1.9.28. PROCESS INTEGRATED INSPECTION OF CASTINGS USING THREE DIMENSIONAL COMPUTERIZED TOMOGRAPHY

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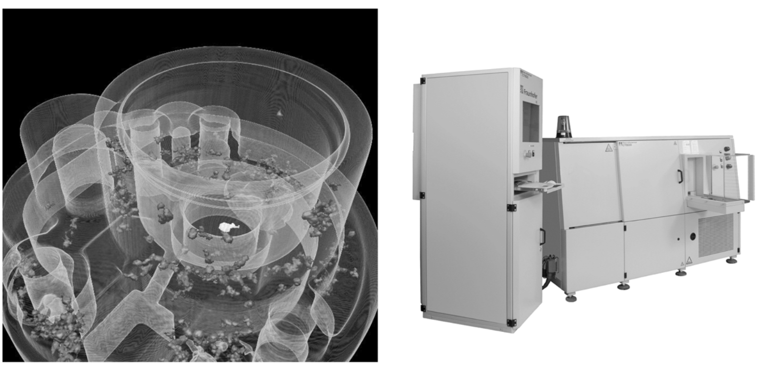
Introduction. Automatic two-dimensional (2D) X-ray inspection of cast parts is a standard quality control measure in foundries today. Typically 100 percent detection of defects in all areas of a cast part is necessary to prevent failure due to material defects. But a 2D projection of a defect does not yield sufficient information on the defect's location in the part or its extent. This lack of information often leads to an unnecessary scrapping of parts which can significantly reduce a foundry's output.

Until recently system cost and processing speed of a Computerized Tomography (CT) system capable of computing three-dimensional (3D) images prevented its widespread use except for special applications, e.g. offline inspection of prototypes in the lab. With the steady advances in processing speed in conjunction with a new detector design and optimized 3D-image processing algorithms, it is now possible to integrate a CT system into the process, offering 3D-reconstruction, fully automatic defect detection and measurement in the cast part in less than 30 seconds per part. Using 3D-reconstruction of the entire part including all defects, yields precise knowledge of flaw properties, location and distribution in the part. This information is vital for improving foundry throughput without sacrificing part quality.

Results. By applying advanced parallel image processing it is possible to test parts inline in a cycle time of 30s total (25s of image acquisition and 5s of part handling), allowing 100% 3D-X-ray testing of all production without cycle time penalty. A 3D representation of the inspection result and the realized 3D CT-system for process integrated casting inspection are shown in fig. 1.



(a) (b)

Fig. 1:
(a) – 3D representation of the inspection result; (b) – realized system for process integrated casting inspection using 3D computerized tomography

A system with these parameters was put into operation in a foundry:

- 66 ms exposure time / 15 frames per second;
- 375 projections per object;
- 256 MB volume size ($512 \times 512 \times 512$ voxels);
- Reconstruction completed after measurement of last projection;
- 30 seconds total time requirement per part.

This system is capable of automatically detecting flaws in aluminum parts down to a size of 1.2 mm at an object thickness of up to 100 mm with under 3% false rejects.

Discussion. A 3D-CT system provides dramatically more information about a part than a 2D system can offer. The information regarding an object feature's depth inside a part is not available in a 2D system, and since features are magnified depending on their location and system geometry, the real size of e.g. a pore can often only be estimated.

A 3D-CT system on the other hand provides exact information about a flaw's location and size inside the object. A 3D-CT-system initially detects more flaws than a 2D-System because of the superior contrast of the reconstruction calculated from a large number of projections compared to the single projection in a single direction used in a 2D system. The availability of the location information in conjunction with the absolute flaw dimensions makes it possible to selectively evaluate each flaw using that information, allowing the use of dynamic thresholds depending on the flaw's location, and ignore non-critical flaws.

It is for instance possible to allow larger flaws in massive areas of a part, and at the same time set a more sensitive threshold in critical areas of the part. A small, normally uncritical flaw may become critical because it appears at the surface after machining. In a 2D system, all flaws could potentially appear at the surface after machining, while on a 3D-CT system it is possible to only mark the future surface after machining as critical, while tolerating minor flaws outside of that area. All this information can be taken into account by an automatic image processing system when making the decision if a part is good or should be scrapped.

In effect, the yield with a CT system can be higher than a 2D system while at the same time offering a higher overall quality level. The more selective classification made possible by 3D-CT can actually reduce scrapping of good parts.

Summary. With the use of parallel computing and efficient algorithms it is possible to use inline 3D-CT-systems in foundries without a penalty on cycle time. The availability of 3D-data allows intelligent flaw detection and a more refined evaluation of cast parts and can even lead to a reduction of scrap parts compared to 2D inspection. It is also possible to perform selected measurements on the part in an inline system.