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1 Scope

This VN, as a whole, applies to cast parts used for the production of drive components for the Business Unit Road of Voith Turbo GmbH & Co. KG, unless stated otherwise in drawings, standards for the individual parts or data sheets or agreed otherwise in the purchase order.

This VN is also applied to prototype cast parts for preseries, close-to-series or series tools. The technical delivery conditions acc. to EN 1559-1 and EN 1559-3 apply to the full extent.

2 Area of application

Applies to unmachined and machined parts of cast iron acc. to

- EN 1561 Grey cast irons
- EN 1563 Spheroidal graphite cast irons
- EN 1564 Ausferritic spheroidal graphite cast irons

hereinafter referred to as "cast iron".

3 Purpose

The present Voith Standard (VN) defines criteria for classification of cast parts, the data to be stated on the drawings, the tests to be performed, the testing methods to be used, as well as the admissible defects at the unmachined and machined parts of cast iron.

4 References to Standards

Number	Title
ASTM A 247	Standard Test Method for Evaluating the Microstructure of Graphite in Iron Castings
ASTM E 186	Reference Radiograph for Heavy Walled (2 to 4.5 inch) Steel Castings
ASTM E 280	Reference Radiograph for Heavy Walled (4.5 to 12 inch) Steel Castings
ASTM E 446	Reference Radiograph for Steel Castings Up to 2 inch in Thickness
ASTM E 689-10	Standard Reference Radiographs for Ductile Iron Castings
DIN 50125	Testing of metallic materials - Tensile test pieces
DIN 55350 11	Concepts for quality management - Part 11: Supplement to DIN EN ISO 9000:2005
EN 444	Non-destructive testing - General principles for radiographic examination of metallic materials by X- and gamma rays
EN 583-1	Non-destructive testing - Ultrasonic testing - Part 1: General principles
EN 1011-8	Welding - Recommendations for welding of metallic materials - Part 8: Welding of cast irons
EN 1369	Founding - Magnetic particle inspection
EN 1370	Founding - Examination of surface condition
EN 1371-1	Founding - Penetration test - Part 1: Sand, gravity castings and low-pressure casting parts
EN 1559-1	Founding - Technical conditions of delivery - Part 1: General
EN 1559-3	Founding - Technical conditions of delivery - Part 3: Additional requirements for iron castings
EN 1560	Founding - Designation system for cast iron - Material symbols and material numbers
EN 1561	Lamellar graphite cast iron
EN 1563	Spheroidal graphite cast iron
EN 1564	Ausferritic spheroidal graphite cast irons
EN 10204	Metallic Products - Types of Inspection Documents
EN 12454	Visual examination of surface discontinuities
EN 12680-3	Founding - Ultrasonic examination - Part 3: Spheroidal graphite cast iron castings
EN 12681	Radiographic testing
ISO 571-1	Non-destructive testing - Penetrant testing - Part 1: General principles
ISO 945-1	Microstructure of cast irons - Part 1: Graphite classification by visual analysis
ISO 6506-1	Metallic materials - Brinell hardness test - Part 1: Test method

ISO 6892-1	Metallic materials - Tensile testing - Part 1: Method of test at room temperature
ISO 8785	Surface imperfections - Terms, definitions and parameters
ISO 9000	Quality management systems - basics and terms
ISO 9001: 2000	Quality Management Systems - Requirements
ISO 9934-1	Non Destructive Testing - Magnetic Particle Testing - Part 1: General Principles
ISO14001	Environmental Management Systems
ISO/TR 945-2	Microstructure of cast irons - Part 2: Graphite classification by image analysis
VDG-Merkblatt P 541	Error comparison catalog for the evaluation of radiographic tests at thick-walled castings of unalloyed EN-GJS materials
VDA volume no. 1	Proof
VDA volume no. 2	Ensuring the quality of supplies in the automotive industry
VDA volume no. 4	Ensuring the quality before series application
VDA 260	Components of vehicles - marking of materials
ISO/TS 16949	Quality management systems -- Particular requirements for the application of ISO 9001:2000 for automotive production and relevant service part organizations
VN 1631-2	Technical drawings; special features
VN3205	Production process and product release (master sample release)

- Unless stated otherwise, the most recent version of the respective standard shall apply.

5 Release conditions

The general delivery conditions acc. to purchase order apply, as well as the requirements of the Voith quality assurance agreement. In particular, the release conditions for master samples acc. to VN 3205 shall apply.

6 Order and drawing specifications

In the purchase order and/or drawing, the following binding specifications and data are included:

- Number of the valid Ordering Instructions and Conditions of Sale with reference to the present Delivery Specification
- Material designation acc. to EN 1560
- Standard wall thickness (EN 1563, section 3.9)
- Marking of part (see item 8.10)
- Mass (see item 8.8)
- Indication of function class (see item 7.1)

In the purchase order and/or drawing, the following additional stipulations may be included:

- Surface protection
- Reference to quality features (acc. to VN 1631), test specifications, test procedures
- Marking of the area from where the sample for the tensile test is to be taken or indication of test specimens (separately cast specimens, parallelly cast specimens, cast-on specimens).
- Marking of critical areas If there are critical areas, they are indicated on the drawing including the admissible properties and tests.
- Indication of required hydraulic and/or pneumatic tightness

7 General delivery conditions

Unmachined and finished parts must correspond to the drawing approved by Voith Turbo.

Castings must be free from sprue, solder, burrs and similar material residues, as well as free from inclusions, gas porosities, stuck welded joints, scrabs and chaplets.

Defects seriously affecting usability (function and/or subsequent process steps) are not admissible and must be removed by the supplier using suitable measures.

7.1 Classification according to function requirements

The classification is made by the responsible Voith development departments by indication on the drawing and/or selection of the corresponding Ordering Instructions and Conditions of Sale

The castings are grouped into the following function classes:

Function class 1

Castings with safety requirements

Function class 2

Castings, statically and dynamically stressed castings with special function requirements

Function class 3

Castings not belonging to classes 1 and 2, without specific function requirements

8 Quality requirements for parts of cast iron**8.1 Material**

Cast iron acc. to

- EN 1561 Lamellar graphite cast irons
- EN 1563 Spheroidal graphite cast irons
- EN 1564 Ausferritic spheroidal graphite cast irons

8.2 Metallography

According to ISO 945-1, microstructure of cast irons, Part 1: Graphite classification by visual evaluation.

Alternatively, the use of ISO/TR 945-2 - Microstructure of cast irons - Part 2: Graphite classification by image analysis - or ASTM A247 - Standard Test Method for Evaluating the Microstructure of Graphite in Iron Castings - is admissible. The metallographic results are to be enclosed to the master sample inspection report, if requested. Upon request (Voith Ordering Instructions and Conditions of Sale), they must be certified by a certificate acc. to EN 10204.

8.3 Internal and external quality**8.3.1 Surface quality discontinuities (unmachined surfaces)**

The unmachined surfaces must show a homogenous appearance and must neither contain cracks nor other defects which might affect the usability of the component and/or the subsequent machining with tools.

Terms and definitions for surface quality discontinuities are defined from EN 1559-2 to EN 1559-6. The surface quality is primarily determined by the processes described in the following standards.

Visual inspection

EN 1370 Founding - Examination of surface condition

EN 12454 Visual examination of surface discontinuities

Magnetic particle testing

EN 1369 Founding - Magnetic particle testing

ISO 9934-1 Non-destructive testing - Magnetic particle testing - Part 1: General principles

Penetrant testing

EN 1371-1: Founding - Liquid penetrant testing - Part 1: Sand, gravity die and low pressure die castings

ISO 571-1 Non-destructive testing - Liquid penetrant testing - Part 1: General principles

The required tests must be defined specifically for the component and must be entered either on the drawing with the relevant areas or defect acceptance criterion or be defined in a separate document (e.g. OICS, VQS or testing instruction).

8.3.2 Surface quality discontinuities (machined surfaces)

- Discontinuities (internal flaws) revealed by mechanical machining can be determined by comparison catalogs, limiting samples or indication of Voith PK. The most frequently found discontinuities are, among others:
Sand inclusions
- Slag inclusions
- Dross
- Gas porosity
- Breakage/cavities

If the admissible Voith PK is indicated to determine the surface discontinuities of mechanically machined surfaces, **the indications do not refer exclusively to pores, but to all discontinuities mentioned.**

Function class 1: No flaws admissible

Function classes 2 and 3: Only scattered and occasional discontinuities (max. \varnothing 1.0 mm) are admissible, provided that the proper use of the parts is not affected (maximum discontinuities per reference area 16 cm²). If the **Voith pore class PK** is indicated on the drawing, the following assessment criteria shall apply to the various classes (**Voith PK0 to PK6**):

Voith PK0:

1. Only discontinuities up to max. \varnothing 0.2mm are admissible
2. No exceptions are admissible

Voith PK1:

1. Reference area 1cm²
2. Admissible discontinuity size max. \varnothing 0.4mm min
3. Max. discontinuity number 2
4. Discontinuities smaller than 0.2mm are not taken into account

For each uniform, finish-machined surface, the following exceptions are admissible at a distance of min. 80 mm:
 A single discontinuity with a max. dimension of \varnothing 0.6 mm is admissible, contrary to 2.)
 Accumulation of 3 discontinuities is admissible with a max. edge distance of 1mm, contrary to 3.)
 Within an area equal to double the diameter of the tapped hole, no further flaws are admissible..

Voith PK2:

1. Reference area 4cm²
2. Admissible discontinuity size max. \varnothing 0.7mm min
3. Max. discontinuity number 2
4. Discontinuities smaller than \varnothing 0,4mm are not taken into account

For each uniform, finish-machined surface, the following exceptions are admissible at a distance of min. 80 mm:
 A single discontinuity with a max. dimension of \varnothing 1.0 mm is admissible, contrary to 2.)
 Accumulation of 3 discontinuities is admissible with a max. edge distance of 1.5mm, contrary to 3.)
 Within an area equal to double the diameter of the tapped hole, no further flaws are admissible..

Voith PK3:

1. Reference area 16cm²
2. Admissible discontinuity size max. \varnothing 1.0mm min
3. Max. discontinuity number 1
4. Discontinuities smaller than \varnothing 0,6mm are not taken into account

For each uniform, finish-machined surface, the following exceptions are admissible at a distance of min. 80 mm:
 A single discontinuity with a max. dimension of \varnothing 1.5 mm is admissible, contrary to 2.)
 Accumulation of 3 discontinuities is admissible with a max. edge distance of 2mm, contrary to 3.)
 Within an area equal to double the diameter of the tapped hole, no further flaws are admissible..

Voith PK4:

1. Reference area 16cm²
2. Admissible discontinuity size max. \varnothing 1.5mm min
3. Max. discontinuity number 1
4. Discontinuities smaller than \varnothing 1,0mm are not taken into account

For each uniform, finish-machined surface, the following exceptions are admissible at a distance of min. 80 mm:
 A single discontinuity with a max. dimension of \varnothing 2.0 mm is admissible, contrary to 2.)
 Accumulation of 3 discontinuities is admissible with a max. edge distance of 2mm, contrary to 3.)
 Within an area equal to double the diameter of the tapped hole, no further flaws are admissible..

If required, limiting samples or error catalogs must be coordinated with Voith.

8.3.3 Internal flaws

Internal flaws are primarily determined by the procedures described in the following:

Radiographic testing

EN 12681 Founding - Radiographic examination

EN 444 Non-destructive testing - General principles for radiographic examination of metallic materials by X- and gamma rays

ASTM E689-10 Standard Reference Radiographs for Ductile Iron Castings

ASTM E446 Reference Radiograph for Steel Castings Up to 2 inch in Thickness.

ASTM E186 Reference Radiograph for Heavy Walled (2 to 4.5 inch) Steel Castings.

ASTM E280 Reference Radiograph for Heavy Walled (4.5 to 12 inch) Steel Castings.

VDG-Merkblatt P 541 Error comparison catalog for the evaluation of radiographic tests at thick-walled castings of unalloyed EN-GJS materials

Ultrasonic testing

EN 12680-3 Founding - Ultrasonic testing - Part 3: Spheroidal graphite cast iron castings

EN 583-1 Founding - Ultrasonic examination - Part 1: Steel castings for general purposes

Ultrasonic testing is only partly applicable to parts of lamellar graphite cast iron.

Cut testing (saw cuts)

Alternatively, the evaluation of internal flaws can also be made by evaluating saw cuts. The position and number of cuts, as well as the evaluation criteria must be coordinated with Voith.

Fotos of flaws for evaluation are shown in 11.1.

The required tests are to be defined specifically for the component and must either be entered on the drawing with the relevant areas and the flaw acceptance criterion or to be defined in a separate document (e.g. OICS, VQS or testing instruction).

8.4 Hydraulic and/or pneumatic leakage test

The leakage test is done according to the indications stated on the drawing or contained in the respective standards. Hydraulic and/or pneumatic leakage test is only done for castings of function classes 1 and 2. Unless stated otherwise on the drawing, this test must be made on the finish-machined casting. The technical data for the test and the acceptance criteria (tightness class, tightness range, leakage test) are either specified on the drawing and/or in the respective standards.

8.5 Strength properties

The mechanical strength properties must be verified on the component (master sample inspection) The sampling spots are indicated by the supplier in the master sample inspection report, if not already defined in the component drawing. Voith Turbo reserves the right to test the strength properties by a tensile strength test of the component. The tensile test pieces are to be defined according to the corresponding material standard; the tensile test is to be carried out acc. to ISO 6892-1.

The measured values must correspond to the limiting values of the material standard stated on the drawing.

The test method of series-accompanying strength monitoring is to be selected at the supplier's discretion. The use of separately cast test bars is admissible as part of process monitoring. In referee cases, the strength characteristics (tensile strength/hardness) of the component are decisive. The strength properties of the presented master samples provide the general characteristic values.

The required number of samples is defined at the supplier's discretion.

The strength properties of heat-treated parts must be monitored continuously by a hardness test.

8.6 Hardness

The hardness test must be performed acc. to ISO 6506-1 at the surface and at flawless areas of the castings or at a broken test specimen that was not subjected to any stress. Any casting skin must be removed by suitable measures. The areas must be chosen in a way to ensure that the functionality of the casting is not affected after grinding off the surface layer. If hardness test positions have been agreed, they must be documented on the blank drawing.

The measured values must correspond to the prescribed limiting values of the material standard stated on the drawing.

The hardness test positions must be documented in the inspection report.

8.7 Surface finish

Measurement of surface roughness acc. to indications on the drawing. The measuring section must not show any surface imperfections. Surface discontinuities must be evaluated acc. to 8.3.1.

8.8 Mass

The mass of the rough casting is to be agreed between supplier and customer according to one of the two following procedures:

Mathematical calculation on the basis of the 3D-CAD data set and the density stated in the material standard, taking into account any necessary machining allowances that are required for shaping.

Arithmetic mean of the values measured at 10 qualified castings

For the mass stated on the drawing, a tolerance of $\pm 5\%$ applies.

8.9 Dimensions and tolerances

The dimensions must be examined on the basis of the drawing and/or the respective standards and/or CAD model.

The sections, connections and inner dimensions that cannot be recorded with the finish-assembled casting must be checked with the component disassembled accordingly.

8.10 Marking

The marking is to be provided according to the instructions in the drawing in an area not influenced by further mechanical machining. It must be clearly legible and contain the following data:

- Voith Turbo material number
- Material designation acc. to VDA260 (components of vehicles - marking of materials)
- Number of casting mold and model for parts of function classes 1 and 2.
- With pattern equipment containing several mold cavities, each mold cavity must be marked on the component.
- Date of manufacture or batch number
- Manufacturer's designation

9 Manufacturing specifications

9.1 Removal of sprues and risers

The castings presented for acceptance must be de-burred and clean, the material residues stated above must be removed with a suitable method to avoid any damage to the component part. If removal turns out to be difficult and requires the use of appropriate equipment, such work must be coordinated between customer and supplier.

9.2 Cleaning

Any flaws on the surface of components not removed by mechanical machining can be removed by means of file, grinding wheel or milling machine; the transition zones of the repaired flaw must not show any edges. In this case, the tests stated under item 8.3.1 must be repeated and the component is considered to be accepted if:

- the flaw has been completely removed;
- The dimensions of the repaired area are within the tolerances indicated on the drawing.

9.3 Repairs

Unless indicated otherwise on the drawing or the respective standards, repairs by welding, partial sealing or impregnating are only admissible after consultation with the Voith Turbo Development and Design Departments. For carrying out such repairs, exact procedures, inspection instructions and acceptance conditions must be agreed. In general, the specifications of EN 1011-8 shall apply to manufacturing and repair welds.

10 Technical series production release

The supplier has to observe the general specifications contained in VN 3205 - Production process and production release (master sample release).

If a tool / pattern equipment contains several mold cavities, at least one component of each mold cavity must be inspected.

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10.1 Addition to master sample inspection

Additional requirements for the sampling of parts made of cast iron for the Business Unit Road of Voith Turbo GmbH&Co KG (addition to VN 3205 - Production process and production release).

		Function class 3	Function class 2	Function class 1
1.	Measuring report	X	X	X
2.	Metallography		X	X
3.	Mechanical properties Strength (R_m [MPa], yield strength $R_{p0.2}$ [MPa], Elongation A_5 [%]) Note: Determination of yield strength and elongation is not possible for lamellar graphite cast iron.	X	X	X
3.1	Verification at separately cast tensile test piece.	X		
3.2	Verification by tensile test piece taken from the component		X	X
4.	Hardness test at heat-treated parts	X	X	X
5.	Surface discontinuities at unmachined surfaces: Visual test Magnetic particle test Penetrant test		X	X
6.	Surface discontinuities at machined surfaces acc. to 8.3.2 and/or coordination of limiting samples		X	X
7.	Internal flaws: Penetrant testing and/or ultrasonic testing and/or saw cuts in consultation with Voith		X	X

10.2 Delivery and marking of the master samples

Samples must always be despatched separately from series-manufactured material; samples must be addressed in separate package units to the goods reception of the recipient factory.

The individual master samples must be numbered to ensure that they can be correlated with the test documents. The master samples must be delivered with a separate delivery notice which must clearly bear the note "Master samples" with the part number and designation.

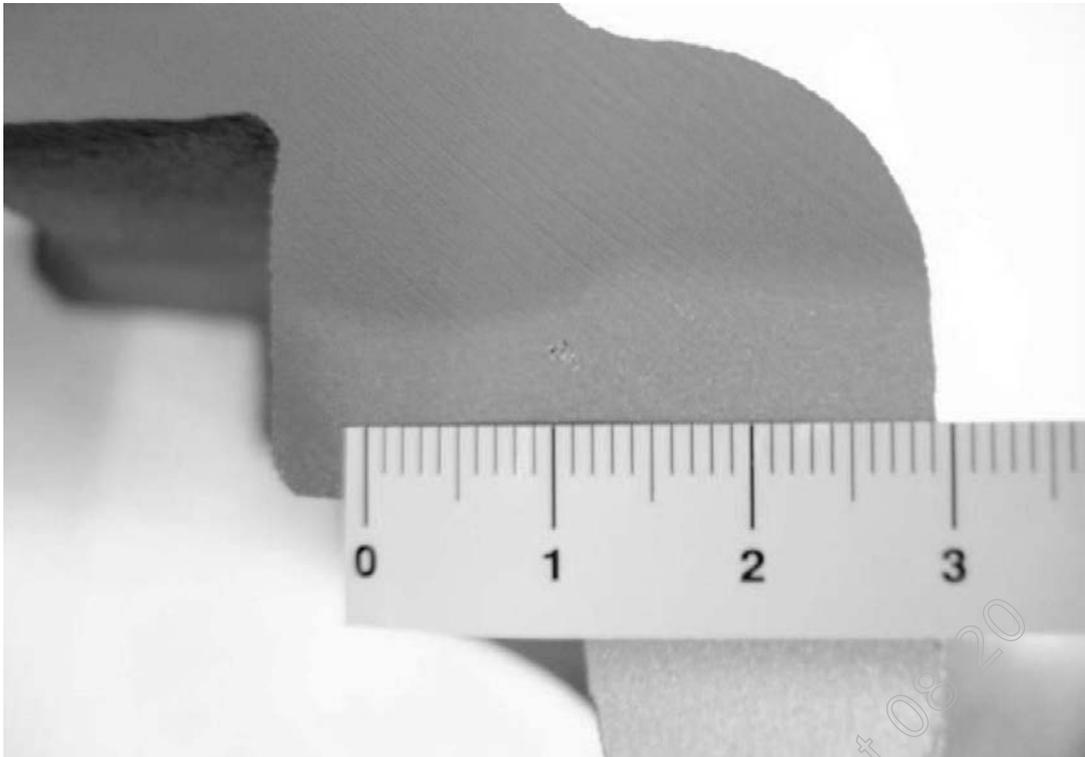
In addition, the packaging units or the master samples must be marked clearly with a material tag (VDA label) and a yellow "Master sample" sticker.

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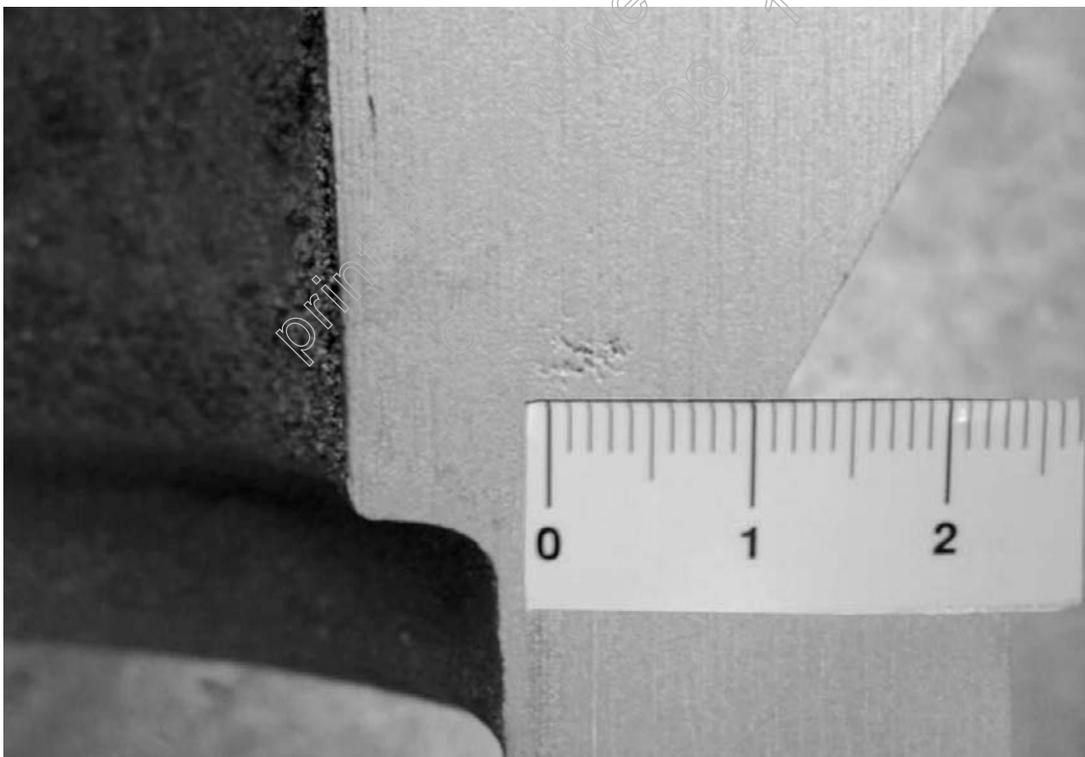
11 Annex

11.1 Quality grades of internal flaws

Assessment of discontinuities (internal flaws) by preparing and assessing saw cuts
Assessment criterion is the max. extension of internal flaws on the cut surface.

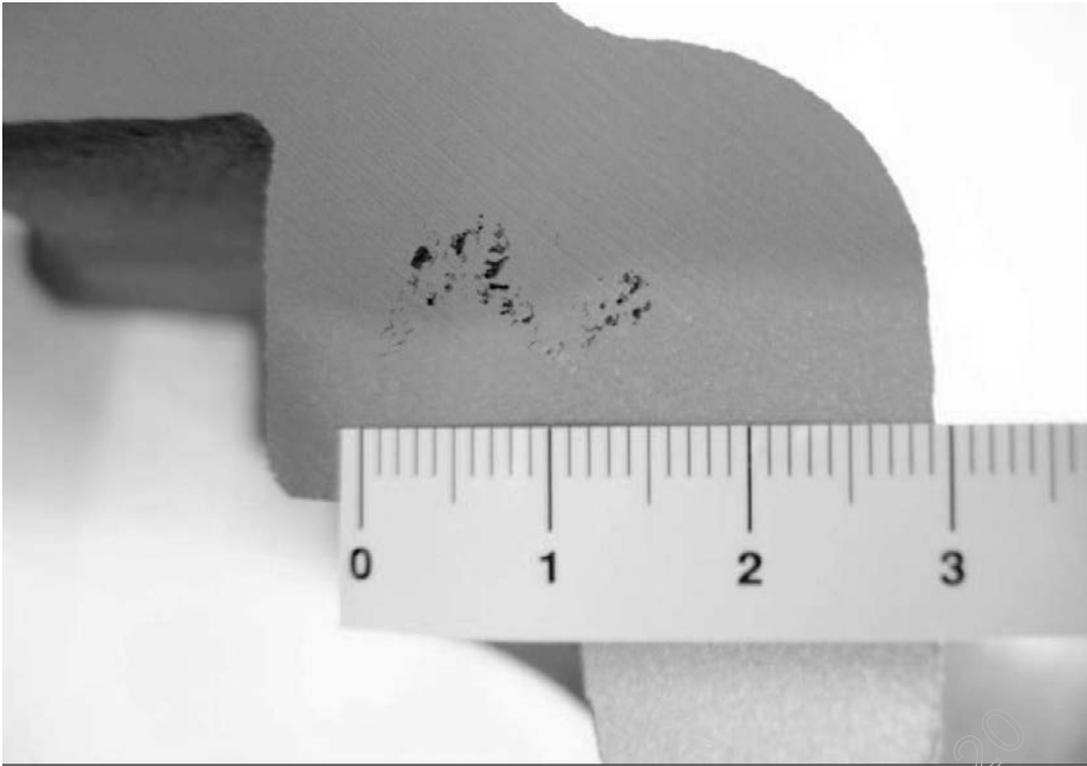


Quality grade 1 Flaw extension 0....2mm



Quality grade 2 Flaw extension 2....4mm

Quality grade 3 Flaw extension 4...8mm



Quality grade 4 Flaw extension >8mm

Further criteria for the evaluation of internal flaws at saw cuts must be determined specifically for the component.

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