Bosch-Norm

BOSCH

N42AP 605

2024-06-25

Porosity of castings

Terms, requirements, determination

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In case of doubt, the original language edition of this Bosch-Norm applies.
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1 Scope

This Bosch-Norm specifies the requirements for the porosity of castings. The determination takes place irrespective of which casting method was used for the production. The objective of this Bosch-Norm is to describe the porosity as well as its uniform entry into technical documents.
This Bosch-Norm covers inner as well as outer volume deficits (porosity). Other defects such as, e.g., sink marks, cold flow marks, stick marks, draw marks, burrs, and heat check patterns are not part of this Bosch-Norm.

2 Terms and definition

The permissible porosity is specified in the form of a porosity key. The prosity features listed therein refer to a reference area within a determined section plane.

The two-dimensional test procedure agreed upon for testing defined characteristics is defined on the finished part drawing, the applicable test specification or the parts list.

If there is no specification for the test procedure, then the metallographic microsection analysis is binding as valid test procedure.
Test procedures deviating from this are defined in the finished part drawing, the applicable test specification or the bill of materials (BOM).

2.1 Definition of the section plane, reference area and measuring fields

The positioning of the section plane should be oriented to the highest loaded points in the component and should be entered in the drawing, if needed. Machined surfaces in the component can also represent possible section planes. Additionally, section planes can be agreed upon between the supplier and Bosch, if required, (e.g. if a collective porosity key was agreed upon).
As long as areas, which indicate process variations, can be identified in the component, the supplier can place further section planes in these areas as a supplement.

Reference areas are defined on the selected section plane. These helps determine the porosity on the component. The reference area should specially consider the cross sections, which are functionally relevant for the component. The reference areas are basically square-shaped. In special cases, deviating shapes can be agreed upon in discussion with Bosch. These can be in the form of a circle, triangle or rectangle. Other shapes are not permitted.
The reference area is to be dimensioned in such a way that it extends over the entire component wall (figure 1). This means, the largest possible square should be chosen, which can be accommodated in the respective wall cross section.

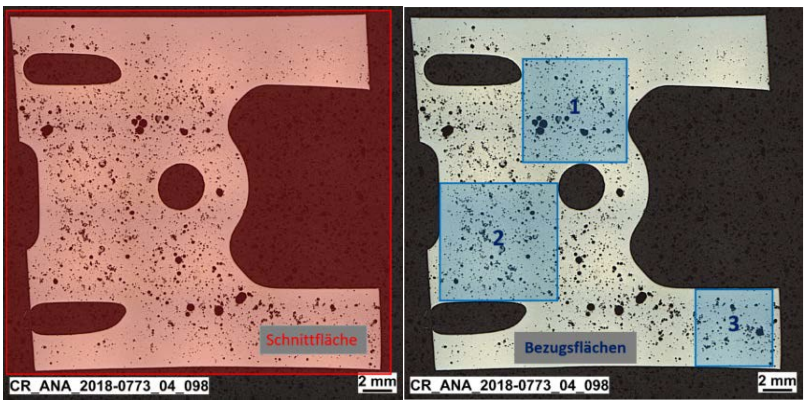


Figure 1: Relation between section plane and reference area (BDG Guideline Reference Sheet P202 (2010-09))

The reference areas for drillings and threads, for which a uniform porosity standard was defined, always covers the entire lateral surface.

Deviating from this, a square reference area is taken as basis for sealing surfaces in drillings. This results from the smaller one of the two available edge lengths of the rectangle, originated from the unrolling of the lateral surface of the cylinder.

The reference area should always be placed at the point of maximum porosity.

2.2 Terms and definition of the porosity key

According to the BDG Guideline P202:2010-09, a porosity key is used for declaration of porosity.

It consists of the following features:

[Rz]- Reference area roughness (µm): If the indication of the roughness is missing, then [Rz]=0 µm is valid, which corresponds to a metallographically polished microsection.

[%]-Pore content: maximum permissible pore surface portion in percent for the agreed reference areas.

[Ø]-Pore diameter/pore length: The maximum pore diameter is indicated in mm.

[A] - Distance of adjacent pores: Minimum edge distance between two adjacent pores. The distance indication refers to the pore diameter **[Ø]** of the smaller of two adjacent pores multiplied by an integer value.

[U] - Disregarded pores: This parameter defines which pores up to which pore diameter remain disregarded in the reference area evaluation.

[Z]-Number of pores: the maximum permissible number of individual pores in a reference area. Pore accumulations are treated as individual pores.

[H], [HR] or [HK]-Pore accumulations: A pore accumulation is existent if the distance between two adjacent pores is less than the diameter of the smaller pore.

[H] - Pore accumulations in the entire reference area,

[HR] - Pore accumulations in the edge area of the reference area (outer third of wall),

[HK] - Pore accumulations in the core area of the reference area (inner third of wall),

The value for [H], [HR] or [HK] can have the following binary values:

0 = pore accumulations impermissible

1 = pore accumulations permissible

If a maximum pore diameter is defined in addition to the pore accumulation, pore accumulations must be treated as individual pores. This means that if the diameter of an initially permissible pore accumulation exceeds the maximum permissible pore diameter, this pore accumulation is impermissible.

[N], [NR] or [NK] Localized aggregated porosity: There is a localized aggregated porosity if the diameter of a pore accumulation exceeds the maximum permissible pore diameter.

[N] - localized aggregated porosity in the entire reference area,

[NR] - localized aggregated porosity in the edge area of the reference area (outer third of wall),

[NK] - localized aggregated porosity in the core area of the reference area (inner third of wall),

[N], [NR] or [NK] can have the following binary values:

0 = localized aggregated porosity impermissible

1 = localized aggregated porosity permissible

If [N], [NR] or [NK] is listed in the pore key but no value is indicated, the value 1 applies automatically, i.e., localized aggregated porosity permissible in the corresponding area.

Pore accumulations are always permissible if localized aggregated porosity is permissible. If localized aggregated porosity is impermissible, it does not mean that pore accumulations are impermissible.

In addition to the BDG Guideline P202, the following porosity feature can be used for the machined surfaces:
[FA] – Fixed distance of two adjacent pores: the minimum permissible edge distance between two adjacent pores on the machined surface. The distance is indicated in mm.

Format of the porosity key:

Bosch N42AP605 - [Parameter 1][Value]/[Parameter 2][Value]/ ... [Parameter n][Value]

For examples of the porosity key, see 2.3.2

2.3 Drawing note

The valid porosity keys have to be noted in finished part drawings and/or corresponding order specifications. There are two options for noting porosity data in the drawing, as collective note or as note for defined areas.

2.3.1 Collective note

Collective note means that the pore surface portion refers to any cross sections in the casting. A collective note can be practical if the collective note can define a maximum permissible porosity for the entire component required by the design.

The following values represent very high requirements on the porosity of cast parts. These porosity requirements are not necessarily relevant and necessary for all cast parts. It has to be avoided that that too high costs are generated by inappropriate high porosity requirements.

for castings made of cast steel and cast iron materials: N42AP 605-%1
for castings made of zinc-base alloys: N42AP 605-%10
for castings made of other materials, such as e.g., aluminum-, magnesium alloys: N42AP 605-%5

Parts of the initial sample and design have to meet the specified porosity specifications and be delivered to Bosch with the corresponding proof. These are used as limit sample.
If the permissible porosity is exceeded in the design parts or first delivery of castings, then this should be thoroughly documented by the supplier. Here, all the affected areas should be clearly depicted.

The measured value has to be noted in the finished part drawing when the limit porosities are exceeded and in case of simultaneous successful testing of parts. Otherwise, the existing notes in the finished part drawing and/or corresponding order specifications continue to apply.

Note: If required by locally high loads or functional surfaces, then notes for defined areas/cross sections are required in addition to the collective key.

2.3.2 Notes for defined areas

Notes for defined areas can be practical if, e.g., no collective key is used and/or locally higher loads are present or the component function requires it.

Example 1:

Bosch N42AP605-%5/Ø2/HK0

Max. permissible pore surface portion 5%, max. permissible pore length 2mm, pore accumulations in the core area of the reference area are not permissible. Since the surface quality Rz is not specified, Rz=0 applies, i.e., metallographically prepared microsection.

Example 2:

Bosch N42AP605-Rz0/Z5/Ø4/U0,5/N1

The roughness of the reference area Rz has to amount to 0 µm (metallographic microsection). The max. permissible number of pores is 5. The max. permissible pore length is 4 mm. Pores smaller than 0,5 mm remain disregarded. Localized aggregated porosity in the entire reference area is permissible.

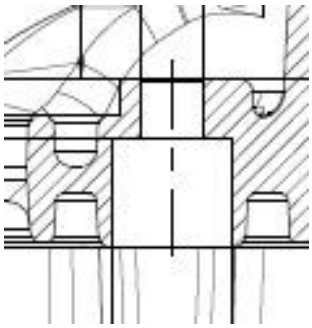
Example 3 (example for machined mating surface):

Bosch N42AP605-Z6/Ø2/U0,4/A3

The max. permissible number of pores is 6. The max. permissible pore length is 2 mm. Pores smaller than 0,4 mm remain disregarded. The distance of two adjacent pores is greater than the diameter of the smaller pore multiplied by the factor 3.

Example 4 (for machined sealing surface in the drilling):

Bosch N42AP605-Z5/Ø0,7/U0,4/H0/A4

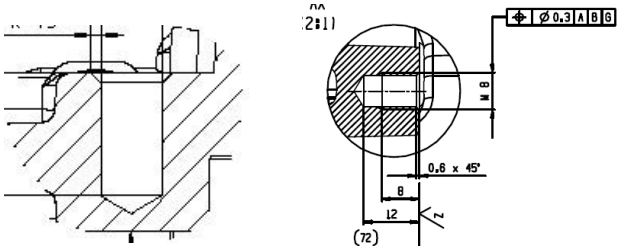


The max. permissible number of pores is 5. The max. permissible pore length is 0,7 mm. Pores smaller than 0,4 mm remain disregarded. The distance of two adjacent pores is greater than the diameter of the smaller pore multiplied by the factor 4. Pore accumulations are impermissible.

Since this is a sealing surface in a drilling, a square reference area is taken as basis. These result from the smaller one of the two available edge lengths of the rectangle originating from the unrolling of lateral surface of the cylinder. The reference area should always be placed at the point of maximum porosity (as descried in 2.1).

Example 5 (drillings and threads):

The reference areas for drillings and threads, for which a uniform porosity standard was defined, always covers the entire lateral surface (as described in 2.1).

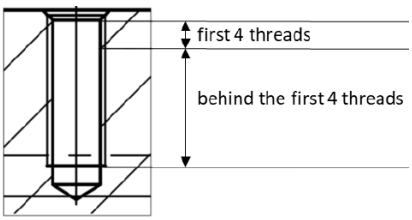


Bosch N42AP605-Ø2/U0,5/A3

The max. permissible pore length is 2 mm. Pores smaller than 0,5 mm remain disregarded. The distance of two adjacent pores is greater than the diameter of the smaller pore multiplied by the factor 3.

Possible special case for threads:

A special case can occur in threads: the reference area always covers the entire lateral surface here as well. Accordingly, both entire lateral surfaces have to be observed and evaluated separately in this case.



In the first 4 thread turns**: Bosch N42AP605-Ø0,6/H0**
After the first 4 thread turns: **Bosch N42AP605-Ø3/H0**

In the first 4 thread turns, the max. permissible pore length is 0,6 mm. Pore accumulations are impermissible. After the first 4 thread turns, the max. permissible pore length is 3 mm. Pore accumulations are impermissible.

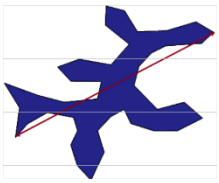
Example 6 (for machined sealing surface)

Bosch N42AP605- Ø0.7/U0.4/H0/FA6

The max. permissible pore length is 0,7 mm. Pores smaller than 0,4 mm remain disregarded. Pore accumulations are impermissible. The minimum permissible edge distance of two adjacent pores must be greater or equal 6 mm.

2.4 Supplements and deviations from the definition of the porosity key as per BDG Guideline P202 (2010-09)

Table 1

Term	Definition
Roughness of the reference area [Rz, µm]	The specifications on the roughness of the casting skin and machined surfaces in drawings etc. retain their validity, even if other specifications on the roughness are made in the porosity key.
Pore content [%]	A pore content of 0% is impermissible. In case of a pore surface portion > 5%, the permissible pore surface portion has to be indicated in 5% increments. With an exception of cast steel and cast iron, a pore surface portion <5% can be given only in coordination with Bosch cast experts. Here, increments of 1 to 4% have to be used. As long as there is a necessity to subdivide the reference area, it can be determined in special cases that none of the partial surfaces may exceed a pore surface portion of 4%.
Pore diameter [Ø]	According to this Bosch-Norm, the pore diameter always refers to the pore length (max. Feret). The index L as used in the BDG guideline P202, is not used in the Bosch-Norm at hand. While indicating the pore diameter, 0,5 mm increments have to be used. Specifications of <0,5 mm are impermissible (in case of diameter <0,5 mm, the definition of a nondestructive test, such as e.g., x-ray test or hole templates, not possible in practice). Exceptions are machined mating surfaces, which serve as reference area. Here, it has to be noted that the specification is situated above the optical resolution of the test procedure to be applied.  Pore length (= maximum Feret) [Ø] (BDG P202 (2010-09))
Disregarded pores [U]	This feature is used in machined surfaces. It is recommended to use [U] only for machines surfaces with sealing function. Values of [U] should be indicated in 0,1mm increments. In case of missing specification, the [U] to be used is automatically based on the surface quality of the reference area and the applied test procedure. The optic resolution of the applied test procedure has to be higher than the given values for the disregarded pores.
Number of pores [Z]	This feature is used only for machined surfaces and metallographically prepared microsections (notes for defined areas).
Fixed distance of two adjacent pores [FA, mm]	This feature is used for machined surfaces (e.g. for sealing surfaces). [FA] should be used for visual inspection method with test gauge. The value [FA] should be indicated in 0,1mm increments.

2.5 General requirements on reference areas supplementing the BDG Guideline BDG P202:2010-09

All porosity keys and features listed therein refer to a reference surface within the respective section plane.

If distinctive areas without given reference area are available, then the supplier must define suitable reference areas and – as far as available – at least prove results according to the collective porosity key.

If there is no collective porosity key, then the most critical porosity specification in the drawing is applied on the reference area newly defined by the supplier. This means, the reference area should always be placed at the point of maximum porosity.

The supplier can additionally define reference areas at random. This specification applies for the point of maximum porosity in the component. The above mentioned apply to the porosity keys which are to be applied.

3 Metallographic analysis

3.1 Quality of the reference area

The recognizability of the pores in the reference area strongly depends on the surface quality of the reference area.
No scratches or scores of other machining traces should be visible while testing a mirror-like surface under the microscope (100-times magnification).
No edge rounding or relief formations may show when testing the evenness of the polished surface.
The microsection may not indicate any deformations or damages through pre-machining stages of the specimen.

3.2 Requirements of the preparation of the cut surface supplementing BDG P202:2010-09

Preparation procedures, which avoid a plastic deforming of the surface and prevent smear up of pores, should be chosen.
Excessive temperature influence (danger of melting the surface) should be avoided during the preparation of specimen (e.g., grinding).
Other influences such as, e.g., damages, contaminations, etc., which influence an assessment of the porosity on these surfaces, have to be eliminated.

Exception: Porosity specifications for casting surfaces left raw and machined surfaces are made without additional preparation while adhering to the state indications of the finished part drawing (see Figure 5).

3.3 Assessment of the porosity in the defined reference area

Machining surfaces and raw contours have to be checked with the naked eye.
Metallographically prepared microsections (Rz=0) have to be assessed with a reflected-light microscope (magnification: at least 20-times).
Specimen which indicate a lower surface quality (Rz= 1-10) are assessed using a microscope at a 10-times magnification.
Specimen which indicate a still lower surface quality (Rz= 11-25) are assessed using a microscope at at least 5-6-times magnification.
Optical aids (magnifying glasses and/or digital photography) with at least 2-times magnification are suitable for specimen surfaces with Rz>25.
An adequate lighting has to be chosen to assess the reference areas. The assessment during overexposure of the figures leads to lower porosity, an underexposure leads to higher porosity. A lateral light irradiation (e.g., in stereomicroscopes) increases the risk of wrongly assessing the porosity.

Note: The indication of defects by the end user can also happen with less magnification than shown above.

Note: The different appearances of microstructure constituents with similar grey tones such as porosity can lead to the misinterpretation of porosity. In case of such materials (such as cast iron, copper red brass etc.), the first prerequisite in the quantitative picture analysis is the selection of the corresponding resolution as well as the setting of grey tones.

3.4 Result of the porosity assessment

Permissible measuring equipment have to achieve 10-times higher accuracy than the values to be tested.
If a reference area is divided into several measuring fields, the area related results have to be calculated by the arithmetic average of the measuring values from all fields (evaluation of the largest possible square).
Absolute values have to be calculated through summation across all measuring fields. Overlapping between the measuring fields is not permissible. The measuring fields have to be joined closely together.
Suitable processes, such as e.g., planimetering/line cut processes have to be used for evaluating.
The measurement of pore diameter and distances should be done with an accuracy of 0,1 mm.
The assessment result from several reference areas is the value of the reference area, on which the highest porosity was determined.

This value is not allowed to be determined through average determination from several reference areas. Porosity contents have to be indicated as integer percentage corresponding to the required pore content. In case of porosity specifications of 5% and greater, the porosity result has to be rounded off in 5% increments. Furthermore, it has to be noted that the rounding up of porosity specification < 4% should take place in 1% increments.
The specification of the determined pore diameter is always rounded up in 0,5 mm increments.

Examples for porosity assessment:

The following collective porosity key was specified for a casting:

Bosch N42AP605-%10/∅2.

The following max. values for pore diameter and pore loss area were determined at different parts of the casting.

Reference area A: Pore diameter 1,8 mm, pore loss area % 13,2; this corresponds to Bosch N42AP605-%15/∅2

Reference area B: Pore diameter 0,8 mm, pore loss area % 2,8; this corresponds to Bosch N42AP605-%5/∅1

Reference area C: Pore diameter 3,6 mm, pore loss area % 8,3; this corresponds to Bosch N42AP605-%10/∅4

The determined porosity corresponds to a porosity key Bosch N42AP605-%15/∅4. This means, the permissible porosity was exceeded.

3.5 Deviation from the specified test procedure

If no other test procedure was specified, the metallographic analysis is binding as valid rest procedure.

If, for example, a supplier wants to deviate from the specified test procedure, then he has to prove a correlation of the applied procedure to the metallographic microsection for the respective casting.
Further test procedures (e.g., CT*) can be qualified for series production control. However, in arbitration cases only results from the prescribed test procedures apply.
Areas critical for strength, production procedures and functions have to be preferred as test areas and be checked regularly.

*The BDG guideline P203 (as of December 12, 2019) is dealing with the porosity analysis and evaluation using industrial computer tomography (CT). Note related to comparability between CT-Images and metallographic analysis can be found in chapter 6, page 19/20 (german version P203).

4 Assessment of the porosity by means of metallographic analysis method

4.1 Evaluation of the reference area

If the reference area is larger than permitted by the recording of the measuring system, then the reference area has to be subdivided. In this case, the reference area has to be subdivided in measuring fields of the same size and geometry. The measuring fields may not overlap here. Then the result of the porosity content in the entire reference area is the arithmetic average of the porosity content of all measuring fields.

Figure 2 Subdivision of the reference area into measuring fields

4.2 Special geometries and special cases for the reference area

Overhangs are permissible in special component geometries. Special component geometries can result from machining surfaces, drafts, variation of the casting shape, such as e.g. roundings, etc. An overhang of the reference area beyond the component geometry is permissible up to 5% of the reference area size (Figure 3). Overhangs have to be deducted during the evaluation of the respective reference area.

Figure 3. Max. permissible overhang area projection at the component border of 5%

The edge length of reference areas on sealing surfaces should correspond to the width of the seal (figure 4a). This applies in the same way for geometries, which generate annulus-like contours, such as e.g., cuts through cylindrical support points for drillings with or without threads or similar geometries. In case of a cross section through a seal, the entire width of the seal profile has to be captured (figure 4b).

In case of sealing surfaces and annulus-like contours, unlimited overhangs of the reference area to the component geometry are permissible. The reference area projection should be deducted while evaluating the reference area.

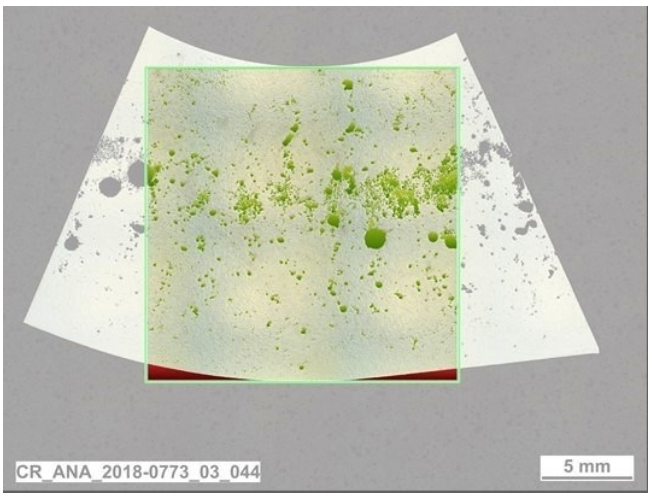


Figure 4a. Reference area overhang on annulus-shaped cuts, e.g., at sealing surfaces

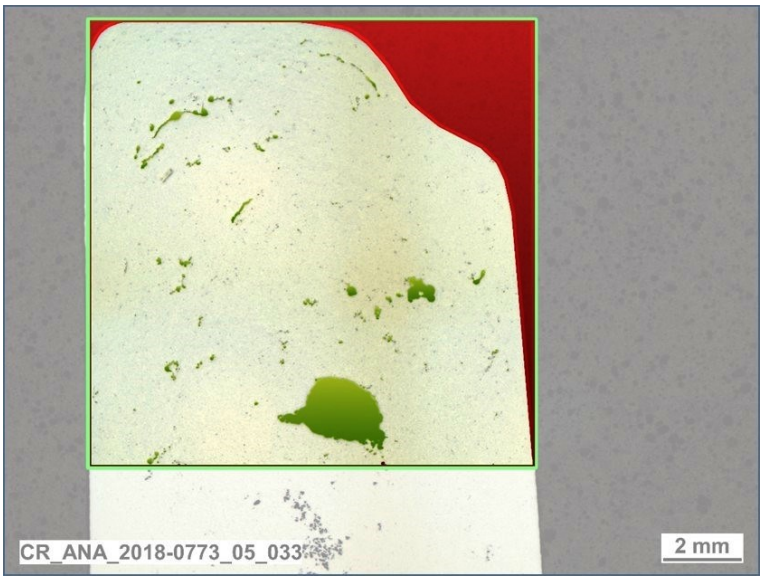


Figure 4b. Reference area overhangs, e.g., on annulus-shaped cuts

In exceptional cases, a function area (e.g. a cut machined sealing surface) can be defined as reference area in its entireness. In this case, the roughness of the reference area corresponds to the specified roughness of the function area. This is then to be shown in the drawing, shaded with porosity specification (Figure 5).

The so-called special case also applies for function areas with slopes.

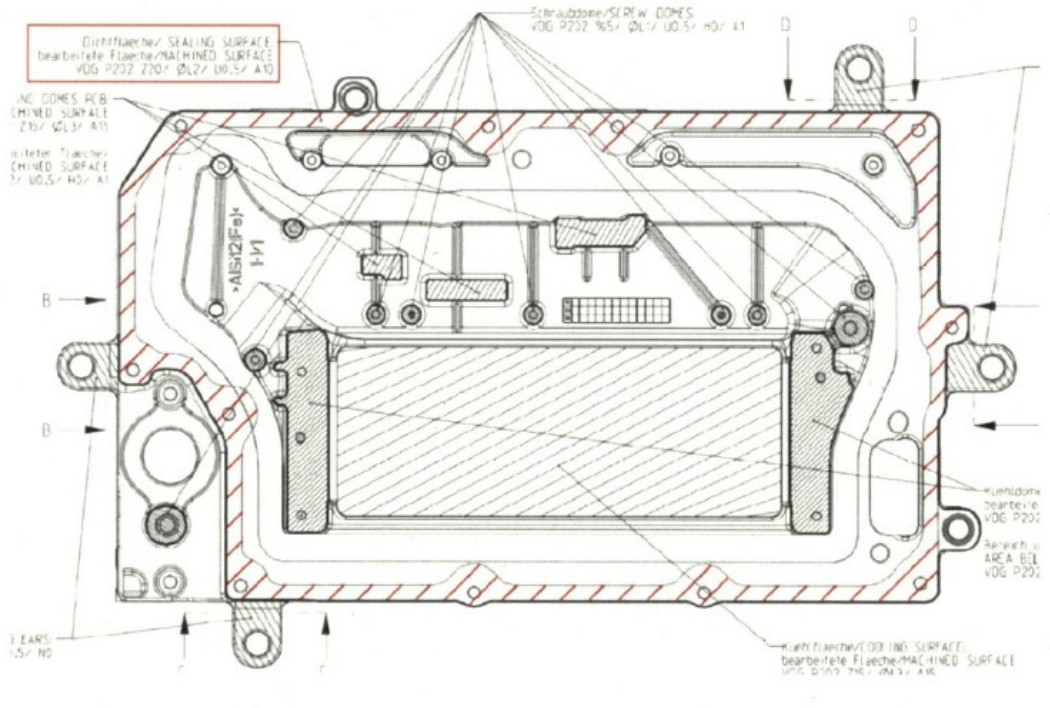


Figure 5. Different function areas completely defined as reference area

If a reference area is located in a passage from a thick-walled to thin-walled area, then the portion in the thick-walled area may not exceed 50% of the reference area (figure 6).

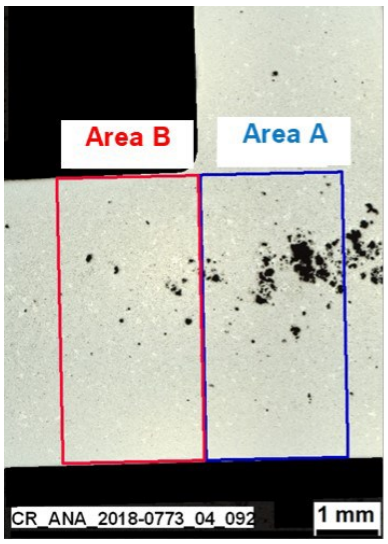


Figure 6. Positioning of the reference area at a thin wall thickness with adjacent thick wall thickness. Permissible is: thin-walled (reference surface B) > thick-walled (reference surface A)

Reference surface A + Reference surface B = square reference area

NOTE: If uncertainness arise in the definition of the reference areas, the responsible development or quality areas of the end user have to be contacted.

Abbreviations

BDG – Federal Association of German foundry industry (Bundesverband der deutschen Gießereiindustrie)

µm - Micrometer

CT-Computer Tomography

Rz - Roughness of the reference area

5 Normative references

The following documents are necessary for using this Bosch-Norm. With dated references, solely the edition referred to applies. With undated references, the last edition of the indicated document applies (including all revisions). Intentionally cited historical documents are additionally identified as "H" in the column "Type."

No.	Document number (edition date)	Title	Type
1	BDG Guideline VDG Reference Sheet P202 :2010-09	Volume Deficits of Castings Made from Aluminium, Magnesium, and Zinc Casting Alloys	Z
2	PVA7800	Test specification; Determination of cavities in aluminum pressure-diecast parts	Z
3	BDG Guideline P203:2019-12	Porosity analysis and assessment using industrial X-ray computed tomography (CT)	Z

Type M = document to be supplied; Z = cited document; H = historical document

A Appendix (informative): Examples of microsections of different porosity content

Figure 1: Porosity content: 0,95%

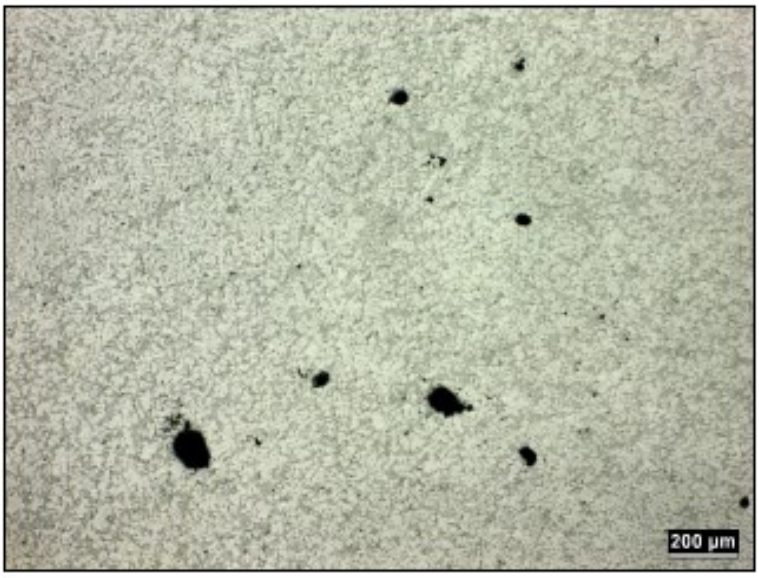


Figure 2: Porosity content: 1,1%

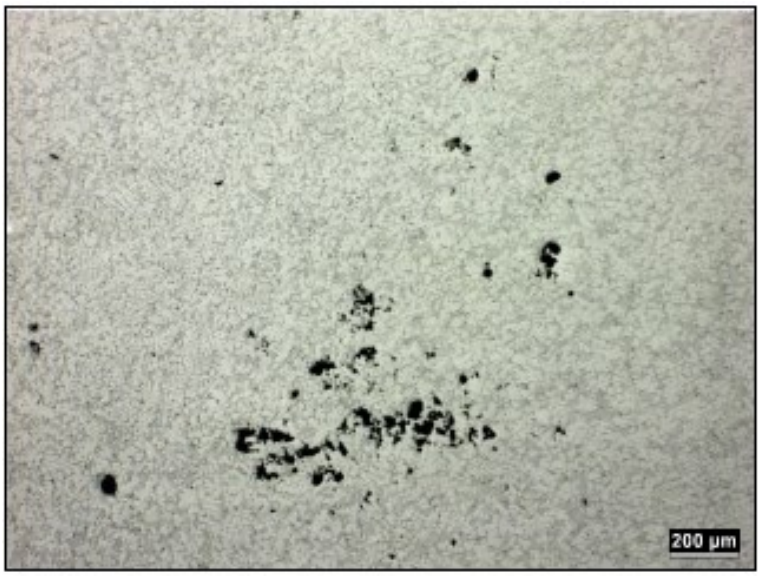


Figure 3: Porosity content: 1,4%

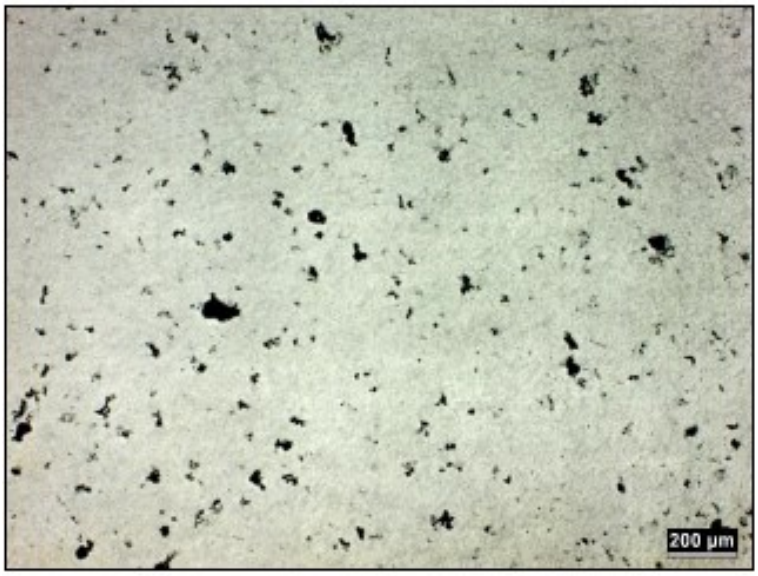


Figure 4: Porosity content: 1,8%

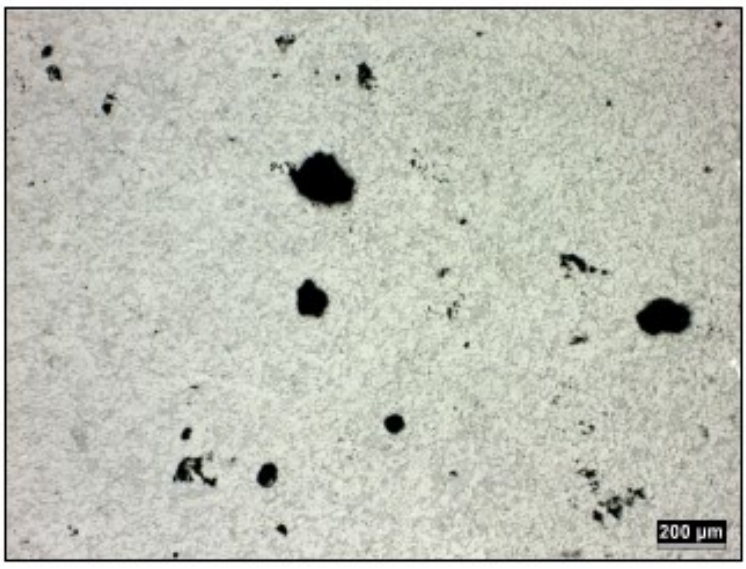


Figure 5: Porosity content: 1,9%

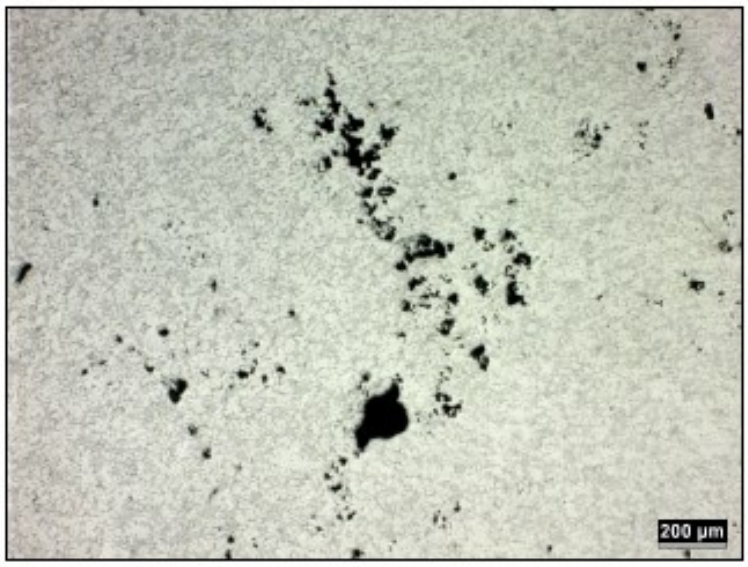


Figure 6: Porosity content: 2,0%

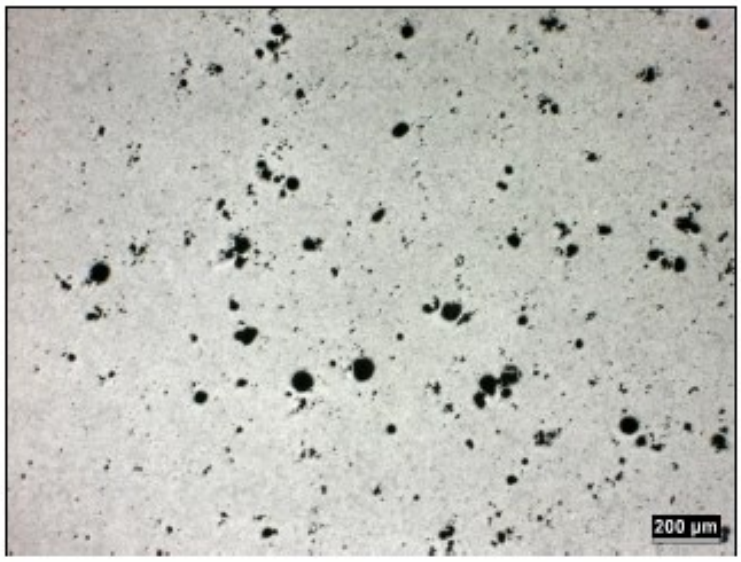


Figure 7: Porosity content: 2,3%

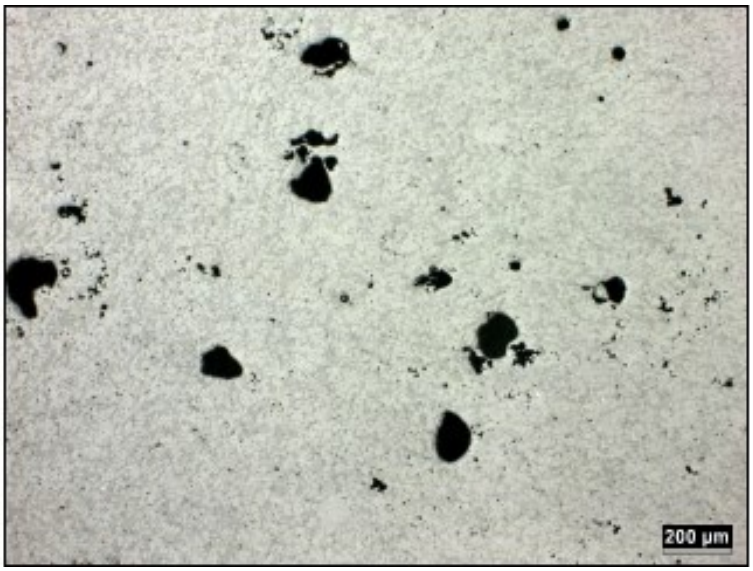


Figure 8: Porosity content: 3,0%

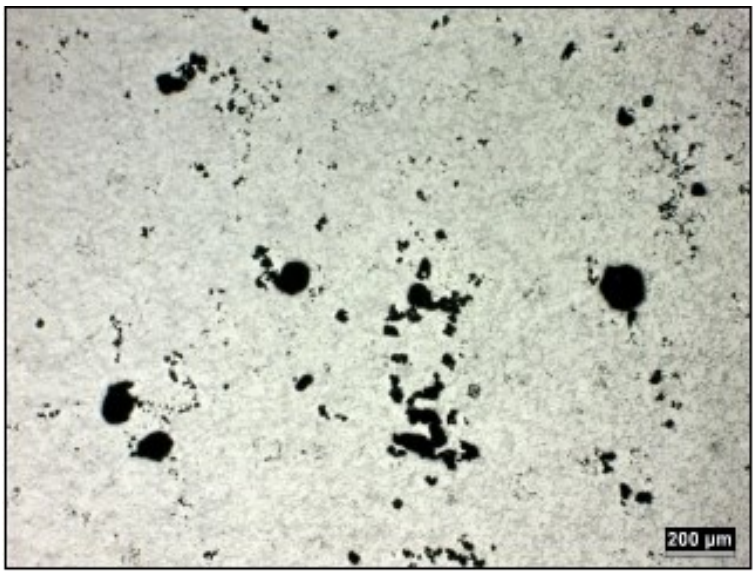


Figure 9: Porosity content: 3,7%

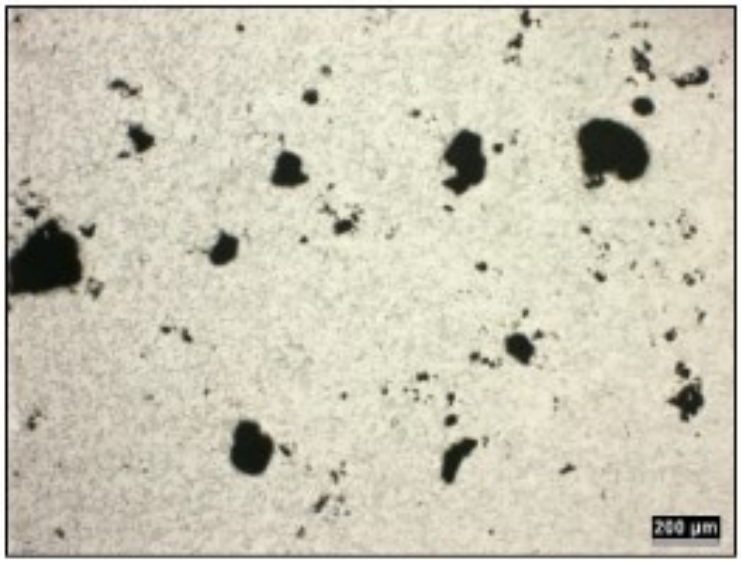


Figure 10: Porosity content: 4,5%

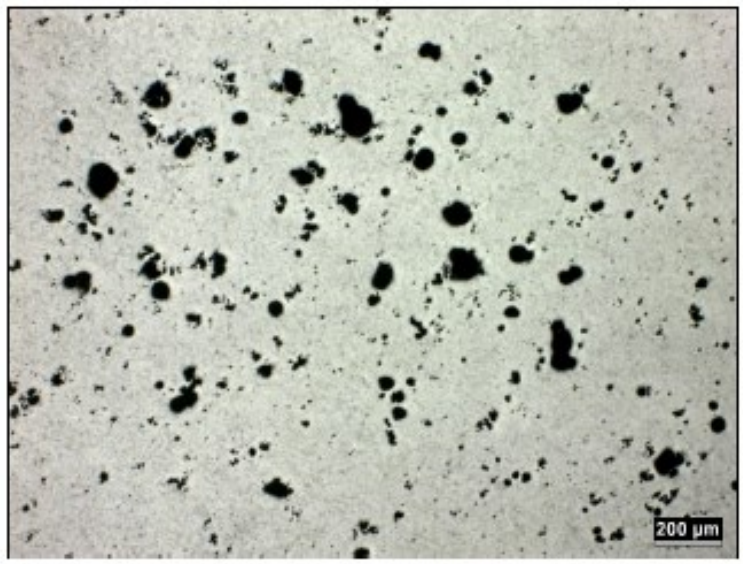


Figure 11: Porosity content: 5,1%

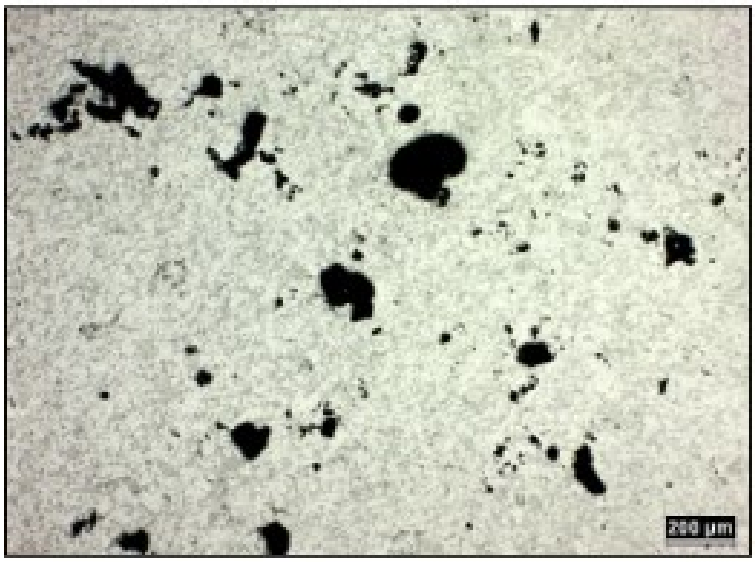


Figure 12: Porosity content: 5,2%

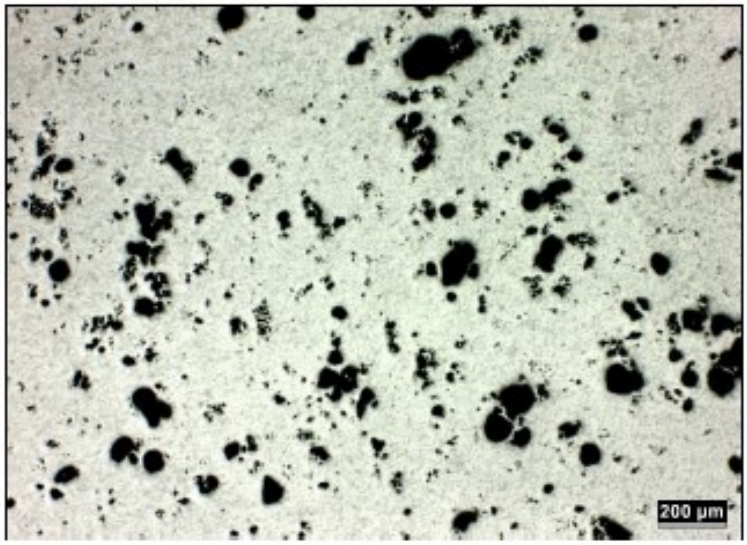


Figure 13: Porosity content: 8,8%

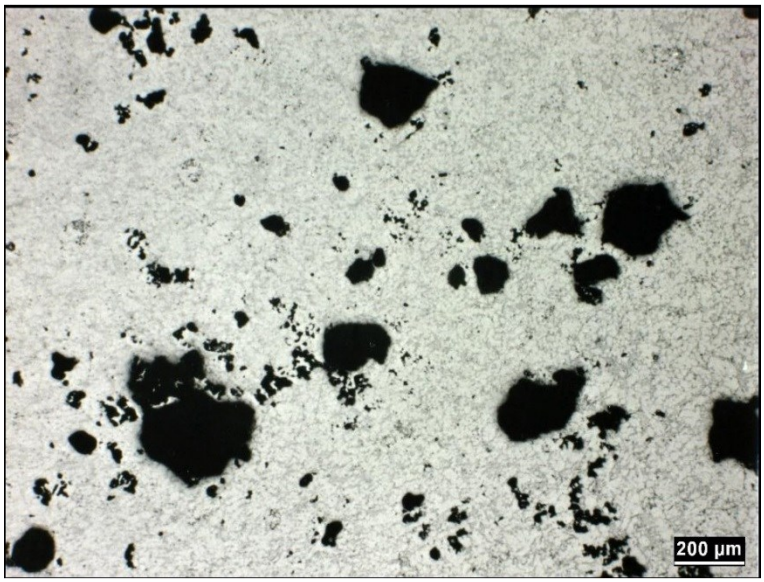


Figure 14: Porosity content: 11,6%

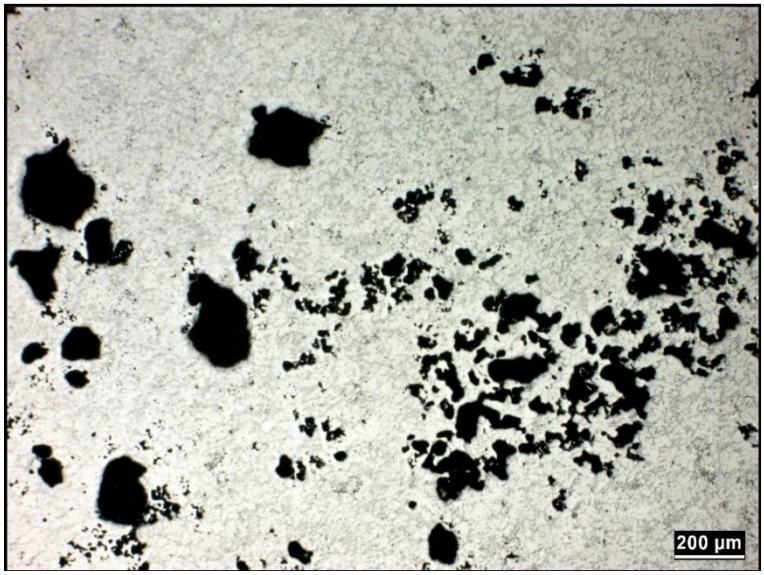


Figure 15: Porosity content: 14,1%

B Appendix (informative): Examples for the assessment of microsections with different porosity content

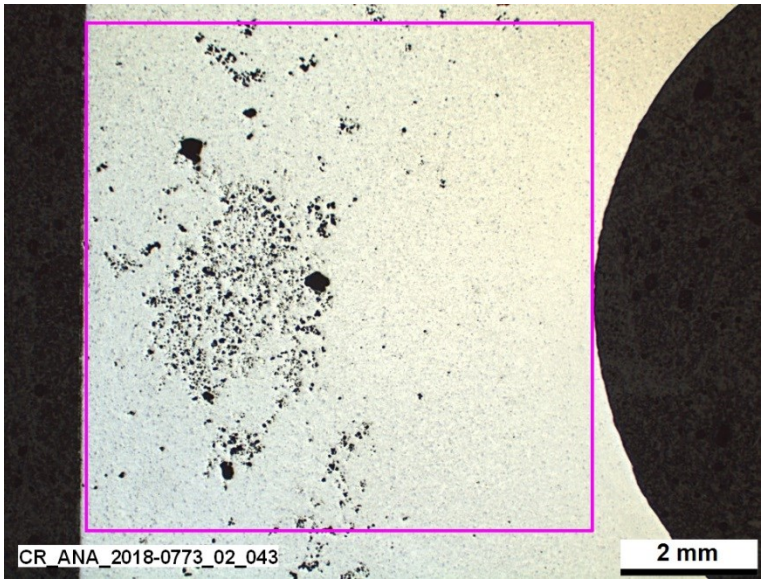


Figure 1

Measured porosity content = 6,0%

Actual – Porosity content according to N42AP605=10%

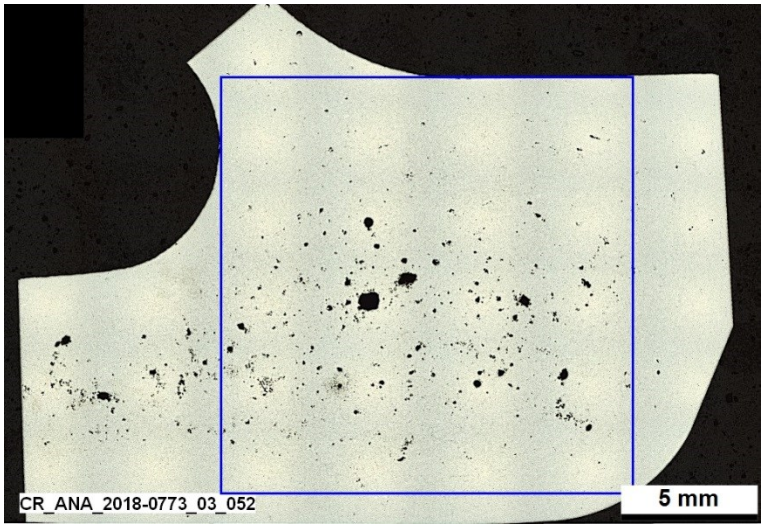


Figure 2

Measured porosity content = 8,1%

Actual – Porosity content according to N42AP605=10%

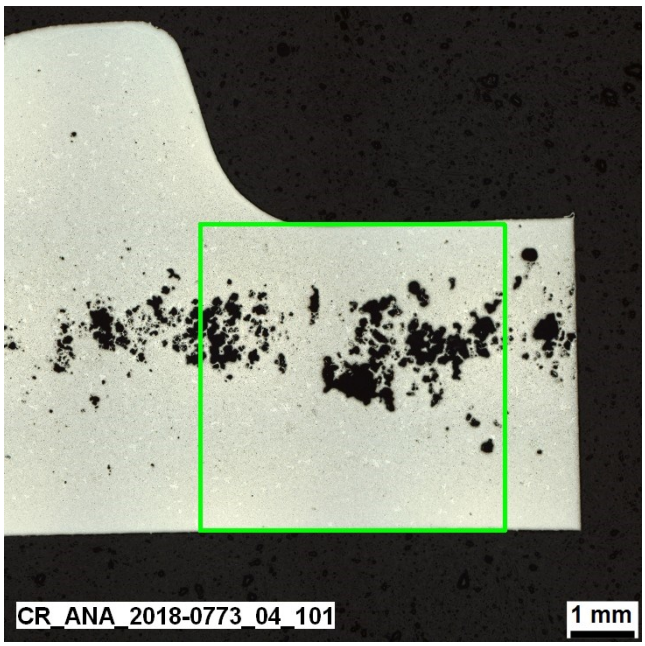


Figure 3

Measured porosity content = 13,2%

Actual – Porosity content according to N42AP605=15%

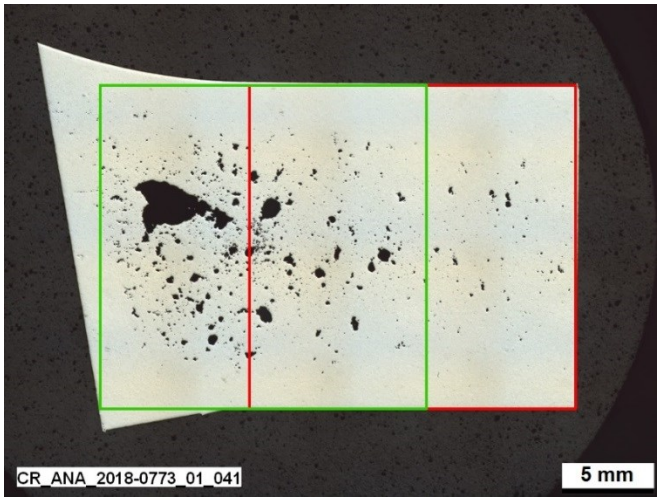


Figure 4

Measured porosity content

Green: 7,6%

Red: 3,2%

Actual – Porosity content according to N42AP605=10%

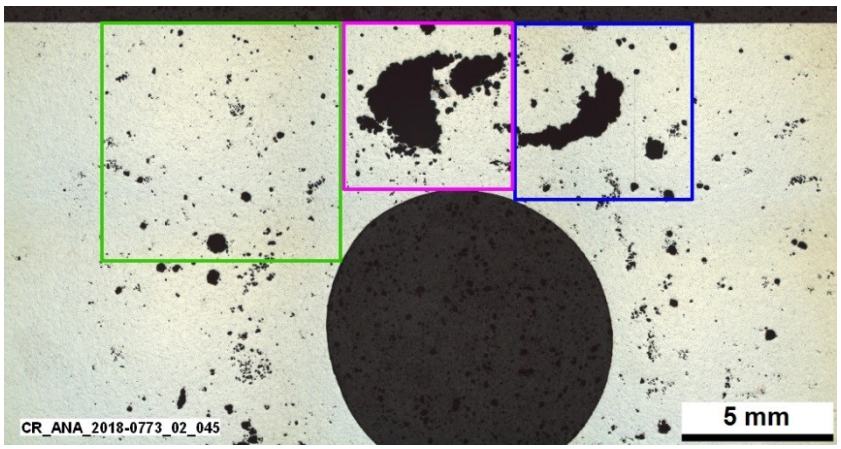


Figure 5

Measured porosity content

Green: 3,9%

Pink: 32,8%

Blue: 16,7%

Actual – Porosity content according to N42AP605 = 35%

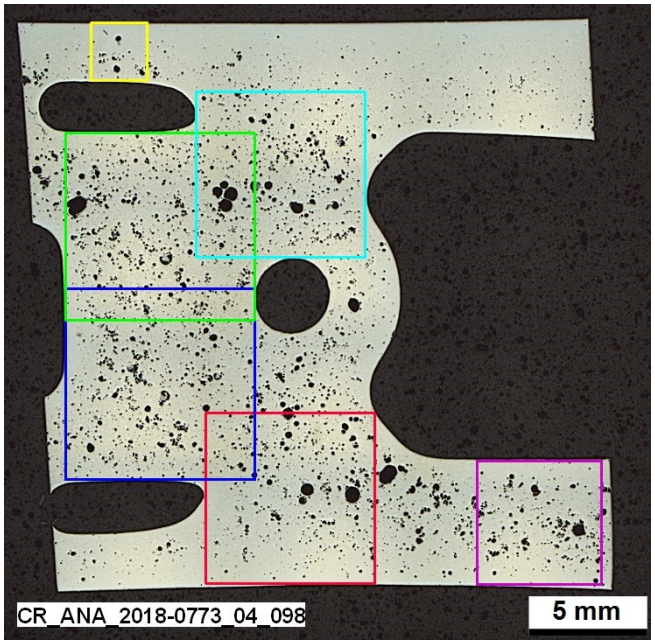


Figure 6

Measured porosity content

Yellow: 7,8%

Green: 14,8%

Turquoise: 13%

Blue: 14,9%

Red: 10,3%

Pink: 9,9%

Actual – Porosity content according to N42AP605 = 15%