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Aluminij in aluminijeve zlitine - Razvrstitev pomanjkljivosti in napake v visokotlačnih, nizkotlačnih in težnostno kokilno ulitih ulitkih

Aluminium and aluminium alloys - Classification of Defects and Imperfections in High Pressure, Low Pressure and Gravity Die Cast Products

Aluminium und Aluminiumlegierungen - Klassifikation von Fehlern und Unvollkommenheiten für Druckguss, Niederdruckguss und Schwerkraftkokillenguss

Aluminium et alliages d'aluminium - Classification des défauts et imperfections des produits moulés par coulée à haute pression, basse pression et gravité

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Contents

Page

Foreword

This document (CEN/TR 16749:2014) has been prepared by Technical Committee CEN/TC 132 “Aluminium and aluminium alloys”, the secretariat of which is held by AFNOR.

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1 Scope

This Technical Report specifies the classification of the defects and imperfections may be present in cast products manufactured by high pressure, low pressure and gravity die casting of aluminium alloys.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

EN 12258-1:2012, *Aluminium and aluminium alloys - Terms and definitions - Part 1: General terms*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in EN 12258-1:2012 and the following apply.

3.1
casting process
process in which molten metal is introduced into a mould where it solidifies

[SOURCE: EN 12258-1:2012, 3.1.1]

3.2
die casting process
casting process in which molten metal is injected under substantial pressure, typically above 70 bars, into a metal die and solidifies under this pressure

Note 1 to entry: Die casting process is also referred to as "pressure die casting (process)" or "high pressure die casting (process)".

[SOURCE: EN 12258-1:2012, 3.1.10]

3.3
permanent mould casting process
casting process in which molten metal is introduced by gravity or low pressure into a mould constructed of durable material, typically iron or steel

Note 1 to entry: A permanent mould casting process where the metal solidifies in a metal mould under low pressure (typically less than 1 bar above atmospheric pressure) is also referred to as a "low pressure die casting process".

[SOURCE: EN 12258-1:2012, 3.1.9]

3.4
casting
product at or near finished shape, formed by solidification of the metal in a mould or a die

[SOURCE: EN 12258-1:2012, 2.5.1]

3.5
dendrite
crystal that has a tree-like, branching pattern, being most evident in cast metals slowly cooled through the solidification range

[SOURCE: EN 12258-1:2012, 4.5.17]

3.6
microstructure
structure of a metal as revealed by microscopic examination of a surface, typically after mechanical and/or chemical preparation, e.g. polishing and micro-etching

[SOURCE: EN 12258-1:2012, 4.5.10]

3.7
dendrite arm spacing
mean distance of adjacent secondary arms of a dendrite

[SOURCE: EN 12258-1:2012, 4.5.18]

3.8
defect
quality characteristic which is lower with respect to the level or state foreseen (usually specified) and which does not allow the product to carry out a function requested

[SOURCE: EN 12258-1:2012, 7.1.2]

3.9
imperfection
quality characteristic which is for a some extent lower with respect to the level or state foreseen or a deviation from a continuous appearance of the base material not yet evaluated against a threshold level (a technical OK / not OK evaluation is not allowed)

Note 1 to entry: The term "inhomogeneity" can also be used.

Note 2 to entry: This does not mean necessarily that the product is not suitable for use. An imperfection needs to be evaluated by means of a proper scale, based on the related specifications, to decide if the product has a quality level making it suitable for the use.

3.10
shrinkage cavity
void left in cast metals as a result of solidification shrinkage

[SOURCE: EN 12258-1:2012, 5.2.10]

3.11
gas porosity
porosity caused by entrapped gas, evolution by evaporated organic release compounds, or by evolution of dissolved hydrogen during solidification

3.12
inclusion
extraneous material accidentally entrapped into the liquid metal and whose possible root causes are melt treatment procedures initiating oxidation, transported to the melt by contaminated ingot surfaces, transported into castings due to abrasion of process equipment, entrapped into the metal surface during hot or cold working

3.13
blister
raised spot whose inside is hollow, that forms on the surface of products and is caused by the expansion of entrapped gas at the opening of the die or during conditions of elevated temperature in subsurface regions, typically during thermal treatment

3.14
hot crack
crack formed in a cast metal or in a welding because of internal stress developed upon cooling at the solidus temperature or slightly above

[SOURCE: EN 12258-1:2012, 5.2.8]

3.15
cold crack
crack in cast metal initiated by mechanical stresses at temperatures significantly below the solidus temperature

[SOURCE: EN 12258-1:2012, 5.2.9]

3.16
corrosion
deterioration of a metal by chemical or electrochemical reaction with its environment

[SOURCE: EN 12258-1:2012, 5.6.14]

3.17
flash
thin protrusion into the parting surface of a die which forms when metal, in excess of that required to fill the impressions, is forced between the die interfaces

4 Classification of defects and imperfections in high pressure, low pressure and gravity die cast products

4.1 General

Defects and imperfections implemented in the present classification are metallurgy-related, i.e. directly bound to high pressure, low pressure and gravity die casting processes.

The defects and imperfections are classified using a scheme based on three levels:

a) The level I is based on morphology/location of defects and imperfections, with reference to the investigation techniques suitable for their detection (visual inspections and controls involving the bulk material): there are internal (Table 1) and external or surface (Table 2) defects and imperfections. Sub-surface defects and imperfections (i.e. so close to the surface that they can affect external aspect detectable by conventional surface investigation techniques) are considered surface defects and imperfections. Finally, the geometrical defects and imperfections (Table 3) refer to the casting shape in terms of dimensions and tolerances.

b) The level II is mainly focused on the metallurgical, physical, chemical and process-based origin of defects and imperfections. They are grouped into several classes according to their general metallurgical origin:

   1) defects and imperfections related to the presence of gas (gas-related defects and imperfections);

   2) defects and imperfections related to material volume contraction during metal solidification (shrinkage defects and imperfections);

   3) defects and imperfections related to thermal contraction prevented by previously solidified metal or by the die (thermal contraction defects and imperfections);

   4) defects and imperfections related to incorrect filling of the die-cavity (filling defects and imperfections);

5) defects and imperfections related to metal/die interaction;

6) defects and imperfections related to the presence of unsuitable phases (undesired phases), originating from the interaction of the metal with external environment during melting, pouring, casting, filling or extraction/ejection from the die.

As previously observed, the knowledge of metallurgical origin could supply starting points for corrective actions (e.g. on process parameters).

c) The level III is used to identify the specific types of defects and imperfections. Usually, the term adopted to describe a particular type of defect and imperfection allows a better definition of its metallurgical origin, which was preliminarily identified in the previous level.

NOTE Other defects and imperfections, related to subsequent operations (handling finishing, machining), have not been considered.

4.2 Classification

Table 1 — Classification of internal defects and imperfections

Level I	Level II		Level III	
A Internal defects and imperfections	A1	Shrinkage defects and imperfections	A1.1	Macro-shrinkage
			A1.2	Interdendritic shrinkage
			A1.3	Layer porosity
	A2	Gas-related defects and imperfections	A2.1	Air entrapment porosity
			A2.2	Hydrogen porosity
			A2.3	Vapour entrapment porosity
			A2.4	Lubricant and/or die release agent entrapment porosity
	A3	Filling-related defects and imperfections	A3.1	Cold joint
			A3.2	Lamination
			A3.3	Cold shot
	A4	Undesired phases	A4.1	Inclusion
			A4.2	Undesired structure
	A5	Thermal contraction defects and imperfections	A5.1	Cold crack
			A5.2	Hot tear, hot crack

Table 2 — Classification of surface defects and imperfections

Level I	Level II		Level III	
B Surface defects and imperfections	B1	Shrinkage defects and imperfections	B1.1	Sink
	B2	Gas-related defects and imperfections	B2.1	Blister
			B2.2	Pinhole
	B3	Filling-related defects and imperfections	B3.1	Cold joint, Vortex
			B3.2	Lamination
			B3.3	Cold shot
	B4	Undesired phases	B4.1	Surface deposit
			B4.2	Contamination, inclusion
	B5	Thermal contraction defects and imperfections	B5.1	Cold crack
			B5.2	Hot tear, hot crack
	B6	Metal-die interaction defects and imperfections	B6.1	Erosion
			B6.2	Soldering
			B6.3	Thermal fatigue marks
			B6.4	Ejection mark
			B6.5	Corrosion of the die

Table 3 — Classification of geometrical defects and imperfections

Level I	Level II		Level III	
C Geometrical defects and imperfections	C1	Lack of material	C1.1	Incompleteness
	C2	Excess material	C2.1	Flash
	C3	Out of tolerance	C3.1	Deformation

5 Definition of defects and imperfections

5.1 General

A short definition of each defect and imperfection is given here. Internal and surface defects and imperfections are grouped on the basis of the phenomena generating them (shrinkage, gas entrapment or development, filling, formation of undesired phases, thermal contraction, metal-die interaction).

Extended definitions, as well as morphology and metallurgical origin descriptions and representative figures/schemes for each defect and imperfection are given in Annex A, as well as possible detection and investigation methods.

Annex B collects the translations of defects and imperfections terminology from English to Italian, French, German and Spanish languages.

Annex C reports, for each defect and imperfection, the typical size and the main detection techniques.

5.2 Shrinkage defects and imperfections

— **Macro-shrinkage (A1.1)**

A relatively large shrinkage cavity with irregular shape formed inside a hot spot due to the volume contraction when liquid metal transforms into solid and not enough liquid metal flows to contrast it.

— **Interdendritic shrinkage (A1.2)**

Several cavities located in interdendritic regions formed when the liquid flow in the mushy zone is inadequate to counterbalance the metal shrinkage.

— **Layer porosity (A1.3)**

Particular case of shrinkage cavities aligned along a specific surface; typically such surface corresponds to the neutral thermal axis/surface of the casting.

— **Sink (B1.1)**

A surface depression related to the presence of a sub-surface shrinkage porosity. The thin metal layer above is not able to sustain stress arising from the contraction of the internal region and from the surrounding pressure, and it plastically deforms.

5.3 Gas-related defects and imperfections

— **Air entrapment porosity (A2.1)**

Small cavities formed as consequence of the presence of air bubbles trapped inside liquid metal. They appear as spherical or ellipsoidal cavities characterized by relatively smooth surface.

— **Hydrogen porosity (A2.2)**

Due to the abrupt reduction of atomic hydrogen solubility in the solid phase, the dissolved hydrogen recombinate to form small cavities with smooth and not oxidized surface.

— **Vapor entrapment porosity (A2.3)**

Cavities similar to air entrapment porosity caused by residual humidity on the die surface.

— **Lubricant/release agent entrapment porosity (A2.4)**

Cavities similar to air entrapment porosity caused by decomposition gases of lubricant and/or die release agent that remain trapped into liquid metal in form of bubbles.

— **Blister (B2.1)**

Small surface areas which blow up if internal pressure of sub-surface gas related porosity is high enough (it increases with temperature) to plastically deform the metal skin that covers it. It is caused by the expansion of entrapped gas at the opening of the die or during conditions of elevated temperature in subsurface regions, typically during thermal treatment.

— **Pinhole (B2.2)**

Rounded cavity usually smooth-walled of varied size, isolated or grouped irregularly, located on the surface or in sub-surface regions, and due to gas rising from core materials.