Drawing up an industrial CT system purchase specification: a Brazilian case study

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Abstract
Computed tomography integration to the quality control loop of Brazilian industries has been continuously growing. Being capable of imaging internal structures of an object, hidden features formerly evaluated only after physically sectioning it became visible through computed tomography. Despite being and engineering technology to be considered in non-destructive analysis and dimensional metrology, the task of selecting an appropriate CT measurement system is not trivial. This paper outlines a general methodology for defining the quotation bases of an industrial CT system suitable for in-line quality control of light metal parts, thus assisting the buyoff activity.

Keywords: industrial CT system, inspection detection, dimensional metrology, buyoff activity

1 Introduction
Computed Tomography (CT) has been more and more integrated to the quality control loop of Brazilian industries. Being capable of imaging inner structures of an object, hidden features formerly evaluated only after physically sectioning it became visible through CT. In addition, great operational advantages over existing coordinate metrology techniques may be observed. Thus, nowadays industrial CT is a key engineering technology in material analysis, non-destructive detection and analysis, and dimensional metrology. Despite the wide spectrum of possibilities opened, CT imposes significant challenges to the industrial users. These are mainly attributed to the complexity of its measurement chain. In fact, many factors may influence the quality of CT-based data evaluations, related to the source, detector, test piece, kinematics and mathematical data further processing [1]. When putting together that complex measurement-error cause system, the potential increment in development and quality control results and the relatively high acquisition and ownership costs, the task of identifying the most appropriate CT solution becomes untrivial. So, this paper describes a methodology for establishing the quotation bases of an industrial CT system suitable for in-line quality control of light metal parts and thus assisting the buyoff activity. The methodology comprises, essentially, raising the technical information associated with some specific classes (section 2) and performing tests with reference samples (section 3). Later on a decision matrix can be drawn taking into account both technical and financial points.

2 Technical background
When selecting a complex measurement system like an industrial CT scanner, first the following issues need to be addressed: (a) equipment selection procedure, to guide the purchase process; (b) measurement need characterization, to compile the bill of requirements; (c) candidate suppliers and equipment, to establish contact persons; (d) benchmark tests, to compare systems; (e) custom tests, to evaluate the effective measurement performance. Considering the CT measurement chain and some other peripheral factors, six classes have resulted: throughput / capability, hardware, software, data handling / exchange, reliability, and services (up-time performance). Other factors like the possibility of inspecting in the production line using radiography or tomography and assisting the development of new products may be relevant.

2.1 Throughput / Capability
Measurement time is of prime importance in production line applications. Required radiography scan and inspection time of internal defects ruled by some technical guideline shall be defined considering the production lead time. Fast inspection mode may be desirable in order to feedback the production line in the right time, albeit keeping sufficient measurement accuracy. Similar reasoning may be used for 3D characterization of internal defects by CT, i.e., complete scanning and online evaluation and reporting of inspection results. Regarding dimensional measurements, benchmark tests should be accounted for in preliminary analyses. Figures specified in the German guideline VDI/VDE 2630-1.3 [2] (e.g., MPE for length measurements) and in ISO 15708-1 [3] (structural resolution) describe the measurement performance for some specific tasks.

2.2 Hardware information
The measurement performance is highly influenced by the CT subsystems: radiation source, high-resolution detector, and kinematics. For the radiation source, its type, voltage range, power, focal spot size and filter plate option shall be considered in preselecting phases; they are directly related to the measurable radiographic length and image sharpness. For the high-resolution detector, its type, active area, pixel matrix, scintillator material and voxel size shall be raised in preselecting phases; they are directly related to the measurement time and resolution. For the kinematics system, the magnification range, raster
option, linear and rotational axis accuracy shall be raised; they influence measurement accuracy and may be impacted by temperature variations. In addition, high-performance computing systems shall be considered, fully integrated for 2D/3D data collection, calculation, evaluation, display/report and storage.

2.3 Software information
For industrial application, graphically interactive and user-friendly interface for adjusting CT scanner settings is a must. Due to their relevance for the CT measurement setup, (a) radiation tube parameters such as acceleration voltage, filament current and spot size; (b) detector parameters such as exposure time, binning, sensitivity, image averaging and voxel size; and (c) sample positioning parameters such as spatial position, angular position and number of projections, shall be conveniently assigned or informed. Under a long-term accuracy perspective, user-friendly qualification routines for the CT scanner subsystems shall be included. CT software shall contain suitable image enhancement tools and filters for radiography and tomography uses, as well as beam hardening and scattering reduction (correction) algorithms. Optimized algorithms for material defect detection and analysis of the samples of interest shall be included. Similar concept may be applied for actual-to-nominal (CAD) comparison (color map). Not only least-squares data fitting method should be considered, but also dimensional tolerance envelope data fitting methods. Online analysis and reporting without any user intervention would be a must for in-line measurements.

2.4. Data handling and exchange
Computational demand for CT dataset reconstruction and posterior analyses is very intense when working with large objects measured at high resolution mode. Processor, memory, graphic board and storage of large files must be considered in the specification of an offline workstation to be integrated with the operational workstation. For suitable data handling, the reconstructed volume file extension may be compatible with CT dataset defect analysis software and metrology analysis software. Communication with the ERP software of the company may be also considered.

2.5. Machine reliability
The return on investment (ROI) of an expensive system like a CT is highly dependent on its reliability over time. Uptime performance shall be ensured by the supplier, through an operational reliable system. For in-line quality control routines, uninterrupted operations may be required, and energy efficiency and environment-friendly solutions would be expected. Reference measuring phantoms for performing interim verification routines of CT scanner subcomponents and thus ensuring measurement accuracy, shall be provided together with proper instructions and optimized fixture system.

2.6. Installation and maintenance
For the correct installation operation of a CT scanner, a complete checklist of the installation site shall be provided by the supplier. Room temperature and CT enclosure temperature specifications must be provided for appropriate operation and measurement performance (e.g., length acceptance test in accordance with VDI/VDE 2630-1.3). For in-line quality control routines, next business day on-site service and spare parts philosophy to minimize downtime shall be considered.

3 Experimental tests
Industrial CT systems may be capable of inspecting internal defects and dimensional features considering measurement accuracy and throughput. Even with all technical information requested in section 2, tests with ‘master test pieces’ are a prerequisite when purchasing a complex measurement system such as an industrial CT. Outcomes from the custom tests will be of great relevance for choosing the most suitable measurement solution. True defect detection capability and dimensional performance would be assessed, as well as the measuring time considering preparation, scanning, post-processing and data evaluation. In this phase, the involvement of supplier’s application department is essential to find the proper scanning settings.

4 Concluding remarks
This paper introduced a methodology for establishing the quotation bases of an industrial CT system suitable for in-line quality control of light metal parts and assisting the buyoff activity. Due to the complex measurement chain, initially, many technical and operational details need to be considered (section 2). For a proper CT system selection, however, experimental tests with ‘master test pieces’ would be necessary, in order to evaluate the influence of the strong interaction between radiation and sample material on the measurement performance (e.g., time and accuracy). These tests will be further described in the final manuscript, as well as the decision matrix created for assisting the buyoff activity.

References

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