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The application of computed tomography in the automotive world – how industrial CT works

Zastosowanie tomografii komputerowej w świecie motoryzacji – jak działa przemysłowa TK

Abstract

This paper shows how industrial computed tomography (CT) works, its benefits and where it can be used in automotive world. As a non-destructive quality control technique (NDT), CT allows not only the measurement and evaluation of external and internal geometry, but is also useful for making reports with a visualisation of an entire component, e.g. a map of shape deviation and internal structural defects.

Keywords: industrial CT, flat beam, cone beam, internal structural defects, dimensional accuracy

Streszczenie

W artykule przedstawiono zasadę działania przemysłowej tomografii komputerowej (TK), jej zalety oraz zastosowanie w branży motoryzacyjnej. Jako nieniszcząca technika kontroli jakości (NDT), TK pozwala nie tylko na pomiar i ocenę geometrii zewnętrznej i wewnętrznej, ale jest również przydatna w sporządzaniu raportu z wizualizacją całej części, np. mapy odchyłek kształtu czy defektów struktury wewnętrznej.

Słowa kluczowe: przemysłowa TK, płaska wiązka, stożkowa wiązka, wady struktury wewnętrznej, dokładność wymiarów

1. Introduction

Technological research and development centres play an extremely important role in the automotive industry during the entire manufacturing process of structural elements starting from the inception of new ideas. The aim of these centres is to design components that can be produced to meet the applicable standards and tests, in accordance with the required quality standards. Usually, the whole process of developing new components takes from three to five years. The stage at which engineers check the quality of the first prototypes and all finished components and products is very important. Then with help comes computed tomography which is very useful machine for testing and assessment of dimensional accuracy and internal structural failures. Industrial computed tomography can also be used in a reverse engineering capacity to scan finished products in order to rebuild the 3D model in CAD software and make improvements; this model can also be used for 3D printing. Finally, after all tests, calculations and modifications of the CAD model and its technical drawing specification, we get a product that meets manufacturer and customer requirements. Figure 1 shows computed tomography – Nikon XT H 225 ST for industrial CT scanning. On the CT table is the final product ready for scanning [1].

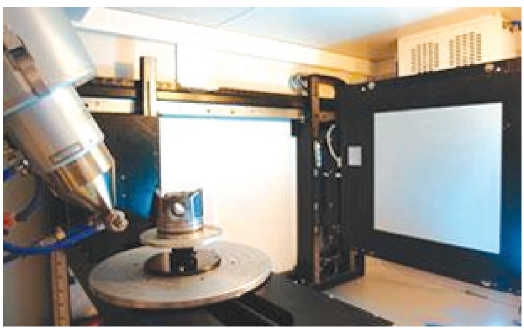

Fig. 1. Computed tomography – Nikon XT H 225 ST [1]

2. Computed tomography – principles

CT – computed tomography is a measuring device that has a wide range of applications in industry despite the fact that people generally think of CT as being a medical tool. The first prototype of computed tomography, the 'EMI schanner', was made in 1968 by G.N. Hounsfield. The name of the technique, the mathematical apparatus and the technological workshop used for generating images and volume elements in a three-dimensional form has changing over time. In 1979, Allan MacLeod Cormack (1924–1998) and Godfrey Newbold Hounsfield (1919–2004), received the Nobel Prize for Medicine for the discovery of computed tomography [2–4]. More about the genesis and principle of operation of each of the five computed tomography generations can be found in references 5 and 6. In the 1980s, industrial applications were found for computed tomography in the form of non-destructive testing (NDT) techniques; it has now become a revolutionary metrology tool for the comparison an evaluation of geometric tolerances and dimensions. This technique allows the measurement of components in both 2D and 3D, but the most important fact is that it allows the mapping of external shapes and the internal structure of the tested component without disassembling it into its individual components for internal measurements [7–11].

Computed tomography is a type of X-ray spectroscopy, it is a diagnostic method that enables the obtaining of layer images of the examined object [2]. Cross sectional images (2D) and 3D reconstructions are created by compiling many projections of flat images of a three-dimensional spatial object, created as a result of X-ray scanning of the tested object in given angular positions [2, 10–15].

There are few common steps to conducting a CT x-ray or a CAT scan. Taking into consideration the purpose of the scan, the radiographer must prepare the subject for scanning, calibrate the system and match the part size and material to an appropriate x-ray source with regard to the level of exposure. The part to be scanned is placed on a rotatory table located between the digital detector panel and the x-ray radiation source. The CT system has to be shut down before the scanning process and exposure to x-rays. As the part rotates through 360 degrees, the x-ray source penetrates through each part of the scanned item. The various densities of the part absorb varying amounts of radiation. The remaining radiation travels to the detector panel, which captures a 2D x-ray image. To obtain a 3D rendering or a 3D model of the scanned part, several hundred to several thousand 2D x-ray images captured while scanning are needed; the next step is to produce a mathematical reconstruction [2, 4, 10–13, 16–19]. For the use of industrial CT systems today, transform methods and a restorative algorithm (based on analytical inversion formulas) are implemented as they are much faster than traditional methods of the reconstruction of CT data sets. This method of reconstruction also allows greatly enhanced image quality and accuracy [19].

Two types of projection systems are most commonly used in industrial CT scanning. One is a system with a flat beam of radiation (see Fig. 2) and the other is with a cone beam (see Fig. 3) [17, 20].

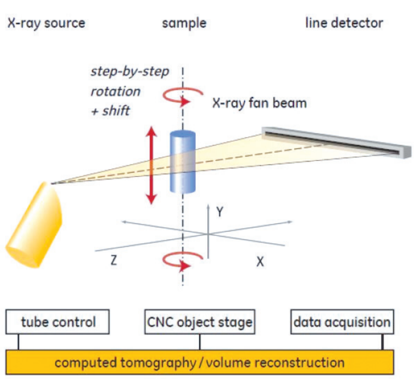

Fig. 2. Scheme of CT with fan beam [17]

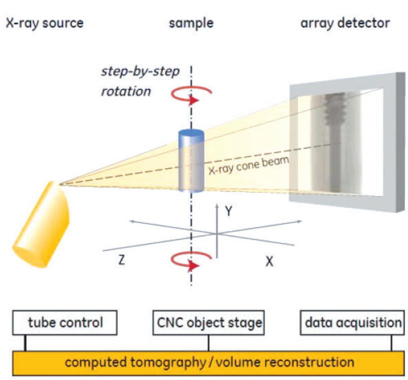

Fig. 3. Scheme of CT with cone beam [17]

3. Benefits of using CT scanning in industrial applications

The main advantage of this technology is the fact that it provides highly accurate testing results without applying any pressure, stress or external forces on the subject being scanned. The following is a brief list of all the major benefits this technology offers:

- non-destructive testing method,
- quantitative density evaluations,
- geometrical representations,
- cross sectional data and 3-dimensional data,
- images are easier to interpret than conventional radiographic data,
- quality control tool for failure investigation and preproduction inspection,
- internal part inspection,
- external part inspection,
- quick and accurate resulting data,
- accessible with the use of outsourced NDT labs,
- saves manufacturing cost (NDT),
- cuts costs and reduces time to production,
- accurate and precise means of measurement,
- enables different types of analysis with one CT dataset,
- non-invasive and non-intrusive method of inspection,
- research and development tool,
- 3D visual representation of part interior.

The following applications of computed tomography within the automotive industry have been identified:

- automotive design and styling,
- automotive component inspection;
  - fault detection and failure analysis,
  - dimensional measurement of internal components,
  - advanced material research;
- assembly inspection of complex mechanisms,
- part-to-CAD comparison (Figs. 4 and 8),
- digital archiving of models.

Fig. 4. Real part scan (STL) to CAD model comparison – plastic part of fan

In the automotive industry, computed tomography is mostly used for quality control, failure analysis and material research. This technology serves as an efficient tool for providing valuable information in any situation in which the internal structure matters. Below is brief list showing the wide range of applications:

- electrical connectors,
- injection nozzles,
- sensors (e.g. Lambda sensors),
- LED light pipes,
- small high-pressure die cast parts, casting inspection (Fig. 5),
- DPF (diesel particulate filters),
- turbine blades and housing inspection (Fig. 6),
- plastic injection moulding (Fig. 7, 8);
  - complex plastic components (e.g. fan),
  - soft, translucent materials where tactile or optical investigation is not option,
  - ultrasonic welding of plastic parts;
- research;
  - material verification and analysis (e.g. structure, porosity, defects) (Fig. 5, 6, 7),
- packaging (Fig. 7).

Fig. 5. Casting inspection [1]

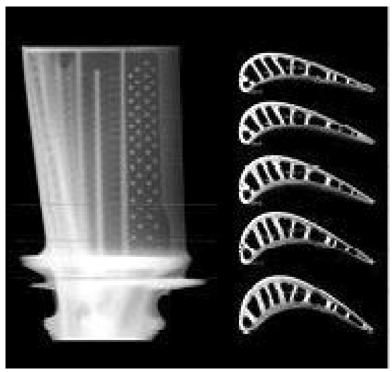

Fig. 6. Turbine blades inspection [1]

Fig. 7. Fan in assembly of cooling module

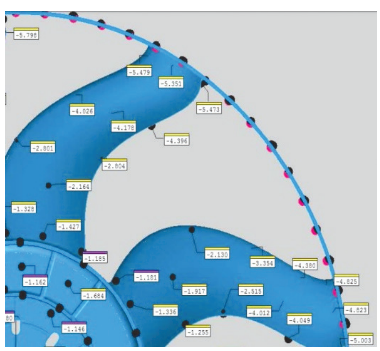

Fig. 8. Fan dimensional accuracy, Part-to-CAD comparison

4. Conclusion

The application of industrial computed tomography in the automotive industry is a very useful and optimal tool for the verification and evaluation of dimensional accuracy, shape and internal structural defects of components. In order to meet customer requirements, tomography is an excellent technique at all stages of product development in order to check quality and make improvements.

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