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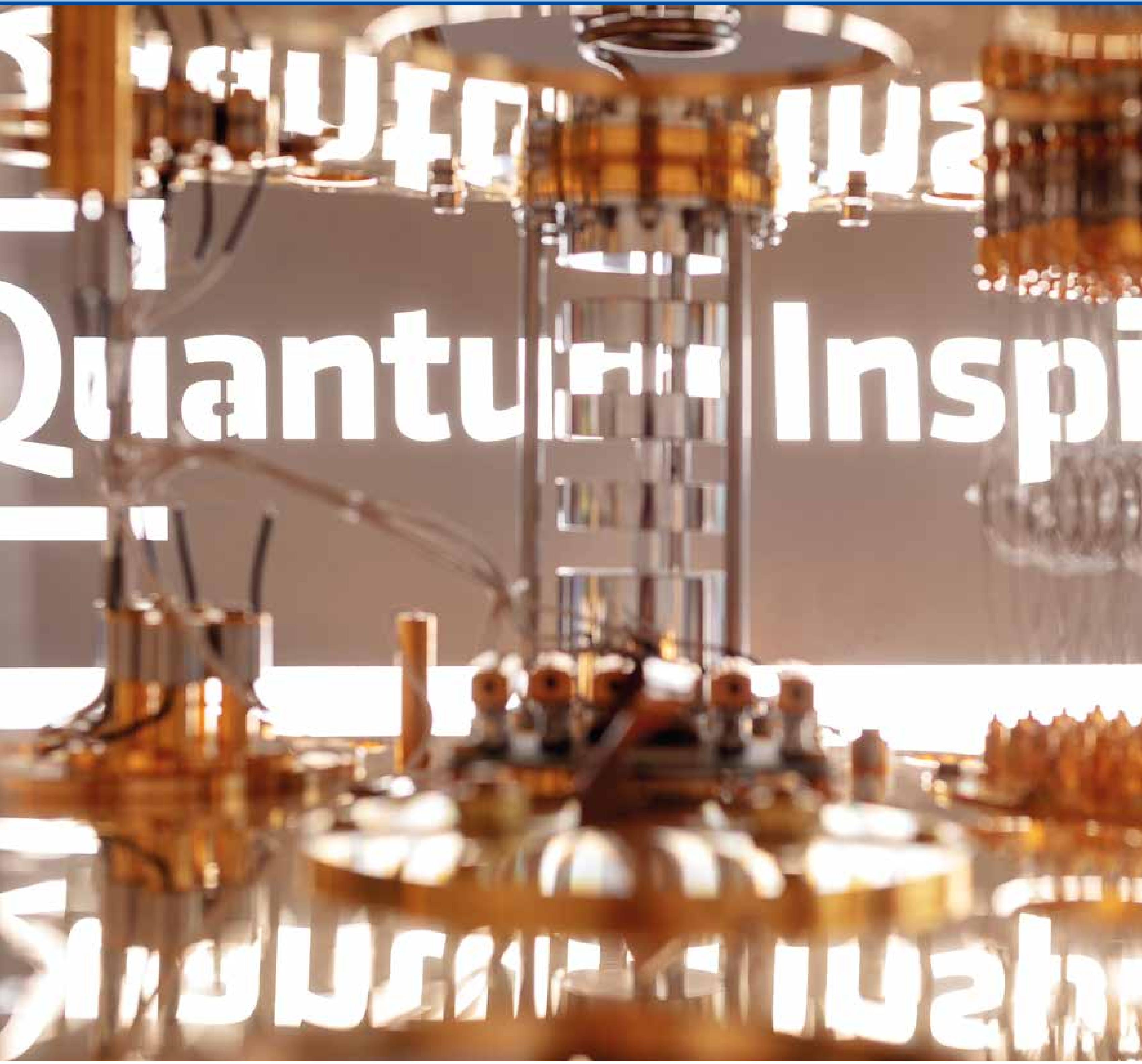

- ITERATIVE LEARNING CONTROL FOR NANOPOSITIONING
- REVOLUTIONISING PHOTONICS ASSEMBLY AND PACKAGING
- HIGH-PRECISION HOT-WATER CONTROL IN CONSUMER APPLIANCES
- GROUND DETECTORS AND INTEGRATED PHOTONICS FOR SPACE COMMUNICATIONS

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The cover photo (featuring the Quantum Inspire quantum computing platform) by Marieke de Lorijn is courtesy of QuTech. Read the News feature on page 29.

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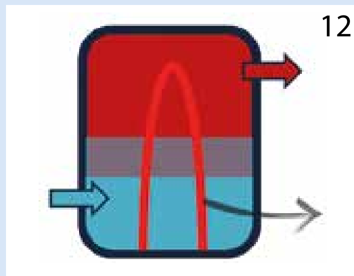
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FEATURES

DESIGN PRINCIPLES FOR PRECISION MECHATRONICS

Repeatability in production machinery for discrete products such as electron guns, as manufactured by Philips Gloeilampenfabrieken in the early 1950s, was considered key for gaining competitive advantage. From modelling of related mechanisms, Wim van der Hoek, who joined Philips as a mechanical engineer in 1949, gained insight and set design rules for predicting dynamic behaviour and improving positioning accuracy. Key was to carefully choose cam functions (set points) without discontinuities in speed and acceleration, to eliminate the disastrous effect of backlash, and to design for high natural frequencies by putting material where it contributes most. Stiffness turned out to be the new design paradigm.

In his lecture notes, "*Het Voorspellen van Dynamisch Gedrag en Positioneringsnauwkeurigheid van constructies en mechanismen*" ("Predicting Dynamic Behaviour and Positioning Accuracy of constructions and mechanisms"), Wim made the conceived insights accessible for next generations of engineers. To this he added "*Des Duivels Prentenboek*" (DDP, The Devil's Picturebook), in which he collected good- and bad-practice examples. Although each individual DDP picture was suitable for direct application, it was primarily intended as an invitation to the engineers to think about and, if possible, improve upon the design.

In the early 1980s, the traditional open-loop cam shaft mechanisms were gradually replaced by servo mechanisms based on feedback control, mainly for flexibility reasons of batch production in manufacturing lines. Gradually, electromagnetic direct drives were introduced allowing for high-bandwidth motion control. First, ASML PAS 5500 wafer steppers were still using cam drives for focus control, but in the early 2000s, full six-degree-of-freedom (6-DoF) motion control was applied in Twinscan systems in an isolated metrology architecture.

Despite the rather revolutionary advances, the importance of design for repeatability, e.g. through statically constrained design, has not changed, among others to guarantee the integrity of high-accuracy parts, such as wafer chucks, metrology frames and projection optics. To further increase control bandwidth, it became beneficial in the 2010 timeframe to introduce the concept of overactuation to avoid excitation of internal mode shapes. Although seemingly contradictory to statically constrained design, overactuation does not necessarily affect repeatability, provided that 'force' actuators are used with very limited residual non-linearities in position and current.

Regarding the relevant dynamics in the design, focus has shifted from creating favourable time responses to shaping of frequency response functions (FRFs). Driven by developments in optical storage, such as CD and DVD players, and later on semiconductor equipment in the 1990s, the understanding of superposition of mode shapes and optimal actuator and sensor placement to 'shape' the dynamic FRFs was key to robust controller design in combination with good performance. Recently, the implementation of passive damping was added to realise suppression of amplifications at resonances and, thereby, sufficient exponential decay of undesired vibrations in uncontrolled DoFs. Damping, which was abandoned for a long time in view of the risk of position uncertainty due to hysteresis, became a new design paradigm.

As a result of increasing complexity at the component level, driven, among others, by Moore's Law, more 'global' mechatronic solutions are required these days to enable better performance at reduced cost [Ref.]. Therefore, it is considered relevant, along the lines of in-depth education and training in design principles for mechanical engineers, to prolong the continuous update of DDP content by Wim and his heritage keepers – Rien Koster, Nick Rosielle and Herman Soemers – with new examples from the field of precision mechatronics, including optomechanics, electromechanics and materials science, along with the longstanding invitation to students and engineers to improve upon them. First ideas in this respect have been exchanged among Dutch universities and will get follow-up on short notice.

Hans Vermeulen
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Ref.: Vermeulen, H., "Mechatronica 2.0, Balanceren van complexiteit op componentniveau, Inaugural lecture" (in Dutch), Eindhoven University of Technology, 13 May 2016.

Note 1: The original theme of this Mikroniek issue was 'Precision mechatronics'. However, most of the scheduled theme-related content was cancelled due to the postponement of the DSPE Conference on Precision Mechatronics.

Note 2: A biography of Wim van der Hoek is in the making. Presentation is scheduled for the 2020 Precision Fair in November.

ILC FOR NANOPOSITIONING

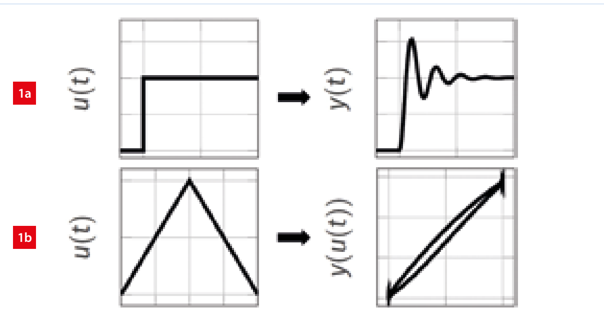
Due to overshooting and hysteresis, the output curve from a piezoelectric actuator can differ from its input signal. The iterative learning control (ILC) method, as developed by piezosystem jena, determines the required setting curve by performing iterations and adjustments on measured curves. Besides the improvement of accuracy, ILC offers advantages such as the production of dynamic movement even above the system's resonant frequency, and flexibility regarding changing conditions of, for example, load and temperature. In addition, there is no longer a need for users to have their systems recalibrated. This brief article presents the algorithm and experimental results.

STEFAN GÖTZ, EIKE SODE AND HAIXUAN YU

Introduction

Founded in 1991, piezosystem jena is one of the world's leading manufacturers of piezomechanic nanopositioning systems and corresponding electronics such as piezo-drivers and amplifiers. Piezo-actuators, piezodrives, nanopositioning solutions, piezocontrollers and motion control systems are used in micro- and nanopositioning applications whenever the highest precision or high dynamics are required. In addition to a broad range of catalog products, piezosystem jena is a leader in customer-specific developments designed to provide optimised systems for very particular applications.

Piezomechanic systems are available as both open-loop systems and traditional closed-loop systems, each having their own advantages and disadvantages. The open-loop systems exhibit drift and the hysteresis phenomenon. Drift is a characteristic of piezoelectric actuators, by which a step change in the applied voltage produces an initial motion that is then followed by a small, but unintentional continuous change over a longer time scale. Hysteresis is another natural characteristic of PZT (lead zirconate titanate) ceramics. When voltage is applied in a positive direction and then in a negative direction, the movement of the actuator will not follow the same path.



The difference between the input signal and the output of a piezoelectric actuator.
(a) Overshoot.
(b) Hysteresis.

AUTHORS' NOTE

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In the Netherlands, piezosystem jena is represented by Te Lintelo Systems.

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Closed-loop systems compensate for these phenomena by measuring the position of the piezo and correcting for deviations. However, this process takes time and therefore reduces the maximum operating frequency, especially when compared with the speed of open-loop systems. As shown in Figure 1, the output of a piezo-actuator can be different from the input signal due to overshoot (Figure 1a) and hysteresis (Figure 1b) behaviour.

These challenges can be successfully addressed with the newly developed ILC method (as incorporated in a controller). During an initial run of the piezo, the target position and actual position are compared and the self-learning system creates a compensated input signal. The output wave is greatly improved after several iterations, which is shown in Figure 2. After the third iteration, the output wave closely matches the desired output waveform.

ILC algorithm

First of all, by using Fourier transformation, the actual position $y(t)$ is transformed to $y(j\omega)$:

$$y(t) \rightarrow y(j\omega) \tag{1}$$

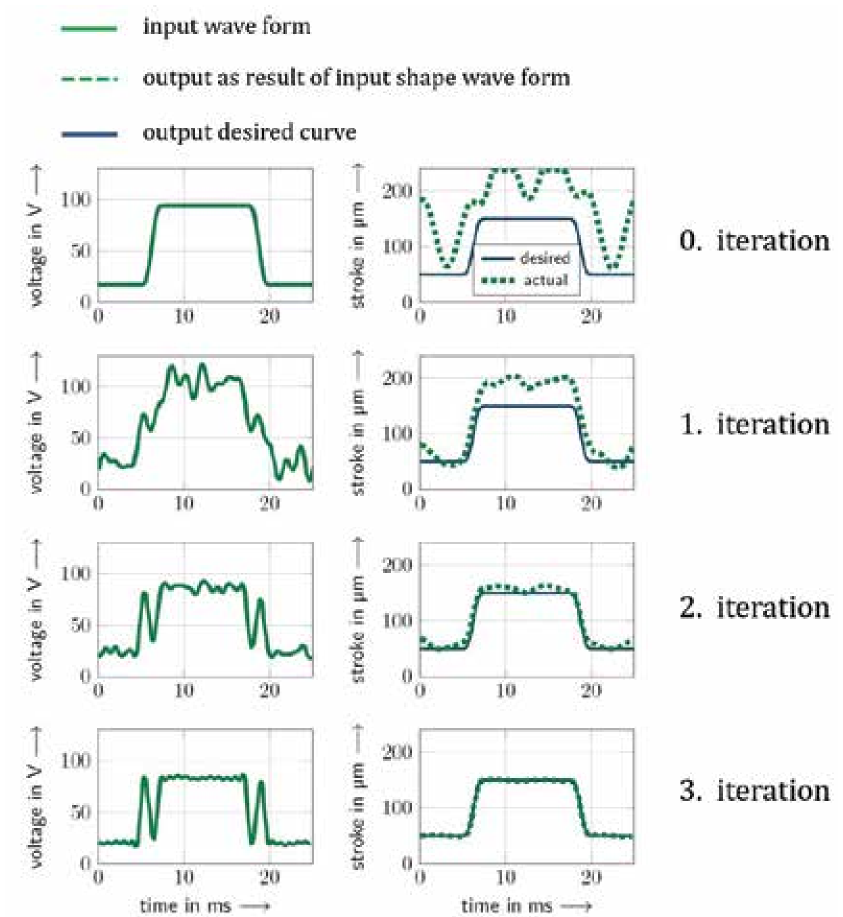
The control deviation $E(j\omega)$ is then calculated by comparing the difference between the desired position $w(j\omega)$ and actual position $y(j\omega)$:

$$E(j\omega) = w(j\omega) - y(j\omega) \tag{2}$$

The next step, the improved plot history $u_{i+1}(j\omega)$ for the next iteration i+1, is calculated by adding up the setting curve $u_i(j\omega)$ of the current iteration i and a correction:

$$u_{i+1}(\omega j) = u_i(j\omega) + E(j\omega)\cdot\rho(\omega) / G(j\omega) \tag{3}$$

Here, $G(j\omega)$ is the transfer function, which is also called the



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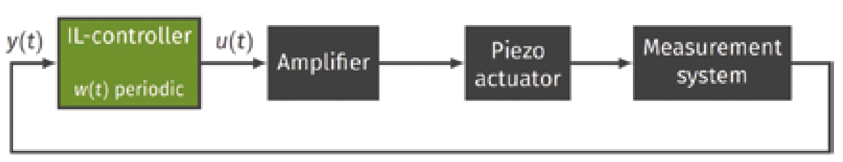
By iteratively changing the input waveform, the output waveform is greatly improved by ILC.

learning function and $\rho(\omega)$ is the learning gain. Finally, the inverse Fourier transformation is used to determine the next period and can be output from now on:

$$u_{i+1}(j\omega) \rightarrow u_{i+1}(t) \quad (4)$$

The ILC method is now given a certain number of periods for the iteration until the difference between the actual position and desired position is very small. The corresponding flowchart is shown in Figure 3.

As a result, ILC can quickly eliminate drift and hysteresis and achieve much better parameters in terms of frequency and speed compared to open-loop and traditional closed-loop systems.



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The ILC flowchart.

4

The PX 200 CAP stage (left) with the 24DV40 controller.

Experimental results

Set-ups

As shown in Figure 4 and Figure 5, two different actuators were used for the tests to validate the ILC method. The first actuator is a PX 200 CAP stage (maximum stroke of 200 µm, 3.2 nm closed-loop resolution) with a 24DV40 controller (16-bit resolution). The second actuator is a nanoX SG stage (maximum stroke of 500 µm, 0.8 nm step resolution) combined with an ENV 800 controller (800 mA current with signal noise < 0.3 mV_{rms} @ 500 Hz).

Measurement results

The measurement for the first set-up is shown in Figure 6. After processing by the ILC method, the actual position $y(t)$ and desired position $w(t)$ are very close to one another. The error between these two measured positions is within the 0.2 µm range. The voltage output of the piezo-actuator shows a highly similar shape compared to the curve for the desired position. Comparable results are obtained in Figure 7 for the second set-up.

Applications

One application for ILC is the pixel-shift or micro-scanning method for high resolution. As shown in Figure 8, the scanning system vibrated in different directions, took four pictures in a very short time and with the aid of the ILC method produced a picture with much higher resolution.

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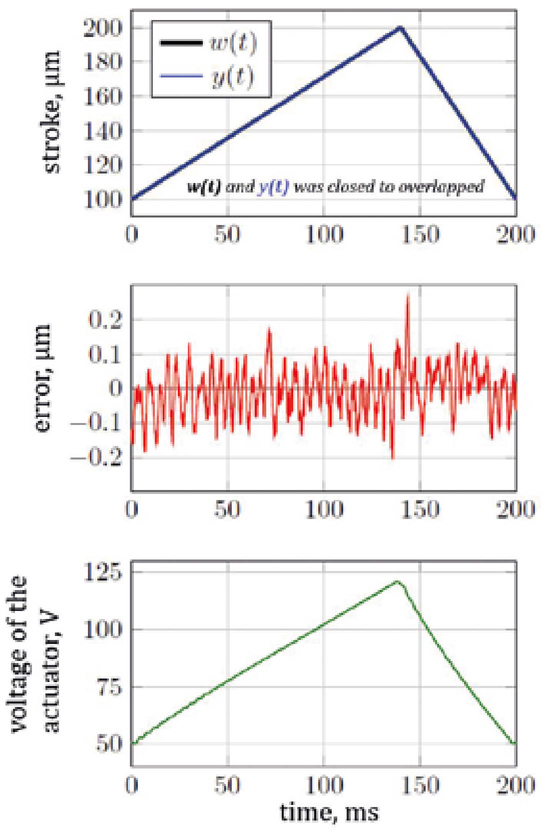
The nanoX SG stage (left) with the ENV 800 controller.



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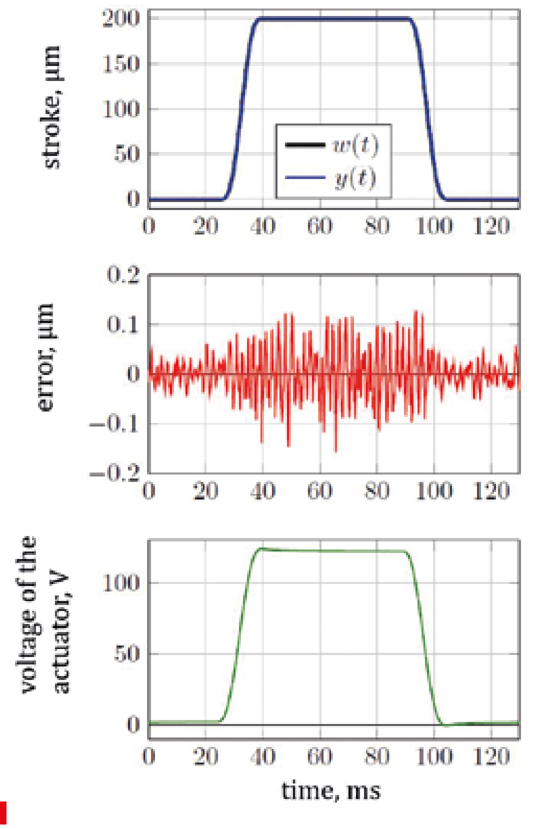
Measurement of the PX 200 CAP stage ILC-controlled using the 24DV40 controller.



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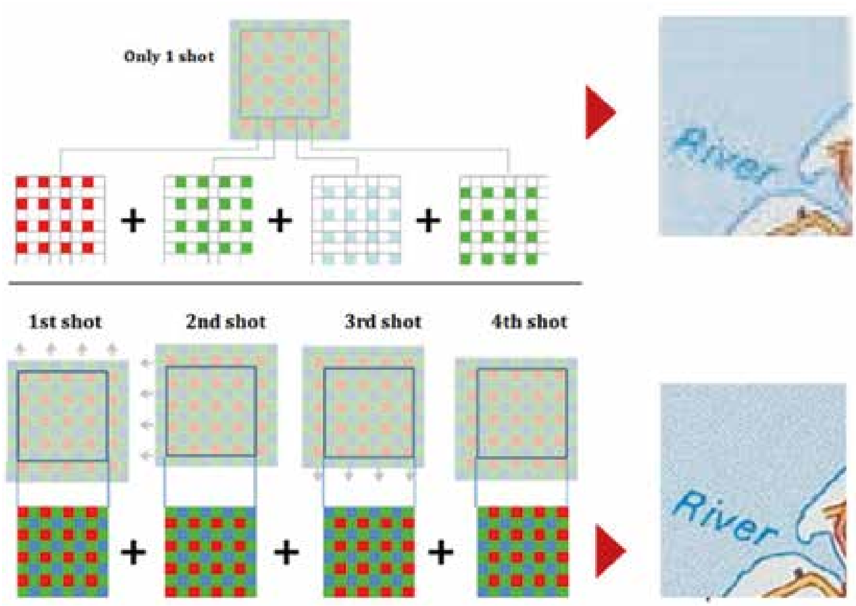
Measurement of the nanoX SG stage ILC-controlled using the ENV 800 controller.

Another ILC application is concerned with a high-speed closed-loop tilting mirror for laser technology. Here, ILC enables high-frequency beam stirring by combining closed-loop repeatability with open-loop speed. The ILC method works with the closed-loop systems and digital amplifiers from piezosystem jena.



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The ILC pixel-shift application showing improved image resolution in the lower image on the right.

THE FUTURE OF PHOTONICS

System integrator Tegema and Physik Instrumente (PI) have started a collaboration to develop automated systems for assembly and packaging technology. They also engage in other partnerships that address integration and alignment issues in the photonics industry.

Compared to microchips, the production of integrated photonic components involves a process step that is definitely more complex, i.e. the coupling technology to connect optical fibre components, such as individual glass fibres or glass fibre arrays, chips, VCSELs (vertical-cavity surface-emitting lasers), lenses, diffractive elements or photodiodes. PI offers fast, high-precision positioning systems (Figure 1) for this manufacturing step with special firmware routines built into the system controllers. These are already used worldwide for the development of photonic components and are also used in pilot production.

However, the market demands a much higher level of automation, for example when handling photonic chips or applying and curing adhesives. Tegema is an experienced system integrator that has yearlong experience with such questions. The assembly and packaging technology contributes to a considerable extent to the total costs of photonic components. The already proven systems from PI form the heart of Tegema's platform concepts for the further automation, by speeding up this process step considerably and minimising the associated costs (Figure 2).

1

PI's new fast multi-channel 6-degrees-of-freedom system for aligning fibres and optical components.

The common factor for photonic packaging is a need for automation, positioning of devices at high accuracy and permanent fixation of the aligned optical elements, in terms of optimum optical throughput. This is historically the strength of Tegema's expertise: development and realisation of automation systems, bonding technologies and micro-manipulation of small components. Now, Tegema has developed a modular platform for the assembly of photonic devices, with a roughly ten times higher throughput than with currently available solutions. A first demo system has already been set up as a proof of concept. Recently, the assembly platform was launched.

Partners

Headquartered in Karlsruhe, Germany, PI is the market and technology leader for high-precision positioning technology

2

The Tegema indigo product line presents a modular automatic assembly solution for operator-assisted, semi-automatic to fully-automated production of photonic devices. Cycle time is below 30 seconds and accuracy is better than 100 nm / 17 µrad.

EDITORIAL NOTE

This article was based on press releases from Tegema and PI.

and piezo applications in the semiconductor industry, life sciences, photonics, and industrial automation. Founded in 1976 and situated in Brainport Eindhoven (NL), Tegema has over forty years of experience in the field of customised precision mechanics and mechatronics and has grown into a multidisciplinary system integrator, focused on developing and optimising production processes.

Chip integration

Besides the partnership with PI, Tegema also joined forces with CITC (Chip Integration Technology Center), a Dutch non-profit innovation centre that specialises in heterogeneous integration and advanced packaging. The aim of this partnership is to develop micro-assembly processes for integrated photonics.

The growth of photonics is mainly hampered by the lack of standardisation in back-end production of integrated photonics packages. That is why every new product demands an innovation in assembly and packaging. This leads to high costs and technological risks. By developing manufacturing processes and manufacturing equipment hand in hand through a highly flexible platform, CITC and Tegema aim to reduce development risks and costs. This will make it possible to market integrated photonics products in a shorter time.
CITC's expertise in microelectronics packaging and Tegema's experience in high-precision alignment equipment will be supplemented by other parties, such as product developers, packaging foundries and end users. Shortly, CITC and Tegema will jointly start to approach parties to develop micro-assembly processes for integrated photonics.

Quantum photonics alignment

The future of photonics, as presented by PI in a PhysicsWorld feature (*www.physicsworld.com/a/automated-alignment-a-game-changer-in-quantum-photonics*), is taking shape along two converging coordinates as on-chip optical integration meets next-generation quantum technologies that exploit the exotic properties of quantum mechanics – entanglement, tunnelling, superposition and the like. The end-game: integrated quantum photonic devices, produced at scale, to controllably manipulate the quantum states of optical materials, opening the way to practical applications like quantum computing, communications, metrology and imaging.

PI's Fast Multichannel Photonics Alignment (FMPA) technology – a set of firmware-level commands built into the vendor's digital nanopositioning controllers, intelligent microrobots and stage controllers – can help developers to automate the optical alignment, test and assembly of quantum photonics devices while driving down production costs.

In integrated silicon photonics and next-generation quantum photonics, a multitude of tiny active and passive optical devices must be aligned for testing and packaging, starting at the wafer level. The common theme is multiple channels, multiple elements, multiple interacting inputs and outputs, multiple degrees of freedom – all need to be aligned and optimised multiple times throughout the manufacturing process, requiring parallel optimisation and nanoscale accuracy – not least in the coupling of on-chip waveguides with optical fibres. Here, FMPA comes in.

Over the past four years, PI has implemented a new generation of algorithms in the controllers for its nanopositioning equipment. These algorithms intelligently seek the optimum of a given optical figure of merit versus position. There are two types of alignment process: area scans to localise the main peak for a given parameter (e.g. optical power, modulation transfer function or modal purity) within a defined region, while parallel gradient searches efficiently optimise one or more such couplings at once – and optionally track them to mitigate drift processes and positional disturbances caused by temperature changes. In the case of a coupling between an on-chip waveguide and an optical fibre, for example, the manufacturer typically wants the alignment to minimise the light loss going from one element to another.

A big driver for FMPA adoption is silicon photonic devices with arrayed-waveguide inputs and outputs – multiple optical channels that must be aligned simultaneously with optical fibres or other elements. To serve that market, PI now has leading industrial players in silicon photonics – the likes of FormFactor in the US (Figure 3), MPI in Taiwan and Tegema in the Netherlands – building high-throughput test and assembly equipment (photonic wafer probers and packaging-automation tools, respectively) based on PI's microrobots, positioning stages and advanced control technology.

3

FormFactor's Cascade CM300 photonics-enabled engineering wafer prober integrates PI's FMPA systems for high-throughput, wafer-safe, nanoprecision optical probing of on-wafer photonic devices. (Image: FormFactor)

INFORMATION
WWW.PI.WS
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GIGABITS FROM SPACE

Sending a lot of data at high speed is one thing – receiving it, another. Dutch solutions are now available for the global laser communication market. TNO and Hyperion Technologies have successfully commercialised an optical component, the so-called Gigabit Detector, for receiving satellite laser links on Earth. Furthermore, a PhotonDelta consortium started a project aimed at the realisation of a robust and versatile hybrid integrated photonics platform for space applications.

Optical ground station operators are challenged with the opportunity of hundreds, if not thousands of small satellites being launched into space – all battling for radio-frequency bandwidth and the precious downlink time when passing over a ground station. This is why a transmission of data via laser links is becoming ever so attractive. Using laser links, or so-called free-space optical links, bandwidth is suddenly not a constraint anymore. New and better data products, near real-time data access, even streaming services become a reality.

The Gigabit Detector taps into a niche market. At the moment, laser communication is not yet widely used in space. Many applications are experimental, scientific, or if commercial, are still not affordable for the mass market, and used only by a small number of clients. With the rapidly growing number of laser communication satellites, an affordable solution for optical ground stations is needed. As a key enabling building block in Gigabit-class optical ground stations, a ground detector called the Gigabit Detector – developed by TNO, the Netherlands organisation for applied scientific research, and space company Hyperion Technologies – is one of the first steps to make this a reality.

EDITORIAL NOTE

This article was based on press releases from TNO/ Hyperion and PhotonDelta.

1

Gigabit Detector GD200, a compact, high-performance detector, used in optical ground stations, capable of receiving data rates up to 10 Gbps.

In essence, a telescope collects light sent from a satellite, and bundles it. The Gigabit Detector (Figure 1) converts the data contained in the laser beam into a digital bitstream. This bitstream is handed over to a high-speed data handling system. The Gigabit Detector can be integrated into optical communication ground stations, as well as into experimental set-ups for optical communication. These can include space, airborne or ground-only applications.

As of now, Hyperion offers the Gigabit Detector to the worldwide market, in accordance with a licence agreement between the two parties. The agreement, signed earlier this year, is a big milestone for a successful market entry of co-developed laser technology, towards which Hyperion and TNO have been working for two years.

FSO Instruments consortium

This success has been made possible thanks to the collaboration of a select group of specialised Dutch companies, together forming the FSO Instruments consortium (FSO stands for Free-Space-Optical). They act as a unique supply chain for laser equipment in the Netherlands, enabling large-scale production of the Gigabit Detector – and more.

The consortium, consisting of VDL, Demcon, Nedinsco, Hyperion and TNO, is working on a number of solutions to serve the global laser communication market – be it for space, air or ground applications. Examples of these products are for example a fine-steering mirror, made available via Demcon; a telescope assembly offered by Nedinsco, and CubeCat, a laser communication terminal for satellites, available via Hyperion.

Hyperion Technologies is an independent Dutch space company located in Delft (NL). Having been active since 2013, it specialises in the development of miniaturised, high-performance and smart components for small satellites as well as satellite platforms for complete missions. This includes both hardware and software. Hyperion follows the philosophy to provide the best-in-class products to its clients worldwide, scratching at the limits of the physically possible within the scope of miniaturisation.

INFORMATION
WWW.HYPERION.SPACE
WWW.TNO.NL

PICs in space

At the end of April, a PhotonDelta consortium kicked off its flagship project. PhotonDelta is the Dutch public-private partnership of companies and knowledge institutes working on the design, development and (volume) manufacturing of integrated photonics technologies and components. The project addresses the realisation of a robust and versatile hybrid integrated photonics platform (Figure 2) that provides scalable solutions for a suite of applications. Moreover, with two proven technology platforms within the Netherlands, InP (indium phosphide) and TriPleX (silicon nitride), the PhotonDelta Flagship project demonstrates scalability to high-volume manufacturing aiming for space-quality modules; the highest quality grade in industry. Hence, this project indirectly also supports several industry and application-driven roadmaps.

The PhotonDelta Flagship project connects and involves the main Dutch industry players in integrated photonics. The consortium is chaired by LioniX International, and involves six SMEs – Bright Photonics, EFFECT Photonics, SMART Photonics, PHIX Photonics Assembly, Technobis Fiber Technologies, VTEC Lasers & Sensors – and the Space and Semiconductor departments from TNO. The companies cover the entire supply chain from chip design and chip manufacturing to assembly, packaging and testing. PhotonDelta is co-initiator and co-funder of the project.

With their proven advantages of size, weight and power consumption photonic integrated circuits (PICs) are on the verge of a breakthrough in space applications, once proven their robustness and reliability for harsh environments. Still OEMs are reluctant, concerned and sometimes resistant to integrate unqualified components and novel platforms. Moreover, and apart from government-funded initiatives, there are few, if any space-qualified industrial sub-contractors in the Netherlands that have a track record of deliveries to European OEMs or have collaborated with integrated device manufacturers in the space industry.

Where electronic integrated circuitry is known for its compactness, high integration density of functions, robustness and excellent reproductivity in scalable volumes, PICs need to prove their mechanical robustness, temperature stability, radiation hardness and scalability to low-cost solutions for many applications in healthcare and automotive, and implementation in complex and novel aeronautics and space systems. With the PhotonDelta Flagship project, the participants will demonstrate a reliable production process with reproducible performance of the PIC platform, proving space requirements can be met.

WWW.PHOTONDELTA.EU

A 30-GHz, RF-to-RF, 1-to-4 integrated optical beamforming network module, using true-time delays, for terrestrial (5G) and satellite communications. The big PIC in the centre is the photonic processor, manufactured in silicon photonics technology, in particular using proprietary ultra-low-loss silicon nitride (TriPleX) waveguides. The smaller 'satellite' chips are the indium phosphide (InP) modulator (left), gain chip, and detectors (PD: photodiodes), respectively. The Hybrid InP-TriPleX platform has RF (gold connectors), DC (white 25-pins connectors) and optical fibre interfaces (16), along with the bias and power that feed the gain chip in the upper left corner of the picture. The compact module is attached to a thermo-electric cooler (TEC) and a copper base plate for accurate temperature stabilisation. (Image: LioniX International)

PRECISION COFFEE

There is a clear trend in consumer appliances, such as coffee machines, towards improved quality and increased personalisation. Consequently, these appliances require higher control accuracy, while costs need to remain low. This article focuses on water temperature control in coffee machines. Varying types of heaters each have their own physical limitations that influence both start-up effects and steady-state behaviour. Accuracy is therefore largely bound by heater choice, but control can still be used to get the most out of the machine. Guidelines are presented for selecting optimal product architectures and control strategies.

NEAL MEIJERS, MIEKE VAN DEN BELT AND HENK VAN DER WULP

Introduction

A key trend in our daily food and beverage consumption is an increasing demand for convenience and personalisation. This, in combination with consumers' growing awareness and knowledge of quality food, creates a market for affordable home appliances that allow for easy personalisation. A good example of this trend is coffee preparation, where appliances nowadays offer a large variety of consistent- and high-quality coffee recipes in convenient ways.

Achieving this level of quality and personalisation requires accurate control of many parameters, especially of temperature and water flow. Optimal coffee extraction requires water between 91 and 96 °C. Lower temperatures will lead to underextraction, causing weak and tasteless coffee, whereas higher temperatures close to the boiling point will cause bitterness [1]. Furthermore, consumers may want to adjust their extraction profile to be slightly sweeter or bitterer by changing the temperature within the 91-96 °C range. Making different coffee flavour profiles that can be easily discerned and reproducibly produced within this range will require a very high degree of accuracy, in the order of +/–1 °C.

As well as ensuring that coffee is extracted at exactly the right temperature, hot-water control also plays a large role in creating steam, which is used to make the milk foam for cappuccinos, etc. However, steaming brings its own challenges and therefore requires other design strategies. This article only considers hot-water control.

Controlling water temperatures and flows might not seem complicated at first glance; however, given strict boundaries of cost price, new legislation and sustainability (material use and energy consumption), it becomes a significant challenge.

PCV Group has extensive experience in the development and realisation of home and professional appliances. From this experience arose the need to develop guidelines to support the selection of the architecture of high-precision hot-water control systems depending on product requirements and the aforementioned boundaries. This article presents and explains the fundamentals behind these guidelines.

Boilers and flow-through heaters

When considering hot-water control in consumer appliances, many types of heaters can be distinguished. Thermal mass, flow velocity and power are only a few of the many properties that influence the required control strategy. The optimal control strategy is not only affected by architectural variations, but is also largely influenced by a wide variety of specifications, requirements and boundaries. Controlling heaters is therefore a trade-off between parameters, e.g. control rate versus reaction rate, or start-up effects versus stability.

The two major sources of temperature error are start-up effects and steady-state errors. Start-up effects refers to the first phase of a dispense, not to preheating the device. For example, a standard espresso is only 30 ml, and thus has a short dispense time. Start-up effects in this case are more dominant than for a typical lungo, which has a volume of

Two types of heaters. (Source: www.espresso-expert.com/boiler-or-thermoblock-which-heating-system-to-choose)
(a) Flow-through heater.
(b) Boiler.

AUTHORS' NOTE

Neal Meijers (senior engineer), Mieke van den Belt (engineer) and Henk van der Wulp (senior consultant) all work at PCV Group, a product design and development company located in Enschede (NL). PCV stands for People Creating Value.
This article is based on a presentation that was accepted for the DSPE Conference on Precision Mechatronics 2020, which has been postponed till 2021.

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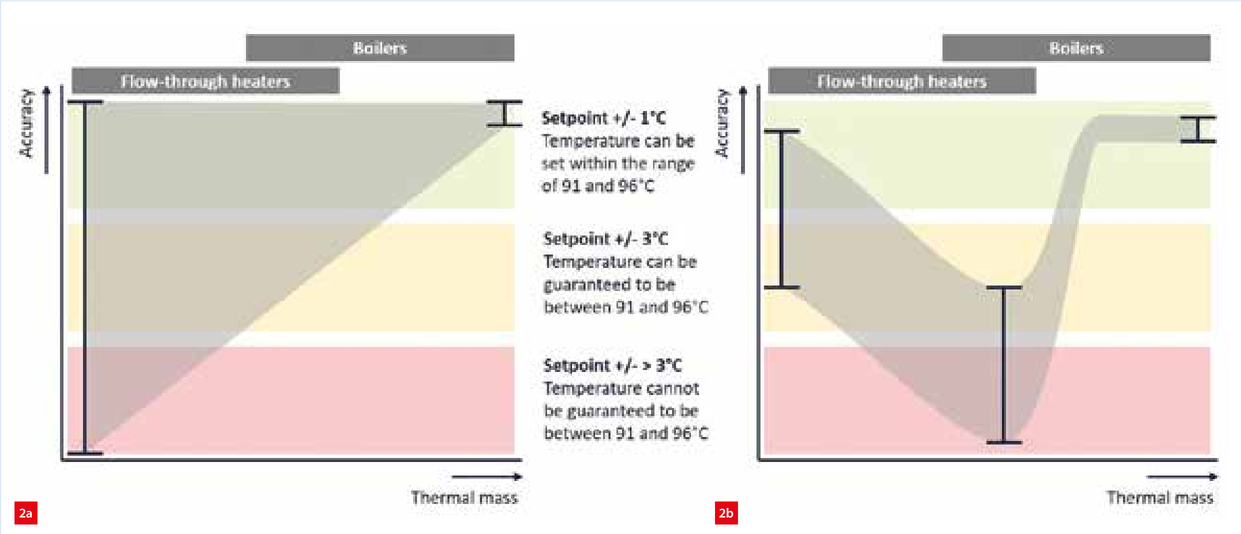


Temperature accuracy that can be achieved. (Source: PCV research)
(a) During steady-state behaviour.
(b) Start-up behaviour.

50-150 ml. For the latter, steady-state effects are much more significant. However, both start-up effects and steady-state behaviour play a large role in every coffee machine and therefore both need to be taken into account.

Heaters can be roughly divided into two groups: boilers, in which water is heated and stored until used; and flow-through heaters, in which water is heated while it flows through the heater for direct use. Examples are shown in Figure 1.

Figure 2 shows the achievable accuracies for boilers and flow-through heaters when used to dispense a typical lungo at typical flow velocities. The grey areas show the bandwidth that can be achieved with different control techniques. These are physical limits, dependent on system architecture and design choices, meaning that even perfect control cannot improve accuracy further.

As can be seen, for obtaining high temperature accuracy in both start-up and steady state behaviour, a large boiler is the optimal choice, as it can heat up water in advance and keep it at a very constant temperature until needed. Very basic control is therefore sufficient, which keeps costs low. However, boilers take up a lot of space and the preheat time is long. The high thermal mass also leads to a high energy usage, especially if only a single cup of coffee is made before cooling down. This makes the larger boilers mostly suitable for professional or catering industry use, rather than for household consumer appliances. The relation between preheat time and thermal mass is valid for all heaters, as thermal mass always leads to a longer preheat time. This is most apparent in the energy consumption of large boilers.

In the lower thermal mass range, i.e. for flow-through heaters and for boilers that are too small to dispense one entire serving, a contradiction occurs. Overall, higher thermal mass typically shows better steady-state results, in so far that high accuracies are easier and cheaper to achieve. However, lower thermal masses, which are a lot harder to accurately control, show much better start-up behaviour.

Limiting physical principles

When establishing guidelines, the first step is thus to select the type of heater that is the best fit for the application. This decision is a trade-off between accuracy, available space, material and development costs. Here, it should be understood that physical principles limit the extent to which accuracy can be improved by control.

The influence of thermal mass on steady-state accuracy is relatively straightforward: the larger the thermal mass, the less effort it takes in control to obtain high accuracy. However, regardless of the quality of the controls, errors in the output temperature of water will occur in the transition from a static (pre-heated) state to an operating state during dispense. Such start-up effects, common in many controlled systems, quickly become highly relevant in a coffee machine, where a single dispense is short. These start-up effects are heater-architecture-dependent and will be discussed separately for boilers and flow-through heaters.

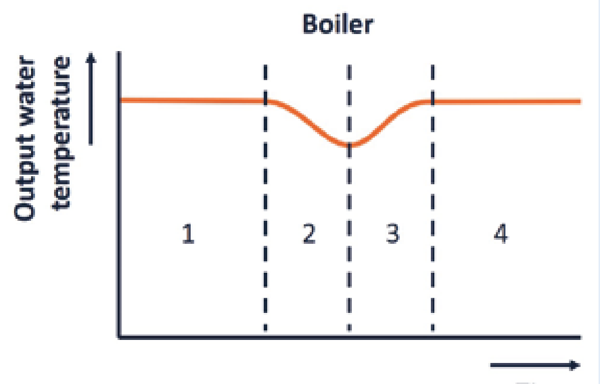
Flow-through heaters

In a flow-through heater, water passes through a long slim heater tube, heating up in the process, much like in a heat exchanger. The driving force of heat transfer in such a system is convection between tube wall and water. This parameter is highly dependent on flow velocity: the convection is at least one order of magnitude higher when water flows compared to when it stands still. This means that there are two equilibria possible: a static one, where the system is pre-heated, but before dispense occurs; and a dynamic one, where water flows through the heater during dispense. In a static situation, the convection to the water is relatively low and consequently the temperature of the heater is homogeneous. Depending on how long the heater has been turned on without flow, the water in the heater will either be the same temperature as the wall of the heater or colder.

When flow starts, convection to the water becomes a more dominant effect, compared to internal conduction of the heater block. This causes a temperature gradient to occur in the heater between heating element and tube surface. Additionally, most heaters are designed such that in order for enough heat to be transferred to the water in a short time, the surface temperature of the heater tube has to be higher than the desired water temperature. This allows for smaller heaters, up to a point.

What this means in practice is that as soon as flow starts, the heater will start to cool down because of convection to the water, and will therefore have to heat up again. At a minimum, the core of the heater will have to heat up to compensate for the heat distribution inside the heater. For smaller heaters, this means having to heat the tube surface to higher levels. This cannot be prepared for in the static situation, as overheating the heater without flow will cause unwanted boiling behaviour, generating steam and thus pressure.

This is where thermal mass, contact area, power and flow rate come into play. A higher thermal mass decreases the speed with which the heater can change its temperature, thereby significantly increasing the time in which the start-up effect takes place. Having surplus power to heat up more quickly, or more contact area will help minimise this effect. This is what causes the limitations as shown in Figure 2. The exception to this effect is having a heater with a high thermal mass and a large surface area, but with a relatively low water flow. In such cases, the start-up effect can be minimised, as the heater barely has to heat up further when flow starts.



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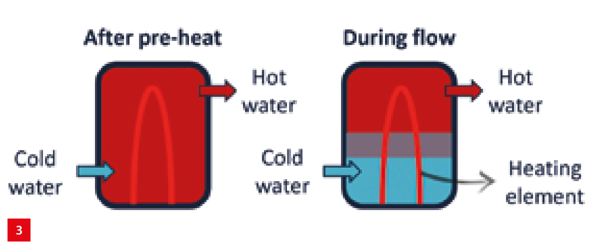
Boiler behaviour over time.
1 Only hot water reaches the outlet, while cold water enters at the bottom.
2 First mixed water is reaching the outlet. The heater is on, but the dynamic steady state has not yet been reached.
3 The boiler is reaching the dynamic steady state.
4 The boiler now functions as a flow-through heater with relatively large thermal mass.

Boilers

Boilers function slightly differently than flow-through heaters. The thermal mass of a flow-through heater is concentrated in the metal mass of such a heater, whereas the thermal mass of a boiler is concentrated in the water itself. The specific heat capacity of water is about five times higher than that of aluminium, and water has a thermal conductivity (when still) that is orders of magnitude lower than that of aluminium. When a boiler is turned on, the water inside starts to move due to the mixing of hotter and colder water. This way, heat spreads through the water. This is a relatively slow effect, however, only relevant when there is no flow. If flow is produced with a pump, and kept laminar, cold water can be pumped into the heater from the bottom, forcing hot water up and thus out of the boiler (Figure 3). This way, the temperature of the water that exits the boiler is not directly affected by the cold water entering the system, because of its low thermal conductivity.

Figure 4 shows how output water temperature in a boiler changes over time. As long as the volume of the boiler is sufficiently large, one dispense can take place fully in phase 1, thereby making the output temperature independent of the input temperature. For small boilers, this is no longer



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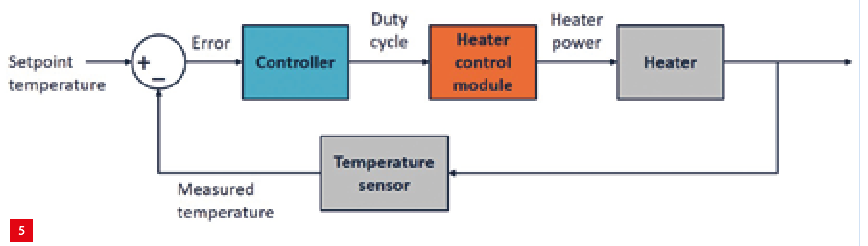
Schematic of boiler behaviour.



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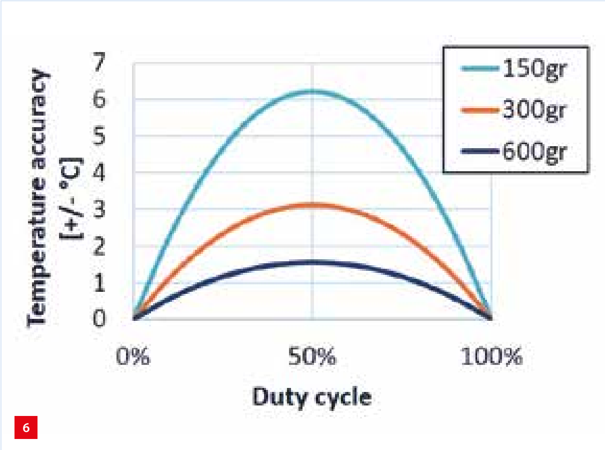
Control diagram for a heater.



Temperature accuracy as a function of duty cycle and thermal mass, as determined by the flicker regulation.

the case, and cooler water will reach the output before it has fully heated up. At this point, the boiler behaves like a flow-through heater with a relatively large thermal mass, causing a significant dip in temperature while transitioning from static to dynamic behaviour.

Control strategies

There are two main contributors to optimising temperature accuracy with controls: the controller and the heater control module. This is shown in Figure 5.

The controller itself, combined with the location of the sensor(s), determines the final accuracy of the output. However, the heater control module can function as a limitation on this controller. Costs for the controller are mainly determined by the development costs: higher accuracy requires a more advanced controller and therefore more development work. The heater control module, on the other hand, mainly affects hardware costs, impacting the appliances' bill of materials. Note that this only considers control based on temperature. Flow-based control is also possible, but variations in flow have an impact on extraction similar to that of changes in temperature.

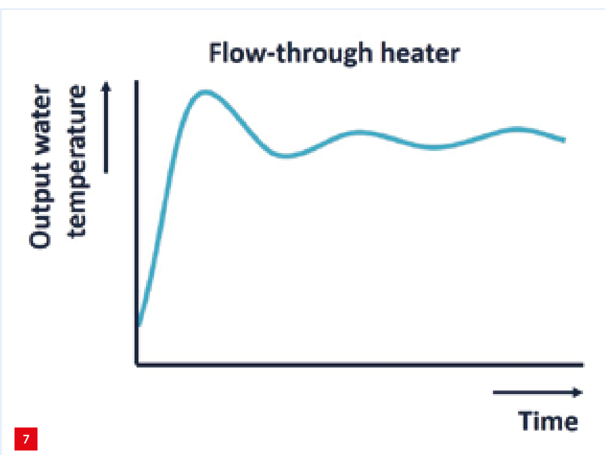
Under normal circumstances, a heater does not require its maximum power, meaning a control module is needed to control the power output of the heater module.
This can be done in several ways, such as:

- Zero-cross on/off control.
- Phase-cutting control.
- A hybrid combination of on/off and phase-cutting control.
- PFC (power factor correction) control.

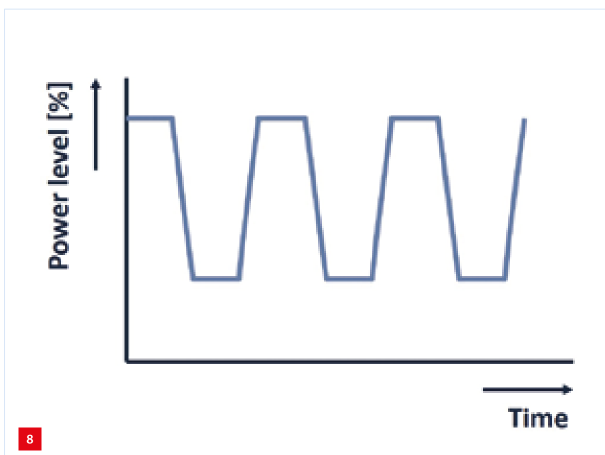
These methods are all limited by EMC (electromagnetic compatibility) compliancy codes, namely the flicker and higher harmonics codes [2, 3].

By far the cheapest solution is zero-cross on/off control, which switches the heater on and off at a set interval. Because of the flicker code, the control interval is limited to an average of 12.5 switches per minute for a 1,400-W heater, which is a very standard power level for this application. This causes a temperature fluctuation depending on thermal mass, as can be seen in Figure 6. In the worst case, which is at a 50% duty cycle, a 600-g heater is required to obtain a temperature accuracy of +/– 1.5 °C. In practice, this limit can be achieved with a lower mass for two reasons, namely that heaters generally run far above the 50% power level and that due to less switching actions during start-up more than 12.5 switches per minute are allowed during the steady state of a dispense. The resulting behaviour is shown in Figure 7.

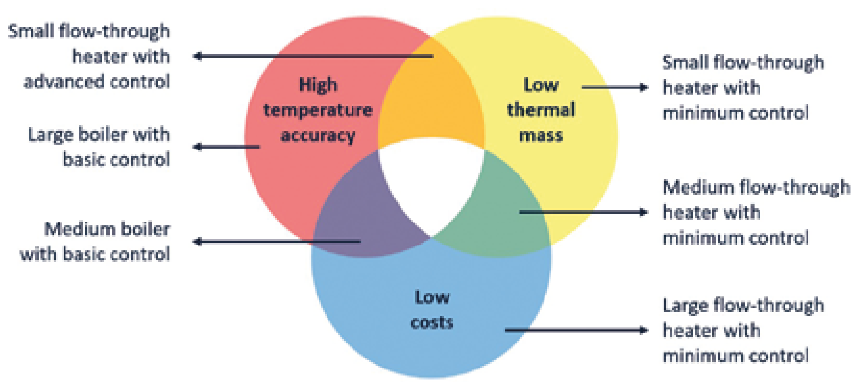
More advanced heater control modules like PFC and phase-cutting solutions are capable of accurately controlling the duty cycle of the heater without breaking flicker regulations. When using one of these solutions, the heater control module no longer acts as a bottleneck in the water temperature performance of the system. These solutions do cause higher harmonics, however, which need to be filtered in order to pass regulation. Such filters are quite expensive, which is a severe limitation for their implementation in many (consumer) devices.



Oscillation in output temperature.



Power level ramp up/down using phase-cutting.



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Trade-off between high temperature accuracy, low thermal mass and low costs.

The use of a hybrid combination of on/off control with phase-cutting is also a possibility. This method uses an on/off method but ramps up and down at every on/off cycle with phase cutting, as shown in Figure 8. This allows for a higher control interval while staying within flicker regulation, leading to improved accuracy. The designer can tune this method to have control intervals that match performance requirements, where higher control intervals lead to higher performance, but also to more harmonics, a larger filter and therefore higher costs.

The chosen design of the heater control module has a significant impact on control costs. The chosen water system and the level of effort put into the controller need to be matched with the chosen water control module. Note that a lower thermal mass design requires the most advanced heater control module to achieve high levels of steady-state accuracy.

Causes of variation

Optimising the controller itself is the last step in achieving high accuracy. There are many sources of variation that impact the heating behaviour of the water system. The most important of these are the variation in mains voltage and the input temperature of the water. Use of a closed-loop controller that takes the physics of the system into account is therefore highly recommended. This step is not detailed further in this article.

Conclusion

As presented in this article, selecting a heater and a control strategy is not an easy and straightforward job, because of the many contradictions. A decision will always be a trade-off between three main aspects, namely temperature accuracy, costs and thermal mass-related properties, such as preheat time and size. This trade-off is shown in Figure 9 and summarised below.

Temperature accuracy

High temperature accuracy is achieved by going for either a very high thermal mass in the form of a large boiler, or a low-thermal-mass flow-through heater. The latter requires advanced control to obtain high accuracy, therefore making it an expensive option. Large boilers, on the other hand, have disadvantages in their preheat time, energy usage and build-in volume. However, they are a very efficient solution for systems that need to dispense a lot of coffee, for example in professional and catering industries.

Costs

Costs are mainly determined by two aspects: hardware and development. Hardware costs are hard to generalise, as both small flow-through heaters and very large boilers are usually expensive. Large boilers, however, can do with much simpler control, making development costs significantly lower than for small flow-through heaters. The cheapest option, being a medium-to-large-thermal-mass flow-through heater with minimum control, makes high accuracy close to impossible.

Preheat time, build-in volume, energy usage

These effects are directly correlated with thermal mass. A higher thermal mass leads to higher preheat times, more build-in volume and a higher energy usage. Regarding these aspects, a lower thermal mass will always be better, however the obvious disadvantages need to be kept in mind: a very low thermal mass requires a lot of control to gain sufficient accuracy, and is therefore expensive, whereas medium thermal masses do not allow for high accuracy. Overall, boilers are slightly more space-efficient than flow-through heaters.

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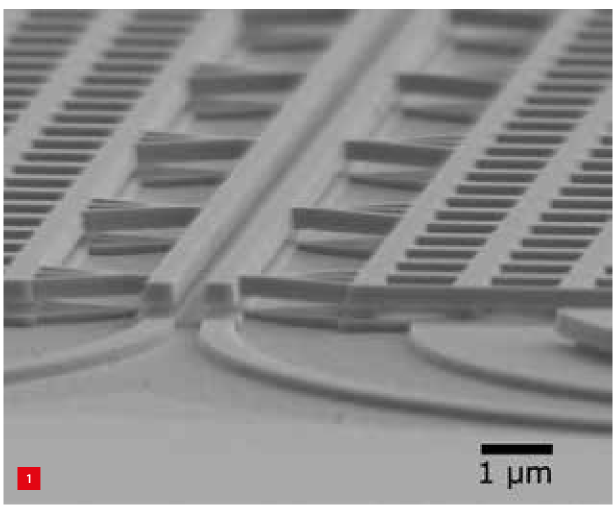
NANOMETROLOGY LAB-ON-A-CHIP

Researchers at Eindhoven University of Technology (TU/e), the Netherlands, have developed a new, integrated optical sensor that provides increased resolution in measurements and paves the way for fully integrated and compact optical sensors including lasers and detectors for on-chip sensing platforms. Such sensors could play a pivotal role in accurate displacement and force measurements at the nanoscale, which is crucial for microchip and nanodevice design and evaluation. This research has been published in Nature Communications.

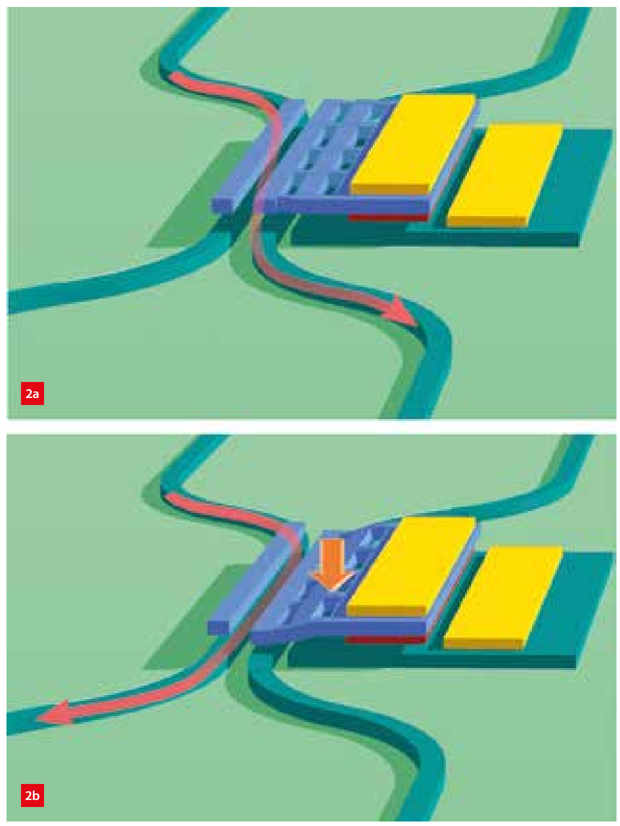
In the age of nanoelectronics, precision is the order of the day. For example, nanostructures can be monitored with nano-optical instrumentation – tiny, light-based systems that measure the smallest of surface variations, forces and movements. As resolution and speed are essential, optical read-out sensors based on optomechanical systems are frequently used in sensing applications such as in atomic force microscopes (AFMs). These devices generate sub-nanometer resolution images by measuring the laser light reflected by the deflection of a cantilever over a surface of interest.

However, traditional laser-based approaches such as those in AFMs can be bulky, which along with the demand for lower cost and higher resolution, motivates the need for an alternative approach. Thanks to developments in nano-optomechanical systems (NOMS), compact optical sensors for the measurement of motion, force, and mass at the nanoscale are achievable. A limiting factor though is the need for a tuneable laser with a narrow linewidth, which can be difficult to adequately incorporate on a device.



1 SEM image of the nanomechanical directional coupler used as a transducer.

To circumvent this issue, TU/e researchers designed a new optomechanical device with a resolution of 45 femtometers in a measurement time of a fraction of a second [1]. Crucially, the device has an ultrawide optical bandwidth of 80 nm, removing the requirement for a tuneable laser. The sensor, composed of transducers, actuator and photodiodes, is based on an indium phosphide (InP) membrane-on-silicon (IMOS) platform, which is ideal for including passive components such as lasers or detectors. Fabrication takes place via a series of lithography steps to define waveguides and cantilever.



Schematic illustration of light passing through the directional coupler.
(a) Before actuation (up).
(b) After actuation (down).

EDITORIAL NOTE

This article was based on a press release featuring work from the TU/e Integrated Photonics Institute.

www.tue.nl/en/news
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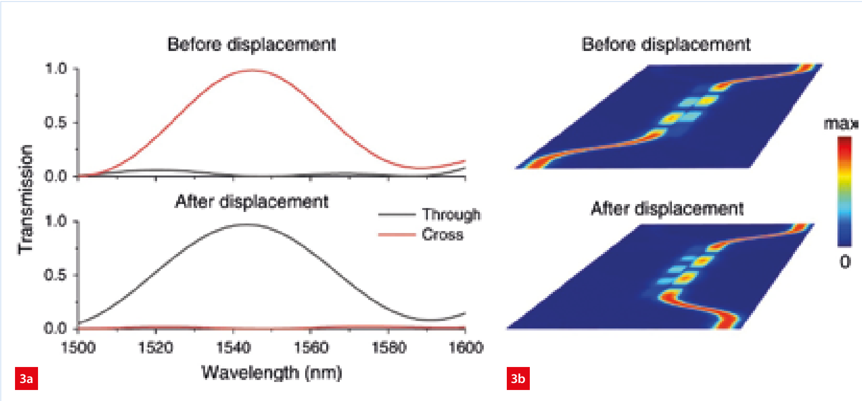

Simulation of the behaviour of an ideal device [2] before and after displacement/actuation (55 nm).
(a) Transmission.
(b) Electric field distribution |E|.

The heart of the transducer is a nanomechanical directional coupler; see the scanning electron microscope (SEM) image in Figure 1. The coupler consists of four evanescently-coupled waveguides – structures that restrict light signals to a particular path and direction – with two waveguides suspended above two output waveguides. When a suspended waveguide is pushed towards the output waveguides on the InP membrane, the relative amount of signal carried by the output waveguides (i.e., their transmission) varies. Figure 2 gives a schematic illustration of light passing through the directional coupler before and after actuation. Simulations of an ideal device [2] demonstrate the transmission effect (Figure 3).

One of the key advantages of this sensor is that it operates in a large range of wavelengths, which eliminates the need for an expensive laser on the device. In terms of cantilever deflection, the sensor also replicates the resolution of cantilevers in traditional, but bulky AFMs. Using this new device as a foundation, the researchers plan on developing an entire 'nanometrology lab' integrated on a chip that can be used for semiconductor metrology and help in the design of the next generation of microchips and nanoelectronics.

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DESIGN AND CONTROL OF PRECISION MECHATRONICS SYSTEMS

The sixth ASPE Spring Topical Meeting on Design and Control of Precision Mechatronics Systems was held from 6-8 May 2020. Due to the Covid-19 situation it was as a virtual event, and a very successful one. The meeting was devoted to the link between precision mechatronics and the fourth industrial revolution (also Smart Industry or Industry 4.0). Precision mechatronic control provides the tools to make physics smart, and thus could well contribute to and benefit from the advancements in automation and digitisation of industrial processes.

WOUTER HAKVOORT

The ASPE Spring Topical Meeting, co-chaired by David L. Trumper (MIT), Chinedum Okwidure (University of Michigan), Dick Laro (MI-Partners) and Wouter Hakvoort (University of Twente), was intended to be hosted at MIT in Cambridge, MA, USA. Unfortunately, due to the coronavirus pandemic, the live event had to be cancelled. The organisers were faced with the decision to either cancel entirely or to go virtual. They opted for the second alternative, motivated by the many interesting contributions they had received. Platform and planning were devised to make the meeting as interactive as possible. Therefore, it was decided to keep the (online) presentations live (instead of transmitting pre-recorded ones) and organise interactive breakout sessions. Furthermore, going virtual provided the opportunity to lower the threshold for participation (time- and moneywise), thus potentially increasing participation.

Participants could communicate via an online platform, which was also used to share information on the tutorials. In addition, interesting papers and information on 'home mechatronics' for students in coronavirus times were shared spontaneously via this channel. Hangout sessions during lunch and after the conference were organised for socialising. The meeting was prepared through practice sessions for the speakers organised by the ASPE office. A backstage communication channel was available for the organisers. Even back-up scenarios for failing internet connections were created.

Tutorials

The eventual meeting provided interesting tutorials, keynotes and general sessions. The tutorials were well visited, partly because the ASML-sponsored scholarships reimbursed the costs for the winning Ph.D. students. In his entry-level tutorial, Amir Barati Farimani (Figure 1), assistant professor in the Department of Mechanical Engineering at Carnegie

Meeting focus: mechatronic systems

Mechatronic systems are critical to a wide range of advanced manufacturing and automation processes. The importance of precision mechatronic system control is only expected to rise with the strong push for smarter and more automated manufacturing processes, as well as systems driven by Industry 4.0. Mechatronic systems in the age of Industry 4.0 are more likely to integrate traditional technologies (i.e. mechanical elements, actuators, sensors, drives, and control algorithms) with emerging technologies like cloud computing, big data analytics and artificial intelligence to achieve high performance.

These degrees of freedom bring new opportunities and challenges for precision mechatronic system design and control, but often lack easily specified requirements on dynamic performance. Many of the frequency-domain tools familiar to control system designers do not readily translate into the time-domain performance that defines system throughput, and quasi-static machine accuracy specifications are of limited usefulness in describing the motion of a lightweight, high-speed tool at a point somewhat distant from the feedback sensors. In addition, the multi-domain nature of mechatronic systems requires designers to be able to trade cost and complexity between the mechanical elements, actuators, sensors, drives, and algorithms that constitute a mechatronic system.

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Amir Barati Farimani: Machine learning and reinforcement learning.

Tom Oomen: Advanced feedforward and iterative learning control.

Ton Peijnenburg: Perspectives on precision mechatronics.

S.V. Sreenivasan: Nanomanufacturing. (Photo: University of Texas)

Sangbae Kim: Robots with physical intelligence. (Photo: MIT)

Mellon University, explained machine learning and reinforcement learning, and reviewed case studies of interest to precision and control engineers with a focus on reinforcement learning. Interactively, the potential for application in precision mechatronics was discussed.

Tom Oomen (Figure 2), associate professor at Eindhoven University of Technology (TU/e), presented a well-received tutorial on advanced feedforward and iterative learning control (ILC) for precision mechatronics. He gave an overview of optimisation-based ILC techniques and outlined their advantages and disadvantages. ILC algorithms achieve exceptional performance for repeating tasks; however, they are far from standard in industrial practice. One of the key reasons is that ILC cannot deal with varying tasks. Therefore, new concepts for advanced feedforward control have been developed in recent years. Oomen discussed extensions of the design framework to multivariable systems, as well as several recent connections to machine learning techniques.

Keynotes

The first keynote was by Ton Peijnenburg (Figure 3) from VDL ETG and TU/e. He presented some interesting views on mechatronics, from the perspectives of both a tier-one design & contract manufacturing partner (VDL ETG) and the TU/e High Tech Systems Center, touching on topics such as AI and machine learning, additive manufacturing, contamination control, robotics and systems engineering. He highlighted the importance of systems engineering for mechatronic design, and the interaction between computer science and the more hardware-oriented mechatronic disciplines was also discussed. Improving on this cooperation could really advance the creation of smart industrial solutions, he concluded.

The second keynote, by S.V. Sreenivasan (Figure 4), director of the NASCENT Engineering Research Center and a professor at the University of Texas, was concerned with scalable nanomanufacturing solutions enabled by precision systems, metrology and real-time control. Common challenges across the nanomanufacturing systems investigated – featuring nanoimprint lithography, high-speed multi-nozzle piezo inkjet systems and deep silicon chemical etching – include: (i) lack of reliable and validated system-level models; (ii) multi-scale physics coupled with parameter uncertainty; and (iii) incomplete in-situ sensing that creates gaps in system understanding. Sreenivasan advocated the use of 'physical analytics', which combines pure data analytics and first-principle modelling as the way to go forward.

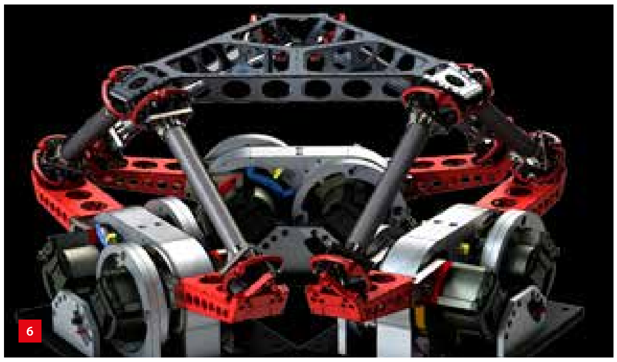
The last keynote lecture, presented by Sangbae Kim (Figure 5), director of the Biomimetic Robotics Laboratory and an associate professor of mechanical engineering at MIT, was about robots with 'physical intelligence' for future robot applications such as elderly care, home service, delivery, and services in environments unfavourable for humans. While industrial robots are effective in repetitive, precise kinematic tasks in factories, the design and control of these robots are not suited for the physically interactive performance that humans do easily. These tasks require 'physical intelligence' through complex dynamic interactions with environments, whereas conventional robots are designed primarily for position control.

Kim attempts to create such robots, in an effort to match the unconscious proprioceptive response of humans: for example, robust four-legged walking robots realised by combining low inertia with high-bandwidth collocated force control and low-bandwidth model-predictive control. Kim showed the latest version of the MIT Cheetah robots (see the video from 2019, [V1]), as well as force-feedback teleoperation arms.

General sessions

The general sessions covered a range of precision mechatronics control topics, from advances in motors, sensing and modelling, to learning types of control and novel mechatronic concepts. In the short virtual presentations, the presenters mostly clearly highlighted the rationale behind their approach. In the breakout sessions, scheduled in parallel after each presentation session, method and details were discussed with the audience. Many presenters brought additional material to support the discussion.

Sil Spanjer from the University of Twente presented his work on the T-Flex, a fully elastic, parallel six-degree-of-freedom (6-DoF) robot, which combines a full flexure mechanical design with novel elastic hinges, optimised feedback control and physics-based learning control (Figure 6). These features enable a combination of 6-DoF motion in the decimeter range with accuracy in the sub-micron range, as well as multi-g accelerations, while having micron-level tracking accuracy. He presented the first results on learning the very repeatable dynamics of a base joint of the robot. Over 95 per cent of the motor current can be predicted by learning, thereby improving tracking. Discussion focused on the repeatability of end-effector motion of the mechanics in view of hysteresis in the elastic joints. This effect is expected to be small, since hysteresis in the elastic deformations of the joints is either measured or counteracted by incompliant (directions of) elements, which helps in 'learning' much of the remaining five per cent. This is supported by measurements on a preliminary version of the complete system.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T-Flex, a fully elastic, parallel 6-DoF robot, as presented by Sil Spanjer.

Conclusion

The meeting was a success, as witnessed by oral feedback and a survey among participants; the tutorials, keynotes and general sessions were judged as great. The breakout sessions turned out to be a worthwhile innovation, providing the opportunity for intense discussions. The main downside of the virtual event nature was the limited (spontaneous) social interaction and networking opportunities. This, however, did not outweigh the advantages and most participants would visit a virtual event again in future.

VIDEO

[V1] Backflipping MIT Mini Cheetah, *www.youtube.com/watch?v=xNeZWP5Mx9s*

INFORMATION
WWW.ASPE.NET

UPCOMING **EVENTS**

Please check for any rescheduling, online reformatting or cancellation of events due to the coronavirus crisis.

Virtual event

7-11 September 2020

European Optical Society Annual Meeting 2020

This event provides a platform for experts in the field of optics and photonics, bridging the gap between research, education and industry.

WWW.MYEOS.ORG/EVENTS/EOS/EOSAM2020.HTML

15-18 September 2020, Geneva (CH)

EPHJ Exhibition

Trade show presenting technological innovation and expertise in the watchmaking and jewellery, microtechnology and medical technology sectors.

WWW.EPHJ.CH

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23 September 2020, Den Bosch (NL)

Dutch System Architecting Conference

The third edition of this conference features system architecting as a distinguishing discipline in the development and commercialisation of complex systems, products and machines.

WWW.SYSARCH.NL

6-8 October 2020, Braunschweig (DE)

Special Interest Group Meeting: Structured & Freeform Surfaces

A special focus will be given to research fields in the following topics: replication techniques, structured surfaces to affect function, precision freeform surfaces, large-scale surface structuring, and surfaces for nanomanufacturing and metrology.

WWW.EUSPEN.EU

19-23 October 2020, Minneapolis (MN, USA)

35th ASPE Annual Meeting

Meeting of the American Society for Precision Engineering, introducing new concepts, processes, equipment, and products while highlighting recent advances in precision measurement, design, control, and fabrication.

WWW.ASPE.NET

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20 October 2020, Veldhoven (NL)

Vision, Robotics & Motion

Network event on flexible, reliable, safe and fast manufacturing as facilitated by automation, robotics, machine vision and motion control.

WWW.MIKROCENTRUM.NL

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29 October 2020, Veldhoven (NL)

Technology for Automotive 2020

Organised by RAI AutomotiveNL and Mikrocentrum, combining the Automotive Congres and the AutomotiveNL Supplier Day. Topics include green & smart mobility, manufacturing & logistics and materials & design.

WWW.TECHNOLOGYFORAUTOMOTIVE.COM

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4 November 2020, Bussum (NL)

National Contamination Control Symposium

Event, organised by VCCN (Dutch Contamination Control Society), comprising a lecture programme, tutorials and an exhibition.

WWW.VCCN.NL

16-18 November 2020, Veldhoven (NL)

Special Interest Group Meeting: Precision Motion Systems & Control

The first edition of this SIG Meeting is organised prior to and partly in parallel with the Precision Fair 2020 (see below).

WWW.EUSPEN.EU

18-19 November 2020, Veldhoven (NL)

Precision Fair 2020

Twentieth edition of the Benelux premier trade fair and conference on precision engineering, organised by Mikrocentrum.

WWW.PRECISIEBEURS.NL

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26 November 2020, Utrecht (NL)

Dutch Industrial Suppliers & Customer Awards 2019

Event organised by Link Magazine, with awards for best knowledge supplier and best logistics supplier, and the Best Customer Award.

WWW.LINKMAGAZINE.NL

3-4 December 2020, Utrecht (NL)

International MicroNanoConference 2020

A wide range of technologies are presented, covering fields such as Health & Life science, Agro & Food, Sustainability & Energy, and Manufacturing & Engineering.

WWW.MICRONANOCONFERENCE.ORG

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2 February 2021, Veldhoven (NL)

CLEAN 2021

This theme day, organised by Mikrocentrum, provides an expert's view on cleanliness, focusing on design, production, assembly and packaging.

WWW.MIKROCENTRUM.NL

March 2021, UK

Lamdamap 2021

Fourteenth edition of this event, focused on laser metrology, coordinate measuring machine, and machine tool performance.

WWW.EUSPEN.EU

3D PRINTING FOR DIRECT RAPID SOFT TOOLING

There is a compelling drive towards the use of additive manufacturing (AM) to manufacture mould tools. Micro-AM platform developer, Nanofabrica, has 3D-printed micromoulds that have been used to shoot dozens of parts in a variety of materials. Thus, hitherto unattainable levels of precision demanded when manufacturing parts with microlevel tolerances have been achieved for the very first time through the use of AM-produced soft tooling.

JON DONNER

As AM matures, there is increasing interest in using AM for the production of mould tools, so called direct rapid soft tooling (DRST). DRST is especially well suited to scenarios in which the goal is small-series production where the cost of a traditionally manufactured tool is prohibitive, and it is also much easier and inexpensive to apply design changes. In addition, increased tool complexity can be accommodated at no extra expense, while increased complexity with traditional micro-injection moulding tools invariably leads to exponential increases in associated time and cost. Hence, Nanofabrica recently assessed the viability of creating AM-produced DRST for short-run production parts and functional prototypes.

Nanofabrica's AM process encapsulated in its Tera 250 AM platform (Figure 1) uses an ultrahigh resolution Digital Light Processor (DLP) engine, achieving repeatable micron-levels of resolution by combining the DLP engine with adaptive optics that electronically controls various critical optical working point parameters such as focus, tilt, and astigmatism. The DLP unit is placed on an optomechanical apparatus which facilitates real-time corrections of other working parameters, mainly location and accuracy in the XY plane. For example, laser distance measurements are used to correct positioning errors. The apparatus also corrects for degrees of freedom such as wobbling to achieve better surface finish on parts. In this way, using an array of sensors, a closed feedback loop is realised, which is at the heart of why the technology achieves very high accuracy while remaining cost-effective as a manufacturing solution.

1

Nanofabrica's Tera 250 AM platform.

Trial results

In its recent experiments, Nanofabrica succeeded in injecting PP, PE and ABS into a 3D-printed mould (Figure 2), which was manufactured with a new material that the company is currently developing. Excellent surface finish was also achieved with an R_z (peak-to-valley) of 0.8 μm in the hardest direction, and an R_z of better than 0.1 μm in the Z-plane. The moulds lasted for 20 shots with a moulding pressure of 400 bar at 230 °C. It took an hour to additively manufacture one mould at the cost of under $20. The materials were injected using an Arburg 35-ton machine.

Nanofabrica is now finetuning the manufacture of its DRST through a combination of design optimisation and improvements in materials. It is working on improving both the material (giving it much higher temperature resistance and strength) as well as the process (focusing on improving the impact pressure and stiffness of the printed soft tool) with the aim of handling tougher injection conditions and a bigger array of injected materials. The aim for the moulds is to last 1,000 shots in the coming months accommodating temperatures of 350 °C and pressures of 800 bar.

AUTHOR'S NOTE

Jon Donner is the co-founder and CEO of Nanofabrica, based in Tel Aviv, Israel. He earned his Ph.D. in nano-optics in Prof. Romain Quidant's Plasmon Nano-Optics group at ICFO in Barcelona, Spain, following a double degree from Tel-Aviv University in physics and electrical engineering.

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www.nano-fabrica.com

AM-produced soft mould tool. (Image: Idan Gil)

Business perspective

These trials should stimulate the business case for a process chain that includes DRST, with a dramatically shorter lead time of about two hours from file to injected part and at costs reduced from thousands to tens of dollars. Using Nanofabrica's Tera 250 precision AM platform to produce DRST capable of manufacturing upwards of 1,000 parts per tool opens up the possibility of small- and even medium-batch manufacturing. Multiple small tools can be manufactured in each AM build, and so manufacturers will be able to produce numerous replacement tools at extremely low cost. In the future, for the cost of one aluminium precise mould (about $10K) one could manufacture 500 soft moulds, leading to about 500K final parts through a significantly faster process. In addition, each tool can be adapted as required, opening up the possibility of increasing speed to first part out, and the ability to correct during the manufacturing process according to market and customer needs.

Moreover, the fact that AM is relatively agnostic to complexity means that AM-produced DRST could also stimulate innovation in product design and manufacture, as well as shorten the product update cycle by preventing manufacturers from shelving product design updates due to the cost of new traditional moulds.

VIDEO

- Nanofabrica: Soft Molds, *www.youtube.com/watch?time_continue=47&v=E6BcqomIleM&feature=emb_logo*

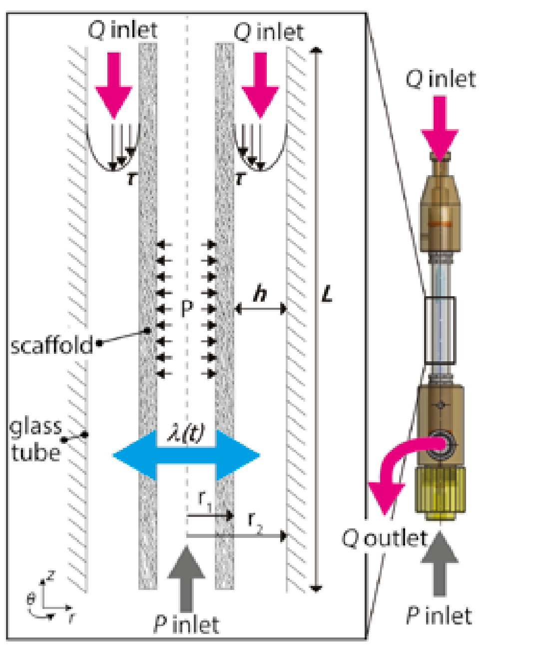
BUILDING AN ARTIFICIAL BLOOD VESSEL

The replacement of cardiovascular tissues is of vital importance in today's healthcare. Instead of applying vessels of biological or synthetic origin, however, it would be magnificent if the human heart could be stimulated to produce such new parts from its own tissue. This could be realised by implanting a smart prosthesis, called a scaffold, to locally incite a regenerative response. To explore such a futuristic tour de force, researchers at Eindhoven University of Technology (TU/e) built a bioreactor to investigate the response of human cells to dynamic blood circulation.

FRANS ZUURVEEN

Essential to the success of this medical tour de force is the human body's ability to regenerate itself locally. In that process, macrophages play an important part. These cells are based on white blood cells and are part of the human immune system. They are able to engulf and digest cellular debris and foreign substances like microbes and other enemies.

TU/e scientists Tamar Wissing [1] and Eline van Haaften [2] have developed a small bioreactor with an artificial blood vessel to investigate the hemodynamic (blood-flow correlated) loading of the vessel (see Figure 1). For the easy application of cyclic and shear stresses, the vessel simulates a blood vessel turned inside out: the shear-stress-active surface on the outside and the cyclic-stress-active surface on the inside.



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The bioreactor consisting of a tubular scaffold with outer radius r_1 = 1.7 mm, centred in a glass tube with inner radius r_2 = 2.3 mm. P is the internal pressure for generating cyclic stress λ(t), Q_{inlet} is the laminar flow for generating wall shear stress τ. The technical set-up is shown at the right.

Making a scaffold base

The artificial blood vessel should be able to function as a smart scaffold, a base that directs cells to infiltrate locally, with the aim of growing and forming new tissue. For that purpose, it needs to have a porous structure to accommodate cellular infiltration. PCL-BU plastic has been selected as the basic material for the synthetic blood vessel. PCL-BU is the abbreviation of polycaprolactone bis-urea, a so-called supramolecular material with arrays of monomeric units that self-assemble to form polymeric networks. Electrospinning technology has been applied to make porous PCL-BU tubes.

Figure 2 shows the principle of electrospinning. It is a fibre production method that uses electric force to draw charged polymer threads. In this case, the collector is a thin, rotatable mandrel to which the spun thread is directed by electrostatic forces. By moving the plastic-fluid injector alongside the rotating mandrel, a tube is formed. When the required thickness has been reached, a usable scaffold results by carefully removing the tube. Given a wall thickness of about 200 µm, this is undoubtedly a challenging precision-technological process.
The TU/e scaffolds were produced with equipment from IME Technologies [3]. Despite the simplicity of the process at first glance, the physics involved is actually rather complex, according to IME. There are numerous material parameters and processing conditions that affect the electrospinning result. Optimising all these parameters for a specific application requires in-depth knowledge of – and practical experience with – the electrospinning process. Furthermore, the electrospinning equipment used should provide optimal control over the relevant parameters while keeping interference with the process to a minimum.

Producing hemodynamic stresses

The ultimate purpose of designing this artificial blood vessel set-up is the investigation of the influence of hemodynamic

AUTHOR'S NOTE

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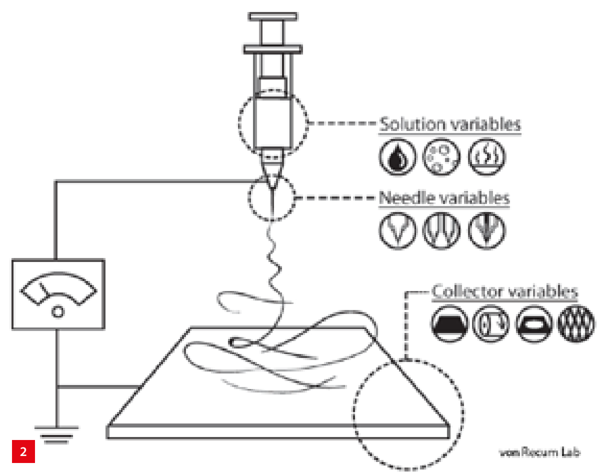

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Schematics of electrospinning, involving a syringe pump attached to a small nozzle, a conductive collector and a high-voltage power source in between. (Image: Delv0n2, Wikipedia)

loading, i.e. cyclic stress and shear stresses, on the formation of new cardiovascular tissue. Figure 3 shows how different levels of loading can be obtained by varying fluid flows Q_{inlet} and Q_{outlet}, as well as pressure P_{inlet}, as indicated in Figure 1.

The various applied hemodynamic forces from Figure 3 involve the cyclic stress $\lambda(t)$ due to internal pressure P in the scaffold tube, and wall shear stress τ due to laminar flow (also called Poisseuille flow) in the space between scaffold and outer glass tube. The dimensionless Reynolds number Re learns when laminar flow becomes turbulent flow. $Re = \rho v L/\eta$, with ρ the specific mass, v the flow velocity, L the length and η the dynamic viscosity. Among other parameters, high viscosity causes flow to become laminar. A relatively high shear stress between fluid and wall characterises laminar flow when compared with turbulent flow.

Finishing the scaffold

Figure 4 shows scanning electron microscope (SEM) images of tubular electrospun fibres with 5 µm diameter, which together form the tubular scaffold. These fibres look rather tangled, but this is a favourable property for the infiltration of cells. Figure 5 shows the scaffold before infiltration.

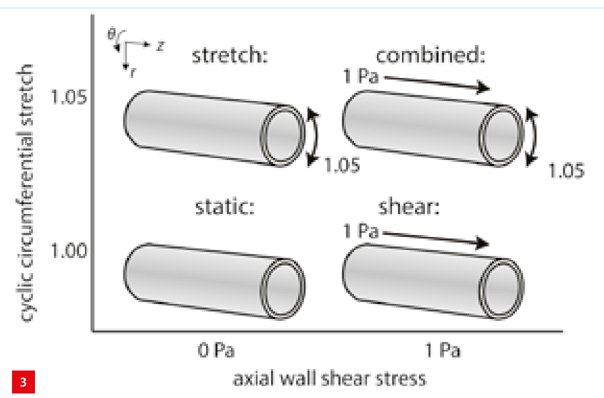

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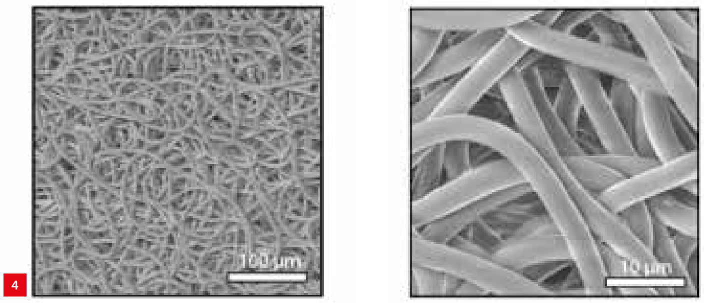
Figure 3. Applied cyclic, shear and combined stresses due to internal pressure P and laminar flow Q_{inlet}, as shown in Figure 1.



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Two SEM images with different magnifications of tubular electrospun PCL-BU plastic for accommodating macrophage cells.

PCL-BU tubes are infiltrated by macrophages derived directly from the patient's blood. Without going into further detail regarding the ultimate scaffold producing process, it can be stated that an important role is played by fibrin, an essential blood component for producing a fibrous protein during the blood-clotting process.
A difficult assessment must be made when designing scaffolds for real vascular applications. On the one hand, they need to fulfil the functions described above; on the other, they must degrade after having fulfilled their tissue-producing task. Ultimately, long-term scaffold presence will result in scar formation and the failure of the prosthesis scaffold. The results of tests with this artificial blood vessel set-up may help in this practical assessment. The set-up also helps researchers to understand the underlying cellular processes and will contribute to bringing scaffolds efficiently into clinical practice.

To conclude

The TU/e blood vessel experiments [4] demonstrate the impact of variations in hemodynamic loading on the biological processes in scaffolds. This research underlines the added value of using precision technology to improve cardiovascular healthcare. Of very great interest is learning how mechanical technology can improve 'futuristic' vascular healthcare: heart surgery almost without using non-human components.

5

The scaffold before the infiltration of macrophages; scale division 1 mm.

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[2] E.E. van Haaften, "On the impact of the mechanical environment in vascular tissue engineering, an in-vitro study", Ph.D. thesis, Eindhoven University of Technology, 2019.
[3] *www.ime-electrospinning.com*
[4] E. van Haaften, T. Wissing, and C.M. Rutten, "Decoupling the Effect of Shear Stress and Stress on Tissue Growth and Remodeling in a Vascular Graft", *Tissue Engineering Part C: Methods*, 24(7), pp. 418-429, 2018.

ECP² COURSE CALENDAR

COURSE (content partner)	ECP² points	Provider	Starting date
FOUNDATION			
Mechatronics System Design - part 1 (MA)	5	HTI	12 October 2020
Mechatronics System Design - part 2 (MA)	5	HTI	5 October 2020
Fundamentals of Metrology	4	NPL	to be planned
Design Principles	3	MC	13 October 2020
System Architecting (S&SA)	5	HTI	28 September 2020
Design Principles for Precision Engineering (MA)	5	HTI	to be planned (2021)
Motion Control Tuning (MA)	6	HTI	23 November 2020
ADVANCED			
Metrology and Calibration of Mechatronic Systems (MA)	3	HTI	27 October 2020
Surface Metrology; Instrumentation and Characterisation	3	HUD	to be planned
Actuation and Power Electronics (MA)	3	HTI	16 November 2020
Thermal Effects in Mechatronic Systems (MA)	3	HTI	8 September 2020
Dynamics and Modelling (MA)	3	HTI	23 November 2020
Manufacturability	5	LiS	to be planned
Green Belt Design for Six Sigma	4	HI	31 August 2020
RF1 Life Data Analysis and Reliability Testing	3	HI	14 September 2020
Ultra-Precision Manufacturing and Metrology	5	CRANF	to be planned
SPECIFIC			
Applied Optics (T2Prof)	6.5	HTI	26 October 2020
Advanced Optics	6.5	MC	17 September 2020
Machine Vision for Mechatronic Systems (MA)	2	HTI	upon request
Electronics for Non-Electronic Engineers – Analog (T2Prof)	6	HTI	to be planned
Electronics for Non-Electronic Engineers – Digital (T2Prof)	4	HTI	to be planned
Modern Optics for Optical Designers (T2Prof) - part 1	7.5	HTI	18 September 2020
Modern Optics for Optical Designers (T2Prof) - part 2	7.5	HTI	11 September 2020
Tribology	4	MC	27 October 2020
Basics & Design Principles for Ultra-Clean Vacuum (MA)	4	HTI	2 November 2020
Experimental Techniques in Mechatronics (MA)	3	HTI	30 November 2020
Advanced Motion Control (MA)	5	HTI	26 October 2020
Advanced Feedforward & Learning Control (MA)	2	HTI	30 September 2020
Advanced Mechatronic System Design (MA)	6	HTI	to be planned (2020)
Passive Damping for High Tech Systems (MA)	3	HTI	17 November 2020
Finite Element Method	2	MC	29 October 2020
Design for Manufacturing (Schout DfM)	3	HTI	15 October 2020

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.

WWW.ECP2.EU

Course providers

- High Tech Institute (HTI)
  WWW.HIGHTECHINSTITUTE.NL
- Mikrocentrum (MC)
  WWW.MIKROCENTRUM.NL
- LiS Academy (LiS)
  WWW.LISACADEMY.NL
- Holland Innovative (HI)
  WWW.HOLLANDINNOVATIVE.NL
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- Systems & Software Academy (S&SA)

Europe’s first quantum computer in the cloud

This April, Europe’s first public quantum computing platform, Quantum Inspire, was launched. The platform was developed by QuTech, based in Delft (NL). QuTech is a collaboration between Delft University of Technology and TNO. With Quantum Inspire, it aims to make quantum computers accessible to the market and society as quickly as possible by providing a platform for training, education and the development of applications.

A quantum computer performs its calculations using quantum versions of bits – so-called qubits. As a world first, Quantum Inspire contains a processor made of highly promising semiconductor ‘spin qubits’. The electron spin qubit is made with the same technique as a classic transistor and is just as small. This makes it suitable for mass production. The platform also provides access to a processor made of superconducting (transmon) qubits – a unique combination. Users can experiment with quantum algorithms and compare the processors.

The quantum computer is seen as a key technology, enabling radically new products and services. It has the potential to solve certain problems much faster than ‘classical’ computers will ever be able to achieve. One example is helping to unravel the complex behaviour of molecules for drug development. Quantum computers calculate using the fundamental laws of quantum mechanics, so the qubits can be both 0 and 1 at the same time. This changes dramatically what can be achieved with some calculations.

Quantum Inspire consists of a number of layers including quantum chip hardware, classical control electronics, a quantum compiler and a software front-end with a cloud-accessible web interface. Such a system is called a full stack. Full-stack systems are essential testbeds for understanding this novel computational paradigm. They can act as technology accelerators because only through careful analysis of the individual system layers and their interdependencies it becomes possible to detect the gaps and necessary next steps in the innovation roadmap and supply chain.

(Photo: Marieke de Lorijn, QuTech)

WWW.QUANTUM-INSPIRE.COM

Robots in the vineyard

In France's Bordeaux region, robots ensure that the wine is organically good. They autonomously eliminate grass and weeds between the vines, making pesticides unnecessar y. To enable the robots to navigate the hilly terrain, the developers took some cues from Mars rovers. The Vitirover, developed by the eponymous company in Saint-Emilion, is one of these robots. It is a fully autonomous lawn mower powered by solar energy. About twenty of these robotic mowers are in use in the vineyards.

This year, Vitirover will deliver 200 more robots, for example for use along railway tracks or in photovoltaics plants. The main benefit of the robot is that it is environmentally friendly and helps to make organic wine. The use of the robot in the vineyards makes pesticides like glyphosate unnecessary. In addition, the robot protects the soil by avoiding the compaction that may be caused by tractors or horses.

As it turned out in the development phase, the unstable soil in the vineyards is quite similar to the surface of Mars. This is why, when drafting the first design specifications, Vitirover collaborated with the European Space Agency (ESA) to review the designs of all of the robots that were developed for Mars missions. The robot negotiates rocky, often steep terrain and is exposed to mechanical stresses every twelve seconds, on average.

The requirements for its motorisation were accordingly high. The mechatronic solutions are the result of a partnership between Vitirover and mdp (maxon France) that goes back more than eight years. The robot is driven by four DC motors, one per wheel. They are brushed DCX 22 L drives that offer maximum power density in a very small installation space. They are highly efficient, which is important in battery operation. The greatest challenge however was elsewhere, namely the three blades that are driven by DCX 32 L series DC motors. The high load tended to damage the ball bearings of the motors, which led to failures. The engineers at maxon finally developed an aluminium bell housing for sustainable protection.

The Vitirover is only 70 cm long and weighs slightly under 20 kg. It cuts grass and weeds at a rate of 300 m/h. (Photo: Sylbie Monin, Vitirover)

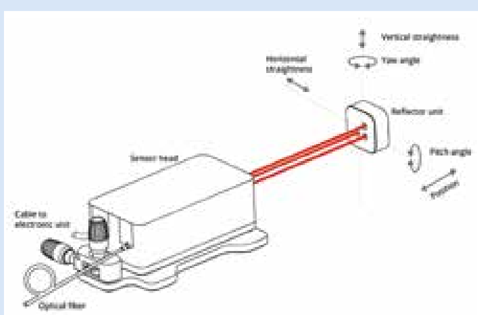
WWW.VITIROVER.FR
WWW.MAXON.COM

Simultaneous length and angle measurement

Many applications in industry and research require high-precision simultaneous displacement and angle measurements. Fast set-up and easy adjustment are particularly important. Triple-beam laser interferometers are precision-length-measuring devices that combine three interferometers in one device. The same highly stable laser frequency is used in all three measuring channels. Thus, three length values can be measured simultaneously with sub-nanometer accuracy. The corresponding angle can be determined with high precision from the difference between two length values and the calibrated beam distance.

SIOS, represented in the Netherlands by Te Lintelo Systems, has launched the Interferometer SP 5000 TR for simultaneous length and angle measurement. The system has a modular design and can therefore be adapted to a wide variety of measurement tasks. The interferometer has a measuring range of more than 5 m, dynamics up to 3 m/s and a sub-nanometer resolution. For measurements with a reflector, an angle measuring range up to +/–12,5° is possible. The fibre-optic coupling of the sensor head and the optionally integrated beam direction detection support easy handling and adjustment. For large measuring ranges or calibration tasks, the use of wireless temperature sensors or the climate measuring station LCS is recommended. The compact and robust design of the three-beam interferometer makes it ideal for high-precision measurements in industry and research and as an OEM instrument.

WWW.SIOS.COM
WWW.TLSBV.NL



Hexapod simulation

Which hexapod is suitable for a specific application and how do external factors influence the limits of the workspace and load? With the hexapod simulation tool from PI (Physik Instrumente) the user can check even before making a decision on which model to buy whether a hexapod is suitable for the positioning task at hand and when it is, which model exactly is suitable. The user can simulate comfortably the workspace, the mechanical load due to masses and external forces, the reference coordinate system, or the pivot point, for example, without having to have in-depth specialist knowledge.

Parallel-kinematic hexapods often are a good alternative to stacked single-axis positioners when used in multi-axis positioning applications. They are more compact, achieve high dynamics on all axes, and they are available in many models for various loads and travel ranges.

Datasheet data only offers limited insight into which hexapod is suitable for a particular application. For example, the workspace limits of parallel kinematics vary according to the current position (translational and rotational coordinates), the current coordinates of the rotational point (pivot point), and the chosen reference coordinate system. With the help of the simulation tool, these limits can be calculated for standard hexapods in Cartesian coordinates, graphically represented, and adjusted to the respective application. Potential mechanical problems in the application can, therefore, already be found and solved without having to own a hexapod or controller.

The same holds true for the load limit value of the hexapod that also varies depending on a number of factors. These factors being the orientation of the hexapod when mounted, the planned load, and especially the position of the centre of mass, the respective position of the motion platform (translational and rotational coordinates) as well as the forces and the torques that work on the motion platform of the hexapod and on the individual struts. These influencing factors can also be simulated with the help of graphical elements such as sliders in order to find out which hexapod model is best suited for the application.

The free software from PI simulates real application situations and makes it easy to choose the right hexapod model. (Source: PI)

WWW.PI.WS/HEXAPODS/SOFTWARE

More AI, automotive and 5G tools from MathWorks

MathWorks' latest release, 2020a, which was launched last month, features a range of new capabilities in Matlab and Simulink. Matlab is a programming environment for algorithm development, data analysis, visualisation, and numeric computation. Simulink is a graphical environment for simulation and model-based design for multi-domain dynamic and embedded systems. The new release provides expanded AI capabilities for deep learning. Engineers can now train neural networks in the updated Deep Network Designer app, manage multiple deep learning experiments in a new Experiment Manager app, and choose from more network options to generate deep learning code.

R2020a also comes with major updates, including:

- Automotive engineers can more easily create driving scenarios using imported road data from high-definition geographic maps and optimise shift schedules for performance, fuel economy, and emissions analysis.
- For wireless engineers, Matlab support for 5G and WiFi-6 technologies has expanded with additional support for waveform generation and cell detection.

WWW.MATHWORKS.COM

Ultrasonic cleaning for sensitive substrates

Sensitive components such as monocrystalline wafers from the photovoltaic and semi-conductor industries as well as optical lenses and prisms and superfinely structured substrates place tough demands on component cleaning. The tiniest of contamination must be reliably removed without compromising the surface. Components must not be subjected to either excessive movement in the medium or excessively high levels of cavitation energy. For these demanding cleaning tasks, Weber Ultrasonics has developed the SonoPower 3S megasound system with frequencies from 500 to 1,000 kHz.

The system comprises a boost generator, which is available in the power classes 250 and 500 Watt, and the matching high-frequency plate transducers. The generator employs various innovative features to ensure that cleaning is gentle on the surface while soiling is removed reliably. These include combined frequency and amplitude modulation, which guarantees homogeneous sound fields and thus prevents standing waves. The scan that comes with the system automatically determines and sets the optimum operating frequency and monitors and adjusts it during the process. This guarantees that the ideal power output is always applied, even in the face of changing operating conditions such as temperature fluctuations or when cleaning and rinsing media are changed.

Weber's new boost generator and high-frequency plate transducer for ultrasonic cleaning of sensitive substrates.

Optimally adapted to the generator, the new high-frequency plate transducers enable an effective cavitation current and thereby efficient further processing of the clean components. The transducers are tailored to the standard dimensions of the wafer industry and can also be produced in other sizes upon request.

WWW.WEBER-ULTRASONICS.COM

Compact optical multiturn encoder

Industry requires small, light, flexible and safe devices designed to work alongside humans on the factory floor: collaborative robots (cobots). They feature lower cost, can be easily programmed by average personnel and are able to provide accurate diagnostic and maintenance information. Encoders for robotics from Lika Electronic, the Italian smart encoder and actuator manufacturer represented in the Netherlands by Tevel, are designed to meet this trend. They are compact with minimum footprint and low profile and are engineered to be integrated directly into motors and narrow spaces. For perfectly matching the new requirements, mechanical and electrical characteristics (through-bore diameter, PCB shape and size, resolution, interface, type of connection, etc.) can be customer-specific. This includes a comprehensive range of standard and frameless high-resolution encoders to suit the accurate position and speed feedback requirements of multi-axis robots. Lika's latest innovation is the AMM8A, an optical multiturn encoder in a small modular design. It comes in a compact, flat, frameless package (only 25 mm thickness) ideally suited for installation in constricted space. This hollow-shaft model offers a large internal diameter (25 mm through-bore) and enables contactless mechanics without integral bearings, preventing wear, friction, fatigue and mechanical stresses. Designed for demanding motion control applications, AMM8A provides high resolution up to 20 bits single turn (1,048,576 counts per rev.) and 16,384 revolutions – so, up to 34 bit overall resolution. An additional incremental track yields sine-cosine 1-V_{pp} signals for speed feedback.

WWW.LIKA.IT
WWW.TEVEL.NL

Asymmetric XY stages

US-based ALIO Industries has launched an innovative nanometer-level precision-positioning solution, asymmetric XY stages. "Over many years, ALIO has been developing precision-positioning solutions for applications that do not require identical travel lengths on both the X and the Y axes", ALIO CEO Bill Hennesey explains. "All the company's XY solutions are standard monolithic ones, because regardless of the requirements for X and Y travel lengths to be different, the alternative – stacked stages – will always compromise performance. Some alternative suppliers offer an XY stack comprising a single-axis crossed-roller stage, which results in poor static and especially poor dynamic performance related to tuning challenges. In these stacked configurations, the lack of lower axis torsional stiffness and the bending moments of the upper axis greatly limit the dynamic responsiveness of the stage."

Before the recent launch of its asymmetric XY stages, when confronted with the need to work with applications that required the accommodation of X and Y axis travel lengths that were not the same, ALIO would sometimes limit travel on the upper axis of its monolith XY stages. This would save on the overall moving footprint, but the square body of the stage would still be larger and heavier than it would need to be based on the required travel for the application.

Now, the new asymmetric stages provide a solution with identical performance, lower moving mass, and a smaller static and dynamic footprint compared to their square-body-designed, monolithic-series counterparts. They also offer a lower working height than traditional XY stacks and do not exhibit the tuning limitations of stacked assemblies. Three standard versions with asymmetric body designs / travel lengths are now available, while customised versions are offered for OEM programmes.

WWW.ALIOINDUSTRIES.COM

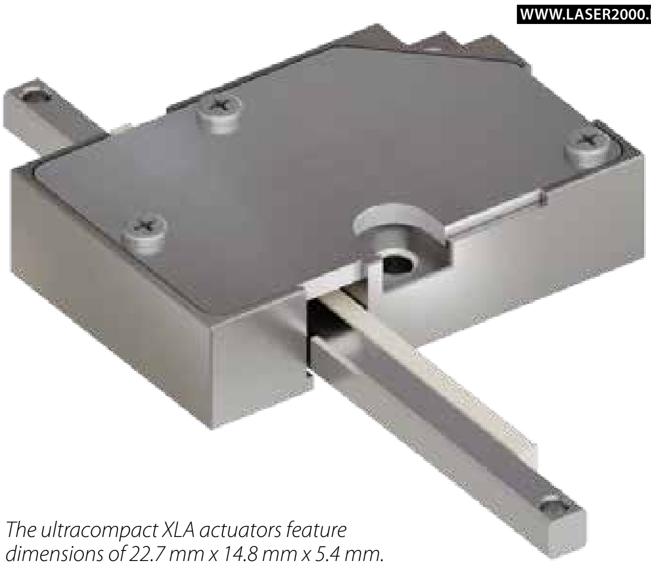
Ultracompact high-speed actuator with integrated encoder

Born out of the Micro & Precision Engineering research group of the KU Leuven university in Belgium, Xeryon was founded by three researchers in 2013. Xeryon focuses on ultrasonic piezo stages, the only noiseless piezo technology that allows high velocities and longer travel with nanometer precision. Xeryon has patented its Crossfixx™ motor, the fastest piezo motor in the world.

Xeryon, represented in the Netherlands by Laser 2000, presents its XLA piezo-driven linear actuator, the world's smallest high-speed actuator with integrated encoder, so the company claims. It comes in two versions, which are both driven by the Crossfixx motor, allowing an extremely compact design, speeds of 200 mm/s and a total weight of less than 6 g. Two cable positions are possible (top or side) and a wide range of rod lengths is available, allowing stroke lengths from 5 to 185 mm.

The XLA open-loop micro linear actuator features an integrated controller and end-to-end motion (using limit switches). Positioning resolution is 50-100 nm. The XLA closed-loop micro linear actuator features an external controller plus integrated position sensor (= go to any position), with 1250, 312 or 78 nm resolution.

WWW.XERYON.COM
WWW.LASER2000.NL



The ultracompact XLA actuators feature dimensions of 22.7 mm x 14.8 mm x 5.4 mm.

Smaller hexapod

At Optatec 2020, scheduled for 17-19 November 2020 in Frankfurt am Main (Germany), motion control specialist Aerotech will be showcasing its newly launched small hexapod HEX150. As its smallest hexapod, the HEX150 with a diameter of 150 mm and a height of 141 mm complements the existing HEX product range featuring diameters of 300 and 500 mm. With its 132 mm outside diameter moving platform (central through aperture of 35 mm diameter), the HEX150 can manipulate loads of up to 10 kg with travel ranges of up to 55 mm (linear) and 50° (rotation), and positioning speeds of up to 50 mm/s. The six degrees of freedom allow the multi-axis system to be used flexibly for a wide variety of applications.

Controlled with Aerotech's new Automation1 control platform, positioning accuracy specifications below 5 µm can be met. Potential applications lie in the manufacture and test of optical components, automotive sensors, electronics, and medical devices. The AC servo motors are connected directly to the ball-bearing spindle, which guarantees high drive stiffness. According to Aerotech, the HEX150 is currently the most precise hexapod on the market.

The new smaller hexapod HEX150 (left).

WWW.AEROTECH.COM

Compact rotary gripper module

Festo has introduced the extremely compact rotary gripper module EHMD for applications where small objects need to be gripped and turned in confined spaces. For example, it can be used in laboratory automation to open small sample vials with ease. The Z-module automatically adjusts to the thread pitches of the caps, eliminating the need for head/adapter changeover times.

Whether for in-vitro diagnostics, cell or genome research or quality inspections in the biotech and pharmaceutical industries, the EHMD is reliable for operations such as preparing and analysing samples, loading centrifuges, gripping, rotating and placing microwell plates or even opening and closing sample vials of different sizes. Combined with a 3D gantry and a camera, it can support quality inspections with cameras, recognise bar codes, or print labels with a label printer. It is also suited for use in light assembly or in the electronics industry.

The EHMD comes in two versions: fully electric or with a pneumatic gripper. Both permit infinite rotation. The optional assembly module with Z-compensation automatically adjusts to the thread pitch of the caps without moving the Z-axis. When powered by Festo's motor controller CMMO-ST, sample containers of unknown size can be gripped with varying levels of force.

WWW.FESTO.COM

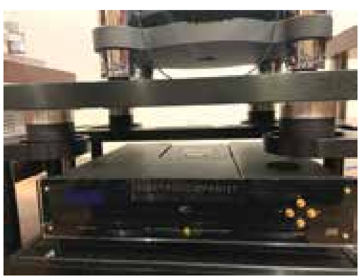
The EHMD module applied in laboratory automation.

Dampers and app help to eliminate bad vibrations

Shocks, oscillations and vibrations can ruin the listening experience of audiophile people. The engineers at the electronics company BaiRuiKe Technology in Shenzhen (China) develop and manufacture high-quality tube amplifiers and the corresponding components. They used to demonstrate the performance of the audio products in a specially designed demonstration room. When the noise from an adjacent workshop where punching labour was carried out proved to be too loud, action had to be taken. Worse than the pure audible volume from next door was the low-frequency interference coming from there, which was transmitted to the audio system.

To eliminate this interference under all circumstances, the Chinese branch of vibration control specialist ACE Stoßdämpfer was contacted. Their first duty was to filter out the oscillation frequency of 20 Hz, the lowest frequency that the human ear can perceive. For this purpose, four PLM-1 low-frequency pneumatic levelling mounts were provided. Usually they protect high-performance and precision machines from unwanted vibrations. A ratio of 1:1 between horizontal and vertical natural frequency ensures high stability and also a very long service life. With their extremely low natural frequency of 3 Hz, they are used as low-frequency vibration isolators in industrial environments, especially on measuring tables, highly sensitive test benches, high-speed presses and production systems.

With eight different types immediately available from stock and a performance that spans a load-carrying range from 45 to 8,800 kg, the small components provided by ACE isolate both individual devices as well as entire constructions from unwanted vibrations. They can easily be fitted and mounted post-construction or engineers can integrate them in the CAD design. Whichever way, these components can be ideally levelled with the help of an integrated valve. Used as a vibration damper, the internal air chamber provides a significant insulating effect from 5 Hz upwards. The PLM-1 is at the lower end of the load range, at 45 kg. For this reason, in this particular case four units were used in an initial test set-up for equipment of the upcoming hifi brand EIZZ.



Together with the low-frequency pneumatic levelling mounts (see the close-up), ACE Stoßdämpfer provided the app VibroChecker PRO, which turns smartphones into professional measuring devices simply by connecting an external USB sensor.

To objectify the first positive impressions, the VibroChecker PRO app together with the external USB sensor Digiducer 333D01 was used. This app, available from the Apple appstore, is the follow-up development of ACE's Vibro-Checker app, which was launched in 2014. The combination of app and USB sensor can turn an iPhone or iPad into a professional, yet lightweight and inexpensive measuring device with which vibrations of up to 8,000 Hz and down to 1 Hz can be measured and evaluated.

WWW.ACECONTROLS.COM
WWW.EIZZ.CN

Funding for asparagus harvesting robot

Cerescon, the developer of the very first selective asparagus harvesting robot, Sparter, has recently secured an additional 3 million euros in funding. Cerescon will be using this extra capital to boost sale and production of Sparter, after the 1-row self-propelling harvesting robot was put through its paces during this year's asparagus harvesting season.

The agricultural industry has seen a whole string of new developments in robotic technology recently. This is no less true in the asparagus sector. Finding sufficient workers to harvest the asparagus is still the biggest challenge facing asparagus growers. The problem has now been intensified by the Covid-19 crisis, increasing the necessity for automation in asparagus harvesting. Many growers are currently being confronted with a 30% shortfall in manual harvesters.

Cerescon must now rise to the challenge of producing Sparter in larger numbers commercially. Over a period of five years, Cerescon aims to expand production to 150 machines annually. They aim to achieve this by working with a number of partners – key players in the Brainport manufacturing industry. Cerescon focuses on R&D and seeks out partners for production, as well as for service and marketing.

Sparter's uniqueness lies in its subsurface detection sensor which not only helps reduce harvesting costs by 50%, but also leads to better quality asparagus being harvested. The technology of the detection has also been optimised, along with the integrated double harvesting robot, sand bed repair, asparagus transport and plastic handling. The self-propelled harvesting robot on caterpillar tracks has been demonstrated amongst a number of growers in the Netherlands and Germany this season. The concept of self-propulsion means no tractor and driver are needed. The 1-row Sparter, operated by one person, can replace a team of around 25 harvesters.

WWW.CERESCON.COM

Prototype of Sparter, the 1-row asparagus harvesting robot from Cerescon, in demonstration. The close-up shows the asparagus cutting knife.

Renishaw metal printer at Fontys

Fontys Engineering University of Applied Sciences in Eindhoven recently became the first such institution in the Netherlands to have a Renishaw AM 400 metal printer. At the same time, Fontys, as the first from the Dutch higher education system, has become a member of sector organisation Flam3D, an independent platform for additive manufacturing (AM) in Flanders (Belgium) and the Netherlands. The institution has also purchased a 3D scanner from GOM, to digitise objects and determine the accuracy of metal-printed products.

In its Objexlab, Fontys wants to focus more on AM, including metal printing, especially for the benefit of the industry in the Eindhoven region. Central questions in Fontys' pre-competitive research are: can metal printing enhance manufacturing efficiency; can products be improved; and can new business be created? In education, metal printing is now part of one of the minors, in which students can gain practical experience in calculating and designing, preparing, printing and finishing metal workpieces. Fontys will host its metal printing activities on the Brainport Industries Campus, where it aims to collaborate with the secondary vocational education sector, machine suppliers and 3D-printing initiatives.

WWW.FONTYS.NL
WWW.FLAM3D.BE
WWW.RENISHAW.COM
WWW.GOM.COM

The Renishaw AM 400 metal printer is equipped with a 400-W optical system, which gives a beam diameter of 70 µm and offers a build volume of 250 mm x 250 mm x 300 mm.

New NTS-Group CEO

Tjarko Bouman will become the CEO of the NTS-Group in Eindhoven (NL) on 1 August 2020. He will succeed the current CEO, Marc Hendrikse, who, on the same date, is leaving the group after 15 years. NTS develops, produces and assembles complex (opto) mechatronic systems and modules for large high-tech machine manufacturers. The group has grown significantly in recent years and achieved a turnover of approximately 280 million euros in 2019. With approximately 1,700 employees around the globe, including about 1,050 in the Netherlands, NTS is one of the larger employers in the high-tech sector. Bouman has extensive experience in international business and industry in general and the high-tech industry in particular. In his previous role, at Vanderlande, he was responsible for the warehousing and parcel business in large parts of Europe and Asia.

WWW.NTS-GROUP.NL

Tjarko Bouman, the new NTS-Group CEO.

Vertical integration – the key to micromoulding success

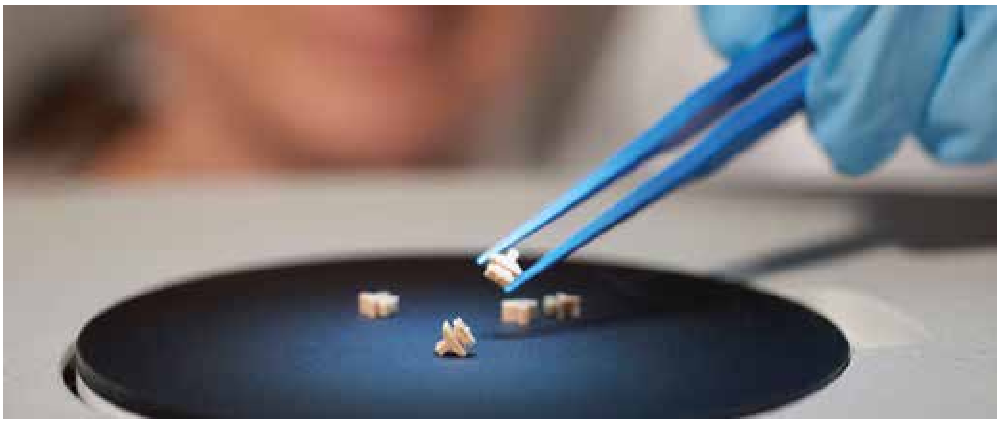
In micromoulding, the achievement of truly exacting and sometimes almost impossibly tight tolerances are key drivers, and sometimes the demand is for tiny thermoplastic parts and components with submicron feature sizes. When micron tolerances matter, the customer and micromoulding provider must enter into a close partnership in product development, and it becomes hugely important that the micromoulder owns, manages, develops, and innovates in every aspect of the supply chain, says Aaron Johnson, VP of marketing and customer strategy at US-based micromoulding specialist Accumold. Hence, vertical integration is required.

"The key is not just to control each element of the development process, but to have it residing under one roof. There is the obvious advantage of teams working together to create optimal outcomes, but there are also very practical reasons. When working in the world of micron tolerances, even shifting a part from one location to another to undertake metrology tests and validation can introduce errors as a humidity change can cause changes in part geometry."

A microproduct development process involves five stages: design & material assistance; micro tool design and fabrication; micromoulding; metrology & validation; automated assembly/packaging. Fundamentally, according to Johnson, a micromoulder should be able to influence the tricky area of design for micromanufacturing (DfMM), including design for tolerance achievement, optimal gate locations, flash and mismatch, prioritising and limiting critical dimensions, and material selection for optimal outcomes.

The objective of all micromoulding projects is the timely, cost-effective, repeatable manufacture of often complex and extremely accurate parts and components, Johnson concludes. The key is to get it right first time, and this can only be achieved by all teams in each stage of the product development process – from design to automated packaging – being engaged early in the process.

WWW.ACCU-MOLD.COM



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