Content

1 Remit and Scope of the Test Specification

The present test specification specifies the procedure for determining particle remnant contamination on steering chain drives and chain drive components. As regards its content it is based on the VDA guideline “Clean Engineering – Particle Contamination of Functionally Relevant Automobile Parts“ (1st edition (draft), 2004, VDA (Verband der Automobilindustrie) Quality Management Center (QMC), Oberursel).

The extent of particle contamination is quantatively assessed by specifying the gravimetrically determined remnant contamination volume (in mg per component), the maximum particle size and particle size distribution (if required).

It is not part of the remit of this test specification to determine non-particle, organic or film contamination (greases, oils etc.), nor to give a purely qualitative assessment of the remnant contamination.
(e.g. visual or aesthetic evaluation)

2 Proof of the Feasibility of the Test Procedure

2.1 General Remarks

In order to determine the particle remnant contamination, the test item is subjected to a cleaning test.
Particles cleaned off it during this process are collected and analysed. In the present state of the art, there are neither absolute methods nor absolute reference samples of defined contamination that are available for cleanliness testing. A proof of feasibility (e.g. test equipment feasibility) on a statistical basis cannot therefore be given. By following the following points, however, reproducibility and comparability of results can be secured.

2.2 Avoiding Disturbance Variables

A meaningful and reproducible remnant contamination analysis requires sampling, handling and processing under clean conditions by suitable qualified personnel. Since random events (test disturbance variables) can affect the test result in spite of all care that might be taken, these must be avoided as far as possible. This presupposes appropriate awareness of the possible disturbance variables. Test disturbance variables are for instance:

a. Abrasion
Abrasion can result in the base material releasing particles that were not originally in adhesion to it. Possible causes are corrosion of the test material by unsuitable cleaning test chemicals , unsuitable test procedures and parameters, we well as mechanical friction during the cleaning test.

b. Manually Generated Particles
Manual processes can result in the generation of additional particles, e.g. formation of splinters on dismantling.

c. Deposited Particles
Improper handling, as well as contamination from environmental factors can result in transfer of additional particles to the test item. Possible causes are improper packaging, transportation and storage of the test item, use of contaminated transport receptacles, use of unsuitable or contaminated gloves etc.

d. Dispersed Particles
Improper handling, as well as environmental factors can result in dispersal of particles from the test item. Possible causes are, for instance, improper packaging (particles remain in the packaging), improper handling (particles are dropped), improper storage of the test item (dispersion of particles due to air currents) etc.

e. Unresolved Particles
Particles adhering to the test item are not detached and therefore not collected, such as splinters seized up in inaccessible work piece areas.

f. Magnetism
In the case of magnetic materials (e.g. ferritic steel) the test item must be degaussed if the remnant magnetic strength is greater than 4 A cm^{-1}. In the event that this is not possible, testing without degaussing is permissible.

g. Residues
Residues such as oils, greases, as well as anti-corrosion and cleansing agents that cannot be dissolved by the cleansing test fluid, give falsification of the gravimetric remnant contamination volume. This must be properly taken into account and documented during evaluation.

2.3 Blank Value

Definition: In a test system (test receptacle, flushing fluid, filter retainer, surrounding air etc.) there are always instances of particle contamination that will also be recorded on the remnant contamination analysis. This remnant contamination volume within the test system that cannot be further reduced in any way by means of thorough cleaning is designated as blank value.

Identification: The blank value is identified by carrying out the procedure mentioned under item 4 “Test Implementation“ using the amount of test media fluid otherwise used but without the test item itself.

Permissible blank value: To be able to give relevant information on the cleanliness of the component, the blank value must be clearly smaller than the remnant contamination volume of the test item. On gravimetrical analysis, the blank value may not exceed 10% of measured total remnant contamination volume. For determining the blank value, the identified particle size may not exceed 50% of maximum permissible particle size. Permissible blank value on automatic particle counting is laid down in Test Specification RSA-3.

Exceeding the blank value: If the permissible blank value is exceeded, the purity of the cleaning test system must be improved, for instance by fine filtration of the cleansing test fluid. If the blank value is determined by the accuracy of the balance (0.1 mg), then a corresponding number of test items must be cleaned individually and the remnant contamination released filtered with a filter, so that the total remnant contamination volume is ten times the blank value. In the case of automatic particle counting this can be discounted, since this procedure is very difficult with a 50mm filter and total remnant contamination in excess of 2mg (particle stratification).

Determination frequency: In the case of an unmodified test system the blank value must be determined every 12 months and documented accordingly. If a new cleansing test fluid is used, or a smaller mesh on the filter, or if remnant contamination volume is inordinately high, or in the event of cases that are suspect, then the blank value must be redetermined.

2.4 Validation of the Method (decay measurements)

Objectives and implementation: On the cleaning test (see item 4) the remnant contamination should be cleaned from the test object as completely as possible. The effectiveness of the cleaning test is checked by repeating the same test stages on a component. Multi-sampling of the same component gives the decay curve of the cleaning test procedure. 6 samplings are to be carried out for assessment to be complete.

Validation criterion: A test procedure or the selected test conditions are to be considered suitable for full cleaning of the

remnant contamination if the validation criterion can be met within the 6 cleaning test stages. This is the case if the final result is smaller than or equal to 10% of the sum of the remnant contamination from all previous stages.

Example:

Cleaning no.	Individual value [mg]	0.1*Sum of remnant contamination [mg]	Criterion
1	15	1.5	not met
2	11	2.6	not met
3	8	3.4	not met
4	5	3.9	not met
5	3	4.2	met
6	1	4.3	met

Non-fulfilment of validation criterion: If the criterion is not met, the selected test procedure or selected test parameters are not suitable for "complete" remnant contamination cleaning. The values determined in this way must be rejected. There must be continuing modifications to the test procedure and the test parameters until the criterion can be met.

Validation frequency: There only needs to be one validation carried out for an existing test procedure. However it should be noted that even seemingly small changes (different cleaning test fluid, modification of ultrasound cleaning etc.) may lead to a clear difference in remnant contamination values. On test items of comparable geometries it is enough to carry out the validation vicariously on a typical component (e.g. a duplex or simplex chain as the case may be).

2.5 Method Calibration on External Analysis

The remnant contamination values determined are only comparable if an identical procedure (cleaning test fluid, ultrasound cleaning type, filter mesh size etc.) is used. In the case of details of remnant contamination values submitted by customers, suppliers or outside service providers, the method used by M-QLA must be calibrated with the method used by IWIS.

3 Materials and Equipment Used

The following materials and equipment are needed to carry out the remnant contamination analysis:

Ultrasound cleaning: A standard laboratory ultrasound cleaning bath with bottom echo (additional side echo is permissible). Critical for cleaning performance is specific (volume-related) ultrasound performance, which should be at least 20 W l^{-1}. Frequency: Typically 35kHz. Procurement sources: Laboratory equipment suppliers (e.g. VWR International AG 64301 Darmstadt) or Bandelin, Berlin.

Cleaning test fluid: ISOPAR G cold cleaning fluid (Procurement source: Deutsche Exxon Chemical GmbH, 50735 Kön) or petroleum ether (boiling range 60 – 90°C). The cleaning test fluid must be fine filtered if necessary.

Filter device: Laboratory Buchner funnel for fibrous filters of 47 or 50mm in diameter for vacuum filtration using glass filter or vacuum pump. Procurement sources: Sartorius 37075 Göttingen, or laboratory equipment suppliers (e.g. VWR International AG 64301 Darmstadt).

Filter: Fibrous filter in polyamide (PA) or polyethleneterephthalate (PET) with a mesh size of **5µm** (edge length of

square holes). Diameter: 47 or 50mm. Either cold stamped or laser cut filter, as required. Procurement source: e.g. Sefar GmbH, 83501 Wasserburg.
Chemical balance: Weighing accuracy: 0.1mg

Other items of equipment: Drying cupboard, desiccator with drying media, beakers, laboratory apparatus.

4 Test Implementation

4.1 Sampling and storage

The test item is taken from production or storage and immediately packed in a dry, sealable plastic bag. The test disturbance variables adduced under item 2.2 must, if at all possible, be avoided, so as to exclude falsification of the remnant contamination value. Up to 5 test items can be packed in one bag.

4.2 Filter Conditioning

The filter must be dried at e.g.105°C in the drying cupboard until a constant weight is achieved. At the same time, the tare weight of the filter must be determined to an accuracy of 0.1mg. Either the conditioned filter must be used straightway, or it must be stored in a desiccator with drying media until used.

4.3 Ultrasound Bath

Cleaning of the remnant contamination from the test item is carried out by extraction in an unheated ultrasound bath with bottom echo at more or less room temperature. The ultrasound bath is to be filled with a defined amount of water. To obtain consistent diffusion of ultrasound cleaning, a few drops of a surface-active agent are to be added to the water (e.g. washing up liquid). The ultrasound bath must always be filled with the same amount of water. The amount is selected so that the specific performance of the ultrasound bath based on the sum of water volume and cleaning test fluid is no less than 20 W l^{-1}.

Cleaning proper is carried out in a glass beaker of suitable size (typically of about 1l content). The beaker must be stood on the bottom of the ultrasound bath without a wire basket. The beaker must be filled with the cleaning test fluid (Isopar G or petroleum ether) until this makes contact with the level of the filled ultrasound bath. The volume of cleaning test fluid used must be documented.

4.4 Cleaning Test Implementation

The cleaning test must be carried out in a component-specific way so that comprehensive cleaning of the remnant contamination can take place. There needs to be demonstration that the chosen cleaning test procedure fulfils the validation criterion (see item 2.4). Here is an example of a validated procedure for determining the remnant contamination volume on chains.

Example for chain: The test item is only taken out of the transportation bag before the actual cleaning test. Any remnant contamination remaining in the bag must be accounted for too. The chain must be ultrasound cleaned freely-suspended in the cleaning test fluid, with about 10 links submerged in the cleaning test fluid. The chain may not touch either the bottom or the sidewalls of the beaker. The submerged section must be cleaned for about 10 seconds.

Then the next section of the chain is cleaned, and so on, until the whole chain is cleaned section by section. For the whole chain, the period of ultrasound cleaning should take a minimum of 3 minutes. After ultrasound cleaning the chain and ancillary items (e.g. chain wheel for running out the chain) must be rinsed on the outside and inside with cleaning test fluid. This rinse fluid must be collected in the beaker, to take into account any remnant contamination that might be contained in it.

4.5 Integral Measuring of Large Components

Integral measuring of large components (chain, chain-adjuster housing, chain wheels, fixing and guide rails etc.) can be carried out using a filter, provided that suspended chains are individually cleaned by ultrasound and the cleaning test fluid filtered by filter. Common ultrasound cleaning of several large components (see above) is not permissible.

4.6 Filtration of the Cleaning Test Fluid

The conditioned filter is placed in the laboratory Buchner funnel. All the cleaning test fluid from the beaker must be poured into the funnel. Any remnant contamination adhering to the inside of the beaker must be transferred as completely as possible by rinsing it several times. Filtration is by vacuum using glass filter or vacuum pump. Once all the cleaning test fluid has been vacuum-extracted, consistent distribution of the remnant contamination on the filter can be attempted by reagitating the remnant contamination without vacuum in the Buchner funnel using a small amount of cleaning test fluid, and then extracting again by vacuum. Note: Consistent distribution facilitates qualitative evaluation of the filter.

4.7 Gravimetric Determination of the Remnant Contamination Volume

Once full filtration is complete the filter is removed and dried in a drying cupboard at e.g. 105°C until a constant weight is achieved. Alternatively, if using highly volatile petroleum ether, then drying can be done at room temperature, provided constant weight is achieved. After drying is complete, the gross weight of the filter must be determined to within 0.1mg. Otherwise, the filter is to be kept in a desiccator with drying media until it can be weighed. The total remnant contamination volume is the difference between gross and tare weight of the filter.

4.8 Qualitative, Stereoscopic Evaluation of the Filter

The filter is assessed by qualified personnel on the stereomicroscope with up to 40x magnification. At lower magnification (6 – 10x) the volumes are first reckoned as percentages of the following remnant contamination types: metal particles, fibres, plastic particles, ceramic particles and other phases. Specific features such as shape, colour, and sheen of the particle classes mentioned are documented.

On magnification up to 40x, the size and type (metallic, ceramic) of the 5 largest damaging particles are identified. Metallic and ceramic particles count as damaging particles. Plastic particles and fibres are not considered when determining the largest damaging particles (they are however taken into account in the gravimetric remnant contamination volume). The particle size is the longest dimension of a particle that can be obtained from laying two parallel tangents against the particle (known as Feret's diameter).

4.9 Quantitative Optical Evaluation of the Filter

In individual cases, quantative evaluation of particle size distribution can only be done using automatic optical particle counting (See IWIS Test Specification RSA-3). This method should be able to distinguish metallic from non-metallic particles and to classify them seperatly. Usually the largest metallic particles are corresponding with the largest damaging particles (LDP).

5 Test Frequency

5.1 Initial Sample Testing

In principle, one-off compliance with the remnant contamination standard must be determined and proven. This is effected as a one-off on 5 parts as part of the quality improvement process or the initial sample testing. There must also be proof that the method used to determine the remnant contamination fulfils the validation criterion (see item 2.4, and that the method has been harmonised with the values determined by IWIS (see item 2.5).

5.2 Ongoing Tests

In addition to the initial sample testing, there must be regular demonstration of remnant contamination standard compliance capability. Selection of components and test frequency is to be determinated by M-QLI within the product audit.

5.3 Testing in the case of Product Families

If a supplier delivers in excess of 5 different components, test certification can be drawn up for product groups (families) by agreement with M-QLA. This means that one component will be tested as representative of a whole product group. The actual component selection is at the discretion of M-QLA with due regard to the following points: component size, component complexity, component cleanability (drill holes, and undercuts etc.), manufacture or processing procedure, and material type (steel, non-ferrous metals, or plastics).

5.4 Testing in the case of Process Modifications

Modifications in processing or washing procedures that result in a change in remnant contamination volume or particle size distribution are notifiable. If a significant change is to be expected, a new remnant contamination analysis for process certification must be carried out.

6. Evaluation, Documentation and Archiving

6.1 Evaluation and Documentation

On the test certificate, the test method must be specified along with the sample designation and date, or the following data need recording: Number of test items measured, type of filter, filter mesh size, cleaning test fluid, cleaning test implementation (handling of test item during cleaning test, specific ultrasound performance etc.) Specifically in regard to chains, the exact chain designation (e.g. D67HP-7) and number of links must be given as well.

For gravimetric remnant contamination values, the total remnant contamination in mg (difference between the gross and tare weight of the filter) must be given, as well as the remnant contamination per component (the latter when measuring several test items as under item 4.5). To obtain better comparability, acute values for remnant contamination volume can also be given:

Generally:	Remnant contamination volume per surface in	mg (1000 cm^{-2}) and reference surface in cm^2
Chains:	Remnant contamination volume per metre of chain in	mg m^{-1}
	Remnant contamination volume per 100 links in	mg $(100\ links)^{-1}$

The size and particle of the 5 biggest damaging particles must be given in µm. The longest dimension of the biggest damaging particle is designated by “GSP“ (or “BDP” in English). In addition the rough volumes in % must be given for the following kinds of particle: Metallic particles, fibres, plastic and ceramic particles, other. Notes regarding shape, colour or sheen of the particles must be documented.

6.2 Archiving the Filters

After evaluation, the filter must be archived for one year in clean conditions in a sealed container in order that stereoscopic re-examination, automatic particle counting or removal of individual particles for a REM/EDX analysis may at any time be possible. Archiving in bags, common storage of several filters, storage or transportation in a vertical position, or heat sealing of the filter is not permissible.

7. Evaluation of the Test Result

Specification of permissible limiting values will take place in dialogue with our customers and suppliers and is based on technical feasibility at reasonable cost outlay. On remnant contamination analysis the remnant contamination volume per component and the largest damaging particle are determined by means of optical particle analysis. The latter only records metallic and ceramic particles.

Measures for minimisation of the remnant contamination volume and largest damaging particle size (LDP) have already been successfully implemented at IWIS. This has led to effective reduction of both these magnitudes.

The values for the largest damaging particle size (LDP) and the remnant contamination volume per component are based on the statistical analysis of all remnant contamination analyses of the production during the period from 2012 until 2014.

Part or component	Largest damaging particle size (LDP) [a]	Remnant contamination [b]
Chains		
simplex chains	1000 µm	5 mg
toothed chain	1000 µm	5 mg
duplex chains	1000 µm	10 mg [c]
System components		
chain wheel	600 µm	3 mg
chain guide	1000 µm	1,5 mg [d]
Chain tensioner		
tensioner housing	600 µm	2 mg [d]
small components of tensioner (spring, check valve, piston etc.)	600 µm	0,5 mg [d]
entire chain tensioner	600 µm	3 mg

[a] median value of the production 2012 - 2014
[b] 95% value of the production 2012 - 2014
[c] 90% value of the production 2012 - 2014
[d] values of 2012 - 2014 not yet included