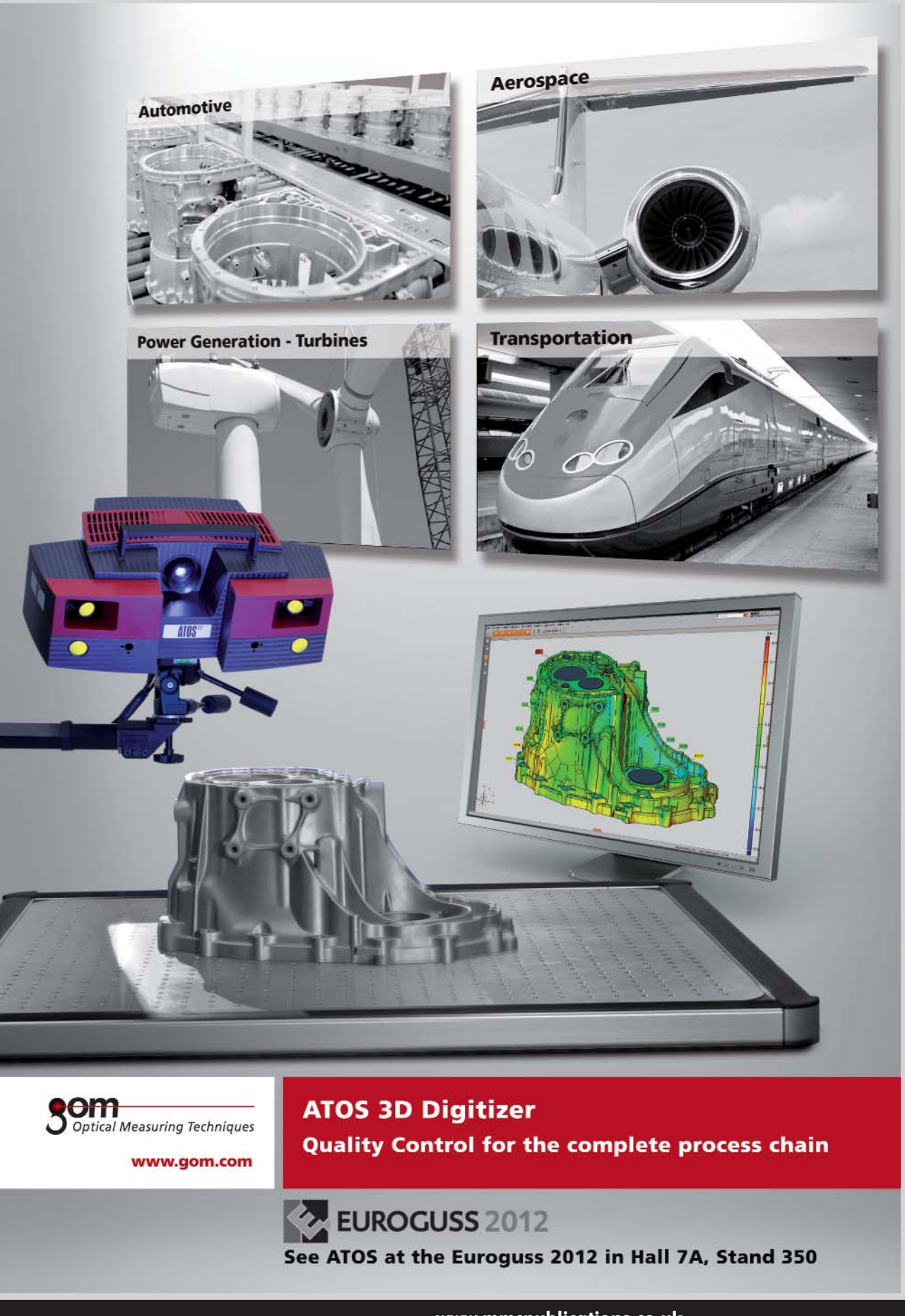
Cast Metal & Diecasting Times



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Alcoa Howmet embraces optical metrology solutions

Full-field 3D digitising surface measurement systems are fast becoming an indispensable tool for quality control in modern product development and production processes. Examples of the advances made by leading optical metrology practitioner GOM are evident at Alcoa Howmet in the UK, as Chris Holding reports.

A leader in its field, Alcoa Howmet of Exeter, UK is a division of Alcoa Power and Propulsion, specialising in the production of complex investment-cast turbine blades and nozzle guide vanes for aerospace and industrial gas turbines. Built in 1970, the site has seen steady expansion to its present two plants, with a combined manufacturing space of 23,760m². The facility covers the complete investment casting process chain from wax pattern production, including its own ceramic core manufacturing and casting process up to finished cast parts. Its work is mainly for European customers presently, including companies such as Rolls Royce, Alstom, Siemens and GE (Figure 1).

Figure 1. Howmet Castings has been an Alcoa business since 1970.

Investment casting

Alcoa sees the investment casting process as having distinct advantages over other manufacturing methods. Flexibility of design means investment castings can be manufactured with complex features, such as 3D contours, thin walls and undercuts. Prototypes as well as large production runs can be produced economically and by incorporating many functional features into a single casting, the break-even quantity can be lowered significantly. A complex casting with many functional features reduces the number of sub-assemblies and the overall manufacturing cost.

Well-engineered designs that select the most effective and functional dimensioning and tolerancing techniques minimise the need for subsequent machining operations. Control of process variables results in a closer tolerance and excellent product consistency. Components can also be cast with ultra-smooth surfaces, without resorting to expensive secondary finishing operations. The controlled solidification casting techniques yield components with improved mechanical properties. Components can be manufactured with the aluminium, titanium, or superalloy best suited to the application.

Alcoa Howmet cast alloys are mainly nickel- and cobalt-based, including IN713, IN738, IN792, IN939, IN6203, Mar-M 002 (crack sensitive nickel super alloy), Mar-M 247, PD21, U500, X40, X45, CMSX-4 (ultra high strength, single crystal alloy).

In addition to its Exeter plant, the company has 10 plants in the USA, three in France, two in Canada and one each in Hungary, Japan and Mexico. Over the last 10 years, Alcoa Howmet globally has gradually integrated the ATOS industrial 3D co-ordinate measuring technique into its turbine-related applications.

GOM mbH - Gesellschaft für Optische Messtechnik was founded in 1990 as a spin-off of the Technical University of Braunschweig. Today, there are an additional six European offices to the headquarters in Braunschweig.

GOM develops and distributes optical measuring systems with its main focus on applications like 3D digitising, 3D co-ordinate measurements, deformation measurements and quality control. Systems are used for product development and for quality assurance, material and component testing. Customers are the automotive industry, aerospace industry and consumer goods industry, as well as their suppliers, numerous research centres and universities. GOM is a single source provider, offering hardware development, software development, production, distribution, training concepts and professional support.

Meeting of minds

Recently, *Cast Metal & Diecasting Times* was given exclusive access to a customer meeting between Alcoa Howmet and GOM representatives to discuss the merits of the GOM ATOS optical metrology systems. Howmet acquired its first GOM stereo camera 3D digitising system in 2001. With a measuring volume of 500mm to capture a single scan in a few seconds, it can measure medium-to-large-sized objects, from a blade to a passenger car. For more throughput, Howmet invested in an additional system nearly four years ago which has advanced techniques regarding speed of acquisition and accuracy (Figure 2). It is equipped with smaller measuring volumes of 100mm and 300mm which offer higher resolution for measuring more detailed shapes, eg ceramic blade cores or internal cooling structures with turbulators. Both are the semi-automatic mobile version of ATOS. The layout department at Howmet Exeter consists of five people operating also two tactile CMM systems. Parts handled range from 40mm to 1m in size, with various requirements for detail and accuracy.

The ATOS machines at Howmet project a white light pattern onto the workpiece, creating millions of precise measuring points within a few seconds. The process-safe systems are self-monitoring and check automatically for valid calibration and unwanted movement after each scan. With more

Figure 2. Customer feedback meeting (left to right) Stephanie Adolf, GOM mbH; Matt Willacy and Steven Edwards, Alcoa Howmet; Kevin Hawley, GOM UK Ltd.

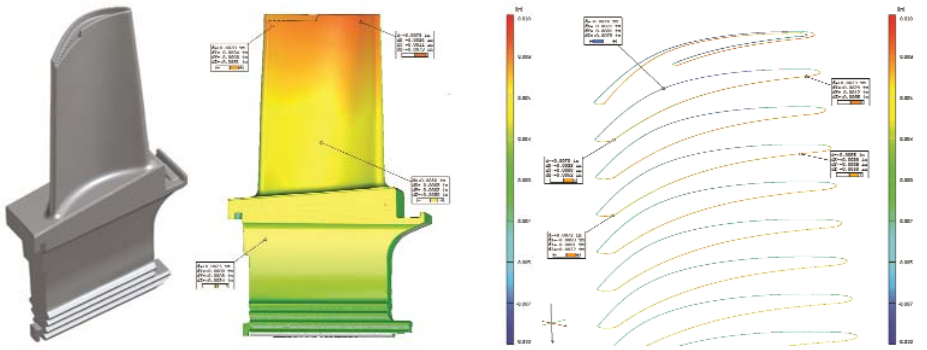

Figure 3. GOM Inspect Professional software shows 3D measurement deviation in a colour plot. Warm colours indicate too much material, cold colours too little (image courtesy of GOM).

than 20 years of experience in developing optical 3D measurement systems, GOM's latest development involves the use of a blue light LED system within the ATOS Triple Scan, which is fully independent to ambient light and improves scanning of shiny surfaces.

Howmet has found that ATOS is suitable for many aerospace customers. The full quality approval of ATOS on new parts is already largely in place at the majority of its customers, while others use similar systems in their general production and are expected to migrate soon. While Howmet has plenty of such work booked in 2012-13, including at least a dozen significant contracts, the business has had to manage a drop in projects, which have lagged behind the global recession.

For Howmet, the profit is only in the finished product now, so the company is focussing on being the best practitioner in directional solidification, single crystal and equiax methods. The company is a casting house with its own moulding shop, core room, casting facilities and alloying capabilities. By working with new alloys and maintaining high quality, a good revenue structure can be maintained.

Howmet approach

Each new customer contract starts with a 3D CAD drawing or model. Howmet looks at the castability and then the process cost. External toolmakers and other suppliers are involved closely in the review phase. An online supplier tooling manual is employed to assist with tenders. There is in effect a complete redesign process each time, using quality (and cost) 'tollgates', where up-to-date best practice and new materials are assessed and incorporated. A general assembly drawing is produced which contains the casting block in sections. Next comes the project plan, where the most effective supply is mapped out. The objective is invariably to validate one or two engine sets with the customer.

Most tooling is owned by customers, although Alcoa has proprietary technology in the single crystal field which the company either retains or deletes on the occasion of a product transfer. Layout Department Technical Manager Steven Edwards explains that the layout department carries out first article validation and inspection. Wax patterns are initially measured by CMM as cast. ATOS capture is used by Alcoa Howmet in its validation, when initial reforming/deforming of cores takes place. It is known that traditional CMM point measurement can be inaccurate, for example with localised residual wax on a larger surface.

In contrast, the ATOS data measures the complete surface leaving no 'blind' areas behind. The output is a colour map, showing the deviation of the whole part to the CAD model, instead of just key points (Figure 3). "This also means a huge advantage in result evaluation and reporting" explains Steven Edwards. "Fifty pages of spread sheets with 400 single points shrink to two or three easy-to-understand pages. It makes part discussing and pinpointing so much easier."

Stephanie Adolf, Manager Sales Operations for GOM (Gesellschaft für Optische Messtechnik mbH) points out other changes introduced by optical metrology: "One trend we observe already is the simplification of drawings when optical scanning is utilised for inspection. Operating with a full surface database, drawings need be less detailed than they used to be. As only few important functional dimensions are defined, eg via shape and position tolerances (Geometrical Dimensioning and Tolerancing, GD&T) and for all other surfaces, CAD data is defined as the master or a profile tolerance is set."

According to Stephanie Adolf, there is also a noticeable trend to include inspection features direct within the CAD model. "One way this can be done is by inspection planning on CAD data in the parametric GOM Inspect Professional software. If inspection features are already attached in native CAD files such as FTA (Functional Tolerances and Annotations), eg by CATIA, these inspection features can also be directly imported and evaluated in GOM inspection software. We expect that inspection and quality control planning will be much more connected to the CAD design phase in the future."

Steven Edwards also emphasises the integration of different departments already in place. Since optical scanning has been introduced at Howmet, the design department is also profiting from scan data. These go back to the designer for FEA simulation and Computational Fluid Dynamics (CFD) analyses, closing the loop over different departments.

Proven advantages

Howmet says it is now seeing what could not be seen before. As a result, the company is being more creative in how it uses the system within the complete process chain. As has been found at other GOM customers, such as the Georg Fischer AG sand casting division in Germany, ATOS does create more discussions with customers but crucially, it leads to transparency in production and customers can improve quality as a result.

General advantages of ATOS researched by GOM suggested that it gives:

- Targeted troubleshooting.
- Reduction of quality iterations.
- Analysis of outcome of corrective measures.
- Flexible analysis (without new measurements) due to having a full surface data base.
- Shortening of time to market.
- Less rejects and rework.

However, the test is always in the practical application of any technology by a customer. Steven Edwards and Senior Layout Engineer Matt Willacy of Alcoa Howmet explained to *Cast Metal & Diecasting Times* exactly where ATOS has improved their operational situation. "The way ATOS benefits Howmet is by reducing lead times on layout inspection, by increasing the number of datum points to work with and then there is the positive customer response" commented Steven Edwards. Several specific examples were then related on the flexibility and usefulness of their GOM ATOS 3D surface measurement machines:

Relaxation of customer's design tolerance: By being able to feed back an object capture via quality controller, engineering and ultimately the designer, the possibility of simulating and improving the design intent arises. Howmet is now in a position to communicate and justify tolerance relaxation on non-critical areas, where previously the whole of a surface had the same drawing tolerance specification. The designer is able to run modified CFD and FEA analyses.

Reverse engineering of engine components: Not only can engine component production tooling undergo

Optical metrology (GOM) comparison with co-ordinate measuring machines (CMM)

The advantages of 3D surface measurement over other measurement devices (tactile CMM, manual measurements etc) are:

- No fixtures are necessary.
- Mobile system goes to the object - no transport of large parts to a measuring room required.
- Short measuring time compared to tactile CMM.
- Tactile CMM inspection (eg of sheet metal, car side panel) of 441 measuring points will take around 480 minutes, compared to an optical inspection of 441 measuring points in some 20 minutes, giving a time saving factor of 24.
- Full 3D part surface measurement means no 'blind' or unchecked areas are left, leading to increasing part safety.
- Easy-to-understand results via full surface comparison as a colour plot deviation.
- Less time necessary for results discussion.
- Clearly laid out results instead of 2D number spread sheets, whereby 100 pages of 2D number spread sheets shrink to one image.

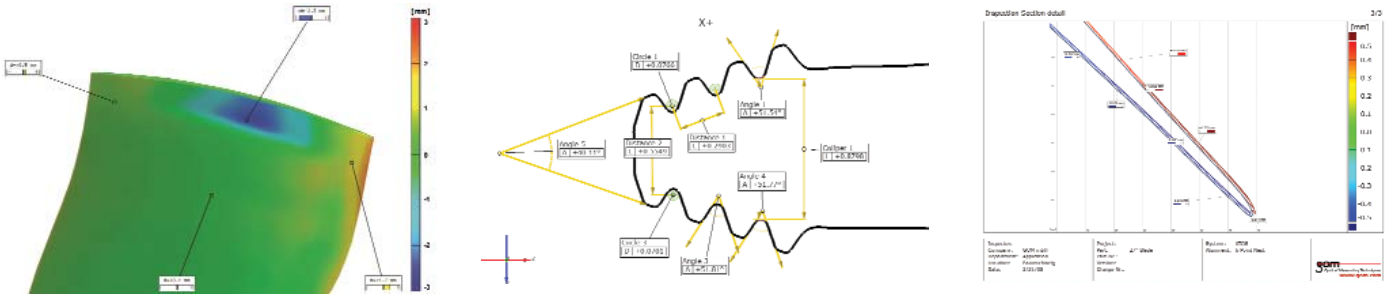

Figure 5. GOM Inspect Software allows for point cloud and mesh processing of any 3D data. It also makes data from the professional version accessible, reducing the workload for Alcoa Howmet's Exeter layout room (image courtesy of GOM).

modifications during engine model life but when a part becomes transferred, there is also a chance of original drawings being left behind and lost. Being able to capture a component fully and produce a precise CAD model is a sound basis for making replacement engine parts.

Targeted tool correction and wear analysis: In around one day, the ATOS system can effectively map the inside cavity of a multi-block tool assembly when closed. In one case, a core appeared to be moving as wax went in. Pin wear of .2 to .3 on a 2mm-3mm diameter pin was found to be the issue. With the wax wall thickness at around 2mm, it is of significant value to solve such issues. The tool assembly capture is also fine to check possible wall thickness between the ceramic core and outer shell before the casting process.

Rapid resolution of process issues: A dint in a blade surface slightly above a blade root caused repetitive quality issues. By investigating each production step with ATOS, the problem was identified in the wax pattern shop. ATOS showed that the operator removing the wax pattern was causing slight blisters with his hand which were showing up clearly in the measurement data. This would have been impossible to detect by a series of costly checks and trials under a tactile CMM regime.

Ability to check tooling accuracy/contraction rate: In the production of near net shape parts, the contraction rate of the tool becomes important. ATOS was used to measure a complete green core when product was not making specification. This showed that the supplier's tool was inaccurate and that the contraction ratio needed adjustment.

Quicker scanning of sections and internal cooling structures: In the established method, a cut blade profile is given an ECM polish. Then a tactile CMM takes XY measurements, after which Siemens NX software is used to spline (join) the point data. This gives a core profile and a core position reference. The process takes around two hours. Using the ATOS stereo camera 3D digitiser, a blade section is simply placed on a rotating table, which gives a true representation in around 15 minutes. In addition to sectional data here, most of the internal cooling structure complete surface is measured for better quality control and faster understanding of core position and dependent wall thickness.

Figure 4 shows an interesting aspect of using ATOS. The object is an aerofoil profile for a robot gripper. Capturing the turbine blade allows creation of the matching gripper profile. When you look at the value of a single cast component, it can range from £400 to £7000. With up to 96 blades on one turbine, it becomes worthwhile to make such bespoke gripper fittings.

3D data evaluation software

To meet customer applications, all measuring technologies including hardware and software are developed within GOM. Besides processing and evaluation of own measurement data, the software packages GOM Inspect Professional and GOM Inspect are now open also for mesh processing, 3D viewing and inspection of 3D data from other sources, such as laser scanners and CT data.

As many companies are using different measuring systems even within one department, the open software packages allow them to have a uniform and consistent evaluation and inspection workflow with 3D data from different systems. Talking about software, Steven Edwards is also impressed by the pace and quality of GOM's software functions. The introduction of the parametric GOM Inspect Professional Software was just the right thing to do. It makes multi-part inspection much faster and easier. Changes in inspection and creation of features can be automatically updated and results are truly traceable.

Howmet is also looking forward to networking GOM Inspect software onto its Windows PCs. Since October 2010, the free website download of GOM Inspect has given inspection, mesh processing and 3D point cloud capability to thousands of engineering companies worldwide, independent from the measuring system used. The free software means results are accessible for colleagues and customers for own/further evaluation, allowing time savings during results discussion. It will also reduce the workload for Alcoa Howmet's Exeter layout room (Figure 5).

Optically tracked touch probes

Many complex metrology applications require the combination of full-field and point-based 3D measurement. The GOM Touch Probe is an add-on to the ATOS 3D Digitiser. It is a calibrated set of point markers which are optically tracked by the ATOS system measuring the online 3D co-ordinate of the calibrated probe tip. It provides measurement in difficult to access areas, pointwise comparison directly to CAD, measurement of primitives, quick measurement of individual points, as well as online alignment. The hand-held touch probe enables the user to switch easily between 3D full-field measurement and online tactile probing of specific single points.

Seeing everything

The evolution of optical metrology has seen a very high pace in the past four years. Comparative developments in tactile CMM seem to be frozen and have related solely to the 'device on end' improvements. The advances are summed up well by Steven Edwards: "The ATOS 3D camera technique lets us see everything. With tactile CMM, we have nothing." Kevin Hawley, Sales Manager of GOM UK Ltd, advises that up to eight million points can now be measured in just a few seconds using ATOS. With its development commitment and customer focus, GOM has leapt up the market ladder into a healthy position. The visit to Alcoa Howmet has fully justified the company's market approach and demonstrates the reward for focussed development work.

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Figure 4. Senior Layout Engineer Matt Willacy sets up for measuring to create a gripper.

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