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I N T E R N A T I O N A L

400 Commonwealth Drive, Warrendale, PA 15096-0001

AEROSPACE STANDARD

SAE AS9132

Issued 2002-02

Data Matrix (2D) Coding Quality Requirements for Parts Marking

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SAE   AS9132

1. SCOPE:

This Standard defines uniform Quality and Technical requirements relative to metallic parts marking performed in using "Data Matrix symbology" (2D) coding used within the aerospace industry. The ISO 16022 specifies general requirements (data characters encodation, error correction rules, decoding algorithm, etc.). In addition to this specification, part Identification with such coding is subject to the following requirements to ensure electronic reading (scanning) ability of the symbol.

The marking processes covered by this standard are as follows:

• Dot Peening
• Laser Marking
• Electro-Chem Etching

Further marking processes will be included if required.

Unless specified otherwise in the contractual business relationship, the company responsible for the design of the part shall determine the location of the Data Matrix Marking. Symbol position should allow illumination from all sides for readability.

This standard does not specify information to be encoded, which are requested by customers, in conjunction with the ATA Spec 2000, chapter 9.

1.1 Convention:

The following conventions are used in this standard :

• The words "shall" and "must" indicate mandatory requirements.
• The word "should" indicates mandatory requirements with some flexibility allowed in compliance methodology. Producers choosing other approaches to satisfy a "should" must be able to show that their approach meets the intent of the requirement of this standard.
• The words "typical", "example", "for reference" or "e.g." indicate suggestions given for guidance only.
• Appendices to this document are for information only and are provided for use as guidelines.

2. NORMATIVE REFERENCES:

• Air Transport Association (ATA), Spec 2000, chapter 9 "Bar Coding"
• Automated Identification Manufacturer, (AIM) "International Symbology Specification-Data Matrix" (ANSI/AIM BC11-1997) Error Correction Code 200 (ECC200)
• ISO 16022 "Information Technology International Symbology Specification Data Matrix"
• AS/SJAC/PrEN 9102 Requirements "First Article Inspection Requirements"

3.   MARKING REQUIREMENTS:

3.1   General Requirements:

• Rows and Columns:

Rows and columns connected with 2D Data Matrix symbology shall conform to ANSI/AIM BC11 or ISO 16022- ECC200 table Symbol Attributes.

• Square versus Rectangle:

Matrix may be square or rectangular within ECC200 requirements. Square is preferred for easier reading.

• Quiet Zone:

The quiet zone (margin) around the matrix shall be equal to or greater than one (1) cell size.

• Round Surface:

If the marking is made on round/curved surface, the symbol coverage shall be less than 16% of the diameter (or 5% of circumference).

• Symbol Size:

To facilitate electronic reading (scanning) of symbol, the overall symbol size should be less than 1 inch (25,4 mm), outside dimension, longest side. If a size over this limit is used, requirements included in this standard shall be applied too.

• Angular Distortion of the Symbol:

Angular deviation of 90 degree plane between row and column shall not exceed ±7 degrees.
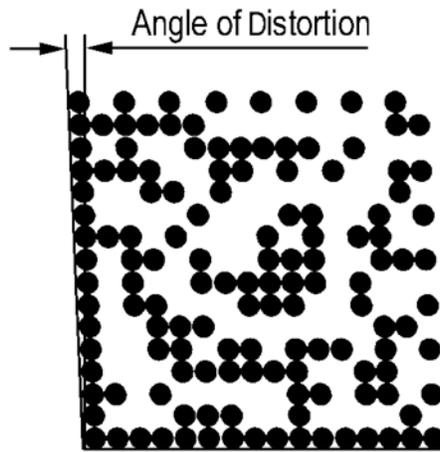
FIGURE 1 - Angle of Distortion

3.2   Dot Peening:

3.2.1   Instructions for Determination of Marking Parameters:

Determine minimum cell size according to the surface texture. See Table 1 (page 5), Figure 2 (inch) or Figure 3 (mm) pages 5 and 6.

Calculate dot size with regard to the above minimum cell size in choosing stylus angle (60°, 90° or 120°) depending on maximum depth allowed by Engineering requirements. See Table 2 page 7 for the optimum dot size.

Determine matrix size depending on the information coded in the matrix. (Reference tables in appendix A for minimum matrix size based on available marking real estate).

Set up machine (e.g., in height, air pressure, force, etc.) for desired dot geometry. Dot to dot touching is permitted but overlapping is not allowed.

3.2.2   Requirements:

• 2D Data Matrix Symbol Nominal Cell Size:

The surface texture of the part affects the readability to a 2D Data Matrix performed by dot peening.

Table 1 and Figures 2 and 3 show the minimum readable cell size requirements to the surface texture of the part.

TABLE 1 - Minimum Readable Cell Size by Surface Texture

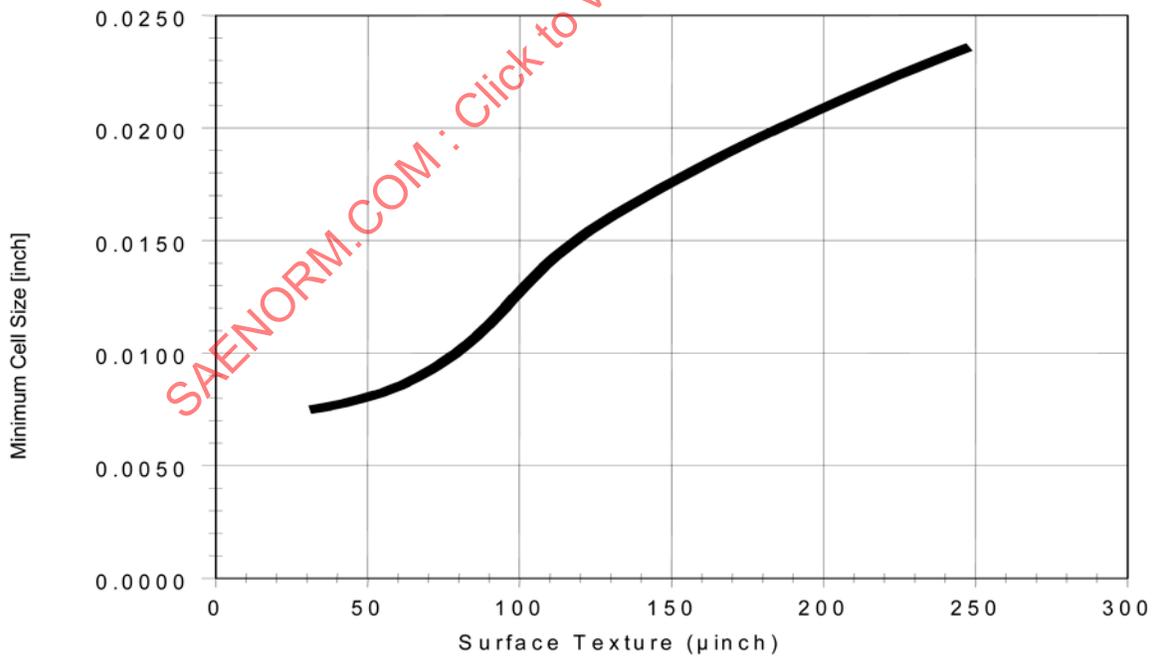| Surface Texture		Minimum Cell Size	
Microinches	Micrometers	Microinches	Micrometers
32	0,8	0.0075	0,19
63	1,6	0.0087	0,22
95	2,4	0.0122	0,31
125	3,2	0.0161	0,41
250	6,3	0.0236	0,60

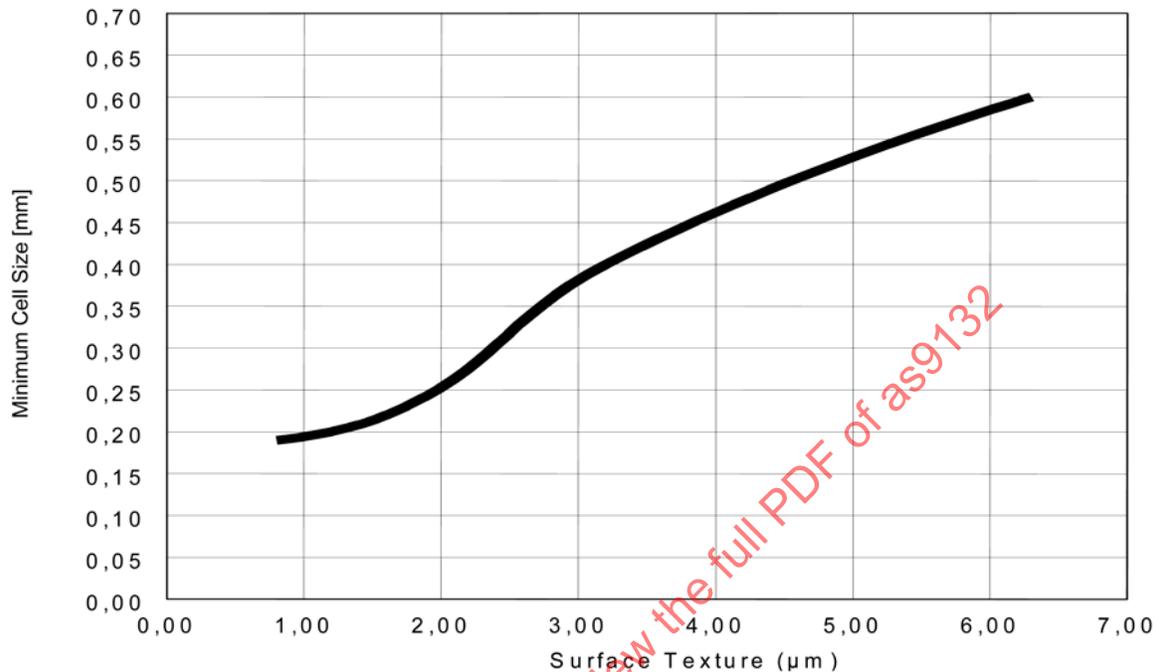FIGURE 2 - Minimum Cell Size (Inch) by Surface Texture (µinch)

FIGURE 3 - Minimum Cell Size (mm) by Surface Texture (µm)

3.2.2   (Continued):

• Data Capacity:

For information, tables in Appendix A for Dot Peening show the symbol size and the data capacity compared to the nominal cell size and the number of rows and columns relative to surface texture. These tables are based on extensive testing.

• 2D Data Matrix Symbol Quality Requirements:

Dot Depth is subject to Engineering requirements. The Dot Depth is based upon the requirements for process, environment survivability and other material considerations.

Stylus Radius is also an Engineering Design requirement. The Maximum tolerance shall not be over than 10% of the Stylus Radius.

Surface Color and Color Consistency are specified as an Engineering requirement. In order to maximize readability, surface discoloration should be minimized.

Stylus Cone Angle (Reference α in Appendix B) is an Engineering requirement. The Cone Angles permitted are 60°, 90° and 120°. The tolerance on the Cone Angle shall be ±2°.

3.2.2   (Continued):

Stylus Point Finish shall be polished. Surface texture shall not exceed 32 µinch or 0,8 µm. Guidance instructions for grinding are given in Appendix B.

Stylus Point Concentricity shall be 0.00016 inch or 0,04 mm total indicator reading, or 0.0008 inch (0,02 mm) radial point displacement. Point concentricity is with respect to stylus centerline.

The Dot Size shall not exceed 100% of the nominal cell size and shall not be less than 60% of the nominal cell size for purposes of readability. The ovality (see Figure 4) of the dot shall not exceed 20% of the cell size. No more than 2% of the total number of cells may contain dots that are outside of these ranges. The minimum dot size shall not be less than 0.0054 inch or 0,132 mm.
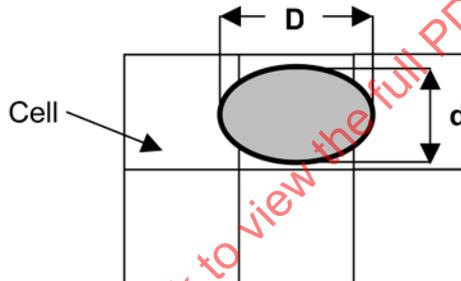
FIGURE 4 - Definition of Ovality
D-d $\leq$ 20% of the Cell Size

Table 2 gives limits for dot size and dot center offset useable whatever the nominal cell size.

TABLE 2 - Limits for Dot Size and Dot Center Offset

Quality	Excellent	Acceptable
Stylus Angle	60, 90 or 120°	
Stylus Point Radius	Subject to Engineering Requirements	
Dot Size (% of the Nominal Cell Size)	70 to 90%	60 to 100%
Dot Depth	Subject to Engineering Requirements	
Dot Center Offset (% of the Nominal Cell Size)	0 to 10%	10 to 20%
Angle of Distortion	±3,5°	±7°

- "Excellent" is the optimum position within the tolerance band.
- "Acceptable" is the position within the full limit of the tolerance range.

3.2.2   (Continued):

Figures 5 and 6 show definition of nominal cell size, dot center offset and dot size.

FIGURE 5 - Definition of Nominal Cell Size, Dot Size and Dot Center Offset

FIGURE 6 - Detail Definition of Dot Size

3.2.2   (Continued):

Appendix C (Table C1 in inches and Table C2 in mm) contains examples required tolerances in comparison to the nominal cell sizes.
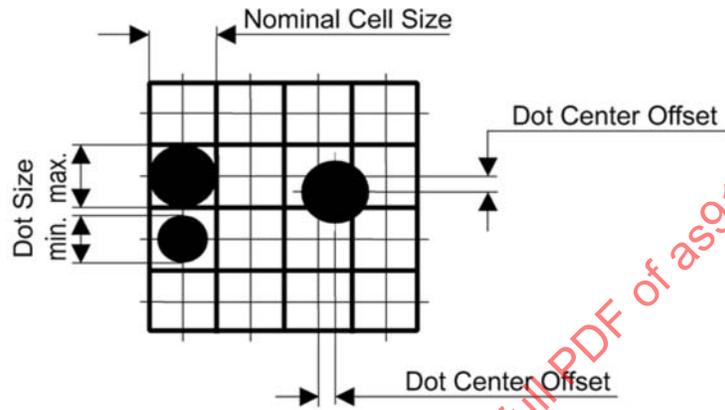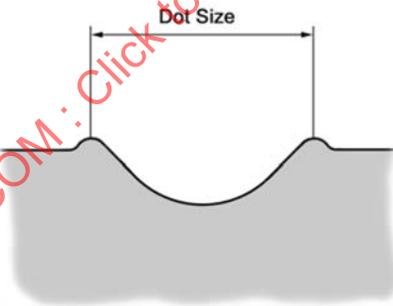
• 2D Data Matrix Symbology Marking on a Colored or Coated Surfaces:

When marking is located on a colored or coated surface, the marking parameters should be validated in an actual production line environment on production parts. The marking process must demonstrate all requirements contained, herein, and shall be validated per Section 4.

• 2D Data Matrix Symbology Marking on Surfaces Which are Subject to Further Surface Treatments by Abrasive Methods:

Surface treatments like Shot peening and Spindle Deburr can affect the readability of a 2D Data Matrix. Therefore the marking parameters should be validated in an actual production line environment on production parts. The marking process must demonstrate all requirements contained, herein, and shall be validated per Section 4.

3.3   Laser:

3.3.1   Requirements:

TABLE 3

Characteristics	Requirements
Laser Spot Depth	• See engineering requirements for limits. Laser spot depth depends upon requirements for physical marking depth, remelt layer, heat affected zone, survivability and other materials requirements.
Laser Spot Size	• Laser spot sizes are typically in the 0.002 to 0.005 inch or 0,05 to 0,127 mm range.
Marking Raised Material (Texture)	• See engineering requirements for maximum surface texture for marking area allowed on part.
Surface Color and Color Consistency	• Marking parameters should be established to optimize color consistency of the symbol.
Cell Size	• Typically in the range of 0.002 to 0.022 inch or 0,05 to 0,558 mm
Surface Height Variation	• The nominal value is equal to the focal length and tolerance is equal to depth of field of the optics.
Cell Fill	• Each cell shall be filled in the range of 80 to 100% .

3.3.2   Instructions for Marking Parameters in Laser:

1.   Determine matrix size in reference to ECC200 (based on the size of the information to be encoded in the matrix and the marking real estate available)
2.   Subject to the laser parameter definition.

NOTE: Further tests are in progress. The next issue of this document will take into account results if needed.

3.4   Electro-Chem Etching:

TABLE 4

Characteristics	Requirements
Cell Depth	• See engineering requirements for limits. Cell depth depends upon requirements for survivability and other materials requirements.
Surface Texture.	• See engineering requirements for maximum surface texture permitted on part.
Surface Color and Color Consistency	• Marking parameters should be established to optimize color consistency of the symbol.
Cell Size	• Minimum cell size allowed : 0.019 inch or 0,5 mm
Cell Fill	• Each cell shall be filled in the range of 80 to 100%.

The matrix size shall be determined in reference to ECC200 (based on the size of the information to be coded in the matrix and the marking real estate available)

The following parameters affect quality of marking: power unit voltage output, time of application, type of media use for printer and type of current used (Alternating Current or Direct Current). Tests should be performed to define the proper set-up for each application.

NOTE: Further tests are in progress in Electro Chem Etching. The next issue of this document will take into account results if needed.

4. MARKING VALIDATION AND MONITORING:

- Marking in Data Matrix shall be decoded after a maximum of 2 shoots using an electronic reading (scanning) device*.
- All characteristics shall be verified during the First Article Inspection (FAI) per AS/SJAC/PrEN 9102 requirements. Appendix D "Example Methodology for Checking Dot Peen Characteristics" may be used as a validation guideline for Dot Peen Marking.
- A Quality Assurance Plan should be developed and instituted which ensures that a FAI validates the quality of the 2D Data Matrix marking process and which monitors/samples the marking process for declining quality of application which in turn affects matrix readability requirements. For Dot Peen, the monitoring may be as simple as detecting approaching dot overlap with a 10X magnifying glass, or when the electronic reading (scanning) appears to be negatively trending towards consistently violating the reading limit of 2 shoots.
- FAI may also apply whenever the marking machine set up is disturbed, or after preventive maintenance or machine repair. This may be applicable in facilitating disposition of marks which cannot be electronically read (scanned) per Quality Assurance Plan requirements.
- Marking equipment should be monitored/serviced through a Preventive Maintenance Plan recommended/developed in conjunction with the equipment supplier to ensure sufficient preventive/ scheduled maintenance and to avoid marking outside of allowable limits.
- Any non-conforming marking shall be submitted to the appropriate non conformance authority for part disposition.

* NOTE: Supplier applying 2D Data Matrix to parts and customer(s) receiving 2D Data Matrix marked parts should use technologically equivalent electronic readers which have proven capability to read 2D Data Matrix applied in accordance with this standard.

PREPARED UNDER THE JURISDICTION OF
SAE COMMITTEE G-14, AMERICAS AEROSPACE QUALITY GROUP

APPENDIX A
DOT PEENING DATA CAPACITY GUIDELINES

TABLE A1

Surface Texture with Ra = 1,50 μm or 60 μin						
Symbol Layout		Data Range	Data Capacity		Nominal Cell Size	
Row	Column		Num. Cap.	Alphanum. Cap.	0,22 mm	0.0087 inch
					Symbol Size	
					[mm]	[inch]
Square Symbol						
10	10	8x8	6	3	2,20 x 2,20	0.087 x 0.087
12	12	10x10	10	6	2,64 x 2,64	0.104 x 0.104
14	14	12x12	16	10	3,08 x 3,08	0.121 x 0.121
16	16	14x14	24	16	3,52 x 3,52	0.139 x 0.139
18	18	16x16	36	25	3,96 x 3,96	0.156 x 0.156
20	20	18x18	44	31	4,40 x 4,40	0.173 x 0.173
Rectangular Symbol						
8	18	6x16	10	6	1,76 x 3,96	0.069 x 0.156
8	32	6x14 (2x)	20	13	1,76 x 7,04	0.069 x 0.277
12	26	10x24	32	22	2,64 x 5,72	0.104 x 0.225

TABLE A2

Surface Texture with Ra = 2,40 μm or 95 μin						
Symbol Layout		Data Range	Data Capacity		Nominal Cell Size	
Row	Column		Num. Cap.	Alphanum. Cap.	0,31 mm	0.012 inch
					Symbol Size	
					[mm]	[inch]
Square Symbol						
10	10	8x8	6	3	3,10 x 3,10	0.122 x 0.122
12	12	10x10	10	6	3,72 x 3,72	0.146 x 0.146
14	14	12x12	16	10	4,34 x 4,34	0.171 x 0.171
16	16	14x14	24	16	4,96 x 4,96	0.195 x 0.195
18	18	16x16	36	25	5,58 x 5,58	0.220 x 0.220
20	20	18x18	44	31	6,20 x 6,20	0.244 x 0.244
Rectangular Symbol						
8	18	6x16	10	6	2,48 x 5,58	0.098 x 0.220
8	32	6x14 (2x)	20	13	2,48 x 9,92	0.098 x 0.391
12	26	10x24	32	22	3,72 x 8,06	0.146 x 0.317

TABLE A3

Surface Texture with Ra = 3,25 µm or 128 µin						
Symbol Layout		Data Range	Data Capacity		Nominal Cell Size	
Row	Column		Num. Cap.	Alphanum. Cap.	0,41 mm	0.0161 inch
					Symbol Size	
					[mm]	[inch]
Square Symbol						
10	10	8x8	6	3	4,10 x 4,10	0.161 x 0.161
12	12	10x10	10	6	4,92 x 4,92	0.194 x 0.194
14	14	12x12	16	10	5,74 x 5,74	0.226 x 0.226
16	16	14x14	24	16	6,56 x 6,56	0.258 x 0.258
18	18	16x16	36	25	7,38 x 7,38	0.291 x 0.291
20	20	18x18	44	31	8,20 x 8,20	0.323 x 0.323
Rectangular Symbol						
8	18	6x16	10	6	3,28 x 7,38	0.129 x 0.291
8	32	6x14 (2x)	20	13	3,28 x 13,12	0.129 x 0.517
12	26	10x24	32	22	4,92 x 10,66	0.194 x 0.420

TABLE A4

Surface Texture with Ra = 3,80 µm or 150 µin						
Symbol Layout		Data Range	Data Capacity		Nominal Cell Size	
Row	Column		Num. Cap.	Alphanum. Cap.	0,45 mm	0.0177 inch
					Symbol Size	
					[mm]	[inch]
Square Symbol						
10	10	8x8	6	3	4,50 x 4,50	0.177 x 0.177
12	12	10x10	10	6	5,40 x 5,40	0.213 x 0.213
14	14	12x12	16	10	6,30 x 6,30	0.248 x 0.248
16	16	14x14	24	16	7,20 x 7,20	0.283 x 0.283
18	18	16x16	36	25	8,10 x 8,10	0.319 x 0.319
20	20	18x18	44	31	9,00 x 9,00	0.354 x 0.354
Rectangular Symbol						
8	18	6x16	10	6	3,60 x 8,10	0.142 x 0.319
8	32	6x14 (2x)	20	13	3,60 x 14,40	0.142 x 0.567
12	26	10x24	32	22	5,40 x 11,70	0.213 x 0.461

APPENDIX B
DOT PEENING - RECOMMENDATION FOR STYLUS GRINDING

A

0.0008 [0,02] A

R

α
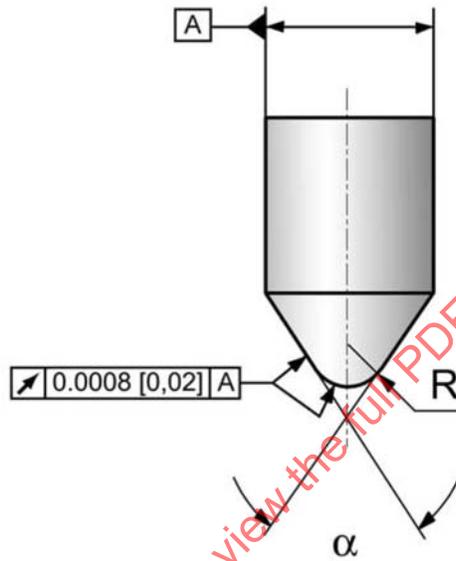
α : 60°, 90° or 120°
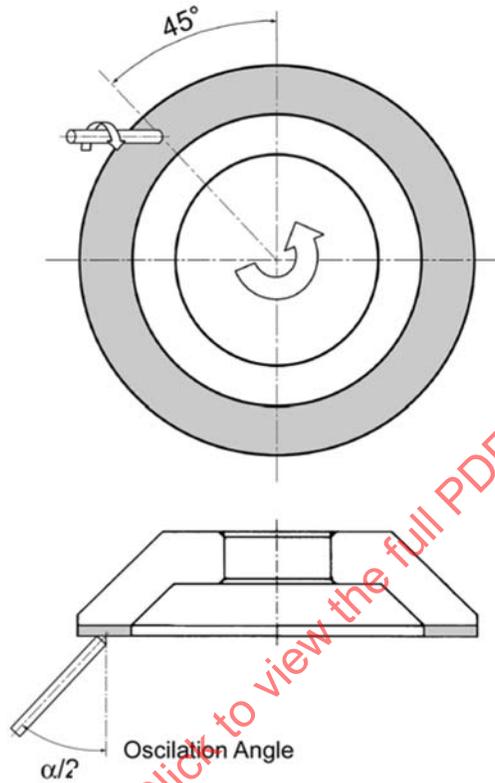
FIGURE B1 - Tolerance on Stylus

FIGURE B2 - Grinding

The grinding of the Stylus Tip is performed with 45° crossed axes of the stylus and the grinding disk. The surface may show tangential grinding scores, which reduce illumination problems.

Stylus is ground with a diamond wheel D20 KBT-C75 with Grinding Speed of:

v_c = 20 - 30 m/s
v_c = 0.80 - 1.2 SF/s.

APPENDIX C
EXAMPLES REQUIRED TOLERANCES IN COMPARISON
TO THE NOMINAL CELL SIZES FOR DOT PEENING

TABLE C1 - Requirements in Inches

Nominal Cell Size	0.0087 [inch]	
QUALITY	Excellent	Acceptable
Stylus Angle	60 or 90°	
Stylus Point Radius	0,0039	
Dot Size	0.0061 - 0.0078	0.0052 - 0.0087
Dot Depth	0.0014 - 0.0029	0.0010 - 0.0036
Dot Center Offset	0.0000 - 0,0009	0.0009 - 0.0017
Angle of Distortion	±3,5°	±7°

Nominal Cell Size	0.0122 [inch]	
QUALITY	Excellent	Acceptable
Stylus Angle	90 or 120	
Stylus Point Radius	0,0059	
Dot Size	0.0085 - 0,0110	0.0073 - 0.0122
Dot Depth	0.0016 - 0.0031	0.0012 - 0.0033
Dot Center Offset	0.0000 - 0.0012	0.0012 - 0.0024
Angle of Distortion	±3,5°	±7°

Nominal Cell Size	0.0161 [inch]	
QUALITY	Excellent	Acceptable
Stylus Angle	90 or 120°	
Stylus Point Radius	0,0098	
Dot Size	0.0113 - 0.0145	0.0097 - 0.0161
Dot Depth	0.0018 - 0.0033	0.0013 - 0.0041
Dot Center Offset	0.0000 - 0.0016	0.0016 - 0.0032
Angle of Distortion	±3,5°	±7°

Nominal Cell Size	0.0177 [inch]	
QUALITY	Excellent	Acceptable
Stylus Angle	90 or 120°	
Stylus Point Radius	0,0079	
Dot Size	0.0124 - 0.0159	0.0106 - 0.0177
Dot Depth	0.0024 - 0.0048	0.0019 - 0.0057
Dot Center Offset	0.0000 - 0.0018	0.0018 - 0.0035
Angle of Distortion	±3,5°	±7°

TABLE C2 - Requirements in mm

Nominal Cell Size	0,22 [mm]	
QUALITY	Excellent	Acceptable
Stylus Angle	60 or 90°	
Stylus Point Radius	0,100	
Dot Size	0,154 - 0,198	0,132 - 0,220
Dot Depth	0,036 - 0,072	0,026 - 0,092
Dot Center Offset	0,000 - 0,022	0,022 - 0,044
Angle of Distortion	±3,5°	±7°

Nominal Cell Size	0,31 [mm]	
QUALITY	Excellent	Acceptable
Stylus Angle	90 or 120°	
Stylus Point Radius	0,150	
Dot Size	0,217 - 0,279	0,186 - 0,310
Dot Depth	0,040 - 0,078	0,031 - 0,084
Dot Center Offset	0,000 - 0,031	0,031 - 0,062
Angle of Distortion	±3,5°	±7°

Nominal Cell Size	0,41 [mm]	
QUALITY	Excellent	Acceptable
Stylus Angle	90 or 120°	
Stylus Point Radius	0,250	
Dot Size	0,287 - 0,369	0,246 - 0,410
Dot Depth	0,045 - 0,083	0,032 - 0,104
Dot Center Offset	0,000 - 0,041	0,041 - 0,082
Angle of Distortion	±3,5°	±7°

Nominal Cell Size	0,45 [mm]	
QUALITY	Excellent	Acceptable
Stylus Angle	90 or 120°	
Stylus Point Radius	0,200	
Dot Size	0,315 - 0,405	0,270 - 0,450
Dot Depth	0,060 - 0,121	0,048 - 0,144
Dot Center Offset	0,000 - 0,045	0,045 - 0,090
Angle of Distortion	±3,5°	±7°