

Improvements in Detector Design for X-ray Inspection of Cast Parts

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ABSTRACT

The results of automatic X-ray inspection of cast parts rely heavily on the quality of the imaging components. Flat panel detectors suffer from a number of flaws, the most serious being long-term stability and image quality.

This paper presents a new X-ray detector design which can increase defect detection quality, cost efficiency and long term stability of an industrial automatic X-ray inspection system.

INTRODUCTION

2D X-ray inspection of cast parts has become an indispensable means of quality control in foundries. Image quality is the key factor in determining a part's quality level for 2D- as well as 3D X-ray imaging systems.

Especially automatic X-ray inspection systems depend heavily on the quality of their imaging components, namely X-ray source and detector. Flat panel detectors, which are increasingly used in the industry today, suffer from a number of flaws that have a considerable impact on the quality and long-term stability of the defect detection capabilities of an automatic X-ray inspection system.

This paper presents a new X-ray detector design, which can increase defect detection quality, efficiency and long term stability of an industrial automatic X-ray inspection system in foundries and other NDT applications. In order to understand the problems with current detectors, their

design and the causes for their short-comings need to be discussed first.

FLAT PANEL DETECTORS

The most commonly used detector design in use today is the flat panel detector (FPD). Flat panel detectors are indirectly converting detectors assembled from various functional layers. Fig. 1 shows the functional principle of such a detector. The X-ray quanta pass through the mechanical protection layer and hit the scintillator, where the X-rays are converted to light. The photosensitive semiconductor layer converts the light into electrical signals, which are processed by the electronics mounted behind a ray shield present to protect the electronic circuitry from the damaging radiation.

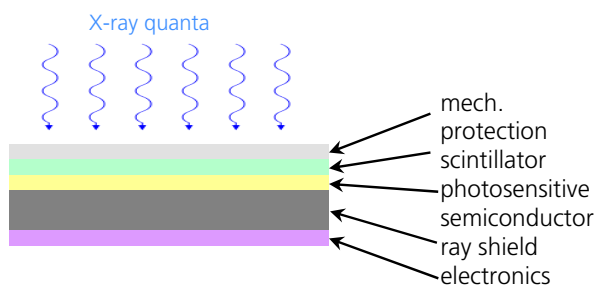


Fig.1: Flat panel detector schematic view

This kind of design comes with a number of drawbacks though. The most serious problem is the durability of the

detector. Not all X-ray photons are converted into light in the scintillator. Those that pass through the scintillator penetrate the photosensitive semiconductor and cause irreversible damage. The damage accumulates over time and causes so-called image lag.

This image lag is an afterglow that can last up to several seconds. It is caused mainly by damage in the photosensitive semiconductor layer preventing electrons from draining quickly. The effect of the image lag is a visible blend of images of the current part being tested and the previous part. Image lag can have a severe impact on automatic image processing algorithms (e.g. artifacts in computer tomography/CT images) or cycle time.

Flat Panel Detectors are Full-Frame detectors, so when the movement is present in detector or object, the smeared image must be cleared first by reading the sensor, which takes typically 150ms (not taking into account the image lag, which is still present).

Other problem areas are dead pixels and pixel clusters. No information is available from these areas, and it is possible to miss small defects if they fall in these areas.

The size of a flat panel detector is also limited. Recently, there is increasing demand to test larger parts, requiring larger detector sizes. But these types of detector can not be built in arbitrary sizes; larger detectors are assembled by mounting smaller detector panels in a matrix. The adjacent areas between the panels are "blind", causing defects that happen to be projected in these areas (aka "gap", "butting cross") to slip through the image processing.

If a detector is used in automated X-ray testing of cast parts, it is common that thousands of identical parts are placed at the same position in front of the detector, resulting in burn-in over time caused by radiation damage. The effect is that the part can be seen as a shadow overlaying the current image. Basically, some areas of the detector are exposed to radiation all the time, and other areas are always more or less "protected" by a part being tested. Even if the types of part being tested change permanently, typically the areas in the center of the detector suffer less radiation damage than areas at the edge of the detector.

This decay of image quality of a FPD is a gradual process depending on many factors with the accumulated dose being the main one, and it can be difficult to determine the point in time when the image quality has become insufficient for reliable quality control and replacement is required. Since an inferior image quality is not tolerable for critical parts, this typically leads to frequent replacement of this expensive part of the imaging chain.

All of these drawbacks have an impact on the image quality and thus on the image processing software for automatic detection in cast parts. Some problems can

be somewhat compensated, but the limited image quality can be a serious problem with the growing requirements in X-ray testing.

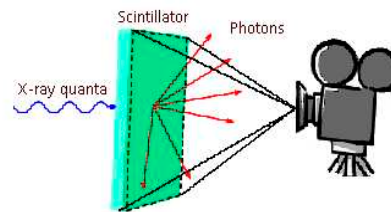


Fig.2: New detector design

NEW DETECTOR DESIGN

To remedy the shortcomings of flat panel detectors and address requirements from the casting industry a new detector was designed.

Fig. 2 shows the functional principle of the new detector concept. The new approach consists of a scintillator screen that is used to convert the X-ray quanta into light, and a camera to capture the image and convert it into electrical signals. The advantage of this approach is that the electronics and especially the sensitive camera chip can be shielded from radiation, preventing radiation damage and thus greatly improving durability and long term image stability of the detector.

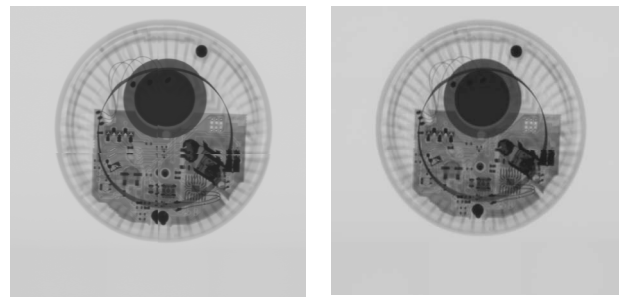


Fig.3: Merging of four sub-images

By arranging several cameras in a matrix aimed at the same scintillator screen, it is possible to build arbitrarily sized cameras with equally growing pixel counts.

The overlapping partial images generated by the various camera modules are merged to form a single, flawless image. Figure 3 shows an image generated by four cameras, before merging and correction (left) and after merging and correction (right). The noticeable butting cross artifacts and individual imperfections of each camera like tilt or differences in magnification, etc. are corrected in sub-pixel accuracy. As a result, the final image is free of pixel defects.

The image lag of this detector type is negligible, the remaining lag mainly being caused by the short time lag inherent to the scintillator.