Objective mottling control at the line with new and innovative testing technologies

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Outline

- Visual evaluation of mottling
  斑块的视觉评估

- Instrumental measurement principle
  仪器测量原理

- Development of a mottling index for defining customer relevant limits
  开发的斑块指数用于设定与客户有关的范围

- Mottling - a process variation
  斑块 - 一个过程的变化
Automotive - Exterior: Surface quality / 汽车 - 外饰：表面质量
Harmony: Uniform Color & Appearance / 和谐一致：统一的颜色和外观

Gloss 光泽
Waviness 桔皮
Color 颜色
Effect 效果
Mottling 斑块
Mottling / Cloudiness of Metallic Coatings / 金属涂料的斑块/云雾
irregular areas of lightness variation / 亮暗区域的不规则变化

- undesirable defect at effect coatings
  是效果涂料上不可接受的缺陷
- especially noticeable on large body panels
  尤其在大的车身面板上容易被发现
- most obvious on light metallic finishes
  在明亮的金属面漆上更容易被看见
Causes and Cloud types / 云雾图影的类型和成因
Orientation clouds / 排列型云雾

Disorientation influenced by wetting behaviour, rheology additive or application method
湿润行为，流变助剂或涂装方法对非定向性的影响

Disorientation influenced by interaction between clearcoat and basecoat: Strike-in effect
清漆和底漆的层间相互作用即“穿透效应”对非定向性的影响
Causes and Cloud types / 云雾图影的类型和成因
Thickness clouds / 遮盖力型云雾

Thickness variations result in poor hiding
涂层厚度的变化降低了遮盖力

Thickness variations result in partial hiding at grazing angle
厚度的变化导致大角度上遮盖力降低
Mottling / Cloudiness of Metallic Coatings / 金属涂料的斑块/云雾图影
How is it evaluated today? / 当今如何进行评估?

- There is a high interest in objectively measuring “mottling”.
  对“斑块”进行客观评估非常重要

- In R&D applications multi-angle spectrophotometers are used to measure lightness variation by “scanning” surface point by point.
  在研发部门使用多角度色差仪对油漆表面进行逐点“扫描”，测量亮度的变化。

- Very time consuming (fingerprint system analysis)
  非常耗费时间（指纹分析系统）

- Some companies have developed cloud reference panels as a ranking tool.
  一些公司开发了斑块参考板作为等级划分的工具。

- Most companies perform a visual check
  大多数公司仍用目视进行评估
Perception of Mottling

Depending on illumination, viewing angle, distance and size

受光源、观察角度、距离和斑块大小的影响
Evaluation of Mottling 斑块的评估
Which pattern size is perceived as mottle? 哪些形式尺寸的斑块能被察觉?

- Experts and non-experts mainly recognize mottle sizes between 50 to 100 mm. Extremes ranged from 25 to 200mm.
  在专家和普通人中大多数认为介于50-100mm的斑块能被感知，极端情况范围是25-200mm.

- Therefore, for visual inspection and measurement a min. sample area of about 300 x 500 mm is recommended.
  因此，对于视觉查看和测量所需样品的最小尺寸建议为300×500mm.
How to measure Mottling
Scanning the mottle pattern

scanning 10 ...100 cm
Measurement  测量
Optical principle  光学原理

Illumination 光源
15° to perpendicular

Detection 45°

Detection 60°

Spot size approx. 4x4 mm
测量点尺寸约:

Detection 15°

Specular Reflection
镜像反射
**Measurement**  测量  
**Minimize the influence of tilting**  受倾角的影响很小

- Detection +15°
- Specular Reflection
  - Detection -15°
- Illumination 光源 15° to perpendicular
- Sample surface 样品表面
Measurement  测量
Minimize the influence of tilting
受倾角的影响很小

Illumination 光源
15° to perpendicular

Detection +15°
观察

Specular Reflection
镜像反射

Detection -15°
观察

Sample surface
样品表面

Object Curvature
样品曲率
radius > 500 mm
半径
The signal is separated by mathematical filters:
通过数字滤波器对信号进行分离:

<table>
<thead>
<tr>
<th>Mottle Size</th>
<th>min. scanlength</th>
</tr>
</thead>
<tbody>
<tr>
<td>Md</td>
<td>6 - 13 mm</td>
</tr>
<tr>
<td>Me</td>
<td>11 - 24 mm</td>
</tr>
<tr>
<td>Mf</td>
<td>19 - 42 mm</td>
</tr>
<tr>
<td>Mg</td>
<td>33 - 72 mm</td>
</tr>
<tr>
<td>Mh</td>
<td>57 - 126 mm</td>
</tr>
<tr>
<td>Mi</td>
<td>100 - 200 mm</td>
</tr>
</tbody>
</table>

Visibility 能见度

Mottle Size 班块尺寸
Min. scanlength 最小扫描长度

Md 6 - 13 mm
Me 11 - 24 mm
Mf 19 - 42 mm
Mg 33 - 72 mm
Mh 57 - 126 mm
Mi 100 - 200 mm

15°
45°
60°
Evaluation of Mottling 斑块的评估
Which pattern size is perceived as mottle?
哪些形式尺寸的云雾图影能被察觉?

<table>
<thead>
<tr>
<th>Small Mottles</th>
<th>Large Mottles</th>
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<tr>
<td>Md 6-13mm</td>
<td>Me 11-24mm</td>
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<tr>
<td>Me 11-24mm</td>
<td>Mf 19-42mm</td>
</tr>
<tr>
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<td>Mg 33-72mm</td>
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<td>Mg 33-72mm</td>
<td>Mh 57-126mm</td>
</tr>
</tbody>
</table>
Visual Correlation Study conducted by BMW

Appearance Panels with different colours and texture

不同颜色和纹理的外观样板
Small clouds are constant (within one colour)
...describe texture of a colour

Differentiation with the „bigger“ clouds
...describe the process relevant mottling

• Small clouds are constant (within one colour) 小的云雾图影是恒定的（一种颜色中）
  ...describe texture of a colour  ...描述为纹理
• Differentiation with the „bigger“ clouds 区别在于大的云雾图影
  ...describe the process relevant mottling ...描述为斑块
Evaluation of Mottling

Texture & Mottling

Small Mottles

Large Mottles

Small Mottles = (Md + 0.5Me) / 1.5

小型斑块

小型斑块

大型斑块

Small Mottles

Large Mottles

Small Mottles = (Md + 0.5Me) / 1.5
Evaluation of Mottling

Mottling is dominated by the max value of the large mottles

Large Mottle: avg. max.

- Sample A: 3.8 4.6
- Sample B: 3.7 3.8

LM = \((0.5M_f + \max(M_g, M_h)) / 1.5\)

SM = \((M_d + 0.5M_e) / 1.5\)

Sample A

Sample B
Evaluation of Mottling

Texture & Mottling - 2 dimensional graph

Visual Ranking:
- clearly noticeable
- visible
- hardly to recognize

Visual Ranking: 视觉等级:
- 清晰的视觉感受
- 视觉可察觉
- 视觉很难察觉
Evaluation of Mottling 斑块的评估
Texture & Mottling - 2 dimensional graph
纹理和斑块 - 2维图表

Visual Ranking:
视觉等级:
- clearly noticeable 清晰的视觉感受
- visible 视觉可察觉
- hardly to recognize 视觉很难察觉

Graph showing evaluation of mottling with visual ranking:
图示斑块评估与视觉等级:

Small Mottles (SM) 15°
Large Mottles (LM) 15°
Evaluation of Mottling 班块的评估
Small & Large Mottles weighted for visual correction
小型 & 大型 班块的权重用于对视觉的修正

- Small mottles in the range of mm to cm overlay Large Mottling and reduce their visibility.
从mm到cm级的小型班块能覆盖大型班块，使得大型班块的可见度降低.

Large Mottling needs to be corrected by influence of SM:
大型班块需要针对小型班块的影响进行修正:

\[ M = LM \times (1 - f \times T) \]

- Texture: Small Mottling with shifted zero (pivotal point):
纹理: 转移零点的小型班块 (中轴点):

\[ Texture = SM - 6 \]
Evaluation of Mottling 班块的评估
Texture & Mottling 纹理 & 斑块

Visual Ranking:
视觉等级:

- 具体可辨认
- visible 视觉可察觉
- hardly to recognize 视觉很难察觉

纹理

\( M = LM \times (1 - 0.05 \times T) \)

\( T = SM - 6 \)
Evaluation of Mottling 斑块的评估
Texture & Mottling 纹理&斑块

Visual Ranking:
视觉等级:

- clearly noticeable 清晰的视觉感受
- visible 视觉可察觉
- hardly to recognize 视觉很难察觉

\[ M = LM \times (1 - 0.05 \times T) \]
\[ T = SM - 6 \]
Visual Correlation Study conducted by BMW

Field study to define customer relevant limit for mottling

A team of 5 people (BMW and BYK) planned and carried out the field study

Evaluation of a variety of cars of different manufacturers in a variety of colours.

Evaluation by measurement with the cloud-runner.

Visual evaluation under standardized conditions

70 participants were analysed.
Visual Correlation Study conducted by BMW
BMW 的视觉相关性研究
Conclusion of field study
领域研究的结论

- Mottling index is a suitable parameter to describe cloudiness
  斑块度指数是一个合适描述云雾图影的参数

- Significant correlation allowed to define limit values
  具有显著的相关性，可以设定限制值

- Mottling index will be implemented in the basecoat release process within the BMW Group.
  BMW 集团将会将斑块度指数在底漆中颁布实施
Mottle-Chart 斑块度图表

Example: Medium Class Models

实例：中型车

Body panels

车身面板
Mottle-Chart 斑块度图表
Example: Medium Class Models
实例：中型车
Mottling – a Process Variations
斑块度-工艺的变化
White Tricoat applied at various plants
在多家工厂的白色三涂层喷涂

![Graphs showing mottling variations at different plants for left front and rear doors at 15° and 60° angles.](image-url)
Mottling – a Process Variation
斑块度-工艺的变化
Striping and Measurement Direction
条纹和测量的方向
Example 实例
Striping and Measurement Direction
条纹和测量方向
Mottling - Irregular distribution
斑块 - 不规则的分布

- **Recommended sample area ~ 30 x 50 cm**
  推荐的样品尺寸约30×50cm

- **10 scans in 1 - 2 cm distance**
  1-2cm间距扫描10次

- **min. scan length: 42 cm for Mh**
  对于Mh测量最小扫描长度为：42cm

  23 cm for Mg & Mh
  对于Mg&Mh需23cm
New: cloud-runner 云雾仪
Control a uniform finish - no more mottling!
控制面漆的一致性 - 不再有过多的斑块!

- Fast evaluation of mottling 快速的评估斑块
- Small to large mottles are measured 测量小型和大型斑块
- Three observing angles 三个观察角度
- Scan length can be varied from 10 cm to 100 cm, 25 points/cm 可设定多种扫描长度，从10cm到100cm，25个点/cm
- Objective measurement results independent of color and curvature 客观的测量结果与颜色和曲率无关
Thank you for your attention
Customer relevant evaluation of cloudiness.

Field study – Customer relevance.

 Evaluated „subjects“:

- Number of cars: 25.
- Car mix consisted of a wide range of car manufacturers.
- Preferably colours with sensitivity to cloudiness, for example silver, grey, champagne.

<table>
<thead>
<tr>
<th>Montag</th>
<th>Dienstag</th>
<th>Mittwoch</th>
<th>Donnerstag</th>
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<td>Jaguar XF</td>
<td>lunar grey</td>
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BMW Group Labortechnik
06.10.2010
T. Schäckeler
Page 35
Customer relevant evaluation of cloudiness.

Field study – Customer relevance.

- Standardized conditions for the visual evaluation.

标准条件用于视觉评估
Customer relevant evaluation of cloudiness.

Field study – Customer relevance.

Participants:

- Total number: 70.
  - Men: 56.
  - Women: 14.

- Qualification:
  - layman to expert/auditor.

Distribution of qualification "paint/technology surface"