DEUTSCHER SCHRAUBENVERBAND E.V.

HERSTELLER MECHANISCHER VERBINDUNGSELEMENTE

Guideline

Evaluation of black coatings of threaded fasteners for the automotive industry

April 2018

Contents

1. Preface

2. Scope 3

3. References 3

4. Fundamentals for evaluating black coatings on threaded fasteners 4

4.1 Basic principles……….4

4.2 Inhomogeneous black coloration arising from inadequate coverage……….4

4.3 Coating corrosion……….6

4.3.1 Inhomogeneous discoloration of black coatings - white haze……….6

4.3.3. Differentiating white corrosion from white haze……….7

5. Conducting the evaluation of black coatings 7

6. Disclosure of the evaluation results 9

7. Appendix 1: Image series 10

8. Bibliography 14

1. Preface

Up to the present, the customary evaluation of black coatings in accordance with DIN 34804 2002 /1/ bases on a comparison of test pieces with categories S1-S10 of a image series in relation to the change with reference to the initial state S0, also rated by comparison to an image series. .

In the year 2012, a round robin test conducted by the Deutscher Schraubenverband (DSV), a leading German association for fastener technology, indicated that the evaluation of test pieces with quite diverse degrees of variation in accordance with this guideline was imprecise.

In the project group “Bewertung schwarzer Oberflächen” (Evaluation of Black Coatings) of the DSV working group “Oberflächenschutzsysteme” (Surface Protection Systems), a modified evaluation guideline was developed with the aim of making the classification and evaluation of black coatings more precise.

To achieve this objective, the evaluation considers more quantifiable criteria and pays attention to the causative mechanism of the changes in coloration.

2. Scope

This guideline serves to evaluate the physical appearance of the black coatings on threaded fasteners with the dimensions $d \geq 5$ mm with regard to degree of coverage and coloration change owing to environmental influences such as corrosion, ageing and mechanical loads.

The evaluation of degree of shine, depth of color and color temperature is not a subject of the present evaluation guideline.

The guideline can be applied correspondingly to threaded fasteners of the size $d < 5$ mm. Still, owing to the compact dimensions and small surfaces involved, the criteria in accordance with Tables 1 and 2 can, where appropriate, only be applied partially or may no longer be appropriate, so that the users of this guideline must come to an agreement with regard to eligibility criteria. A review of the applicability of this guideline for threaded fasteners with dimensions $d < 5$ was not conducted.

3. References

None

4. Fundamentals of the evaluation of black coatings on threaded fasteners

4.1 Basic principles

In contrast to DIN 34804, this guideline does assess the appearance of black coatings on threaded fasteners at the time of evaluation independently of previously occurring loads such as corrosion testing or mechanical loading as a result of discharge processes (tipping/pouring) or transport cycles.

Experience with the black coatings commonly seen in the market indicates that essentially three different typical discoloration patterns of black coatings should be considered:

1) Punctate or inhomogeneous light coloration caused by deficient coverage of silver base layers by black coating layers
2) more or less strongly pronounced inhomogeneous white or gray coloration (also often marked by white haze (English term)
3) more or less strongly-pronounced white coloration with voluminous, granular reactive products (white corrosion)

The discoloration mechanisms 2) and 3) are also designated as coating corrosion.

The quality of black coatings after loading via previously described load types is strongly dependent on component geometry and processing methods. Threaded fasteners are mass-production items and are thus processed in the most inexpensive manner available using tumbling processes. During these procedures they are subjected to mechanical loading via bulk processes such as tipping (pouring) and transport. Such mechanical stresses increase with expanding component weight. Mechanical loads can be reduced significantly using frame coating processes; these are decidedly more expensive than tumbling processes, however.

4.2 Inhomogeneous black coloration arising from inadequate coverage

Coatings based on zinc or zinc alloys are commonly used for the corrosion protection of threaded fasteners. In their natural state, zinc layers and zinc-alloy layers are silver-colored. In galvanic zinc and zinc alloy layers, the black appearance is achieved by a black passivation and/or a black topcoat. Zinc flake base coating layers may be imbued with a dark coloring. To achieve a homogeneous appearance of the entire coating system, black cover coatings which are applied to the (silver or dark-colored) base coat are used.

Causes for inadequate coating coverage could be

- inhomogeneous, only spotty coverage via the coating process of the black cover coat
- partial removal of the black cover coat by mechanical processes such as scratches, nicks, abrasion etc. (Mechanical abrasion of the black cover coat arises most often in the area of the outer edges.)

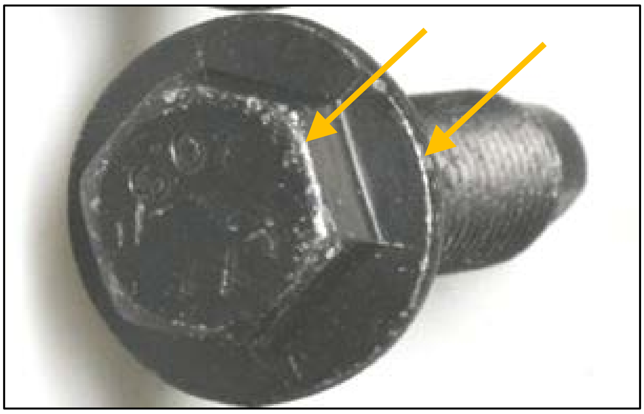


Image 1. Example of zinc flake coating with black cover coat – local abrasion after mechanical load

Definition of edge length: The length of an edge is defined as the continuous limiting line of a surface (Image 1). For evaluation with regard to coverage, the length of the defects per edge length of a given edge is assessed.

4.3 Coating corrosion

In cathode corrosion systems, discolorations of the surface indicate the effect of the cathode corrosion protection mechanism through the initial reaction of the sacrificial metal (usually zinc) contained in the protective layers, which reacts in place of the base material to be protected.

The reduction or delay of coating corrosion/white corrosion (e.g. achieved through passivation) is of technical importance in that it delays a corrosive attack on the anodic sacrificial metal (e.g. zinc), thus prolonging the protective effect of the sacrificial metal.

In determining the requirements that a surface protection system should fulfill, the user should differentiate which of the following have priority:

- corrosion prevention aspects
- visual / decorative aspects

For example, the white haze formation typical for ZnNi-layers does not reduce protection against base metal corrosion, but the white discoloration can still be undesirable from the decorative or aesthetic requirements.

With each reduction in the permissible degree of color change, the expenditures for the coating system will rise, making the choosing of requirements under cost aspects both a worthwhile and advisable endeavor.

A final, nonambiguous differentiation between white haze and white corrosion with only a visual examination is not always possible (see Image 3) and could require a more indepth, detailed examination method if the situation warrants. Such methods might include optical or scanning electron microsopy, element analysis or similar.

4.3.1 Inhomogeneous discoloration of black coatings - white haze

White haze is defined as a flat-spread, more continuous (as opposed to punctate) non-granular white or gray discoloration of a black surface. White haze formation often arises in ZnNi coating systems. During this process, owing to the typical crack structure of the surface in ZnNi coating layers, a corrosion reaction begins. The white corrosion products of this reaction quickly seal the crack structures, consequently initiating a substantial deceleration of the corrosion reaction. The white haze thus formed can be visually detrimental but does not impair the corrosion protection properties of the protective coating layer.

Image 2. Example of ZnNi, black passivated, with a black topcoat – white haze after corrosive loading

4.3.2 Inhomogeneous discoloration of black coatings - white corrosion

White corrosion is usually described as the white corrosion products of zinc. In contrast to white haze, the white discolorations in white corrosion consist of voluminous, granular structures.

Image 3. Example ZnFe, black-passivated, with coating black topcoat – white corrosion after corrosive loading

4.3.3. Differentiation of white corrosion and white haze

Distinguishing white corrosion from white haze unequivocally by means of visual evaluation does not always succeed, because the the characteristic properties of these conditions (see 4.2.1. and 4.3.2.) can be ambiguous.
The following properties may be used to aid in the distinction:

1. White haze disappears or becomes less visible on a wet surface, whereas white corrosion remains visible.

2. A surface displaying white haze appears smooth, while a surface with white corrosion manifests in a rougher surface owing to bulky, granular reaction products.

3. White haze appears after a short test period (approx. 24 h) in salt spray tests and retains its intensity up to e.g. 240h. In the case of white corrosion, within a test interval of e.g. 72h, a substantial increase in discoloration is discernible.

5. Conducing the evaluation of black coatings

Unless otherwise agreed, the following procedure is valid for the evaluation of black coatings on threaded fasteners:

1. The **test surface** is the entire head surface above the head-bearing surface. In the case of combination parts with disc, the test surface also includes the visible upper side (surface facing the head) when resting on the screw head, and the side surface of the disc.

2. **Single-part testing**. The evaluation takes place individually for each component part of an inspection lot. The number of components to be evaluated must be agreed upon. If no agreement is in effect, n = 5 test components shall be evaluated and the result stated in accordance with Kap. 6.

3. The evaluation must take place directly on the test piece **with the naked eye at reading distance** and under illumination (daylight, white, 1000-1500Lx, D65).

4. The surface of the test pieces is to be evaluated in a dry condition in order to establish the evaluation class.
   For the differentiation of white haze and white corrosion, evaluation in a wet condition may be ordered. (see 4.3.3).

   Note: Evaluation based on photographic images, especially owing to formatting (size, brightness, contrast etc.) and image quality (resolution, exposure), can lead to a strongly deviating result.

5. The evaluation is done by assignment into classes in accordance with the image series conformity guide in Section 7 or according to the quantitative reference values in Table 1 and 2. (Note: The choice and classification of the image series conformity guide were chosen in agreement with the classification in Tables 1 and 2.)

   In the event of arbitration, the evaluations in Tables 1 and 2 should be used.
   It is recommended to apply the evaluation with respect to degree of coverage (Table 1) before conducting corrosion testing, because corrosion products could arise during testing, making later evaluation of coverage difficult or impossible.

Damage type	D Incomplete coverage				
Class **Kl**	**0** [1)]	**1**	**2**	**3**	**4**
Evaluation criterion	--	punctate	punctate	flat-spread	flat-spread
DM [mm]	homogeneous black surface without color defects	≤ 1	≤ 2	≤ 3	Greater than Kl 3
FA [%]		≤ 5	≤10	≤25	
KL [%]		≤ 25	≤ 50	> 50	
Comparative image chart	Chart 1 K0	Chart 1 K1	Chart 1 K2	Chart 1 K3	Chart 1 K4

Key
DM: Diameter / maximum dimension / greatest diagonal of defect
FA: Area ratio of test surface with defects / discoloration
KL: Defect ratio in % of edge length (def.: see Chapter 4.2)

1) Ideal condition (new condition, optimal handling, etc.)

Tab. 1. Evaluation matrix (degree of coverage)

Damage type	K Corrosive			
Class Kl	Evaluation criterion	**G** **White haze**	**W** **White corrosion**	Comparative image chart
0		homogeneous black surface without color defects		Chart 1 K0
1	Description	slight, flat-spread	punctate	Chart 1 K1
	DM [mm]	--	≤ 1	
	FA [%]	≤ 10	≤ 5	
2	Description	flat-spread	flat-spread	Chart 1 K2
	DM [mm]	--	--	
	FA [%]	≤ 25	≤ 25	
3	Description	flat-spread	flat-spread	Chart 1 K3
	DM [mm]	--	--	
	FA [%]	≤ 50	≤ 50	
4		greater than Kl 3	greater than Kl 3	Chart 1 K4

Key
G: White haze W: White corrosion

DM: Diameter, corrosion point
FA: Area ratio of test surface

Tab. 2. Evaluation matrix (white corrosion, white haze)

6. Reporting of evaluation results

The evaluation is to be documented for all test pieces (Number n). The component with the least favorable evaluation (highest class) normally determines the evaluation result.

Notwithstanding the above, other evaluation methods may be agreed to (e.g. mean value formation using the individual evaluations, or specification of all individual evaluations).

Reporting variant A (specification of the single, i.e. the highest damage class)
DSV-RL Klx, n = x (D, W, or G)

Example: DSV-RL Kl 2, n=4 (D)
In words: Evaluation in accordance with DSV-RL Class 2 (coverage) of 4 test pieces

Owing to the partially imprecise separation between white corrosion and white haze, this information in the results disclosure is to be evaluated as informative.

Reporting variant B (statement of the damage type: corrosion; coverage)

DSV-RL Dx Ky, n = x (W or G)

Example: DSV-RL D0 K1, n=4 (W)
In words: Evaluation in accordance with DSV-RL (DSV guideline) Coverage Class 0, Corrosion Class 1 (white corrosion) of 4 test pieces

Owing to the partially imprecise separation between white corrosion and white haze, this information in the results disclosure is to be evaluated as informative.

7. Appendix 1: Image series

Instructions for use:
The image series is meant to support the application of the evaluation matrix (Tables 1 and 2).

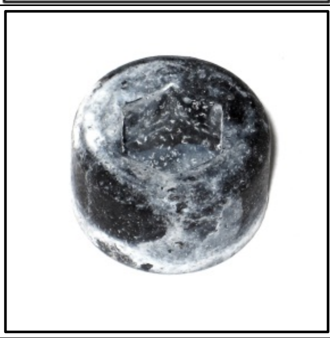
1 cm

Chart 1 (Examples 1 to 3)

	1	2	3
K0			
K1			
K2			
K3			
K4			

1 cm

Chart 1, continued (Examples 4 to 6)

	4	5	6
K0			
K1			 (S2)
K2			 (S4)
K3			 (S6)
K4			 S8)

Note:
Column 1, 2: White corrosion
Column 3: White haze
Column 4: White haze, Class 4 white corrosion
Column 5: Incomplete coverage
Column 6: Reference to DIN 34804

8. Bibliography

/1/ DIN 34804 2002 /1/

END OF DOCUMENT

In case of questions or comments to this guideline, please consult

- Horst Dieterle (E-Mail: horst.dieterle@kamax.com ; Tel.: 06633-79-426) oder
- Dr. Stefan Beyer (E-Mail: sbeyer@schraubenverband.de; Tel.: 02331-9588-45)