DSPE MIKRONIEK

2021 (VOL. 61) ISSUE 2

PROFESSIONAL JOURNAL ON PRECISION ENGINEERING

- THEME: MICROSYSTEMS
- WATCH INNOVATION BASED ON COMPLIANT MECHANISMS
- DUAL-LOOP CONTROL STRATEGY TO COUNTERACT GEAR BACKLASH
- TUNING THE STIFFNESS OF COMPLIANT ORTHO-PLANAR MECHANISMS

MIKRONIEK IS A PUBLICATION OF THE DUTCH SOCIETY FOR PRECISION ENGINEERING – WWW.DSPE.NL

DSPE
YOUR PRECISION PORTAL

COURSE OPTO-MECHANICAL SYSTEM DESIGN

27, 28 & 29 September 2021
Eindhoven

The course focuses on the mechanical and mechatronic design for optical systems and is intended for mechanical, mechatronic and optical engineers involved in opto-mechanical system design.

The teachers will guide you through the diverse landscape of opto-mechanical system design. They will begin with the basics and show approaches and solutions for many design issues along the way. The teachers are experienced engineers, who know the tricks of the trade in opto-mechatronics, system architecture, system design and engineering, and opto-mechanical engineering.

Together they draw upon more than 100 years of experience in this field at Dutch universities and research institutes and in the high-tech industry.

Participants: Maximum of 25
Investment: Non DSPE members: 1800 euro
DSPE members: 1600 euro (excluding VAT)

Teachers

Lennino Cacace

Senior Opto-mechatronic System Architect in Research and Semiconductor at AC Opto-mechanix / Senior Researcher Fellow Opto-mechatronics at Delft University of Technology

Jan Nijenhuis

Senior System Engineer at TNO of opto-mechanical systems for space, astronomy and semiconductor industry

Pieter Kappelhof

Technology Manager, Hittech Group / Master track manager Opto-mechatronics, TUDelft / Track record as System Designer of optical systems in research and industry

Gabby Aitink-Kroes

Opto-mechanical systems-designer for (space)astronomy / Senior Design Engineer at the Netherlands Space Institute for Space Research (SRON)

www.dspe.nl/education

PUBLICATION INFORMATION

Objective
Professional journal on precision engineering and the official organ of DSPE, the Dutch Society for Precision Engineering. Mikroniek provides current information about scientific, technical and business developments in the fields of precision engineering, mechatronics and optics. The journal is read by researchers and professionals in charge of the development and realisation of advanced precision machinery.

DSPE
YOUR PRECISION PORTAL

Publisher
DSPE
Julie van Stiphout
High Tech Campus 1, 5656 AE Eindhoven
PO Box 80036, 5600 JW Eindhoven
info@dspe.nl, www.dspe.nl

Editor
Hans van Eerden, hans.vaneerden@dspe.nl

Advertising canvasser
Gerrit Kulsdom, Sales & Services
+31 (0)229 – 211 211, gerrit@salesandservices.nl

Design and realisation
Drukkerij Snep, Eindhoven
+31 (0)40 – 251 99 29, info@snep.nl

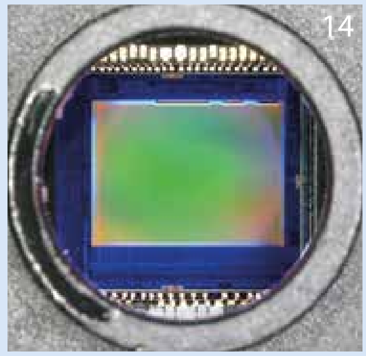
Subscription
Mikroniek is for DSPE members only.
DSPE membership is open to institutes, companies, self-employed professionals and private persons, and starts at € 80.00 (excl. VAT) per year.

Mikroniek appears six times a year.

ISSN 0026-3699

The cover image (featuring an exploded view of the Slimline Monolithic Manufacture) is courtesy of Frederique Constant. Read the article on page 5 ff.

IN THIS ISSUE



14

16

FEATURES

TO BE AGILE OR NOT TO BE?

In an ever faster-paced world, the answer is obvious: we should definitely be 'agile', to learn to adapt swiftly to different circumstances. Yet should we embrace the agile methodologies so popular in software development (Scrum, Scaled Agile Framework, etc.) in other disciplines such as precision engineering?

Software development walls often show flourishing post-it collections used by dynamic self-steering teams that deliver very frequent product updates for customers. Software development is now basically agile development around the globe. In extreme cases, it results in multiple releases every hour. Hardware development has been slower in adopting these agile technologies. The key advantage of software development is that innovation is faster and yields more results, with cross-silo development and more customisation, so it is not surprising that 'hardware companies' such as ASML (Scaled Agile Framework) and Bosch (Scrum at scale) are working currently on an agile transition.

However, this transition is not a straightforward one for hardware development, in the same vein as it was not easy for software development. To make software development agile, many steps require revision: requirements and test creations become intertwined; planning is critical; software testing needs automation; etc. Every aspect of the development process has to facilitate the creation of releases.

For precision engineering and hardware development in general, inherent limitations will not allow such extremely fast releases; for instance, material handling and transportation will always introduce delays. However, production with high flexibility is already possible: automotive production lines are succeeding in producing individual cars seconds apart. Hardware development is still far away from keeping up with this flexibility of the production process. Fortunately, for hardware engineering, many fields are progressing to enable agility: systems engineering is crossing the boundaries of disciplines (every boundary is a delay); digital engineering and digital twins are creating digital connectivity; 3D printing for prototyping/testing; platform development; etc.

Though all these fields and process supports are extremely important, we, humans, are the critical factor in achieving these fast innovations. Not surprisingly, agile methods encourage human interaction: the Manifesto for Agile Software Development (*www.agilemanifesto.org*) starts with "Individuals and interactions over processes and tools". Agile methods hence put heavy emphasis on self-steering teams, intense interaction between teams (program increment planning events), cross-disciplinary value chains (development trains), and customer involvement. This is equally so at Eindhoven Engine.

At Eindhoven Engine, we want to accelerate innovation to match the 'exponentiality' of the world. We are introducing agility in the transition from research to development, to accelerate a process that up until now is essentially linear (and time consuming). With currently 15 projects in key areas of the Brainport region (healthcare, mobility, precision engineering, etc.), the Eindhoven Engine ecosystem is building. Agile methodologies (self-steering teams, cross-disciplinarity, customer involvement) shorten the path to innovation. The realisation of innovation is powered by the integral support of bright minds at all levels from Eindhoven University of Technology, TNO and Fontys University of Applied Sciences (the founding fathers of Eindhoven Engine), hospitals and companies. If you are keen to be involved in our community or to actively participate in this ecosystem, do not hesitate to contact us.

Paul Desmedt
Programme manager at Eindhoven Engine
p.a.c.desmedt@tue.nl, www.eindhovenengine.nl

(Photo: Bart van Overbeeke)

SLIMLINE MONOLITHIC MANUFACTURE

Last month, Swiss watchmaker Frederique Constant launched a technological breakthrough in the field of precision timekeeping. Redefining the principles of mechanical watch regulation, its Slimline Monolithic Manufacture delivers industry-leading precision by ticking ten times faster than most mechanical movements. Etched from silicon, its monolithic oscillator, designed as a compliant mechanism by Dutch company Flexous Mechanisms, replaces an assembly of several parts and eliminates many of the major weaknesses of mechanical watches. The high-frequency oscillator fits inside a traditional movement configuration, housed inside a 40-mm case.

The way mechanical watches are regulated has not changed during the last three centuries. The invention of the sprung balance in the 17th century has exerted a lasting influence on mechanical watchmaking. Since then, mechanical watches have relied almost exclusively on the sprung balance. Consisting of a thin, coiled spring attached to the balance wheel, it allows the balance to oscillate back and forth at a constant frequency. In doing so, it controls the speed at which the gears of the watch rotate and influences the rate. Although it has been improved over time, the principle of the sprung balance has remained unchanged and virtually unchallenged for over three centuries.

1

Presented in a 40-mm round case, the Frederique Constant Slimline Monolithic Manufacture features an elegant dial with a guilloché/stamped hobnail pattern, printed Roman numerals paired with Breguet-style hands. The pulsating high-tech oscillator is visible in an aperture at 6 o'clock, while the pointer date at 12 o'clock was designed to create a classic counterpoint [V1].

Watch principles

The basic principle behind a mechanical watch is as follows:

Energy → Transmission → Escapement → Oscillator

The energy (stored by a coiled spring in a watch) is released in discrete bursts by the regulating organ, which is comprised of an escapement and an oscillator. The escapement transmits impulses to the oscillator (the balance wheel for the vast majority of mechanical wristwatches). The escapement, in turn, is regulated by the oscillator. Each oscillation, therefore, allows the gear train to advance or 'escape' a determined amount.
For a bit more background on watch principles, see the Slimline Monolithic Manufacture video [V1].

Compliant mechanisms

In watchmaking, compliant or flexible mechanisms are the next big thing, opening a new realm of possibilities. Given the elastic properties of certain materials like silicon, it is possible to create compact, precise monolithic components to replace some of the assembled mechanical parts. Frederique Constant now has used these flexible, jointless structures in the design of its revolutionary oscillator. They have replaced the 26 components of their standard assortment (i.e., assembly of watch components) with a single component fitted with two regulation weights. Made of monocrystalline silicon, the monolithic oscillator also integrates the escapement anchor in its flexible structure.

EDITORIAL NOTE

This article was based on the presentation during the press event for the launch of the Slimline Monolithic Manufacture, a press release by Frederique Constant, and input from Nima Tolou, CEO of Flexous Mechanisms.

Three innovations distinguish the oscillator:
1. A small-size one-piece oscillator.
   Thanks to the geometry of flexures and masses, it is possible to produce for the first time a flexible pivot oscillator in the footprint of a traditional balance wheel.
2. An ultrathin oscillator with a new anchor system.
   The escapement anchor is incorporated into the oscillator and, for the first time, its function is integrated into the flexures allowing a substantial reduction in size while keeping all the functions in one thin silicon layer.
3. Adjustment weights to regulate the flexure oscillator.
   These weights are just like those used on a traditional free-sprung balance. Watchmakers can easily fine-tune the frequency and precision by simply turning two weights.

Monolithic oscillator

Frederique Constant integrated the concept of a monolithic oscillator in its new Slimline Monolithic Manufacture watch design (Figure 1) and developed it in collaboration with Flexous Mechanisms (see the text box on the right). The distinctive technical objectives for an innovative flexure oscillator were straightforward:
1. A size comparable to that of a traditional balance to fit inside a standard movement with minor adjustments.
2. The highest possible frequency.
3. An 80-hour power reserve.
4. A cost-effective formula that would allow the manufacture of significant quantities at a reasonable price.

The engineering of the oscillator's flexures and geometry enabled reduction of its dimensions to the size of a conventional regulator and increased its frequency for enhanced accuracy. The new topology of the flexures and masses constitutes an unprecedented compact size for a flexure pivot oscillator (9.8 mm in diameter and 0.3 mm in thickness). For the very first time, the anchor has been integrated within the flexure. The design combines high frequency with low amplitude (6° versus ~300° for a regular balance wheel), which prevents excessive speeds in the mechanism and increases accuracy. For confidentiality reasons, no more details of the oscillator design can be disclosed.

While many traditional mechanical movements operate at a frequency of 28,800 vibrations per hour, the Slimline Monolithic Manufacture represents the first Swiss-made mechanical watch oscillating ten times faster, at 288,000

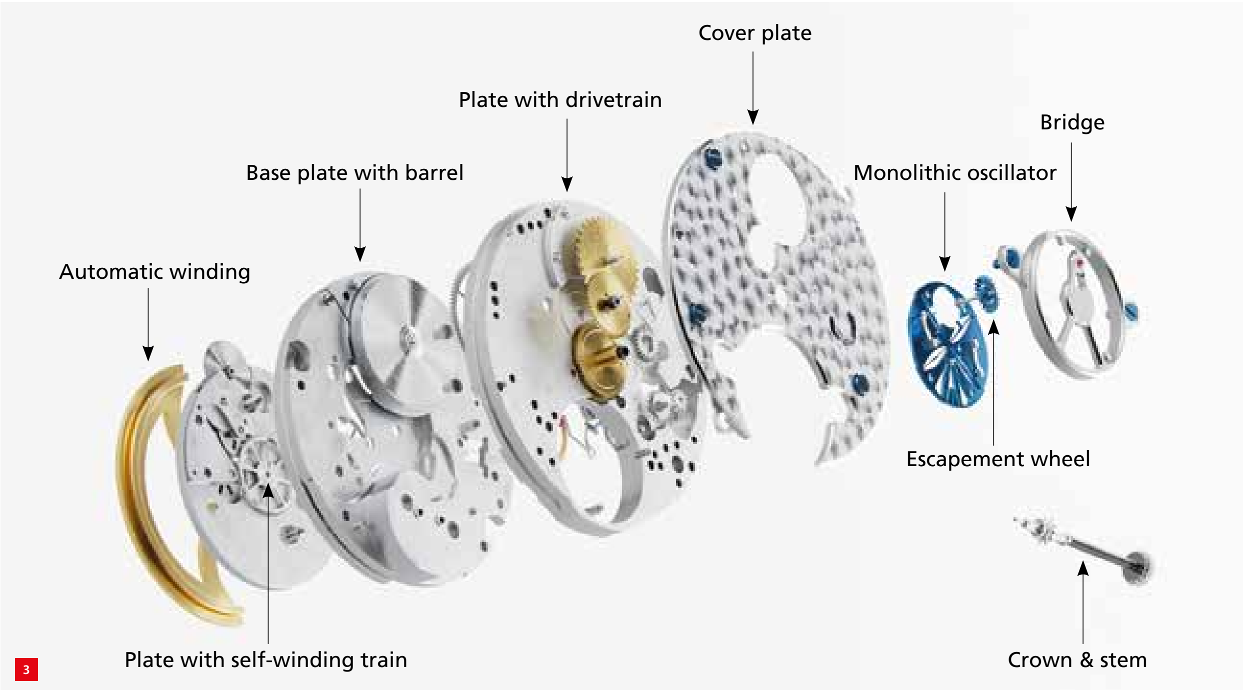
Watch partners

Frederique Constant is a watchmaking manufacture located in Geneva, Switzerland. The maison was founded in 1988, "to offer quality Swiss watches at competitive prices, with the aim of democratising luxury Swiss Made watches".

Flexous Mechanisms is an independent horology technology company specialised in the design and development of flexible watch parts with the focus on mechanical watches. Flexous was founded in 2012 in Delft (NL), as a spin-off of the research in the field of flexible mechanisms at Delft University of Technology. Flexous develops and produces custom-made innovative watch parts from concept to product, "to bridge the fields of traditional watch making and 21st century flexible mechanism design".

WWW.FREDERIQUE-CONSTANT.COM
WWW.FLEXOUS.COM

The new flexure oscillator.
(a) Close-up of the monolithic mechanism, containing a total of six flexures. The escapement wheel is shown in purple.
(b) Mounting of the adjustment weights.



Exploded view of the Slimline Monolithic Manufacture, showing the various components.

vibrations per hour, i.e. 40 Hz. Despite this high frequency, the efficiency of the mechanism delivers more than twice the run time of a regular watch.

The choice of material for the oscillator eliminates key weaknesses of traditional sprung balances. Monocrystalline silicon is 100% anti-magnetic, resilient to fluctuations in temperature (due to a specific treatment), less sensitive to gravity and four times lighter than a regular assortment. The absence of mechanical coupling means a lower generation of friction and wear on the parts. Consequently, less power is needed to drive the escapement wheel and the oscillating system. This results in reduced force between the components: 2.5 times less torque/couple is generated. In particular, the energy waste related to the stop & go motion of the Swiss lever escapement is eliminated. Finally, yet importantly, silicon does not require lubrication. This enhances the long-term reliability of the escapement and avoids the oiling demands generated by high frequency.

The rate regulation is performed using adjustment weights, just like the system used in a traditional free-sprung balance. The setting system is extremely precise, dividing time intervals in hundredths of a second versus tenths of a second for regular mechanical movements running at 4 Hz.

Given the innovative design of the escapement, the traditional devices to measure the rate of the movement (which rely on the ticking sound of the movement) are inoperative. To determine the average rate in seconds per day, laser cameras taking 250,000 images per second were used.

Smooth motion

It soon became apparent that a traditional gear train could not cope with the high speed of a 40-Hz regulator. This led to the design of a completely new base movement, automatic calibre FC-810, capable of performing with the speed of the new silicon oscillator. The entire kinetic chain had to be re-engineered, and the gear train was fitted with four wheels between the barrel and the escape pinion, instead of the three wheels found in a conventional movement. However, the efficiency of the regulator still manages to deliver the 80-hour power reserve. Figure 3 shows an exploded view of the complete watch design [V1].

In a regular mechanical movement beating at 28,800 vibrations per hour, the seconds hand makes eight moves to complete one second. With the FC-810 Monolithic Manufacture calibre, the seconds hand performs 80 moves per second, delivering very smooth motion. A nice analogy can be made to a bird flapping its wings: the 'coarse', slow flapping of a pigeon vs. the smooth, high-speed flapping by a hummingbird. Enabled by its low weight and efficient musculature, a hummingbird can hover in mid-air in front of a flower to gather its meal for the day; nectar.

VIDEO

[V1] *www.youtube.com/watch?v=PBjtEoHnV70*

POSITIVE, NEGATIVE OR CLOSE TO ZERO

Compliant ortho-planar mechanisms can be fabricated from a single sheet of material and they can move out of the plane in which they are fabricated. In this work, a design of such a mechanism is proposed in which stiffness compensation is applied. With a finite-element model, the force-deflection relation of the buckled mechanism was modelled and it was shown that by changing the design parameters, the stiffness of the mechanism can be tuned such that it can be positive, negative or even close to zero. The mechanism was prototyped and the force-deflection relation was measured to validate the simulations.

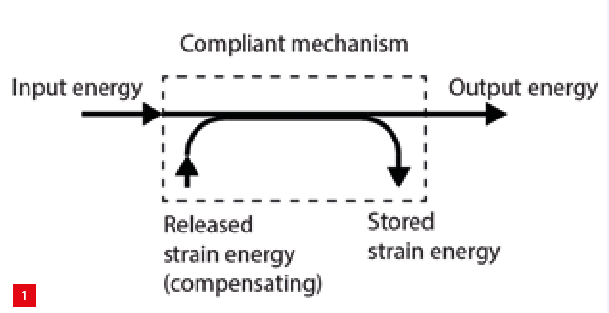
THIJS BLAD, RON VAN OSTAYEN AND NIMA TOLOU

Introduction

Compliant mechanisms are mechanisms in which motion is the result of a deflection of flexible members. These mechanisms have the advantage over their conventional counterparts that they are easier to fabricate, can be more compact and are free of friction, play and wear. Currently, these mechanisms are already applied in for example accelerometers and microphones, and in the future they can be used in applications such as energy harvesters [1].

However, a drawback of compliant mechanisms is their inherent stiffness, a property which describes the extent to which the mechanism resists deformation. Due to this stiffness, a significant part of the input energy is stored as strain energy in the deforming flexible members, and is thus not used for the intended function of the mechanism. As a result, the mechanism may have a poor mechanical efficiency, low range of motion, and high natural frequencies.

In order to overcome this problem, the stored strain energy may be compensated by releasing strain energy in another part of the mechanism [2]. Preloading is a simple way to introduce such compensating energy in the mechanism.



Energy flow in a compliant mechanism where stiffness compensation is applied.

During motion, the energy will flow from preloaded parts to deforming parts of the mechanism. This principle is known as stiffness compensation (see Figure 1) and can be used to achieve zero-stiffness behaviour.

In recent work [3] [4], the principle of stiffness compensation has been applied to a special type of compliant mechanisms called compliant ortho-planar mechanisms (COMs). COMs can be fabricated using planar manufacturing methods and they can move out of the plane in which they are fabricated. Compared to mechanisms that move in-plane, this has the benefit that these mechanisms allow for larger motions while remaining compact, as their parts do not collide.

Design and analysis

In order to apply the principle of stiffness compensation, the mechanism shown in Figure 2 was designed. The mechanism consists of a wide and a narrow section and can be fabricated from a single sheet of material. The energy that is necessary for the stiffness compensation is embedded in the mechanism by preloading, which is done by compressing the mechanism such that it buckles out-of-plane.

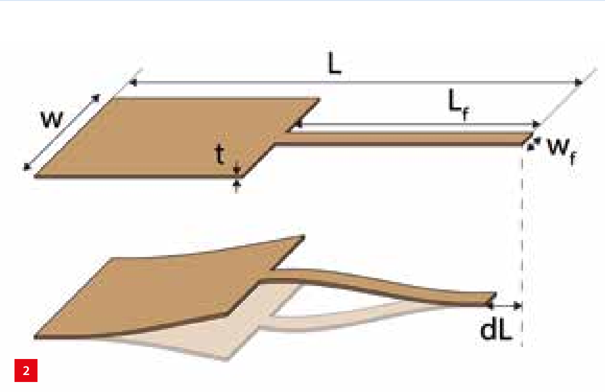
Table 1
Relevant design parameters of the design shown in Figure 2.

Parameter	Value (mm)
L	20
L_f	12.1
dL	0.4
w	2
w_f	0.2
t	0.1

AUTHORS' NOTE

Thijs Blad (Ph.D. candidate) and Ron van Ostayen (associate professor) are members of the Mechatronic System Design research group in the department of Precision and Microsystems Engineering at Delft University of Technology (NL). Nima Tolou is the CEO of Flexous Mechanisms (see also the previous article), located in Delft.

t.w.a.blad@tudelft.nl
www.pme.tudelft.nl



Design of the compliant ortho-planar mechanism before and after preloading.

The design parameters of the mechanism are given in Table 1. The mechanism has a length, L, and a thickness, t, and is compressed over a distance dL. Moreover, the wide and narrow sections have widths of w and w_f, respectively. The narrow section is called the flexure, and the parameter L_f is introduced to identify its length.

When the mechanism is buckled, it takes the shape of a bridge extending out of plane. Two states are shown in Figure 2, which can be identified as 'knee-up' and 'knee-down', and the mechanism can be moved between these states. The stiffness of the mechanism during this motion can be found by analysing its force-deflection relation.

For most compliant mechanisms, the force required to move the mechanism increases with increasing deflection and the mechanism is said to have a positive stiffness. However, in this design the shape of the force-deflection relation can be tuned by the choice of L_f. As a result, the stiffness that can be found for this mechanism can be positive, negative or even (close to) zero.

To analyse mechanical behaviour of the mechanism, a finite-element model was built in ANSYS. In this model, the mechanism was first buckled by constraining one end of the mechanism in all directions, and displacing the other end. Small imperfections were incorporated in the model to prevent the simulation to crash due to singularities in this preloading step. After the buckled shape was achieved, a displacement was applied at the interface of the wide section and the flexure. Over the range of motion of the mechanism, the reaction forces were recorded at regular intervals to determine the force-deflection behaviour. The force-deflection relations were simulated for different variations of the flexure length L_f and the results of this analysis are shown in Figure 3.

From the figure, it can be seen that very interesting force-deflection relations are found for this mechanism. First of all, the force-deflection relations are clearly nonlinear and show a different stiffness at different parts of the curve. It can be observed that for small deflections the mechanism has a low stiffness, as an almost flat force-deflection relation is found. The force-deflection relation rapidly steepens for larger displacements, which is the result of the mechanism being straightened and loaded in tension.

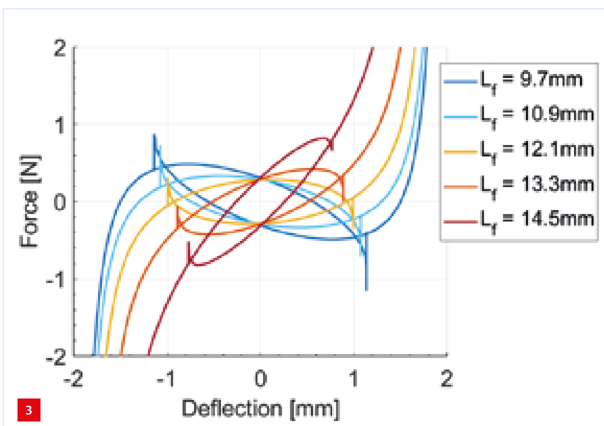
Furthermore, it can be found that the force-deflection relations do not follow a single curve, but make an oval shape. This oval shape actually consists of two load paths, which correspond to the 'knee-up' and 'knee-down' states of the mechanism. When the mechanism is moved from one side to the other, there is a point where the mechanism rapidly changes between these states, a behaviour which is called snap-through.

When looking at the orientation of the oval-shaped part of the force-deflection relation, this part can slope upwards, slope downwards or can be relatively flat. It can be seen that in this mechanism, the slope is dependent on the value of the design parameter L_f. When this parameter is increased, an increasingly upwards-sloping force-deflection relation is found. This means that the level of stiffness compensation can be tuned by changing this parameter. For example, a value of L_f = 12.1 mm was found to result in a mechanism with the flattest force-deflection relation.

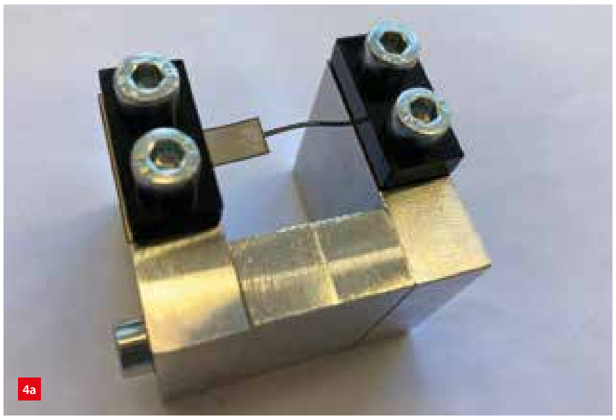
Fabrication and experiments

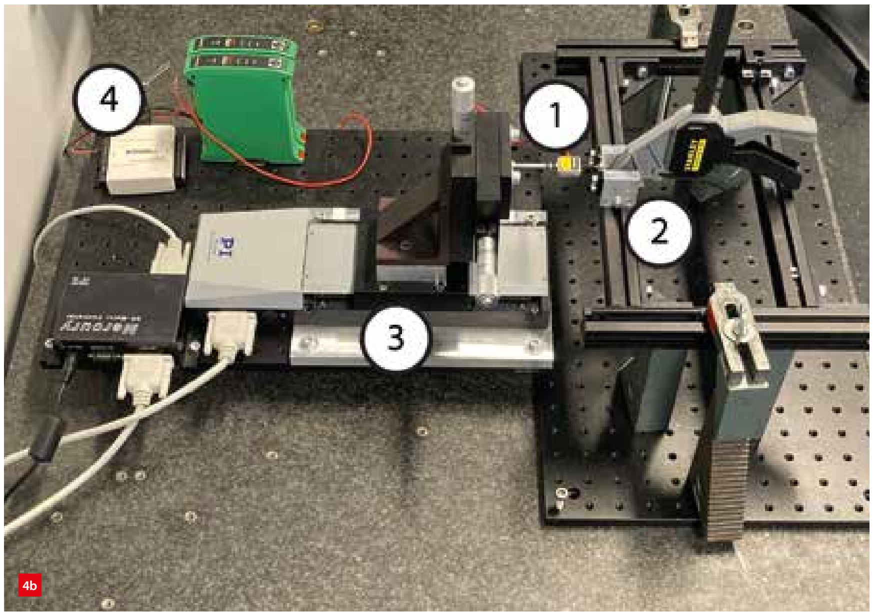
The mechanism was fabricated from a sheet of 0.1 mm thick spring steel (E = 190 GPa) using laser micromachining. For this, a Spectra-Physics Talon 355-15 diode pumped solid-state (DPSS) UV laser system with a wavelength of 355 nm and maximum power of 15 W at 50 kHz was used.

The mechanism was clamped in an aluminium frame consisting of a base plate and two sliding sides. These sides are aligned using dowel pins and can be clamped to the base



Results of the finite-element simulations showing the force-deflection relations of the mechanism for different variations of the design parameter L_f.

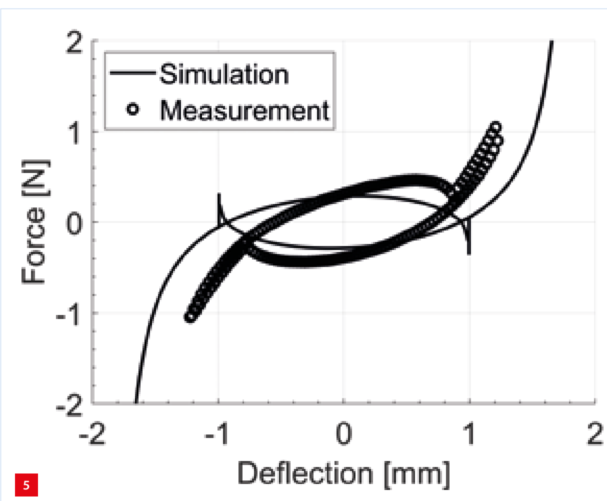




Experimental realisation.
(a) Assembled prototype of the mechanism.
(b) Set-up used to measure the force-deflection relation. See text for explanation of the various elements.

by tightening the bolts on the sides. The assembly process was as follows. First, a spacer with a thickness of 0.4 mm (i.e., compression distance d*L*) was placed between the sides and the base of the frame and the bolts were tightened. Next, the beam was mounted to the frame by clamping it between the aluminium and a PMMA bracket. In this state the beam is stress-free and therefore not buckled. Then, the bolt on the side was released such that the spacer could be removed and was subsequently tightened again such that the sides of the frame had moved exactly the thickness of the spacer compared to the stress-free configuration. This introduced an axial preload and the mechanism could buckle out-of-plane to one of its stable positions. The assembled structure is shown in Figure 4a.

The force-deflection relation of the mechanism was evaluated experimentally with the set-up shown in Figure 4b. For this a FUTEK LRM200 force sensor (1) was connected to the mechanism (2) and displaced by a PI M-505 motion stage (3), from which the internal encoder captured position data. Data was recorded using an NI USB-6008 (4) in 100 steps with a resolution of 20 µm. The probe was fixed to the beam at the interface of the flexure using a rolling contact and a magnet. This ensured that the probe would remain in contact with the mechanism at all times. In Figure 5, the measured and simulated force-deflection relations are compared.



Simulated and measured force-deflection relations of the compliant ortho-planar mechanism.

Conclusion

From Figure 5, it can be seen that the effects found during the simulations were also observed in the measurements, and that a good correspondence was found. This validates that the used model is able to accurately simulate the mechanics of the buckled mechanism. Moreover, with the proposed design it has been shown that stiffness compensation can be applied in compliant ortho-planar mechanisms and that close to zero-stiffness behaviour can be achieved.

REFERENCES

[1] Blad, T.W.A., Farhadi Machekposhti, D., Herder, J.L., and Tolou, N., "Design of a Motion Energy Harvester Based on Compliant Mechanisms: A Bi-Stable Frequency Up-Converter Generator", in *Proceedings of the Advances in Mechanism and Machine Science*, pp. 1619-1626, Springer International Publishing, Cham, 2019.

[2] Gallego, J.A., and Herder, J.L., "Criteria for the Static Balancing of Compliant Mechanisms", *American Society of Mechanical Engineers Digital Collection*, pp. 465-473, 2011.

[3] Blad, T.W.A., Van Ostayen, R.A.J., and Tolou, N., "A Method for Tuning the Stiffness of Building Blocks for Statically Balanced Compliant Ortho-Planar Mechanisms", *Mechanism and Machine Theory*, 162, 104333, 2021, *doi:10.1016/j.mechmachtheory.2021.104333.*

[4] Mariello, M., Blad, T.W.A., Mastronardi, V.M., Madaro, F., Guido, F., Staufer, U., Tolou, N., and De Vittorio, M., "Flexible Piezoelectric AlN Transducers Buckled through Package-Induced Preloading for Mechanical Energy Harvesting", *Nano Energy*, 85, 105986, 2021, *doi:10.1016/j.nanoen.2021.105986.*

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

Virtual event

4-5 May 2021

Matlab Expo 2021

Online envent for Matlab and Simulink users, featuring keynotes on electrification in the aerospace industry, the interactions between natural and artificial intelligence, 5g, and building knowledge in an interdisciplinary world.

WWW.MATLABEXPO.COM

Virtual event

7-10 June 2021

Euspen's 21th International Conference & Exhibition

The event features latest advances in traditional precision engineering fields such as metrology, ultra-precision machining, additive and replication processes, precision mechatronic systems & control and precision cutting processes.

WWW.EUSPEN.EU

16-17 June 2021, Den Bosch (NL)

Vision, Robotics & Motion

This trade fair & congress presents the future of human-robot collaboration within the manufacturing industry.

WWW.VISION-ROBOTICS.NL

14-15 September 2021, Eindhoven (NL)

DSPE Conference on Precision Mechatronics 2021

The fifth DSPE conference on precision mechatronics, organised by DSPE, will be a special edition, in view of the uncertain pandemic situation. It will combine two elements: (1) inspirational presentations from multiple invited international speakers from adjacent applications areas like bio-inspired mechatronics, robot-assisted surgery, virtual reality, artificial intelligence and more; (2) the opportunity of the community to meet/network and exchange ideas in a pleasant atmosphere including a BBQ.

WWW.DSPE-CONFERENCE.NL

15-16 September 2021, Den Bosch (NL)

Materials+Eurofinish+Surface

At this event, a combination of three trade fairs, product developers, product designers, engineers, R&D professionals, production staff, materials specialists and researchers can meet the entire materials value chain.

WWW.MATERIALS-EUROFINISH-SURFACE.COM

21-23 September 2021, St. Gallen (CH)

SIG Meeting Advancing Precision in Additive Manufacturing

Special Interest Group (SIG) Meeting hosted by euspen and ASPE, focusing on, a.o., dimensional accuracy and surface finish from AM, design for precision, standardisation, metrology, and integration of AM into an overall holistic manufacturing process.

WWW.EUSPEN.EU

27-29 September 2021, Eindhoven (NL)

Opto-Mechanical System Design course

The course focuses on the mechanical and mechatronic design of optical systems, and is intended for mechanical, mechatronic and optical engineers involved in opto-mechanical system design. It will also be a very valuable course for any engineer interested in opto-mechanical design approaches and solutions.

WWW.DSPE.NL/EDUCATION

10-11 November 2021, Den Bosch (NL)

Precision Fair 2021

The Benelux premier trade fair and conference on precision engineering, organised by Mikrocentrum.

Precision Fair

WWW.PRECISIEBEURS.NL

15 November 2021, Düsseldorf (DE)

Gas Bearing Workshop 2021

Fourth edition of the initiative of VDE/VDI GMM, DSPE and the Dutch Consulate-General in Düsseldorf (Germany), focused on gas-bearing components and technology for advanced precision instruments and machines.

WWW.GAS-BEARING-WORKSHOP.COM

17-18 November 2021, Raaba (AT)

SIG Meeting Micro/Nano Manufacturing

SIG Meeting hosted by euspen, focusing on, a.o., micro- & nanomanufacturing technologies and applications, machining technologies for moulds and microparts, metrology & quality control for microparts, microreplication and additive techniques, and assembly & handling.

WWW.EUSPEN.EU

24 November 2021, Utrecht (NL)

Dutch Industrial Suppliers & Customer Awards 2021

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

WWW.LINKMAGAZINE.NL

1-2 December 2021, Den Bosch (NL)

Food Technology 2021

Knowledge and network event about high-tech innovations in the food industry.

WWW.FOOD-TECHNOLOGY.NL

8-9 december 2021, Eindhoven (NL)

RapidPro 2021

The annual event that showcases solutions for prototyping, product development, customisation and rapid, low-volume & on-demand production.

WWW.RAPIDPRO.NL

NO MORE GEAR BACKLASH

Can loads be positioned dynamically, with high precision and no oscillation, despite mechanical backlash and elastic components? maxon offers a solution by means of dual-loop control, as a way of making drive systems more precise and more efficient.

JUERGEN WAGENBACH

Moving loads with an electrical drive is usually done with a system that uses an encoder on the motor shaft to provide the position and velocity information for control. High encoder resolution and precise detection of the motor shaft reaction are essential for dynamic position control. From the point of view of the application, however, it is ultimately the precision of the output-side load movement that is critical for the quality and dimensional accuracy of the goods produced.

Gearheads, spindles, and drive belts can have a negative effect on this performance. Depending on the direction of movement, the gear backlash may result in a different load position on the output side. Elasticity may cause delays and oscillations at the start or stop of the movement. The first solution that comes to mind is to mount the encoder on the output shaft, instead of the motor shaft. However, rather than success, this results in even worse system performance.

In the case of a mechanism with backlash or elasticity, dynamic and precise load positioning requires the use of a system in which control is based on two encoder systems:

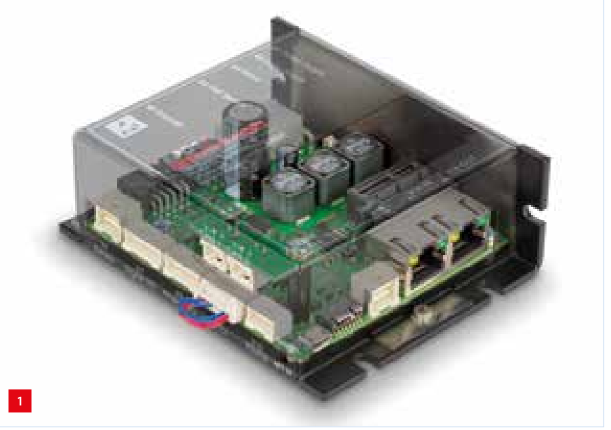
- One rotary encoder, the auxiliary encoder, is rigidly connected to the motor shaft. It should already be part of the motor combination.
- Another encoder, the main encoder, is connected to the moved load on the output side.

To process the signals from these two encoder systems, dual-loop control is required. maxon's EPOS4 positioning controllers (Figure 1) augment this dual-loop control with a second-order filter and a gain scheduler to counteract mechanical resonance and gear backlash. The EPOS Studio commissioning software provides a Regulation Tuning tool, which automatically determines parameters for the complex controller structure and plots the transfer function of the drive.

Control architecture

EPOS4 uses a cascade control structure for the dual-loop control (see Figure 2):

- The innermost control loop provides field-oriented control of motor current based on the motor current measurement as a feedback signal.
- The middle control loop (auxiliary control) controls the motor speed based on the encoder on the motor shaft.



1

maxon's EPOS4 positioning controller.

- The outermost control loop (main control) controls the position of the load based on the encoder system on the load.

A detailed view of the EPOS4 dual-loop control structure is shown in Figure 3.

Main control loop

The main control loop is made up of a proportional (P) controller, a gain scheduler, and a second-order filter (the main loop filter). A path planner supplies the desired position of the load and its desired velocity and acceleration as input variables for the main control loop. Another input variable is the current position of the load, as measured by the encoder on it.

Gain scheduler

The EPOS4 dual-loop control uses the gain scheduler to eliminate negative effects from gear backlash. The gain scheduler does this by automatically adjusting the P gain of the main control loop. If the tracking error – the deviation of the actual load position from the desired position – is too large, a high P gain will be applied, resulting in rapid reduction of the error. As the tracking error becomes smaller, the P gain is reduced as well, so that oscillation does not occur in the drive, despite gear backlash.

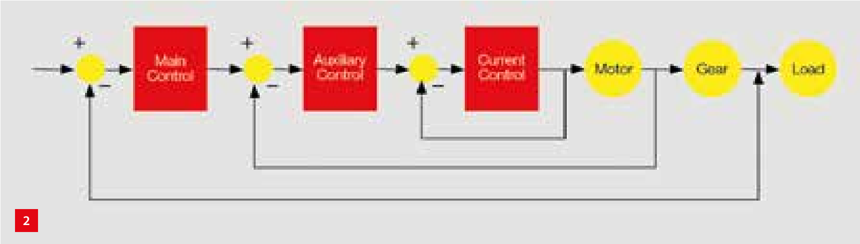
Main loop filter

If there is a certain amount of elasticity between the motor and the load due to couplings, belts, or long spindles,

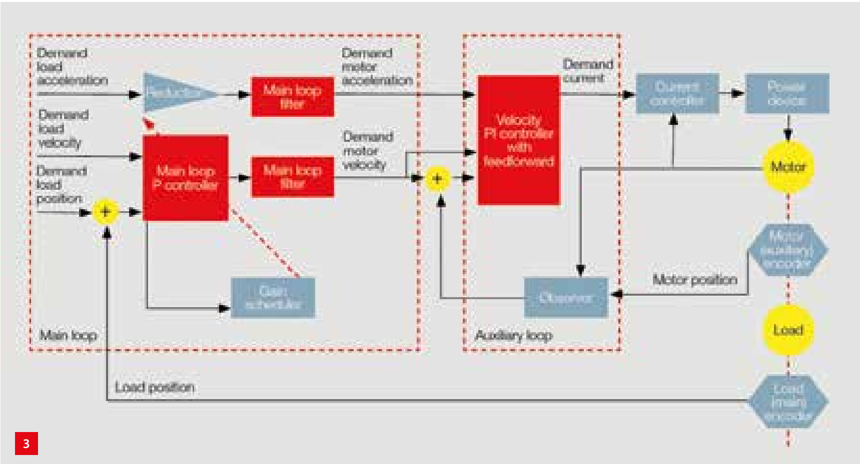
AUTHOR'S NOTE

Juergen Wagenbach is a motion control specialist at maxon, a provider of high-precision drive systems, headquartered in Sachseln (Switzerland).

www.maxongroup.com
www.drive.tech



The dual-loop architecture consists of three integrated feedback loops.



A detailed view of the components of the dual-loop control system.

resonant frequencies could cause amplifying oscillations. These could increase to the point where control becomes unstable. In order to prevent this, the EPOS4 dual-loop controller uses a second-order filter, of the notch-filter type. This filter suppresses the resonant frequency range in the output signal from the main control loop, thereby preventing harmonic oscillations in the drive train.

Auxiliary control loop

The auxiliary control loop consists of a proportional-integral (PI) controller with feed forward (FF), and an observer that estimates the motor speed from the position data of the motor encoder and the motor current measurements.

Auto-tuning procedure

To simplify commissioning, maxon's EPOS Studio software features an integrated auto-tuning wizard to determine and validate the parameters of the dual-loop controller. The auto-tuning procedure consists of two experiments that are carried out automatically:

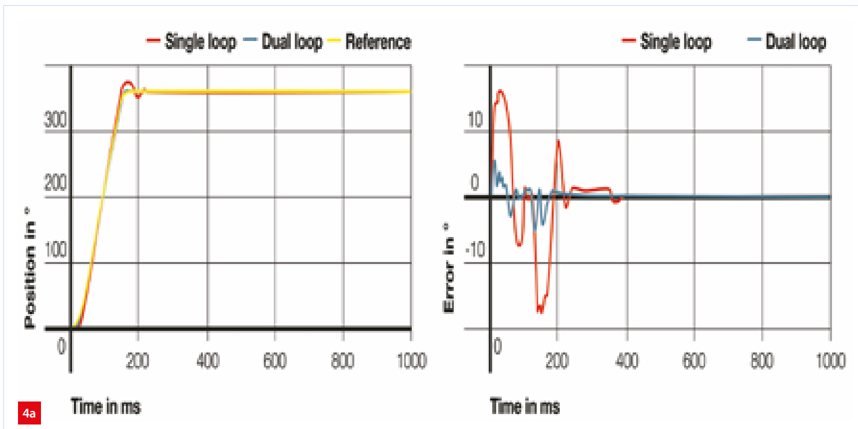
- Experiment 1 triggers oscillations of the motor shaft. These oscillations are used to determine the mass inertia, the torque constant, and the friction in the motor. The parameters for the auxiliary loop controller and observer are then calculated on the basis of the data identified.
- Experiment 2 is used to calculate the parameters for the main control loop and the notch filter. A PRBS signal (= Pseudo-Random Binary Sequence) is used to excite the plant. Based on the resulting input-output data, the transfer function is identified and presented as a Bode plot.

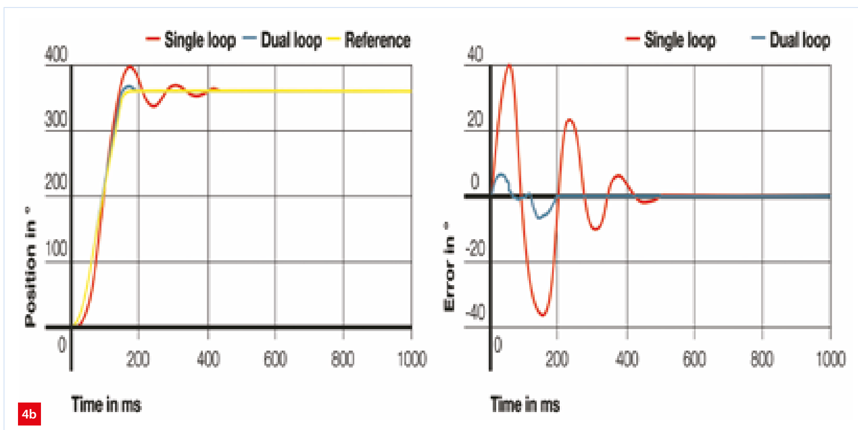
The Bode plot can be exported. It assists control engineers in system analysis with optimising the mechanical design, and with manual adaptation of the control for specific applications.

Single- vs. dual-loop control

The following graphs show the differences in reference response and tracking error for a system with gear backlash (Figure 4a) and a system with an elastic coupling (Figure 4b). The graphs compare single-loop control with an encoder on the load, and automatically tuned dual-loop control with an encoder on both the motor shaft and the load.

Dual-loop control is a way of making drive systems more precise and more efficient. maxon offers not only all the components required, but also a great deal of experience in consultation – from the initial idea and the system design through to full-scale commercial production.





Load position profile, showing reference response (left) and tracking error (right).
(a) System with gear backlash.
(b) System with an elastic coupling.

DRY CLEANING OF DELICATE SENSORS

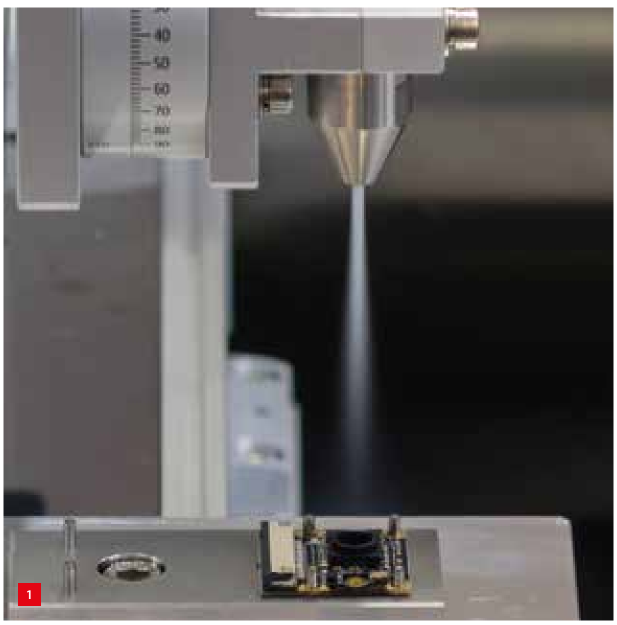
Fully autonomous and assisted driver systems have advanced rapidly in recent years, and the pace of development continues to accelerate. Vision systems are key, and their ability to function properly and reliably is heavily dependent on the cleanliness of the components used. The scalable CO_2 snow-jet technology quattroClean developed by acp systems offers an efficient and reliable solution for cleaning delicate image sensors and system housings. The dry-cleaning process is highly suited to automation, for integration into manufacturing systems, including cleanrooms.

DORIS SCHULZ

Assistance systems for autonomous or assisted driving employing modern, ever more sophisticated sensors and increasingly intelligent camera systems should function safely and reliably. This is in part dependent on the cleanliness of the various components. For obvious reasons, wet chemical cleaning is not an option, and conventional blow-cleaning with compressed air is often unable to remove all, if any, of the adhering particles and filmic contaminants. This method is unable to meet today's cleanliness requirements in a reliable and reproducible manner.

Residue-free solution

With its scalable quattroClean snow-jet technology (Figure 1), acp systems offers a dry, gentle, and residue-free solution. It has already proven itself over a number of years in serial applications for cleaning image sensors, such as CCD or CMOS, including their (often flexible) control and processing circuit boards. It is residues from the production process that need to be removed, such as flux or adhesive residues, particles, fibers, dust, and abrasion. A few years ago, typical cleanliness demands were still "no particles larger than five micrometers"; nowadays, it is specifications in the two-to-three-digit nanometer range that must be met. At the same time, neither the active sensor, contacts nor printed circuit board (PCB) may be damaged by cleaning.



1

The scalable quattroClean snow-jet technology ensures that image sensors with the highest particulate and filmic cleanliness requirements are cleaned in a dry, gentle, and residue-free manner.

Due to the huge increase in cleanliness requirements, the dry process is now often used to clean housings for camera systems. Regardless of whether the parts are made of metal or injection-moulded plastic, they are subjected to mechanical vibrations and temperature fluctuations during their subsequent operation. As a result, any particles that were not removed, or substances outgassing from processing media residues (in the case of metals) and release agents (in the case of plastics) could impair the function of the sensor.

Gentle process

The technology, which has already been implemented in more than 1,500 cleaning systems, uses liquid carbon dioxide as a cleaning medium. Non-corrosive, non-flammable and with an indefinite shelf life, it is formed as a by-product from chemical manufacturing processes and biogas energy generation, thus making it climate neutral.

The heart of the cleaning system is a wear-free two-component ring nozzle. The medium, which is appropriately purified to meet the high product cleanliness requirements, flows through this. On exiting the nozzle, the CO_2 expands to form fine snow, which is then bundled by a separate jacketed jet of compressed air and accelerated to supersonic speed.

The easily focused jet of snow and compressed air impacts the surface to be cleaned at a temperature of –78.5 °C, triggering a

AUTHOR'S NOTE

Doris Schulz is a journalist. Her agency, based in Korntal, Germany, specialises in PR solutions for technical products and services. This article was commissioned by acp systems, a German provider of advanced cleaning and connecting technologies for automated production. All images are courtesy of acp systems.

www.schulzpressetext.de
www.acp-systems.com

combination of thermal, mechanical, sublimation and solvent effects. The interaction of these four mechanisms of action removes particulate and filmic contaminants such as particles, abrasion, dust, flux, and release agents, including processing media, in a reliable and reproducible manner. The cleaning process is so gentle on materials that it can even be used to clean sensitive, delicate, and finely structured surfaces.

Process development is tailored to customer requirements and validated through trials in acp's technical centre. In this way, the optimal process parameters are determined, such as the flow rates for compressed air and carbon dioxide; the number and type of jet nozzles; the selected zone and dwell time; and the sequence of movements during the cleaning process.

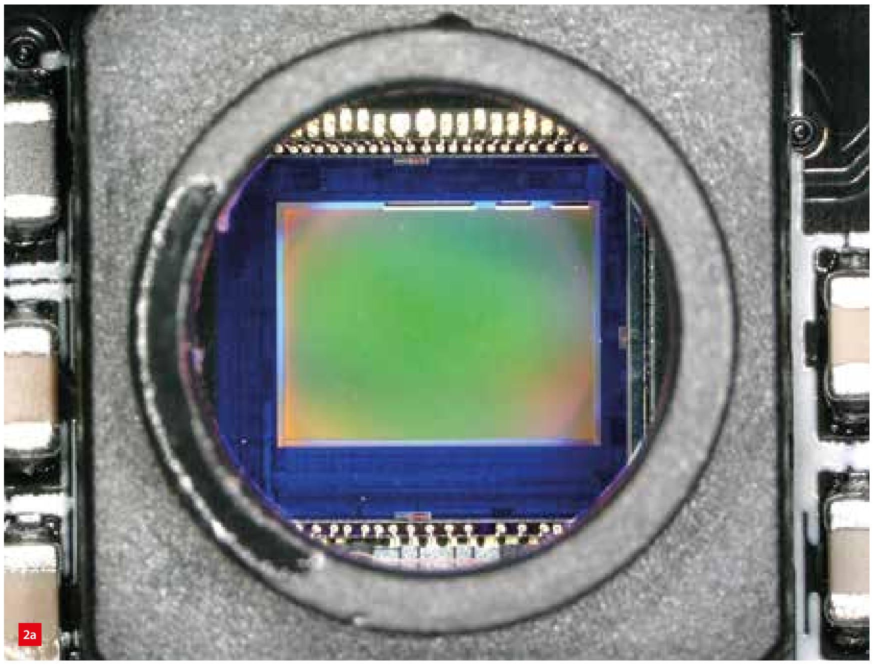
Automation

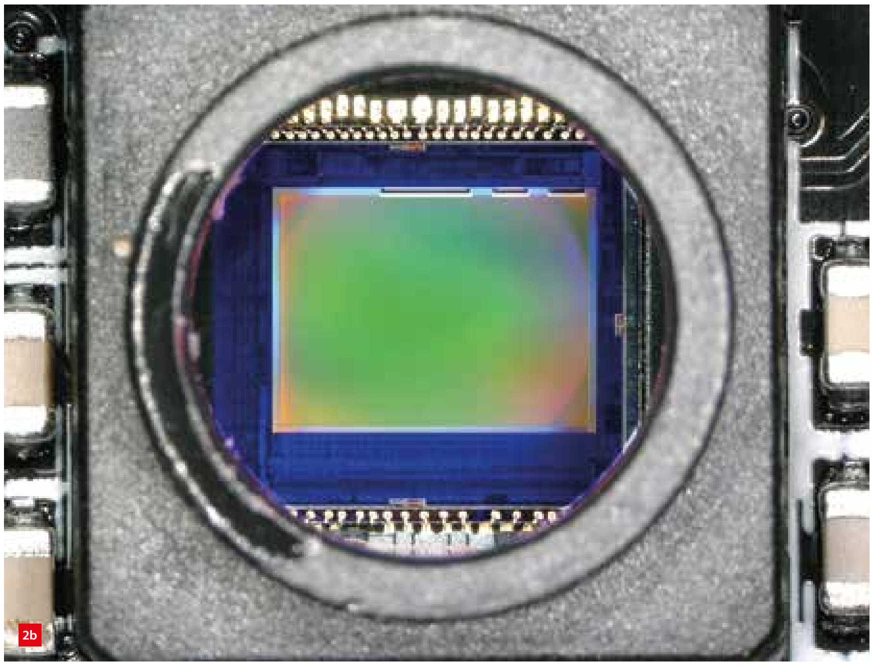
To meet high cleanliness standards and short cycle time demands generally required for such products, acp designs fully automated cleaning systems from standardised modules to suit the customer's application and production conditions (Figure 3). Besides cleaning the parts, and depending on the situation and customer specifications, the systems can be designed to perform other process steps such as separating, aligning, and testing electronic functions.

Robots are typically used to handle the parts in the cleaning station including upstream and downstream processes in assembly, and other handling solutions are also possible on request. The compact cleaning systems are ready for integration into production lines with networked production processes. Modular systems for cleaning sensors and housing parts in parallel can also be implemented.

3

The modular concept allows different processing steps to be integrated into the system, such as separation, alignment, and cleaning, as well as electronic function tests.


2a


2b

Particles and filmic contaminants on the image sensor as well as on the PCB can be reliably and reproducibly removed.
(a) Before cleaning.
(b) After cleaning

Systems designed as mini-environments for use in cleanrooms are specified to high-purity in the supply of liquid carbon dioxide and compressed air. The media supply system, extraction system and other components, including automation and pick & place, are always selected to match the respective cleanroom classification Another focus is on optimal flow conditions to ensure the fast and reliable transportation of detached impurities away from the product.

MILLING, HARD-TURNING AND GRINDING IN ONE MACHINING CENTRE

Hard-turning does not always achieve the required finish; that calls for a grinding operation which removes the traces of roughness caused by the ultra-hard tool point. To avoid damaging vibrations, however, precision hard-turning requires an extremely stiff machining centre. Some machining centre manufacturers have already succeeded in combining hard-turning and external grinding, but Spinner Machine Tools is the first to integrate hard-turning, external grinding and internal grinding in one machine. It's an impressive achievement, because the Microturn Grind can mill accurately as well.

FRANS ZUURVEEN

In conventional lathes, the cutting tool moves while the work piece stays stationary, apart from the necessary rotation. In modern turning machining centres, it is the tools that stay stationary and the work piece that moves. This facilitates the application of a turning machining centre for milling. The maximum versatility thus acquired is one of the most important properties of the Microturn Grind, which is designed, manufactured and marketed by Spinner Machine Tools in Sauerlach, near Munich in Germany. Founded in 1950, Spinner produces currently more than 1,000 machining centres and other precision tools each year. This article features the Microturn Grind, which is the most unique Spinner product as this machining centre is the only one that combines hard-turning and internal grinding. Figure 1 shows the Microturn Grind with the safety door open. Its maximum turning diameter equals 150 mm and the maximum turning length is 250 mm.

Hard-turning

Figure 2 shows the hard-turning process on a Microturn Grind. Yet why did this process, as an alternative for grinding, only take off at the beginning of the 1990s? That's because two evolutions contributed to its development: one, the availability of new cutting tool materials and; two, the creation of more stable, accurate and stiffer turning machines.

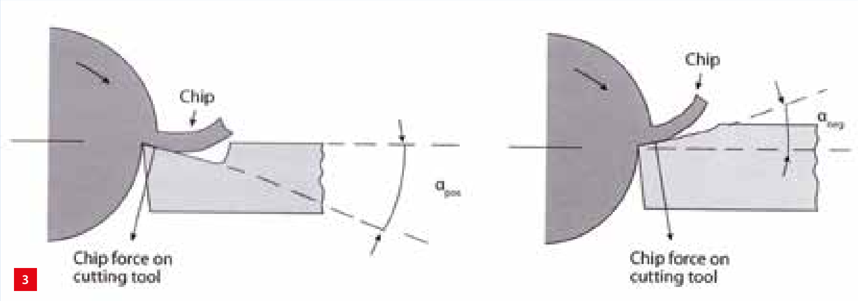
For many decades now, synthetic diamond has been used for the precision turning of non-ferro metals. This hardest of all materials cannot, however, be used for the machining of steel, because diamond reacts with the carbon in the steel. Fortunately, the ceramic material boron nitride with a cubic crystalline structure solved this problem, because while its hardness approximates that of diamond, it does not react with the carbon in steel. There is only a polycrystalline structure, which is called PCBN. High-precision hard-turning

1 The Spinner Microturn Grind machining centre with open safety door.

2 Hard-turning on a Microturn Grind.

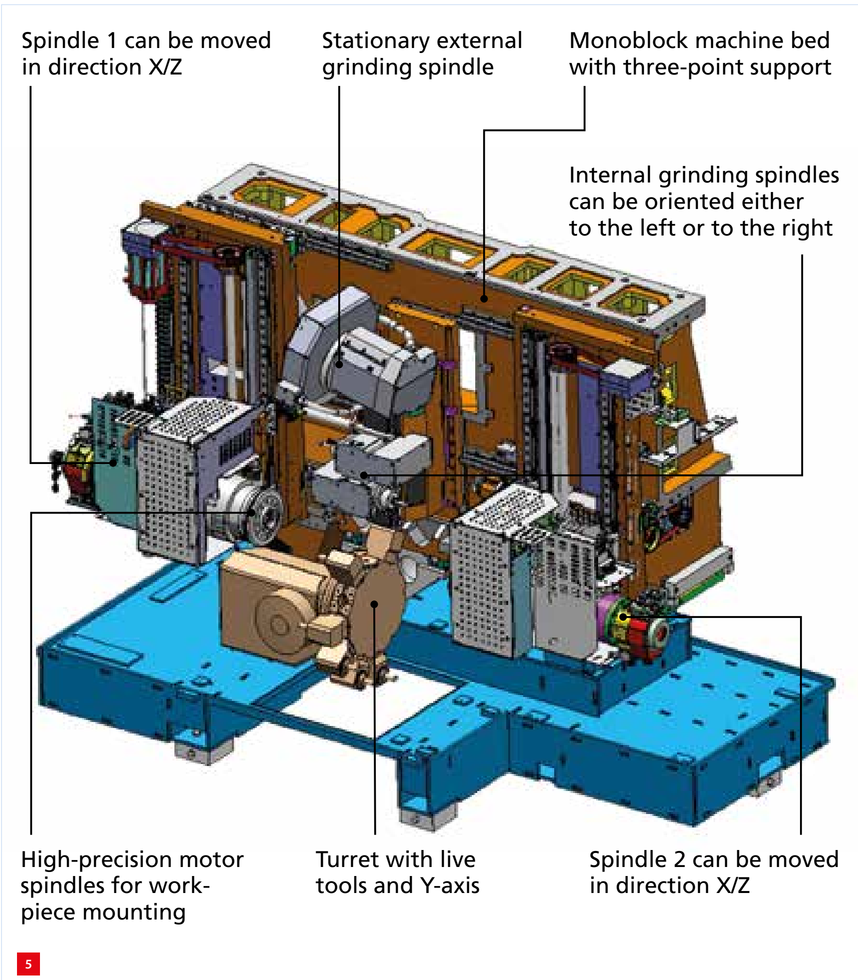
AUTHOR'S NOTE

Frans Zuurveen, former editor of Philips Technical Review, is a freelance writer who lives in Vlissingen (NL).

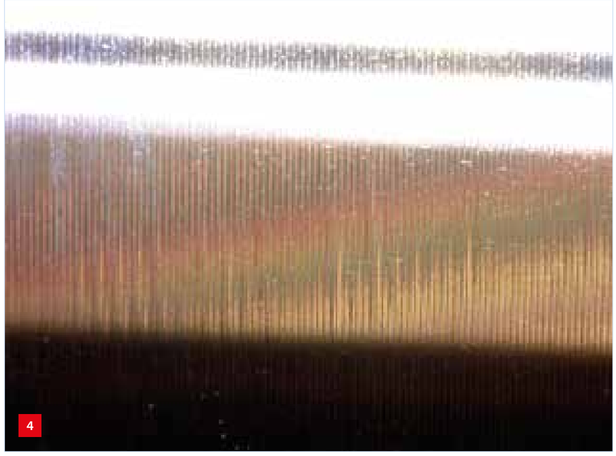


Explanation of the negative cutting angle a_{neg} (at right) required for the hard-turning process. The backpushing force is called chip force in this figure. (Modified from www.oocities.org/venkatej/mech/tomc/tomc.html)

requires tool bits with a relatively low CBN content of about 50 per cent, with the rest being a ceramic binding agent.
In general, turning hardened steel with PCBN requires a negative cutting angle (see Figure 3), in most cases without the need for cutting or cooling fluid. In a conventional lathe, however, the high backpushing forces, due to turning with a negative cutting angle, cause vibrations that have a negative effect on work-piece form and roughness. The only way to avoid the influence of the high tool backpushing force (also called chip force) is the application of a machining centre with an extremely high stiffness and stability, such as the Spinner Microturn machines.



Explanation of the structural set-up of the Microturn Grind with a maximum of accessories.



A hard-turned surface with clearly visible traces of the PCBN cutting point.

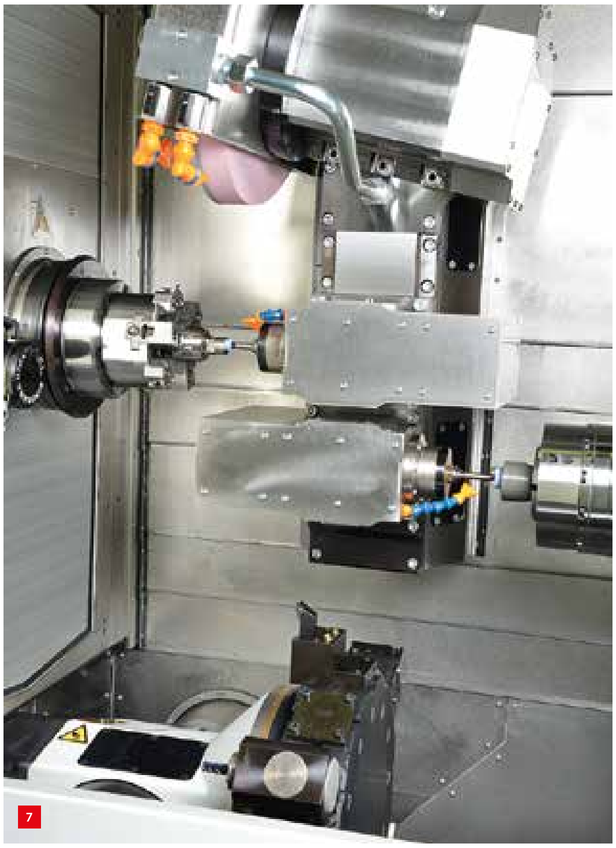
Why grinding?

Hard-turning is an alternative for grinding because it enables shorter cutting times, as grinding requires more time and energy per unit volume than turning. Another difference between turning and grinding is that the latter makes it possible to remove an extremely small quantity of material, for instance with a thickness of only 1 μm. On the other hand, hard-turning is characterised by a minimal chip thickness of about some hundredths of a millimeter.
A hard-turned surface will show the marks of the applied PCBN cutting tool point. Figure 4 shows such a surface, on which the traces of the cutting point are clearly visible. That is why precision parts often require a finishing grinding operation of some micrometers of chipping thickness to remove the traces of hard-turning. The Microturn Grind is the only machining centre that is able to perform this on the outside as well as on the inside of a precision work piece. Removing hard-turning traces is of vital importance for applying seals on rotating shafts.

Machine lay-out

Figure 5 shows the structural set-up of the machining centre in its version with a maximum of cutting equipment. The

The external grinding wheel with a maximum outside diameter of 400 mm.



7

The pair of spindles for internal grinding with either left or right orientation.

main structure is made of cast iron, a material with better internal damping properties than steel. The structure rests on three supporting points on the machine base plate. This design avoids torsional stresses caused by temperature differences. Short force transmitting distances between tool and work piece also contribute to machining stability.

8

The indexing turret for holding twelve tools, motor driven when necessary, with BMT45 coupling interfaces.

Figure 6 shows in detail the external grinding wheel with an outside diameter of (maximum) 400 mm. It is inclined by 12° enabling angular infeed grinding and end-face machining. It has automatic precision balancing and water cooling of the built-in motor spindle. The Swiss firm Fischer produces these spindles according to Spinner specifications. Fischer also delivers the two internal grinding spindles for a maximum speed of 90,000 rev/min. Figure 7 shows these internal grinding spindles, one with left orientation, the other with right orientation.

Figure 5 also shows the two identical main motor spindles with X, Z-positioning, which enable the hard-turning and finishing of opposite sides of a work piece without reclamping. These spindles are made by Spinner and have an accuracy of 0.5 µm for the rotation axle. Spinner manufactures 1,000 spindles a year, each with selected pretensioned shoulder ball bearings and ultra-accurate ball running races.

Figures 5 and 8 also show the indexing turret for holding tools in twelve positions. When necessary, each position can handle a driven tool for drilling, thread tapping or milling, for example. Accurate Hirth gearing takes care of the indexing of the turret and standard BMT45 interfaces provide extra tool clamping reproducibility. The turret is mounted on a Y-slide to facilitate milling, among other things.

Of course, the slides in the Microturn Grind are covered with shields to prevent damage caused by penetrating chips. The guides are special Schneeberger high-precision products with rollers. The slide positions are measured with Heidenhain optical scales with a resolution of 0.1 µm. The guides are motor driven with recirculating ball screws.

Of course, the high-precision hardware, i.e. slides and spindles, must be controlled with advanced software. For that purpose, the Microturn Grind uses the Siemens 840D Solution Line software. The turning cycles conform to Siemens standards, just like the other Spinner hard-turning products, but the grinding cycles from the Microturn Grinds are in-house Spinner software developments.

Difficult internal machining

When considering the unique features of internal-cavity grinding and hard-turning, one wonders how far and with what level of stability tools are able to enter into a precision product: the deeper the cavity, the more the instability of a tool increases.

Axel Spinner, CEO of Spinner Werkzeugmaschinenfabrik, explains the difficulties concerning this problem. “We perform internal hard-turning operations on our machines rather frequently. There are limits on these operations due to the relation between diameter and length, of course. That is because the drilling rod for the internal cutting has a limited stiffness and this causes bending and vibrations due to the high cutting forces. The accumulation of chips in the cavity may create problems as well. Currently, we can hard-turn holes with a length-diameter ratio of three. It is better to use hard-turning technology first to realise a grinding depth that is as small as possible. Critical internal grinding operations with thin grinding rods are possible by pre-turning with an ultimate grinding depth of only 0.02 mm, for example. Faster and more accurate results are then achievable. Our Microturn Grind is the only machine in the world that combines the advantages of both technologies in one working cycle."

To conclude

The product in Figure 9 proves the precision abilities of the Spinner Microturn Grind machines. It shows a rather complicated hollow shaft with tolerances in the µm area with internally hard-turned and ground cylindrical cavities. Thanks to the versatile mechanical design of the Microturn Grind with precision slides and spindles, this product could be machined in one working cycle without any reclamping.

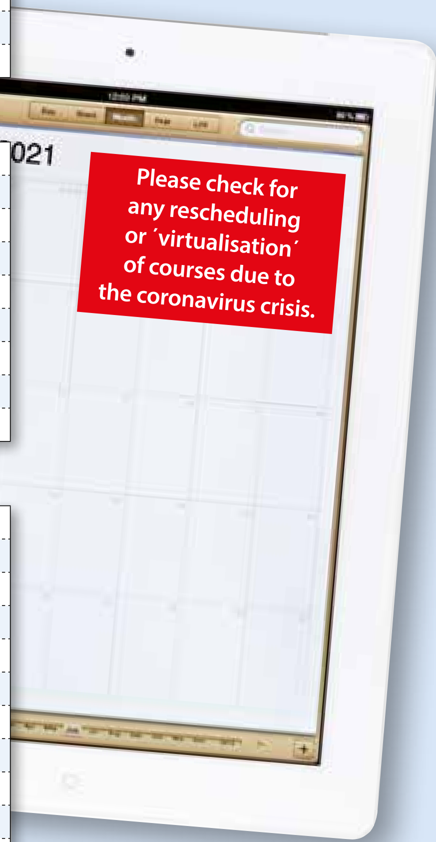
A precision work piece from hardened steel. It has been finished internally and externally with a Microturn Grind machining centre.

INFORMATION
Spinner Machine Tools is represented in the Netherlands by Limas CNC-machinery.

WWW.SPINNER.EU.COM
WWW.LIMASCNC.NL

ECP² COURSE CALENDAR

COURSE (content partner)	ECP² points	Provider	Starting date
FOUNDATION			
Mechatronics System Design - part 1 (MA)	5	HTI	11 October 2021
Mechatronics System Design - part 2 (MA)	5	HTI	8 November 2021
Fundamentals of Metrology	4	NPL	to be planned
Design Principles	3	MC	22 September 2021
System Architecting (S&SA)	5	HTI	31 May 2021
Design Principles for Precision Engineering (MA)	5	HTI	21 June 2021
Motion Control Tuning (MA)	6	HTI	14 June 2021
ADVANCED			
Metrology and Calibration of Mechatronic Systems (MA)	3	HTI	2 November 2021
Surface Metrology; Instrumentation and Characterisation	3	HUD	to be planned
Actuation and Power Electronics (MA)	3	HTI	29 June 2021
Thermal Effects in Mechatronic Systems (MA)	3	HTI	15 June 2021
Dynamics and Modelling (MA)	3	HTI	30 November 2021
Manufacturability	5	LiS	to be planned
Green Belt Design for Six Sigma	4	HI	20 September 2021
RF1 Life Data Analysis and Reliability Testing	3	HI	20 September 2021
Ultra-Precision Manufacturing and Metrology	5	CRANF	to be planned
SPECIFIC			
Applied Optics (T2Prof)	6.5	HTI	1 November 2021
Advanced Optics	6.5	MC	24 February 2022
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	to be planned (Q1 2022)
Modern Optics for Optical Designers (T2Prof) - part 2	7.5	HTI	10 September 2021
Tribology	4	MC	11 May 2021
Basics & Design Principles for Ultra-Clean Vacuum (MA)	4	HTI	6 December 2021
Experimental Techniques in Mechatronics (MA)	3	HTI	5 July 2021
Advanced Motion Control (MA)	5	HTI	11 October 2021
Advanced Feedforward & Learning Control (MA)	2	HTI	23 June 2021
Advanced Mechatronic System Design (MA)	6	HTI	to be planned
Passive Damping for High Tech Systems (MA)	3	HTI	23 November 2021
Finite Element Method	2	MC	20 May 2021
Design for Manufacturing (Schout DfM)	3	HTI	30 September 2021



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
- Cranfield University (CRANF)
  WWW.CRANFIELD.AC.UK
- Univ. of Huddersfield (HUD)
  WWW.HUD.AC.UK
- National Physical Lab. (NPL)
  WWW.NPL.CO.UK

Content partners

- DSPE
  WWW.DSPE.NL
- Mechatronics Academy (MA)
  WWW.MECHATRONICS-ACADEMY.NL
- Technical Training for Prof. (T2Prof)
  WWW.T2PROF.NL
- Schout DfM
  WWW.SCHOUT.EU
- Systems & Software Academy (S&SA)

Mikrocentrum director Geert Hellings resigns

Geert Hellings will step down from his position as general manager of Mikrocentrum on 1 July 2021. He has led Mikrocentrum, the knowledge and network organisation for the (Dutch) high-tech and manufacturing industry, for more than 18 years. Since he took office as director in May 2003, the organisation has grown in every way: the membership of the High Tech Platform has increased to almost 600 and more than 6,000 students attend approximately 600 courses (170 course titles) annually, while the number of visitors to the trade fairs and theme days reached over 19,000 in 2019.

Mikrocentrum has repositioned itself in recent years, according to a press release. Partly due to its move to the multifunctional building in Veldhoven (NL), Mikrocentrum has been able to innovate and adapt its knowledge and network role to meet industry requirements. The new accommodation is ideal for facilitating core tasks. Even in a difficult Covid-19 year, with numerous limitations, it appears that the requirements for safe meetings and courses can be anticipated flexibly.
The past months have been used to develop various online courses and webinars, and to prepare the organisation for a restart of larger-scale activities, says Hellings. "We've survived the Covid-19 period well to date. As a financially healthy organisation, we've been able to keep our employees on board and with them all their expertise. The courses are running again, online and recently also physically." The relocation of the trade shows, such as the Precision Fair, to larger accommodations will help to ensure these events can be organised to be Covid-19-proof.

Hellings therefore thinks that 1 July is a good and logical moment to hand over the baton. "Because of Covid-19, I have taken this step a little later than I had personally planned. I do not mind, as I'm pleased that we've been able to guide Mikrocentrum, together with all our colleagues and relations, through this difficult period." After 1 July, the departing director will have more time to take up his old field, applied physics, among other things, and in this way remain involved in the manufacturing industry.

WWW.MIKROCENTRUM.NL

Obituary Eef Reker (1944-2021)

On 8 February this year, Eef Reker died at the age of 76. He was a very dedicated employee of Eindhoven University of Technology. After completing his military service, he started in 1965 as a technician in Prof. Wim van der Hoek's group, *Constructies en Mechanismen*, and later became the lab manager. After Van der Hoek's retirement in 1984, the group was led by prof. Rien Koster and then by dr. Nick Rosielle. Reker retired in February 2005.

Reker had enormous practical expertise and was able to transfer this easily to mechanical engineering students. He taught generations of students the intricacies of making technical drawings. He was also deeply involved in the training of young engineers, based on his motto: Not only design a solution, but also make it yourself. Many students and colleagues were therefore allowed to work in his workshop, guided by his practical instructions, on their graduation work or on private projects. He instructed them on how to handle the tools with care. In this way, he imparted to them an appreciation for the actual manufacturing as part of the total design process, and also for the professionals they would have to talk to in order to get their design made. Strict but fair, amiable and honest, is a fair characterisation of Eef Reker.

Reker also contributed to drawing the figures for Van der Hoek's famous lecture notes, *Des Duivels Prentenboek*. After his retirement, Reker could still be found regularly in 'his' lab, even when his hearing and vision had seriously deteriorated. Last year, he was an important link in the completion of the book on his first professor/employer, "*Wim van der Hoek – Een constructief leven*".

In addition to his work at the university, Eef Reker was also very involved in social activities, in particular the shooters' guilds in his province, North Brabant. In 1998, he received a royal decoration: he was appointed a member of the Order of Oranje-Nassau because of his commitment to the promotion of craftsmanship and the interests of technicians, at the level of both the faculty and the university, and because of his cultural achievements.

(Input by Maarten Steinbuch, Paul Vrancken, Harry van Leeuwen and Lambert van Beukering)

Eef Reker working in his lab at a lathe. He was the technician in Wim van der Hoek's group for twenty years. On the right (in 1998), he proudly shows the royal decoration that he has just received. (Photo on the right: Bart van Overbeeke)

New System Architecting Masters training programme

High Tech Institute is starting an intensive System Architecting Masters (Sysam) training programme for system architects and systems engineers. It consists of three intensive blocks of training of four days each with several months in between for assignments on the job, coaching and peer review. Half of the training itself consists of essential systems engineering and system architecting topics. The other half comprises intensive exercises with practical situations, such as convincing stakeholders and being able to turn resistance into buy-in.

The objective of the Sysam training is to give participants confidence as a technical leader by learning them what to do, what not to do and why. They will be able to lead the systems engineering processes with a structured approach, using the NASA Systems Engineering Handbook as a reference. Bringing people together, challenging them, convincing them, inspiring them and creating an optimal vibe to lead their team to the best results for all stakeholders. Participants will experience how the CAFCR framework (which employs five 'views': Customer Objectives, Application, Functional, Conceptual and Realization) supports them in applying sound systems engineering in a practical manner. This framework serves as a mindset that will get the most out of their leadership role and systems engineering processes.

There are several months between the four-day training blocks, during which the teachers coach the participants. Intermediate sessions are also planned where the participants exchange experiences with each other. To ensure quality, the number of participants in Sysam is limited to a maximum of twelve. This also ensures that participants can effectively exchange experience about their projects.

WWW.HIGHTECHINSTITUTE.NL/COURSES/SYSTEM-ARCHITECTING-MASTERS

New quadruple UHV fibre feedthrough

LouwersHanique, a specialist in manufacturing extremely accurate products in technical glass, advanced ceramics and special material combinations, has developed a new quadruple UHV (ultrahigh-vacuum) feedthrough for single- or multimode-fibre applications. Using direct glass-metal joining makes it possible to deliver feedthroughs without any unnecessary welds, resulting in no virtual leaks. The same joining also provides for unprecedented integration and ensures unique high-performance functionality. According to LouwersHanique, the result is the most advanced feedthrough, in terms of outgassing and purity, as well as functionality and reliability.

Glass and ceramics can directly be bonded with various metal types that the company routinely processes, e.g. tungsten, molybdenum, platinum, nickel, stainless steel, aluminium and titanium. This allows the production of diverse types of hermetic connectors, such as sub-D, Harting power connectors, LEMO signal, coax and high voltage, as well as various optical fibre types. Within the same footprint, connector types can be changed, and new combinations supplied to match individual requests.

Depending on specifications, the functionality is guaranteed for temperatures from cryogenic up to 500 °C, without degradation, and in other harsh and high-pressure environments. LouwersHanique's solutions are used by leading OEMs in the semiconductor market, including lithography, and in advanced analytical systems such as electron microscopes.

Earlier this year, LouwersHanique, located in Hapert (NL) in the greater Eindhoven region, was acquired by Muon, headquartered in Eerbeek (NL). Muon is a group of companies that develop and manufacture micro-precision components for applications in healthcare, semiconductor, digital printing and filtration.

WWW.LOUWERSHANIQUE.COM
WWW.MUONGROUP.COM

Better theta-axis option

ETEL has introduced the high-precision DXRH rotary axis system, to offer developers of highly accurate semiconductor/electronics machines a new and better theta-axis option as either a stand-alone or system-integrated solution.

ETEL's new DXRH incorporates a 360,000-lines encoder and bearing technology from parent company Heidenhain, as well as ETEL's toothless (ironless), zero-torque-ripple direct-drive technology for high speed stability. Because of its unmatched mechanical characteristics due to the combination of Heidenhain's components and ETEL's direct-drive motor technology, it is comparable to air-bearing solutions without the associated complexity, so ETEL claims.

The DXRH was designed in response to the needs of the semiconductor industry, being especially suitable for wafer process control applications such as overlay and critical-dimension metrology, and thin-film metrology. It is also well suited for photonics applications. The DXRH provides a high accuracy of ±3 arcsec without calibration, position stability of ±2.5 milliarcsec (i.e., ±1.8 nm at R = 150 mm), bidirectional repeatability of ±0.25 arcsec, and a radial runout of ±1 µm. The module is ISO class 1 cleanroom-compatible.

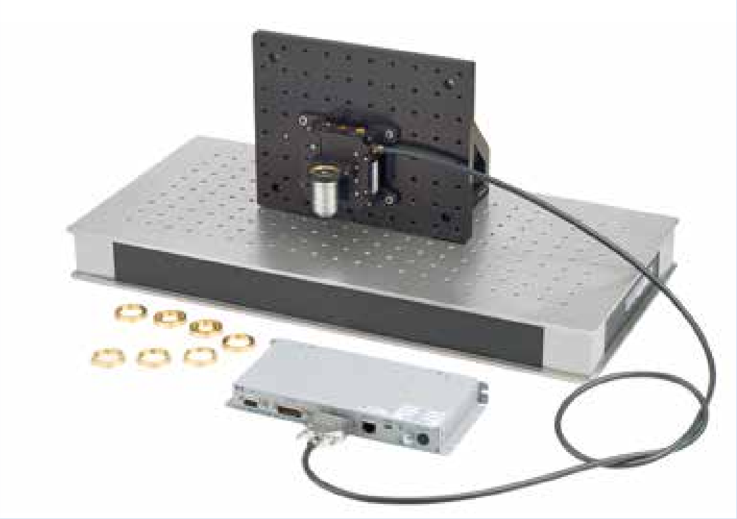
WWW.ETEL.CH/MOTION-SYSTEMS/ROTARY-AXES/DXRH

Vertical positioning

Numerous applications in microscopy and industry require vertical positioning systems with large travel range, high dynamics and precision. With the new V 308 voice coil PIFOC, PI now offers a magnetic direct-drive-based solution that unites all these requirements. The core element is a single-axis slider with high-precision lateral crossed-roller guides placed on the base body. The slider is driven by a centred PIMag® voice-coil motor, which was specifically developed for high dynamics.

The travel range of 7 mm can be limited upwards and downwards with adjustable hard stops by the user. Acceleration is up to 8 m/s², the maximum velocity 200 mm/s. This results in step-and-settle times of below 15 msec for 100 nm and 250 nm step sizes at ±15 nm error band. The high-resolution optical PIOne linear encoder is used to achieve the high precision requested. A minimum incremental motion of 10 nm and a bidirectional repeatability of 25 nm (at 100 nm travel) can be realised.

A special feature is the magnetic weight force compensation. This ensures a levitation of the slider and mounted load without power supply and it so prevents an uncontrolled crash in case of a power failure or when switching off the controller. For a flexible use of the axis – when switching the objective, for example – the user can adjust the counteracting force and compensate an overall load (objective and holder) of up to 1 kg. Because of this, the axis acts as a horizontal axis even when being used vertically.

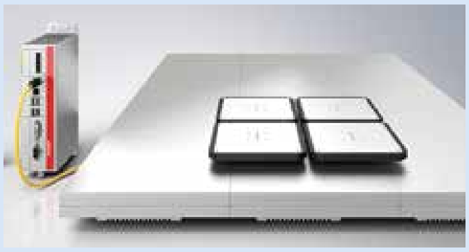


WWW.PHYSIKINSTRUMENTE.COM

Free-floating movers

Automation and motion specialist Beckhoff has introduced the eXtended planar motor system. Free-floating planar movers (maximum load 6 kg) move jerk-free and contact-free in six degrees of freedom at up to 4 m/s over planar tiles that can be arranged in any desired layout. The movers are kept at a defined distance by electromagnetic forces. Travelling magnetic fields generated in the planar tiles provide for a precise and highly dynamic positioning of the movers.

The XPlanar system offers maximum flexibility in layout and architecture, maximum positioning flexibility and simplification of machines and plants. Contaminants from transported goods are not spread throughout the plant; liquids can be transported without spilling over; wear and emissions due to friction are eliminated. The XPlanar system represents a new drive concept for general machine manufacturing and in the food and pharmaceutical industries, and in both vacuums and cleanrooms. With appropriate surface finishing, the planar motor system is also available as a hygienic design version.



WWW.BECKHOFF.COM

Satellite communications and radar toolboxes

MathWorks' latest release, 2021a, 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. New products introduced in R2021a include Satellite Communications Toolbox, Radar Toolbox and DDS Blockset, a Simulink add-on that gives system and algorithm engineers developing software for DDS-based embedded systems (DDS = data distribution service) a full model-based design experience.

WWW.MATHWORKS.COM

Micromoulding micro-optics

Micro-optics are typically tiny lenses, beam splitters, prisms, light pipes, and other optical components in the range of 20 microns to 1 mm in size, or larger optical components with micron features. They allow manufacturers to continue the industry-wide drive towards miniaturisation in applications where light is involved, while at the same time reducing manufacturing costs, and are used today in an array of applications such as sensors, medical diagnostics, datacom applications, wearables including include fitness-type devices and medical diagnostic devices, and emerging technologies such as augmented reality glasses and contact lenses.

Here, micromoulding is the manufacturing technology of choice. Given the exacting tolerances that micro-optic components demand, micromoulders must have experience of processing very small parts, with unique requirements when it comes to handling and packaging. For example, Accumold, located in Ankeny, IA, USA, uses its own micromoulding machines made in-house to stretch the envelope and attain the small scale necessary for micro-optics parts, and also achieves the absolute flatness required (the surface relief feature depth of diffractive optical elements being in the range of a few hundred nanometers to a few micrometers, and refractive microlens arrays measuring less than 100 microns).

Use of injection moulding for micro-optic manufacture requires the optimisation of design, mastering, tooling, and production steps, meaning a close interaction between supplier and product developer is vital. Micromoulders will routinely be required to assist in the design, tooling, and manufacture of micro-optic devices such as 250-micron fibre-optic lenses, parallel array products, demux devices, and diffractive lenses. They may also need experience of moulding attenuated resins and adding IR, anti-reflective, and reflective coatings onto plastics. The demands associated with running micro-sized optical couplers, integrating lenses into housings, replicating lens profiles within a quarter wave, and realising lens surface finishes within 50 Å, require that micromoulders have a dedicated tooling expert on staff to advise on and optimise design for micromoulding and tooling. But tooling challenges and validation are only two considerations, according to Accumold. Also of key importance is moulding process parameter control and post-moulding handling, assembly and packaging. Micromoulding micro-optics requires the full package.

WWW.ACCU-MOLD.COM

The microscopic origin of dissipation

Researchers from Delft University of Technology (NL) have provided supporting evidence for the existence of a nonlinear dissipation mechanism in mechanical systems. As a result of this mechanism, the loss of energy in mechanical vibrations is greater as the amplitude of the vibration increases. Dissipation is the loss of 'useful' energy during thermodynamic processes, such as friction. To prove its nonlinear nature, the researchers from the Dynamics of Micro and Nanosystems group in the department of Precision and Microsystems Engineering used graphene nanodrums of only a few nanometers thick. Last February, Nature Communications published their results.

As there have been few possibilities to influence the damping force in nanosystems until now, this research paves the way to exciting possibilities to better understand the origin of dissipation at the nanoscale and realise ultrasensitive controllable sensors. For this study, with funding from the European Research Council (ERC), the researchers worked with colleagues from Ben Gurion University (Beersheba, Israel) and the Kavli Institute of Nanoscience in Delft.

Mechanical sources of dissipation play a key role in modern physics, with applications that span nanomechanics, biomechanics, materials science, and quantum computing. In clocks and other vibrating mechanisms, energy loss is usually proportional to the speed of the vibrating object. But in special circumstances, where one resonant frequency of the resonator is exactly twice as high as another resonant frequency, these losses suddenly become much greater, as additional energy is lost through the coupling between these modes of vibration. Using light, the researchers tuned the interaction between the vibrational states of a graphene nanodrum in such a way that one mode vibrates exactly twice as fast as another. In doing so, they also showed that with this mechanism it is possible to control the damping force via the coupling strength between the two vibration modes.

One of the researchers, Ph.D. candidate Ata Keskekler, draws the analogy with playing a guitar. "Normally, the rate at which the sound of a guitar string decays is independent of how hard you pluck it. However, if we make an analogy between a nanoresonator and a guitar, in this work we find a mechanism that indicates that if you tune another string close to a note that is the first octave of the string that is played, the rate of decay becomes dependent on how hard you pluck it. The closer to the octave, the stronger is this dependency."

WWW.PME.TUDELFT.NL

Design for Mars

Six of these maxon DCX 10 motors, Ø 10 mm, brushed, are steering the Mars helicopter (on the right).

Earlier this year, NASA's Mars 2020 mission landed the Perseverance rover and the first Mars helicopter on the red planet. Just like in previous missions, these vehicles are fitted with drives supplied by maxon, based on standard catalogue products modified for the specific mission. The drives (precision motors and gearheads) need to meet extremely high quality standards in order to qualify for a challenging mission to Mars.

The first challenge is to survive the rocket launch. This means that the motor must be resistant to shock and vibration. Shocks occur mainly during staging, which is when the first stage separates from the rest of the rocket. The resulting forces would destroy normal motors because the rotor would become separated from the stator. That's why the drives are reinforced, for example by encapsulating the rotor and using special welds, special retaining rings, and optimised materials.

During the trip to Mars, the drives need to survive the vacuum and radiation. The most damaging radiation comes from high-energy particles from outside the solar system, which can damage the electronics. Specially hardened electronics is required for the Hall sensors on the motors. For redundancy, they are installed in pairs. In a vacuum, the durability of components is important. For example, a glue that undergoes changes in its chemical properties and loses its adhesiveness after a few days in a vacuum, is unacceptable.

Rockets can carry only a limited mass to other planets. To make the drives as light as possible, unusual shapes and thinner housings are used, or titanium instead of steel. Often the smallest possible drive sizes are used, because the operating time required is usually shorter than for industrial applications. Higher wear is therefore acceptable.

Upon arrival, the motor must work flawlessly for the entire duration of the mission. Due to the thin Mars atmosphere, the lubricants need to be resistant to outgassing and need to retain their properties. Especially for brushed DC motors, it is necessary to use the right brush mixture. No patina forms on Mars, which is why special brushes were developed and impregnated with a lubricant (silver graphite with 15% MoS_2). This is one of the most important modifications, because regular brushed motors fail after only a few hours in a vacuum.

With a Mars mission, any kind of risk is unacceptable. Therefore, it pays to test every single component and assembly, and document the tests comprehensively. The models used on mission must be identical to the units that are qualified, because these are exposed to the same strains in tests as in real life. They are put on a shaker, exposed to temperature cycles, and subjected to durability tests. The process takes a lot of effort, but is of crucial importance, because outer space is unforgiving.

MARS.MAXONWORLD.COM

Automation Technology

Festo BV
Schieweg 62
2627 AN DELFT
The Netherlands
T +31 (0)15-2518890
E sales@festo.nl
W www.festo.nl
Contact person:
Mr. Michiel Deen

Festo is a leading world-wide supplier of automation technology and the performance leader in industrial training and education programs.

member DSPE

Cleanrooms

Brecon Group
Droogdokkeneiland 7
5026 SP Tilburg
T +31 (0)76 504 70 80
E brecon@brecon.nl
W www.brecon.nl

Brecon Group can attribute a large proportion of its fame as an international cleanroom builder to continuity in the delivery of quality products within the semiconductor industry, with ASML as the most important associate in the past decades.

Brecon is active with cleanrooms in a high number of sectors on:
* Industrial and pharmaceutical
* Healthcare and medical devices

member DSPE

Connect 2 Cleanrooms BV
Newtonlaan 115
Zen Building
3584 BH Utrecht
Nederland
T +31 (0)85-130 16 66
E info@connect2cleanrooms.com
W www.connect2cleanrooms.nl

Developing the most appropriate cleanroom to transform your production is our passion. Our scalable and connected cleanrooms have been delivering regulatory compliance to our clients since 2002. We innovate to overcome your contamination control challenges – resulting in a new generation of scalable cleanrooms that set an unprecedented benchmark in the industry.

member DSPE

Development

TNO
T + 31 (0)88-866 50 00
W www.tno.nl

TNO is an independent innovation organisation that connects people and knowledge in order to create the innovations that sustainably boosts the competitiveness of industry and wellbeing of society.

member DSPE

Development and Engineering

TBRM Engineering solutions
De Witbogt 2
5652 AG Eindhoven
T +31 (0)40 8517 500
W www.tbrm-es.nl

TBRM Engineering solutions (previously Segula Technologies Nederland B.V) is part of the TBRM Group. TBRM-ES is an engineering company which operates internationally and aims at supporting customers by providing services from consultancy to complete project solutions including delivery of hardware, which are carried out either at the customer's location or at TBRM-ES.

TBRM-ES aims at providing innovative solutions for both existing OEM companies, as for small start-ups: Together we can create opportunities!
In addition, we aspire to be a company which distinguishes itself with a high degree of commitment, honesty, accessibility, professionalism, customer focus, quality, and an entrepreneurial spirit, where the team element is paramount in the working environment.

member DSPE

Education

Leiden school for Instrumentmakers (LiS)
Einsteinweg 61
2333 CC Leiden
The Netherlands
T +31 (0)71-5681168
E info@lis.nl
W www.lis.nl

The LiS is a modern level 4 MBO school with a long history of training Research instrumentmakers. The school establishes projects in cooperation with industry and scientific institutes thus allowing for professional work experience for our students. LiS TOP accepts contract work and organizes courses and summer school programs for those interested in precision engineering.

member DSPE

Electrical Discharge Machining (EDM)

CVT precisie draadvonken

CVT BV
Heiberg 29C
5504 PA Veldhoven
The Netherlands
T +31 (0)497 54 10 40
E info@cvtbv.nl
W www.cvtbv.nl

Partner high tech industry for wire EDM precision parts. Flexible during day shifts for prototyping. Outside office hours low cost unmanned machining. Call and enjoy our expertise!

member DSPE

terhoek edm & precision solutions

Ter Hoek Vonkerosie
Propaanstraat 1
7463 PN Rijssen
T +31 (0)548 540807
F +31 (0)548 540939
E info@terhoek.com
W www.terhoek.com

INNOVATION OF TOMORROW, INSPIRATION FOR TODAY
Staying ahead by always going the extra mile. Based on that philosophy, Ter Hoek produces precision components for the high-tech manufacturing industry.

We support customers in developing high-quality, custom solutions that can then be series-produced with unparalleled accuracy. That is what makes us one of a kind.
It is in that combination of innovative customization and repeated precision that we find our passion. Inspired by tomorrow's innovation, each and every day.

member DSPE

Lasers, Light and Nanomotion

LASER 2000

Laser 2000 Benelux C.V.
Voorbancken 13a
3645 GV Vinkeveen
Postbus 20, 3645 ZJ Vinkeveen
T +31(0)297 266 191
F +31(0)297 266 134
E info@laser2000.nl
W www.laser2000.nl

Laser 2000 Benelux considers it her mission to offer customers the latest photonics technologies available.
Our areas of expertise are:

- Piezo- and stepper motion products for nano- and micro positioning
- Lasers, scanners and laser machines for industry and research
- Light metrology instruments for LED and luminaire industries
- Light sources for scientific applications
- Laser safety certified products

TLS te lintelo systems bv photonics. our passion! 35 YEARS

Te Lintelo Systems B.V.
Mercurion 28A
6903 PZ Zevenaar
T +31 (0)316 340804
E contact@tlsbv.nl
W www.tlsbv.nl

Photonics is our passion!
Our experienced team is fully equipped to assist you with finding your best optical business solution.
For over 35 years TLS represent prominent suppliers in the photonics industry with well-educated engineers, experience and knowledge.
Over the years we became the specialist in the field of:

- Lasers
- Light metrology,
- Opto-electronic equipment,
- Positioning equipment
- Laser beam characterization and positioning,
- Interferometry,
- (Special) Optical components,
- Fiber optics,
- Laser safety

Together with our high end suppliers we have the answer for you!

member DSPE

Mechatronics Development

SIOUX TECHNOLOGIES

Sioux Mechatronics Competence Centre
De Pinckart 24
5674 CC Nuenen
T +31 (0)40 2635000
E info.ccm@sioux.eu
W www.sioux.eu

Sioux Technologies is a global technology partner that supports or acts as the R&D department for high-tech companies. We help leading companies with the development, industrialization and creation of their products, from concept stage to a prototype and/or delivery of series production. Commitment, motivation, education and skills of our employees are the solid basis for our business approach. Together with the customer, we bring high-tech to life.

member DSPE

MTA creating mechatronics

MTA B.V.
Maisdijk 12
5704 RM Helmond
T +31 (0)492 474992
E info@mtagroup.nl
W www.mtagroup.nl

CHANGING THE GAME OF MECHATRONICS.
We develop mechatronic products in such a way that they can be produced in series, at a pre-defined price point, at a pre-defined quality level and with the shortest time-to market.
Our unique "V^2-way of working" enables viable business cases.
Product and production design run concurrently and are continuously coordinated and synchronized during the development process.
This is how we make a difference in the world of mechatronics.

member DSPE

Mechatronics Development

MI-Partners
Habraken 1199
5507 TB Veldhoven
The Netherlands
T +31 (0)40 291 49 20
F +31 (0)40 291 49 21
E info@mi-partners.nl
W www.mi-partners.nl

MI-Partners is active in R&D of high-end mechatronic products and systems. We are specialised in concept generation and validation for ultra-fast (>10g), extremely accurate (sub-nanometers) or complex positioning systems and breakthrough production equipment.

member DSPE

Metal Precision Parts

Etchform BV
Arendstraat 51
1223 RE Hilversum
T +31 (0)35 685 51 94
F info@etchform.com
W www.etchform.com

Etchform is a production and service company for etched and electroformed metal precision parts.

member DSPE

Micro Drive Systems

maxon benelux
Josink Kolkweg 38
7545 PR Enschede
The Netherlands
T +31 (0)53 744 0 744
E info@maxongroup.nl
W www.maxongroup.nl

maxon is a developer and manufacturer of brushed and brushless DC motors, as well as gearheads, encoders, controllers, and entire mechatronic systems. maxon drives are used wherever the requirements are particularly high: in NASA's Mars rovers, in surgical power tools, in humanoid robots, and in precision industrial applications, for example. To maintain its leadership in this demanding market, the company invests a considerable share of its annual revenue in research and development. Worldwide, maxon has more than 3.050 employees at nine production sites and is represented by sales companies in more than 30 countries.

member DSPE

Micro Drive Systems

FAULHABER Benelux B.V.
Drive Systems
High Tech Campus 9
5656 AE Eindhoven
The Netherlands
T +31 (0)40 85155-40
E info@faulhaber.be
E info@faulhaber.nl
W www.faulhaber.com

FAULHABER specializes in the development, production and deployment of high-precision small and miniaturized drive systems, servo components and drive electronics with output power of up to 200 watts. The product range includes brushless motors, DC micromotors, encoders and motion controllers. FAULHABER also provides customer-specific complete solutions for medical technology, automatic placement machines, precision optics, telecommunications, aerospace and robotics, among other things.

Physik Instrumente (PI)
Benelux BV
Hertog Hendrikstraat 7a
5492 BA Sint-Oedenrode
The Netherlands
T +31 (0)499-375375
F +31 (0)499 375373
E benelux@pi.ws
W www.pi.ws

Stay ahead with drive components, positioners and systems by PI. In-depth knowledge, extensive experience and the broadest and deepest portfolio in high-end nanopositioning components and systems provide leading companies with infinite possibilities in motion control.

member DSPE

Motion Control Systems

Aerotech Ltd
The Old Brick Kiln
Ramsdell, Tadley
Hampshire RG26 5PR
UK
T +44 (0)1256 855055
E sales@aerotech.co.uk
W www.aerotech.co.uk

Aerotech's motion control solutions cater a wide range of applications, including medical technology and life science applications, semiconductor and flat panel display production, photonics, automotive, data storage, laser processing, electronics manufacturing and testing.

Motion Control Systems

Newport Spectra-Physics B.V.
Vechtensteinlaan 12 - 16
3555 XS Utrecht
T +31 (0)30 6592111
E netherlands@newport.com
W www.newport.com

Newport Spectra-Physics B.V. is a subsidiary of Newport, a leader in nano and micro positioning technologies with an extensive catalog of positioning and motion control products. Newport is part of MKS Instruments Inc., a global provider of instruments, subsystems and process control solutions that measure, control, power, monitor, and analyze critical parameters of advanced processes in manufacturing and research applications.

member DSPE

Physik Instrumente (PI)
Benelux BV
Hertog Hendrikstraat 7a
5492 BA Sint-Oedenrode
The Netherlands
T +31 (0)499-375375
F +31 (0)499 375373
E benelux@pi.ws
W www.pi.ws

Opt for state-of-the-art motion control systems from the world's leading provider PI. Developed, manufactured and qualified in-house by a dedicated and experienced team. Our portfolio includes a wide and deep range of components, drives, actuators and systems and offers infinite possibilities in motion control on a sub-micron and nanometer scale.

member DSPE

Optical Components

Molenaar Optics
Gerolaan 63A
3707 SH Zeist
T +31 (0)30 6951038
E info@molenaar-optics.nl
W www.molenaar-optics.eu

Molenaar Optics is offering optical engineering solutions and advanced products from world leading companies OptoSigma, Sill Optics and Graticules Optics.

member DSPE

Piezo Systems

HEINMADE BV
Heiberg 29C
NL - 5504 PA Veldhoven
T +31 (0)40 851 2180
E info@heinmade.com
W www.heinmade.com

As partner for piezo system solutions, HEINMADE serves market leaders in the high tech industry. Modules and systems are developed, produced and qualified in-house.

member DSPE

Piezo Systems

Physik Instrumente (PI)
Benelux BV
Hertog Hendrikstraat 7a
5492 BA Sint-Oedenrode
The Netherlands
T +31 (0)499-375375
F +31 (0)499 375373
E benelux@pi.ws
W www.pi.ws

High-precision piezo systems and applications that perform on a sub-micron and nanometer scale: world leader PI develops, manufactures and qualifies these in-house. With a broad and deep portfolio with infinite possibilities in components, drives, actuators and systems at hand, our experienced team is dedicated to find the best solution for any motion control challenge.

member DSPE

Precision Electro Chemical Machining

Ter Hoek Vonkerosie
Propaanstraat 1
7463 PN Rijssen
T +31 (0)548 540807
F +31 (0)548 540939
E info@terhoek.com
W www.terhoek.com

As Application Centre we possess the required knowledge to support our clients in every phase of development and process selection.
With our own PEM800 machine we can also use PECM in-house for the benefit of our clients.

member DSPE

Ultra-Precision Metrology & Engineering

IBS Precision Engineering
Esp 201
5633 AD Eindhoven
T +31 (0)40 2901270
F +31 (0)40 2901279
E info@ibspe.com
W www.ibspe.com

IBS Precision Engineering delivers world class measurement, positioning and motion systems where ultra-high precision is required. As a strategic engineering partner to the world's best manufacturing equipment and scientific instrument suppliers, IBS has a distinguished track record of proven and robust precision solutions. Leading edge metrology is at the core of all that IBS does. From complex carbon-fibre jet engine components to semiconductor chips accurate to tens of atoms; IBS has provided and engineered key enabling technologies.

member DSPE

ADVERTISERS INDEX