

Helical 3D Computed Tomography as an Advanced Inline NDT Method

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ABSTRACT

Computed Tomography (CT) is a well established method for non-destructive reconstruction of an object's interior structures. It is especially well suited for use with e.g. light metal alloys, injection molded plastic components or composite materials. The CT volume data can either be evaluated manually or automatically through the use of image processing software.

Recently helical CT has become available for use in industrial quality testing of light alloy cast parts. This paper discusses the use of helical CT as an additional tool for inline inspection in a production environment.

INTRODUCTION

Two-dimensional (2D) X-ray inspection of cast parts is a standard quality control measure in most European foundries today. Complex structured parts can be difficult to test using 2D inspection, so computed tomography is available as an advanced 3D-testing method, promising complete information about the inner structures of a part. A 3D-CT system provides exact information about a flaw's location and size inside the object.

The data generated by CT can have limitations though. The reconstructed data is often tainted with artifacts caused by various phenomena, e.g. the number of images fed into the reconstruction algorithm correlates with image quality.

This paper presents helical computed tomography as an advanced 3D testing method, offering major improvements compared to standard CT using the Feldkamp algorithm. While standard CT is based on rotational movement of the X-Y plane, typically using start-stop-motion, in order to generate the images to be fed into the reconstruction

algorithm, helical CT introduces motion on the Z axis as well, resulting in a helical sequence of images. This helical motion eliminates artifacts typically associated with the Feldkamp algorithm, and results in superior image quality. Other artifacts can be reduced or eliminated with appropriate algorithms as well, which is beyond the scope of this paper.

In conjunction with the elimination of the start-stop-motion through the use of an X-Ray camera with a suitably high frame rate, the data acquisition speed as well as the image quality of the resulting volume data can be greatly improved, creating new applications for CT and making helical CT suitable for inline use on the factory floor.

PRINCIPLE OF OPERATION

In order to understand the differences between standard circular CT and helical CT, it is necessary to briefly compare their principles of operation. [Figure 1](#) shows the schematic view of an X-ray CT system. The object is placed in the cone beam of an X-ray tube, with an X-ray detector generating a 2D-image of the object.

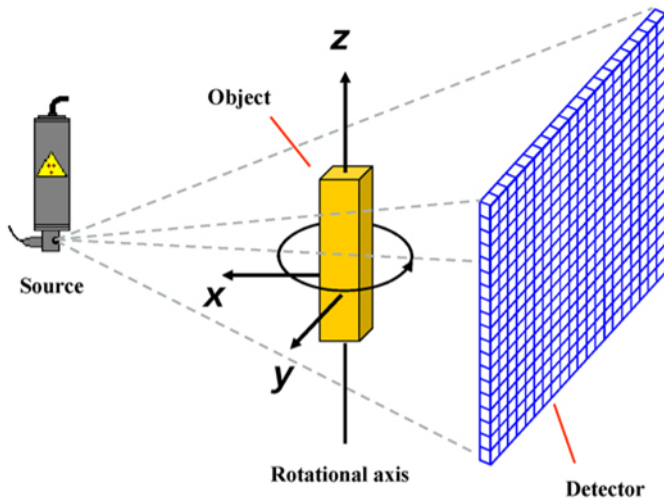


Fig. 1. Principle of operation of standard CT

By generating images from several hundred different perspectives (typically 256-512 projections) through a *single* rotation of the object, a three-dimensional *Volume* of the object can be calculated [1, 2]. Currently the rotation of the object typically takes place in a stop-and-go motion because movement during the recording can cause blurred images.

If the object is too tall to be measured with a single rotation, the object can be moved, and another section of the object can be measured in a consecutive pass.

The principle of operation is virtually identical for helical CT, except that the object is moved along the rotational axis *during* the scan. Instead of recording a sequence of images of one plane, as is the case with the circular CT setup, the images taken from the various angles are projected from different vertical positions of the object.

The amount of vertical advance per revolution depends on many factors, but as a rule of thumb 1.5 revolutions are used for an object utilizing the height of the detector. For objects exceeding the effective detector height, proportionally more images respectively revolutions are required.

The reason why helical CT provides drastically better data can be explained with Tuy's condition [3], stating that reconstruction without artifacts requires complete data. Simply speaking, complete data requires that every plane of the object must intersect with the object's trajectory. With Feldkamp's filtered back-projection, this is not the case, since the circular trajectory does not intersect with any of the horizontal planes, hence the data is not complete. The helical trajectory however intersects with every plane with a helical CT, hence the data is complete satisfying Tuy's condition.

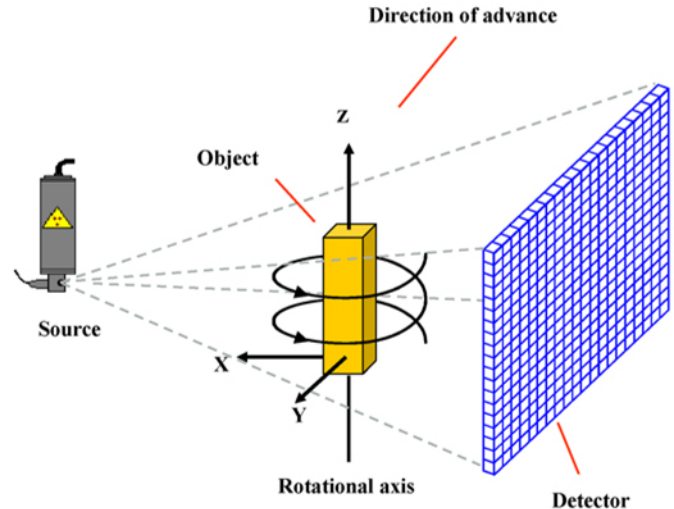


Fig. 2. Principle of operation of helical CT

ADVANTAGES OF HELICAL CT

The main advantage of helical CT over circular CT using the Feldkamp algorithm is a dramatically increased image quality and reduction of artifacts. With circular CT, parts of an object further away from the central beam of the cone are increasingly smeared (see Fig. 4, left). For helical CT, the image quality is constant regardless of the Z-position in the volume. Especially object details in the X-Y-plane benefit from the increased image quality.

Another advantage of helical CT is the fact that the length of the object to be tested is only limited by the movement range of the Z-axis. The helical CT algorithm does not have an inherent height limit, so it is ideally suited for long objects, offering consistently high image quality independently from the Z-position. With circular CT, the only option to record tall objects is a set of successive partial tomographies. Existing CT systems can also be easily upgraded with helical CT, since only the additional axis and a software upgrade are required.

The only disadvantages of the helical CT are the additional cost of the precision Z-axis, and depending on the circumstances possibly more projections compared to circular CT.

TEST DATA

In order to point out the shortcomings of the circular CT and demonstrate the quality improvement offered by helical CT, an object was selected that contains considerable detail in the X-Y plane: a stack of CDs (see Fig. 3). The stack has a height of 90 mm with a diameter of 125 mm, the material is mainly polycarbonate.