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Advanced metrology of surface defects measurement for aluminum die casting

S.J. Świłło*, D. Myszka
Institute of Manufacturing Technologies, Warsaw University of Technology,
Narbutta 85, 02-524 Warsaw, Poland
* Corresponding author. E-mail address: s.swillo@wip.pw.edu.pl

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Abstract

The scientific objective of the research is to develop a strategy to build computer based vision systems for inspection of surface defects in products, especially discontinuities which appear in castings after machining. In addition to the proposed vision inspection method the authors demonstrates the development of the advanced computer techniques based on the methods of scanning to measure topography of surface defect in offline process control. This method allow to identify a mechanism responsible for the formation of casting defects. Also, the method allow investigating if the, developed vision inspection system for identification of surface defects have been correctly implemented for an online inspection. Finally, in order to make casting samples with gas and shrinkage porosity defects type, the LGT gas meter was used . For this task a special camera for a semi-quantitative assessment of the gas content in aluminum alloy melts, using a Straube-Pfeiffer method was used. The results demonstrate that applied solution is excellent tool in preparing for various aluminum alloys the reference porosity samples, identified next by the computer inspection system.

Keywords: Non-destructive testing, Aluminum die casting, Surface defects, Topography measurement, Scanning method

1. Introduction

In spite of a significant progress in monitoring and controlling processes, the presence of defects in castings is an important issue. This is particularly true in the case of defects that become apparent only at customer's premises, after removing an outer layer of the casting skin in the machining process, rarely during operation. Frequently, especially in the case of mass production, the inspection carried out in foundry does not have the possibility to examine all castings for the occurrence of internal defects, and hence having them disclosed by the customer is the situation rather inevitable. This is why quite special importance has the opportunity to create a relatively easy way for the detection of defects in castings after machining, which will eliminate the adverse effects of their presence during operation, ensuring at the same time proper back flow of information on the presence and type of defects from the customer to the producer of castings. Preventing defects always consists of four stages: defect detection, identification of its type, establishing the causes and measures leading to a removal of the source of the defect. The first two stages must be completed in the place where the machining of castings is done.

About 50 types of defects were classified, of which internal defects in the form of areas of different size and shape not filled with metal, i.e. voids or foreign matters – contaminating the metal, though forming a relatively small group, are the most severe, because of problems with detectability and grave impact they have on the operational properties of the product. Among the above-described defects, the most frequent internal defects revealed during machining of aluminum alloy castings are blowholes, and gas and shrinkage porosities [1]. On defects of this type, studies described in this research will focus.

The scientific objective of the research is to develop a strategy to build computer based vision systems for online inspection of surface defects in products, especially discontinuities which appear in castings after machining [2]. However, vision inspection technique provide only a simple response about defects location and additional solution is required to create a mathematical model to identify a mechanism responsible for the formation of casting defects. For that reason, in addition in the development of the vision system solutions it is planned to use a advanced computer techniques based on the methods of scanning. This method will allow investigating if the, developed in the project, tasks of control and identification of surface defects have been correctly implemented for an online vision inspection

2. State of art

The project focuses on cast aluminum alloys, which are very frequently used in high volume production and onto which high quality requirements, particularly with regard to mechanical properties, are imposed. Studies aiming at the development of backgrounds of a online vision system, allowing for the start up of a smart control of the surface of machined castings will be undertaken. Overall, the surface quality inspection is intended to focus on broadening of the scientific understanding of the aluminum casting process. Particular, the project is focused on developing a guideline information that enhance understanding and provide all process parameters necessary to make informed decisions in terms of inspection.

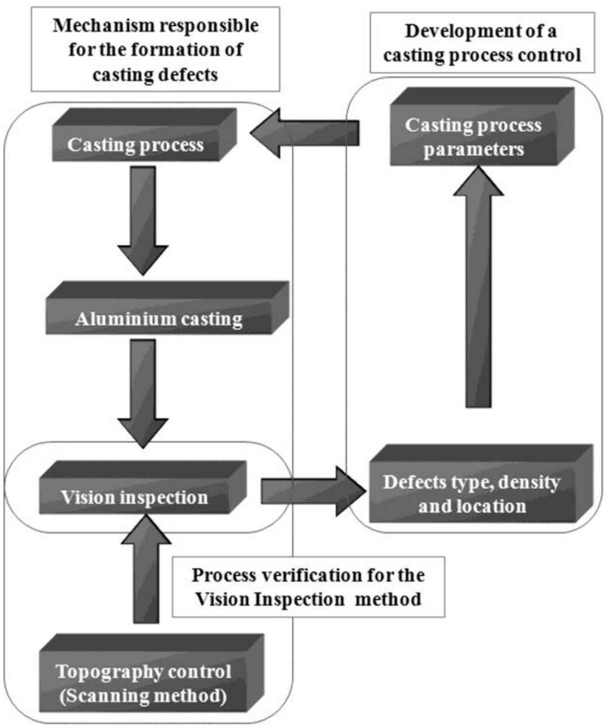

Fig. 1. A research concept to control and inspect of casting defects based on advanced computer technique

The main thematic areas of the project will be:

- Identification of defects using vision technique
- System learning process based on neural network,
- Computed 3D inspection using scanning technique,
- Examination of defects using a Straube-Pfeiffer method.

Each of the thematic subjects are listed on Fig. 1 and mentioned above has been described in detail below, with a focus on innovative solutions in the planned research. The research concept in specifically focused on the following tasks: know how, investigation, development and verification. To verify the proposed methods for identification of defects in castings, preliminary studies have been conducted and results were demonstrated in the next sections. The basis for analysis was obtaining aluminum samples and examining the possibility of identification of surface defects using the proposed numerical solution. The studies helped to demonstrate that numerical procedures allow the identification of surface defects.

3. Casting process

In this part of the planned tasks it is expected to test the, described earlier, numerical procedure for image processing and learning systems, using real castings. The reliability of the diagnosis of defects by the vision system based on the analysis of shape and size of the areas not filled with metal (voids, possibly voids with contaminants) will be evaluated.

At this stage, the research work will be realized to make casting samples with gas and shrinkage porosity defects type. These and other defects (for example these appeared as cause of not precise machining of casting surface, cracks or scratches) will be listed in the specification of all the flaws identified, and in this way all the necessary information will be obtained, including classification and decision of the system to reject or accept the casting.

For this task it is planned to use special camera for a semi-quantitative assessment of the gas content in aluminum alloy melts (LGT gas meter), using a Straube-Pfeiffer method. It will be an excellent tool in preparing for various aluminum alloys the reference porosity samples, identified next by the vision system. This method will be used to obtain samples of different porosity, and then the results of identification will be evaluated for the gas content in melt as measured by different techniques and compared with the results obtained by the vision system.

In Straube-Pfeiffer method, the sample of liquid alloy solidifies under reduced pressure in a LGT gas detector (Fig.2). The application of reduced pressure during solidification of aluminum alloy sample allows a rapid reaction of gas evolution from the melt and growth of bubbles. Owing to this, it is possible to detect the presence of gas even if its amount is very small. The sample solidification is carried out at an appropriate speed, to enable the gas contained in metal to liberate and escape from the solution in the form of bubbles, but at the same time to prevent its escape into the atmosphere, by making it “arrested” in the sample. Creating these conditions for sample solidification is possible through selection of appropriate design, heat capacity and material of the crucible as well as the degree and rate of evacuation of the solidification chamber. Thus obtained metal sample is characterized by a specified degree of porosity.

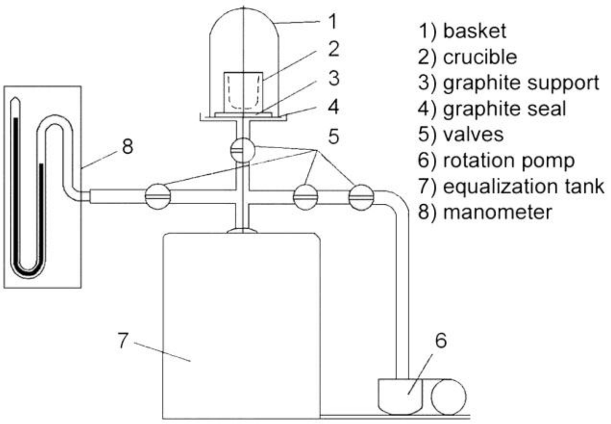

Fig. 2. Scheme of LGT aperture

The content of gas in melt can be determined in three different ways by:

Estimate - this method involves observation of the solidification process. The severity of melt contamination with gas is proportional to an increase in the sample volume. For example, if the sample surface forms a large convex meniscus, and possibly cracks on the top surface, this indicates that the sample is very gassy. If the top surface of the sample does not have a meniscus, or has a concave meniscus, this indicates a small quantity of gas or its absence.

Comparison - this method is based on a comparison of sample microstructure with the microstructure of standard reference sample, i.e. in counting the number of pores per 1cm2, measuring them and comparing with standard scale porosity.

Computation – this method consists in weighing the sample in water and in air, calculating then the specific mass of gas and porosity. The amount of gas contained in the sample is calculated, and it is approximately equal to the total gas content in liquid metal. The calculations can be applied to alloys with a low degree of gassing.

Additionally, castings samples will be prepared with special feeding system – designing for simulation of contraction porosity appearing. Special steel mould will be used for filing with molten two aluminum alloys characterized by different level of feeding and contraction regulated by appropriate temperature of pouring. It'll cause creation of different defects like contraction porosities. This defects and the others - connected with gas porosity - will be useful to classification and verification by visual system.

4. Surface topography measurement

The essence of this project is to provide a method for obtaining and analysing images of the examined surface, allowing the unambiguous stating of a defect with identification of its type. As auxiliary tools in the development of this solution it is planned to use advanced computer techniques based on the method of scanning. These methods will help clarify the mechanism of the formation of casting defects and examine the correctness of the implementation of tasks designed in this project for control and identification of surface defects during an online inspection. The planned inspection with the use of this advanced method of analysis of the topography of defects is a time-consuming process. It is therefore anticipated to take measurements in an offline mode, but due to the high precision of the measurement (resolution up to 0.5 μm), it will be possible to determine not only the geometry of the defects but also their distribution in the casting space. it is planned to design and build a scanning system (based on the previously gained experience [3,4]), extending the existing field of the application of this solution to include the measurement of small areas (tenths of a millimeter).

For that reason, a new shape measurement method, which combines the fiber-optic interferometric fringe projection method and effective numerical spatial phase unwrapping method, is proposed. Simplicity of system arrangement determining low set-up cost is the main advantage of the method presented. The presented theoretical description is based on especially constructed method of automated analysis of the fringe patterns carried by the suitable use of Fourier transform and phase unwrapping. The optical geometry of the static projection and recording system is shown in **Fig. 3**. The x-axis is chosen as in the figure, and the y-axis is normal to the plane of the figure and to the reference plane, and z is the distance between the object surface and the reference plane.

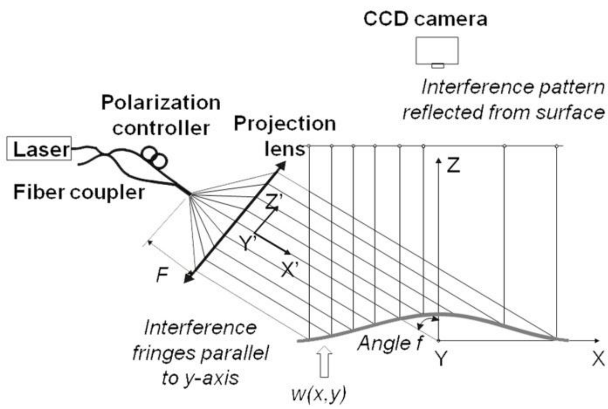

Fig. 3. Model of advanced computer techniques to measure topography

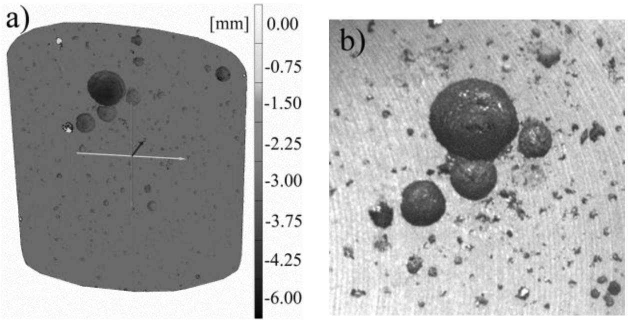

Fig. 4. The results of preliminary studies: a) topography measurement of surface defects, b) original image of selected surface defects

To verify the proposed method for defects topography measurement of in castings, preliminary studies have been conducted. For this purpose, the next generation of mobile 3D digitizer was used to determine the feasibility of implementation of the tasks covered by project design. The basis for analysis was obtaining images of the aluminum alloy samples and examining the possibility of identification of surface defects using the proposed numerical solution. The studies helped to demonstrate the limitation of proposed numerical procedures for identification of surface defects. Examples of samples with well visible detected defects are shown in Fig. 4ab.

5. Summary

In this study a new approach was demonstrated by using the advanced computer techniques based on the methods of scanning to measure topography of surface defect in offline process control. Next, in order to make casting samples with gas and shrinkage porosity defects type, the LGT gas meter was used. The primary goal of the research is to improve productivity and quality in the manufacturing casting process. This is one of the most fundamental problems of research studies in process casting design that has significant influence on manufacturing cost.

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