TECHNISCHE UNIVERSITÄT DRESDEN

Fakultät Elektrotechnik und Informationstechnik Institut für Aufbau- und Verbindungstechnik der Elektronik

Enhancement of Process Capability of Solder Paste Printing

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Goals

Zero defect quality =

printed volume	**=**	**target volume**
printed area	**=**	**target area**
solder paste height	**=**	**target height**
Deviations (x/y)	**=**	**0**
Deposit shape	**=**	**Cylinder/Cube**

for every printed deposit !

Realization:
Mean ⇒ target value

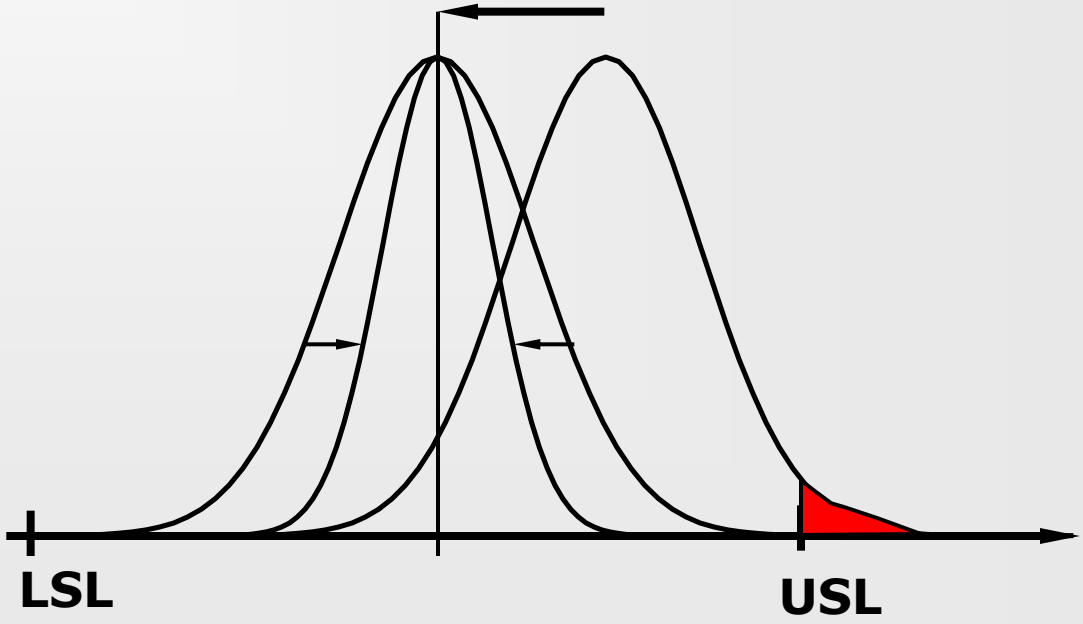
Minimize standard deviation

Possible evaluation:

Process capability

C_{pk}>1,5 (six-sigma-quality)

Theoretical defect rate:
≈3,4 DPM



Challenges:

Control of the means
+
Systematical decrease of the standard deviations

Through changes of :

solder paste
stencil
solder paste printer
Setup
operator
surrounding conditions
....
Including the interactions

⇒ Capable processes !

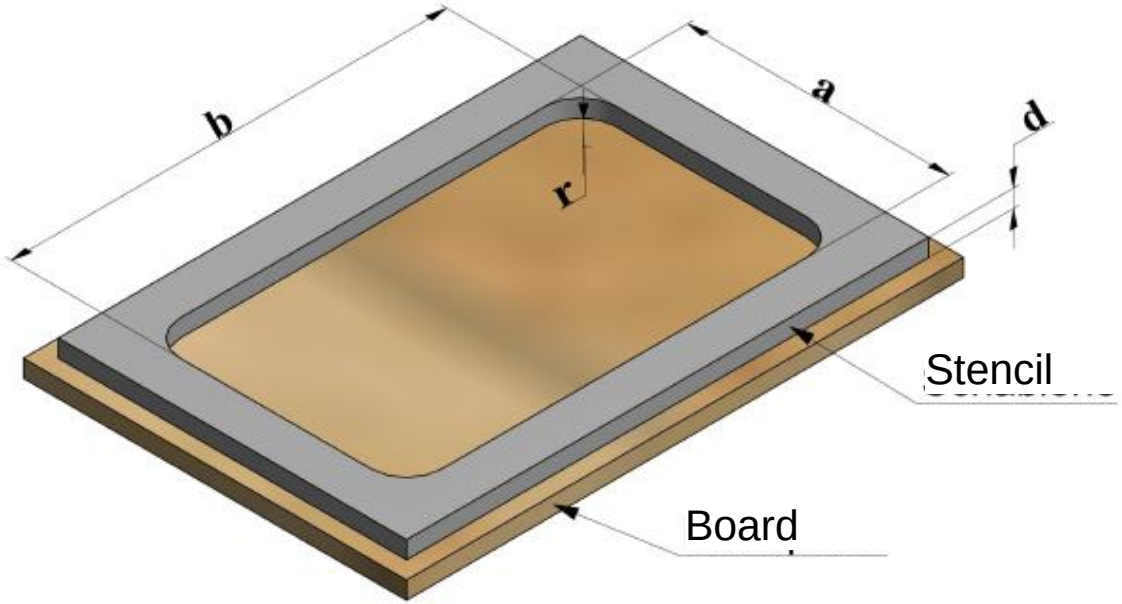
Analysis goals

- **Analysis of two different solder paste (grain 3/5)**
- **for typical structures (Chips, QFP, BGA, ...)**
- **Variation of of the width/length proportion (aspect) of the rectangle structures**
- **two typical printing sequences**
- **two stencil technologies (electro polished (AE), electro polished + Plasma (AEP))**
- **two stencil thicknesses (100/150 µm)**

Responses:

- **Printed volume**
  (specification limits ±30% of the stencil structure opening)
- **printed area**
- **solder paste height**
- **x/y deviation**
- **Influences of the squeegee force**

Layout Rules for the Stencil



a - Width

b - Length

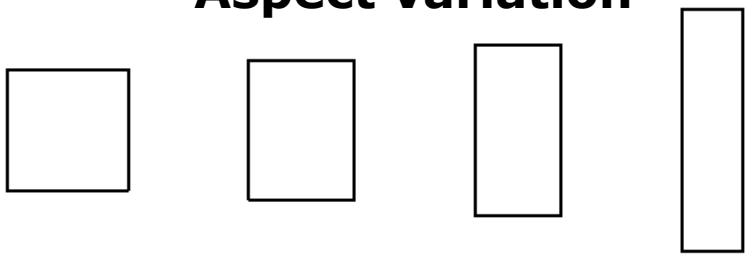
r - Corner radius

d - Stencil thickness

$$\text{Area Ratio} = \frac{a \cdot b - r^2(4-\pi)}{2d \cdot \left(a + b + r(\pi - 4)\right)} > 0,66$$

$$\text{Aspect Ratio} = \frac{a}{d} > 1,5$$

Aspect variation



1:1

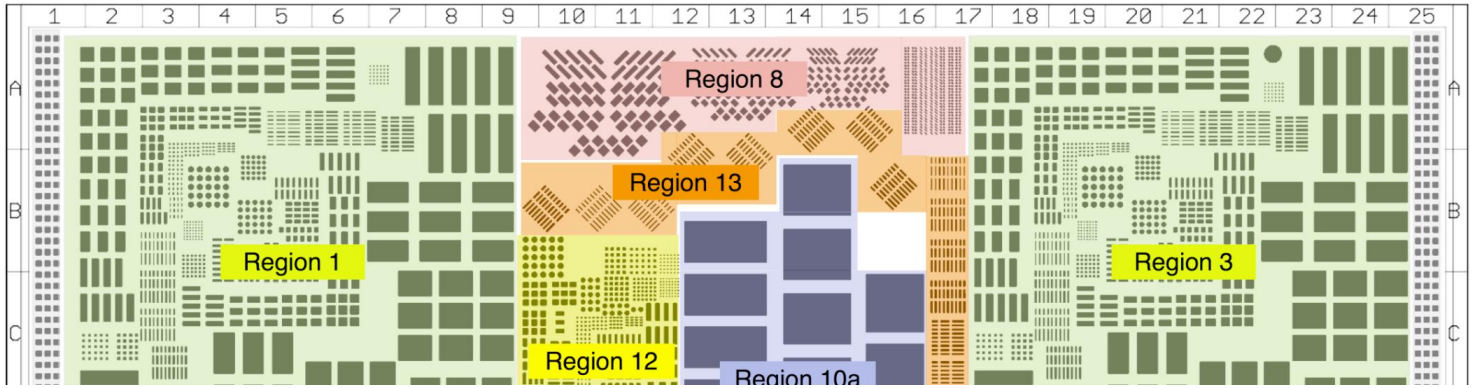
Example structures and critical areas

Chiptyp	Area in mm^2	Aspect	Area Ratio [d=100 µm]	Aspect Ratio [d=100 µm]	Area Ratio [d=150 µm]	Aspect Ratio [d=150 µm]
0201	0,09	1,00	0,795	3,000	0,530	2,000
	0,09	0,75	0,786	2,600	0,524	1,733
	0,09	0,50	0,744	2,120	0,496	1,413
	0,09	0,25	0,622	1,500	0,415	1,000
0402	0,64	1,00	2,064	8,000	1,376	5,333
	0,64	0,75	2,042	6,930	1,362	4,620
	0,64	0,50	1,942	5,657	1,295	3,771
	0,64	0,25	1,639	4,000	1,092	2,667

QFP-Structures

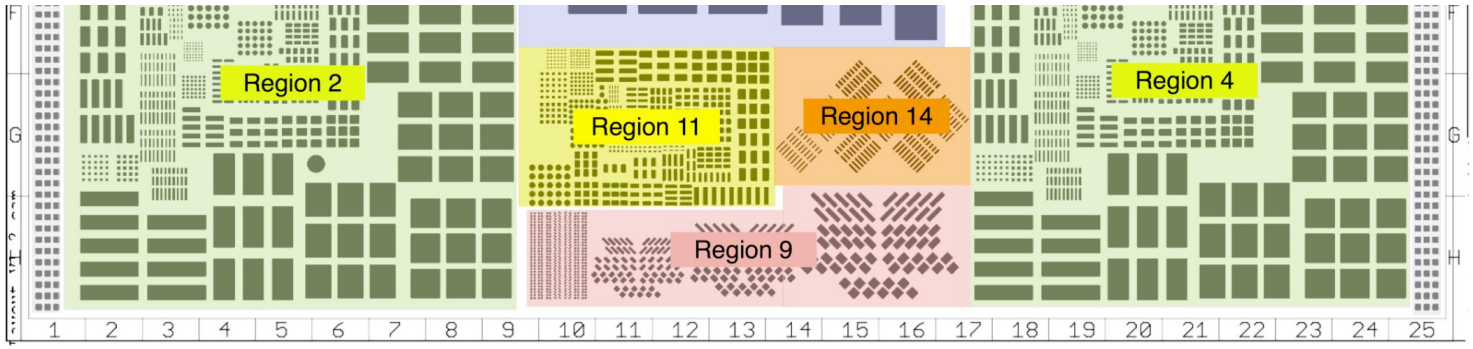
Bzg.	Area in mm²	x in µm	y in µm	Area Ratio [d=100 µm]	Aspect Ratio [d=100 µm]	Area Ratio [d=150 µm]	Aspect Ratio [d=150 µm]
L1000	0,150	150	1000	0,669	1,500	0,446	1,000
	0,200	200	1000	0,859	2,000	0,573	1,333
	0,250	250	1000	1,033	2,500	0,689	1,667
	0,300	300	1000	1,193	3,000	0,795	2,000
L1500	0,225	150	1500	0,694	1,500	0,463	1,000
	0,300	200	1500	0,902	2,000	0,601	1,333
	0,375	250	1500	1,097	2,500	0,731	1,667
	0,450	300	1500	1,281	3,000	0,854	2,000
L2000	0,300	150	2000	0,708	1,500	0,472	1,000
	0,400	200	2000	0,925	2,000	0,617	1,333
	0,500	250	2000	1,132	2,500	0,755	1,66
	0,600	300	2000	1,330	3,000	0,887	2,000

Test Board



Overall: 10500 single structures

Measured by a KohYoung solder paste inspection system



1. Test section: **16 times printing of the test board (without cleaning)Board 1 – Board16 (= printing number)**

2. Test section: **Testing sequence with waiting times**

print 6 Boards→ cleaning → wait 0 min

print 6 Boards→ cleaning → wait 10 min

print 6 Boards→ cleaning → wait 20 min

print 6 Boards→ cleaning → wait 40 min

print 6 Boards→ cleaning → wait 60 min

print 6 Boards
=„Waiting time" 0..60 and „Print after clean"

The printing setup was not changed during the full printing experiment !

⇒ **52 prints per combination**

⇒ **520 prints overall**

⇒ **25.000.000 data values !**

Evaluation procedure

- Calculation of the relative printed volume
  (100% = target volume = volume of the stencil opening)
  and the relative printed area (analogous)
- Elimination of clear outliers
- Creation of groups inside of the data
  Chip types, orientation, pitch, ...
- Calculation of the means, standard deviations and the C_p -C_{pk}-values inside of the groups (Chip/BGA/QFP)

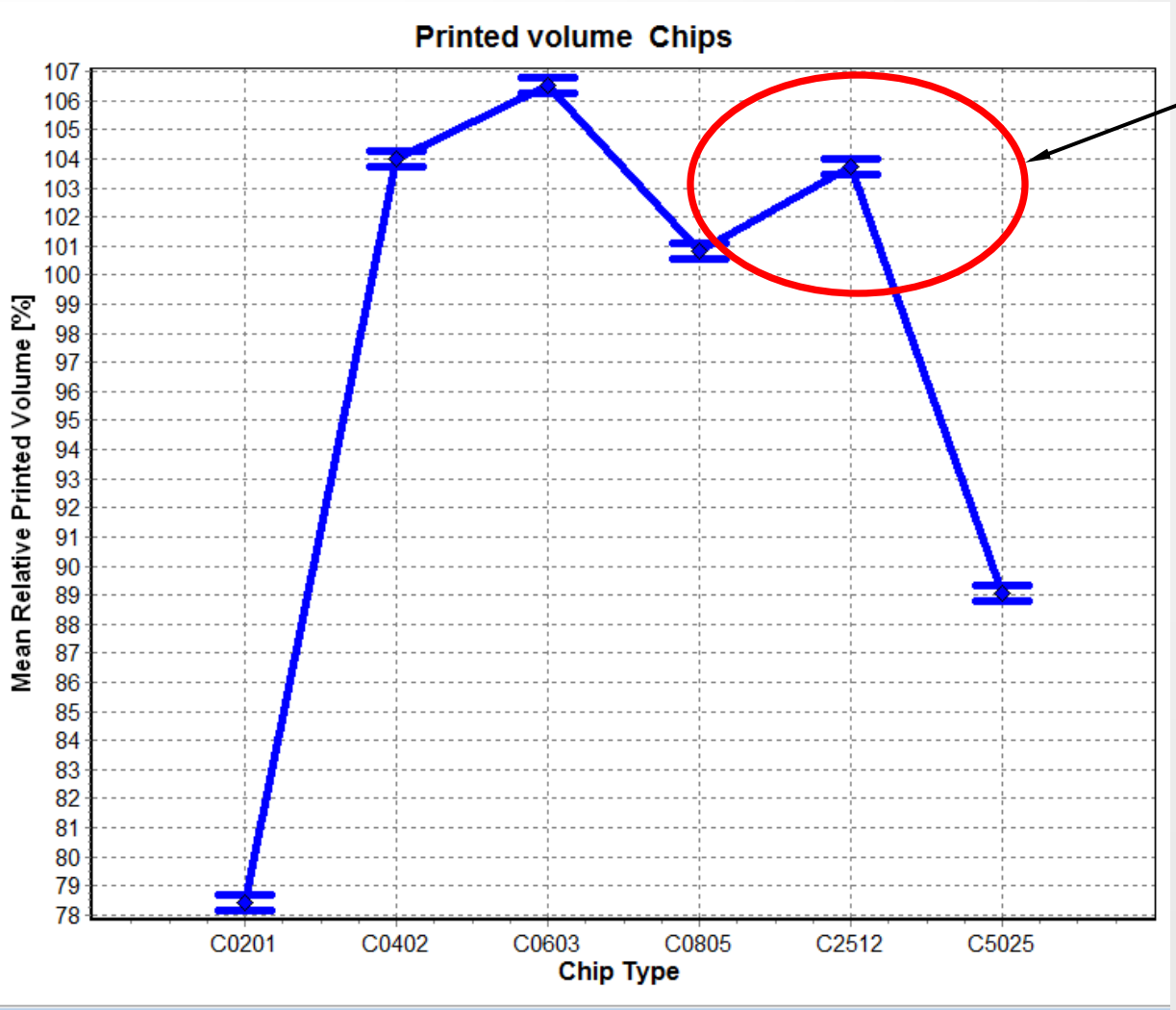
Evaluation tool:

Multi-factor-variance analysis (ANOVA) including the calculation of the main effects and the twofold interactions; calculations devided by the three test sections

Analyzed factors:

Paste grain
Stencil technology
Stencil thickness
printing number
Orientation
Pitch/Chip type
printing number after a cleaning procedure
waiting time

Analyse of Chips – Chip Type



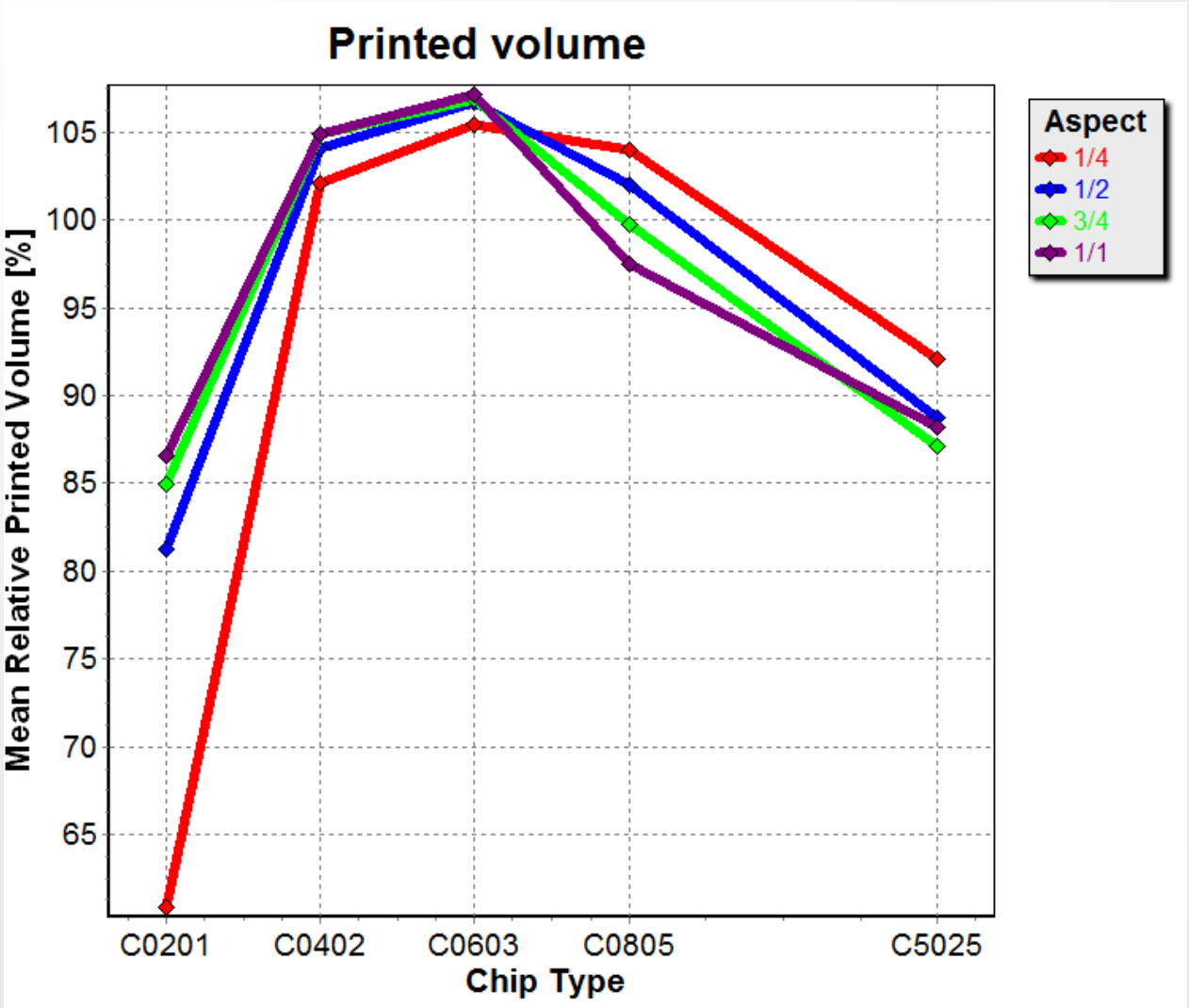
Special effect !
Analysis later !

The target (100 % relative volume) will only reached by the 0402..0805

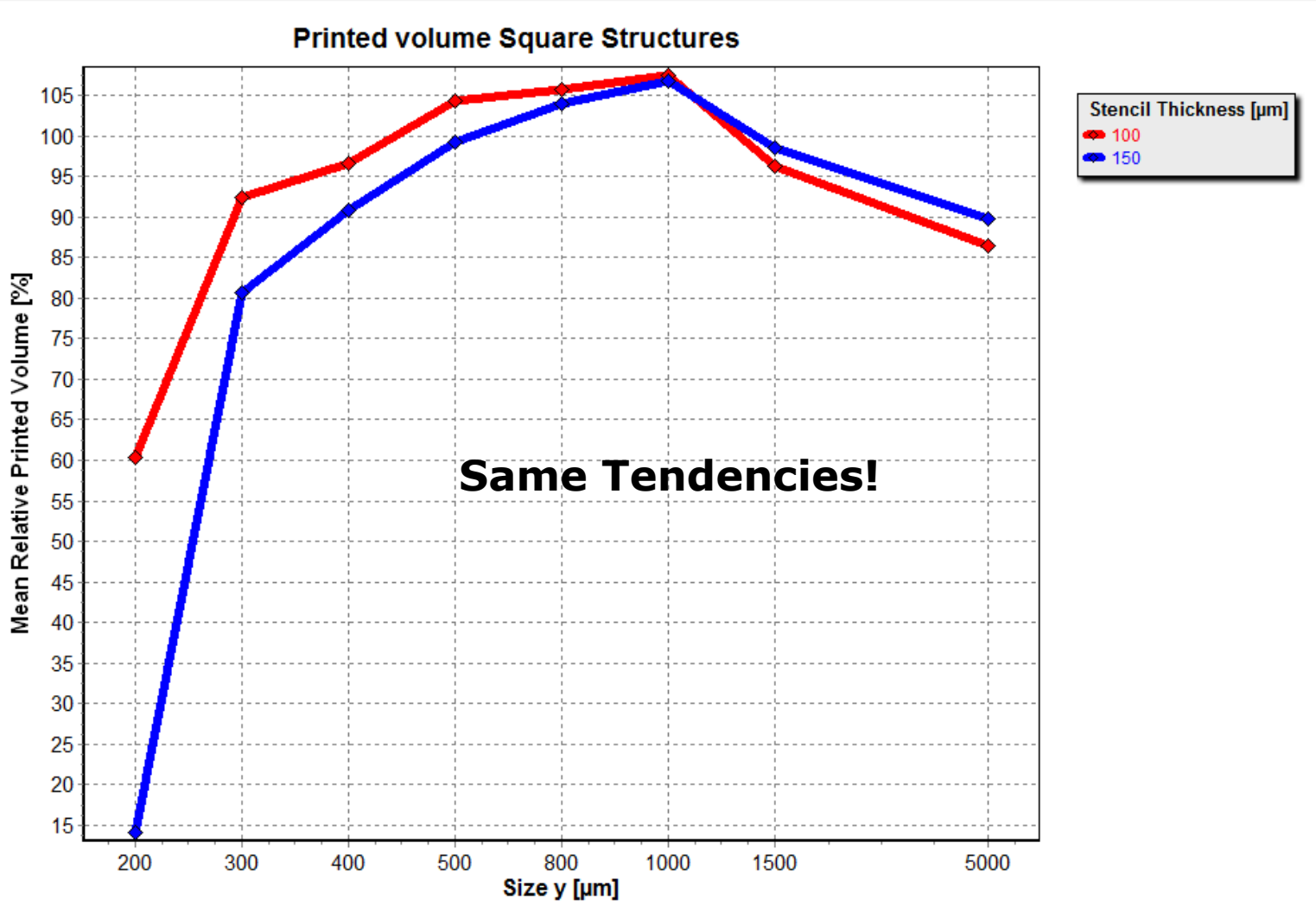
The other structures have lower relative printed volume!

The changes of the volume will be influenced especially by the solder paste height !

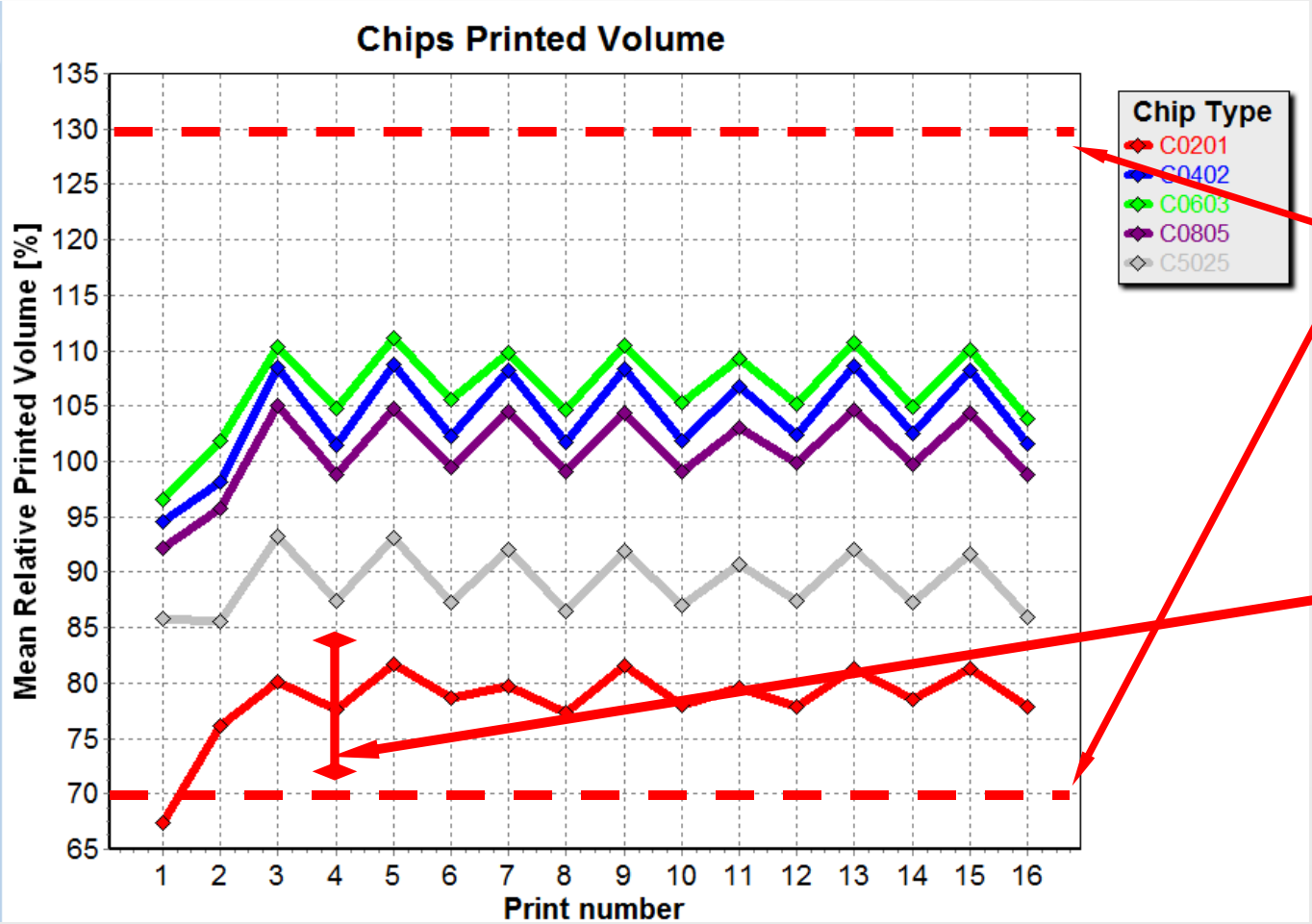
Analyse of Chips – Influence of the aspect



Analysis of Squared Structures



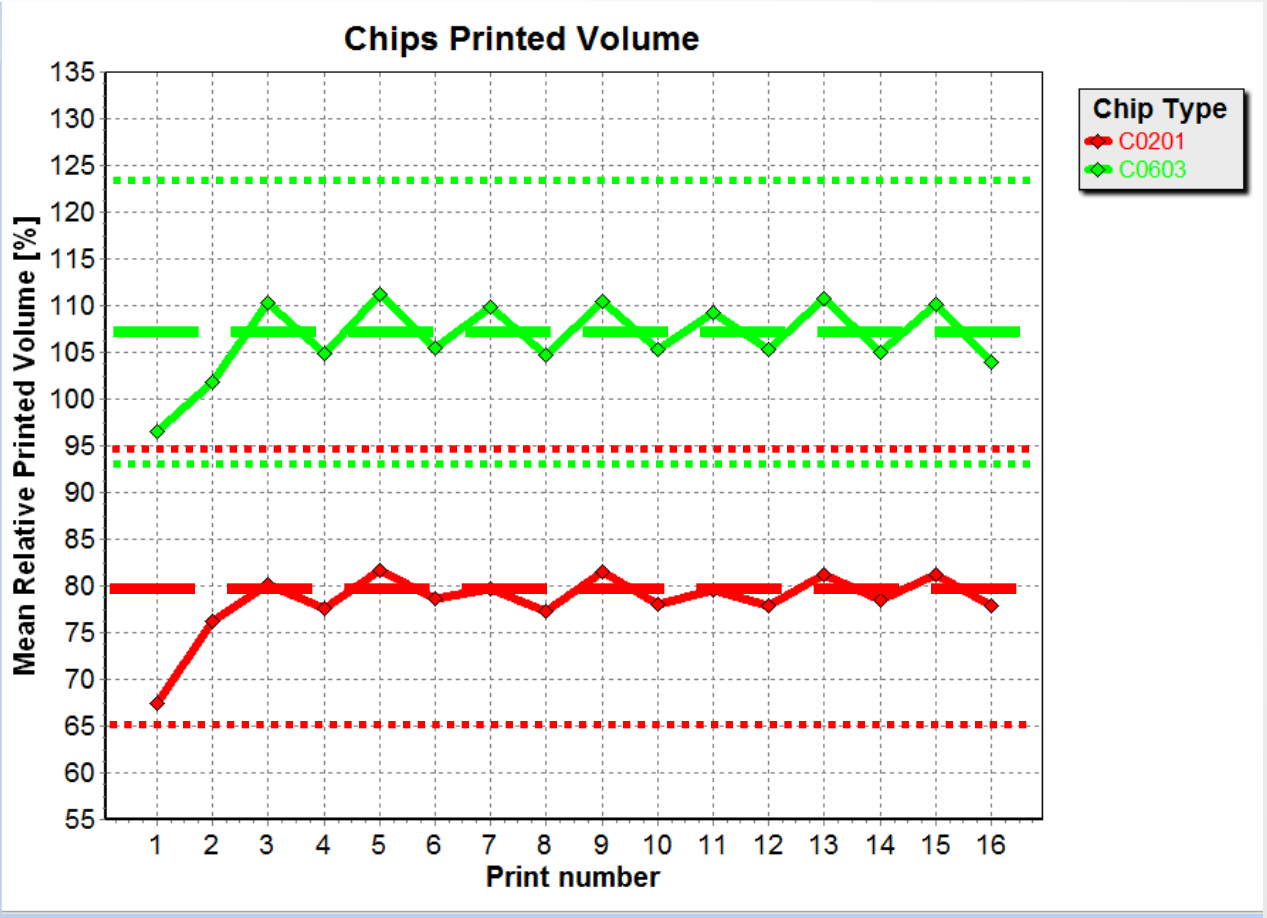
Structure Size and Process Capability



Common used specification limits for all structures (100%±30%)

Relative high probability for a specification violation ! = Low process capability !

Make it better - Possibilities (1)



1. Change of the definition of the nominal value for every chip type

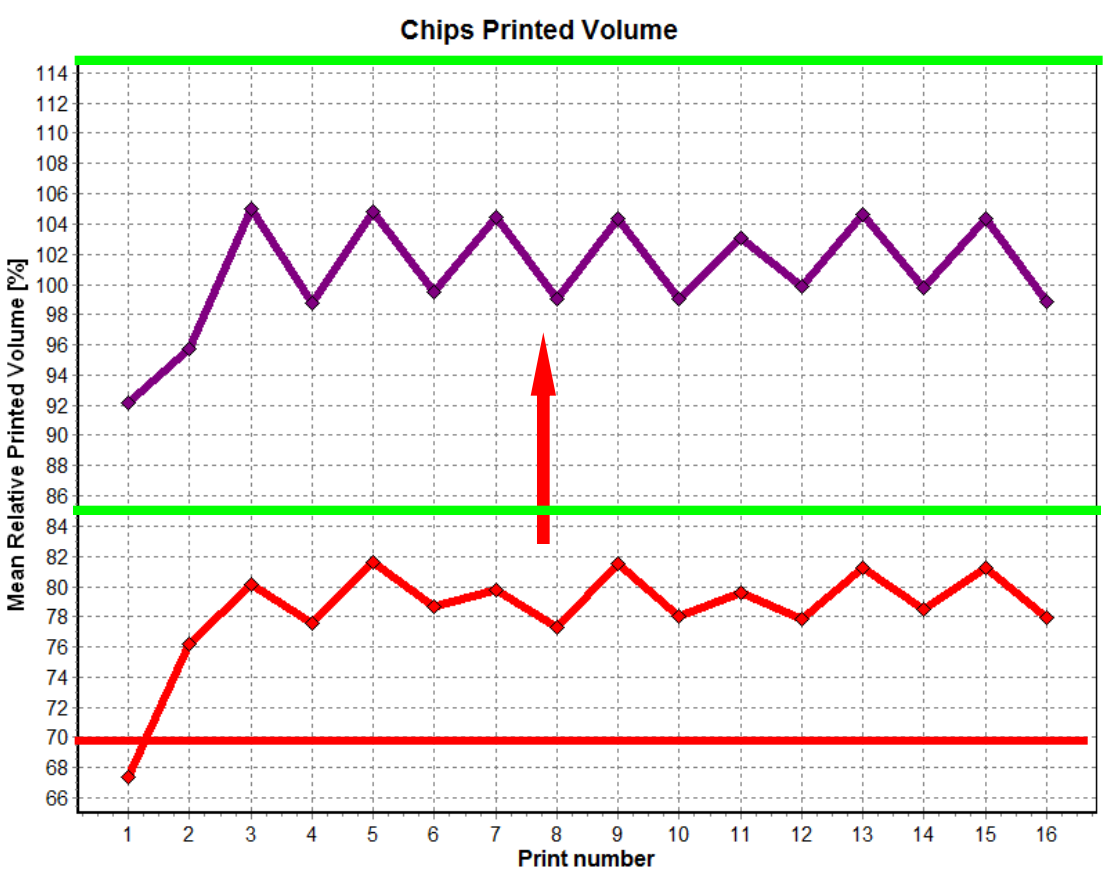
0201 100% ⇒ 80 %

0603 100% ⇒ 108 %

2. Decreasing of the specification width for every component

± 30 % ⇒± 15 %

Make it better – Possibilities (2)



Enhancement of the size of the opening structure of the stencil!

For example: Increasing the size of a 0201 structure of about 20% !

Make it better – Possibilities (3)

The adaption of the control of the printing proces is necessary:

- **The differences of the relative printed volume based on the internal rules of the printing process (Maximum 0603..0805)**
- **Changes of the printing setup don't avoid such differneces**

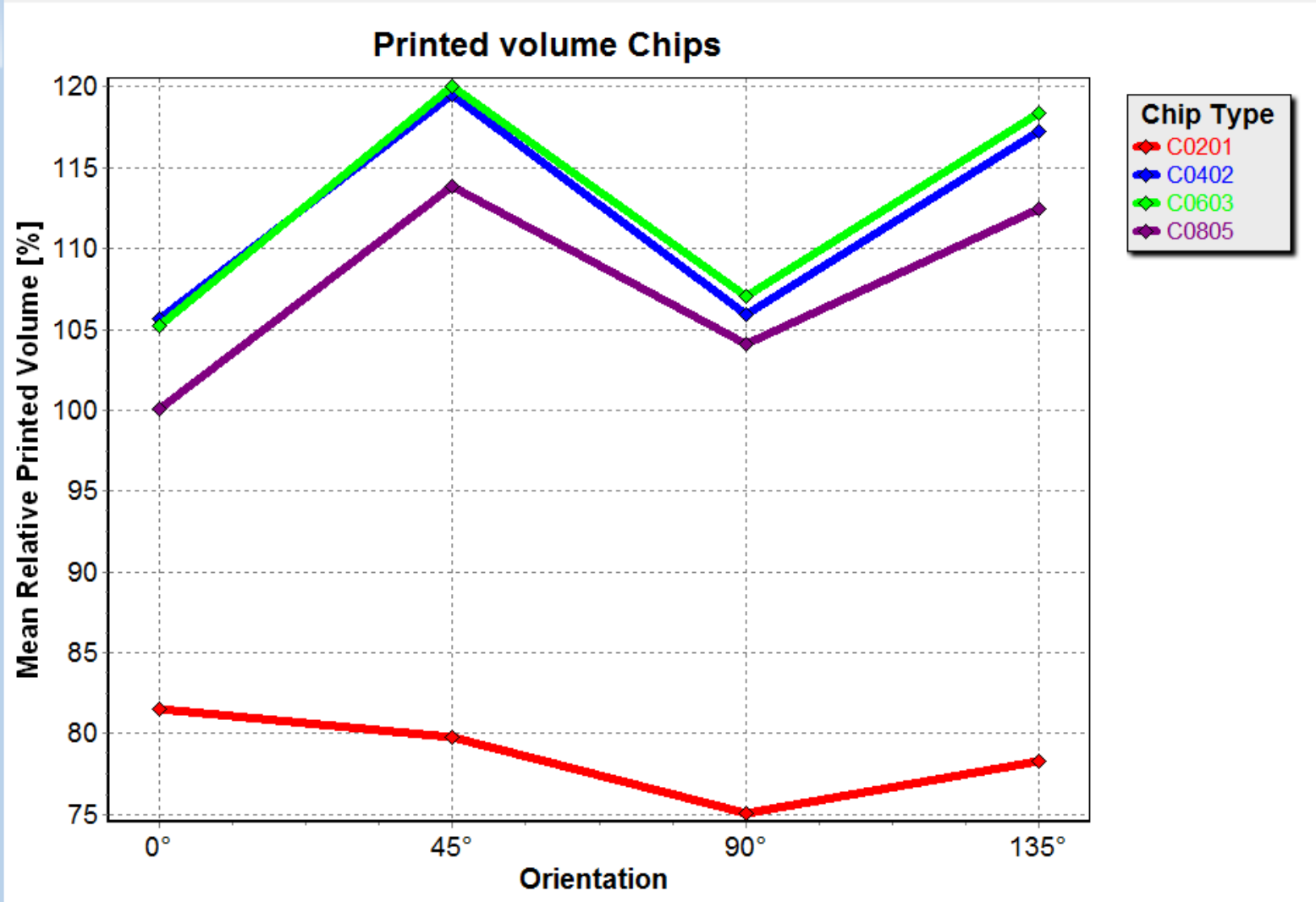
Advantages of the adapted control procedures:

- **Minimization of violations (especially without a defined source) of the specification limits**
- **Possibility to decrease the specification width ⇒ increase the probability to detect systematical changes**

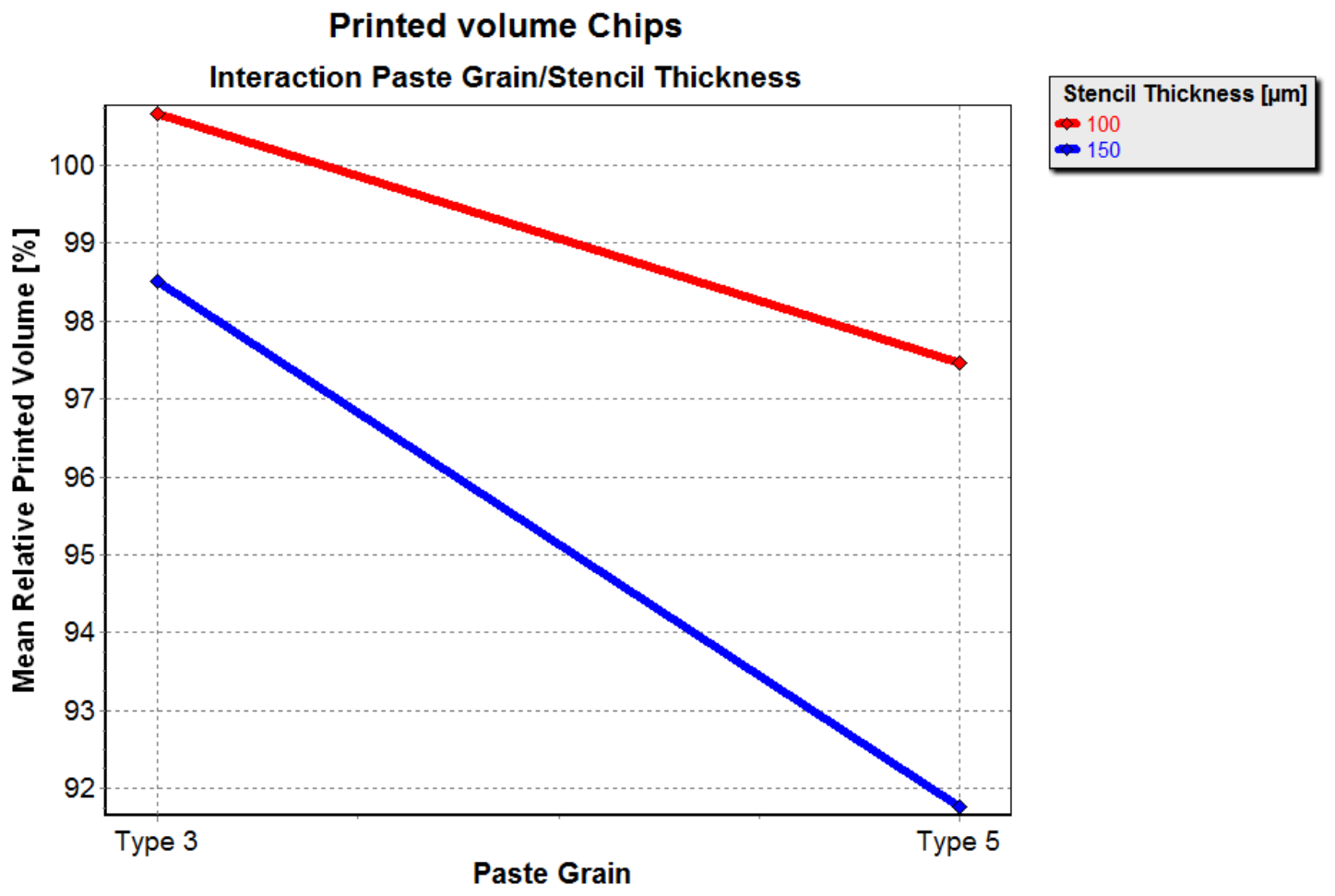
Disadvantages

- **Needs changes of the software of the control equipment**
- **Learning process for the precise setup of this adaption necessary**
- **It is not so easy to change rules used over a lot of years!**

Chips – Influence of the Orientation



Influences of the Stencil Thickness and the Paste Grain



Analysis of the Process Capability versus Rules of 0201

Chiptyp	Area in mm²	Aspect	Area Ratio [d=100 µm]	Aspect Ratio [d=100 µm]	C_{pk} [d=100 µm]	
					Paste K3	Paste K5
0201	0,09	1,00	0,795	3,000	2,069	3,395
	0,09	0,75	0,786	2,600	1,952	3,234
	0,09	0,50	0,744	2,120	1,597	2,684
	0,09	0,25	0,622	1,500	0,868	1,434

The given layout rules are mostly correct !

It is necessary to make this rules a little bit more precise !

Chiptyp	Area in mm²	Aspect	Area Ratio [d=150 µm]	Aspect Ratio [d=150 µm]	C_{pk} [d=150 µm]	
					Paste K3	Paste K5
0201	0,09	1,00	0,530	2,000	0,830	0,984
	0,09	0,75	0,524	1,733	0,742	0,982
	0,09	0,50	0,496	1,413	0,311	0,513
	0,09	0,25	0,415	1,000	-0,803	-2,438

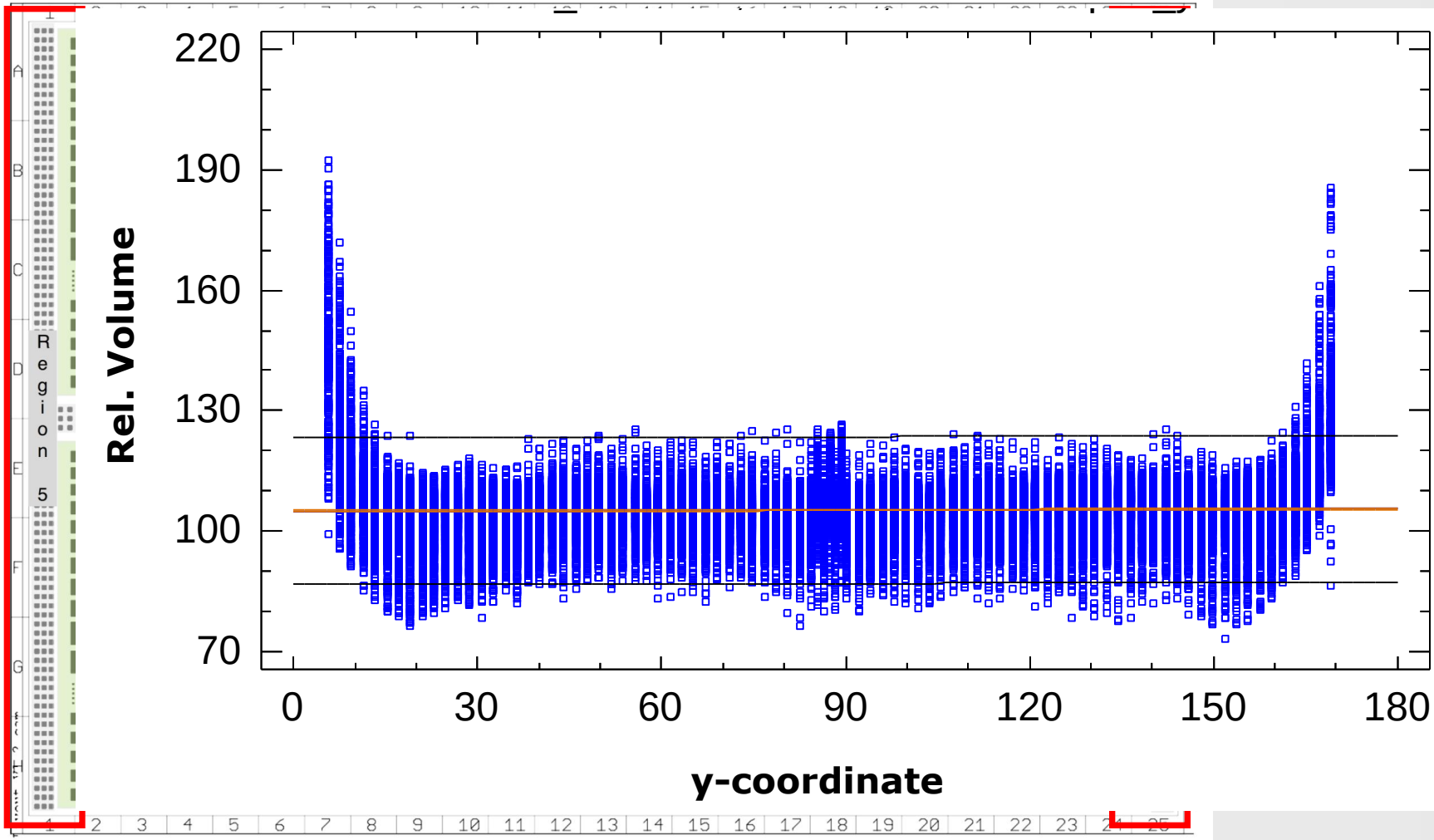
Analysis of the Process Capability versus Rules of QFP

Bzg.	Fläche in mm²	x in µm	y in µm	Area Ratio [d=100 µm]	Aspect Ratio [d=100 µm]	C_{pk} [d=100 µm]	
						Paste K3	Paste K5
L1000	0,150	150	1000	0,669	1,500	1,081	2,179
	0,200	200	1000	0,859	2,000	2,271	3,766
L1500	0,225	150	1500	0,694	1,500	1,559	2,591
	0,300	200	1500	0,902	2,000	2,672	4,140
L2000	0,300	150	2000	0,708	1,500	1,744	2,680
	0,400	200	2000	0,925	2,000	2,613	3,786

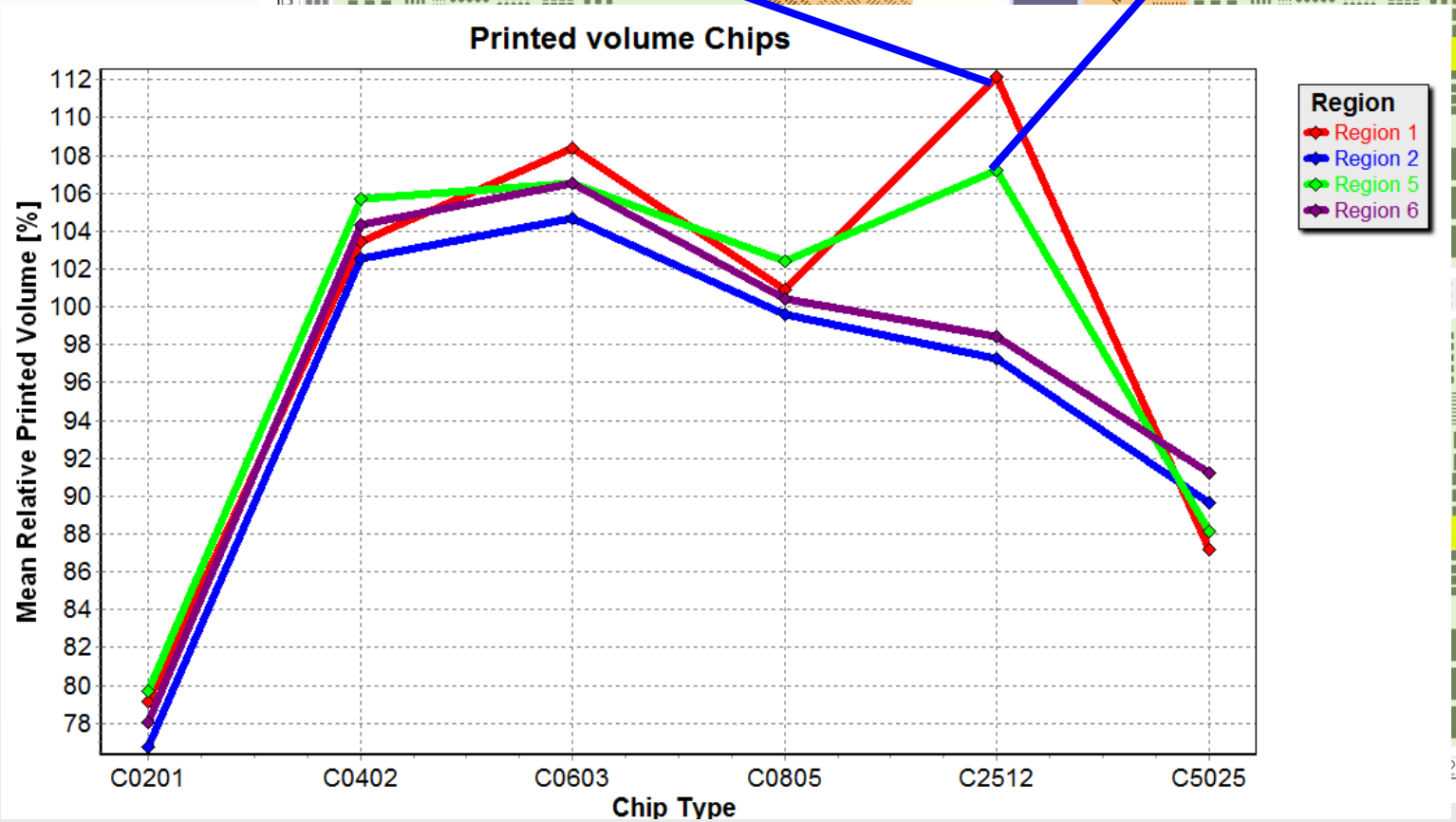
Bzg.	Fläche in mm²	x in µm	y in µm	Area Ratio [d=150 µm]	Aspect Ratio [d=150 µm]	C_{pk} [d=150 µm]	
						Paste K3	Paste K5
L1000	0,150	150	1000	0,446	1,000	-0,063	-0,179
	0,200	200	1000	0,573	1,333	1,721	1,785
L1500	0,225	150	1500	0,463	1,000	0,359	0,163
	0,300	200	1500	0,601	1,333	2,357	2,403
L2000	0,300	150	2000	0,472	1,000	0,560	0,235
	0,400	200	2000	0,617	1,333	2,435	2,433

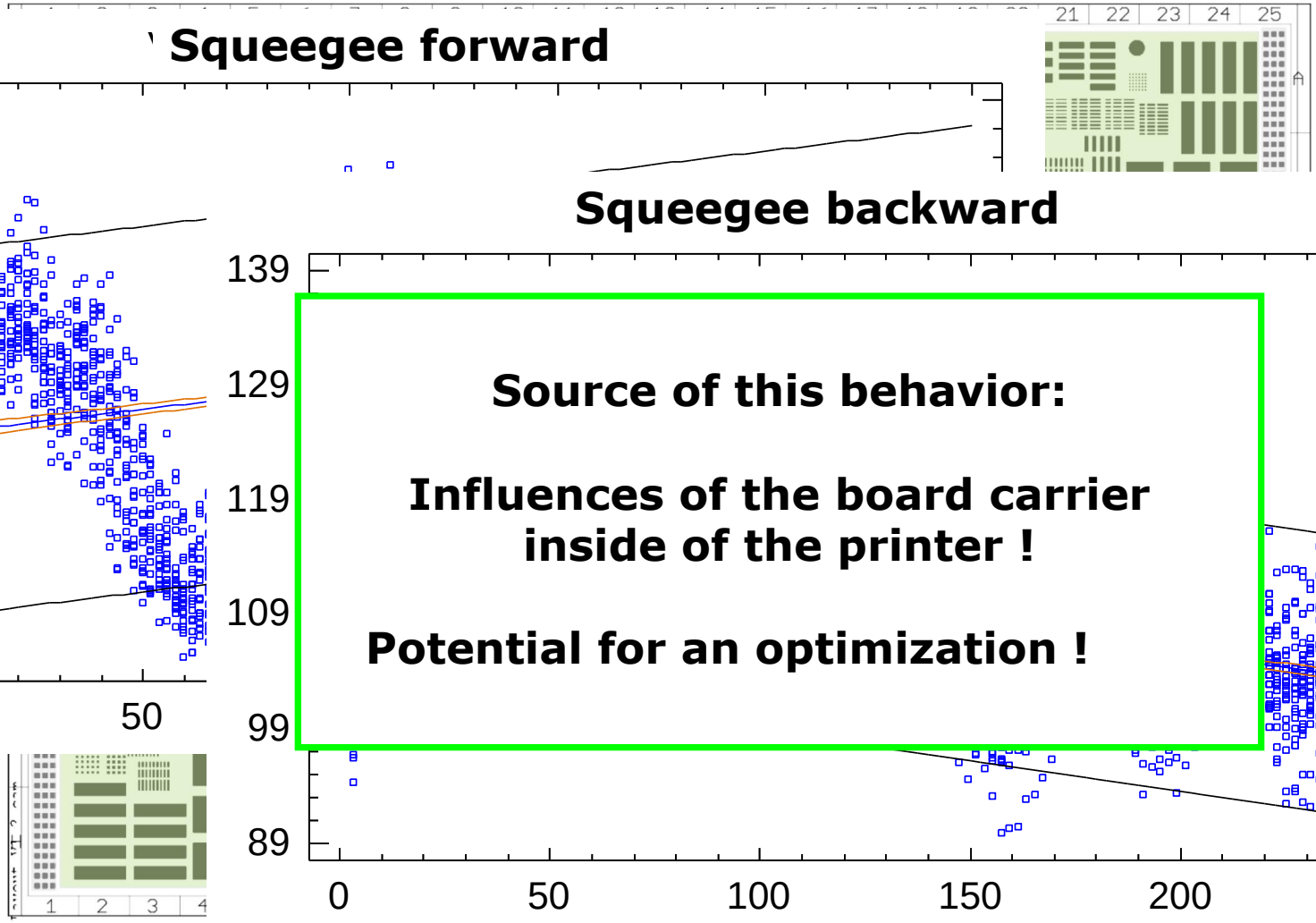
Based on these results the layout rules must be adapted !

The adaptions must be proofed by additional experments !

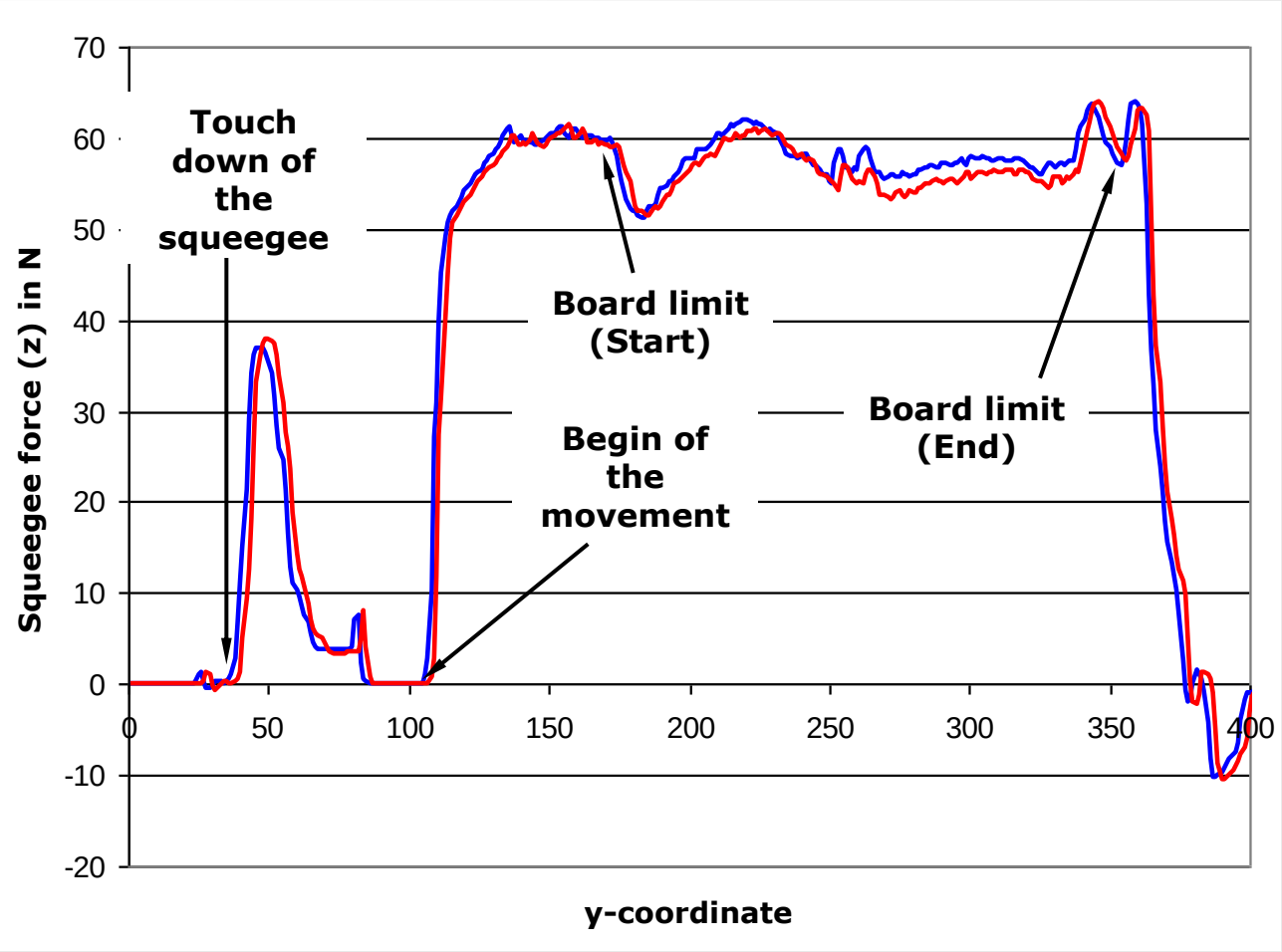

Region 5
Rel. Volume
220
190
160
130
100
70
0
30
60
90
120
150
180
y-coordinate

Special Effects (2)

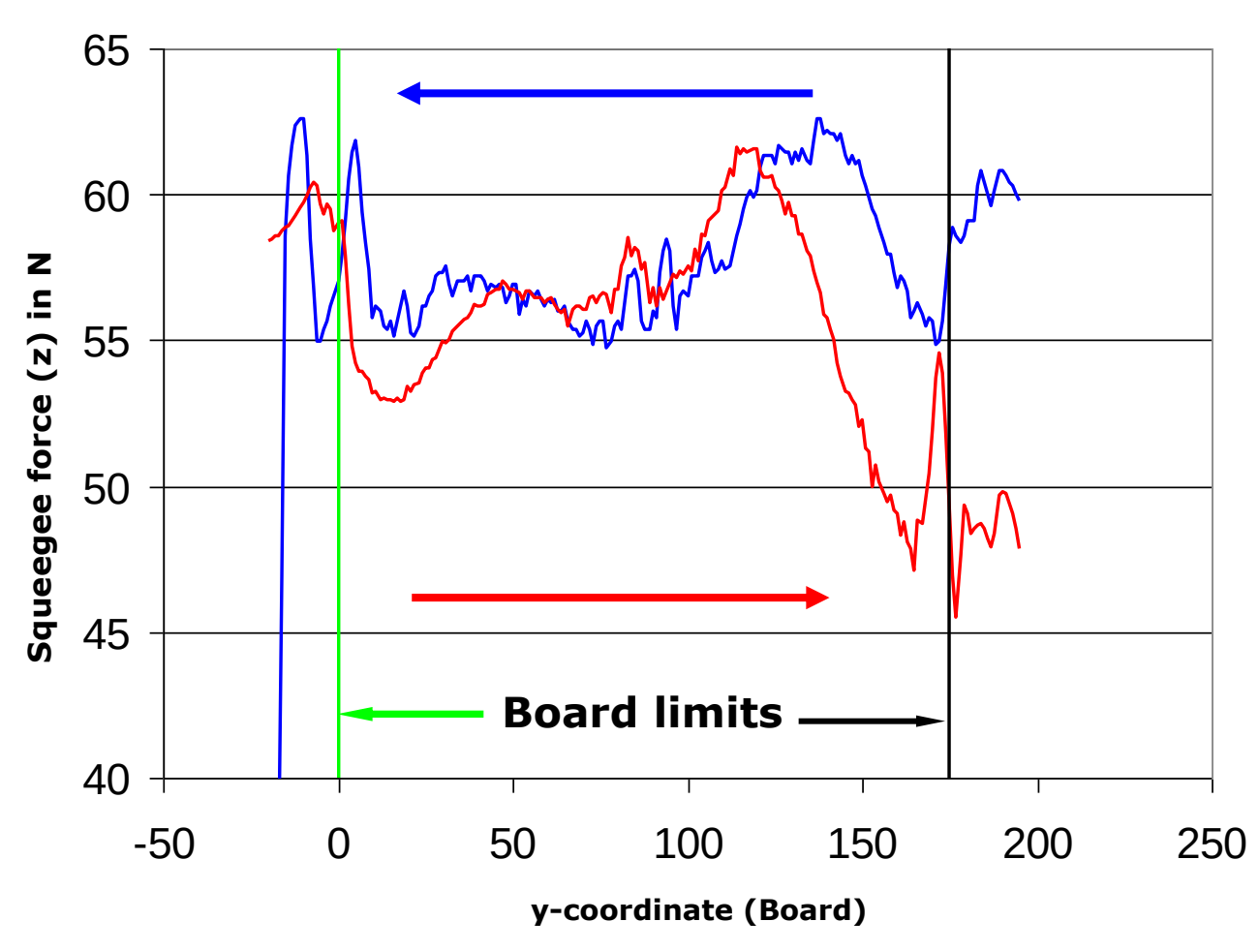



Squeegee forward
134
124
114
104
94
0
50
21 22 23 24 25
Squeegee backward
139
129
119
109
99
89
0
50
100
150
200
250
Source of this behavior:
Influences of the board carrier inside of the printer !
Potential for an optimization !
1 2 3 4

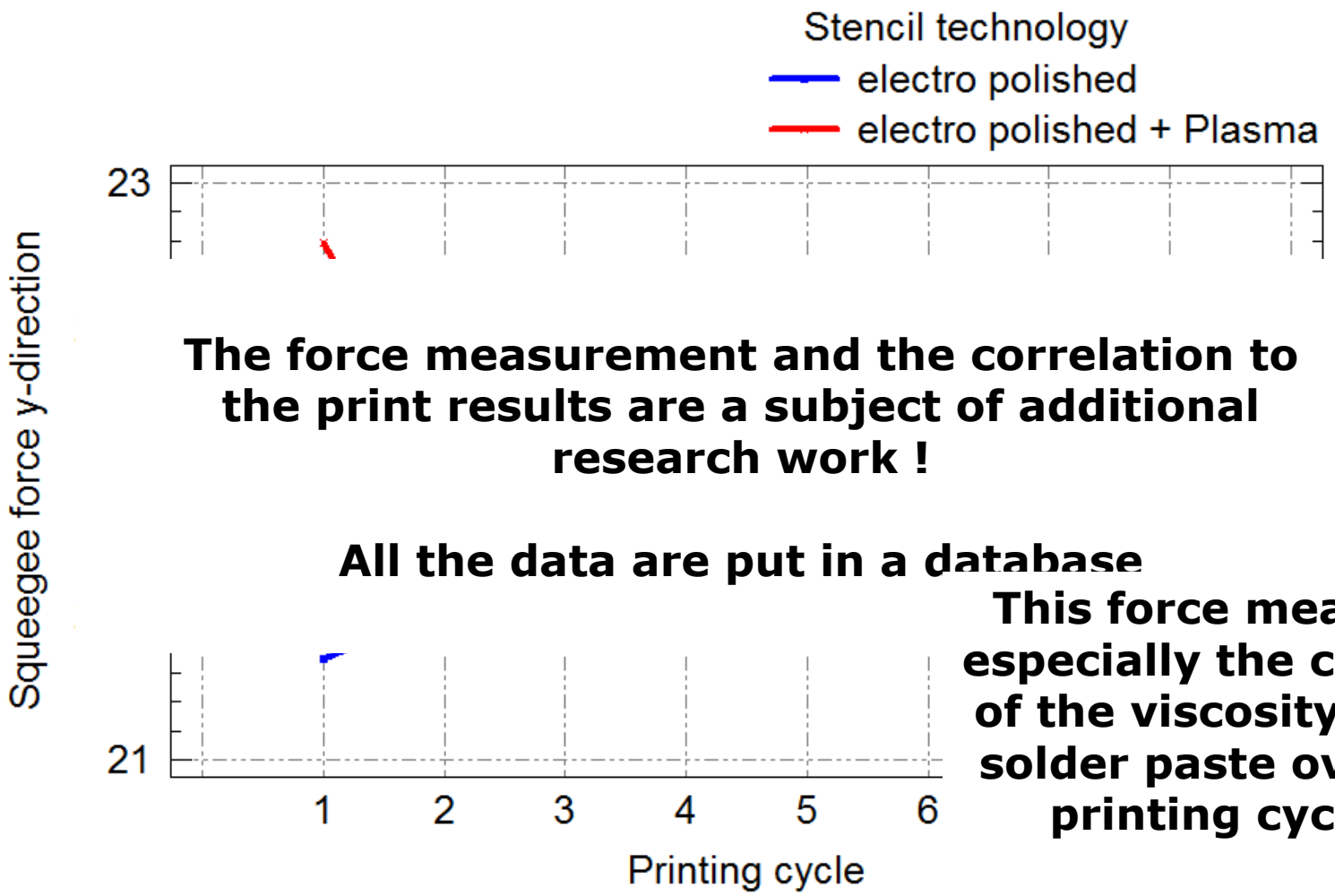
The squeegee force measurement sensor is build inside of the squeegee head!
Setup of the force: 50 N



Squeegee Force Measurement (2)



Analysis of the Squeegee Force y-Direction



The force measurement and the correlation to the print results are a subject of additional research work !

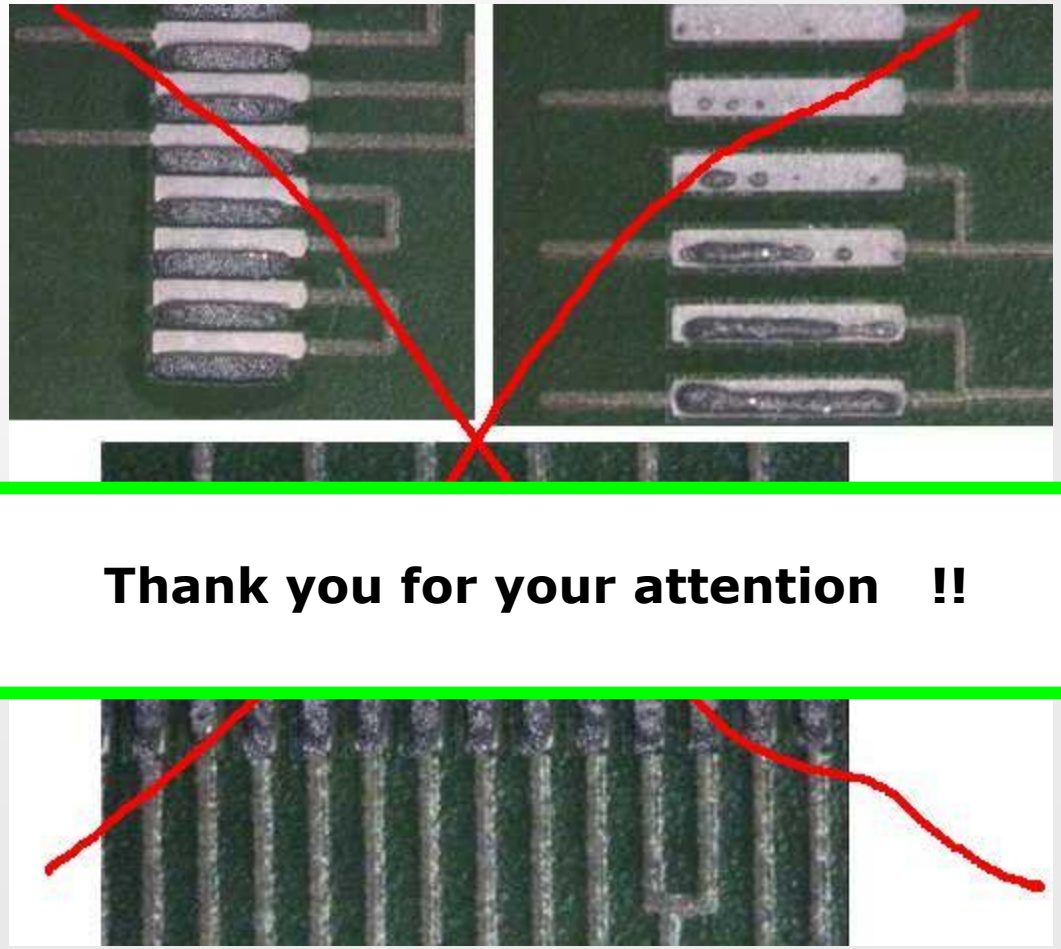
All the data are put in a database

This force measures especially the changes of the viscosity of the solder paste over the printing cycles!

Summary

All this effects help us, to control the means of all characteristics, to decrease the standard deviations and increase the proces capability

- The measuring results can be used for a definition of the sizes of the structures of the stencil
- The printed volume is a function of the solder paste type and the printing system
- The calculation of capability values should be based of the demands of the concrete application and not from the opening of the stencil structure
- The orientation of the structure opening has a big influence to the printed volume.
- A engaging procedure of about 4..5 prints is to be recognized after a cleaning.
- Waiting times from more than 30 minutes during the production leads to higher values of the standard deviation and less capability values.
- The squeegee direction has a big influence to the y-deviations of the printed deposits
- The influences of the carrier of the board and the squeegee forces are a goal for necessary future works !



Thank you for your attention !!