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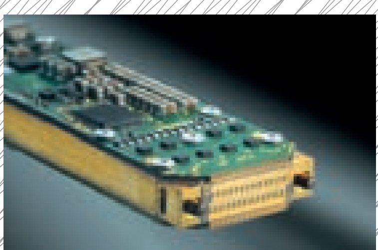
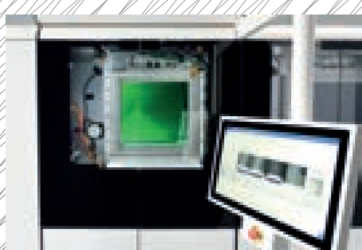
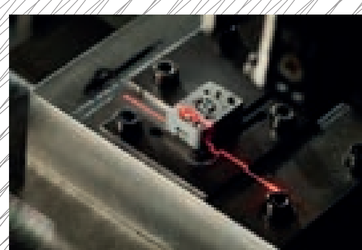
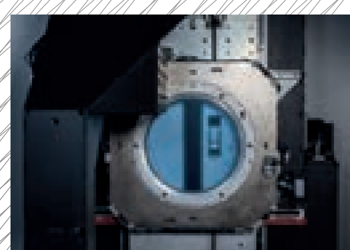
■ **DSPE CONFERENCE 2016** REPORT ■ DIE-BONDER **SYSTEM ARCHITECTURE**
■ THEME: **ADDITIVE MANUFACTURING** ■ **PRECISION FAIR 2016** PREVIEW

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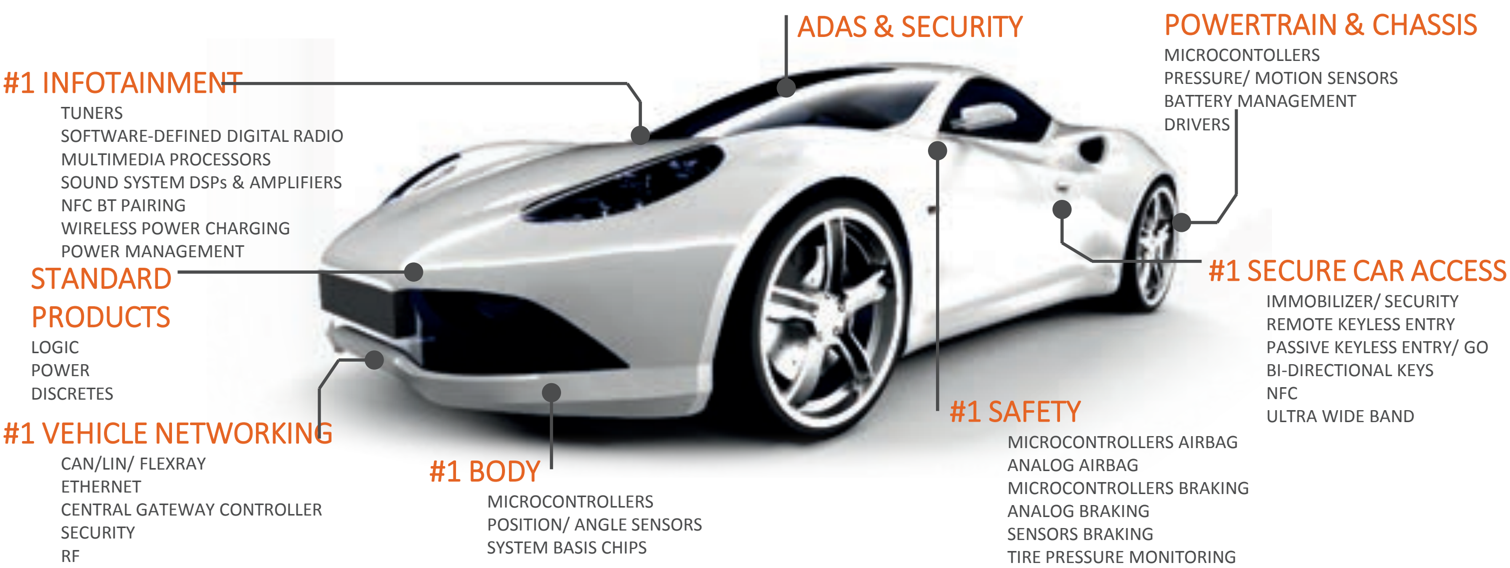

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FEATURES

3D METAL PRINTING HAS GROWN UP, BUT DUTCH MANUFACTURING IS STILL PLAYING CATCH-UP

During the past two years, additive manufacturing (AM) technologies – more commonly known as 3D printing – have matured rapidly. Initially, poor part and process performance limited potential applications to rapid prototyping. Now, series production of structurally loaded parts in demanding applications is within reach. But what has changed during the past two years and what will be the impact of this change?

Recent innovations in computer aided design (CAD) and engineering (CAE) software have improved their usability and capability. Now, engineers can optimise a design for function, leading to complex but highly efficient designs. The promise of increased operational efficiency has led to a focus of industry and research. Subsequently, there is better understanding of AM's design freedom and its process windows. Now, these complex designs can be produced accurately and cost-effectively by select organisations. The result? Less resources used in the operational phase. A major challenge remaining is that software is not able to optimise a design for manufacturing. This requires the experience of a skilled design engineer, of whom there will be a great shortage in the market.

With more demanding applications, new requirements on part and process performance emerge. For specific applications, such as medical, dental and aerospace, certification and regulation are now in place. As a result, AM is (becoming) the main production method in various applications, e.g. dental bridges, medical implants, aerospace brackets and specific tooling. Novel testing methods are being developed, which align with the high-mix, low-volume nature of AM. These methods – such as process simulation or in-situ process monitoring – enable flexible validation before or during production. As opposed to post-production testing based on statistics, which limits the benefits of AM. In addition, increased speed and ease-of-use are required. A new generation of metal AM machines is coming to market, geared towards industrial series production of functional end products. The MetalFAB1 by Additive Industries is a good example.

A fully digital value chain – supported by AM – enables radically new business models. However, understanding the benefits of AM is challenging. It requires you to look beyond what is right in front of you and often results in increased process complexity. For example, a medical implant produced with AM may be five times more expensive. But due to digital planning and a better form fit, the operation time is reduced and the patient return rate reduced. These benefits affect multiple elements in the value chain and require collaboration and communication to capture. For most organisations this is challenging; it requires people to take ownership of a problem and take control of internal and external processes. For true business model innovation, the interaction with the customer must also change, involving the customer early on and continuously.

Few organisations know how to do this and the Netherlands is no exception. Successful implementation of metal AM requires two to three years of dedicated focus for a single organisation. While the number of metal AM machines in the Netherlands has increased in the past two years, adoption is far from reaching critical mass. Compared to the global and European situation, the sense of urgency is missing here. Will the Dutch manufacturing industry be able to catch up? If so, it must act now and act fast.

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LONG STROKE / SHORT STROKE

As equipment and solution provider for NXP's back-end semiconductor factories, the Industrial Technology & Engineering Center (ITEC) has introduced the successor of its high-speed die-bonding and die-sorting platform, the ADAT3-XF. It includes 300mm wafer handling capability, increased throughput & accuracy as well as improved serviceability and shorter conversion times. The development team faced a few interesting challenges, such as a complete redesign of the frame and the introduction of a short stroke / long stroke wafer table with balance-mass functionality.

THIJS KNIKNIE, KEES HAZENDONK AND JOEP STOKKERMANS

The ADAT (Automatic Die ATach) platform is a pick & place machine dedicated to back-end semiconductor processes.

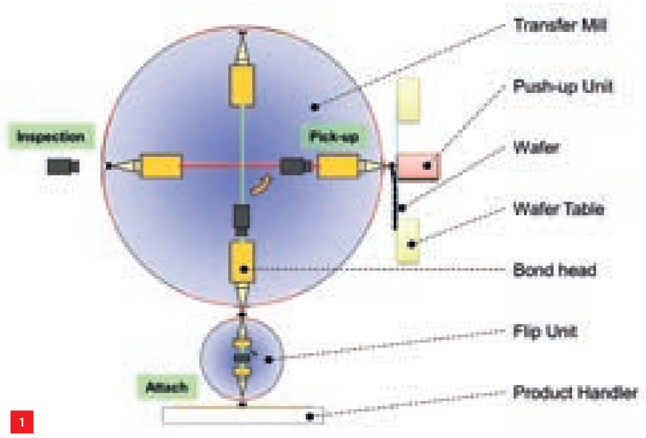
Two main processes are key in the ADAT:

- Die bonding: in this process a semiconductor device (die) is picked up from a sticky foil with separated dies, usually from a sawn wafer. The die is bonded (attached) on a variety of substrates (lead frames) by solder flux/paste, glue or an eutectic bonding process.
- Die sorting or taping: a product (bare silicon or a package) is picked up from the foil and placed in tape, which is sealed after placing the product.

ADAT3 architecture

The ADAT3 concept is centred around its Transfer Mill, a rotating axis with four so-called bond heads (Figure 1). The concept of having four rotating bond heads enables parallelised pick & place processes, roughly doubling the production speed compared to a sequential pick & place process. The wafer is positioned vertically in the machine by the Wafer Table. For a fast and repeatable pick-up process, a Push-up Unit is located behind the wafer to push up a die from the wafer foil. Below the Transfer Mill a variety of Product Handlers is positioned for die placement on several substrates (lead frames) or tape.

The breakthrough (patented) transfer mill concept was introduced with the ADAT3 in 2003 and boosted the machine speed with a factor of two with respect to the earlier ADAT2 with transfer arm. For flip-chip production, a flip unit is optionally positioned under the transfer mill.



1 *ADAT3 architecture. Three steps can be distinguished: Pick-up, Inspection and Attach, indicated with green boxes. Contributing modules are depicted with dashed lines.*

Why a new ADAT3-XF platform?

The ADAT3 die-bonding and die-sorting platform has proven its competitive advantage for the last 15 years in terms of output speed and product placement accuracy and by enabling new package innovations and processes. At this moment the current ADAT3 architecture is at its limits in terms of accuracy and speed. The next step in the ADAT3 roadmap includes further speed and placement accuracy improvements, 300mm wafer handling capability, but also extending product quality inspections and platform flexibility. The additional "XF" in ADAT3-XF therefore stands for extended speed (Fast), Flexibility and Functionality.

High-level requirements

Basically, the challenge is to have a capability for higher speed and a smaller die placement accuracy within the same concept. This implies that the shorter cycle times that are required for speed-up should not result in unacceptable dynamic disturbances to the positioning modules.

AUTHORS' NOTE

The authors all work at NXP ITEC in Nijmegen, the Netherlands. They wish to acknowledge their development partners MI-Partners, Sioux CCM, VDL ETG and Cortexon for their collaboration and support to meet time-to-market. This article was, in part, based on a presentation at the DSPE Conference 2016 (see the report on page 45 ff.).

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The XF platform will also have capability for new applications. Maintaining the vision of the ADAT platform to be a one-stop-shop for high-speed die-bonding and die-sorting applications, the new applications and processes are added to the existing platform.

Additionally, the assembly factories and supply chain demand a more flexible platform in terms of conversion time and cost of ownership. Modularity, accessibility and shorter conversion times thus get full attention as well.

NXP and ITEC

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The NXP Standard Products business is an industry leading supplier of Discrete, Logic and PowerMOS semiconductors focussed on the Automotive, Industrial, Computing, Consumer, and Wearable application markets. NXP Semiconductors announced an agreement to divest its Standard Products business to a Chinese consortium. At the close of the transaction, the NXP Standard Products business will be branded Nexperia, which will be headquartered in Nijmegen, the Netherlands.

The NXP Industrial Technology & Engineering Center (ITEC) is an internal industrial solution provider of semiconductor back-end equipment and manufacturing IT. ITEC is an integral part of the business unit Standard Products. Competing in high-volume, low-cost markets requires a focus for lowest cost of ownership in the manufacturing set-up and infrastructure. A large part, from waferfab to final test, is controlled by internal manufacturing. The development of exclusive, high-end solutions brings a competitive edge to NXP's standard products manufacturing. Vertical integration enables businesses by tailored solutions and exploiting the synergy with package innovation and test innovation.

Project management

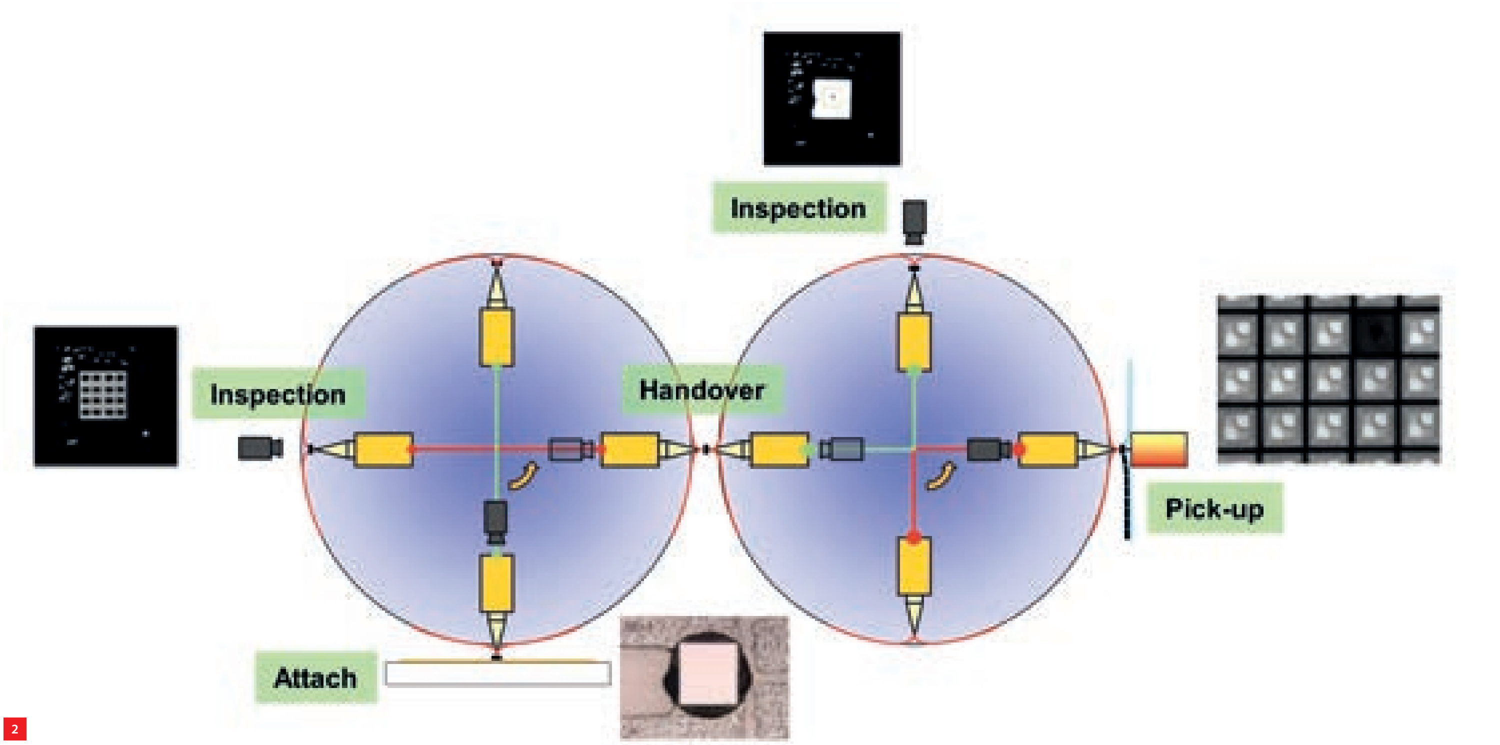
Development of new (mechatronic) modules such as the frame, transfer mill, wafer table and push-up unit started in the pre-development team as high-level-definition building blocks for the new platform. For every building block a small team continued with conceptual modelling calculations and the definition of alternative solutions. In the architecture team, with all disciplines represented, the alternatives were ranked and the best solution was worked out further. In the development phases the design teams adopted standardised techniques within NXP to judge the design: FMEA for risks and failure, DfX for performance excellence and quality, and DfMA for manufacturability and costs. As buying of these complex mechatronic modules was soon abandoned as an option, co-developments with among others MI-Partners and CCM were started, led by the architects of NXP ITEC.

The choice of working with co-developers (MI-Partners was actually already involved in an earlier stage for concept studies and defining architecture) made it possible to use the experience and extra resources of the co-developers to build prototypes and redesign them if necessary and allowed in the short time frame. In parallel with the prototype projects, module improvement projects, software and motion control developments started at ITEC. In the end the usage of co-developers, controlled by the architecture team, and parallelised software development resulted in a very short time-to-market and first-time-right result.

ADAT3-XF architecture

Double Transfer Mill

To add more flexibility in machine configurations and to benefit even more from the power of the transfer mill concept, the XF platform introduces the 'double-mill' concept. This enables fast conversion from flip to non-flip processes and secures the roadmap for speed-ups.
Figure 2 shows the concept schematically. Products are picked up by the Pick-up Mill from a sawn wafer on foil at the right hand side. After quality and alignment inspection on the top, the product is handed over to the Attach Mill. A second quality and alignment inspection is done on the other side of the product and the product is placed on the lead frame. After placement the third inspection is done.



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2 *ADAT3-XF transfer principle. See text for explanation.*

3 *General functional behaviour of the ADAT platform.*

The double-mill concept introduces more calibrations and adjustments; with two transfer mills it is required to mechanically align four bond heads with respect to each other on one transfer mill and with respect to the other transfer mill. The alignment problem is solved by using dedicated alignment cameras and an innovative way of calibrating and compensating.

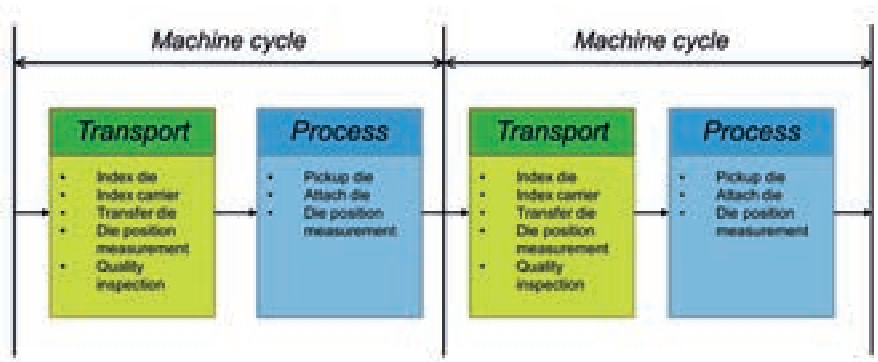
Machine cycle
The ADAT3 platform combines micrometer pick & place accuracy with extremely short cycle times. This is realised by innovative mechatronic design; however, even more important is the machine cycle design. A simplified overview of the ADAT machine cycle is shown in Figure 3.

The processes can be roughly divided into:
- A transport or die-select phase: all indexing modules are moving to the next position and inspections are done on processed and unprocessed products.
- A process or die-transfer phase: pick-up, handover and attach processes take place together with additional inspections.

It must be said that this is a very rough division, because in practice the machine cycle of the ADAT is highly integrated and optimised for machine speed. Transport and process functions overlap and interact. This requires perfect synchronisation and minimal communication delays, which is realised by the software architecture and a dedicated motion control platform: FlexDMC.

Dynamics & control
The pick & place processes in the ADAT require an index step for almost all modules. This implies that the modules have a requirement on settling behaviour, rather than tracking behaviour. This gives two advantages:
1. Offsets and low-frequency drift phenomena can be compensated by adapting the setpoints based on information from the inspection optics. This can be seen as a low-frequency feedback loop with the inspection result as input and the position setpoint as output.
2. Dynamic disturbances are acceptable provided they settle quickly enough after finishing the setpoints.

In the ADAT3 all modules involved in die transfer are mounted on a single frame. An advantage of this architecture is that the modules have fixed reference



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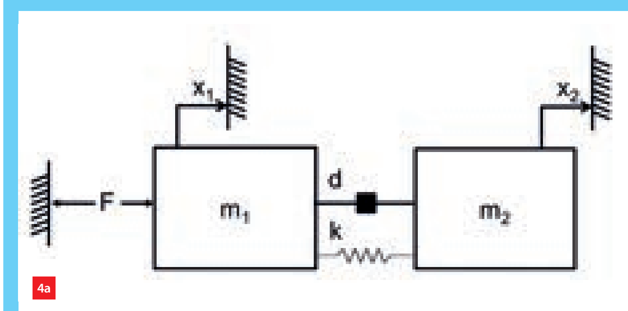
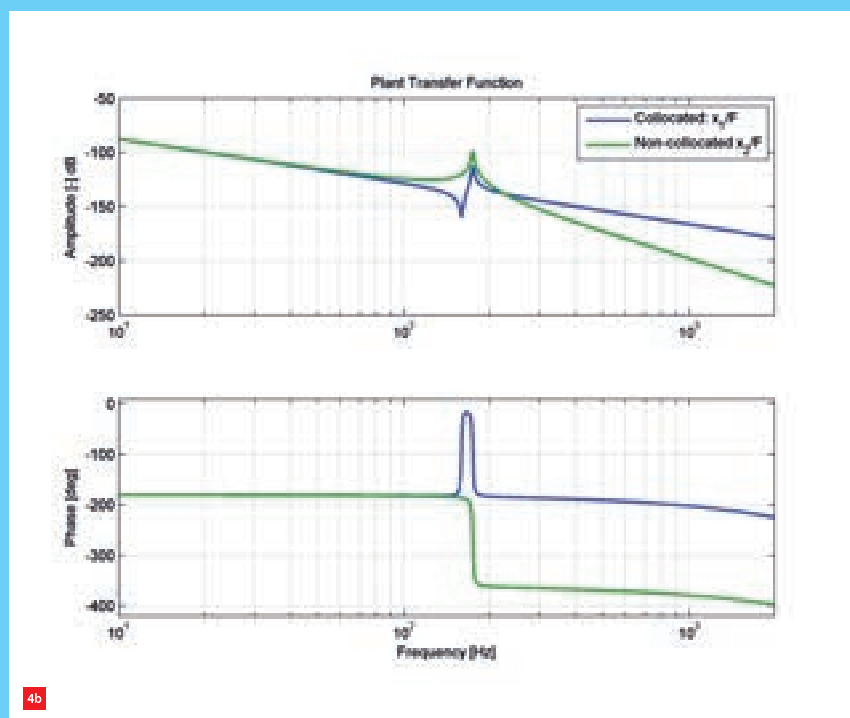
positions with respect to each other, so metrology and inspections are relatively straightforward. All modules can have local measurement systems that are referenced to each other by the inspection optics. This gives the opportunity to design so-called collocated controllers: the sensor is placed as close to the actuator as possible.
With mechanical designs that are dynamically optimised this results in controller bandwidths that easily go beyond 100 Hz. This is a powerful combination for high-speed indexing with micrometer settling accuracy, because the feedback controllers with these high bandwidths are well able to suppress disturbances.

A disadvantage of placing all dynamic modules on a single frame is that the modules experience reaction forces from each other as disturbances. This dynamic crosstalk gives limited measurement and positioning accuracy. Figure 5 provides insight in how frame dynamics influence the process accuracy. For modules that are measuring relative to the frame, the frame accelerations are seen as a disturbance on its controlled position. In fact, if the module has to stand still with respect to the frame, it has to exactly follow the acceleration profile of the frame too.

Collocated and non-collocated control

Intuitively one may choose to control the position of the point of interest as best as possible by placing the sensor in the feedback loop close to this position. This is called non-collocated control. This gives the most accurate information about the point of interest. However, the mechanical design often has compliant parts between the actuator and the point of interest and this gives control challenges.

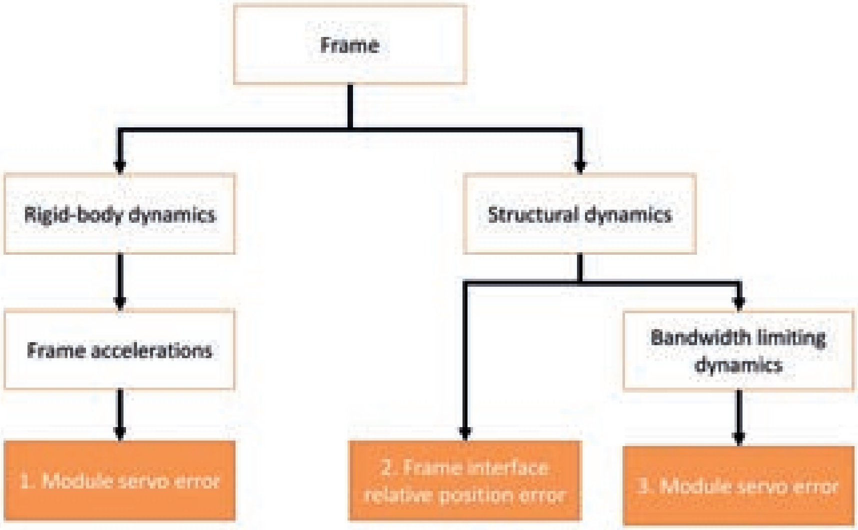




4 *Two-mass model with compliance. For collocated control, the sensor position would be x_1, for non-collocated control the sensor would measure x_2.*

Figure 4 shows the transfer functions of a simple compliant mechanism for both the situation of collocated and non-collocated control. It can be seen that for collocated control, an anti-resonance/resonance phenomenon is seen, giving a phase increase of 180 degrees between these frequencies. In case of non-collocated control, the phase drops 180 degrees permanently.
In general, this implies that a stable controller can only be one with a bandwidth significantly lower that this mechanical resonance frequency. For the collocated case, the resonance results in degradation of the positioning performance at the point of interest, but only for disturbances above the resonance frequency, when m_2 decouples from m_1. The bandwidth can be higher, giving better disturbance rejection and settling behaviour.

Increasing the resonance frequency – thus improving the mechanical design – decreases the disadvantage of non-collocated control: the achievable bandwidth becomes higher. However, this is not always possible in systems with a high level of functional integration, because the designs become less 'pure' in terms of dynamics.



5 *Breakdown of frame dynamics towards position errors.*

Regarding the ever increasing machine speeds and integrated functionality on the indexing modules, a direct reduction of the module reaction forces by lowering mass and acceleration does not advance the machine in the roadmap. Therefore, a drastic frame redesign was chosen as one of the first steps in the ADAT3-XF platform development.

Several ways of reducing the crosstalk were implemented in the new frame design. Each will be discussed in one of the following sections:

1. Increase frame mass.
2. Design a predictable low-frequency damped suspension.
3. Limit reaction forces towards the frame.
4. Design internal frame resonances to be above the significant setpoint frequency content.
5. Avoid disturbances of supporting functions.

1. Increasing the frame mass

A higher frame mass reduces the accelerations of the frame as a result of reaction forces:

$$F_{\text{reaction}} = M_{\text{module}} \cdot a_{\text{module}} = M_{\text{frame}} \cdot a_{\text{frame}} \quad (1)$$

$$a_{\text{frame}} = (M_{\text{module}} / M_{\text{frame}}) \cdot a_{\text{module}} \quad (2)$$

This only holds when the frame is a 'free mass'. In practice the frame is suspended and the suspension frequency and damping largely influence the response on dynamic reaction forces. Therefore, a second design change was made with respect to the ADAT3 frame.

2. Predictable low-frequency damped suspension

In precision systems two ways of frame suspension can be found:

a. As stiff as possible
   This gives a high suspension frequency, provided that the floor stiffness is higher than the frame suspension stiffness. The available reaction mass of the frame is extended into the factory floor (up to the suspension frequency).
b. As weak as possible
   This gives a low suspension frequency. If low enough, the suspension frequency is only marginally excited by the modules, because the frequency content of the setpoints lies above the suspension frequency. Above the suspension frequency the frame acts as a free mass, making Equations (1) and (2) valid (in the absence of damping). In addition floor vibrations have limited effect on the servo performance.

In NXP's factories, the assembly equipment is placed on an elevated floor, but in other factories on a reinforced concrete floor. Additionally, different platform configurations have different masses, so the suspension frequency can vary significantly. This makes the frame dynamic performance unpredictable and in extreme cases the suspension frequency coincides with the setpoint base frequency and will result in extremely high frame accelerations that have a dramatic impact on the servo performance of the modules on the frame.

For positioning performance of the dynamic modules on the frame it is therefore required to suspend the frame such that the suspension frequency is lower than the base setpoint frequency and – most important – that this frequency is predictable and repeatable. Due to the large variation in processes running on the ADAT3-XF, it may still happen that the machine cycle frequency coincides with the suspension frequency. That is why the suspension is also heavily damped, using damper elements with extremely high damping.

3. Limiting reaction forces

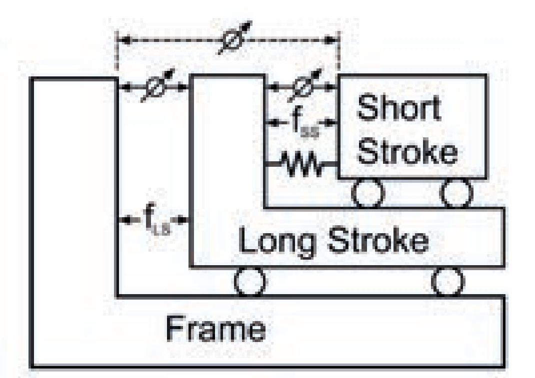
The sum of all reaction forces of the servo systems should be limited to avoid high frame rigid-body accelerations. However, the speed requirements will in the future result in higher accelerations of the modules. Therefore, balance masses are applied where necessary. In the ADAT3-XF this is implemented in the new wafer table.

XF Wafer Table – balancing the reaction forces

A clear example of using balance masses to reduce reaction forces to the frame is the new wafer table design (Figure 6). This module has integrated functionality (wafer positioning and foil expansion) and thus a relatively high mass and has to make indexes within 16 ms, leading to high accelerations and unacceptably high reaction forces towards the frame, if not compensated.

After a concept study and feasibility study with MI-Partners, an innovative stage concept was formed. The concept is schematically shown in Figure 7. The long stroke / short stroke concept is well established in semiconductor industry, but in this concept the long stroke has integrated balance-mass functionality. This is possible, because the long stroke itself has a limited positioning accuracy requirement and the short stroke control is referred to the frame. Therefore, the long stroke can have a low bandwidth and can act as a balance mass, slowly traveling along with the short stroke's high-speed indexing setpoints.

MI-Partners was responsible for prototype development of the stage and finalised the project with a second design phase to add serviceability and robustness, making the first steps in the industrialisation phase. NXP ITEC integrated the stage in the ADAT3-XF platform and processes .



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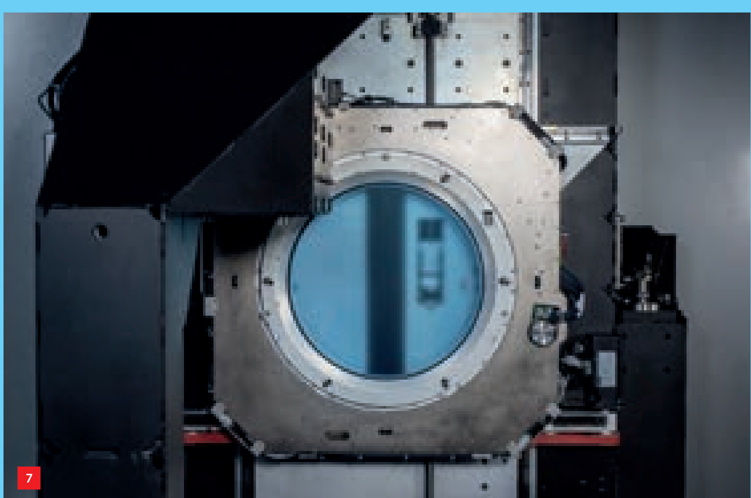

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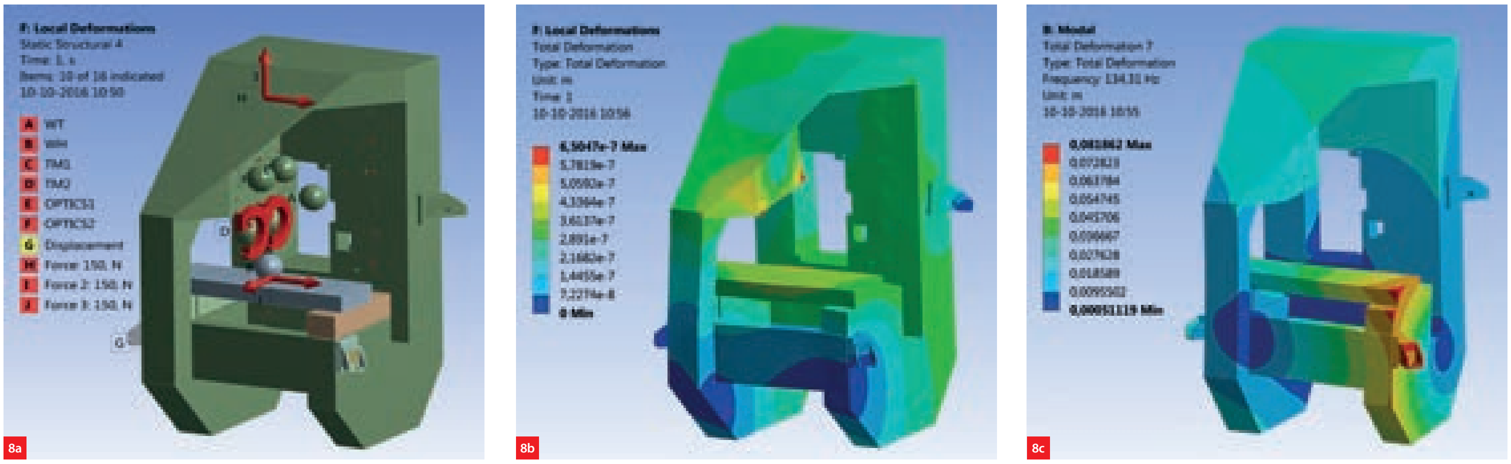
6 *Wafer table concept including long stroke / short stroke and integrated balance mass.*

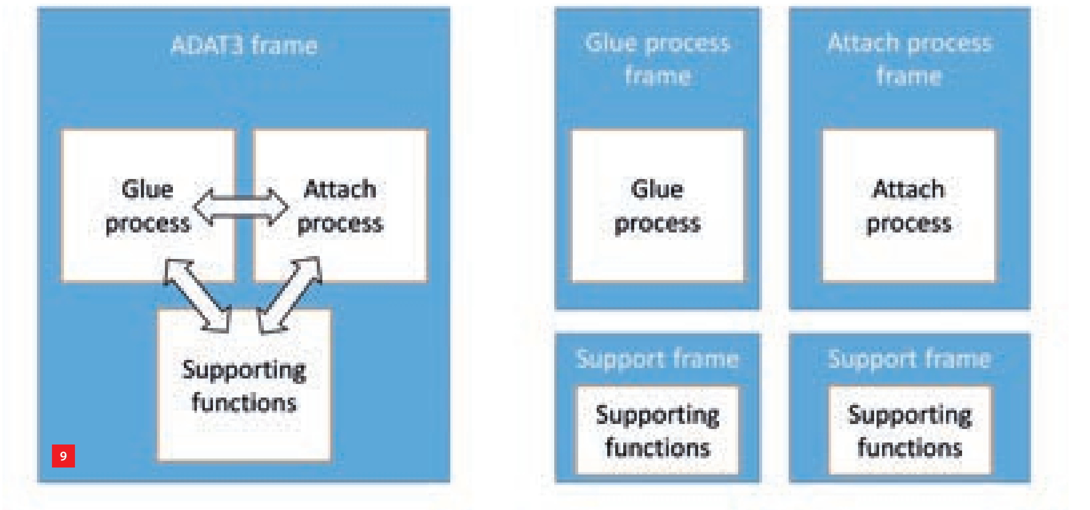
7 *The realised wafer table on the ADAT3-XF frame.*

4. Designing internal frame resonances above setpoint
Besides the rigid-body accelerations, the internal dynamics of the frame can directly influence both the relative positions of the modules and the positioning accuracy of the servo systems. The internal dynamics of the frame are therefore designed to be above the significant setpoint frequency content. This required a few drastic redesigns of the ADAT3 frame; the most eye-catching feature is a connection to the front of the frame, seen in Figure 8 at the front left side of the frame. This was necessary to have a stiff interface for the two transfer mills, as discussed above.
The design is such that serviceability and design volume of existing and future modules on the frame are compromised as little as possible. Figure 8 presents examples of FEM simulations that predict the deformations of the frame under quasi-static (acceleration) load and the dynamic behaviour.

5. Avoiding disturbances of supporting functions
The low-frequency suspended process frame is designed for micrometer performance of the core processes on the ADAT3-XF. Supporting functions like the Wafer Exchange module, Dereel and Reel units and covering are mounted on a support frame to ensure these modules do not influence the process and to be able to design these modules more cost-effective and with less volume constraints.

A specific process on the ADAT3 involves dispensing glue or flux on the lead frame. After this step (and lead frame transport) the attach process places the semiconductor device on the glue. The high-speed dispensing process introduces significant disturbances on the other modules. For the XF it was therefore decided to separate this process from the attach process and place the complete functionality on a separate frame, the Input Station (Figure 9).
The largest advantage of this choice is that the glue process can be developed further without influencing the attach process. Future glue or flux deposition technologies thus can be developed fully isolated from the rest of the machine. A disadvantage is that the transport has to take place between separate frames, leading to less repeatable positions and the need for automatic alignment during each transport. However, semi-autonomous transport and handling systems are widely available for these kind of products.





8 *Examples of FEM calculations to predict quasi-static deformation (the two on the left) and mode shapes (on the right).*
(a) The reaction forces of all modules modelled as a static force acting on the frame.
(b) The associated deformation; deformations stay below 1 μm.
(c) The results of a modal analysis on the frame; the first internal resonance in the simulation is above 130 Hz.

9 *Schematic layout of the ADAT3 system architecture (left) and the ADAT3-XF architecture (right). In the ADAT3, the glue and attach processes are placed on the same frame, giving dynamic crosstalk (indicated with the arrows). In the ADAT3-XF, the glue and attach processes and supporting functions are dynamically isolated from each other.*

Conclusion

With the introduction of the ADAT3-XF platform architecture, a predictable and modular system has become available for NXP's assembly factories, allowing high-bandwidth motion control. This secures the roadmap for further machine speed and accuracy improvements and adds 300mm wafer handling capabilities to its portfolio. The increased predictability and modularity makes it possible to react faster on future requests and enable separate developments on the glue and attach processes.

By organising the developments in parallel with trusted innovation partners it was possible to realise the ADAT3-XF (Figure 10) with a short time-to-market and first-time-right designs.

10 *ADAT3-XF, the result of a joint development project.*

PRINTING BY THE RULES

The additive manufacturing (AM) of high-quality products requires knowledge of the 3D-printing process and the related design guidelines. Allthough AM has been around for some years, many engineers still lack this knowledge. Therefore, Fontys University of Applied Sciences sets great store by training of engineers, education of engineering students and knowledge sharing on this topic. As an appetiser, this article offers a beginner's course.

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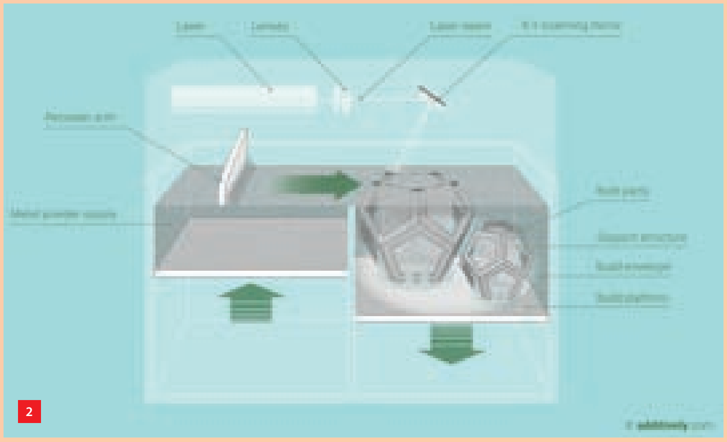
AM has most definitely been a hype in recent years and is now producing relevant applications; see Figure 1 and other articles in this issue. Nevertheless, many engineers have not familiarised themselves with AM's 'unique selling points':
- customisation of parts and products (for example, for medical applications and spare parts);
- freedom of design (complex features that cannot be conventionally machined);
- mass reduction and stiffness optimisation (using topology optimisation: putting material only where it will add value);
- integration of functions (potentially leading to new design principles);
- specific material properties (of optical surfaces, for example).

One of the barriers for adopting AM may be the lack of knowledge of the appropriate design guidelines. At the ObjeXlab of Fontys University of Applied Sciences, these AM design rules are the subject of research and knowledge sharing, through research projects, education and training. The focus is on the design guidelines for two popular AM technologies, i.e. SLM (selective laser melting) and FDM (fused deposition modelling), for metals and plastics, respectively; see the box on the next page.

1 *Conventional design of a steel-cast bracket (left) and the corresponding topology-optimised design of the titanium AM-made bracket (right), printed on an EOS machine. Source: Airbus Group Innovations*

SLM and FDM

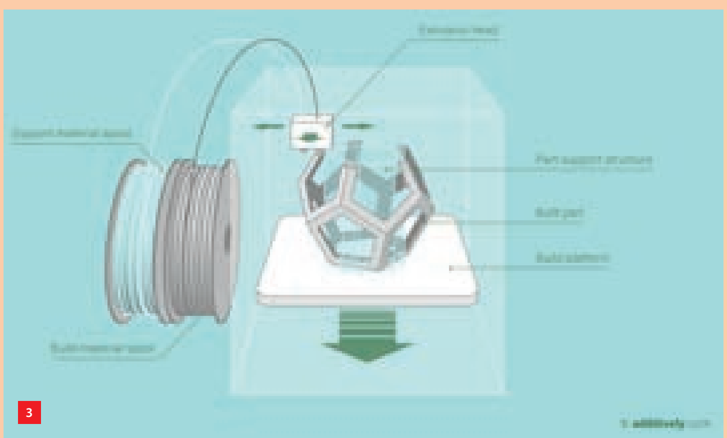
With SLM (Figure 2) a metal powder is distributed equally in a thin layer over a build platform (powder bed), by means of a roller or a squeegee. Typical layer thickness is around 25-100 μm. An (X,Y)-controlled laser beam melts together the powder particles in the build layer (and with the layer below). After building a slice of the component, the platform will sink by one layer thickness and a new layer of powder will be applied over the previous one.



2 *Selective laser melting (SLM) printing principle.*

The powder bed can be heated to reduce excessive temperature differences between the particles that should be joined together and the superfluous particles. Also, the atmosphere inside the machine should be low in oxygen content to reduce unwanted oxidation. This can be achieved by applying a nitrogen or argon atmosphere or by means of evacuation (electron beam melting). After the component has been built, the unused powder should be removed (after cooling down to room temperature), the part has to be separated from the build plate and mechanical stress has to be relieved. Density will be 99-100%; sintering is not necessary.

With FDM (Figure 3) a plastic wire (filament) is fed into a heated extruder where the solid plastic is weakened and pressed through a nozzle. This nozzle is moved in the horizontal plane by means of a software-controlled gantry. The movement path of the nozzle corresponds to the slice outline of the layer to be built. Below this nozzle is a build platform which is lowered each time a layer of the object has been built.

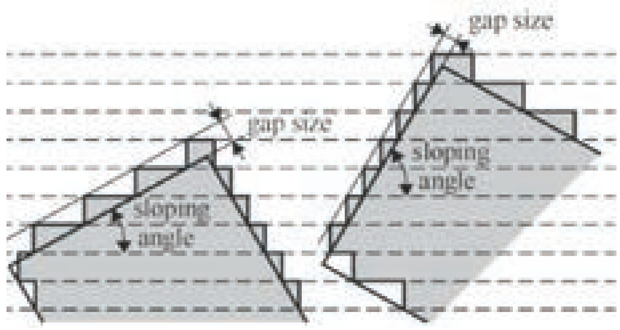


3 *Fused deposition modelling (FDM) printing principle.*

SLM design rules

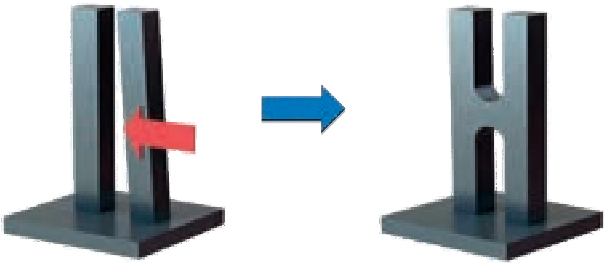
Some important SLM process parameters are layer thickness (vertical pitch), laser power, scan velocity and distance between print tracks (hatch distance). The printing resolution is determined by the interplay between these parameters and the powder composition (type and size distribution). For a high-resolution print, low laser power, low scan velocity and low layer thickness are required, whereas a high building speed requires high laser power, high scan velocity and a thick powder layer.

Naturally, the resolution of the printing process influences the surface roughness, depending on the sloping angle of the surface under hand; this is called the staircase effect (Figure 4). The steeper the surface that is being printed, the smoother the result, depending on the layer thickness. The exact nature of the melting process also has its influence on the surface quality. For high-quality surfaces, remelting or other post-processing options are required.



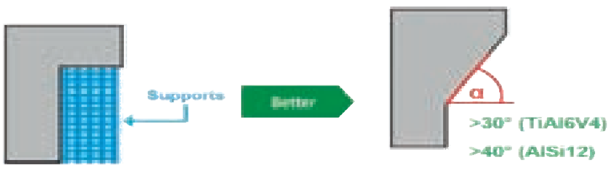
4 *The staircase effect.*

A product-specific design parameter that has to be considered is the printing orientation of the product. Mechanical properties of SLM-printed products are, to a large extent, independent of the printing direction, but they do depend on the scan strategy. The orientation of the product with respect to the build plate (and hence the total processing set-up) can be selected in a trade-off between productivity (the number of parts stacked on the build plate for one printing run) versus the interaction of the squeegee with the product (the risk of damaging thin or thin-walled parts of the object). The squeegee movement has to be as much as possible in the 'stiff direction' of each part of the product. Stress relief considerations also play a role in determining the optimum printing orientation.
An alternative is to increase the stiffness by adding support structures, for example 'bridges' that connect vulnerable parts (Figure 5).



5

Support structures are also required in the case of strongly overhanging structures (Figure 6) or in the case of thin-walled structures (transfer of surplus heat, see below). Of course, these support structures have to be avoided as much as possible, as their printing and removal afterwards takes up additional process time and introduces the risk of damaging the part. This may require modifications to the design. But merely tilting the original design may also decrease the need for support.



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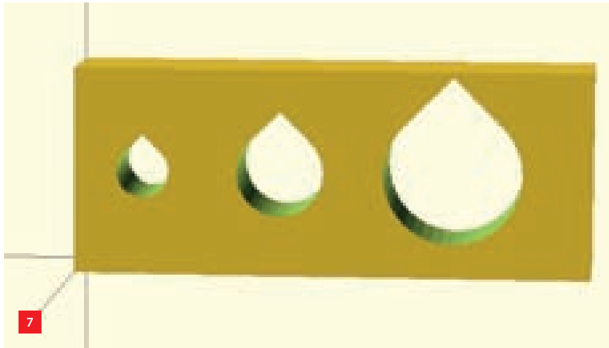
A special challenge in AM is the printing of holes. Their diameters should not be less than 2 mm, or powder will stick to the wall of the hole. In the case of very shallow holes (or vertical holes), smaller diameters can be achieved. From machining history, round holes are standard in any design. With drilling, the orientation of the hole is not relevant for the outcome, but with AM it definitely is. It is preferable to orient the part in such a way that a hole has to be built in the vertical direction. This is because when printing a hole in the horizontal direction, the lower and upper parts will be become rough due to the staircase effect – thermal and surface tension effects may also come into play – and the upper part may require a support structure.

When there is no definite need for a round hole, a droplet-like hole may be an alternative (Figure 7). The steeper surfaces at the top do not need a support. This is a typical example of the new possibilities unveiled by AM that cannot be achieved by conventional machining (drilling).



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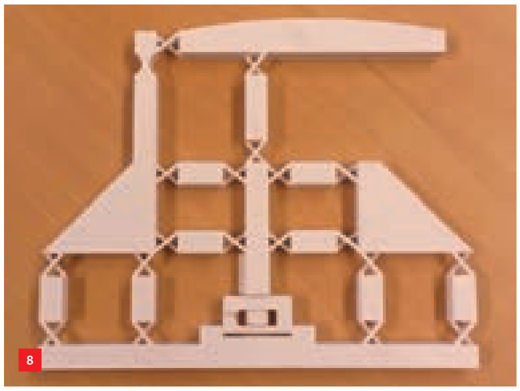
Thermal aspects play an important role in the printing process and must therefore be dealt with. The laser injects a lot of power into the part being printed. As the powder more or less behaves like a thermal insulator, all the heat has to dissipate via the product itself. In thin-walled structures, increasing cross-sections or adding internal grids within the product may therefore promote dissipation.

In the design the removal of support structures and superfluous powder after printing has to be accounted for. Relevant aspects include accessibility for external tools (such as – cheap – band saws or wire-erosion tools), 'vents' for removal of the powder, and preventing damage to the product at the support connection points.

Similarly, post-processing has to be taken into account in the design. For example, mounting options can be provided in the design. Ideally the build plate is used for mounting, but when necessary supports (for example, non-functional cross-connections) can be added for taking up clamping loads or relieving machining stresses and strains. A well-known procedure (also used with casting) for obtaining high-accuracy products is to print excess material that will be removed in a precise post-processing (e.g. machining) procedure.

FDM design rules

For high-tech applications of parts under mechanical load, metal printing using SLM for example appears to be the prime candidate, but with the 'simple' FDM technology 'serious' plastic products can also be printed, see Figure 8.



8

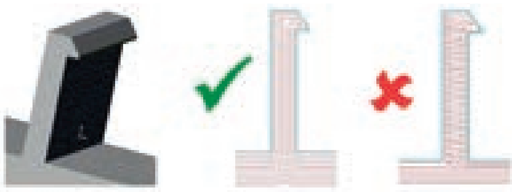
5 *'Bridges' can connect vulnerable parts to increase stiffness.*

6 *Modification of the design in case of an overhanging structure, in order to prevent the need of a support structure.*

7 *With a droplet-like hole the (steeper) surfaces at the top do not need a support. (Source: 3D Design For 3D Printing by tinygeek in 3D-Printing, www.instructables.com)*

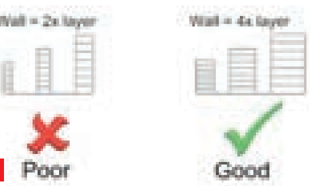
8 *A monolithic linear guiding mechanism utilising elastic cross-hinges has been printed by Fontys students. They proved that a low-cost FDM printer can produce a complex product like this and showed that it functions properly, without claiming that it meets industrial specifications.*

For the FDM process, similar considerations as with the SLM process apply, regarding aspects such as the staircase effect and the need for support structures. The quality, density and mechanical properties of FDM-printed products are determined by the binding process between the filaments. Products exhibit anisotropy, with the highest tensile strength in the printing direction, which therefore has to match the orientation of external loads (Figure 9).



9 *Matching the the printing direction with the orientation of external loads.*

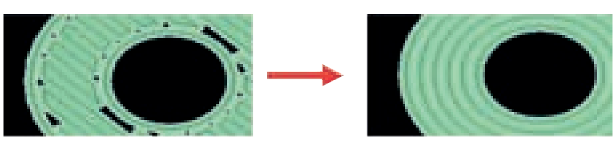
Here, the printing resolution is primarily determined by the diameter of the filament after exiting the printer nozzle. This diameter also determines the required thickness of thin-walled structures. As a minimum, twice the filament diameter is taken, but three or four times this diameter is recommended for better quality (Figure 10).



10 *Recommended thickness of thin-walled structures.*

Research has been conducted at ObjeXlab on the printing of sloping surfaces. It was found that for angles as low as 25° (with the horizontal plane), printing without adding support structures is feasible, depending on the printing strategy. For example, with an Ultimaker printer it is possible to first print the 'infill' of a structure and then the contour/edges. This improves the internal cohesion and hence the strength. Some other printer suppliers provide 'closed' software, which does not allow for selecting the optimum printing strategy.

When printing infill filaments, 'filling effects' occur: when the printer nozzle scanning movement reverses its printing direction, voids may occur. This can be prevented by using thinner filaments, decreasing the raster distance or devising clever strategies, such as for a circular structure (Figure 11).



11 *Recommended printing strategy for a circular structure, in order to prevent the occurrence of voids.*

To conclude

Not much more than a tip of the veil has been lifted. Many design rules may seem logical, but explicit formulation may help prevent design errors. Sets of design guidelines for additive manufacturing are 'under construction'. Sharing knowledge on this topic may advance the adoption of 3D-printing.

ObjeXlab research programme

Fontys University of Applied Sciences in Eindhoven in 2012 took the initiative to set up a laboratory for AM, called 'ObjeXlab'. As part of the Centre of Expertise High Tech Systems & Materials at Fontys (CoE HTSM), ObjeXlab aims for a public-private cooperation to explore AM opportunities in applied research projects with both industrial (engineers, researchers) and educational participants (students, teachers).

The ObjexLab research programme comprises five AM areas:

1. Processes: determining optimal parameters for FDM and SLM printing processes.
2. Design guidelines.
3. Killer applications: investigating competitive advantages via product attributes that would be impossible using conventional manufacturing technology.
4. Material properties: analysing the properties of printed products.
5. Hybrid technologies: combining AM with conventional manufacturing technologies such as machining, and integrating different printed/machined materials (plastics, metals) in one product.

AM design rules online

Searching on the internet for 'additive manufacturing design guidelines' yields a lot (scientific publication) hits. Practical information is also available online. For example, the 3D-printing service providers Materialise and Shapeways each present design guidelines for a variety of materials.

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WWW.SHAPEWAYS.COM/MATERIALS


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MULTI-CENTRE, MULTI-MATERIAL ADDITIVE MANUFACTURING

EDITORIAL NOTE

This article has been contributed by the AMSYSTEMS Center.

The strategic partnership agreement for additive manufacturing (AM) signed this spring by TU/e and TNO has been named the AMSYSTEMS Center (Additive Manufacturing Systems Center). In contrast to other AM knowledge centres, this new centre will focus mainly on the development and research of production equipment for smart, personalised and multi-material products. The centre also intends to establish a new TU/e professorship and research group.

Eindhoven University of Technology (TU/e) and TNO, the Netherlands Organisation for applied scientific research, intend to develop the AMSYSTEMS Center into a leading European knowledge centre in the field of systems for AM. It will undertake fundamental and applied research to develop innovations that are ultimately brought to market by the affiliated companies or spin-offs that emerge. Katja Pahnke, Managing Director of TU/e High Tech Systems Center (HTSC), and Erwin Meinders, Director Additive Manufacturing TNO, are the initiators and since June this year have been joint executive directors of the AMSYSTEMS Center.

The partners want the AMSYSTEMS Center to enable the development of high-tech systems that focus mainly on producing integrated and smart electronics, personalised medical products, printed food as well as pharmaceutical and high-tech products. Examples include complete implants, prostheses, dental bridgework, smart electronics like the E-pill, smart connectors and integrated or spare parts for high-tech equipment that can be printed on the spot as and when needed.

Strategic collaboration

"The strategic collaboration with the HTSC sees the high-tech mechatronics knowledge of TU/e and the industrial AM knowledge of TNO come together in a joint and unique knowledge proposition for industry", Erwin Meinders says. "The added value of the partnership is evident in the proposition that has been realised. We have established a Smart Industry Fieldlab MultiM3D, with more than ten industrial partners, we have been awarded a Future Fund investment for an AM pilot line, and have started up a Ph.D. programme along with a number of public-private research programmes."

The centre will also be training the experts and scientists that are needed for the emerging 3D-printing industry, in part through the establishment of a new 'Systems Mechatronics for Advanced Manufacturing' TU/e professorship and research group. The recruitment process for the new professorial position has already begun. The aim is that within four years some 25 Ph.D. students will be doing research and more than 50 full-time employees will be working at the center. Currently, seven Ph.D. positions

1 *Executive directors of the AMSYSTEMS Center, Katja Pahnke and Erwin Meinders: "The added value of the partnership is evident in the proposition that has been realised." (Photos: Bart van Overbeeke (left) and TNO)*

have been defined and at TNO some 40 researchers are engaged in this area.

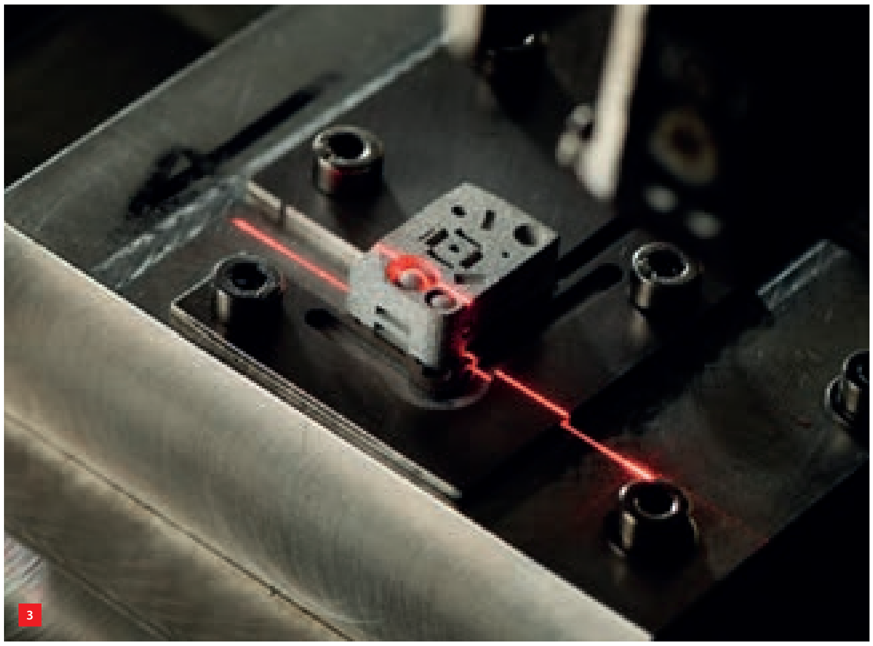
Ph.D. research

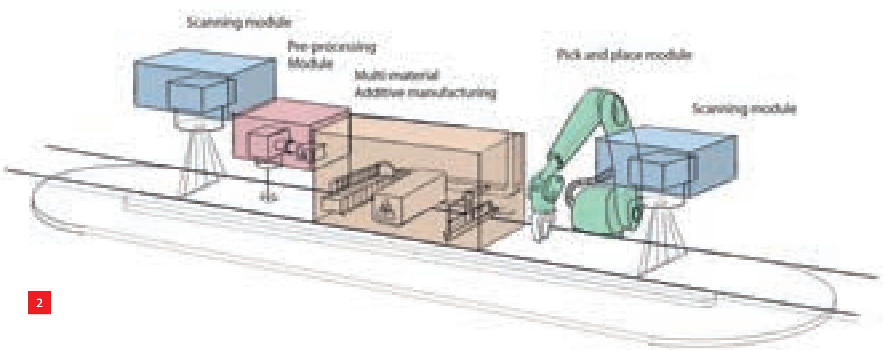
One of the doctoral students who has begun within the centre is Thomas Hafkamp. Following his TU/e Master at the department of Mechanical Engineering (specialising in Control Systems Technology, graduating in the design principles group), he started his Ph.D. research for the AMSYSTEMS Center on 1 March 2016. "AM equipment has to be scaled up to larger product formats and higher product quality if the needs of high-tech industry are to be met. To be able to achieve this we have to investigate modelling, measurement and control in industrial AM processes", Thomas Hafkamp explains.
"The AMSYSTEMS Center has come up with three Ph.D. assignments for the additive production of high-grade ceramic products, each concentrated on one of these three aspects", Hafkamp continues. "My research is geared to the control side of the print process and the aim of my research is to develop new equipment concepts and integrated control architectures."

The challenge faced by Thomas Hafkamp in his research is the simultaneous scaling up of the three characteristics of AM equipment: from its current small format to industrial scale, to boost the product quality and reproducibility, and to increase production speed. "To further develop AM technology new concepts need to be generated on the basis of a holistic, systematic approach that is able to tackle these challenges (scalability, quality, productivity) at one and the same time," he clarifies.

Cross-fertilisation

The collaboration between TNO and HTSC is already very noticeable and will become ever more evident, according to Hafkamp. "Given the powerful multidisciplinary nature of AM, there is plenty of potential for cross-fertilisation between and perhaps even within the two organisations. It's something I already see happening during the regular meetings of the AMSYSTEMS Center."





2 *Manufacturing system for smart customisation of complex products through multi-material AM. (Illustration courtesy of PrintValley)*

3 *Scanning a 3D-printed product.*

7 December 2016: The next generation of 3D printing

The AMSYSTEMS Center will be working very closely with industry; the plan is to enable some tens of industrial partners to participate in research programmes in the coming years. To encourage new collaborations the centre is organising 'The next generation of 3D-printing' on 7 December this year in the TNO building on the TU/e campus in Eindhoven, the Netherlands. The event will kick off with the opening of the Fieldlab Multi-Material 3D Printing (MultiM3D), a joint initiative of TNO and TU/e HTSC. The MultiM3D Fieldlab is a co-creation platform and network for stakeholders in the multi-material AM value chain.

At the halfway point of the day the AMSYTEMS Center business relations will be given insight into the various possibilities that AM offers, like integrated and smart electronics, personalised medical products, printed food, and pharmaceutical and high-tech products. Lab tours and fascinating keynotes by René Gurka (BigRep) and Daan Kersten (Additive Industries) are also on the programme. The most recent AM developments can be found at the technology market. The latest demos and studies will also be presented and 3D-printed products will be on display.

INFORMATION
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Surface Quality: 10-5 scratch-dig per MIL-PRF-13830b
S1 Surface Flatness (coated): $<\lambda/10$ p-v at 633nm on select substrates
S1 Surface Flatness (uncoated): $<\lambda/10$ p-v at 633nm
Usable Bandwidth (Ravg ≥ 99.0%): Y1: 1020-1100nmm, Y2: 510-560nm, Y3: 340-370nm, Y4: 255-275nm
Reflectance: (0°):R > 99.9%, (45° P): R > 99.6%, (45° S): R > 99.9% , (45° UNP): R > 99.8%
LDT: Y1: 25J/cm² at 1064nm, Y2: 20J/cm² at 532nm, Y3: 15J/cm² at 355nm, Y4: 10J/cm² at 266nm

Waveplates

Product Code: QWPM (Multiple Order), QWPO: (Compound Zero Order)
Optical Material: Laser Grade Crystal Quartz
Retardation Error (At 23°C): $< \lambda/850$ at 1064nm, $<\lambda/450$ at 532nm, $<\lambda/300$ at 355nm, $<\lambda/200$ at 266nm.
Surface Quality: 10-5 scratch-dig per MIL-PRF-13830b
TWD (coated): $<\lambda/10$ p-v at 633nm
Reflectance (at λ ≥266nm): R<0.2% per surface at selected wavelength (R<0.1% typical)
LDT: 19J/cm² at 1064nm, 20ns, 20Hz

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Material: Standard Grade Corning 7980 1-D (Fused Silica) or Schott N-BK7
Surface Quality: 10-5 scratch-dig per MIL-PRF-13830b
S1 Surface Figure (coated, per surface): $<\lambda/10$ p-v at 633nm on select substrates
***Reflectance (at λ ≥266nm):** up to R<0.25% per surface at selected wavelength
***LDT:** Y1: 15J/cm² at 1064nm, 20ns, 20Hz

*Can be made available with R<0.2% per surface at selected wavelength (R<0.1% typical), LDT: 19J/cm2 at 1064nm, 20ns, 20Hz

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FIRST INDUSTRIAL 3D METAL PRINTING SYSTEM DEVELOPED AT THE SPEED OF LIGHT

Three years ago, Additive Industries started developing the first truly industrial 3D metal printing system, building on the mechatronic and system engineering experience of the Dutch Brainport region. In one year a functional model was realised, and one year later, in 2015, a beta version was presented, which is now being tested by launching customers. Currently, the first production machines are under construction. The MetalFAB1 system offers substantially improved performance over the 'prototyping' machines available in the market.

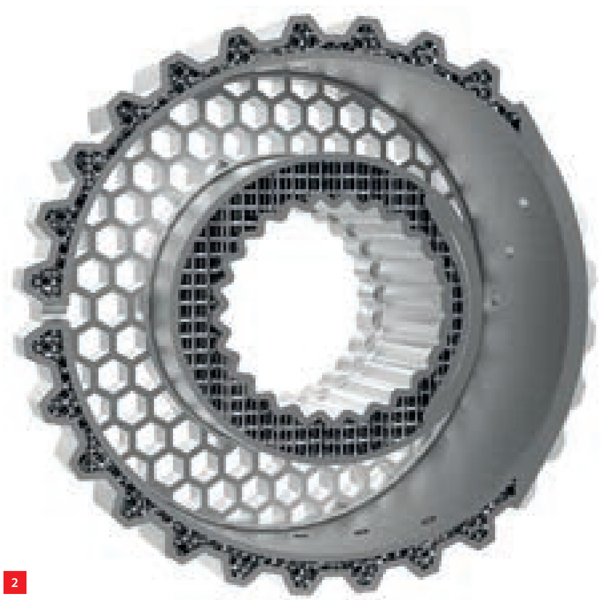
Additive Industries, based in Eindhoven, the Netherlands, was the initiator of the AddLab consortium (read the article on page 32 ff.) to expand its knowledge of the 3D-printing process and to have printing machines available for testing new concepts. After the AddLab programme was finished as planned, Additive Industries continues development, with forty people on board at the moment. Launching customers are testing the beta version of the MetalFAB1 and the first machines in a first production series are already under construction. To this end Additive Industries continues its collaboration with development and production partners recruited from the Brainport ecosystem: system suppliers NTS-Group, MTA and VHE Industrial Automation, and a multitude of second- and third-tier suppliers.

1 *The MetalFab1 6-module version, with from left to right the controls module, two build chambers, a human-machine interface, the stress-relief heat treatment furnace, a storage module (for build plates and printed products), another human-machine interface, and the (un) loading or exchange module. (Photos: Bart van Overbeeke/Additive Industries)*

The industrial-grade additive manufacturing machine – using the well-known laser-based powder bed fusion process, and integrated Additive World software platform – will, so Additive Industries promises, deliver up to a tenfold increase of reproducibility, productivity and flexibility as compared to the machines available in the market, which were engineered for making prototypes or one-off products. According to Additive Industries, the improved performance is achieved by robust and thermally optimised equipment design, smart feedback control and (auto-)calibration strategies, elimination of waiting time and automation of build plate and product handling.

The modular design of the MetalFAB1 system – a customer-driven venture, not a technology-driven development – allows for customer- and application-specific process configuration. Multiple build chambers with individual integrated powder handling make this industrial 3D printer the first to combine up to four materials simultaneously in one single machine (each print chamber will be used for one material only, as switching materials requires extensive cleaning). The size of a single build envelope (420 x 420 x 400 mm^3) places the MetalFAB1 among the largest 3D metal printers available.

Rob van Haendel, Lead Mechanical Engineer, can address some of the challenges encountered in the development phase, but details of the design of the machine cannot be published, as Additive Industries is in the middle of developing a patent portfolio. "Our machine architecture concept is new to the 3D-printing world, because of the automation and feedback loops, but to us, 'born and bred' in the Brainport region, it was not new at all. Here the mechatronic approach is customary: collecting as much information from the machine as possible and using this for intelligent control."



2

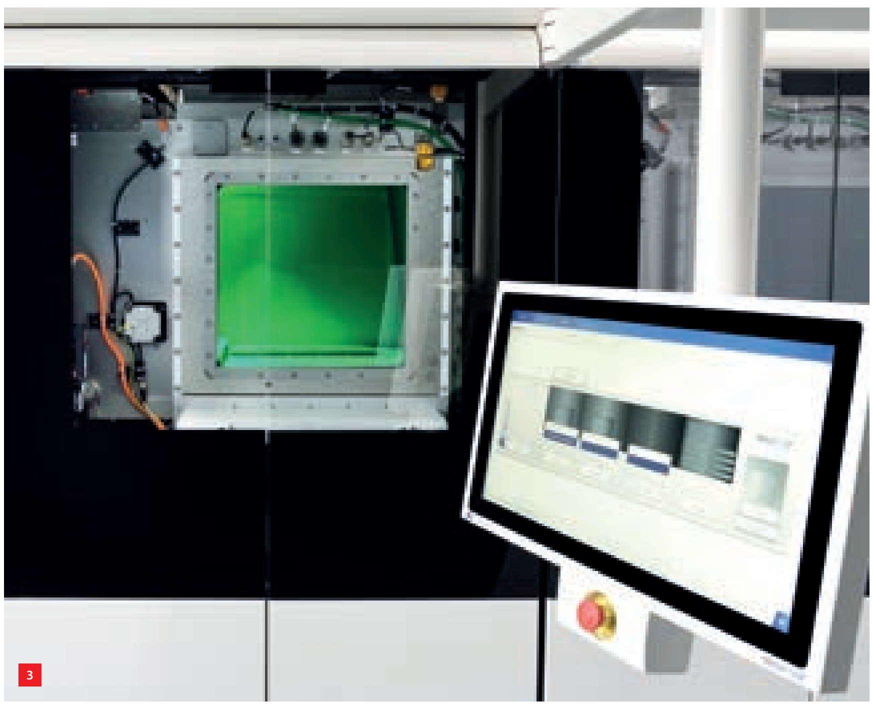
Modular architecture

The design of the MetalFAB1 is built upon a modular architecture, which is a characteristic feature of many high-tech mechatronic systems originating in the Brainport region. The development process is guided by the well-known V model, which is perfect for controlling the interfaces between modules. "At the system level you can define the interfaces between the various modules, which can then easily be outsourced. This allows us to focus on the things that are not so easy to specify, such as integrated software, process and application development, for which we are still in the learning curve."

The modular architecture also enables an easy upgrade of the system. For example, up to now an operator is required for loading build plates and unloading the printed products. This can, however, easily be robotised. Furthermore, in principle it is possible to expand the build volume of the system. But this does require a considerable hardware engineering effort, as the footprint of the system roughly equals three times the build plate dimensions in both horizontal directions.

Material qualification

The MetalFAB1 is delivered with a baseline process developed by Additive Industries, but it is up to the customer to help fine-tune the process and tailor it to his needs, according to Van Haendel: "For each material we select one qualification, considering aspects such as availability and cost price, which we use in all the tests. We release the results and help our customers tweak the settings if they decide to use another material specification."



3

2 *One of the MetalFAB1 beta systems was sold to GKN Powder Metallurgy, the world's leading manufacturer of precision automotive components. (Image: GKN)*

3 *The build chamber with human-machine interface.*

Each material to be printed requires its own process development. A so-called fishbone diagram contains over 60 parameters that are relevant in the process. The optimal settings for these parameters are all material-specific. Materials for which the process has been developed up until now include aluminium, tool steel, stainless steel 316, titanium, and inconel. Cobalt-chrome and various aluminium alloys are on the wish list.

Powder handling

A particular material challenge is powder handling, Van Haendel says. "At one moment it behaves like a fluid, in other cases it is more like a solid." The powder handling has been automated, but this required a lot of experimenting and hardware iterations, as it is not an easy subject for extensive simulations. The design was set up in such a way that no risk of inflammation is present. For example, the process is conducted under an argon or nitrogen atmosphere, in order to keep the oxygen concentration below 1%, as well as for disposal of 'welding' fumes. The argon or nitrogen flow is filtered and recirculated. The oxygen concentration is monitored continuously; if it becomes too high the pump for powder evacuation is switched off immediately.

Lasers

In the MetalFAB1 the printing process can be executed with one to four lasers, which run in parallel but can individually melt patterns in the powder layer under hand. The exits of the laser guides are located closely together above the build plate, at a relatively large height. This configuration was chosen to minimise the deviation of the beam orientation from vertical as much as possible (and hence the deformation of the laser spot from circular to elliptical). The set-up is modular; laser units can be added at a later stage, up to the maximum of four. The productivity increase by adding lasers is nearly linear. This feature is one of the factors in the promised tenfold increase in productivity. A MetalFAB1 print module with four lasers can print up to 1 m^3 of metal in one year.

Resolution

Additive Industries typically aims at a layer thickness of 50 µm, but values down to 30 µm, usually for relatively small products, can be attained in the MetalFAB1. The material specification, for example regarding the powder size distribution, has to match this layer thickness. A related parameter is the offset at the beginning and the end of a printing pass. This offset is required when the edge of the laser focus does not coincide with the edge of the melt pool. In this respect the melting behaviour, determined by the material's heat conductivity, has to be taken into account.

The vertical resolution of the printing process depends on the pitch of the motion stage that guides the build plate, whereas the horizontal resolution is determined by the optical system that steers the laser beam over the 2D layer to be printed. Inaccuracies are introduced by process variations and the discretisation of the product in the design software. For small products the accuracy of the MetalFAB1 is +/– 50 µm, and for larger products a length measure has to be added, arriving at a maximum of 0.2 mm inaccuracy for such products.

Thermal aspects

A highly critical phenomenon is of a thermal nature. The lasers for the selective melting process (up to four, 500 W each) inject a maximum to 2 kW of power in the part that is being printed. This will therefore heat up, to approximately 200 °C, depending on the specific material. The exact value can be calculated in advance. Especially for aluminium, with its high thermal expansion coefficient and relatively low melting point this is relevant.

For optimum quality, the part has to retain this temperature during the entire process, with the aid of a closed-loop controller. This means that in the beginning the build plate has to supply a high amount of additional heat to the part to reach this level quickly. After a while, a steady state will be reached, with the laser(s) injecting heat to the top of the part, and the build plate to the lower part of the product. The thermal effects require that the build plate is made of the same material as is used for printing. This also facilitates an easy start of the build-up process, with a good (welding) connection of the first printed layer to the build plate.

For the relaxation of mechanical stresses introduced by the thermal regime, the MetalFAB1 comprises a heat treatment furnace. This is currently the only integrated post-processing option. Outside the machine the printed piece first has to be separated from the build plate with the aid of a band saw or wire-erosion. Further post-processing can then be performed. Additive Industries aims to integrate further post-processing steps in the MetalFAB1 in the future.

Calibration

One of the biggest mechatronic challenges was posed by the optical calibration. The laser spot has to be focussed on exactly the right position, within a few micrometers. This accuracy is absolutely necessary when the multiple laser beams, with a focus diameter of 100 µm, for example, have to be focussed on the same position. Rob van Haendel: "This requirement has to a large extent determined the machine layout." Because of the industrial character of the machine, the calibration routines have been automated. Calibration objects are available that can be supplied by the robot of the machine at a customer's request.

4 *Handling functionality.*
(a) The (un)loading unit or exhange module.
(b) The robot for handling (and transporting between modules) of build plates and printed products.

Validation

The MetalFab1 printing process can achieve a density of over 99.5% as compared to bulk material. Considerations that determine the optimum density include productivity (a higher density specification will lower the productivity, because smaller line widths have to be printed) and thermal effects. Higher laser power will generate a more complete melting process, but when too much laser power is delivered, the part in production will become too hot and deformation will increase.

For validation of the printed parts, Additive Industries initiated collaboration with the US company Sigmalabs: its pyrometer and photo diodes were incorporated in the functional model for monitoring the melt pool. The information from these sensors can be combined intelligently to produce a statement about the quality of the printing process. This information has to be correlated with the outcomes of tests of, for example, tensile strength and fatigue behaviour in order to be able to be conclusive about the quality of the printed product. Monitoring the external geometry of the product during printing is not useful because of thermal effects (warping, shrinking after cooling). After the product has cooled down, measurements can be made with a 3D scanner or a coordinate measurement machine. Their results will support the end qualification of the printed product. ■

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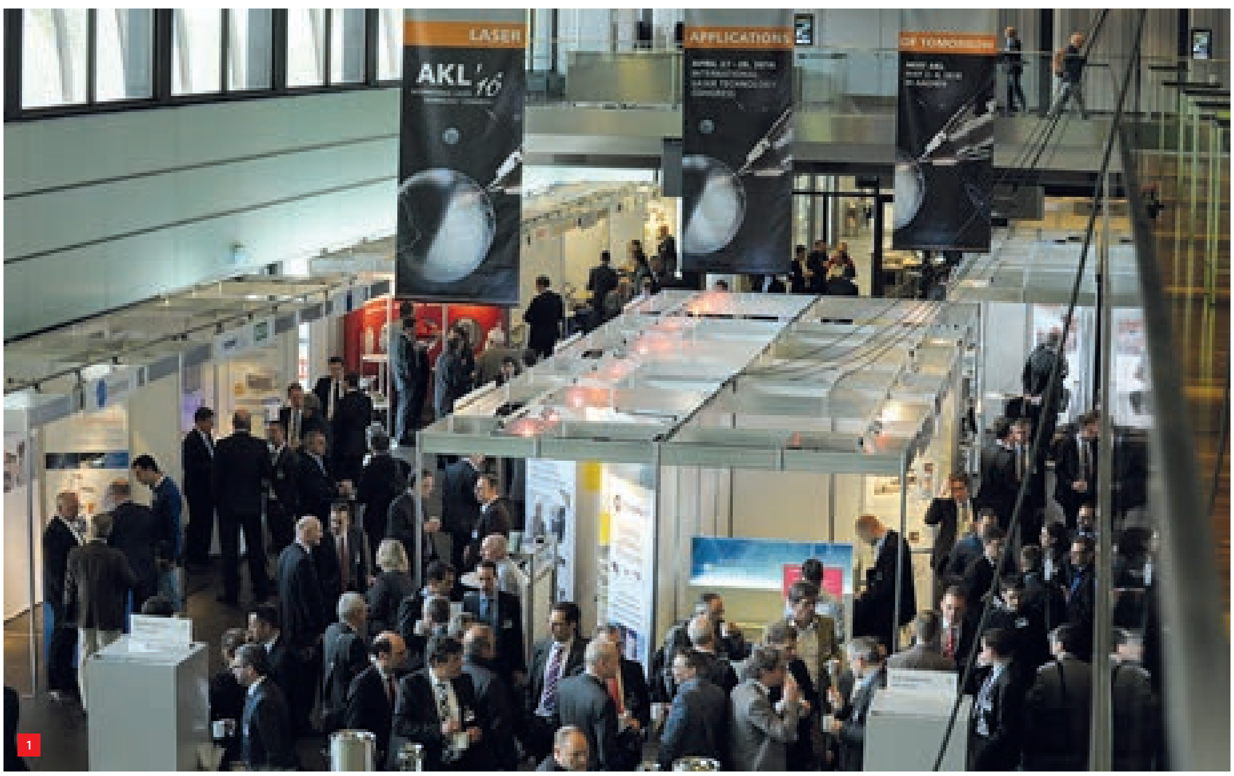
FOCUS ON STATE-OF-THE-ART HIGH-ENERGY LIGHT SOURCES

Lasers in different configurations are essential multi-tools in both science and industry, spanning from lidar surveying over surgery to precision micro-machining. Many advanced light sources also fit perfectly within the forthcoming digital 'Smart Factory of the Future'. The Fraunhofer Institute of Laser Technology (ILT) is a dynamic breeder overflowing with laser R&D, rapid transfer of developments and applications, and high-ranking spin-offs – hence a natural organiser of the biannual AKL International Laser Technology Congress. A first-hand report of the 2016 edition.

JAN WIJERS

One of the best occasions to get a high-level grip on the latest laser technologies and laser systems is offered by the renowned AKL International Laser Technology Congress. The eleventh edition, AKL'16, was organised this spring by Fraunhofer ILT in Aachen (Germany) and attracted nearly 700 participants from 27 countries. It is the central networking platform (Figure 1) for application-oriented laser technology, clearly showing that R&D is an ever ongoing process. Almost 55 years after the acronym LASER (Light Amplification by Stimulated Emission of Radiation) turned into reality, developments are still being made at an amazing pace. The focus is on laser systems as a promising, unequalled industrial enabler in widespread micro, macro and high-precision applications.



1 *Active networking at the AKL'16 exhibition.*

AUTHOR'S NOTE

Jan Wijers is a freelance technical writer from Eindhoven, the Netherlands. Formerly active as a manufacturing technologist within the main Philips Research Lab, he still specialises in traditional and non-conventional machining processes.

Advantages	Limitations
Contactless machining	Heat generation (up to vaporising)
Independent of mechanical material properties (in general)	Relatively low to medium efficiency
Extreme processing speed	Quite high initial capital investment
High mobility and flexibility in operation	Optical character laser (technology- and service-intensive)
Reproducible process	Safety aspects (radiation, high voltage, vapour)
High energy density	Medium to high energy consumption
Burr-free machining	
Lightweight 'tool' almost without wear	
Easy automation	

Table 1
Pros and cons of industrial laser systems.

These developments lead to a lot of novel applications, for example in breaking down physical limits. As heat – and consequently cooling – is still a major challenge in lasers, processing and application research has led to smarter, more efficient ways to address these issues. Ongoing discussions about future high-power 'light' innovations open up a wider insight in laser trends, which are being transferred to industry – and in the AKL setting to the many congress participants.

Selecting the appropriate laser

As was the case at earlier editions, those that were in need of selecting the appropriate laser for their application from a wide and still growing spectrum could, during this year's AKL event, find help for the proper answer by attending the seminar Laser Technology ABC's. See also Table 1.

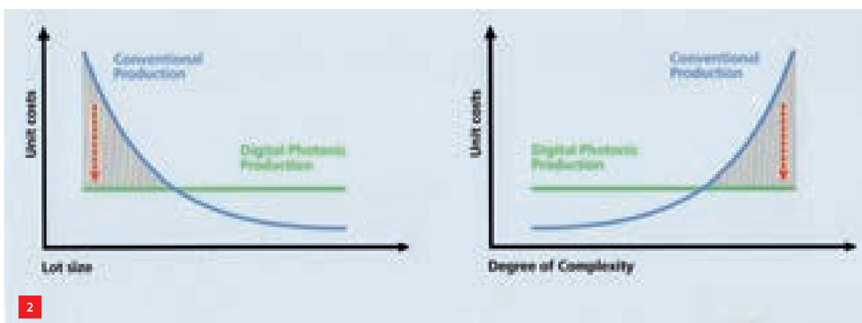
Industrially very rapid on the rise are the reliable, simple and compact ytterbium (Yb) doped fibre lasers, excelling in optical efficiency, reduced energy consumption, possibility of raised repetition rates and extended lifetime. Everyday practice has proven that they especially render processing advantages in e.g. micro-drilling and cutting of relatively thin sheet metal and small high-precision welding. Nevertheless, the latest models of compact direct diode lasers are knocking on the door as those semiconductor types today are already comparable in brightness and are, therefore, starting to become unstoppable rivals to fibre lasers.

EUV sources are seen by, for example, ASML as a – still challenging and therefore studied at the ILT institute – means towards manufacturing even finer detailed integrated semiconductor chips. The extreme ultraviolet light with high intensity is generated by hitting a launched tin microdroplet on the fly in vacuum bringing about a plasma flash (400,000 °C) by a CO_2 pulse of 13.5 nm wavelength.

Additive manufacturing

Prior to the AKL'16 congress, the Laser Additive Manufacturing Forum covered the (future) possibilities of layerwise manufacturing. One of the up until now fairly unnoticed side effects – of what formerly was defined as rapid prototyping and manufacturing – is that it sort of signals the revival of near-net-shape generation, well-known for casting, of small product series and of one-of-a-kind complicated geometries. So, if AM is really going to set the pace in the near future, rough pre-processing operations will be greatly reduced in workshops and factories, and post-processing (finish machining) will prevail.

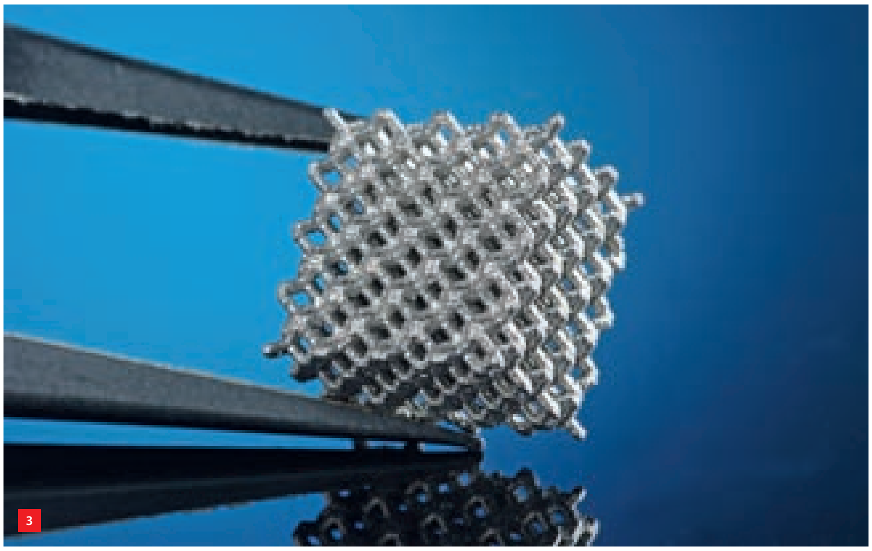
So, even in the world of machine tool building, the potential impact of additive manufacturing (AM) – nowadays generally classified as 3D printing – is causing some concerns. However, at the Metav show in Düsseldorf earlier this year, the VDW (German Machine Tool Builders Association) was quite outspoken. In their well-founded outlook, they stated that traditional metalworking will only encounter a minor impact (< 1% decrease in machine tool sales) in the next five to seven years caused by changing over to AM. In their eyes, AM is not to be seen as a disruptive technique, but rather as a new process complementing traditional machining, with a completely different approach regarding lot size and complexity (Figure 2).



2 *Lot size versus complexity in conventional and digital photonic (laser-driven AM) production.*

Powder bed versus laser torch

When talking about new ways to produce metallic parts, two processes emerged from AKL'16 that clearly dominate: selective laser melting (SLM) and laser metal deposition (LMD). SLM functions on the base of a powder bed with rather limited dimensions, and is widely spread, with a wide, industrially accepted, database of parameters. Nowadays, hybrid configurations are getting inside the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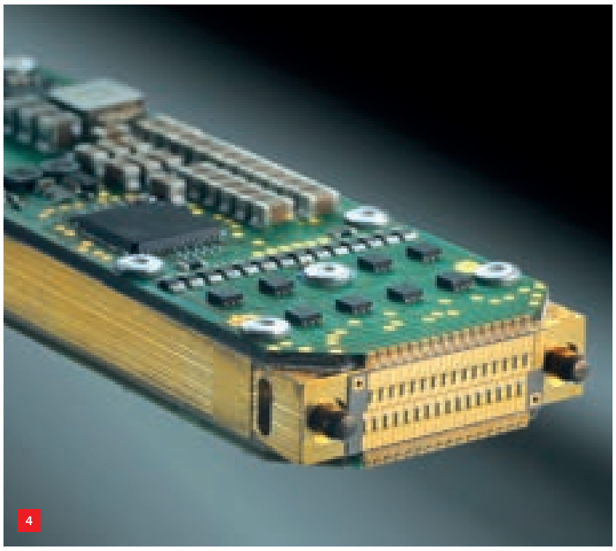
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3 Open bionic ('designed after nature') ILT sample built with SLM.

4 Pixelated heating module of 32 VCSEL arrays with integrated driver.

5 New 4.8 kW output VCSEL power package.

industrial spotlight for a product generation with almost no restrictions in design combined with finishing by CNC precision milling, turning as well as grinding, on a single machine tool of a somewhat higher complexity.
SLM is now even possible in bioresorbable metals, with special adaptations as shown in Aachen, such as pre-heating and an optimised shield gas circulation, for rather microcrack-sensitive, special substrates (Figure 3).

Even for very large parts LMD – using a laser torch with integrated and well-controlled powder flow – offers a faster, more multifunctional solution. Modelling (computer simulation) of the injected powder particles has gone to great lengths and is already in use to obtain an optimal homogeneous feed of material on the spot.
Advanced positioning systems such as Aerotech motion control and software are now used in a variety of AM applications, confirming the AM race towards higher precision and quality.

Laser heating

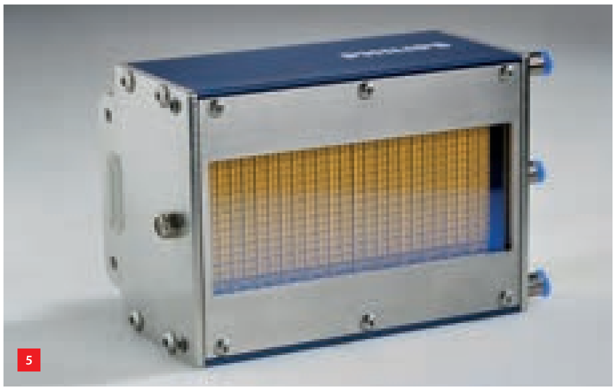
Lots of processes in modern industry require some kind of external heating. Philips GmbH Photonics, of the newly born Philips Lighting company, is making inroads with a recently unveiled invention for specific kinds of thermal processing – the European Laser Institute honoured it with the Innovation Award Laser Technology 2016. Processes involved are melting, curing, annealing, alloying and drying of nearly all technical materials. This concerns emerging laser application fields such as solar cells, carbon fibre tape laying, semiconductor wafer annealing, high-speed digital printing and – in the future highly productive – 3D printing, but also forming and welding plastics.

Commonly, specific heating of relatively large surfaces in industrial applications is an enormous challenge, accomplished by traditional heat sources such as gas burners and halogen lamps. These kinds of 'clumsy' tools are rather restricted regarding, for example, power intensity on the spot: they react slowly in a thermal sense, and they lack a sufficient degree of volumetric selectivity.
On the other hand, conventional lasers – typically characterised by high power and high brilliance at high investment – up to now typically feature a single, fairly small-sized, intense spot. Thermal processing of extended areas in that case requires either costly defocussing optics or a fast scanning system.

Diode breakthrough

The novel vertical-cavity surface-emitting laser diodes (VCSELs, Figure 4) with reduced power consumption bring a perfectly fitting, easy-to-integrate and (optionally) closed-loop dosing solution, especially for demanding heating jobs, in a tailored, highly efficient and cost-effective way.
These solid-state GaAs-based microlasers are manufactured fully controlled in the traditional, semiconductor process.

VCSELs emit 1-10 mW power on near-IR wavelength (800-1,100 nm) perpendicular to the original wafer surface, as opposed to standard edge-emitting high-power diodes. The real power here sits in the numbers: up to 500 overlapping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VCSELs on one single square millimeter – which can be coupled LED-like in a number of arrays and then stacked in a compact and robust housing (Figure 5) – nowadays bring a maximum of 100 W at only several centimeters working distance.

The new Imalux direct laser system, incorporating a VCSEL module, can generate larger areas of homogeneous light or patterns which can be controlled in space and time to have almost any structure (Figure 6). This appears as an oscillating switching mode inside a well-defined rectangular cross section with a high level of process control on the outer surface of the product, without the need for additional optics. The first proven, down-to-earth application of this Philips achievement is, strictly speaking, literally an almost invisible, 'leading-edge' one – bonding the edges of ready-to-use furniture panels in a seamless way.

6

6 *Sample of innovative structured heating solution.*

'Cold' laser machining

Other sections of science and industry are urgently pressing for advanced tools with lower operating temperature at the interface where the laser beam interacts with the substrate. Specific technologies – for example polishing, modification of texture or in 'cold' micro-machining – were highlighted during AKL'16, offering new business opportunities.

A bit more exotic is the hybrid LMJ laser MicroJet process – described in more detail in *Mikroniek* vol. 55 (4), pp. 29-35, 2015 – with a laser beam guided inside a tiny water jet with an extremely long working distance up to 100 mm.

At the moment, other ultrashort pulsed (USP) sources are already available that accomplish complex tasks that were not feasible before with any other type of laser. The increasingly shorter pulse duration with a high beam quality helps – up to a threshold between pico- (10^{-12} s) and nanopulses (10^{-15} s) – to minimise the heat-affected zone. When the correct set of adjustable parameters is used, USP-lasered surfaces can do without post-processing as almost no heat is put into the substrate surface. This was previously achieved by relatively slow moving bridge-type machines, whereas now an almost weightless laser beam dynamically scans the outside geometry at extreme velocities.

ILT showed decisive advances which can be selectively used in the preparation of material surfaces – without any trace of topography changes – to realise an improved bond (in laser welding, laser hard soldering or laser glue curing) or for local removal of certain coatings. The latter can even be used on new technical materials such as fibre-reinforced plastics. Imagine what the future may have in store with femtolasers in the picture and scientists and technicians starting to talk about attoseconds.

Modifying surface functionality and aesthetics

As AKL'16 also signals, lasers are increasingly becoming the key to achieve highest orders in industrially required quality. Not only for surface roughness but also for functional modification of the structure. Form, quality, structure and finish of the surface have a critical influence on product lifetime. Besides, one should not forget that the profile of each surface is made up of form deviation, waviness and surface roughness. Knowing the exact surface roughness, or R_a, of a product (feature) is only of any value in direct relation to functionality.

Laser structuring might be advantageous in a tribological sense, i.e. preventing seizing (jamming due to sliding friction) of interacting surfaces in relative motion. Typically during metal removal processes such as turning, systematic, open-ended traces originate. Lubricating oil can easily be forced out of such a contact area. A random pattern resulting from a grinding or honing cycle, or a mini crater surface resulting from a specific set of spark erosion parameters, will to a greater extent block leakage of fluids. With laser structure modifying, a similar situation is created, whereby the separate circular indentations (produced by the circular laser spot) retain more of the lubricating medium for an extended period of time.

In addition, the surface quality improves thanks to the laser material polishing action. This is done purely by locally remelting a microlayer, without any material removal of the substrate, followed by a smoothing action as a result of the interfacial surface tension.

In addition, there is the possibility of improving a modern design with aesthetical aspects. In that aesthetic respect, the Swiss company of GF Machining Solutions pointed, at their AKL stand, to the latest P400U model (Figure 7), bound to penetrate into SMEs. This high-end machine tool is capable of generating microstructures on specific mould inserts or precision components with differing details that look and feel like leather, with or without glossy effects. This is realised with a continuously varying melt pool with in-process modulated laser power at a frequency of 10-100 Hz. The look and haptic feel of surface structures can generally be validated visually by using a ruler of texture samples for reference.

7 GF Machining Solutions P400U laser structuring machine.

8 One of the Fraunhofer Arnold exclusive laser polishing machines. The inset shows a laser-polished sample product.

Down in the deepest 'dungeons' of the ILT laboratory, a Fraunhofer Arnold machine tool (Figure 8) was detected which automatically performed laser polishing cycles on complex 3D mould surfaces. Rather new in the German R&D programs is this superfinish machining action on certain SLM-produced parts with an almost unrestricted freedom of complexity in the geometry. In principle, the freely styled contour stays unimpaired.

Conclusion

The AKL'16 International Laser Technology Congress brought no visionary new laser, process controlling, measuring or monitoring concepts into the open. But both leading academic and industrial specialists scored with practical cases and systems covering substantially better performance in specific applications. Among the major topics should be mentioned the drive for highest power at an ever increasing repetition rate, the extreme wall-plug efficiency in modern fibre laser systems, ultrashort pulsing for cold(er) material processing and, not to forget, advanced types of fibre and diode laser systems are taking the lead in several application fields. Specific technologies – for example, high-quality polishing, 'cool' micro-machining, industrially validated 3D printing processes (leading to lightweight products), and surface structuring – were highlighted.

The next edition, AKL'18, will take place in Aachen on 2-4 May 2018. ■

INFORMATION
WWW.LASERCONGRESS.ORG
WWW.ILT.FRAUNHOFER.DE

FROM ADDLAB TO ADDFAB

Three years ago, Additive Industries opened the doors of AddLab in Eindhoven, the Netherlands. Eight partners from the manufacturing industry joined this pilot plant for 3D metal printing, which became a hot spot of the Dutch additive manufacturing (AM) industry. Last month, the AddLab initiative officially ended and continued as AddFab, aimed at moving from the laboratory to industrial fabrication. KMWE, NTS-Group and Machinefabriek de Valk will run together the new AddFab.

AddLab was the first Dutch 3D printing pilot factory for the production of industrial metal parts. It was built on the ambition to develop a broad range of high-tech and high-end manufacturing applications for 3D metal printing. As a privately funded, shared facility, AddLab was run by a team of AM professionals who supported the partner companies in the exploration of the AM technology and the production and supply of 3D printed metal parts for end-users. The success of AddLab is reflected by the fact that all partners will continue to invest in AM, each with their own focus and vision.

1 *The official handover from AddLab to AddFab. From left to right, Edward Voncken (KMWE), Daan A.J. Kersten (Additive Industries), Marc Hendrikse (NTS-Group), John Hagelaars (Machinefabriek de Valk), Arno Gramsma (KMWE) and Remco Pennings (Additive Industries). (Photo by Harry Kleijnen)*

New initiative

As of 1 October 2016, KMWE, NTS-Group and Machinefabriek de Valk have officially continued their AddLab collaboration within a new initiative, the privately funded AddFab. Their former AddLab partners Frencken and MTA remain involved as second-line parties for the 3D printing of parts. The ambition for this shared printing factory is to develop world-class metal AM applications by creating lighter, compact, integrated, more complex 'functional' products and parts with better performance/characteristics. The AddFab facilities include various high-end 3D printers, a heat treatment oven, a 3D scanner and more. Additionally, AddFab is backed by the manufacturing and qualification capabilities of the partner companies.

AddFab is located in Eindhoven, currently on the Strijp-T industrial estate, and is set to move to the Brainport Industries Campus; the green light for realisation of this future home of the high-tech manufacturing industry in the Dutch Brainport region has recently been given. "Our move from Strijp-S, where Additive Industries has taken up all of the AddLab space, to Strijp-T really is an intermediate step", Edward Voncken, CEO of KMWE and one of the driving forces behind the Brainport Industries Campus, says. "On the campus AddFab will become part of the shared facilities in the so-called Atrium. AddFab will retain the way of working of AddLab for another period of three years. Through collaboration and risk sharing we want to strengthen our leading position. When AddFab has become a success, KMWE and Machinefabriek de Valk may open up an industrial print factory within their companies."

2

2 *Example of the freeform design and realisation of a heat exchanger. Pictures provided by Machinefabriek de Valk)*

Industrialisation

"We have shifted our focus, hence the new name, towards fabrication, industrialisation, quality management and commercialisation", Arno Gramsma, director of the KMWE 3DP business unit, explains. "We want to build on what has been learnt from AddLab and produce industrial cases that can set engineers thinking and convince customers of the potential. For conventional manufacturing, such as machining, the level of knowledge and experience is very high and standards have evolved, but even there discussions about design and manufacturability occasionally arise. For 3D printing we have to go through a similar learning curve, but hopefully it will be steeper. The design consequences for serial production and post-processing have to be considered carefully. For example, preparing a printed product for post-process machining requires a zero position for reference; its definition is not self-evident in the case of an organic design. And will shot peening work for complicated structures with holes and cavities? Also, the supply chain will have to be prepared for the 3D printing of parts. Etcetera, etcetera."

AddFab will extend the collaboration with software companies and educational partners. Education and training will be an important task of AddFab, Gramsma continues. "We have to train engineers to take a different perspective on the design and the lifecycle of products. When to use 3D printing, and when conventional, subtractive production methods, such as machining for highest accuracy? How to 'build up' material to create a hole instead of drilling it? We also have to educate our future customers, show them what is possible with 3D printing and what is not. They have to understand the business case, for example lowering the total cost of ownership. Therefore, AddFab also has to take on the consultant role."

Design principles

In its three years of existence a great deal has been learnt at AddLab, Jeroen Jonkers, design engineer of NTS-Group, confirms. "We have explored all the relevant aspects of AM, for a large variety of products, materials, applications and post-processing options. We have solved many issues and now have a clear perspective of the possibilities. Individually, the partners could not have reached this level. Now, in AddFab we want to refine our knowledge and extend our experience to industrial applications."

One of Jonkers' goals, from the NTS-Group perspective, is to apply design principles in AM designs to develop high-tech mechanisms. Such mechanisms may contain, for example, leaf springs and struts for high-precision positioning. Jonkers: "The advantage of 3D printing is that you can design lightweight yet stiff parts with organic shapes which avoid the build up of stress and strain concentrations. We already produced a monolithic alignment mechanism with four degrees of freedom, which has an amazing number of functions united in one part. It is nice to see that system architects can come up with theoretical design concepts which can actually be produced. 3D printing bears the promise of becoming a serious production technique for fine mechanics."

3 *AddFab is making the transition from the lab to the fab, from pioneering with 3D printing designs and processes to industrial applications and series production.*

Quality management

With the handover from AddLab to AddFab the years of pioneering have come to an end, Edward Voncken states. "We have made large investments, which have resulted in a lot of knowledge but no significant turnover yet. 3D metal printing has been a hype for a long time, but now the market signals a transition from the lab to the fab. Airplane manufacturers are taking the lead. Airbus has selected parts for 3D printing, and GE already uses printed parts in the construction of engines. Moreover, it has recently taken over the printer manufacturers Arcam and SLM Solutions."

Nowadays, quality management and validation of printed parts are crucial issues, according to the AddFab partners. Parts built up from powder differ in their material properties from products machined from bulk. Supplying the product with a material certificate attached does not make much sense for 3D printing, as end product properties will be different from the powder specifications. Engineers, but also quality managers and certifying bodies, have to get used to that fact and qualifications processes have to be reconceived.

Voncken concludes: "So the concept of making a design and sending it online to an arbitrary print shop is not yet feasible. It will take some time before ISO standards for 3D printing are in place." Therefore, the three AddFab partners promote the Brainport Industries Campus as a place to be for industrial 3D metal printing.

INFORMATION
WWW.ADDFAB.NL
WWW.YOUTUBE.COM/CHANNEL/UCZF1C0PBMZJ4WEXJZTU7QCW

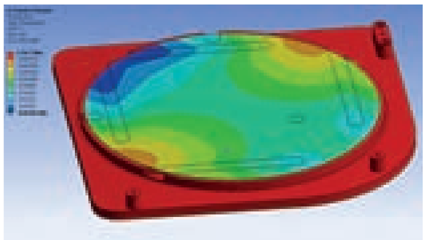
AddFab founding fathers

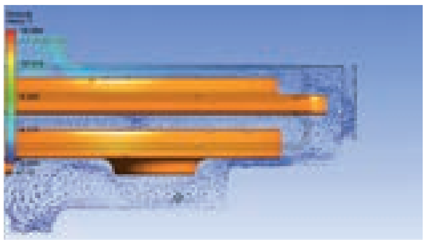
KMWE
KMWE, headquartered in Eindhoven, the Netherlands, is a supplier for the high-tech equipment industry and the aerospace industry, specialising in the high-mix, low-volume, high-complexity machining and 3D metal printing of functional critical components, and in the assembly and engineering of fully tested mechatronic systems.
The KMWE 3DP business unit offers engineering and 3D metal printing services and supports its customers in the technical and commercial trade-off between the unique 3D printing feasibilities and the established machining technologies. The 3D printing services include topology optimisation and engineering, prototyping for both 3D printing and machining, and business case validation.
WWW.KMWE.COM

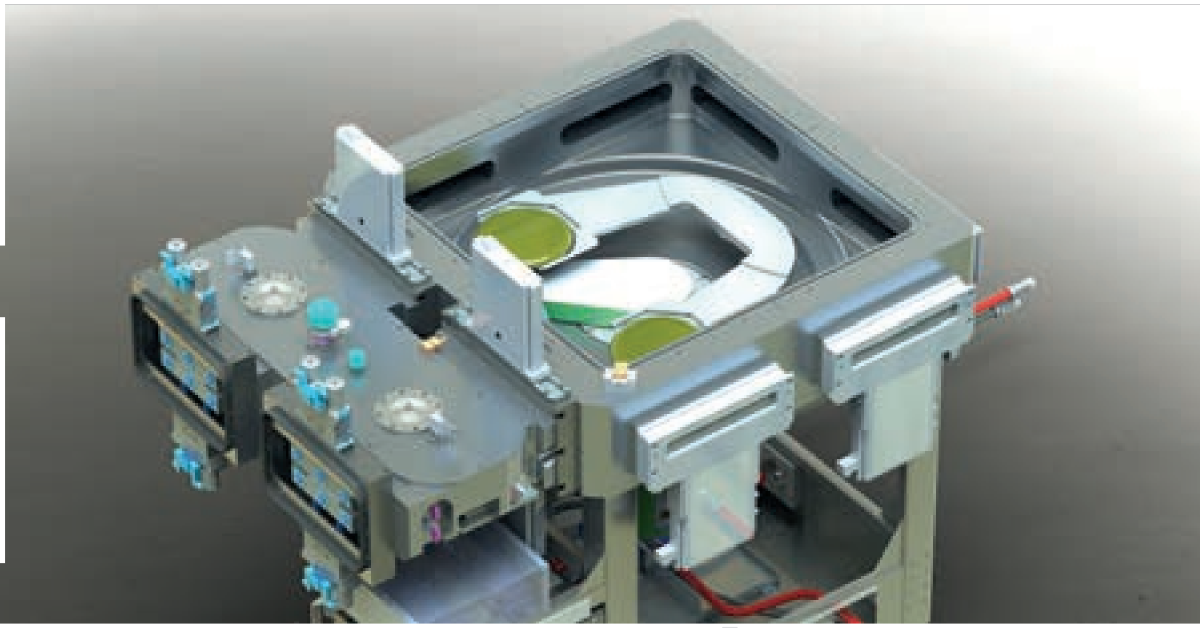
NTS-Group
As a first-tier supplier Eindhoven-based NTS-Group develops, manufactures and optimises opto-mechatronic systems, modules and components for international, leading and high-tech OEMs that develop and market high-mix, low-volume, high-complexity machines.
For 3D printing, NTS-Group has various interests. Firstly, applying the AM development knowledge in designs for customers when it has added value. Consequently, the manufacturing with 3D printing in-house in order to support NTS-Group's understanding of 3D printing in development. In parallel, NTS-Group is a development and construction partner of printing equipment OEMs.
WWW.NTS-GROUP.NL

Machinefabriek de Valk
Based in Valkenswaard, close to Eindhoven, Machinefabriek De Valk is specialised in the production of mechanical components in all common steel types, non-ferrous metals and plastics, as well as in the full production and assembly of modules and machines. De Valk offers additional services such as hardening, anodising, nickel plating, sheet-metalworking and engineering.
It is de Valk's vision that 3D printing is a design-driven innovation that indicates a radical shift in the technological perspective and will create new markets. It introduces bold new ways of competing as it can radically change the appearance and functionality of products.
WWW.MACHINEFABRIEKDEVALK.NL

VDL Enabling Technologies Group


Thermal analysis


Contamination control



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MEETING POINT FOR PRECISION TECHNOLOGY AND DSPE MEMBERS

On 16 and 17 November 2016, the sixteenth edition of the Precision Fair will once again be the international meeting point for precision technology. This free event at the NH Conference Centre Koningshof in Veldhoven, the Netherlands, features some 300 exhibitors (specialised companies and knowledge institutions), among which nearly sixty DSPE members.

The Precision Fair has a two-day lecture programme which lists fifty presentations. The special Big Science keynote track was very successful last year and is therefore again on the menu. It features projects like CERN (nuclear research), ITER (nuclear fusion energy) and E-ELT (astronomy). (Dutch) high-tech suppliers can learn about their recent technological developments and new tenders. The International Meet & Match Event will be hosted on both fair days as well.

Exhibition

The heart of the fair, however, is the exhibition, which covers a wide array of fields, including optics, photonics, calibration, linear technology, measuring equipment, micro-assembly, motion control, piezo technology, precision tools, sensor technology, software and vision systems. A sneak preview of a few innovations on display is presented on the following pages.

Awards

Just before closing each fair day, event partner DSPE will organise an award ceremony. On Wednesday 16 November, the Ir. A Davidson Award will be presented to a young precision engineer who has worked for some years in a company or institute and who has a demonstrable performance record. On Thursday 17 November, the Wim van der Hoek Award will be presented to the person with the best mechanical engineering design graduation project at one of the three Dutch universities of technology.

Media partner Mikroniek will report on the highlights of the Precision Fair 2016 in its December issue.

DSPE members exhibiting at the Precision Fair 2016

Stand number	
288	4TU.High Tech Systems
150	Alten
293	Avans Hogeschool
166	BKB Precision
199	Bosch Rexroth
162	Bronkhorst Nederland
125	Ceratec Technical Ceramics
96	Connect 2 Cleanrooms
130	Demcon Advanced Mechatronics
235	Dürr Ecoclean
275	Dutch Society for Precision Engineering
132	ECN (Energieonderzoek Centrum Nederland)
281	Ertec
138	Etchform
139	Festo
129	Focal Vision & Optics
293	Fontys Hogeschool voor Engineering/Mechatronica
103	Frencken Group
6	Germefa
34	Groneman
293	Haagse Hogeschool
31	Heidenhain Nederland
105	Hembrug Machine Tools
38	Hittech Multin
101	Ter Hoek Vonkerosie Rijssen
293	Hogeschool Utrecht
48	Holland Innovative
276	The House of Technology
135	IBS Precision Engineering
120	Irmato

Stand number	
277	Janssen Precision Engineering
292	Leidse Instrumentmakers School
282	MathWorks
5	Maxon Motor
267	Mecal
128	Mevi Fijnmechanische Industrie
200	MI-Partners
7	Mitutoyo Benelux
269	Molenaar Optics
203	MTA
134	Newport Spectra Physics
25	NTS-Group
260	Oude Reimer
181	Phaer
194	Philips Innovation Services
137	PI Benelux
16	Roelofs Meetinstrumenten
293	Saxion Hogeschool
157	Settels Savenije group of companies
104	Sioux CCM
119	Sumipro
86	Technobis Group
51	Teesing
140	Tegema
37	TNO
112	VDL ETG
228	Veco
144	VSL

Impression of the Precision Fair 2015. (Photo: Jan Pasman/Mikrocentrum)

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Precision

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VDL ETG: Ultra-Clean Transfer Modules

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Precision Fair 2016

Wednesday 16th and Thursday 17th November 2016

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7

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260

Exhibitors

Stand number	
218	2-S BV
279	3D SYSTEMS LAYERWISE
221	4PICO BV
288	4TU. HIGH TECH SYSTEMS
99	AAE BV
80	ACE STOßDÄMPFER GMBH
70d	ADRUU BV
2	ADVANCED CHEMICAL ETCHING LTD
19	AEMICS BV
245	AEROLAS GMBH
156	AEROTECH LTD
114	AJB INSTRUMENT BV
218	VAN DEN AKKER FLUID SERVICE BV
150	ALTEN
280	ALTRAN
153	ALUMECO NL BV
180	AMADA MIYACHI EUROPE
94	AMMERTECH BV
131	ANTERYON BV
23	ART CCG CAULIL CYLINDRICAL GRINDING BV
177	ATB AUTOMATION
126	ATTOCUBE SYSTEMS AG
293	AVANS HOGESCHOOL
20	AVERNA NV
106	AXXICON MOULDS EINDHOVEN BV
157	BAKKER FIJNMETAAL
184	BALLUFF BV
95	BDM BEARING DESIGN & MANUFACTURING BV
225	BERGHOFF GROUP
84	BETECH GROUP
166	BKB PRECISION
123	BKL ENGINEERING BV
232	BLUE ENGINEERING BV
70h	BLW KUNSTSTOFFEN BV
116	BOA NEDERLAND BV
199	BOSCH REXROTH BV
261	BOUMAN HIGH TECH MACHINING
58	BRAINPORT INDUSTRIES
162	BRONKHORST NEDERLAND BV
21	BRUKER NEDERLAND BV
109	B&S TECHNOLOGY BV
122	BUSCH MICROSYSTEMS CONSULT GMBH
251	C3 TOOLING BV
278	CAPABLE BV
251	CCC PROJECTS & ENGINEERING BV
125	CERATEC TECHNICAL CERAMICS BV
249	CERATIZIT NEDERLAND BV
196	CLEANPART GMBH
240	COLANDIS GMBH
96	CONNECT 2 CLEANROOMS LTD.
117	CONTOUR FINE TOOLING BV
182	CONWAY NEDERLAND BV
190	COORSTEK NETHERLANDS BV
3	CUSTOM SPECIAL TOOLS BV
3	CZL TILBURG BV
88	DCD
22	DEKRACOAT BV
227	DEMACO HOLLAND BV
246	DEMATECH PARTS & PROJECTS
130	DEMCON ADVANCED MECHATRONICS BV
91	DIAMOND KIMBERLIT BV
216	DIXI POLYTOOL BV
53	D&M VACUÜMSYSTEMEN BV
115	DOEKO BV
70c	DRALINE BV
235	DÜRR ECOCLEAN GMBH
149	DUTCH PRECISION TECHNOLOGY
214	DUTCH SCIENTIFIC
275	DUTCH SOCIETY FOR PRECISION ENGINEERING
132	ECN (ENERGIEONDERZOEK CENTRUM NEDERLAND)
142	EDMUND OPTICS GMBH
172	ELTREX MOTION BV
211	ENCOMA BV
289	ENTERPRISE EUROPE NETWORK / KAMER VAN KOOPHANDEL
271	EPIC EUROPEAN PHOTONICS INDUSTRY CONSORTIUM
243	ERNST & ENGBRING GMBH
201	EROWA AG
281	ERTEC BV
229	ETALON AG
138	ETCHFORM BV
27	EURO-TECHNIEK EINDHOVEN BV
59	EUSPEN
193	FAES CASES
49	FARO BENELUX BV
93	FAULHABER
244	FEINMECHANIK ULRICH KLEIN GMBH
139	FESTO BV
154	FIJNMECHANISCHE INDUSTRIE GOORSENBERG BV
45	FMI HIGHTECH SOLUTIONS
129	FOCAL VISION & OPTICS
293	FONTYS HOGESCHOOL VOOR ENGINEERING/MECHATRONICA
26	FORMATEC CERAMICS BV
103	FRENCKEN GROUP
4	GELDERBLOM CNC MACHINES BV
191	GENTEC BENELUX
6	GERMEFA BV
281	GF MACHINING SOLUTIONS INTERNATIONAL SA
95	GIBAC CHEMIE BV
52	GIBAS NUMERIEK BV
283	GIMEX
146	GLYNWED BENELUX BV
236	GOM OPTICAL METROLOGY
34	GRONEMAN BV
293	HAAGSE HOGESCHOOL
15	HARTMETALL-WERKZEUGFABRIK PAUL HORN GMBH
205	HAUCK HEAT TREATMENT EINDHOVEN BV
31	HEIDENHAIN NEDERLAND BV
234	HEMABO PRECISIE KUNSTSTOFTECHNIEK
105	HEMBRUG MACHINE TOOLS
12	HEXAGON METROLOGY BV
261	HIGH TECH MACHINING TWENTE BV
38	HITTECH MULTIN
185	HIWIN GMBH
101	TER HOEK VONKEROSIE RIJSSEN BV
293	HOGESCHOOL UTRECHT
18	HOGETEX BV
48	HOLLAND INNOVATIVE BV
70e	VAN HOOF GROEP BV
70b	VAN DER HOORN BUIGTECHNIEK
175	HOSITRAD VACUUM TECHNOLOGY
276	THE HOUSE OF TECHNOLOGY
135	IBS PRECISION ENGINEERING BV
133	IKO NIPPON THOMPSON EUROPE BV
141	ILT FINEWORKS BV
265	INNPLATE BV
47	INSCOPE BV
188	IPS TECHNOLOGY
120	IRMATO
76	ISP SYSTEM
277	JANSSEN PRECISION ENGINEERING BV
202	JEOL
85	JEVEKA BV
195	JFA
186	J.J. BOS BV
118	JOB PRECISION
50	KAYDON CORPORATION
87	KEYTEC NETHERLANDS BV
36	KISTLER BENELUX
46	KMWE PRECISION SYSTEMS & PRECISION COMPONENTS
217	KNF VERDER BV
158	KUSTERS & BOSCH FIJNMECHANISCHE INDUSTRIE BV
70a	KUSTERS GOUMANS BV
54	KUSTERS PRECISION PARTS
170	LAB MOTION SYSTEMS
197	LANDES HIGH END MACHINING BV
152	LARSEN PREMIUM PRECISION PARTS
90	LASERTEC BV
254	LASER TECHNOLOGY JANSSEN BV / LTJ
97	LASOS LASERTECHNIK GMBH
215	LEERING HENGELO BV
292	LEIDSE INSTRUMENTMAKERS SCHOOL
42	LEMO CONNECTORS NEDERLAND BV
242	LEYBOLD NEDERLAND BV
163	LM SYSTEMS BV
136	LOUWERSHANIQUE
183	LUCASSEN GROEP BV
198	MAGISTOR STRAAL- & VERSPANINGSTECHNIEK
15	MAKE! MACHINING TECHNOLOGY BV
208	MARPOSS GMBH
173	MASÉVON TECHNOLOGY GROUP
282	MATHWORKS
110	MAT-TECH BV
5	MAXON MOTOR
267	MECAL
102	MELLES GRIOT BV
189	MELOTTE NV
70f	METAALHUIS
40	METRICCONTROL
128	MEVI FIJNMECHANISCHE INDUSTRIE BV
238	MICRO-EPSILON MESSTECHNIK GMBH & CO.KG
224	MICROW GMBH
6	MIFA ALUMINIUM BV
65	MIKROCENTRUM
200	MI-PARTNERS BV
7	MITUTOYO BENELUX
6	MOGEMA BV
269	MOLENAAR OPTICS VOF
203	MTA BV
10	MTRC SPECIAL PLATING BV
168	MTSA TECHNOPOWER BV
30	MURAAD BV
124	MYTRI BV
176	NATIONAL PHYSICAL LABORATORY
75	NEITRACO GROEP
127	NEWAYS TECHNOLOGIES BV
134	NEWPORT SPECTRA PHYSICS GMBH
293	NHL KENNISCENTRUM COMPUTER VISION
28	NIJDRA GROUP
108	NIKON METROLOGY
207	NORDSON EFD
25	NTS-GROUP BV
107	OCEAN OPTICS BV
239	OERLIKON BALZERS COATING NV
259	OLYMPUS NEDERLAND BV
134	OPHIR SPIRICON EUROPE GMBH
260	OUDE REIMER
98	OWIS GMBH
72	PARKER HANNIFIN BV

237	PETERS METAALBEWERKING BV	143	SENTECH SENSOR TECHNOLOGY BV	226	UNITED SPRINGS BV
41	PFEIFFER VACUUM BENELUX BV	83	SERVOTRONIC BVBA	79a	UNIVERSITY RACING EINDHOVEN
181	PHAER BVBA	157	SETTELS SAVENIJE GROUP OF COMPANIES	257	VACOM VAKUUM KOMPONENTEN & MESSTECHNIK GMBH
194	PHILIPS INNOVATION SERVICES	82	SICK BV	44	VACUTECH BV
137	PI BENELUX	11	SIGMACONTROL BV	121	VARIODRIVE AANDRIJF- EN BESTURINGSTECHNIEK BV
151	PINK GMBH VAKUUMTECHNIK	104	SIOUX CCM	273	VCCN
24	PM-BEARINGS BV	209	SKF BV	112	VDL ETG
220	PNEUTEC	78	SMARACT GMBH	13	VDL GL PRECISION BV
178	POLYWORKS BENELUX BV	164	SMC	60	VDMA ELECTRONICS, MICRO AND NANO TECHNOLOGIES
9	PRECISION MICRO LTD	223	SMINK GROUP BV	228	VECO BV
285	PROBOTICS BV	219	SOLID POINT PRECISION MANUFACTURING S/B	70g	VIA ENGINEERING DEURNE BV
222	PRODIM INTERNATIONAL BV	35	STEEN METROLOGY SYSTEMS	113	VIRO ECHT BV
145	PROMIS ELECTRO-OPTICS BV	8	STEMMER IMAGING BV	144	VSL
72	QUANTUMCLEAN	167	STT PRODUCTS BV	33	WEISS NEDERLAND BV
55	REITH LASER BV	119	SUMIPRO BV	241	WEISS TECHNIK NEDERLAND BV
148	RELIANCE PRECISION MECHATRONICS	210	TBP ELECTRONICS BV	99	WERTH MESSTECHNIK GMBH
165	RENISHAW BENELUX BV	86	TECHNOBIS GROUP	233	WIJDEVEN INDUCTIVE SOLUTIONS BV
100	RIJKSDIENST VOOR ONDERNEMEND NEDERLAND	117	TECHNODIAMANT ALMERE BV	17	WILTING
247	RJ LASERTECHNIK GMBH	6	TECHNOLOGY TWENTE BV	126	WITTENSTEIN CYBER MOTOR GMBH
50	RODRIGUEZ GMBH	147	TECNOTION BV	230	W.L. GORE & ASSOCIATES GMBH
16	ROELOFS MEETINSTRUMENTEN BV	51	TEESING BV	81	WTS CLEANROOM TECHNOLOGY SYSTEMS
43	ROFIN-BAASEL BENELUX BV	140	TEGEMA	284	WZW OPTIC AG
160	ROMÉDES SPECIALS BV	97	TE LINTELO SYSTEMS	92	XERYON BVBA
255	ROMEX BV / BENELUX	206	TELMASTAAL NV	253	YAMAZAKI MAZAK NEDERLAND BV
44	DEROOVERS VACUUM & PRECISION TECHNOLOGY BV	161	TEVEL TECHNIEK BV	174	YASKAWA BENELUX BV
155	DE ROOY SLIJPCENTRUM BV	192	THK GMBH	14	ZEISS
89	SALOMON'S METALEN BV	37	TNO	159	ZME FIJNMECHANISCH ATELIER BV
293	SAXION HOGESCHOOL	169	TONASCO MALAYSIA SDN BHD		
171	SBN NEDERLAND BV	29	TOTAL SUPPORT GROUP		
79	SCHAEFFLER NEDERLAND BV	251	TOWA EUROPE BV		
39	SCHNEEBERGER GMBH	231	TSD TOOLING SPECIALIST DERKSEN BV		
1	SCHUT GEOMETRISCHE MEETTECHNIEK BV	235	UCM AG		

INNOVATIONS ON DISPLAY

PM-Bearings (stand number 24)
ACCI, optimised anti-cage-creep mechanism

A PM-Bearings innovation on display is the optimised anti-cage creep mechanism, the ACC-Integrated (ACCI). Fully integrated into the design, the mechanism is a robust system which controls the movement of the roller cage in a linear guide. It is designed not only for demanding applications such as extremely high accelerations (e.g. in wire bonding) with more than one billion strokes, but also for UHV (e.g. lithography) applications where precision of movement is important. The new anti-cage-creep mechanism, the ACCI, prevents the roller cage from running off the tracks of the precision cross-roller guide and has no impact on its load rating. A combination of gear rack and pinion controls the cage movement.

The ACCI mechanism in a linear guide.

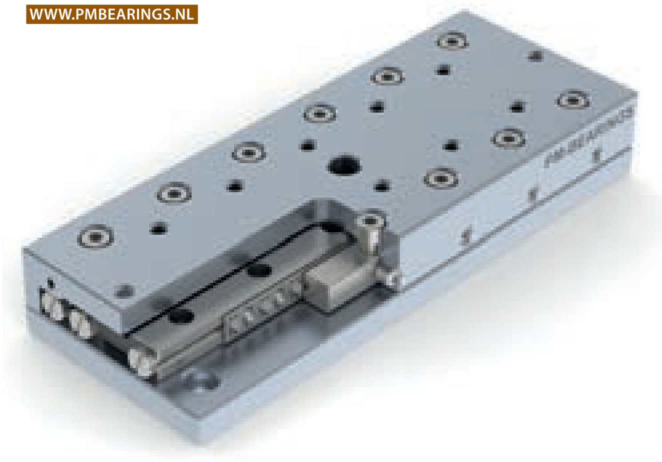
The cage-creep phenomenon occurs in highly dynamic applications where the cage creeps out of its original position as a result of inertia forces, in vertical applications or due to inaccuracies during assembly. The creep is usually in the micron range, but long-term use can extend this to millimeters and prevent the stroke length from being achieved. PM developers have designed a gear rack which is machined into the material in the V-groove at the bottom of the roller track using electrochemical machining, a contactless machining process. The gear rack is aligned flush with the running surfaces of the roller elements to prevent undesirable forces from acting on the ACCI mechanism.

Precision cross-roller guides are used in applications where smooth running capabilities, extremely low friction, high load capacity, stiffness and high accuracy are required. The stroke length is limited and is determined by the length of the roller cage. Due to the interplay of properties, the guides are often used for very specific movements, often in the micron range. The lack of play in the cross-roller guides results in very high placement accuracy and production rates with a long service life.

The cylindrical rollers are cross-mounted in a plastic cage, which holds them in place. The negative play (pretension) causes elastic distortion of the rollers, eliminating any play in the movement of the cross-roller guide. The moving portion of the anti-cage creep mechanism is mounted in the centre of the cage in order to distribute the forces evenly across the cage.

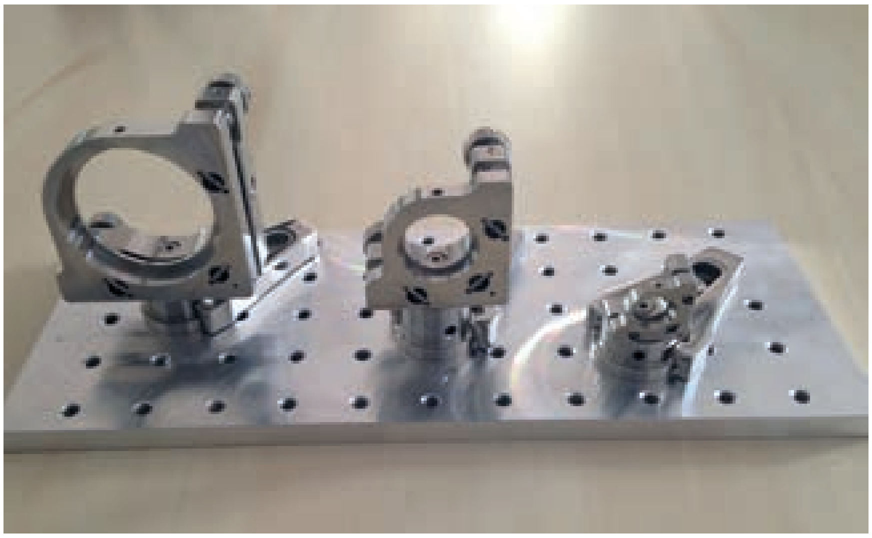
A complete set of precision linear guides with ACCI comprises four rails and two roller cages. End pieces are optionally available for mounting in the ends of the rails to protect the guide from dirt. PM-Bearings is the Dutch manufacturer of precision linear guides, roller tables and customer-specific positioning systems and modules. ■

WWW.PMBEARINGS.NL



A roller table with the cross-roller linear guide.

Molenaar Optics (stand number 269)
Vacuum-compatible OptoSigma product range



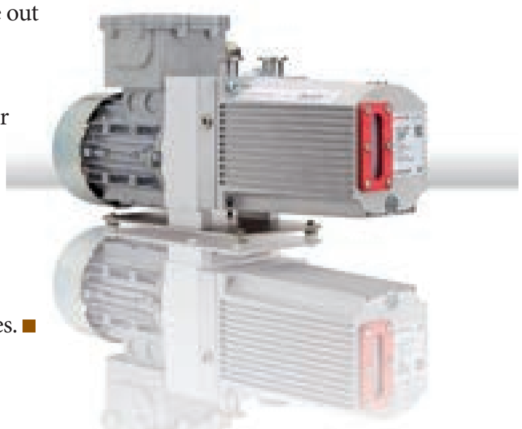
OptoSigma has added a range of vacuum-compatible mirror holders, lens holders and mounting base products to its opto-mechanical components catalog. This comprises a series of 2-axis adjustable mirror holders and a series of fixed lens holders, each holding optics with diameters between 12.7 mm and 50.8 mm. To prevent unwanted outgassing, screws have been equipped with venting holes and grooves. Adjustable parts use special vacuum-compatible grease. Further series of clamp-bases, posts, postholders and base plates are available for mounting the holders. All components are made from stainless steel. OptoSigma previously introduced several series of vacuum-compatible manual and motorised stages with linear, rotation and goniometer movement. ■

WWW.MOLENAAR-OPTICS.NL

Pfeiffer Vacuum (stand number 41)
Magnetically coupled rotary vane pump Duo 11 ATEX

The Duo 11 ATEX rotary vane pump, which meets ATEX directive 2014/34/EU, was brought to the market by Pfeiffer Vacuum for processes taking place in potentially explosive atmospheres or conveying explosive gases and vapours. As such, it satisfies the most stringent explosion protection requirements. The ATEX certification applies for both the interior and exterior of the pump. The Duo 11 ATEX is classified as equipment category 3G and temperature class T4. It can convey all gases up to and including explosion group IIC.

The pumping speed is 9 m^3/h at 50 Hz and 10.5 m^3/h at 60 Hz. The Duo 11 ATEX is equipped with a frictionless magnetic coupling. The shaft seal rings that are used with other rotary vane pumps can be dispensed with as a result. The extra safety which the magnetic coupling provides is important in explosive atmospheres: without shaft seal rings, it is impossible for media inside the pump to escape out through faulty shaft seal rings.



The new Duo 11 ATEX from Pfeiffer Vacuum can be used in hazardous gas atmospheres that are present in applications such as research experiments, various industrial processes, biotechnology, chemistry laboratories, and gas-filling machines. ■

WWW.PFEIFFER-VACUUM.COM

Connect 2 Cleanrooms (stand number 96)
Clean air solutions

Connect 2 Cleanrooms presents scalable modular cleanroom systems that can reduce failure rates and improve consistency, adding value and improving efficiency for the customer's process. Building upon 14 years' experience delivering contamination control solutions for mission-critical environments in the precision technology sector, Connect 2 Cleanrooms specialises in developing bespoke modular cleanrooms to suit each client's particular process and budget.
On display will be the modular cleanroom construction options of softwall, hardwall or monobloc partition system. Also an adjustable cleanroom unit has been developed which can be fitted at mission-critical elements of the manufacturing process line, HEPA-lite™, and an innovative laminar flow cabinet, the UD Flow Booth. HEPA-lite™ canopies are ideal for the precision technology sector, as they can be incorporated into a modular cleanroom and automated to slide back, giving overhead access to machinery inside. ■

WWW.CONNECT2CLEANROOMS.NL

SIOS (Te Lintelo Systems, stand number 97)
Calibration interferometer for 5-DoF measurements

The new calibration interferometer SP 15000 C5 with a length measuring range of 50 m is designed for high-accuracy linear, angular and straightness calibrations on positioning axes. Thus, synchronous and continuous 5-DoF (5 degrees of freedom) measurements are possible, with horizontal and vertical straightness components being measured by a pivotable optics. Using a 90° beam deflection vertical axes can be measured too. The angular resolution is 0.0004 arcsec on a pitch and yaw angular measuring range of ± 5°, while the length resolution is 0.1 nm. Straightness measurements are possible over a range of ± 4 mm with a resolution of 10 nm in an axial zone of 6.5 m.

The 5-DoF calibration interferometer of SIOS Meßtechnik is easy to handle with the help of extensive adjusting and mounting accessories. The fibre-coupled sensor head can be adjusted quickly and accurately by an integrated beam direction detection module. The calibration software is valid according to the current standards DIN ISO 230-1 and VDI / DGQ 3441.

A correction module for various machine controllers is available. All measurement and calibration steps can be synchronised with a positioning-control unit. Extensive options for galvanically isolated triggering of the system enable the control of the measured value recording.

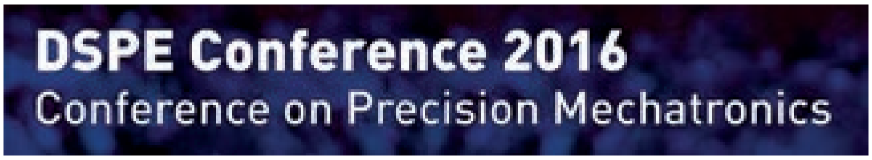
Applications include the simultaneous acquisition of five DoFs on guides and translation stages, and the calibration of high-precision axes, machine tools and coordinate measuring machines. ■

WWW.SIOS.DE

"FARMERS, PIONEERS AND PRECISION ENGINEERS"

During the two-day DSPE Conference on 4 and 5 October 2016 at De Ruwenberg in Sint Michielsgestel, the Netherlands, a large number of young precision engineers participated in both presentations/posters/demos and the audience. That promises many more fine scientific, technological and business developments in our precision engineering field in the near future. 'Farming' and 'pioneering' were present in many respects, and coincidently met in the asparagus harvester story.

JOS GUNSING



AUTHOR'S NOTE

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This year's theme of the DSPE Conference was "Farmers, Pioneers and Precision Engineers", inspired by the discussion about sustainable business and prosperity generated from precision engineering know-how and the role that (new) application areas play. The balanced programme of presentations, posters and demos covered a wide range of fundamental and practical issues in precision engineering, both at a system and a component level. This review contains a few highlights, including the three award-winning contributions.

Keynotes

Maarten den Braber, Singularity University Netherlands, talked about "Exponential technologies to solve humanity's great challenges". He gave an inspiring lecture on how exponential developments can improve our lives especially aiming for the big challenges in water, mobility, health and food. SingularityU organises a lot of events in order to demonstrate the importance of exponential developments for making real changes in society, ranging from (cost of) computing power, solar cells, information/book distribution concepts, artificial meat, self-driving cars, sustainable

1 Once again the DSPE Conference attracted a decent crowd. (Photos: Iris Wuijster)

housing communities, additive manufacturing, change to a service community (e.g. mobility as a service), and artificial human organs.

The keynote by Jo van den Brand (Nikhef) was entitled "How to measure a gravitational wave from a binary black hole merger". Most of the audience was quite possibly overwhelmed by the special relativity theory physics he presented. The important slides were those on the various measuring instruments like LIGO (USA) and Virgo (Italy). On 14 September 2015, LIGO detected, for the very first time, a gravitational wave, caused by the merging of two black holes more than a billion light years away. The set-up of a global network of gravitational wave detectors was described.

The next decade may see the construction of the so-called Einstein Telescope, which has a triangular shape with 10 km arms/beams, allowing the investigation of gravitational waves in the lower-frequency bandwidth. The challenges in terms of sensitivity are enormous: 10^{-18} m movement must be detected. The accuracies are in the range of a hair's width compared to the distance to Proxima Centauri, the nearest star that is 4.25 light years away.

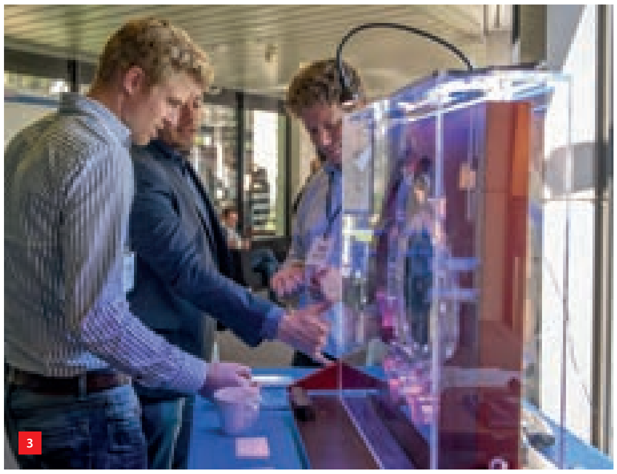
Vibration isolation is of the utmost importance, apart from the fact that in the Virgo instrument a volume of 7,000 m^3 has to be kept at a 10^{-10} bar ultra-high vacuum level. Thus many precision engineering challenges must be addressed in order to serve science.

2

Proton therapy

Sanjeev Pandya of Advanced Oncotherapy presented "Future in cancer care with advanced light technology". In oncology, avoiding damage to tissue surrounding a tumour is of the utmost importance. Application of protons accelerated to 230 MeV proves to be very effective from this point of view. Using the proton's property that most of its energy will be released just before it stops moving (the so-called Bragg peak), the protons can be aimed such that most of their energy will be released inside the tumour. Surrounding tissue will therefore not be harmed to the extent that is usual in conventional radiotherapy.

Advanced Oncotherapy is situated very near CERN, where applied technology originates. Several of the employees have been working for CERN. Four systems have been sold already and now engineering and development work is being carried out to get the first system up and running. The linear accelerator (24 m length, 230 MeV at 60% speed of light, 3 GHz) in its current state of design requires a lot of very accurately machined components of high-purity copper. Building on the experience of the first systems development, work will start on more affordable systems.



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2 *The conference is a meeting place for junior and senior precision engineers, professors included.*

3 *Focus on the demo.*

4 *From left to right, the awards were handed out by Franks Sperling (Nobleo, chairman of two conference sessions) and Marc Vermeulen (ASML, chairman of the best contribution awards panel of judges), to Ad Vermeer (Cerescon), Stefan Lampaert (TU Delft) and Eric Hennis (Nikhef).*

Three awards

Three contributors received an award at the end of the conference. One of the award winners is concentrating on a completely new system for the agriculture sector deploying insights from high-tech to the maximum. The poster award went to extreme research in the field of interferometry for detecting gravitational waves; extreme accuracies are necessary to obtain results in this application area. Finally, the demo award went to research on a very special component, ferrofluid pocket bearings.

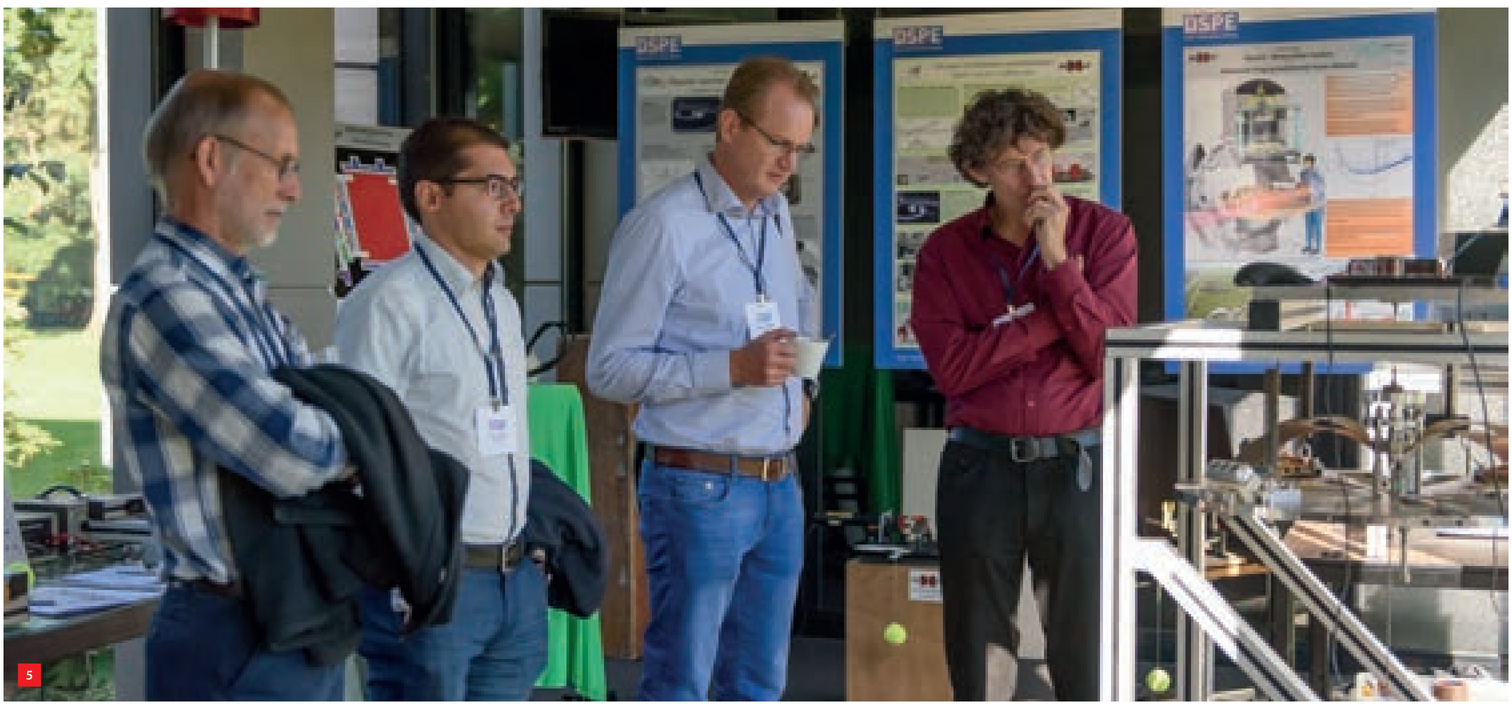
Presentation award: Ad Vermeer (Cerescon),
"High volume harvesting machine for white asparagus"
Many crops can be harvested automatically, white asparagus not yet; its harvest is very labour-intensive and thus expensive. The asparagus season runs for ten weeks in April, May and ends in the last week of June. Labour costs comprise 30% of the sales price; another concern is damage to asparagus spears and variation in quality. Ad Vermeer took up the automation challenge with his start-up company Cerescon.

The detection of asparagus has to be carried out subsurface, to prevent violet colouring. Several detection principles have been investigated: microwave heating with IR-detection, and radar. Although the latter seemed to be the most promising on the long run, the development time and cost appeared to be too long. Therefore, a principle was chosen with a proximity sensor on a stick. Several of these sensors are dragged through the soil, and can be retracted within milliseconds after spotting an asparagus spear in order to avoid damage. The position of the asparagus spear is thus recognised and used for the picking/cutting mechanism (two per row).

All this takes place at a speed of 0.5 m/s by the tractor pulling the 3-row harvesting machine. One hectare per hour can therefore be harvested. Due to the thorough detection it is sufficient to harvest once every three days. The machine is designed to work in a two-shift/day cycle and thus offers a 50% reduction in the harvesting costs. A user group is in place representing a major part of the 3,200 hectares of asparagus fields in the Netherlands. Improving reliability and robustness is the main development and engineering challenge in order to enter the market before the asparagus season in 2018.

Demo award: Stefan Lampaert (TU Delft),
"Modelling & Design principles of plano ferrofluid bearings"
Stefan Lampaert demonstrated the possibilities and theoretical backgrounds of a ferrofluid pocket bearing both on poster and with a model. The combination of magnetic field, the ferrofluid and the enclosed air pocket provides a specified stiffness. A bearing can thus be made with a controlled stiffness. Ferrofluid bearings where the loading capacity is purely dependent on a magnetically pressurised ferrofluid are also possible, but these were not considered here. Fluid friction levels can be predicted. It will be interesting to see whether ferrofluid bearings can become an interesting alternative for air and magnetic bearings for moderate speed and stroke applications.

In a separate presentation session, Lampaert showed a nm-accuracy stage applying ferrofluid bearings; a low-cost stage version (250 Euro) already attains sub-µm accuracy levels.



5 *Eric Hennes with his demo in the 'Nikhef pavilion'.*

Poster award: Eric Hennes (Nikhef), "130 years of Michelson Interferometers from 1 cm to1 million km"
Eric Hennes showed the developments in the application of Michelson interferometers for fundamental research and the required precision subsystems. Meanwhile, the equipment for measuring gravitational waves has reached a huge geometrical scale with the aid of interferometry. The current Virgo detector with two perpendicular 3km-long arms has a sensitivity which can be expressed as the strain measurement of a hair's width at a distance of approximately the nearest star system in space.
In order to increase the sensitivity and investigate other gravitational wave frequencies, concepts are being developed for the aforementioned Einstein Telescope (interferometers placed in a underground triangle with 10 km sides; the Netherlands is a strong candidate to house this facility) and a similar set-up in space where three satellites, orbiting with a million kilometers between them, will form a triangle.

Final word

The DSPE Conference 2016 was very enjoyable. A word of thanks to all people directly involved, organisers, presenters and the enthusiastic audience. The atmosphere was very agreeable and informal on both conference days, especially during the breaks and the social event. The location De Ruwenberg, including the possibility to go outdoors in a pleasant and green environment, made a strong contribution. DSPE looks forward to the next edition, the fourth conference, in 2018. ■

6 *A special word of thanks to Annemarie Schrauwen and Adrian Rankers who, for the third time, were in charge of organising the conference.*

MI-Partners – partners in mechatronic innovation

High-precision and fast moving systems are key at MI-Partners, dedicated to helping companies worldwide go a step further. Innovative mechatronic solutions are provided for different segments, from semiconductor to geophysical industry. MI-Partners is involved in an early stage of development, creating a concept and working this out to a fully functional machine.

MI-Partners is a leading centre of expertise in the field of mechatronics, and is active in developing high-tech mechatronic products and systems, like accurate stages (from micrometer to sub-nanometer accuracy and stability), fast handling systems (200 m/s^2 and several m/s) and vibration isolation systems (passive and active < µm/s^2). The complete cycle of predevelopment, design, realisation and testing of high-tech systems can be covered.

Competences

- System architecture/system design
- Precision mechanics
- Dynamics
- Control theory
- Predictive modelling
- Thermal analysis
- Air- and magnetic bearings
- Fast prototyping

X-Y-θ stage design by MI-Partners.

Knowledge projects

MI-Partners has grown in recent years into a company with about 30 highly educated engineers. In these years, extensive experience has been gained in a wide range of projects. The majority of projects are carried out based on contract R&D. Besides these customer projects, MI-Partners challenges itself with internal knowledge development projects. Since most of the external projects are confidential, these internal knowledge projects are used to explore new technologies and demonstrate competences.
In this context, a state-of-the-art magnetically levitated through-wall stage was developed (*Mikroniek* vol. 53 (1), pp. 30-35, 2013).

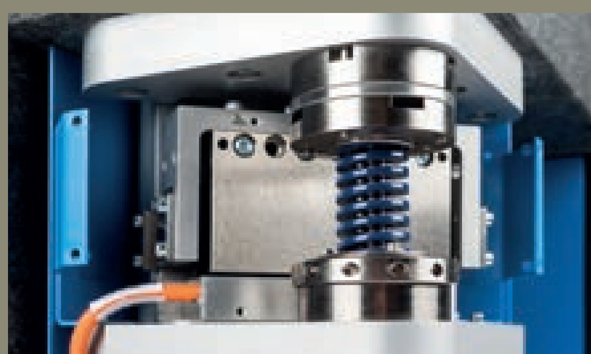
Mechatronic system design

One of the more recent projects is the development of the gantry stage fair demonstrator commissioned by Bosch Rexroth. This demonstrator turned out to be such a success that a second demonstrator was developed internally with the addition of active vibration isolation mounts. This fair demonstrator shows the complete palette of a mechatronic system design:

- Managing all involved expertise: dynamics, control, mechanical and electrical design.
- Lightweighted and stiff design of stages resulting in an obtainable stage bandwidth of > 100 Hz, < 1 µm repeatability.
- Predictable lifetime by e.g. the use of flexures ensuring smooth running at any time.
- Selection and integration of cost-effective components, for example sensors, actuators and control hardware.
- Vibration isolation system with unique high modal damping of > 20% at 5 Hz.
- Smart control strategies to improve machine performance:
  - MIMO control of the gantry actuator stage;
  - force cancellation to cancel out accelerations on stage level.

This demonstrator will be showcased at the Precision Fair 2016, on 16 and 17 November in Veldhoven, the Netherlands. ■

MI-Partners' active vibration isolation mounts provide floor vibration isolation and force cancellation of stage acceleration forces.



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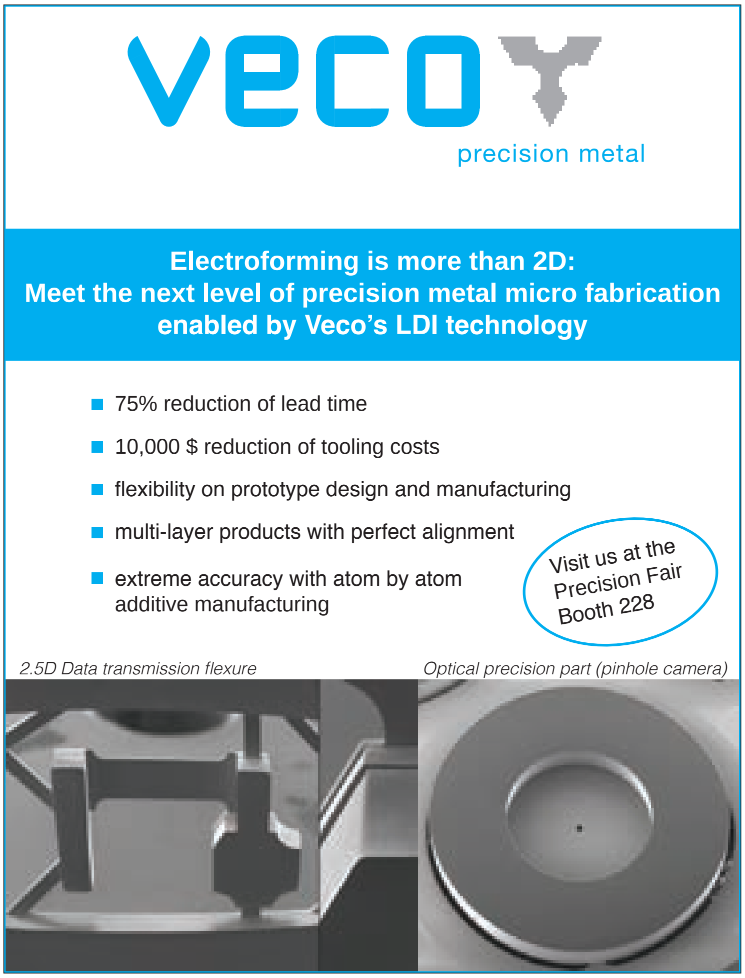
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DIMENSIONAL ACCURACY AND SURFACE FINISH IN ADDITIVE MANUFACTURING

During the last week of June, ASPE and euspen organised the 2016 Summer Topical Meeting. Nearly 100 people (75/25 academia: industry) from all over the world attended the conference to catch up on the latest research on dimensional accuracy and surface finish in additive manufacturing (AM).

DAAN DAMS AND CAS WIJNSTOK

The conference was organised by ASPE (American Society for Precision Engineering) and euspen (European Society for Precision Engineering and Nanotechnology) in Raleigh, North Carolina, USA, (Figure 1) and started off with three tutorials. During these sessions, which took half a day each, in-depth information was provided on topics such as computed tomography (CT) metrology on AM parts, value propositions for AM and principles of surface metrology and multi-scale analysis. The focus was on selective laser melting (SLM) and fused deposition modelling (FDM).

1 *The ASPE-euspen 2016 Summer Topical Meeting on dimensional accuracy and surface finish in AM was held in Raleigh, North Carolina, USA.*

The following three days were filled with technical sessions comprising a variety of lectures on subjects ranging from university research on process optimisation to industrial companies putting AM to practical use. Poster sessions and rapid-fire sessions were held in between the lectures. During the plenary rapid-fire sessions conference participants had the opportunity to give a short, mostly humorous, talk about their work, company, department, or university.

Practically all steps of the AM process were covered by the lectures, with the vast majority being research-oriented, which is not really surprising as AM still needs a lot of development before it can be broadly used for industrial applications.

Research

An interesting topic in the lectures was the in-situ measurement that enables on-the-fly quality control and adjustments of the printing process parameters. This offers the possibility of stopping a print job when an error occurs instead of finishing the print job and discovering the error afterwards. This could save a lot of time and money and will also improve the part quality. In addition, the characteristics of printed parts were discussed. The parts created with SLM can best be compared to casted parts. One could consider AM of metal parts as free-form casting. Similar product defects are to be expected and the process itself has similar challenges, such as shrinkage and residual stresses.

With respect to the quality control of printed parts, a lot of research is carried out on CT metrology. This technique is used to quantify the internals (e.g. cavities, cracks, and impurities) and externals (e.g. surface roughness, shape, and dimensional accuracy) of the part. The quantification of these characteristics is important in the field of quality control.

Regarding surface metrology it was pointed out that the R_a measurement of surface roughness is not suitable to properly quantify the actual surface. The measurement, for example, does not discriminate between deep cracks or high peaks on a surface. New methods are being developed and can already be put into practice in order to properly quantify the surfaces of parts. The proposed methods allow for scalability, which means that it is possible to quantify the surface roughness, shape, and even dimensional accuracy of an AM part based on the information of one measurement.

AUTHORS' NOTE

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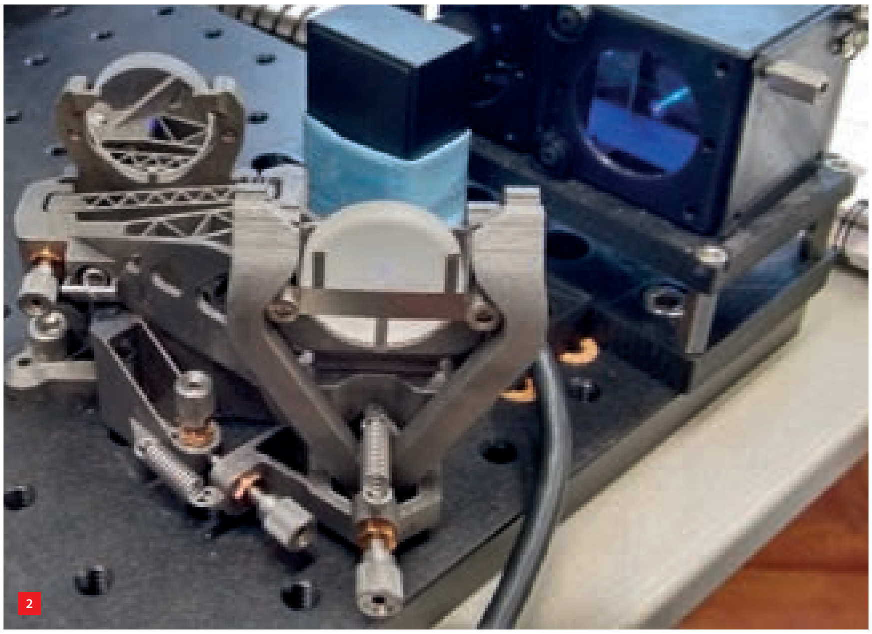
Industrial applications

During a small part of the lecture programme industrial applications were covered as well. General Electric (GE) presented an aircraft turbine part redesigned for AM. This single part replaces a thirty-component assembly. As the aerospace business is a conservative business, quality control was a major part of the work to get the part approved for use on aircraft.

VDL ETG demonstrated two AM parts for high-tech applications. One of the presented parts was a wafer handler end-effector, containing an internal vacuum channel. Cleanliness and the geometric dimensions are of vital importance for this part. The other part was a laser alignment module, which is a housing for two mirrors, containing integrated flexures. The module permits the adjustment of the angle and position of a laser beam. Because it is a monolithic part there is no play and hysteresis present.



Other lectures with a more commercial angle covered direct printing in genuine (multi)colours and laser polishing of AM parts. The latter can be used for jewellery; however it can also be of interest for the medical market with examples including AM joints in the human body that need a smooth surface.

At the end of the conference it was clear that a lot of progress has been made in the field of dimensional accuracy and surface finish in AM. However, we are not there yet. A lot of research still needs to be carried out. Furthermore, it would be interesting to see more AM cases carried out in industry being presented. Hopefully this wil be the case at the next topical meeting on dimensional accuracy and surface finish in AM, to be planned.

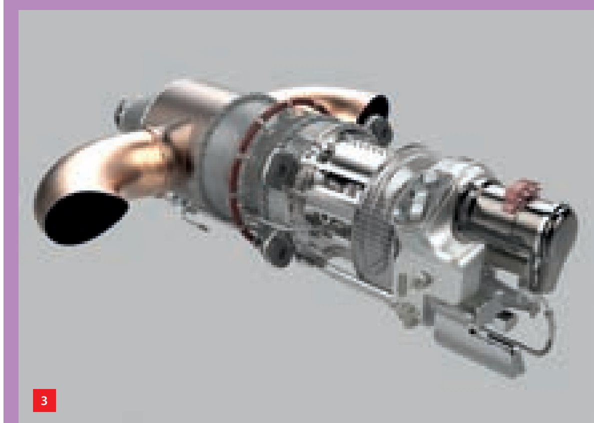
2 *VDL ETG demonstrated an AM-produced laser alignment module: a housing for two mirrors, containing integrated flexures.*

3 *A drawing of GE's new advanced turboprop engine, of which a significant portion will be produced using AM. (Image: GE Aviation)*

GE expanding in AM

Last month, GE, one of the contributors to the Topical Meeting, announced plans to acquire two suppliers of additive manufacturing equipment, Arcam and SLM Solutions Group. Arcam, based in Mölndal, Sweden, invented the electron beam melting machine for metal-based AM, and also produces advanced metal powders. SLM Solutions Group, based in Lübeck, Germany, produces laser machines for metal-based AM. The additive effort will utilise GE's global ecosystem, and will be centred in Europe.

In July, GE Aviation introduced into airline service its first additive jet engine component – complex fuel nozzle interiors – with the LEAP jet engine, the new, best-selling engine from CFM International, a 50/50 joint company of GE and Safran Aircraft Engines of France.
GE Aviation is also using AM to produce components in its most advanced military engines. In the general aviation world, GE is developing the advanced turboprop engine for a new Cessna aircraft with a significant portion of the entire engine produced using AM.



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AM IN LARGE DIMENSIONS

Additive manufacturing (AM) expands its application area thanks to larger and more accurate printing machines. Thales Alenia Space uses AM for an unprecedented large antenna support and Fraunhofer ILT helped Siemens' Clean Energy Center to develop additively manufactured gas turbine blades in a flexible modular design. Both high-end, large-scale AM applications deserve a closer look.

FRANS ZUURVEEN

AUTHOR'S NOTE

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When considering AM prototyping, one of the main advantages is the absence of the need to produce expensive tools. On the contrary, AM makes it possible to manufacture a prototype by directly transmitting CAD files to an AM machine. Despite the relatively long time to build a product from tiny particles, the complete prototype production cycle is much shorter because tooling requires weeks or even months.

Another advantage is the possibility to considerably reduce the number of components in an assembly. This advantage also applies to technologies like casting or injection moulding, but these technologies ask for expensive tools again. An important advantage of 3D AM is the integration of difficult-to-machine internal cavities.

At least two of these advantages apply to each of the examples discussed hereafter.

Antenna support

Thales Alenia Space in Cannes, France, a joint venture between Thales and the Italian company Finmeccanica, is active in the fields of space telecommunications, navigation, earth observation, exploration and orbital infrastructures. Alenia Space acquired the order from South Korea to design and make the communications satellites Koreasat-5A and Koreasat-7. They will be launched in 2017.

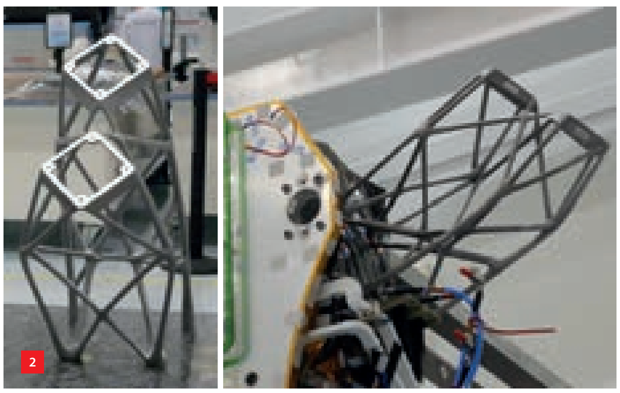
1 *The previous design of the antenna support for satellites, with milled connecting rods (in yellow and purple), and aluminium honeycomb panels (in grey) with inserts (in green). (Illustration courtesy of Thales Alenia Space).*

One of the stringent demands when designing space vehicles is to reduce the mass of components as much as possible, because a rule of thumb states that putting a mass of 1 kg into space costs about € 20,000. In that respect, one of the tasks was to reduce the mass of the antenna supports in both satellites, requiring the redesign of an existing component, see Figure 1. This was a lightweight assembly of different parts: two honeycomb panels with metal inserts and four connecting rods.

The application of AM was considered, but the large dimensions of the support, up to 0.5 m high, seemed to be a showstopper. However, Poly-Shape SAS in Salon-de-Provence, France, helped with the redesign and appeared to have in-house AM machines, using selective laser melting (SLM), for very large products.

The SLM process as applied by Thales allows the building of large parts with an accuracy of a few tenths of millimeters. In this case, the functional interfaces need to be post-machined with respect to the locations of the holes or flatness requirements.

Rethinking the design in AM technology asks for utilising the properties of laser melting, without replicating the former geometry, of course. The design was optimised in several iterations, in which CAD data underwent redesign and smoothing. After that, the concept was subjected to



2 *Two AM-built antenna supports with a height of 447 mm (on the left). Traditionally machined squares for the antenna support are clearly visible, as well as four machined points below for the fixation in the satellite structure, as shown on the right. (Photos courtesy of Thales Alenia Space).*

mechanical analysis and simulation. Finally, the design was adapted to the process-related circumstances in the AM machines of Poly-Shape, resulting in a product of 447 mm x 204.5 mm x 391 mm, as shown in Figure 2.

Thales Alenia Space selected an AlSi7Mg alloy for these supports, because of its high strength, stiffness and resistance to corrosion. An extensive validation process revealed a porosity rate of less than 1%. Also, the tensile and shear strength values appeared to be more than sufficient, and fatigue tests showed positive outcomes as well. Minor deviations in the geometry and a small crack could be corrected with simple reworking.

Poly-Shape

French company Poly-Shape is specialised in the production of prototypes with AM technology. It has 28 metal printing machines with different values of build volume at its disposal. The largest one with a building volume of 630 x 400 x 500 mm^3 is currently an X line 1000R from the German company Concept Laser. This AM machine – of which the housing is completely closed – is equipped with two lasers and a rotating mechanism, allowing to prepare a second building operation during printing, thus avoiding downtime.

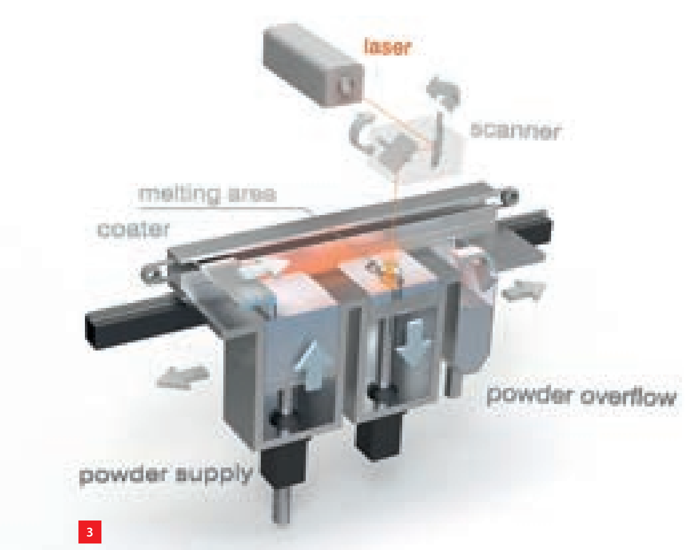
The next-generation model, the Concept Laser X line 2000R, has an even bigger build envelope of 800 x 400 x 500 mm^3, which is unique in the world. This follow-up model also operates with a turntable and two lasers, each delivering 1,000 watts of power.

The LaserCUSING process technology from Concept Laser, see Figure 3, works with a layer thickness between 20 to 80 μm with particle dimensions between 10 and 45 μm. To prevent corrosion, the printing action takes place in an inert nitrogen atmosphere. LaserCUSING works with a unique stochastic exposure strategy by laser melting the metal powder in chessboard-like square segments. This procedure ensures a significant reduction in stresses, with reduction of warping and better accuracy as favourable results.

Gas turbine blades

In Siemens' Clean Energy Center in Ludwigsfelde, Germany, research on improving the performance of gas turbines asks for rapid prototyping of blades. Traditionally new blade designs are manufactured with casting processes, but such technologies ask for tools, which are expensive and cause large cycle times. However, impatient researchers don't want to wait and ask for prototypes to be delivered within a few days. That's why Siemens and Fraunhofer ILT (Institute for Laser Technology) in Aachen, Germany, have together developed a flexible SLM technology for producing gas turbine guiding blades in an extremely short time.

Figure 4 shows a stationary gas turbine blade manufactured in this innovative process. It consists of three parts: the blade itself with a complicated internal cooling channel, and two platforms at both sides of the blade. These three parts are made separately, because each of them requires a specific design to achieve the required properties. The parts are joined by a special soldering process developed by Siemens, of which details are not available. But it is understandable that common brazing materials like silver do not suffice, because the complete component is tested at a temperature of 1,500 °C.



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3 *Working principle of the LaserCUSING process (courtesy of Concept Laser). A new layer of metal powder is deposited by moving the coater.*

4 *A complete stationary gas turbine blade consisting of three parts of Inconel 718 soldered together. (Photo courtesy of Fraunhofer ILT).*

5 *The AM-manufactured guiding blade on a base plate which functions as an SLM substrate. (Photo courtesy of Fraunhofer ILT)*

The modular building technology described before facilitates the gas turbine optimisation process, because alternative geometries can be tested in a relatively short time. Figure 5 shows the middle blade part after SLM building. The material of the blade, as well as the platforms, is nickel-based superalloy Inconel 718. This is a precipitation-hardenable alloy designed for exceptionally high yield, tensile and creep-rupture properties at high temperatures. The base plate in Figure 5 is made from a cheap kind of steel and functions as the substrate during the SLM process in a commercially available AM machine. The overall form accuracy of the complete turbine blade is about 0.4 mm.

To conclude

These two examples give evidence of the statement that the potential of AM is far from being exhausted. The availability of larger and more accurate AM machines and the decrease of the metal particle size will both gradually extend the application area of this promising technology. ■

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PRECISION-IN-BUSINESS DAY: STRETCHING THE BOUNDARIES FOR HIGH-PRECISION ASSEMBLY AT TEGEMA

Last month, DSPE and YPN (Young Precision Network) organised a Precision-in-Business (PiB) day at Tegema. The event attracted a decent crowd of about thirty DSPE and YPN members, with the young members being in the majority, and it marked the 'retirement' of Robert Swinckels from ASML as PiB day organiser on behalf of the DSPE board. After eight years of organising PiB days, over fifteen in total, he has passed the baton over to fellow board member Marty van de Ven, founder of The House of Technology.

Multidisciplinary engineering company Tegema (based in Son, near Eindhoven, the Netherlands) develops, innovates and realises processes and systems from idea until functional model, prototype or (pre-)production series.Tegema performs customer-independent research to bring solutions to the next level.

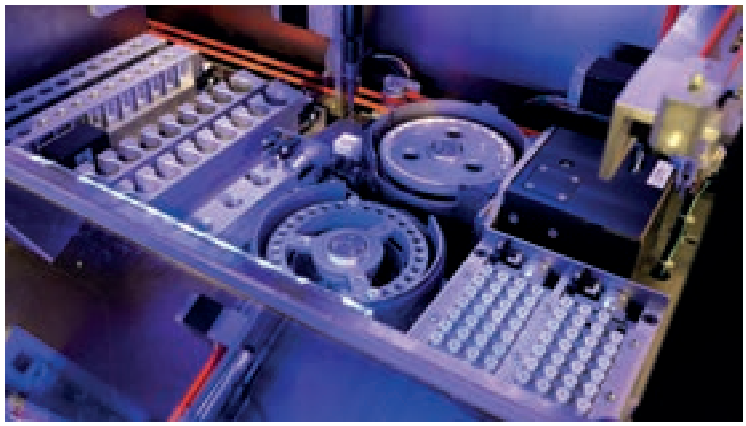
Technology roadmap

Based on (future) societal needs, Tegema has identified five promising technologies on which to focus its R&D. This Tegema technology roadmap comprises photonics/fibre optics (big data); microdispensing and -positioning (miniaturisation); system architecture, modelling and simulation (increasing complexity and decreasing time-to-market); green mobility (sustainability); and zero-defect manufacturing (quality, no waste). For these technologies Tegema develops demonstrators, in collaboration with academic researchers, so that all the knowledge and expertise is available when customers come forward.

Microdispensing technology

The PiB day's motto was "Stretching the boundaries for high precision assembly", and it was kicked off by Tegema director Martin van Acht. Following a brief introduction of his company – "My challenge is to find the most difficult project in the market" – he presented the microdispensing technology: "A journey to the smallest droplet". Basically, microdispensing is a kind of micro-assembly, i.e. putting tiny droplets on a substrate. Driven by medical and analytical applications, this field of technology has developed rapidly. In its roadmap, Tegema has progressed from nano- to pico- to femtolitres (cubic micrometers), the level at which the manipulation of individual cells comes within reach.

Van Acht described the 'holy triangle' of microdosing as an interplay between dosing methods & requirements, substrate surface properties and fluid & analyte properties, making the research a highly multidisciplinary and multi-physics venture. Currently, the attolitre level is coming into sight, offering the perspective of DNA manipulation, for example.



Diagnosing illnesses may require a large number of tests, while only a limited amount of blood from the patient is available. Tegema developed a blood testing machine that can test even the smallest samples. (Photo: Bart van Overbeeke)

Trade-off

Next, system architect Theo Bookelmann discussed the design of high-accuracy, high-throughput process machines, focussing on the motion aspects. Many motion design decisions are determined by the trade-off between accuracy and cycle time. The specified cycle time can be translated into required accelerations, which in turn lead to a certain level of motor currents. The accelerations may cause vibrations and the motor currents generate heat dissipation. Both phenomena adversely affect the motion accuracy.

This trade-off will have its impact on the evaluation of motion outsourcing options. On the one hand, the best supplier for a dedicated purpose can be selected, with a flexible design team providing customised solutions. As an alternative, a platform approach can be followed, in which a fixed main supplier base is used for a basic set of platform building blocks, hardware as well as software.

Effective reuse

Bookelmann argued that well-defined specifications and criteria are essential, but these are not enough in supplier selection. Specifications at the limit of the suppliers' capabilities present a major project risk. An important role is played by integration aspects between the parts and modules supplied by the various parties: consequences of changes in dimensional and lay-out requirements, differences in control experience, and more. On top of this, thermal effects constitute a special topic for which no generic approaches or solutions are available.

Platform thinking, on the other hand, building on the close connection with selected suppliers, enables fast and accurate estimation of price and performance, and the effective reuse of knowledge, tools and platform elements developed in previous projects. Tegema can provide dedicated solutions as well as support platform development.

Hyperconnector

System architect Merijn Wijnen showed how Tegema is exploring the boundaries of high-end optics, for example in fibre-optics-related projects such as the so-called hyperconnector. This connecter was designed to facilitate data communication at 40 terabytes per second. Tegema developed the assembly system for connecting 750 optic fibres to the hyperconnector. The connector base plate contains 750 holes that are 140 μm wide, into which the individual fibres have to be inserted without the glass touching the Si walls as this will cause immediate fibre breakage. An ingenious fibre manipulation procedure was devised to accomplish this.

Wijnen also discussed topics such as image reconstruction, miniaturisation of optical instruments, modelling of lens-camera systems, simulation of image transfer in optical systems, and selection of the suitable optical components. "Always double check the information and advice from your supplier", said Wijnen to his audience in conclusion.

Tegema director Martin van Acht during the tour.

Tour

The official part of the PiB day was concluded with a tour of the Tegema premises, featuring a variety of appealing projects. One example was the glassless 3D TV technology based on the Ultra-D optical system developed by SeeCubic. The Ultra-D system provides the stereoscopic effect; it is a square array of small lenses positioned at a well-defined distance in front of the LCD screen. Tegema developed the assembly line for mounting this system onto the LCD screen.

Other Tegema projects on display included the hyperconnector, the transmission for an electric bike (green mobility), and a medical diagnosis device.

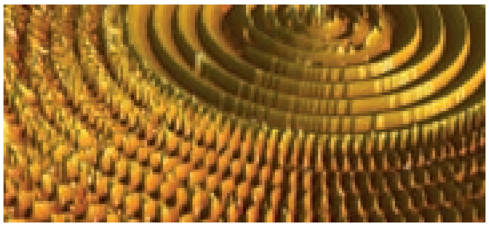
The successful PiB day was concluded with networking and a few drinks (no 'half litres' of beer, however).

WWW.TEGEMA.NL

UPCOMING **EVENTS**

9-10 November 2016, Copenhagen (DK)
Special Interest Group Meeting: Structured & Freeform Surfaces
Meeting of the euspen SIG Structured & Freeform Surfaces. Topics include replication techniques, functional surfaces, precision freeform surfaces, large-scale surface structuring, nanomanufacturing and metrology.

WWW.EUSPEN.EU



16-17 November 2016, Veldhoven (NL)
Precision Fair 2016
Sixteenth edition of the Benelux premier trade fair and conference on precision engineering, organised by Mikrocentrum. See the preview on page 37 ff.

WWW.PRECISIEBEURS.NL

Precision Fair

18 november 2016, Eindhoven (NL)
HTSC Consortium Day
The Eindhoven-based TU/e High Tech Systems Center organises this day with the goal of setting up a number of research consortia, each having one or two OEMs on board, a number of suppliers and one or more knowledge institutes. Other universities, such as Delft, Twente, Wageningen and Leuven, are invited to participate. The research areas include Beyond rigid body, Contamination Control, AgroFood/HighTech, IoX for High Tech Systems and Manufacturing, System Design, Material on Demand, Complex Software, and Design for Total Cost of Ownerschip.

WWW.TUE.NL/HTSC

30 November 2016, Utrecht (NL)
Dutch Industrial Suppliers & Customer Awards 2016
Event organised by Link Magazine, with awards for best knowledge supplier and best logistics supplier, and the Best Customer Award.

WWW.LINKMAGAZINE.NL

13-14 December 2016, Amsterdam (NL)
International MicroNanoConference 2016
Microfluidics, photonics and nano-instrumentation are the main topics of this industry- and application-oriented conference, exhibition and demo event.

WWW.MICRONANOCONFERENCE.ORG

23-24 January 2017, Coventry (UK)
Special Interest Group Meeting: Quality Control for Additive Manufacturing
Topics include the UK strategy for additive manufacturing, dimensional metrology & non-destructive testing (NDT), surface metrology, in-process metrology & NDT, and materials metrology.

WWW.EUSPEN.EU

15-16 March 2017, Wotton-under-Edge (UK)
Lamdamap 2017
Twelfth edition of this event, focused on laser metrology, coordinate measuring machine and machine tool performance. Venue is the Renishaw Innovation Centre.

WWW.LAMDAMAP.COM

27 March 2017, Düsseldorf (GE)
Gas Bearing Workshop
Second edition of the initiative of VDE/VDI GMM, DSPE and the Dutch Consulate-General in Düsseldorf (Germany). Gas bearings are important components or integral technology of most advanced precision instruments and machines. This workshop invites all engineers, scientists, system architects and users of gas bearings to share the state-of-the-art.

WWW.GAS-BEARING-WORKSHOP.COM

18-19 May 2017, Aachen (GE)
29th Aachen Machine Tool Colloquium
Since 1948, the Aachen Machine Tool Colloquium has given trend-setting impulses for production technology in a 3-year cycle. The general topic of AWK 2017 is "Internet of Production for Agile Enterprises".

WWW.AWK-AACHEN.DE

29 May – 2 June 2017, Hannover (GE)
Euspen's 17th International Conference & Exhibition
This event will once again showcase the latest advances in traditional precision engineering fields such as metrology, ultra-precision machining, additive and replication processes, precision mechatronic systems & control and precision cutting processes. Furthermore, new topics will be addressed covering the revision of the SI and applications of precision in biomedical sciences.

WWW.EUSPEN.EU

Venue of Euspen's 17th International Conference & Exhibition, the Hannover Congress Centre. (Photo: Christian A. Schröder/Wikipedia)

ECP² COURSE CALENDAR

COURSE (content partner)	ECP² points	Provider	Starting date (location, if not Eindhoven, NL)
FOUNDATION			
Mechatronics System Design - part 1 (MA)	5	HTI	to be planned (Spring 2017)
Mechatronics System Design - part 2 (MA)	5	HTI	31 October 2016
Design Principles	3	MC	8 March 2017
System Architecting (Sioux)	5	HTI	14 November 2016
Design Principles Basic (SSvA)	5	HTI	22 November 2016
Motion Control Tuning (MA)	6	HTI	30 November 2016
ADVANCED			
Metrology and Calibration of Mechatronic Systems (MA)	3	HTI	22 November 2016
Actuation and Power Electronics (MA)	3	HTI	-
Thermal Effects in Mechatronic Systems (MA)	3	HTI	28 November 2016
Summer school Opto-Mechatronics (DSPE/MA)	5	HTI	to be planned
Dynamics and Modelling (MA)	3	HTI	12 December 2016
Summer School Manufacturability	5	LiS	to be planned
Green Belt Design for Six Sigma	4	HI	to be planned
RF1 Life Data Analysis and Reliability Testing	3	HI	14 November 2016
SPECIFIC			
Applied Optics (T2Prof)	6.5	HTI	to be planned (March 2017)
Applied Optics	6.5	MC	2 February 2017
Machine Vision for Mechatronic Systems (MA)	2	HTI	to be planned (April 2017)
Electronics for Non-Electronic Engineers – Basics Electricity and Analog Electronics (T2Prof)	6	HTI	to be planned (September 2017)
Electronics for Non-Electronic Engineers – Basics Digital Electronics (T2Prof)	4	HTI	6 February 2017
Modern Optics for Optical Designers (T2Prof)	10	HTI	to be planned (Autumn 2017)
Tribology	4	MC	1 November 2016 (Utrecht, NL) 14 March 2017
Design Principles for Ultra Clean Vacuum Applications (SSvA)	4	HTI	to be planned (Spring 2017)
Experimental Techniques in Mechatronics (MA)	3	HTI	to be planned (Spring 2017)
Advanced Motion Control (MA)	5	HTI	7 November 2016
Advanced Feedforward Control (MA)	2	HTI	14 November 2016
Advanced Mechatronic System Design (MA)	6	HTI	to be planned (Spring 2017)
Finite Element Method	5	ENG	in-company only
Design for Manufacturing – Design Decision Method	3	SCHOUT	in-company
Precision Engineering Industrial Short Course	5	CRANF. UNI.	to be planned (Cranfield, UK)

ECP² program powered by euspen

The European Certified Precision Engineering Course Program (ECP²) has been developed to meet the demands in the market for continuous professional development and training of post-academic engineers (B.Sc. or M.Sc. with 2-10 years of work experience) within the fields of precision engineering and nanotechnology. They can earn certification points by following selected courses. Once participants have earned a total of 45 points, they will be certified. The ECP² certificate is an industrial standard for professional recognition and acknowledgement of precision engineering-related knowledge and skills, and allows the use of the ECP² title.

ECP2EU.WPENGINE.COM

Course providers

- Engenia (ENG)
  WWW.ENGENIA.NL
- The High Tech Institute (HTI)
  WWW.HIGHTECHINSTITUTE.NL
- Mikrocentrum (MC)
  WWW.MIKROCENTRUM.NL
- LiS Academy (LiS)
  WWW.LISACADEMY.NL
- Schout DfM (SCHOUT)
  WWW.SCHOUT.EU
- Holland Innovative (HI)
  WWW.HOLLANDINNOVATIVE.NL
- Cranfield University
  WWW.CRANFIELD.AC.UK

Content partners

- Dutch Society for Precision Engineering (DSPE)
  WWW.DSPE.NL
- Mechatronics Academy (MA)
  WWW.MECHATRONICS-ACADEMY.NL
- Settels Savenije van Amelsvoort (SSvA)
  WWW.STTLS.NL
- Sioux
  WWW.SIOUX.EU
- Technical Training for Professionals (T2Prof)
  WWW.T2PROF.NL

SRON – meeting extraterrestrial requirements

To answer fundamental questions about the universe, space phenomena, exoplanets and our own Earth's atmosphere, SRON Netherlands Institute for Space Research keeps pushing back the boundaries of technology and instruments for scientific research from space.
Astrophysicists and environmental researchers at SRON and throughout the world need new groundbreaking telescopes and instruments. Instrument scientists and engineers within SRON continuously work on those instruments in close collaboration with international partners of considerable repute.

High-end engineering expertise is needed to build actual space-qualified instruments and support their development in the preceding testbeds. SRON can pride itself on a broad range of in-house expertise teams: Mechanical Design and Realization, Analogue Electronic Design, Digital Electronics/Software Engineering, Electronics Realization, and Product Assurance & Quality Assurance. These teams closely cooperate with SRON's instrument scientists and the lithography section. They improve, test, validate and eventually build and implement detectors and their associated systems for new space missions, for space agencies like NASA, ESA or JAXA.

The development model used for vibration testing the cryogenic detector assembly as designed and built for the future Xifu instrument on the ESA-led X-ray Athena mission.

Design to survive launch
SRON's Mechanical Design and Realization team has a staff of 14 people split over SRON's two locations in Groningen and Utrecht. They are responsible for reliable space-qualified hardware that meets the highly specific functional challenges as well as the very specific requirements of the space agencies.
The engineers also support the development of detector technology into space-applicable detector systems for the future, which need complex components for cryogenic testbeds.

The team designs and manufactures instruments like extremely precise voice-coil-operated mechanisms, for example for optical beam steering, as well as the stable platforms on which ultra-precise optics, sensors and electronics are integrated. The hardware structure must also shield detectors and electronics from magnetic fields or from interfering electromagnetic waves.

Another challenge is that many instruments are operated at cryogenic temperatures below 4 K, with detectors at even 50 mK, to obtain the highest possible detector sensitivities. Last but not least, everything that the engineers design must be able to survive immense forces during launch. To design these compact, thermally isolating, shielding and mechanically stable support structures and instruments, SRON has developed several tools for modelling thermal, magnetic and structural behaviour.

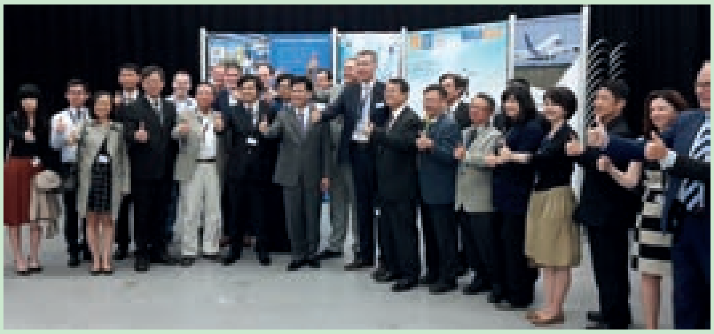
Realisation
Both of SRON's locations feature high-end facilities for the design, manufacture, assembly and (cleanroom) integration of the instruments. The hardware is often manufactured in cooperation with qualified suppliers. The validation of the structural integrity and performance of instruments is carried out in-house and at external testing facilities. SRON system engineers carry out the data analysis, evaluation and final assessment. ■

A gold-plated PCB with two UV LEDs, as used in the high-voltage-regulated X-ray calibration source of the JAXA-led Hitomi mission. This calibration source was developed in collaboration with the Dutch company Photonis.

INFORMATION
WWW.SRON.NL

IBS and KMWE receive Taiwanese trade mission

A delegation, consisting of Mayor Lin of Taichung, Taiwanese ambassador in the Netherlands Tom Chou and 60 visitors from local government, institutes and several Taichung companies, visited IBS Precision Engineering and KMWE on a Sunday in late September.



The Taiwanese delegation at IBS. The tall person in the middle is IBS CEO Henny Spaan.

During this visit IBS demonstrated some of their newest technology, in particular the Industry 4.0 solution 'Rotary Inspector', which delivers a clear and traceable quality statement for 5-axis machine tools, as well as the 'Alicia' machines which are being built by IBS for CERN as part of the Alice Detector upgrade. At KMWE the visitors were guided through the advanced factory of KMWE Precision Components, where complex parts are machined for the high-mix, low-volume, high-complexity market.

IBS and KMWE combined this visit with the closure of the MIT project "From product to process measurement". For this project, funded by the Dutch government, IBS and KMWE have been working together to develop the Rotary Inspector. This innovative machine tool measuring system has been developed by IBS and tested in live production at KMWE. Providing rapid confirmation of current performance against desired specification, the Rotary Inspector provides a key part of any maintenance routine for 5-axis machine tools. The goal of the Rotary Inspector is to improve product quality and to reduce scrap and costs. By measuring the machine instead of the product, the process can be certified and outcomes optimised.

At the end of the day a ceremony took place where a Memorandum Of Understanding was signed between IBS and the Taiwanese Industrial Technology Research Institute (ITRI) for further collaboration and R&D using IBS's patented technology in the Taiwanese machine tool industry.

Demonstration of the Rotary Inspector during the visit of the Taiwanese delegation. (Photo: Nicole Minneboo)

Call for Ir. A. Davidson Award candidates

At the Precision Fair 2016, on Wednesday 16 November, the Ir. A. Davidson Award will be presented on behalf of the DSPE board. The prize aims to encourage young talent and is intended for a young precision engineer who has worked for some years in a company or institute and who has a demonstrable performance record that has been recognised internally and externally. Candidates must also use their enthusiasm to have a positive effect on young colleagues.

DSPE board member Toon Hermans, managing director of Demcon Eindhoven, calls for nominations of suitable candidates (self-nominations excluded).

TOON.HERMANS@DEMCON.NL
INFO@DSPE.NL

In 2014 the Ir. A. Davidson Award was presented to Rens Henselmans, system architect at NTS-Group, (left) by DSPE board member Toon Hermans. (Photo: Jan Pasman)

Renishaw unveils the new XM-60 multi-axis calibrator

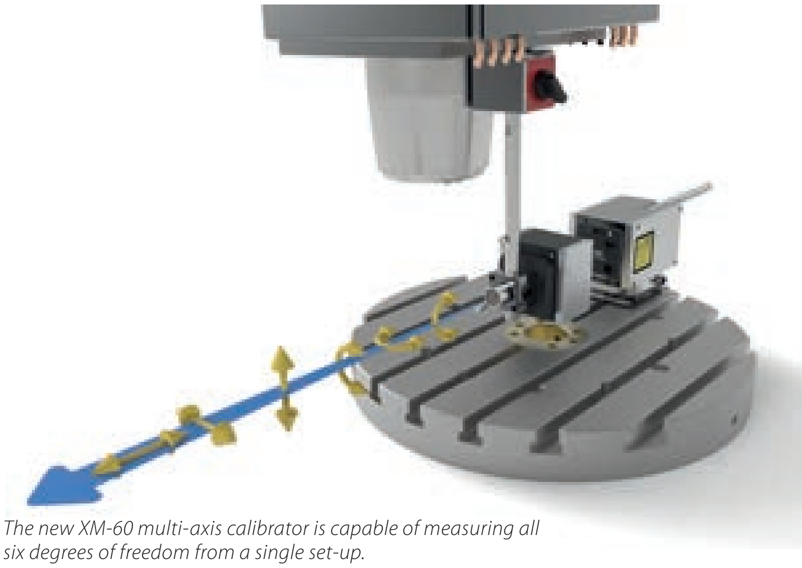
Renishaw, a world-leading metrology specialist, has introduced its new XM-60 multi-axis calibrator, capable of measuring all six degrees of freedom from a single set-up, in any orientation for linear axes. It offers significant improvement in simplicity and time saving over conventional laser measurement techniques.

As demands on component tolerances increase, manufacturers are now required to consider all error sources from the machines producing parts; angular errors as well as linear and straightness errors. XM-60 captures all these errors in a single set-up. Designed for the machine tool market, the XM-60 multi-axis calibrator complements Renishaw's calibration product line, which includes a laser system, a rotary axis calibrator and a wireless ballbar. The XM-60 uses the XC-80 environmental compensator to correct for environmental conditions.

The XM-60 multi-axis calibrator provides a highly accurate laser system that incorporates unique technology with a patented optical roll measurement and fibre optic launch system. The compact launch unit is remote from the laser unit, reducing heat effects at the point of measurement. It can be mounted directly to the machine on its side, upside down and even on its back, which is particularly beneficial in areas with difficult machine access. The Renishaw XM-60 has been designed to measure machine errors directly, reducing the inaccuracies which can result from complex mathematics used in some alternative measurement techniques. Direct measurement makes comparison before and after machine adjustments easy.

XM-60 provides users with powerful machine diagnostic capability through the measurement of all degrees of freedom from a 'single shot'. By capturing three linear and three rotational error sources during any measurement, users can discover the source of their errors, rather than the effect which is often seen when only performing linear measurement. Handling all of this data is performed by the Explore 2.0 application. To support the release of the XM-60 multi-axis calibrator, a new version of Renishaw's CARTO software suite will be released to guide users through the workflow of the measurement process.

WWW.RENISHAW.COM/XM60



The new XM-60 multi-axis calibrator is capable of measuring all six degrees of freedom from a single set-up.

Océ and partners invest in future of inkjet technology

Last month, the official kickoff of a €6.3 million inkjet research program took place at Océ headquarters in Venlo, the Netherlands. The resulting knowledge will be used to develop future generations of Océ printers. The results can also be used in the jetting of materials other than ink. High-speed jetting technology has the potential to be applied in digital manufacturing techniques and revolutionise the way we make things.

The program is titled Fundamental Fluid Dynamics Challenges in Inkjet Printing, abbreviated FIP. It is a unique cooperation between the Dutch Foundation for Fundamental Research on Matter (FOM), the Eindhoven University of Technology (TU/e), the University of Twente (UT) and Océ.
The FIP programme will focus on the research of complex fluid dynamics phenomena, including the interactions with the print heads and substrates.

The FIP program will be coordinated by Detlef Lohse, Professor and Chair of Physics of Fluids, UT. The research will focus on drop formation, the prevention of air bubbles and the drying of drops on paper. It will also explore the interaction between ink and different types of substrates. The findings will contribute to the development of the inkjet technology of the future.

At Océ, inkjet is used in high-speed production printing systems that produce up to 1,714 full-color A4 images per minute. The market for high-speed inkjet printing is growing rapidly. For instance, digital book printing is growing by 15% per year. With inkjet technology, printing-on-demand is moving beyond paper. It is already possible to print 'functionality'. In pilot projects, Océ jetting techniques are printing resist directly onto copper for the production of printed circuit boards. Another example is the printing of coatings onto OLED screens.

WWW.OCE.COM

Observation of the sun with hitherto unattainable accuracy

Already today solar researchers can see that there is activity on the solar surface. But current instrumentation does not enable them to see the causes. As of 2019, the DKIST (Daniel K. Inouye Solar Telescope) on the Hawaiian island of Maui will make it possible to see them. With a mirror diameter of four meters it will be the largest solar telescope in the world and therefore provide a very detailed view of the sun's surface.

The optical power of the DKIST is prerequisite for the instruments mounted on the telescope to be able to open up new insights into the processes on the sun to scientists from all over the world. One of these instruments, the Visible Tunable Filter (VTF), is being developed by the Kiepenheuer Institute for Solar Physics (KIS) in Freiburg, Germany. The VTF will make it possible to examine precisely defined, very narrow wavelength bands of the light radiated from the solar surface. This permits the solar researchers to glean information among other things about plasma temperature, pressure ratios, magnetic field strengths and plasma movements on the solar surface and acquire data about changes in the magnetic field of the sun.

The principle of the VTF is very simple. The sunlight is guided through an air gap between two coated, semitransparent glass plates. This causes interference of the light multiply reflected in the air gap. This leads to filtering of the wavelengths, the filtered spectral range results from the width of the air gap and thus from the distance between the glass plates. To be able to select one wavelength of sunlight to within a few picometers, both plates have to be positioned absolutely parallel to each other with nanometer precision.

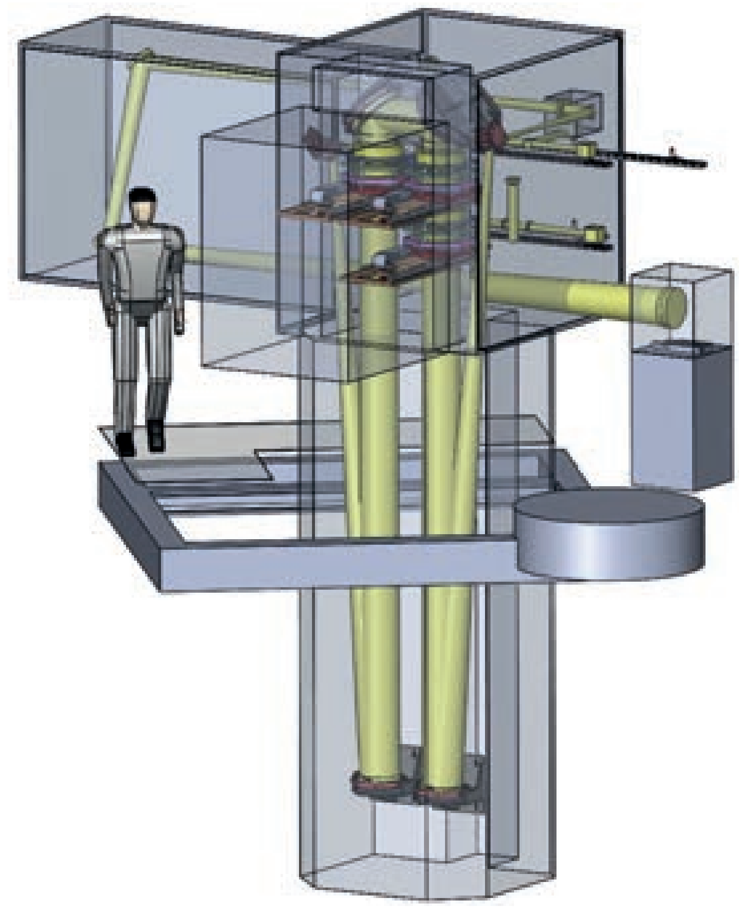
With the VTF, however, it is not just a matter of examining only one wavelength constantly. Much more interesting are the changes between the different wavelengths. Accordingly the glass plates will be moved permanently towards and away from each other in nanometer steps, in fact hundreds of times during the course of a two-hour measurement. For this, the measuring system must be able to perform measuring steps of 20 pm. Furthermore, measurement errors over a period of one hour must not exceed a total of 100 pm.

Tests are currently being performed on a scaled-down version of the VTF at the Kiepenheuer Institute for Solar Physics. Six Heidenhain linear encoders of the LIP 382 model with standard scanning head and customised linear scale are mounted around the two glass plates. They determine the position of the plates – three for the top plate and three for the bottom plate. In the current test series the reliable and continuously repeatable accuracy of the setup has reached 0.17 nm per hour. The goal is 0.1 nm per hour.

DKIST.NSO.EDU

WWW.KIS.UNI-FREIBURG.DE

WWW.HEIDENHAIN.DE



Conceptual layout of the Visible Tunable Filter (Source: DKIST). Below a Heidenhain LIP 382 incremental linear encoder.

New multisensor CMMs

Leading metrology and manufacturing solution provider Hexagon Manufacturing Intelligence has introduced its latest multisensor coordinate measuring machines (CMMs), the new Optiv Performance 663 and 664 Dual Z. The multisensor concept of the Optiv Performance line enables a variety of sensor configurations for tactile and contactless measuring and scanning tasks in a single system. Different workpiece features can be inspected by the appropriate sensors without reclamping, saving valuable measuring time.

Based on the same technology as the highly-successful Optiv Performance 443, the new CMMs feature low-vibration granite construction, precise mechanical linear guides on all axes, backlash-free precision drives, and integrated temperature compensation – resulting in a level of structural quality that means the machines can be used close to production. With the Optiv Performance 663 boasting a measurement range of 610 x 610 x 305 mm and the Optiv Performance 664 taking the Z-direction range up to 405 mm, the new CMMs further increase the range of parts that can be inspected.

To ensure optimal use of the entire measurement volume, the new Optiv Performance models can be equipped with Hexagon's Optiv Dual Z option, giving them two independent vertical axes for the optical and tactile sensors. This prevents the inactive sensor from impeding machine movement, so features deep within the workpiece remain accessible for easier part programming and the risk of collisions is minimal. Optiv Dual Z technology also enables the use of a motorised indexable probe head as a carrier for the tactile sensor.

The Optiv Performance 663 and 664 Dual Z also offer a simple and quick solution for measuring tasks involving rotationally symmetrical workpieces. Features distributed around the circumference of the part are made accessible by clamping in the workpiece using the CNC rotary axis. This Optiv Dual Rotary option allows the entire rotary axis to swivel on an additional axis.

Also available as an option on the Optiv Performance 663 and 664 Dual Z is Hexagon's CMM monitoring system MMS PULSE. Using a network of sensors to monitor temperature, vibrations, humidity and machine status, MMS PULSE provides machine operators with a more complete picture of the environment when results are obtained.

WWW.HEXAGON.COM

One of Hexagon's new multisensor CMMs.

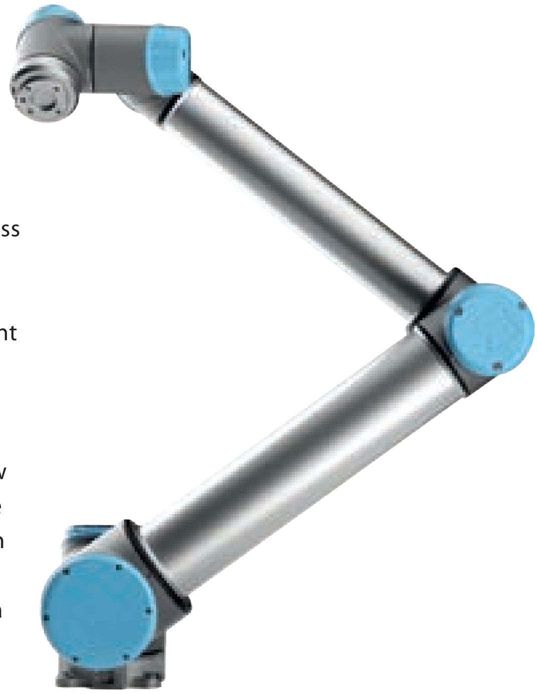
Robots cleared for cleanroom operation

Universal Robots' lightweight collaborative robot arms can now be implemented in controlled environments. After successful tests in accordance with VDI 2083 Part 9.1, the international industrial guideline concerning the various functions and measures of cleanroom technologies, the robot arms and the accompanying controller boxes made by the Danish pioneer in human-robot collaboration have been awarded the certification for cleanroom applications by the international certification organization TÜV SÜD.

In compliance with the industrial norm ISO 14644-1, the robots UR3, UR5 and UR10 are now authorised for the global use in cleanroom environments of cleanroom class ISO 5. The controller box, in turn, has received authorisation for cleanroom class ISO 6. The controller box may be upgraded for deployment in cleanrooms requiring the class ISO 5 with a few technical modifications. In the Federal Standard 209E, often referenced in the USA, ISO 5 and ISO 6 are the equivalent of class 100 and class 1,000 respectively.

TÜV SÜD's test seals for Universal Robots' robotic arms and controller boxes now allow the deployment of UR robots in areas where aspects regarding purity and hygiene – such as particle emission, easy-to-clean surfaces and extreme reliability – are decisive criteria for precise automation processes.

WWW.UNIVERSAL-ROBOTS.COM



The largest of the Universal Robots range, the UR10 industrial robot arm, is now authorised for the global use in cleanroom environments of cleanroom class ISO 5. Just as UR3 and UR5 are.

Fast computational modeling for additive manufacturing

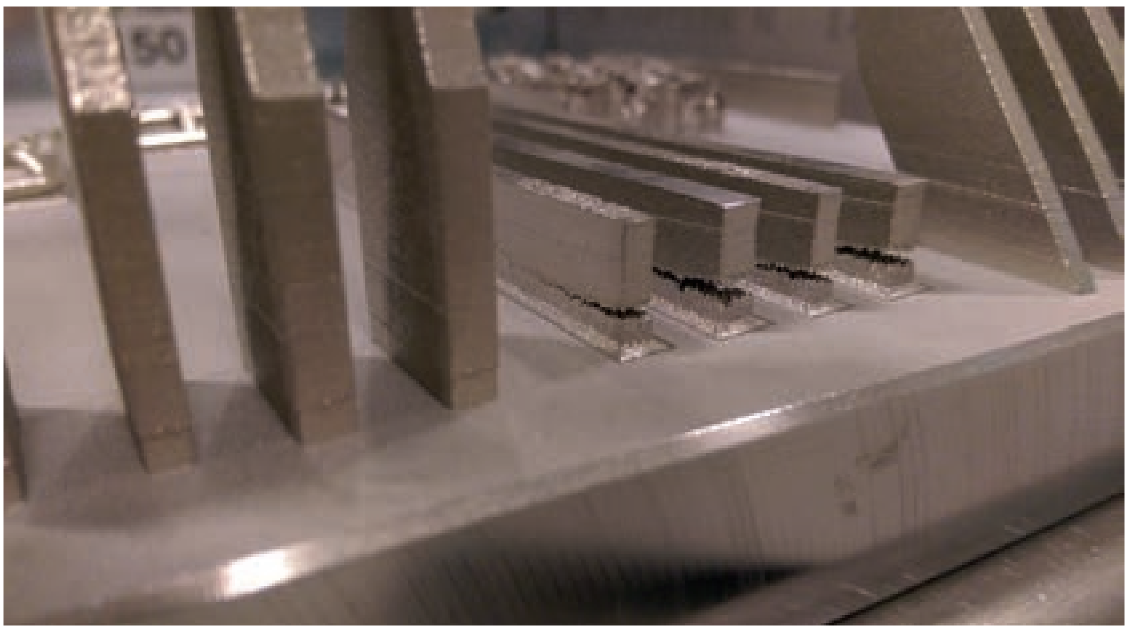
As additive manufacturing (AM), or 3D printing, becomes more commonplace, researchers and industry are seeking to mitigate the distortions and stresses inherent in fabricating these complex geometries. In the US, researchers at the University of Pittsburgh's Swanson School of Engineering and Pittsburgh-based manufacturer Aerotech recently received a $350,000 grant from the National Science Foundation to address these design issues by developing new, fast computational methods for additive manufacturing.

The ability to create geometrically complex shapes through additive manufacturing is both a tremendous benefit and a significant challenge, according to the researchers. Optimising the design to compensate for residual distortion, residual stress, and post-machining requirements can take days or even months for these parts.

To mitigate these challenges, the researchers will first develop a simple yet accurate thermomechanics model to predict residual stress and distortion in an AM part. Next, they will develop a topology-optimisation method capable of generating designs with both free-form surfaces and machining-friendly surfaces. This will compensate for the geometric complexity and organic nature of AM parts, which contribute to their potential for distortion and post-machining problems. These approaches will then be developed and tested using real parts and design requirements provided by Aerotech.

Aerotech's Stephen Ludwick expects that "the tools developed through this collaboration will allow us to produce the complex parts enabled by AM with a minimum of trial-and-error and rework. This in turn allows us to design stiff and lightweight components in our high-speed motion systems which are also used by other companies engaged in AM."

ENGINEERING.PITT.EDU
WWW.AEROTECH.COM



The supporting structures failed for these four fatigue test bars. The stress build-up in the longer length of the bars created an excessive curling force on the outer edges of the support structures, resulting in fracture.

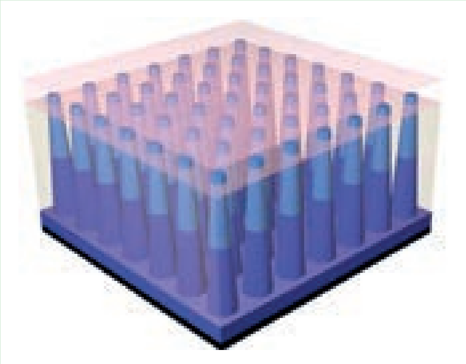
TU Eindhoven breaks world record for nanowire solar cells

Researchers at Eindhoven University of Technology, the Netherlands, have gained a new world record for the efficiency of nanowire-based solar cells: 17.8 percent. These types of solar cell have been around for just a few years but in terms of efficiency are catching up to other types and are thus very promising for the sustainable energy supply. In contrast to other types of solar cell, nanowire solar cells are not composed of solid, flat layers. They comprise a 'lawn' of vertical wires of around two hundred nanometers thick, or 300 times thinner than a human hair. These nanowires capture the light and convert it into electricity.

The previous record, of 15.3 percent, was held by Sweden's Lund University. The efficiency percentage indicates how much of the sunlight that falls on the cell can be used as electrical energy. Theoretically, the limit for nanowire solar cells is 46 percent, considerably higher than that for flat, layered solar cells at 34 percent. In addition, nanowire cells are quite cheap to produce by comparison.

If the nanowire cells are to become commercially viable, they need to be price-competitive. And to be that, a yield of around 25 percent is needed along with an improved production process. In terms of costs, big gains can be made by switching from the relatively rare material indium phosphide to the much more abundant semiconductor silicon.

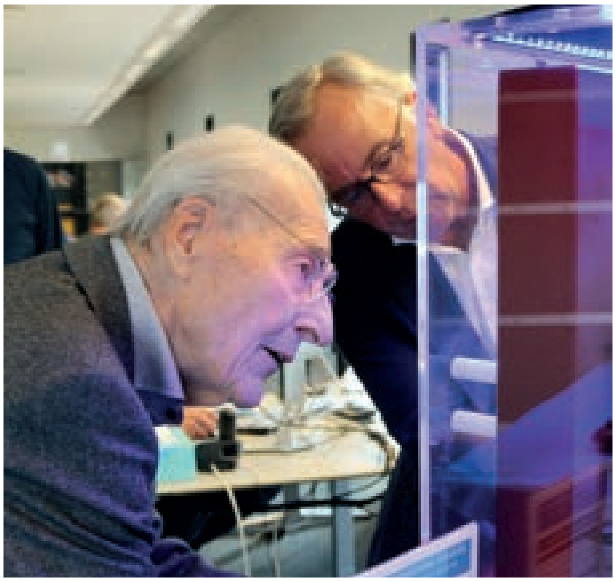
The solar cells were manufactured in a cleanroom. It was discovered that the nanowire cells absorbed up to twenty percent more light because the wires acted as a kind of antenna to capture the light. Additionally, they are using five times less material than flat solar cells. Another factor that contributes to the performance is that the wires concentrate the light, to an extent that is determined by their diameter.



A visual of the structure of a nanowire solar cell.

WWW.TUE.NL

JPE celebrates 25th anniversary by honouring Wim van der Hoek



Wim van der Hoek (left) and JPE founder and CEO Huub Janssen admire one of JPE's masterpieces.

As part of the 25th anniversary celebration of Janssen Precision Engineering (JPE), Professor Emeritus Wim van der Hoek (92) performed the official opening of JPE's new conference room. Professor Van der Hoek (Mechanical Engineering, Eindhoven University of Technology, 1961-1985) was one of the Dutch pioneers in the field of precision engineering. He inspired and shaped countless students on both a technical as well as a personal level. This is illustrated by the warm contacts which he, and his wife Aat, carefully maintained with many of them up until today.

Therefore, it seemed only natural to name the conference room after him as an acknowledgment of his contribution to the field of precision engineering, but above all as an appreciation of his involvement with the precision engineering community, including JPE, over so many years.

After several years of experience in the high-tech industry at companies like ASML and Philips, Huub Janssen founded Janssen Precision Engineering in 1991 in Maastricht-Airport, the Netherlands. JPE has grown into a highly skilled and independent engineering group for the development and realisation of high-tech machinery and instruments where accurate positioning is involved.

WWW.JPE.NL

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