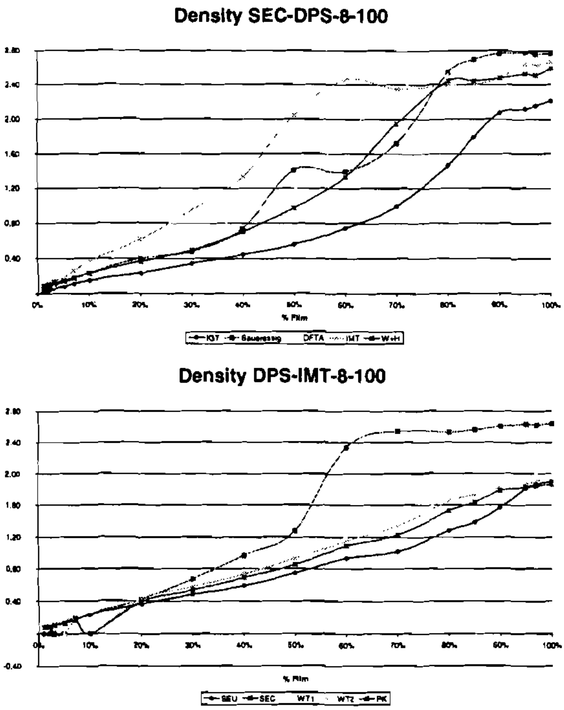
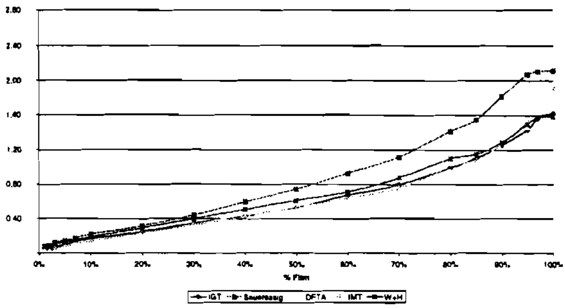
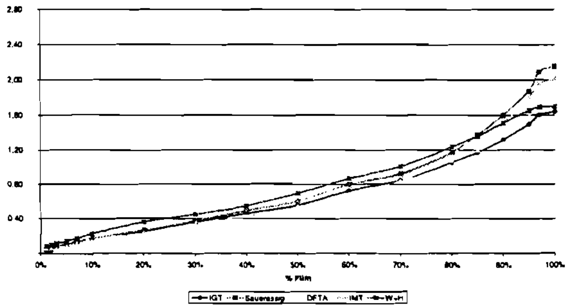


Figure 11: influence of the paper (plate DPS)

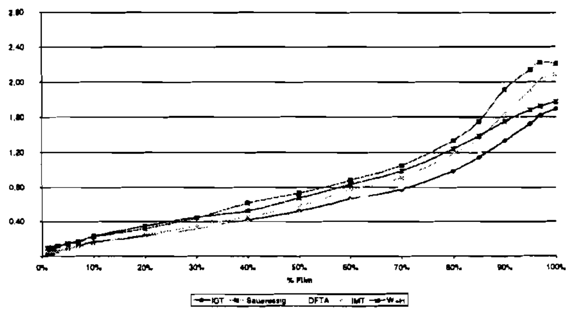
Density SEU-DPS-8-100



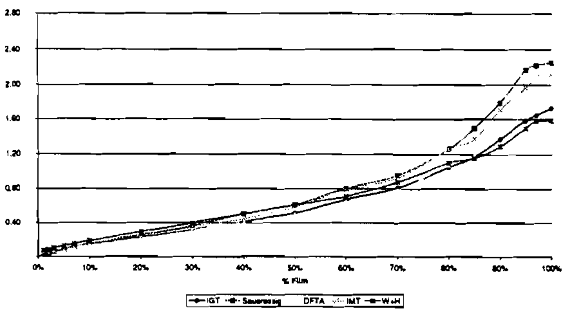
Density PK-DPS-8-100



Density WT2-DPS-8-100



Density WT1-DPS-8-100



The diagrams demonstrate a good correlation between 4 of the 5 presses and a less successful correlation for the last one. This does not signify that it will not be possible to use the Saueressig Flexoproofer for trials in the future but it is necessary to take into consideration the fact that the density obtained is always about 20% higher than with the other presses. The same conclusion is to be noted at the 200 µm nip pressure and with the 12 cm3/m2 anilox roller. It is interesting to note one exception: the curves of the IMT and Saueressig crossed at 85% for the 200 µm nip pressure (figure 12). This is not due to a modification of the comportment of the Saueressig flexoproofer but to high densities in the 0-85% range at 200 µm with the IMT press.
Regarding the correlation between the 4 other presses, it is necessary to distinguish 3 different parts for the evaluation:

- 0 – 30% : the range of the density variation is on average 12% between the IMT, DFTA and IGT presses and about 23% for the W+H press. This means for a 0.35 average density, the IMT, DFTA and IGT densities are between 0.33 and 0.37 and the W+H density between 0.31 and 0.39

- 30 – 80% : in this part the density variation on average remains at 12% for the IMT, DFTA and IGT presses and is reduced to 16% for the W+H press. (D=1.0 => 0.94 < IMT,DFTA,IGT <1.06 and 0.92 < IMT,DFTA,IGT,W+H < 1.08)

- 80 – 100% : the last part of the curves shows a greater dispersion, the percentage is common to the 4 presses and about 20%. (D=1.6 => 1.44 < IMT,DFTA,IGT,W+H < 1.76)
  A possible explanation for this divergence in the high tone area could be the variation in the volume of the anilox rollers: the printing was carried out with 8 cm3/m2 in all the presses but it would be interesting to measure the volume of all the anilox rollers with the same method!

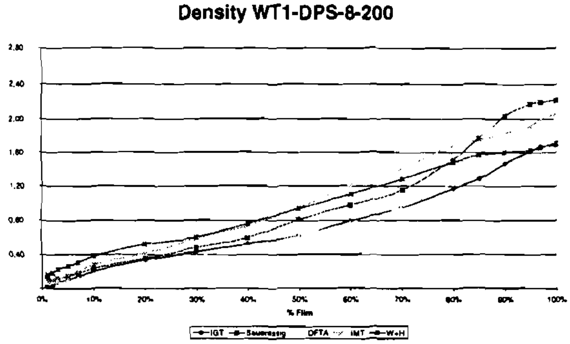


Figure 12: the "crossing" at 200 μm

To have a good overview of the results and get a global image of the correlation between the different presses and simulation systems it is possible to project the 129 600 density measurements using the multivariate statistical analysis method. Figure 13 is the representation of the complete configuration with all the systems and the figures 14 to 18 show the partial representations for each system. The ellipses contain the points inside the 95% confidence region of the model. The quality of the model is quantified by the R2 and Q2 factors. Models with Q2 and R2 values over 0.9 are very relevant. The established models show values between 0.936 and 0.959. Diagram 19 allows to detect the outliners and to quantify the deviation to the model. The analysis of the outliners confirms the 2 problems detected by the conventional density diagrams: outliners are due to the SEC coated paper and the WH press by running with high nip pressures.

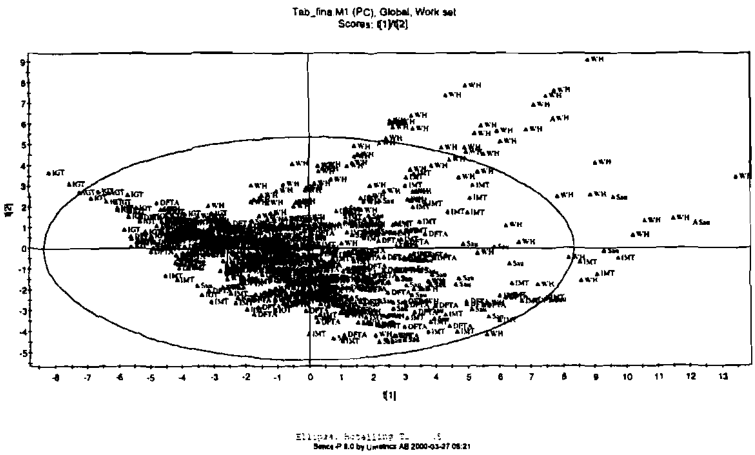


Figure 13: global representation of the density measurements

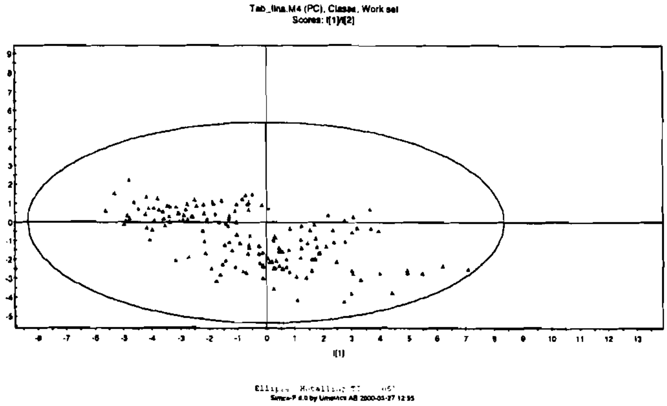


Figure 14: Repartition of the "DFTA" Density measurements

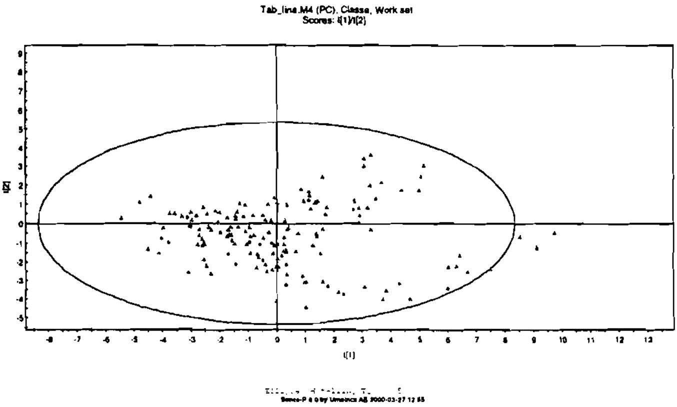


Figure 15: Repartition of the "IMT" Density measurements

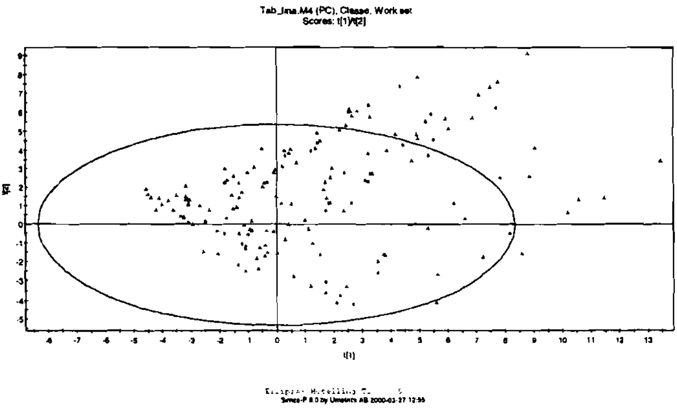


Figure 16: Repartition of the "WH" Density measurements

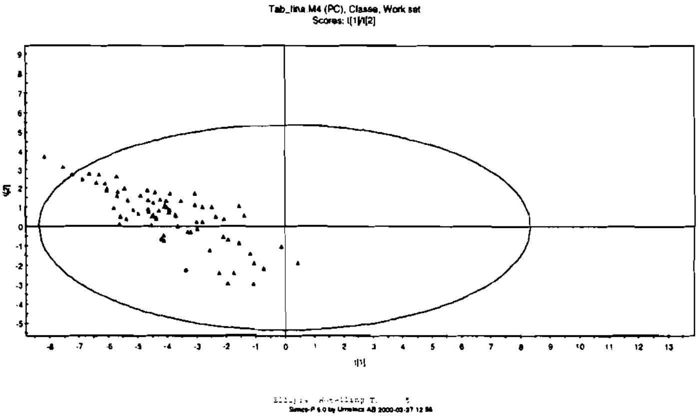


Figure 17: Repartition of the "IGT" Density measurements

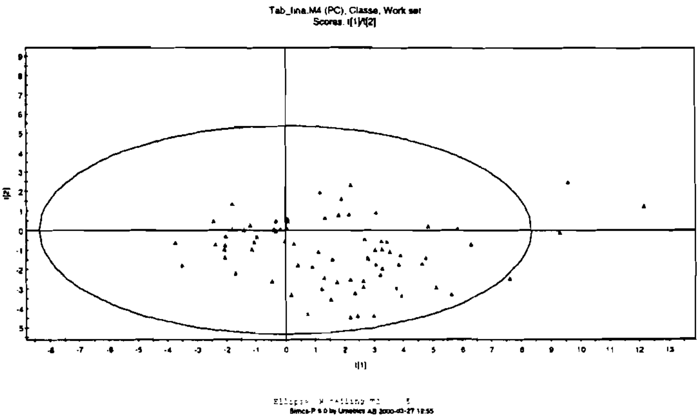


Figure 18: Repartition of the "Saueressig" Density measurements

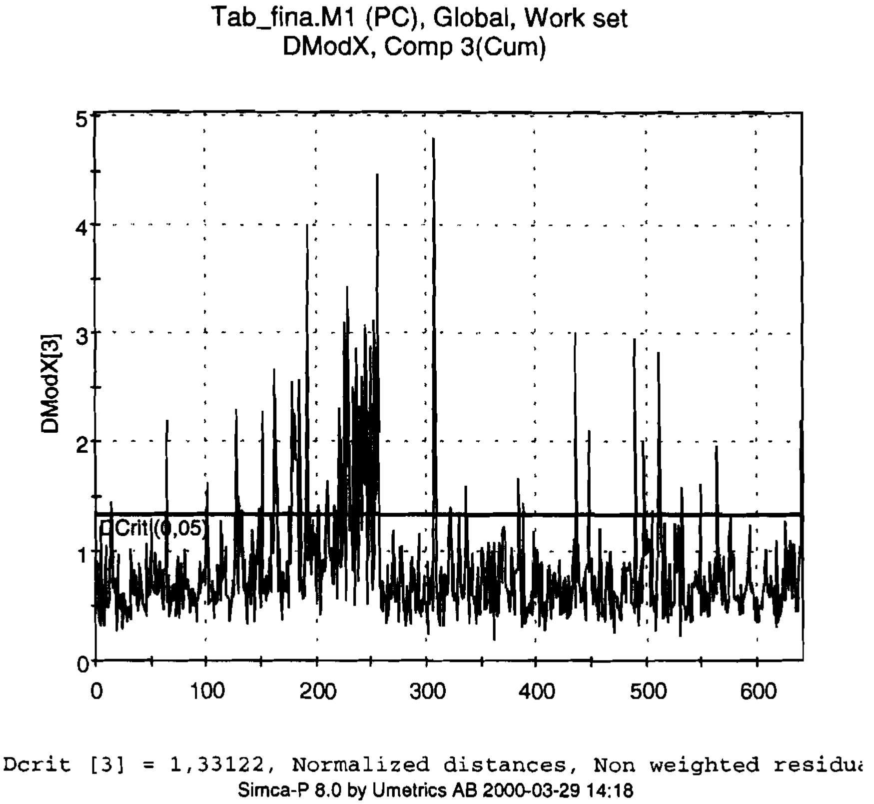


Figure 19: Distance to the model (outliners)

6. Conclusion

This analysis proves that when taking care of certain limiting parameters like width, speed or stability of the devices it is really possible to determinate a correlation between the different printing presses and modelling devices. The fluctuations measured stay in an acceptable area. Only the coated quality was outside the tolerances. Of course the study of the density variations have to be supplemented with further analysis to quantify specific surface defects and edge sharpness but this research would mean further investigation using multivariate statistical analysis and image analysis.

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