3D Engineering Solutions
10597 Chester Rd
Cincinnati, OH 45215
Phone: 513.771.7710
Fax: 513.771.2120
rglassburn@3d-engineering.net

The Business Case for Industrial CT Scanning

Prepared by

Rob S. Glassburn, P.E.
3D Engineering Solutions

10597 Chester Rd
Cincinnati, OH 45215
Phone: 513.771.7710
Fax: 513.771.2120
rglassburn@3d-engineering.net

3D Engineering Solutions Background

3D Engineering Solutions (3DES) is an advanced engineering services company specializing in reverse engineering, metrology and design. At the core of our business is the collection of accurate geometrical data from real world objects and then using that data for our customer for their various business critical operations. That data can be collected on tiny medical instruments to large buildings or ships.

The real world objects are captured as data in a Point Cloud or Voxel data set. A point cloud is a collection of millions of individual XYZ data that describes the object being studied. A voxel data set is the Computed Tomography (CT) equivalent which can be thought of as many box shaped 3D elements fit together to form a volume. Each element represents the X-ray abating properties of a very small region. Both types of data are an accurate representation of the surfaces, volume and features of a part that is useful for engineering purposes by virtually every manufacturing entity.

Once we have the data we use it in the creation of Computer Aided Design (CAD) models and drawings, ISO 17025 certified inspection reports, and other Engineering services.

We have assembled a team of talented and dedicated degreed Engineers and Architectural graduates. These are highly skilled and trained individuals with over 100 years of combined experience. We have developed a client base of over 600 customers in almost every industry using our existing technologies. Our existing data collection technologies include: Long range and short range laser scanning, fixed Coordinate Measuring Machines (CMM), industrial CT scanning and structured light scanning. Most of these technologies can be performed directly at the customer's facility or at our temperature controlled lab in Cincinnati.

CT Scanning

CT or CAT scanning is most known in the medical industry for diagnosing illness and disease by using X-rays to see internal body structures. The system works by taking multiple digital x-ray images from many angles and combining them into a three-dimensional model that can be used to evaluate internal structures of humans and animals. Industrial CT scanning uses the same technology that has been intensified and improved on for dimensional accuracy. It is capable of scanning through very dense parts and providing a look at the internal structures of industrial objects without having to cut them up to see inside also called Non-Destructive Testing (NDT).

These devices rely on digital images produced from X-ray sources. The X-ray sources are not constant but are generated as the machine is powered up. The X-ray sources are created from a small area and shot through the part in either a cone or a fan shaped pattern. This resulting X-ray strength is detected on either a panel type detector (DDA) or a line type detector (LDA). The detected X-ray quantity is

10597 Chester Rd
Cincinnati, OH 45215
Phone: 513.771.7710
Fax: 513.771.2120
rglassburn@3d-engineering.net

translated into an electrical signal and converted to a gray scale value for that detectors pixel. The whole image is either a full rectangular image or a single line image. The part is rotated and then additional X-ray images are taken. Additionally, the part may be translated vertically and more images taken. All of these X-ray images are then combined and a mathematical model is created. The model is composed of Voxels (Volumetric Pixels). Each voxel has a corresponding gray scale value that signifies its relative density (X-ray abatement ability). Since an X-ray is a photon, the images produced are subject to the same issues/errors/noise (artifacts) as visual light images. The software knows many of the common ones and applies filters to remove the effect of some of these.

Using a LDA instead of a DDA eliminates more of the artifacts caused by stray scattering of X-rays as they bounce of and around the objects being measured. By only having a single line being detected at one time, the effects of stray X-rays is heavily reduced. There is even a Curved LDA design (Nikon) that improves on this concept by angling the detector elements toward the source of the X-rays. This reduces the noise potential additionally in at least a couple of ways. The nominal X-rays are pointed directly at the sensor so the possibility of scattering due to a high angle of incidence X-ray is greatly reduced. The filters that are on the detector elements also tend to reduce high angle of incidence X-rays. The net effect is a stronger electrical signal not subject to as much noise that must be compensated for and therefore allows a better image contrast.

There are practical limits to CT scanning. Very thick parts of high density will limit the ability to image a part. If the part density/thickness is so great that X-rays will not penetrate the entire part being examined, then no image is able to be detected on the underlying detector. This constraint is also partially due to the mathematical model that is created. Each image of the image stack (thousands of individual X-ray images) needs to have valid data for each element represented by the part being examined. If data is missing from an image, this affects the math model being generated and will affect other areas of the part.

It is safe to CT scan most non-living components. The CT scanning equipment itself is heavily shielded to protect the operators. Since the intensity of the X-rays of an industrial CT scan is much greater than a medical scanner, living things would not likely survive. We know of only one instance that the underlying part was in some way visibly changed. As we understand it, some ceramic parts may change color.

This ability to see inside a part or an assembly without destroying it is of great value for many design troubleshooting and manufacturing needs. It solves many current issues that have no great solutions otherwise. The opportunities in NDT scanning service where industrial CT scanning technology can help are as follows:

10597 Chester Rd
Cincinnati, OH 45215
Phone: 513.771.7710
Fax: 513.771.2120
rglassburn@3d-engineering.net

1) Internal passage visualization and measurement

2) External feature data capture which are obscured by the line-of-sight restrictions of optical scanning methods

3) Visualization and quantification of porosity

4) Assembly visualization while it is under the actual stressed assembled condition

A common example of internal passages is cooling passages on aerospace turbine blades which are critical to the performance of their turbines (FIGURE 1).

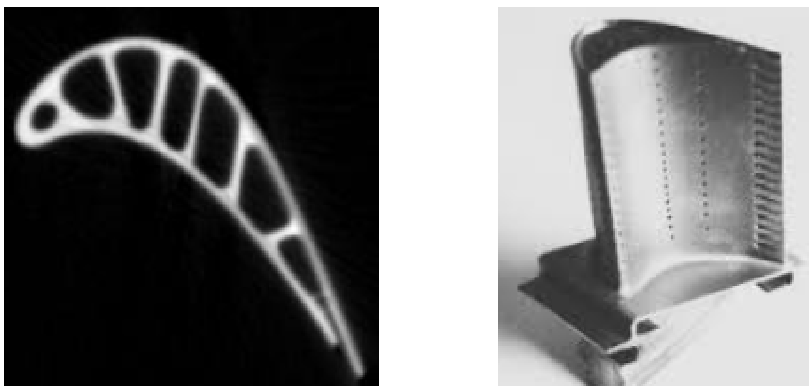

FIGURE 1: Left – 2D CT slice of a turbine blade showing cooling passages. Right – external shot of a turbine blade showing cooling holes.

Modern aircraft engine components are often run beyond their melting temperatures in order to gain greater efficiencies. This is possible through the use of massive amounts of cooling air which is channeled to the hot sections of the engine and eventually thru the turbine blades themselves. If the wall thickness of the turbine blade is not adequate or a cooling channel is blocked, the blade can fail which would cause the blade to melt and cause a critical failure of the turbine. Since the cooling passages are not visible, they must be checked by x-ray and in fact are. However, an x-ray only gives a single slice view and not a full three-dimensional view of the part. Industrial CT scanning provides this ability.

Another issue that is seen with optical measuring techniques relates to an obscured line-of-sight (FIGURE 2).

10597 Chester Rd
Cincinnati, OH 45215
Phone: 513.771.7710
Fax: 513.771.2120
rglassburn@3d-engineering.net

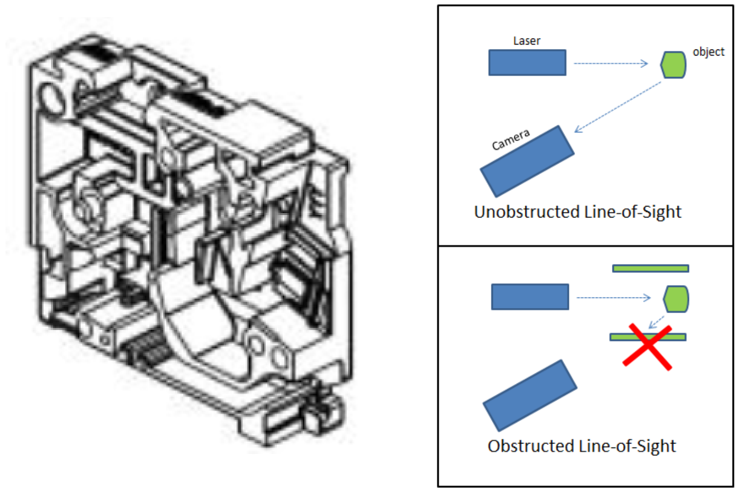

FIGURE 2: Left – an injection molded plastic part with high feature density. Right Top – Typical line-of-sight between the laser, the object being scanned and the camera. Right Bottom – An illustration of an obstructed line-of-sight.

For objects with a dense population of features, the angle between the laser, the object and the camera interferes with the ability to collect data. We are then left with an incomplete data set. Since industrial CT scanning does not require a visible light line-of-sight, this issue is avoided. This allows a full data set to be extracted and accurately measured.

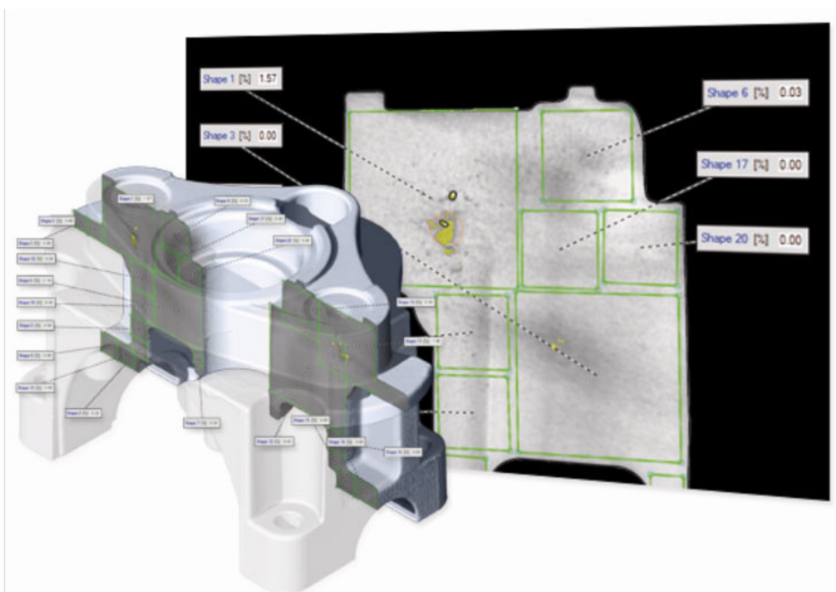

FIGURE 3: An example of porosity in a metal casting. The lower left corner shows CT scan data and the image to the right shows one cross sectional X-ray image that is highlighting various pores or holes that are internal to the casting.

10597 Chester Rd
Cincinnati, OH 45215
Phone: 513.771.7710
Fax: 513.771.2120
rglassburn@3d-engineering.net

Porosity in metal castings or plastic parts is the condition of having unwanted pores (FIGURE 3). These pores can cause high stress areas or leaks in parts. Due to the methods of creating the parts, they are often hidden beneath the surface. Industrial CT scanning allows us to virtually view the inside of components without destroying the part in the process. This can be especially helpful in situations where these castings are later machined. We can predict if the final machined part will expose any pores that would intrude onto the machined surfaces. Exposed pores on a machined seal gland surface can for example inhibit sealing efficiency.

Next, consider the assembly of components that make up a coffee maker (FIGURE 4). The components are often made of different materials with different densities (or x-ray abating properties). Industrial CT scanning allows us to separate components by looking at their effective density difference. This is due to the fact that X-rays are attenuated differently by different materials (denser materials block more X-rays than less dense materials). This gives us the ability to see inside the assembly of parts allowing us to understand if there is a bad internal wiring connection or perhaps one internal component was bent during manufacturing and is causing or would cause an issue in use. All this can be done without having to disassemble the part to visual inspect it. In fact, we don't even have to take it out of its original box or packaging! Since the box is a different density than the materials of the coffee maker, it can be separated out. This could for example be used to sort for a particular manufacturing defect in finish packaged product. The possibilities that CT scanning allows for our customers are quite numerous.

Industrial CT scanning solves each of these issues.

FIGURE 4: A typical coffee maker