The Future is Now:
The Impact of Industrial
Computerized Tomography
on the Castings Industry

You might be surprised to know cast metal products can be found in 90 percent of manufactured goods and equipment throughout the world. From critical components for aircraft and automobiles to home appliances and surgical equipment, cast metal products play an important role in today's economy especially in the United States. The U.S. is the world's largest supplier, shipping $18 billion worth of products annually (according to the Office of Industrial Technologies report, *Metal Casting – Industry of the Future*).

As the casting industry continues to experience rapid growth, it is not without its share of challenges. Requirements regarding material handling competence and the complexity of casting alloys are rising. Also, the increased demand for completely finished cast parts, as well as support for the development of new parts, has metal casting manufacturers struggling to keep up with the pace.

Many manufacturers are researching ways to improve and increase productivity as they are using more complex parts in almost every application. For example, the electrification of the auto industry is just one of the marketplace trends with enormous implications for many foundries. Lightweighting, additive manufacturing (also known as 3D printing), conversions from other forms of production to castings, exporting, and reshoring are other marketplace trends that are affecting the industry.

Global automakers will spend $255 billion on research and development (R&D) for electric vehicles (EVs) through 2023, *according to AlixPartners' Global Automotive Outlook* study on the future of the auto industry. The booming growth in R&D, as well as the need to produce very intricate parts, will drive opportunities for better inspection techniques of high-end casting products like those installed in electric vehicles. This white paper will focus on how Industrial Computerized Tomography (CT) can provide a great benefit to design engineers in evaluating next generation part designs for a variety of applications and the role of Industrial CT and Computerized Axial Tomography (CAT) will play.

Trends in the Casting Industry

One of the best examples of the new trends in the casting industry come from the growing number of electric vehicles. Many countries are adopting more stringent policies on emissions with projections of a complete ban on automotive internal combustion engines (ICEs) in the Netherlands by 2025 and India by 2030. Automotive manufacturers are accelerating production of EVs and plug-in hybrid electric vehicles (PHEVs) faster than anticipated to keep up with this demand.

Market forecasts for EVs and PHEVs point toward a promisingly high annual growth rate. The global EV market is estimated to reach almost $46 billion by 2025, a good indication that automakers and suppliers will need to remain in high gear to keep up with technology. Several factors are steering the upswing in R&D by automakers, such as the ability to:

- Lower manufacturing costs
- Maintain safety levels
- Improve fuel economy
- Lower emissions
- Lower vehicle maintenance costs

R&D must continually improve operations to drive down manufacturing costs and ensure safety as next-generation vehicles take the road.

Fewer, More Complex Parts Needed

EVs are relatively simpler to build, with only *20 moving parts versus the 2,000 parts it takes to currently produce a traditional vehicle*[1]. Engine and transmission components like the drivetrain, cylinder head, engine block, and gear box – all which use castings – will eventually go away. This will create the need for new parts, made from lightweight, more expensive, harder-to-cast materials, and they will be more geometrically complex.

Lightweighting

Lightweighting makes vehicles more fuel efficient and offers better handling. All vehicles lose efficiency as weight increases, but it's especially true for EVs because the battery is very heavy. To account for the battery's weight, EVs are designed with far fewer parts than traditional vehicles. The need to reduce weight in EVs and PHEVs will naturally lend itself to lighter weight materials like aluminum, magnesium, and carbon fiber. Using more structural components to replace multiple individual components lowers the car's weight substantially. Structural applications are being used increasingly in the premium segments for applications such as suspension domes; longitudinal carriers; cross-members; doors; gauges; and A-, B-, and C-pillars.

Worldwide, aluminum foundries will benefit greatly from the trend toward lightweight construction. Global aluminum foundry production is estimated to reach *17 million tons by 2020*[2]. The use of aluminum in automobiles will double from around 12% to 25% of global consumption with 30 million tons used by 2025.

Lightweighting is important for other industries as well, such as aerospace. A small savings in weight on an aircraft can mean big fuel consumption savings (also great for the environment) and better energy efficiency due to less lift force and thrust required. In addition, benefits include *better acceleration, higher structural strength and stiffness, longer flight duration and better safety performance*[3]. But, using lighter weight materials poses major inspection challenges as they are geometrically complex. The need for accurate testing is crucial.

Industrial Computerized Tomography

Due to these trends, the future holds more opportunity for casting errors. Manufacturing must inspect these parts for internal defects and industrial CT offers the best ability to detect potentially crucial discontinuities. A leading technology in the medical field since the 1970s, CT has become a powerful observation tool in the industrial realm. A CT scan produces a two-dimensional density map of a cross-sectional slice of an object's interior. These 2D slices can be combined to produce a 3D image of practically any part, object, or product of nearly any material. This is a cost-effective solution that is critical for any application for which a manufacturer wishes to see inside an object without destroying it.

After creating a 3D model, it is possible to define a surface in the CT volume. Several methods can determine the surface of a 3D model—including ISO50, local threshold, etc. (Different techniques are used, depending on the CT image quality requirements.) Once the surface has been determined, the data can be converted to point clouds. The point cloud can be triangulated by connecting three adjacent points to form triangles all over the surface. This dataset can be transformed by measurement and reverse engineering software tools.

Today's industrial CT scanners provide valuable data for initial prototyping and optimizing production processes. They can detect potential part failures even on larger and denser parts due to the minute detail. These images assist manufacturers with fatigue analysis to identify finite cracks and inconsistencies in part or drawing comparisons. Substrate bonding issues, uneven material flow, density, and porosity problems can also be detected through the accuracy of CT images. In post-production, CT screening can improve productivity by eliminating issues likely to cause possible problems.
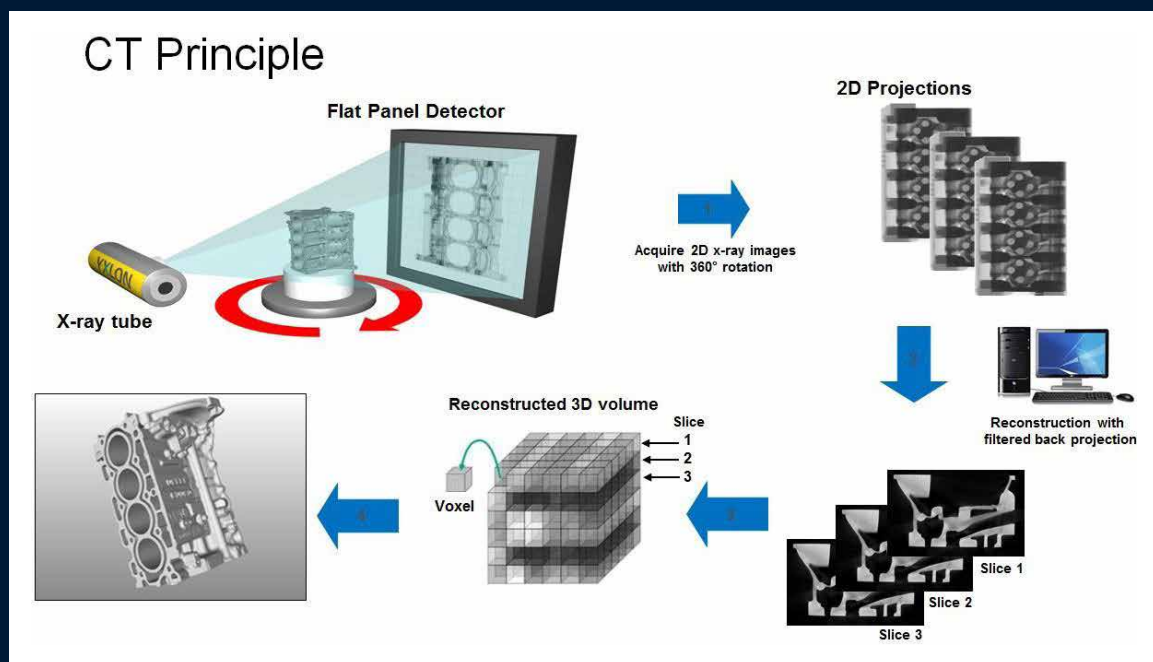
The Role of CT in Casting

Due to these trends, the future holds more opportunity for casting errors. More complex castings, more expensive parts, and parts that are critical to safety all increase the need for better inspecting. The increased complexity can make the components more difficult to inspect, both in development and production. CT can support several phases of the design and build process.

Reverse Engineering
If a new product uses design features from an older part, CT can reverse-engineer components that don't have updated CAD files. Reverse engineering

a part using industrial CT scanning can be faster and more accurate than rebuilding a component from scratch. Scanning legacy parts can generate new, highly accurate CAD models. The data is stored as an STL (stereolithography) file to a number of compatible formats. This data can then be modeled with other relevant formats as needed. In addition, reverse engineering can be used for analytical and testing purposes.
Reverse engineering is also very common to scan parts that physically interface with a new product and access to the digital 3D models from the CAD design is not accessible.

CT-Scan of a historical cylinder head
to cast a new one after having reworked the data.

Comparison of new and
old cylinder head

Metrology

CT has a number of metrology uses. A CT scan can be compared to a CAD model to detect mold deviations or core shifts in aluminum castings. Comparing two parts produced at different times over the lifetime of a mold assesses mold wear.

Comparing a cast part to a machine CAD file can identify open pores where leaks could form. CT can also identify tool wear by scanning the parts produced at specified intervals so dimensional changes can be identified and visualized.

CT is widely used to gather data for creating compliance reports on each cavity of multi-cavity dies for injection-molded plastic parts. It is also invaluable for measuring the properties and geometry of an initial sample item against its specifications for producing a First Article Inspection Report (FAIR) for a specific manufacturing process.

Over the past few years, CT has become accepted as an alternative or complementary method to a coordinate measurement tool. It allows measurement of internal features without the need to destroy a part to access them. Modern technical designs use geometric dimensioning and tolerancing (GD&T) to communicate tolerances.

Standards like The American Society of Mechanical Engineers' (ASME)Y14.5 and International Organization for Standardization (ISO) 1101 provide a set of rules that are commonly used today throughout the industry.

There are several advantages of metrology CT:

- **Programmable repeatability:** During multi-part inspections, report outcomes can be programed to include corresponding regions of interest (ROI), and results are provided shortly after scanning.
- **Clean data sets:** For most applications, CT requires no data merging or smoothing, making typical surface STL data sets "watertight".
- **Non-destructive 3D data acquisition:** Once the volume data is captured, any dimensional feature can be added after the scan.
- **Non-contact scanning:** Soft materials (e.g., rubber) that would yield by any touch can be scanned without the need to contact them.
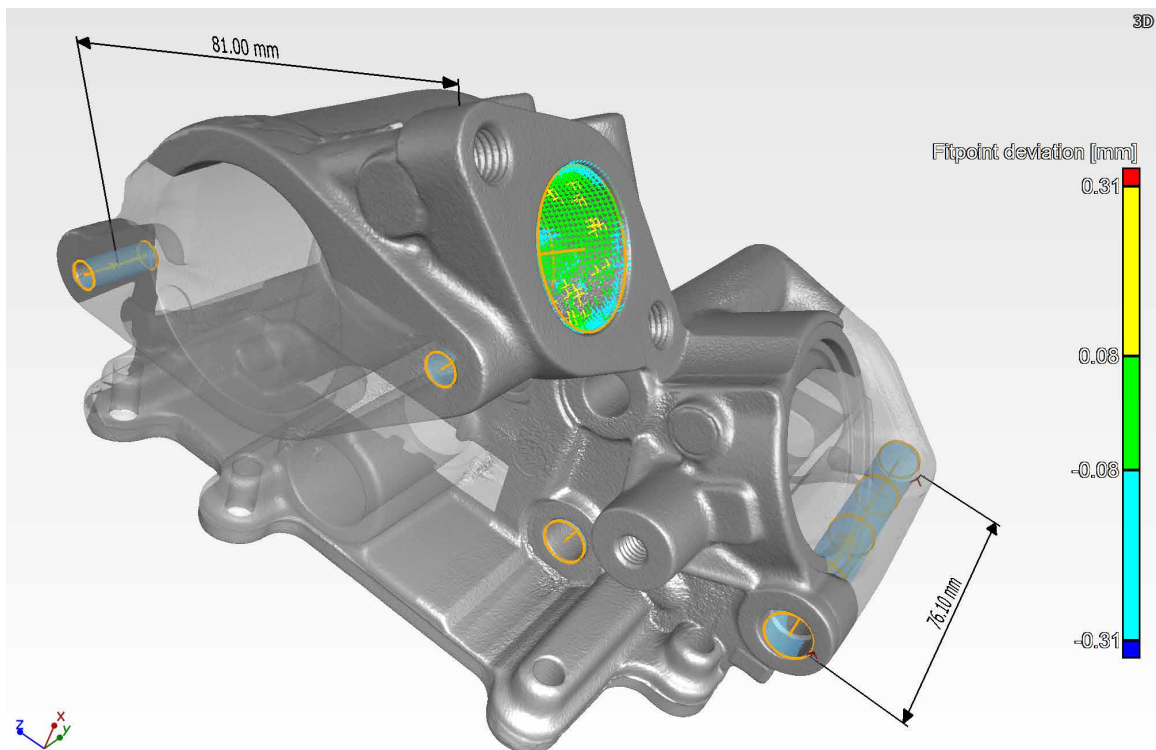
Pre-Production

Once the design is complete, then qualifying the process – including the tools and molds – is crucial prior to production. Industrial CT can detect discontinuities within the part design and quantify findings such as porosity. Engineers can then determine if the discontinuities fall within an allowable porosity or if it is a defect. It can also help qualify molds by confirming the actual parts being produced are in dimensional compliance with specifications.

Software can be used for flow and casting simulations. Engineers can create the mold for a part and simulate the process of injecting the liquid aluminum into the mold and the cooling. This shows the effect on the porosity of the part. When the part is actually produced and CT scanned, they can compare it to the simulation.

Quality Control

Typical casting flaws can occur in all casting techniques that involve materials such as iron, aluminum, magnesium or zinc. These include porosities (pores and blisters), blowholes, thermal cracking, dimensional changes, and inclusions which all can be detected by non-destructive industrial CT. Moreover, CT provides geometric measurements of all inner structures and analyses of wall thicknesses. All this information is indispensable, especially during prototype qualification. For components in the automotive industry like cylinder heads, determining wall thicknesses following the casting process and finish machining provides critical information about the material's stability and thermal conductivity.

Cast parts that don't meet specification can be sorted out early. Engineers can use the data to draw conclusions regarding casting quality from the types of flaws found, thereby increasing productivity by initiating appropriate improvement measures.

Summary

As the casting industry continues to grow and shift toward more complex and lighter weight components, this puts a sharper focus on quality control for safety and reliability of the parts and components created. Industrial CT inspections can be implemented throughout the casting process from research and development through production. The time and costs savings enhance and accelerate the return on the investment making it an efficient and highly effective solution.

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