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# Automatic Surface Defects Detection in Castings

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**Abstract: Researchers have introduced a new technology for detecting the surface defects in the aluminium die casing which is a camera based vision system. The issue of surface defects in casting aluminium die is prevalent across the foundry industry and their identification is of utmost importance in maintaining the product quality. The casting surfaces are the regions of materials and components that are most loaded. The impact of corrosion and the loads which are introduced thermally and mechanically are mainly directed at the castings surface. Castings may develop surface discontinuities such as cracks or tears, inclusions due to chemical processes or foreign material in the molten metal, and pores that greatly influence the material's ability to withstand these loads, depending on the processing techniques and part design. Surface defects can serve as a concentrative stress inducing a point of fracture. In this area, if a pressure is applied, the casting can fracture. The human visual system is well suited for success in environments of variation and change; on the other hand, the visual analysis systems involve regular examination of the same picture type to spot abnormalities. It usually results in long, costly, inconsistent inspection. Computer-based visual inspection presents the human inspectors with a viable alternative. Machine vision system developed by authors uses an image processing algorithm based on updated edge detection method by Laplacian of Gaussian to identify defects in different sizes and shapes.**

**Keywords: Aluminium Die Castings, Casting defects, Inspection, Image Processing, Non-destructive testing.**

## INTRODUCTION

Aluminium alloys (Fig. 1) are commonly used in all fields of technology, especially in aircraft, road and rail communication, in the maritime, chemical and machinery building industries. The casting process will result in internal discontinuities such as fractures, blowholes, porosity of the shrinkage and porosity of the gas etc. The existence of these flaws is often the source of casting rejections, because they deteriorate the mechanical properties, causing casting walls to lose their stiffness and, as a result lower the quality of the surface linked together. The classic structural elements which are highly sensitive to the quality of the surfaces joined include: front faces of the cylinders in the engine body, piston of the cylinder and the handles of the transmission systems. Their quality and functionality is a critical factor in operating without failures. In addition, small sizes of pores cause different difficulties when it comes to exposing the presence of defects in castings using non-destructive inspection methods. Therefore, the identification and analysis of surface defects in goods is among the most critical and difficult to solve production quality issues in many industries.

The project aims to create a computerized system to determine the consistency of aluminium castings, while opening up new science and analysis resources and creating opportunities to better understand the processes that follow the development of surface defects in castings. This will lead to a better understanding and scientific investigation of factors limiting the process of casting aluminium parts. Such studies will help in future efforts to eliminate surface defects early on [1].

**Figure 1: Examples of Aluminium Castings**

Therefore, particular significance benefits the possibility of creating a relatively easy system to detect the defects in castings after machining, removing their negative post-effect during service and maintaining a clear backflow of knowledge about the nature and sort of defects from the casting customer to the castings manufacturer. The widely employed methods based on visual examination of the inspected part's surface appearance are ideal only in the manufacturing region with varied variety and short lots of manufactured products, and as such are distinguished by the high cost and outcome that largely depends on the human factor.

Constructing an incorporated vision system for inspection and online control will provide a basis for the development of this type of industrial equipment, the use of which can bring significant benefits by improving the quality and economy of a significant part of the engineering and automotive manufacturing [2].

*Present state of Knowledge:*

In recent times the search for defects on the surface of cast aluminium engine blocks (Fig.2) has presented different solutions. One is the method of ultrasonic assessment of the degree of porosity in aluminium alloy castings. This approach is focused on coefficient damping and ultrasonic wave velocity measurements [3]. Changes in the intensity of these attenuation waves contain information about the causes for their frequency. The method's key drawbacks include the size and shape of the defects and their position, rendering the approach less reliable.

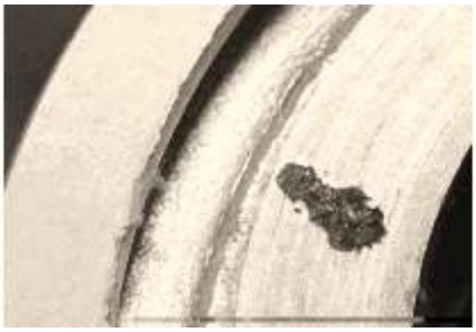

**Figure 2: Example of Surface Detect**

The issue of determining defects in aluminium castings is a widely understood feature of defects in the foundry industry which is considered to be the most important element in the consistency of such items in development. There is a large group of cast pieces, which are exposed to heavy working loads during service, rendering the job of ensuring high quality of the joined surfaces in these devices one of paramount importance. Sadly, as a consequence of the activity of thermal, mechanical and corrosive impacts, these materials are subject to various surface defects.

The presence of defects in castings is an important factor despite significant progress in controlling and monitoring processes. This is especially true in the case of defects that only become apparent at the premises of the customer, after removing an outer layer of the casting skin during most of the machining process, rarely during procedure. Frequently, especially in the case of mass production, the examination carried out in the foundry does not have the possibility to investigate all castings for the incidence of internal defects, and therefore the condition is rather unavoidable to have them revealed by the consumer.

That is why very unique value has the opportunity to create a relatively easy way to detect defects in castings after machining, which will reduce the adverse effects of their occurrence during service, while at the same time ensuring a clear backflow of knowledge on the nature and sort of defects from the consumer to the castings manufacturer. Defect Prevention comprises of 4 stages: detection, identification, introducing the cause and finding the solution to eliminate the defect sources. The first two stages occurred at the place where the castings' machining are performed.

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Near about 40 to 60 kinds of detects were identified, wherein the internal defects exists in various different forms, shape and size which are not filled with the metal or voids in the form of contaminating metal which are the most critical. This comprises of the defects like: “Blowhole” with smooth sides, reflecting a metal void, round or oval form. Blowholes may occur at various casting pieces, typically in groups. There are two main reasons why blowholes are formed: gas emitted from the sand mould or heart, and gas emitted from the metal (rarely) during solidification [4]. "Shrinkage cavity" reflecting a metal void usually conical or cylindrical in form, often with irregular (very rough) coarse-crystal coating [5]. This occurs as a consequence of shrinking (reduction in volume) of alloy during solidification, in the case of inadequate liquid metal casting feeding. "Micro-shrinkage" (or porosity shrinkage), which creates a thick cluster of tiny (or very sub-microscopic) voids with strong contours and rough walls. This occurs through solidification as a consequence of uncompensated shrinkage (lack of liquid metal feeding), and can be viewed as a dispersed shrinkage cavity. The existence of the micro-shrinkage (centred or dispersed cavity) depends mainly on the alloy's chemical composition, and the temperature variance in casting. "Slag inclusions" which are the inclusions of varying backgrounds, shapes and sizes that exist in the melt [6]. More often it's the slag in a pouring system on the top of the molten metal. "Sand inclusions," which are circular, differing in thickness, positions filled with molding content in the volume of the alloy. Sand inclusions are induced by corrosion on the surface of the mould cavity or, for other purposes, by intrusion of molding sand into the mould cavity [7]. “Foreign metal" which may exist in the case of aluminium alloys in the form of un-melted alloy product pieces.

Among the defects mentioned above, blowholes and gas and shrinkage porosities are the most prevalent internal defects discovered during the manufacturing of aluminium alloy castings. Studies described in this project will focus on defects of this type. When the surfaces with defects are put into service, there is an imminent danger of sudden and unexpected failure which obviously disqualifies the casting functionality leading to significant losses in material and cost of replacing. Typical structural elements that are extremely sensitive to the quality of the joined surfaces include: transmission system handles, cylinder pistons and front faces of the cylinder in engine bodies [8].

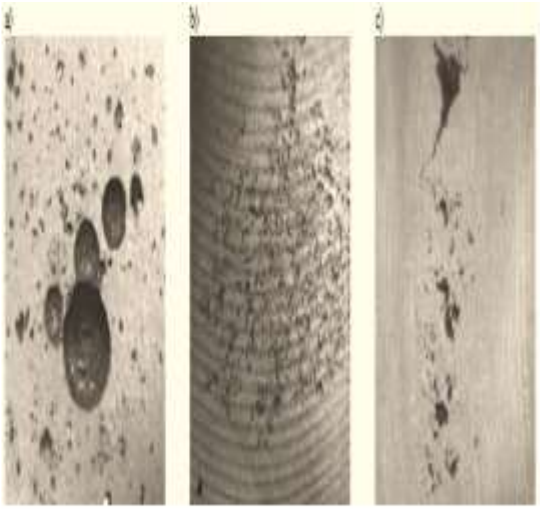


**Figure 3: Example of different types of defects revealed on the casting surface after machining a) Blowholes, b) Shrinkage Porosity, c) Shrinkage Cavity**

The efficiency and consistency are a critical element of its service. In such situations it is of paramount importance to carefully inspect the quality of the surface in the inspected cast object. This method is one of the most important non-invasive techniques pertaining to studies of this type of damage, and one of the most frequently used visual techniques. A widely employed visual inspection-based control device is well designed for working in a wide variety of products, but it is distinguished by high costs, is inefficient, and the results depend largely on the human factor.

## METHODOLOGY

First of all, work on defect detection involves the creation and modification of the vision, illumination, and mechanical systems coupled with sophisticated image processing. The mixture of measuring devices and numerical methodology can shape the basis of a solution leading to computerized vision system design and construction. Photos of the analysed surfaces are required to be obtained in combination with the activation of alternately working illumination and numerical analysis of those photos. The starting point for a computer-aided casting quality image analysis will be the design of a proper lighting system, allowing visual distinguishing of casting defects on the machined surface. Consequently, the proposed lighting system solution (Fig.4) is based on the diffuse illumination in a direction perpendicular to sample 3. The view of the observed surface 5 with well evident pores and other artefacts 4 on the surface passes through the lens 2 through camera 1.

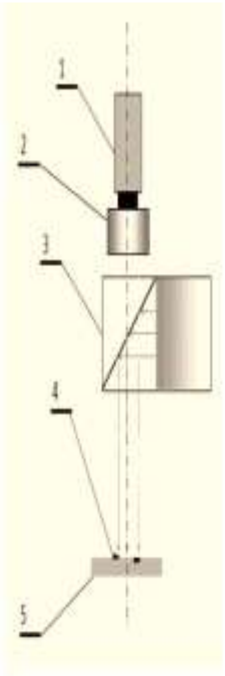


**Figure 4: A New Camera Based Machine Vision System for the Automatic Inspection of Surface Defects**

It will be possible to eliminate the interruption in the illumination of the observed target by falsifying the accurate detection of surface defects owing to the proposed solution in the context of an automated vision system. Next part of the project was digital image processing to highlight the obvious casting defects. A tweaked filter called "Laplacian of Gaussian" was used to achieve this goal, widely used as a numerical method to identify areas with abrupt changes in contrast edges. This filter is highly sensitive, hence the two-step implementation process. First, use Gaussian filter to smooth the image, and then use Laplace filter to designate the edges of artefacts with variable contrast. Nonetheless, in reality these two procedures are merged into one, using an alternate character of the second derivative operator and turning the formula Laplace-Gaussian into a single equation:

$$LoG(x,y) = -\frac{1}{\pi \cdot \sigma^4}\left[1 - \frac{x^2+y^2}{2 \cdot \sigma^2}\right] \cdot e^{-\frac{x^2+y^2}{2\sigma^2}} \qquad (1)$$

Where the features of this filter are first and foremost defined by the importance of the sigma factor (σ). This will cause the sensitivity of the identification of defects to be constantly changed, allowing the user to determine the level of sensitivity at which he can consider the casting defects. To complete this approach, it is necessary to alter the filter mentioned above by adding an additional parameter (T) to the numerical method, allowing the user to adjust the sensitivity of the identification of defects (defects), which is a limiting factor of the use of this filter. To summarize the result of the numerical image processing technique, a single distinct convolution method was used, thanks to a simpler notation version of the combination Gaussian and Laplace filters (1) at a particular sigma value (determining the precision of defect identification-the first parameter). In the next step, an identification procedure was conducted where the function thus calculated passes through a zero point and ultimately rejects those areas where the average intensity values are lower than the present value (the second parameter that determines the sensitivity threshold of the detection of casting defect). Finally, the third parameter (λ) was used to group the identified defects, which allows to determine how to identify the detected defects based on their characteristic size and shape. The previously mentioned concept of a vision system and the explanation of the numerical analysis of the photographs of faulty casting surfaces indicate that the quality control of casting defects can be made fully automated.

In addition to the existing numerical algorithm for image processing, it is intended to use an advanced learning technique, based on computational intelligence (CI) methods, which will enable the automated selection of the coefficients referred to above (σ, λ, T), specify the efficiency of the defect detection process and exclude the involvement of the consumer in the program at the initial stage of the process. These factors will be values of the input quantities, while the detection correctness will be the quantity of the output. These factors will be values of the input quantities, while the detection correctness will be the quantity of the output. The latter number is necessarily of a single type, indicating it is not constant (e.g. 1-the right identification outcome, 0-error). Nevertheless, experience has shown (among others, the experience of the researchers of the proposal) that treating this form of performance quantity as constant is desirable, although the learning range will only include the severe values, i.e.0 and 1. It makes for better estimation of the significance and essence of the effect of specific amounts of feedback on final decisions.

Preliminary studies have been conducted to validate the existing methods for detecting defects in castings. A vision program has been developed and configured for this function (Fig. 5a) to assess the viability of implementing the activities covered by project management. The basis for the analysis were images of the samples from the aluminium alloy and the possibility of identifying surface defects using the proposed numerical solution. The studies have helped to demonstrate that image processing and the lighting technique allow surface defects to be identified. Details of samples with observed defects clearly evident are shown in Fig. 5b & 5c.

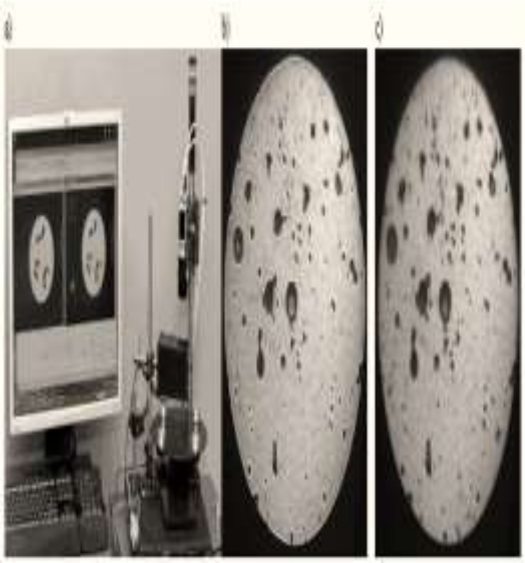

**Figure 5: The Result of Preliminary Studies a) A New Camera Based Machine Vision System for the Automatic inspection of surface detects, b) Result of Identification of Surface Detects, c) Original Image**

## CONCLUSION

The project's scientific aim was to create and build computer-based vision systems for online inspection of surface defects in items, especially discontinuities that occur after machining in castings. The purpose of the work is to provide a system for collecting and evaluating images of the surfaces examined, allowing for an unmistakable and reliable identification of defects and determining their form. In addition to the numerical algorithm built for image processing, it is expected to use an advanced learning technique, focused on computational intelligence techniques, which will require the automatic selection of the filter coefficients to describe the quality control mechanism. To monitor and detect surface defects in die casting after machining, a new vision inspection method and image processing algorithm were successfully implemented in this paper.

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