PROPOSAL OF A CLASSIFICATION OF DEFECTS OF HIGH-PRESSURE DIECAST PRODUCTS

E. Gariboldi, F. Bonollo, M. Rosso

The paper gives an introduction to the one of the current actions of the WG "Quality of High Pressure DieCast (HPDC) products" within the TC "High pressure diecasting" of the Italian Association of Metallurgy,
The preparation and dissemination of common tools to allow foundries to define a proper, comparable, quality standard is in fact one of the current targets of this WG. The basic tool, to which this paper refers, is a common terminology and classification of defects of HPDC products.
An initial survey of literature and industrially adopted classifications of defect in components cast in metallic dies, revealed that the geometry and origin-based approaches are often mixed giving rise to a wide range of hybrid classifications.
The proposed classification of defects of HPDC products, discussed within the WG with the contribution of several foundries, is a multi-level, hybrid-type classification. In the first level defects are grouped on the basis of their position (surface/internal and geometry defects) according to the typical control operations during which they can be detected and to the effects of defects on the functionality of the parts.
The second level of the classification groups defect in classes according to their general metallurgical origin. The proposed classification doss not specify defect/cause correlations, but gives starting points to the identification of their specific causes. In order to better specify these features the analogies between the origin of internal/surface defects are highlighted by corresponding names for Level II classes: gas-related, shrinkage-related, filling-related, thermal contraction defects and undesired phases. In addition the class of metal/die interaction defects is proposed for surface defects.
The specific defects identified are those included in the third level of the classification. In the present paper an introduction to the general classes of defects defined in Level II is proposed.
The action of the WG concerning defect classification of HPDC parts will be completed with the compilation of the official document including the proposed classification and multi-language terminology equivalences.

KEYWORDS: high-pressire die-casting, defects, classification

INTRODUCTION

It is well established that defects represent a critical feature for die-cast components. Defects could be of different types and differently impair properties and functionality of components, as reported in several studies concerning Al low pressure and high pressure diecast products [1, 2, 3, 4a, 5].

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Recently the "Quality of high pressure diecast products" within the TC "High pressure diecasting" of the Italian Association of Metallurgy carried out a statistical analysis on the production of High Pressure DieCast (HPDC) aluminium components by Italian foundries [6]. The 47 foundries contributing data handled yearly a total of 193000 t of Al alloys (raw materials) with a corresponding turnover of $915*10^6$ €. Fig. 1a gives an idea of the application fields and of their relative economical importance for the Italian and for the foreign markets. In this survey, 5

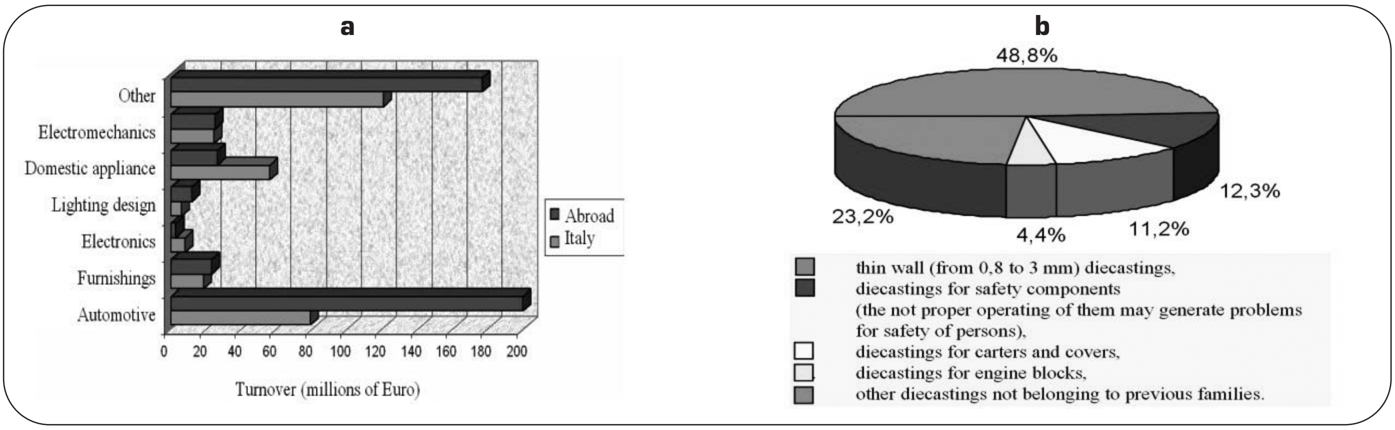

Fig. 1

a) Turnover for Italian and foreign markets for different application fields of Al-alloy HPDC products; b) Distribution of HPDC production (raw material) among the 5 family of die casting parts.[6].

a) Fatturato relativo al mercato italiano ed estero nei diversi settori di applicazione dei prodotto pressocolati in lega di alluminio. b) Ripartizione dell'Impiego di lega di alluminio nelle 5 famiglie di getti pressocolati [6].

families of die-cast products were taken into account: parts including thin sections, safety components (for example brackets), products that can be assimilated to carterss and covery to engine blocks and other components. The customer requests and controls for each product family were investigated and the results for two families are schematically presented in Fig. 2. It is clear that different geometries and typical needs for each product family lead to focus the attention on different features of the parts (for example to pressure tightness, the presence of porosity etc.) and to suitable control techniques directly or indirectly related to defects to be revealed.

A few introductive remarks on defects in cast products are needed before presenting the proposed classification of defects in HPDC products.

First, it is interesting to make some comments on the results of "round-robin" tests on the presence of defects in HPDC products for different application fields published by Brevick [7]. In this study the rejection of die cast parts during their machining step or during the following visual control and pressurized leak test was examined (Fig. 3). Even considering the specific goals and the features of interest for this experimental analysis (excluding parts damaged during machining, only the machined surfaces were taken into account for detecting defects), the investigation clearly showed that most of the defects are of metallurgical type, i.e. they are related to the melting/casting/solidification and cooling steps of the manufacturing process.

As a matter of fact, metallurgical defects are those taken into account in several classification of die-casting defects. Often they exclude other type of defects, directly related to operations following the ejection of the cast part from the die such as the removal of feeding channels and dross, to handling or machining of the parts. On the other hand, the example pro-

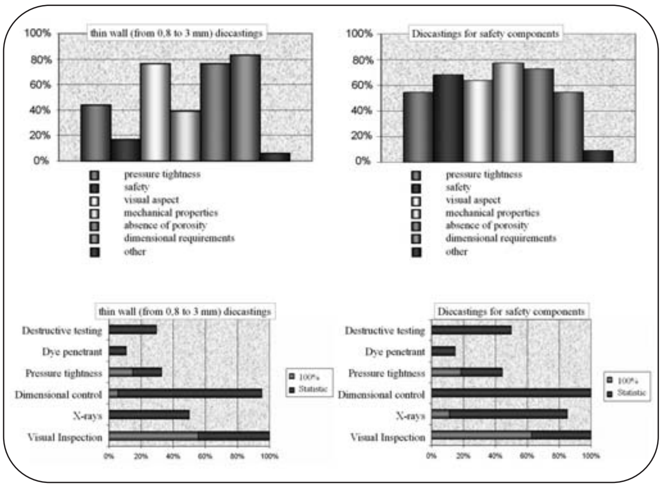

Fig. 2

Requirements (top) and control methods (bottom) for two different families of HPDC products [6].

Richieste (in alto) e controlli richiesti alle fonderie per due famiglie di getti pressocolati [6].

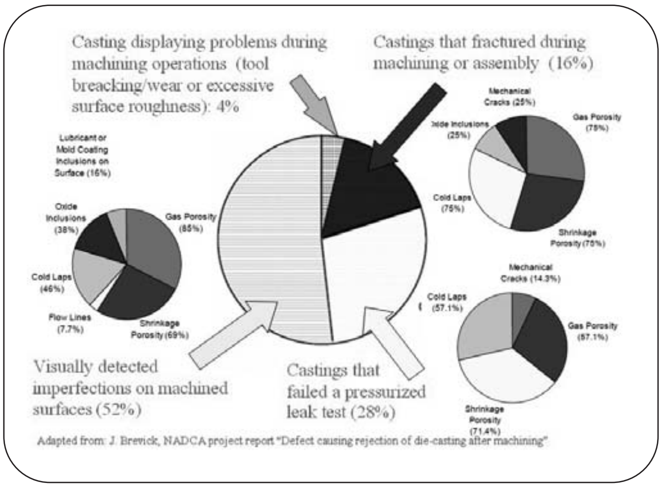

Fig. 3

Results of an analisys of the rejection causes of HPDC products [7].

Risultati di un'analisi sulle cause di scarto di getti pressocolati [7].

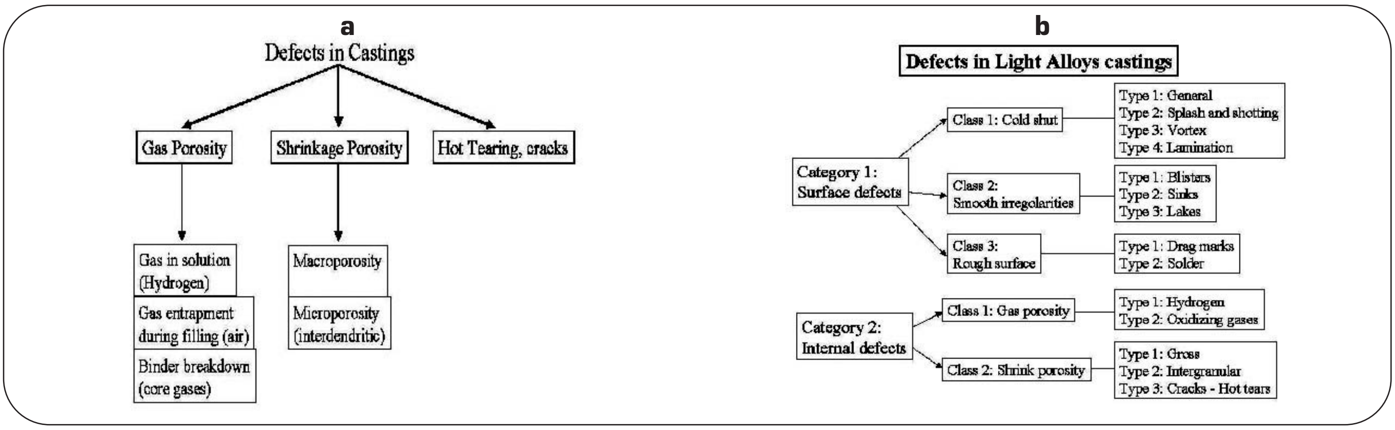

Fig. 4

Classification of casting defects according to Campbell [8] (a) and Cocks [9] (b).

Classificazione di difetti di getti proposte da Campbell [8] (a) e Cocks [9] (b).

posed by Brevick [7] shows that these operations can also bring to surface and reveal at visual controls defects of metallurgical origin.

Focusing now the attention of metallurgical defects, their list can be widened with respect to that taken into account in the previous example, including surface defects on unmachined surfaces and other internal defects, not revealed by machining operations. Internal defects are particularly critical for HPDC products since their detection and evaluation involves non destructive tests more costly and less effective that controls suitable for surface defects.

Another preliminary remark to be done before presenting defect classifications is that the analysis of defects performed on a specific production can assist a foundry to monitor quality of the produced parts, to keep a quality standard, for example by rejecting parts having defects outside specified limits. Further, the analysis of defect data can provide the foundry of useful to define information correlations between defect type/distribution and their origin so that it could be possible to define process modification to be adopted for improving quality.

Lastly, all the analyses of defect data can not leave out of consideration a fundamental step to be preliminary done: different types of defects need to be clearly identified. This will also help both foundries and customers in the following steps of identification of limits for rejection of die-cast parts.

The compilation and dissemination of common tools to allow foundries to define a proper, comparable, quality standard is one of the current targets of the WG "Quality of HPDC products". The first tool to be proposed and promoted to foundries corresponds to the above fundamental step earlier defined is a common basis of language, i.e. a terminology of defects. This is the main focus of the present paper.

SOME EXAMPLES OF CLASSIFICATION OF DEFECTS IN DIECAST PRODUCTS

The need to deal with the relatively wide range of defects that can be found in HPDC products, leads to organize them into classes (i.e. to classify them) according to specific criterions. Also the proposal of a terminology document for defect identification can not leave out their classification.

Two are the main approaches for defect classification of cast components proposed in literature or currently adopted by foundries. Defect can be distinguished on the basis of their geometry/location or on the basis of their metallurgical origin or specific causes (part geometry, cast alloy, die characteristics, die lubrication, process parameters, etc.). The main advantage offered by classifications based on the defect origin/causes approach is that strategies to be adopted in order to improve product quality can be guessed and, in the second case, directly defined. The main disadvantage of this approach is that the origin/cause of the defect must be defined concurrently to defect identification. This is particularly critical when defects are classified on the basis of specific causes, since a single defect can be due to several concurring factors. Further, this approach is less suitable for direct application in foundries with respect to geometry/position-based approaches, where specific inspections can be proposed to reveal different defect groups.

A survey of proposed defect classifications of cast products, some of which more general, other specifically developed for an alloy class or for die-casting or even more specifically for the HPDC process, [4b, 8-11] was done. Examples of two defect classifications are presented in Fig. 4. In addition to literature references, also customer or foundry specifications for aluminium alloy castings were taken into account. It was observed that generally the two approaches earlier described were mixed in different ways, generating a wide range of hybrid classifications. It was also observed that geometry defects such as distortion, bending, regions out Of tolerance, were included in defect classifications when of metallurgical type.

CLASSIFICATION OF DEFECTS FOR HPDC PRODUCTS PROPOSED BY THE WG "QUALITY OF HPDC PRODUCTS"

On the basis of the previous comments on the presence and classification of defects in cast products and on the specific targets of the WG, a new defects classification was elaborated.

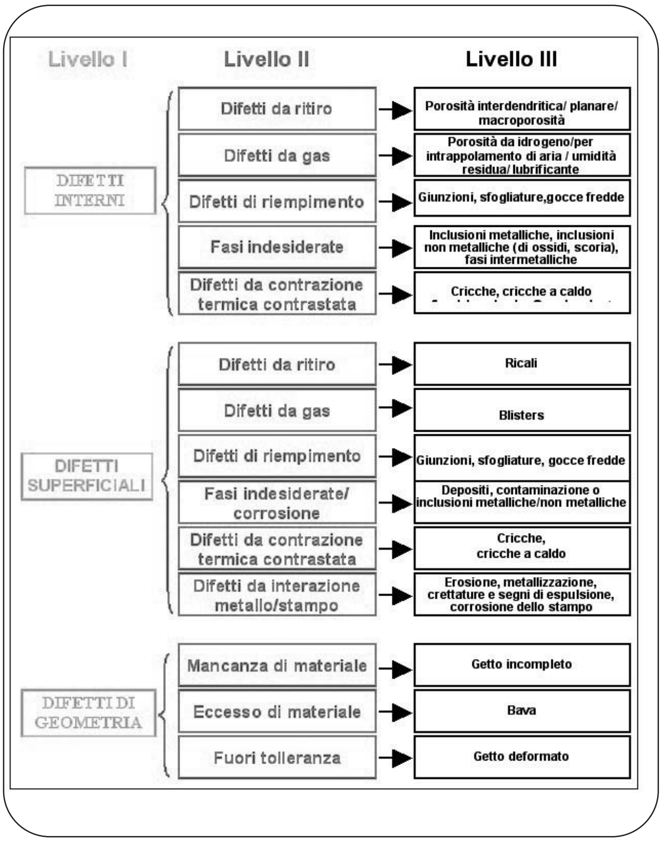

Fig. 5

Proposed classification of HPDC defects (Italian version).
Classificazione proposta per difetti in getti pressocolati (versione italiana).

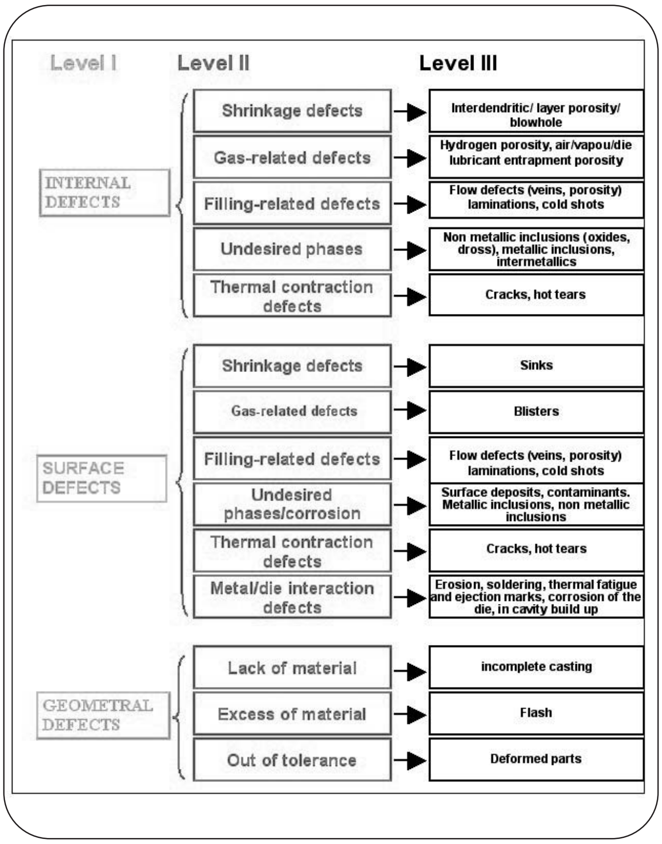

Fig. 6

Proposed classification of HPDC defects (English version).
Classificazione proposta per difetti in getti pressocolati (versione inglese).

The guidelines for the classification were presented in April 2006 [12] and the classification was better defined by the WG in the following year with the precious contribution of several foundries. The proposal refer to metallurgically-based defects of HPDC products. Defects directly related to handling, finishing, machining operations following ejection from the die were excluded from the classification, even if it is well known that they could be possible causes for product rejection. In this way the range of defect type was not excessively widened.

The present classification of HPDC defects is of hybrid type and multi-level, as schematically shown in Fig. 5 and 6. In the first level (level I) the defect geometry/location approach is followed, taking into account the different types of controls performed on cast parts to reveal defects: dimensional, visual inspections and controls involving the bulk material. Thus three wide groups of defects are defined in level I: geometry, surface and internal defects. Sub-surface defects are included in surface defects when they are so close to the component surface to affect surface features and to be detected by surface control methods.

Level II is based on the defect origin approach. Defects are grouped into several classes according to their general metallurgical origin:

• defects related to the presence of gas (gas-related defects);
• defects related to material volume contraction during metal solidification (shrinkage defects);
• defects related to thermal contraction prevented by previously solidified metal or by the die (thermal contraction defects);
• defects related to incorrect filling of the die cavity (filling defects);
• defects related to metal/mould interaction (metal/die in the specific case of HPDC process)
• defects related to the presence of phases different from the suitable ones (undesired phases), originated by the interaction of the metal with external environment during or related to melting, casting, filling or extraction/ejection from the mould/die;

As previously observed, the metallurgical origin taken into account in level II is of general type and it is not directly related to the specific causes of the defects. Nevertheless, the knowledge of metallurgical origin could supply starting points for corrective actions (including alloy/die process parameters). For this reason, a clear correspondence between classes of defects in internal and surface defects was considered useful and the same names were given to analoguous Level II classes of internal and surface defects.

As far as geometry defects are concerned, a geometry approach was followed also for Level II. and excess or lack of material as well as other unsuitable geometries were considered as different classes.

The exact terminology and definition of each defect is given in level III. Frequently the term adopted for the single defect in Level III better specifies the metallurgical origin of level II. In a few cases, the presented terms correspond to those adopted

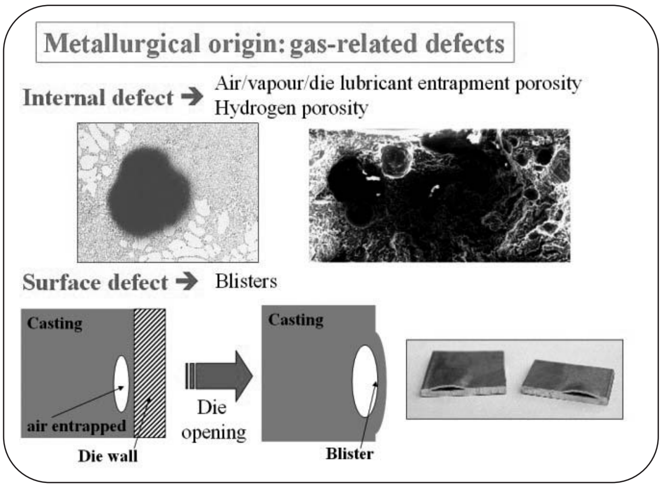

Fig. 7
Example of gas-related internal and surface defects.
Esempi di difetti interni e superficiali legati alla presenza di gas.

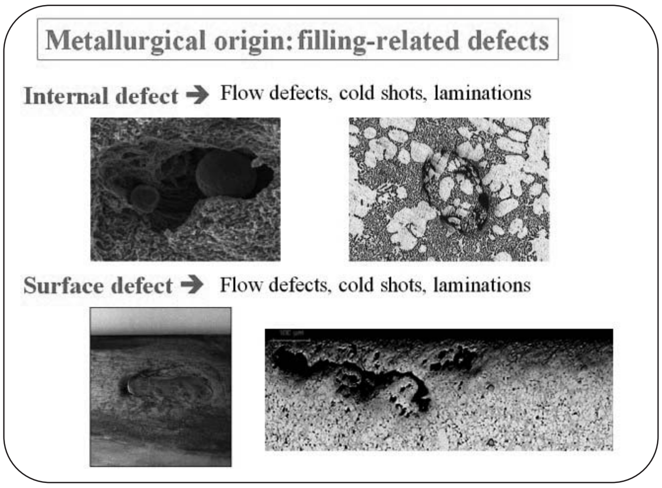

Fig. 8
Example of filling-related internal and surface defects.
Esempi di difetti di riempimenti interni e superficiali.

in European standard EN 12258-1 (when ever applicable) [12]. The final document on the classification, now in progress, will include terminology in different languages, a short description for each defect with illustrations and reference macro/micrographs to help readers and foundries in identification of defects found in cast parts.

WHAT DOES A METALLURGICAL-ORIGIN APPROACH FOR LEVEL II MEANS?

It has been already explained that level II (and partly level III) are based on the metallurgical origin of defects. Since the same metallurgical origin can lead both to internal/surface defects, parallel Level II classes are given for these two groups of defects. These classes will be now presented focusing on the above features without the aim of completing defect description or considering all defect that could be found in HTDC parts.

Gas related defects

This class of defects are discontinuities formed when gas is in solution into molten metal or when, for different reasons, this latter contains gas bubbles. The gas-related internal and surface defects will now be presented, stressing their common metallurgical origin.
Internal gas-related defects are spherical or round-shaped cavities (often known as porosity for their small size) characterized by their smooth surface. Four different gas-related defects are proposed in Level III (Fig. 7).
Hydrogen porosity. When gas (typically hydrogen) is dissolved into molten metal, discontinuities originated during solidification due to the abrupt reduction of gas solubility in the solid phase/s. In fact, gas rejection from the solid metal causes gas concentration and bubble formation during solidification of the surrounding metal. Cavities are rather small and homogeneously distributed.
Air entrapment porosity. It forms when air bubbles remain trapped in the liquid metal. This is the most frequent gas-related defect in HPDC products. Air bubbles can form in turbulent liquid metal vein either when it is in the shot sleeve, in filling channels or inside die cavity.
Vapour entrapment porosity. Residual humidity on the die surface become vapour when it comes into contact to molten metal and then becomes trapped into it.
Die-lubricant entrapment porosity. It forms when 'uncontrolled' lubricants combustion occurs as die-lubricants directly come into contact with molten metal and its combustion products become trapped into it.
The morphology and spatial distribution of defects as well as their brightness, colour and/or the presence of oxides on their surfaces can suggest the gas causing their formation.
Gas-related surface defects are commonly known with the term **blisters**. These consist in small surface areas that blown up when the internal pressure of sub-surface gas-related porosity plastically deformed the thin metallic surface layer covering it (Fig. 6). The metal deformation occurs easily at relatively high temperatures, at which the metal yields under relatively low stress. This could happen both as the cast is ejected from the die or during following heat treatings, Similarly during heat treatings of coated cast parts, gases can flow out of the metal and the coating can blow up. This latter phenomenon, sometimes referred as outgassing, in the present classification is considered as blister. Thus, blisters represent a typical example of defect of metallurgical origin that can be revealed or emphasized by following operations during the manufacturing process.

Filling defects

The filling-related defects are caused by anomalous liquid metal flow. During filling of the die cavity, liquid or partially solidified metal veins at different temperatures and sometimes covered by oxide films can incorrectly come into contact (in some cases even with completely solidified metal) causing metallurgical inhomogeneities. The degree of imperfect metallic continuity can vary according to specific situations and it is particularly low when oxide films separate the solidifying flows. For these reasons, filling-related defects can be revealed when even limited mechanical stress is applied, such as for example during machining operations. Depending on their final location, these defect can result as surface of internal defects, but substantially remains of the same type. For this reason the same terms were adopted for level III: flow defects, laminations, cold shots (Fig. 8).

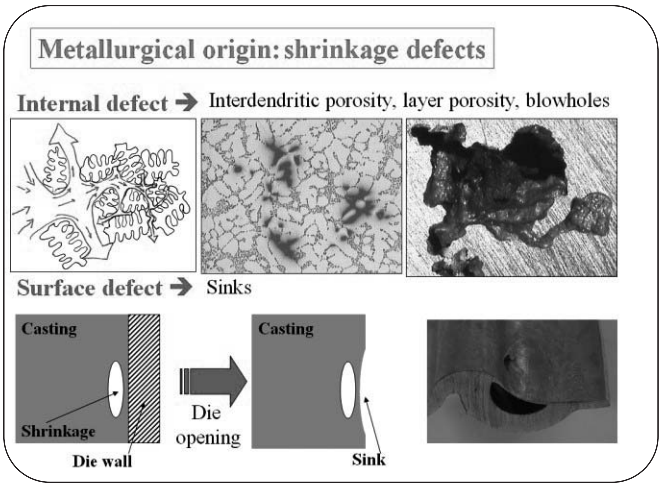

Fig. 9

Example of shrinkage-related internal and surface defects.

Esempi di difetti di solidificazione interni e superficiali.

Flow defect. This defect forms when a relatively cold metal portion, at least partially solidified and in some cases covered by an oxide film meets another warmer metal vein that can flow around it. When the flows meet close to the surface they give rise to a wrinkled surface or to linear depressions due to the deformation of the cooler and more viscous flow. In the present classification the term "flow defect" is adopted also for defects that are separately identified in other classifications (for example they could be referred in some cases as veins). In fact, the appearance of the defect can vary depending on the conditions of the metal flows at the moment of their confluence and on their location,

Lamination. This defect, often considered only as a surface defect, consists in a thin surface metallic layer having a separation surface form the bulk metal almost parallel to the component surface and with imperfect adhesion to the inner metal. Laminations form when a relatively warm metal vein flows between a cooler one and the die, also as a result of irregular movements or deformations of the die.

Cold shot: It forms when a small portion of molten metal accidentally comes into contact to the die and rapidly cools. Its rapid solidification leads to a finer microstructure with respect to that of the surrounding region, from which it could also be separated by a thin oxide layer. In any case the presence of a cold shot means an at least partial microstructural discontinuity with respect to other regions of the cast. In some cases the metal flowing into the die can cause detachment of some of these rapidly solidified regions and can drive them inside the cavity, without completing their melting. Thus, cold shots can also be internal defects.

Shrinkage defects

Shrinkage defects are metal discontinuities that form as a result of the volume contraction during solidification in regions where local metal filling is insufficient or even absent. This occurs in regions which are locally the last to solidify (hot spots). Such regions are often well inside the cast part, but in some cases they are so close to the die surface to give rise to surface defects. When shrinkage defects are of internal type, they can be either in the form of interdendritic porosity, **layer porosity or blowholes**, depending on their size and location. In the case of surface defect, they are termed sinks. Some representative examples of these classes of defects are shown in Fig. 9.

Interdendritic porosity: Interdendritic porosity forms when liquid metal can not adequately flow inside interdendritic regions. The resulting small-size discontinuities are interconnected and can affect pressure tightness.

Blowhole: It is relatively large shrinkage cavity, formed at hot spots. Its dimensions are related to the volume of the unsuitably filled region. Blow holes are characterized by rough and spongy surfaces for the presence of emerging dendrites as a consequence of the interrupted growth. Blowholes can also be surrounded by interdendritic porosity.

Blowholes and interdendritic porosity can be considered as the extremes of a continuous range of defect sizes and distributions, that depends on a combination of factors including the alloy on one side and geometry/process parameters on the other. In many situations the identification of the particular shrinkage defect can be ambiguous.

Layer porosity: In this case shrinkage defects are aligned along the neutral thermal axis/surfaces of a cast components. These surfaces can be locally approximated as planes where the component thickness is far smaller than other dimensions. Solidification fronts converge along these surfaces and liquid metal can not efficiently flow within dendrites in the mushy zone, forming series of shrinkage discontinuities which can appear aligned on proper metallographic sections.

Sink: It is a surface defect that occurs when, during the cast solidification, an hot spots localizes close to the metal/die interface. This could be for example the case of component with relatively wide plane surfaces or with internal corners. Thin metal layer (skin layer) that rapidly solidified when metal came in contact to the cooler die is not able to sustain stresses arising from the contraction of the sub-surface solidifying region and it deforms (sinks) toward the interior of the cavity (see Fig. 9).

Thermal contraction defects

These defects consist in cracks formed during solidification or cooling to room temperature when tension stresses arising for the material contraction resulting from solidification or cooling exceed UTS at the local metal temperature. In the two cases defects are termed as hot tears and cracks, respectively. These terms in Level III are the same for internal and surface defects since in general a single defect can be accounted both as surface and as internal defect.

Crack: This defect forms at relatively low temperature (far from the solidification range) where the greater thermal contraction of the cast with respect to the die is prevented by a particular part/die geometry. Tension stresses generated into the cast component can locally reach relatively high values, causing cracking. Cracks originated from ejection or handling operations can not be included in this kind of defect.

Hot tear. This type of defect arises when local UTS is exceeded in the solid portions of solidifying metal (often the last solidifying regions).

Both cracks and hot tears often occur in regions of stress localization, either due to macroscopic geometrical reasons or to the presence of previously formed microstructural defects (as, for example, gas-related or interdendritic porosity).

Undesired phases

The surface or the bulk material of HPDC parts can reveal the presence of phases different form the desired ones for each

region: i.e. a thin layer of greyish aluminium oxide on the surface, and a suitable microstructure according to the cast alloy. Most of the types of undesired phases are of surface type. In other cases they can be both internal or surface defects, depending on their location.
Most phases are undesired mainly for their higher hardness, stiffness, brittleness and for the fact that they create microstrctural discontinuities, resulting as crack nucleation sites or becoming part of the preferred crack path (either when the crack has a metallurgical origin or as it occurs after die-casting operations, such as for example during service). Particularly undesired phases, often in the form of small internal/surface particles, are **non metallic inclusions** (including oxides, dross). Also **intermetallics** or **metallic phases** can be some times indentified as undesired phases.
Other types of undesired surface phases can be revealed at visual inspections by unexpected colours. Among these defects are: **contaminations** and **deposits**. They refer to layers of non-metallic substances of variable thickness, adhesion and local distribution, deposited during die-casting operations. More specifically, contaminations defects are signs of an interaction of the metal with the environment or with particular substances to which it locally comes in to contact One typical example of deposit is the excess of die-lubricant transferred from the die to the cast part.

Metal-die interaction defects

This Level II class of defects exists only for surface defects and it includes a set of unsuitable surface morphologies caused by the interaction of the metal with the steel die. Most of these defects are a direct consequence of geometry modifications of the die surface and they are termed according to the degradation phenomenon occurred to the die: erosion, soldering, thermal fatigue marks, corrosion of the die, in cavity build up (Fig. 10).
Thermal-fatigue marks. These marks are a set of small net-textured reliefs, sometimes referred also as crocodile skin. They form from correspondingly thermal fatigue cracks on the die surface.
Soldering. These defect consist in a localized lack of material on the cast component as a consequence of the formation of relief zones made of adherent intermetallic phases (Al-Si-Fe) and of aluminium alloy progressively layered over them (and sometimes partially/locally detace). Soldering often occurs in region of the die exposed to liquid metal at relatively high temperature and flow rates.
Erosion. This defect is caused by a progressive removal of the material from the steel die by erosive wear, which reflects in regions of excess material in the cast parts. The die erosion is generally more relevant in regions of the die where the liquid metal flows at particularly high flow rate and temperature erosion. It can also occur by cavitation (implosion of gas bubbles) at the die surface.
Corrosion of the die. This defect consists in surface roughness of the cast product resulting from a corresponding die surface attacked by the environment (corrosion phenomena).
In cavity build-up. Die lubricant or calcium carbonate can remain on the die and progressively accumulate (build-up) causing poor finishing of HPDC products.
Ejection mark: These are localized regions of the cast part plastically deformed in the ejection direction. They are often due to undercuts as a result of modifications of the geometry of the die or of the cast part (for example by one of the previously described erosion/soldering phenomena). The term

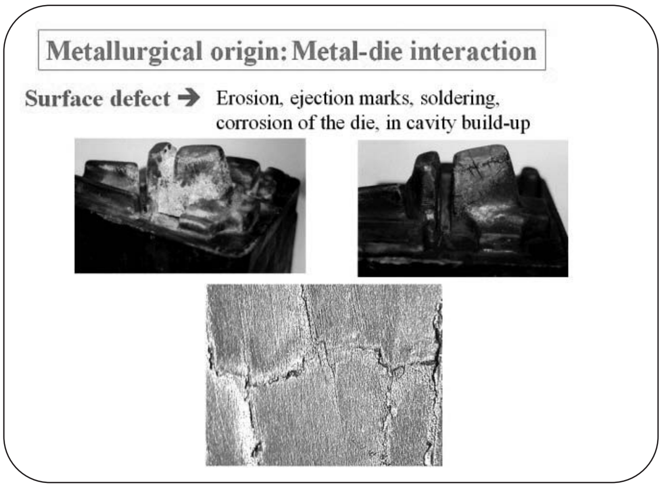

Fig. 10
Example of metal/die interaction surface defects.
Esempi di difetti superficiali di interazione metallo/stampo.

"ejection marks" does not refer to the marks left on the component in the locations of the ejector pins and due to their incorrect geometry/position. These latter kind of defect are considered as geometry defects.

CONCLUSIONS

The paper gives an introduction to one of the current actions undertaken by the WG "Quality of HPDC products" within the TC "HPDC" of the Italian Association of Metallurgy, concerning the classification and terminology of defects of HPDC products.
An initial survey of literature and industrially adopted classifications of defect in parts cast in metallic dies, revealed that the geometry-based and origin-based approaches are often mixed creating a wide range of hybrid classifications.
The proposed classification of HPDC products, discussed within the WG with the contribution of several foundries, is a multi-level, hybrid-type classification. In the first level defects are grouped according to their position (surface/internal and geometry defects) following the typical inspection operations during which these defects can be detected and considering the effect of defects on the functionality of the components. The second level of the classification groups the defects into classes according to their general metallurgical origin. In this level analogies between the origin of internal/surface defects are highlighted. The proposed classification does not specify cause/defect correlations, but suggests starting points to the identification of specific causes. In order to better specify these features, the general classes of defects defined in level II were presented in the present paper. The specific defects taken into account for this classification are those identified in level III, where metallurgical origin is often more precisely specified by the adopted terminology.
The action of the WG concerning defect classification of HPDC parts is still in progress with the definition of the multi-language terminology equivalence and with the compilation of the official document including the proposed classification and terminology translations. For further information, suggestions and contributions, contact The authors of the present

paper writing to the Italian Association of Metallurgy at info.aim@aimnet.it (refering to "HPDC defeca classification").

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ABSTRACT

PROPOSTA DI UNA CLASSIFICAZIONE DI DIFETTI DI GETTI PRESSOCOLATI

Parole chiave: pressocolata, difetti, classificazione

La memoria presenta l' attuale stato di avanzamento di una delle azioni intraprese dal Gruppo di Lavoro Qualità dei getti pressocolati, attivo entro il Comitato Tecnico AIM "Pressocolata", tra i cui obbiettivi generali si colloca quello di predisporre degli strumenti comuni perché le fonderie possano definire e proporre un proprio standard qualitativo. Tra questi strumenti è compresa anche una comune definizione e classificazione dei difetti, oggetto della presente memoria. Dopo una disamina delle proposte in letteratura, è stata elaborata e presentata una prima classificazione dei difetti di origine metallurgica riscontrabili nei getti pressocolati. Essa è stata successivamente discussa all'interno del GdL, con il particolare coinvolgimento delle fonderie. Ne è risultata ciò che costituisce la parte centrale della memoria.
La classificazione è di tipo ibrido e multi-livello. I difetti vengono infatti classificati in primis secondo la loro posizione (difetti superficiali, difetti interni, difetti di geometria), in relazione alle fasi del controllo in cui possono essere riscontrati e ai possibili riflessi sulle caratteristiche funzionali dei getti. A questo primo livello di classificazione ne segue un secondo, che identifica diverse classi di difetti correlandoli alle cause metallurgiche che li originano. La classificazione proposta non consente di risalire direttamente alle cause tecnologiche specifiche del singolo difetto (e da qui alle soluzioni), ma vuole offrire un orientamento nella loro individuazione. Per questo motivo sono state individuate nel livello II classi parallele di difetti interni e superficiali per la comune origine metallurgica: difetti da gas, da ritiro, di riempimento, da contrazione termica, fasi indesiderate. In aggiunta alle precedenti classi, tra i difetti superficiali è stata definita anche quella relativa all'interazione metallo/stampo. Nel terzo livello sono identificati i singoli difetti considerati nella classificazione. Laddove possibile, la terminologia utilizzata per essi specifica meglio la loro origine metallurgica rispetto a quanto già definito nel livello II.
L'azione del GdL ora presentata è tuttora in corso con la definizione delle equivalenze dei termini in più lingue e la redazione del documento ufficiale contenente la classificazione.