DEUTSCHER SCHRAUBENVERBAND E.V.
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Recommendation

Evaluation of the Technical Cleanliness of Screws, Bolts and Nuts for the Automotive Industry

February 2016

Contents

1. Scope

This recommendation serves as a construction aid for the classification of cleanliness-relevant construction parts, for the definition of suitable surface coatings and for the determination of limit values for cleanliness.

With regard to the requirements of the automotive industry, this recommendation describes the achievable levels of particulate cleanliness in functionally relevant fastener components, especially for threaded fasteners made of steel. Not included here is guidance on organic contamination (*e.g. oils, grease*) and cleanser residues.
In order to define a requirement for the technical cleanliness of screws, bolts and nuts, an integrated approach to the processes involved is essential, not to exclude the value creation of the individual product. In so doing it is important to consider processes such as sorting, packaging, transport and assembly, for example. Owing to the demands placed on technical cleanliness, these must be coordinated between customers and suppliers.

Agreed and implemented measures always lead to increased costs. Technical cleanliness must thus be understood as an additional payable feature of the product.

The following sources provide a foundation for the methods used to determine technical cleanliness: VDA Volume 19 and ISO 16232, Parts 1-10

2. References

- VDA 19: 2004
  Inspection of Technical Cleanliness – Particulate Contamination of Functionally Relevant Automotive Components
- VDA 19-2: 2010
  Technical cleanliness in assembly—Environment, Logistics, Personnel and Assembly Equipment
- ISO 16232, Parts 1-10
  Road vehicles – Cleanliness of components of fluid circuits

3. Some basic facts on technical cleanliness

Residual contamination is defined as particles with which components are contaminated after their manufacture and which can impair or hamper the further production process or the proper functioning of the relevant component or assembly.

Technical cleanliness in terms of the standards relates to the absence and limitation of defined particulate contamination. A complete absence of particle adhesion (*solid matter*) is not possible; therefore, appropriate requirements must accept an allowable degree of defined particle (*residual*) contamination. Vague wording such as “free of particles” must be replaced by clearly defined and verifiable parameters.

In the sense of this recommendation, a distinction is made between metallic and nonmetallic particles. A definitive differentiation of both particle types is not possible using optical microscopy. Yet with the use of polarization-optical effects, a metallic particle (“*with metallic sheen”*) can be identified with a relative probability. Particles which have not been identified as having “metallic sheen” are classified as “without metallic sheen.” This does not replace reliable information regarding the metallic or nonmetallic character of the respective particle. A reliable classification requires special, cost-intensive test procedures.

Examples of metallic particles (those with metallic sheen):
Machining chips, metallic sandblasting residues, metal scraps, zinc flakes etc.

Examples of non-metallic particles (those without metallic sheen): lacquer or varnish, plastic, nonmetallic blast media residues, abrasive residues etc.

The hardness of particles cannot be determined using optical microscopy. For this reason, distinguishing hard from soft particles is not possible with the standard methods in use to measure technical cleanliness.

In addition to particles, fibers without metallic sheen having a length/width ratio of at least 10, such as paperboard remnants, hair or lint, may also appear. Mainly due to their significantly lower compactness, fibers must be differentiated fundamentally from particles and viewed separately in their evaluation.

The level of technical cleanliness required for a given component depends on how it is to be used. The achievable level of technical cleanliness of threaded fasteners is influenced first and foremost by the component geometry and the surface coating, apart from the production process and the packaging.

3.1 Selecting suitable surfaces

To achieve a high level of technical cleanliness, a suitable surface treatment or coating must be chosen for the component. Metallic surface coatings which tend towards flaking (*e.g. all types of zinc-flake coatings*) are not suitable or have only limited suitability in this regard.

Suitable surface systems conducive to a high level of cleanliness are, for example:

- phosphate coatings
- electroplated zinc and zinc-alloy coatings, with and without sealants.

  Note: Better levels of cleanliness are achievable without oiling or lubricant coating. In these cases, however, higher friction coefficients and greater process fluctuations should be expected, at least in the assembly of threaded fasteners with metric threads. The user shall therefore consider which objective has priority in view of the intended use of the component before placing the order *(If cleaning takes place after an oiling or lubricant treatment, these are usually "washed off" in the process. Consequently, the process step of a cleaning is usually carried out before a coating to reduce the friction coefficient. This sequence may cause a re-contamination in case of a friction-reducing coating or wetting, which must be taken into account).*

Not suitable or only suitable within limits are, for example:

- Zinc-flake coatings, with and without top coat

  Note: Zinc-flake coatings tend toward disproportionate abrasion during handling, transport and assembly. The determination of a decay curve in accordance with VDA 19 is not possible with zinc-flake coatings.
- Adhesive, locking and / or sealing thread coatings in accordance with DIN 267-27 and DIN 267-28.

3.2 Component geometry

The component geometry significantly influences the determination of the technical cleanliness level. Because many standards require the data showing maximum particle load / component, the area to be evaluated (*in cm²*) and the geometry of the component shall be taken into account in the specifications for cleanliness requirements. The following is fundamentally applicable:

"The particle load / component increases with increasing component surface area"

The surface of a product increases approximately by the square of its linear expansion (*e.g. the length, the diameter etc.*), and the particle load rises in an approximately linear relationship to the component surface area, although the specific load of smaller components tends towards somewhat higher values.

The surface area and geometry of the component shall always be taken into account in the component-relevant specification of the gravimetric particle load (*mg/component*) as well as in the particle-size distribution (*the number and size of the particles/component*). Analogous to the procedure in VDA 19, it is generally recommended to convert the data to an area of 1000 cm² or, if specifying per component, at least to make allowance for its surface area (*in cm²*).

3.3 Packaging

To minimize abrasion and to avoid recontamination during transport and storage processes, suitable packaging (*e.g. pouch packaging, vacuum packaging, single-unit packaging)* must be provided by the supplier. If the packaging requested by the customer does not comply with the cleanliness requirement, the contracting parties must coordinate suitable measures.

4. Determining technical cleanliness

The cleanliness evaluation is described extensively in customer standards, in VDA 19 and in ISO 16232, Parts 1-10. Therefore, only a summary of the evaluation follows here:
Note: The cleanliness test is fundamentally a random sample test. A test of this feature is not possible using automatic testing devices.

The cleanliness test should be the last step taken before shipment to the customer to account for any possible influences arising from previous process steps.

a) Cleaning the component

Possible test cleaning methods are spraying, ultrasound, agitation or (pressure) rinsing.
The method is often determined by the customer. The suitability of the test cleaning method must be validated with the aid of the decay curve (*see VDA 19 and ISO 16232*).

b) Determination of blank value

The blank value represents the total value for the contamination not coming from the component. It is the result of a complete test without the component. The allowable blank value must be determined / defined in advance. It may not normally exceed 10% of the required value.

c) Evaluation procedure

There are basically two different evaluation procedures:

Gravimetric analysis procedure

In this procedure, the particle mass (*in mg*) per surface area (*converted to 1000 cm²*) and/or per component is determined. In the latter case, the component size must also be taken into account (*see Section 3.2*).

As a standard, the use of a 15 µm PE filters is recommended. In filters with smaller nominal mesh width, there is a chance that non-relevant contaminants could also be captured (*e.g. oil or phosphate residues in oil arising from possibly phosphated and oiled surfaces).*

Note: During the extraction of threaded fasteners coated with lubricants, these can exhibit a higher contamination weight during gravimetry than the actual level of residual contamination.

Granulometric analysis procedure (morphology, particle size)

In this procedure, the number and size (*length, width*) of the particles (*in µm*) per component or per area (*converted to 1000 cm²*) are determined.

Note: A count of particles < 25 µm is not expedient with the magnifications used today for metrological and wave-physics reasons.

d) Rating the results

The level of technical cleanliness is derived using random sampling. Because particle sizes are naturally subject to greater variation than for example physical characteristics (*such as hardness and diameter*) of the products, a process capability corresponding to today's requirements is not possible. The often called-for maximum particle size is subject to an extreme value distribution and is therefore encumbered by extreme variation. It is recommended, therefore, that the cleanliness requirements, like lifetime data in accordance with VDA 3.2, be linked with reliability data /1/.

In cases of dispute, appropriate arrangements between customer and supplier (*e.g. type and method of retesting)* shall be coordinated.

In many specifications, a combination of gravimetric analysis and identification of the largest particle is required.

5. Specifying requirements for technical cleanliness in drawings

Requirements for technical cleanliness in component drawings as a rule lead to increased costs of production and/or testing which, depending on limit value, can take on considerable proportions. Limit values must therefore be chosen thoughtfully and in coordination with the supplier.
In so doing it shall also be taken into account the fact that values determined by the producer cannot be directly compared with those of the customer because the specimens are measured at different places in the process chain.
In specifying requirements for technical cleanliness in drawings, it is thus necessary to observe the agreements regarding cleanliness testing in accordance with VDA 19 (*Appendix A, Items A.1 to A.4*).

The reference values listed in Appendix 1 of this directive serve to help select appropriate surface treatment systems and to define realistic requirements for technical cleanliness. These values were determined by producers of threaded fasteners for the automobile industry by their own or external testing laboratories as well as with the support of *Original Equipment Manufacturer* (OEM) testing laboratories. They are not guaranteed values, which especially applies to “maximum particle size” (*see Section 4 d*), and concerns exclusively fasteners with external threads. Corresponding data on fasteners with internal threads must still be determined. The values in Appendix 1 are achievable only using adapted processes. A reduction of these values is not possible without corresponding higher expenditures, in which system-specific limits must be observed. These limits are essentially determined by the surface treatment system and the allowable cleaning procedures.

Every cleaning to reduce particle load is usually carried out after application of the surface treatment system and has, more or less, a significant influence on its properties. It is important to allow for the fact that this especially affects resistance to corrosion, which may be reduced, and the abrasion properties, which can result in higher friction coefficients.

The delivery of the product in a defined cleanliness condition requires packaging that conforms to cleanliness expectations. For example, due to relative movements of bolts/nuts towards one another, abrasion particles may be generated, resulting in a higher particle load after transport than before it. If suitable packaging is missing, the level of cleanliness can only be assured ex works and not at delivery. With suitable packaging, a warranty ends at latest with the commissioning of the product at the customer’s or with the opening of the packaging.

6. Cost analysis

For components with requirements for technical cleanliness, particular specifications always prevail. These relate to production (*clean-room environment, filter technology, special cleaning processes*), testing (*determination of decay behavior*), packaging, handling, storage and transport, and are fundamentally related to increased cost.

7. Appendix 1: Achievable levels of cleanliness in fasteners with external threads after coating (*)

Surface treatment system	**Blank (+oil)**	**Black oxide**	**Phosphated**	**Galv. zinc or zinc alloy**	**Galv. zinc or zinc alloy + sealant**	**Zinc-flake (**)**
Test surface or component surface (cm^2)	Particle mass of the test surface/ component surface	Particle mass of the test surface/ component surface	Particle mass of the test surface/ component surface	Particle mass of the test surface/ component surface	Particle mass of the test surface/ component surface	Particle mass of the test surface/ component surface
≤ 20	0,3 mg	0,5 mg	1 mg	0,3 mg	0,3 mg	(3 mg)
21 - 50	0,5 mg	1 mg	2 mg	0,5 mg	0,5 mg	(5 mg)
51 - 100	0,6 mg	2 mg	3 mg	1 mg	1 mg	(10 mg)
101 – 400	1 mg	3 mg	5 mg	2 mg	2 mg	(25 mg)
401 - 1000	3 mg	7 mg	10 mg	5 mg	5 mg	(60 mg)
Maximum particle sizes	600 µm	800 µm	800 µm	600 µm	800 µm	2000 µm

(*) The values listed in the table base on mean values of random samples and cannot be seen as guaranteed values. The listed values apply to fasteners with external threads.

(**) This surface treatment system is not suitable for satisfying high cleanliness requirements, especially in bulk materials handling.

Important note: Siliceous sealants/topcoats can negatively influence achievable cleanliness levels.

8. Literature

/1/ J. Böttner, EJOT GmbH & Co. KG, Bad Laasphe
Optimierte Prozessgestaltung zur Sicherstellung hoher Bauteilsauberkeit
Herstellung, Verpackung, Transport;
(Optimized process design for the assurance of a high level of component cleanliness—production, packaging, transport);

DSV-Workshop „Schraubmontage“ (DSV workshop on the assembly of threaded fasteners) on September 13, 2012, in Dresden

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