COMMON DEFECTS IN POWDER BED FUSION TECHNOLOGIES

Abstract

This document aims to present a classification for common defects found in materials processed by powder bed fusion technologies. Indeed, by studying the state of the art, it appears there is no synthetic document which proposes a classification of all defects found in parts made with this process. Thus, a classification is hereafter proposed, widely inspired by a work done in the framework of casting of aluminum alloys by Bonollo and Fiorese. The document is directly linked to the deliverable LIV-M-031-L10-508.

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Author(s	*Fonction(s) & name(s)*	*Reseach Engineer*	*Benoit TRANCHAND*
Checker(s)	*Fonction(s) & name(s)*	*Project Leader* *Quality Manager*	*Céline LARIGNON* *Stéphane BENAZET*
Approver	*Fonction & name*	*Head of Metallic Materials Department*	*Simon PERUSIN*

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1 Introduction

Additive manufacturing by powder bed fusion generates an important number of defects. All these defects are highly diverse in terms of their nature their origin, size and shape.

A bibliographic study about "*Common defects in powder bed fusion technologies*" was proposed in November 2019 (LIV-M-031-L10-508 –[1]). The following document is directly derivate from this deliverable where a classification was already proposed.

This classification will allow the organization of a defect database in the framework of the ANDDURO project. This database will be fed by defects found in the analysis made in the framework of the project such as microscopic analysis or X-Rays CT scans.

2 Method of classification and proposition of a classification

The method proposed by the IRT Saint Exupéry used hereafter (Table 1, Table 2 and Table 3) to classify defects and imperfections in powder bed fusion technologies is widely derived from the work of Bonollo et al. [2], [3] in the framework of the StaCast project, focusing on the development of new quality and design standards for aluminium alloys cast products. They would like to make more understandable the physical origin of the defects and imperfections produced during casting processes than the existing classifications [4]–[6].

The principle of this classification is illustrated in the Figure 1. Authors chose to classify defects among three levels:

1- The first level refers to the location of the defect: internal, external or geometrical. For this level, it could be noted that a subsurface defect, internal, could have consequences on the surface of the studied part. So such defect could induce surface, external, or geometrical defect. The first level will be noted with the letters A, B or C.
2- The second level refers to the physical origin of the defect. The physical origins are gases, lack of fusion (often abbreviated with "LOF"), undesired phases, balling… The second level will be noted with a number next to the letter of the first level: A1 or B3 for examples.
3- The third level specifies the second level when necessary. It allows to strongly link the formation of the defect with a process parameter.

1st Level	2nd Level		3rd Level	
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	Vapor 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

Figure 1: Extract of the classification proposed by Fiorese et al. [3] : case of internal casting defects and imperfection.

Several issues encountered for proposing this classification and then for describing each phenomenon have to be highlighted.

The main issue to be resolved for classifying is the identification of the physical phenomenon which is at the origin of the defect. As said previously, lot of studies allow the definition of a process map and identify key parameters which, if they are outside this process map, cause an increase of defect rate in the material. In most studies, the physical phenomenon linked to defects creation is not clearly identified.

Our proposition of classification is presented in the Table 1, Table 2 and Table 3. Compared to the deliverable LIV-M-031-L10-508 [1], the content of the Table 2 has been completed by a technical specification for additive manufactured parts in alloy Ti6-4 provided by Airbus [7]. Table 3 is created by compilation of the articles from Todorov et al. and Reinarz et al. [8], [9].

The description of some classes is developed in the deliverable LIV-M-031-L10-508 [1].

1st Level	2nd Level		3rd Level	
A Internal defects	A1	Gas-related defects	A1.1	Powder Induced pores
			A1.2	Vaporized alloys element
			A1.3	Inert gas entrapment
			A1.4	Hydrogen pores
	A2	Shrinkage defects	A2.1	Shrinkage defect
	A3	Lack of fusion defects	A3.1	Hatching induced LOF
			A3.2	Interlayer LOF
			A3.3	Spatter induced LOF (screening)
	A4	Cracks	A4.1	Liquation cracking
			A4.2	Solidification cracking
			A4.3	Strain-age cracking (SAC)
			A4.4	Ductility Dipe Cracking (DDC)
	A5	Undesired phases	A5.1	Inclusion
			A5.2	Precipitates
			A5.3	Oxides
			A5.4	Microstructural heterogeneity

Table 1: Classification of internal defects.

1st Level	2nd Level		3rd Level	
Surface defects	B1	Melt pool induced	B1.1	Balling
			B1.2	Spattering
			B1.3	Swelling
			B1.4	Ejected powder // Denudation
	B2	Cracks	B2.1	Residual stress induced
	B3	Surface roughness	B3.1	Powder size induced
			B3.2	Stair stepping induced
			B3.3	Sintered powder

Table 2: Classification of surface defects.

1st Level	2nd Level		3rd Level	
Geometrical defects	C1	Out of tolerance	C1.1	Stair stepping effect (inclined surfaces)
			C1.2	Deformation (stress induced- retraction)
			C1.3	Down skin surfaces collapsing
	C2	Excess of material	C2.1	Remaining support

Table 3: Classification of geometrical defects.

3 Conclusions and outlooks

Based on the work of Fiorese and Bonolo et al. [2], [3], this document proposes a classification for defects found in powder bed fusion for alloys AS7G06, Ti6-4 and 718 mainly based on the work done in the deliverable LIV-M-031-L10-508 [1].

The classification allows, by using data from the literature, to present a morphology description of the defects as well as a physical origin of the defect.

This proposed classification is the starting point for the defect database implementation in the dedicated IRT's software.

The next steps consists in implementing the previous classification in the software and fill this defects database with the project's results already achieved and to come.

4 References

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