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Improving X-Ray Assessment of Internal Defects Using Filters for Digital Image Processing

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Abstract
Non-destructive testing (NDT) is an essential solution for assessing the integrity of industrial parts without compromising their utility. In this study, the use of X-ray radiographic technique for the evaluation of internal defects in lightweight alloys was investigated, with emphasis on the application of image processing filters. In particular, the performance of the Flash! Filter, a tool integrated into the Rhythm Review software designed to reduce noise and improve contrast was implicated. The study focused on AlSi12(Cu) alloy die-casting parts with wall thicknesses between 3.5 and 13.0 mm. The results showed that the use of the Flash! Filter allows more accurate detection of porosity and cold fill defects, ensuring correct classification according to ASTM E-505. The images processed with this filter showed a significant reduction in background noise and an increase in contrast compared to the raw images, contributing to a more detailed assessment of discontinuities. In addition, the application of the Laplacian filter highlighted the boundaries of the defects by analyzing sudden density changes.

Keywords
X-ray, Flash! Filter, porosity in Al-alloy

1. Introduction

Industrial processing of metallic materials requires reliable methods to ensure product quality, durability and compliance with safety regulations, often involving product integrity assessment [1, 4]. Non-Destructive Testing (NDT) techniques are the best approach for components inspection without compromising their usability or functionality. Furthermore, these techniques offer additional advantages, including cost-effectiveness by reducing waste and avoiding failures [2] with potentially serious consequences such as in the aerospace, automotive and energy industries [3]. X-ray radiography along with visual, ultrasonic, dye penetrant and magnetic particle inspections are integrated as NDT methods. X-ray inspection has the advantage of being a quick-response method, particularly for Al-alloys due to their low density enabling easy penetration of the high-energy electromagnetic radiation.

A critical aspect of components evaluation when using X-ray radiography at industrial scale is the sharpness of obtained images. A well-defined X-ray image allows an accurate assessment of internal defects, ensuring the identification of small inclusions or porosity. In this purpose, parameters such as X-ray penetration energy, exposure time, detector sensitivity, noise reduction and contrast improvement filters for image processing have a fundamental role in optimizing image quality [4, 5].

Researchers are still interested in finding the best combination of methods so that the X-ray image to be the best reflection of reality using robust deep neural networks, self-attention guided model or Gaussian denoising filters [5 - 8].

The aim of the present investigation is to determinate the impact of Flash! Filter image processing usage on the internal defect evaluation of some Al-alloy components, with the focus on how is influencing the right and correct interpretation of specific die-casting defects. The main aspects of its functionality are included in Table 1 [9].

Internal defects were classified in severity level according ASTM E-505 and also measurements of defects areas were included. The study highlights the need to use noise reduction and contrast magnification filters in X-ray investigation to fulfil product quality requirements.

Table 1. Main aspect of Flash! Filter functionality

Aspects	Details
Type of image processing	Multi-scale enhancement: This involves analysing the image at multiple levels of detail. It does not modify or remove the raw image data, but rather simply adjusts its presentation for easier interpretation.
Purpose and benefits	Fast optimization (1-3 seconds) for easier visual defect detection. Reduce analysis time and simplify workflow. Increase Probability of Detection (POD) by clarifying details.
Key Technical characteristics	Unlike other methods that can add or remove detail, Flash! Filter maintains the raw data, only changing the way it is visualized. One-click for automatic image optimization.

2. Material and Methods

In order to evaluate the internal defects by X-ray, a number of five flange-type die-casting parts made of AlSi12(Cu) alloy were investigated. Their wall thickness is between 3.5 ÷ 13.0 mm. These parts were provided from serial production of a local die-casting company.

Non-destructive testing was carried out using a Seifert X-Cube Compact equipment build by General Electric (GE). Even the maximum penetration capacity is 160 kV [10], for the present study were used values between 55-65 kV depending on the wall thickness of the casting part. VISTAPLUS system allows to operate the image optimisation with Flash! Filter, Gray, LUT or arithmetic filters (e.g. Laplacian) and also measuring the internal defects.

The Flash! Filter instrument used for improving quality images of metallic parts by X-ray evaluation ensure noise reduction and contrast enhancement, making the internal defects more visible. It is a module for Rhythm Review Software designed for NDT radiographic inspection, being dedicated for casting and welding parts evaluation.

Internal defects evaluations were graded according to ASTM E-505-22. This standard is a guide enabling recognition of discontinuities in die-casting parts of Al- and Mg- alloys. Radiographs references illustrated in the standard are rated as type (porosity, cold fill, shrinkage, foreign material) and severity level (1 to 4) depending on the wall thickness of die-casting part [11].

3. Results and Discussion

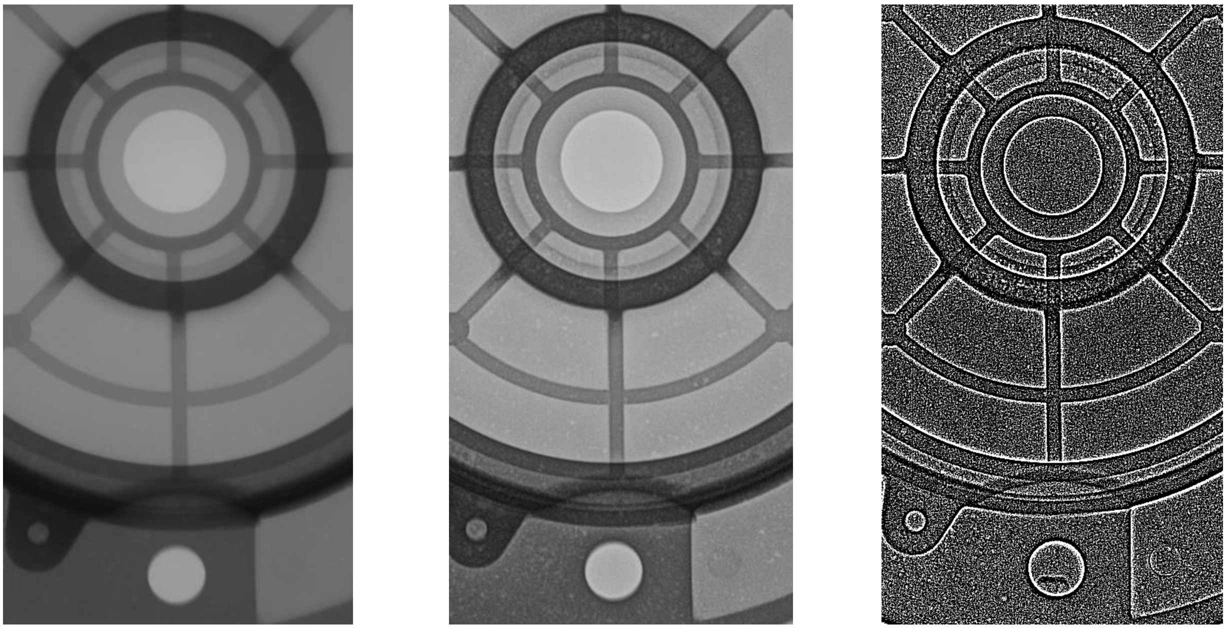
Using a penetration capacity of 60kV, in Figure 1 are shown different digital images of a flange-type die-casting part made of AlSi12(Cu) alloy with and without image processing filters.

In Figure 1(a) it can be seen a quite blurred or noisy image when the filter for digital image processing isn't used. Some porosity can be observed in small amounts in (a) and in much larger amounts and areas in (b). Arithmetical image filtering by Laplacian analysis is used for edge sharpening and boundary detection. As can be seen in Figure 1(c) this filter highlights areas of sudden density change that exhibit highest contrast. The use of digital image processing filters have a strong impact on quality assesemnet of internal defects.

In Table 2 are indicated the occurrence and evaluation of internal defects as porosity and cold fill for all five sample parts. The numbers from this table indicate how many parts have a certain severity level from the total parts checked. After data analysing it can be concluded that without noise reduction and contrast enhancement filters as Flash! Filter some defect would have remain undetected, furthermore the severity level was decreased. Using filters for digital image processing it can reveal defects that were not visible before. Without image filters porosity of severity level 2 was classified as severity level 1.

Four of some internal defects' measurements are indicated in Figure 2. Porosity and cold fill defects were classified according to ASTM E-505 depending on the wall thickness of the sample part. This standard illustrates radiographs references and severity level of internal defects that may appear in die-casting Al-alloy parts.

Internal defects dimensions were measured on these processed digital images with values between 20.78 ÷ 0.89 mm^2.

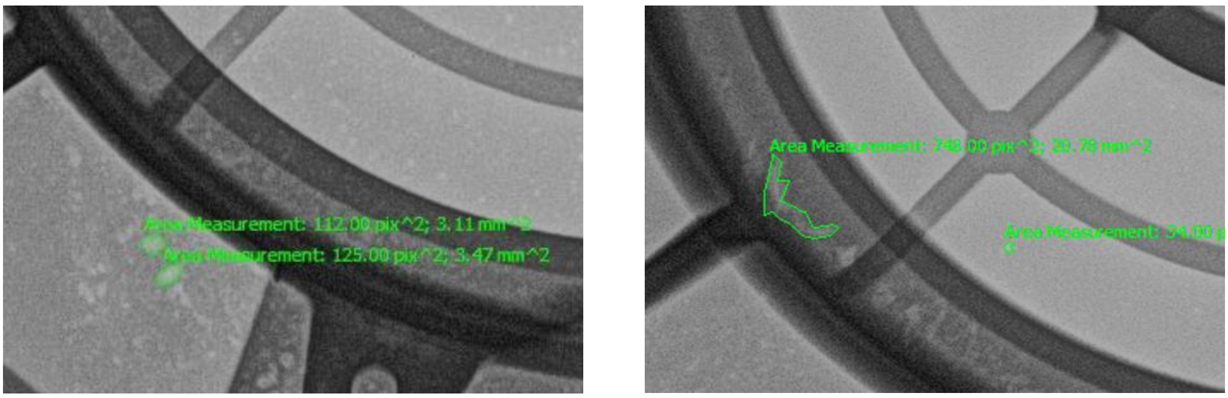


a) b) c)

Fig. 1. X-ray images of porosity in a flange-type die-casting part made of AlSi12(Cu) alloy at the same penetration capacity: a) without filter, b) with Flash! Filter, c) with Laplacian filter

Table 2. Evaluation of internal defects by type and severity in each part

Porosity	with Flash!Filter	without filter	**Cold fill**	with Flash!Filter	without filter
Severity level 1	5/5	4/5	Severity level 1	1	2
Severity level 2	4/5	2/5	Severity level 2	2	1
Severity level 3	2/5	0/5	Severity level 3	1	0
Severity level 4	0/5	0/5	Severity level 4	0	0



a) b)

Fig. 2. X-ray images of internal defects measurements using Flash! Filter for wall thickness between 3.5÷9.5 mm

a) porosity at severity level 3; b) cold fill at severity level 3

The application of digital filters, such as Flash! Filter not only improves the visibility of internal defects, but also helps optimize the manufacturing process. By accurately detecting of porosity and cold fill defects, engineers can adjust die-casting parameters such as temperature, plunger velocity or injection pressure to reduce the incidence of these issues. This proactive approach helps prevent material waste and increase process efficiency, thereby reducing production costs and improving the quality of the end product.

4. Conclusions

Non-destructive testing techniques are essential for quality and safety assurance in critical industries, providing effective solutions for detecting of internal defects without compromising product integrity. The correct identification and classification of defects, such as the severity of the porosity level, has a direct impact on the reliability of aluminium alloys components.

The use of Flash! Filter minimizes the risk of underestimation of internal defects evaluation. For example, porosity defects that were initially rated at severity level 1 were reclassified to level 2 when the image processing was applied. Therefore, it confirms their importance for a correct defects analysis.

By improving defect visibility and detectability, Flash! Filter allows qualified operators to accurately identify and classify defects according to ASTM E-505 guidelines, providing an objective and reliable evaluation.

This paper emphasizes the importance of using noise reduction and contrast enhancement filters, as well as exploring advanced technologies for accurate representation of internal defects.

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