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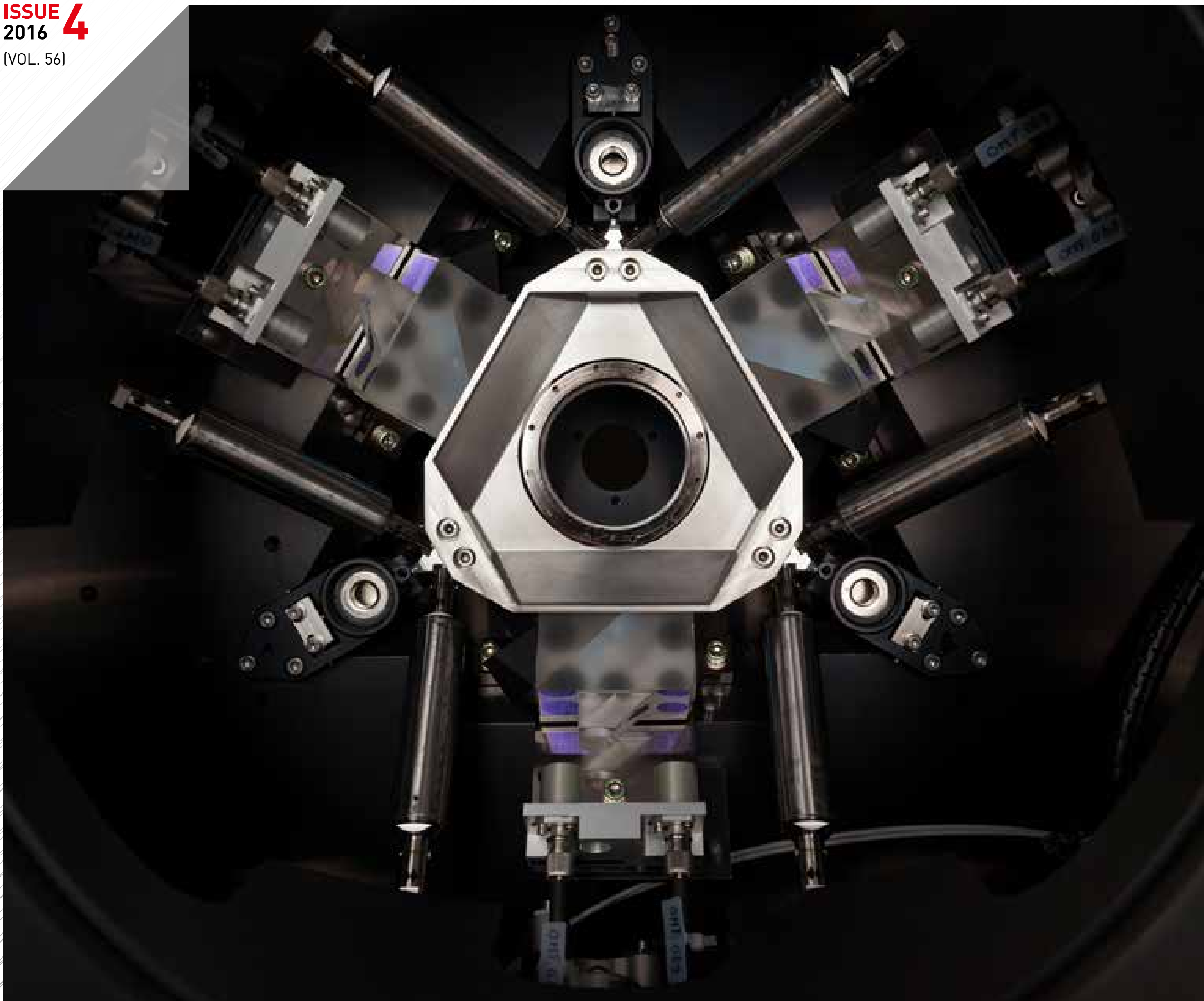
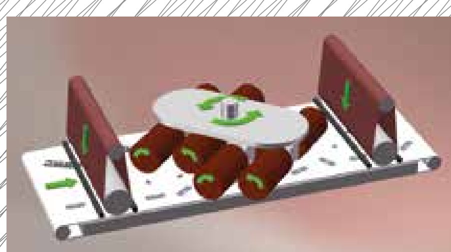


- **DEBURRING**, THE FINISHING TOUCH
- **STRUCTURED AND FREEFORM** SURFACES
- FOCUS ON ROBOTIC **GRIPPERS**
- **DSPE CONFERENCE 2016** CATALOGUE



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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.

60th anniversary DSPE YOUR PRECISION PORTAL

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The main cover photo (featuring a hexapod used in an AFM) is courtesy of TNO Technical Sciences. See the DSPE Conference programme on page 24 ff.

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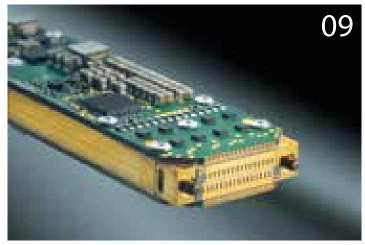
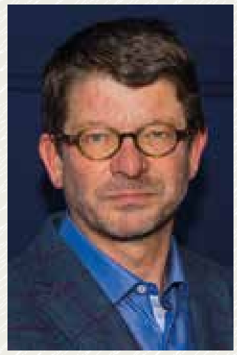


FEATURES

FARMING, PIONEERING AND INTERNATIONALISING



Next month, the third DSPE Conference on Precision Mechatronics will take place at the inspiring Ruwenberg location in Sint Michielsgestel, the Netherlands. We are looking forward to this very nice, content-rich social event. Practising precision engineering means networking. Many participants will be eager to present themselves and show their precision engineering designs. I am pleased that we have succeeded in becoming a 'warm' society of specialists who are willing to share knowledge with each other in an atmosphere of goodwill. We are sharing, we are creative, we are thinking outside the box. That is, from an international perspective, our added value when it comes to creating high-tech systems.

Let's go abroad and offer our capabilities to our international customers. This is exactly what the conference theme aims for: 'Farmers, Pioneers and Precision Engineers', inspired by the discussion about sustainable business and prosperity generated from precision engineering know-how and the role that (new) application areas play.

The community's success depends on maintaining and deepening existing knowledge (farming) and exploring new knowledge (pioneering). Therefore, it is essential to continue working in the current application areas, while also developing and investing in new ones. Maintaining the current success and simultaneously developing new knowledge and application areas is an exciting challenge for the Dutch precision engineering community.

A major aspect of creating high-tech systems is systems engineering, including tolerance budgeting. To create the best performing system, all tolerances and their interactions should be carefully treated. This is the way to obtain optimal results. DSPE will explore more activities in this area to make members aware of the value of systems engineering.

Areas we are currently working on in our society include semiconductor industry, precision instruments and medical, industrial, cryogenic, automotive, robotics and agricultural systems. Constant innovation keeps our work interesting and spreading our wings internationally will add an extra dimension. However, extra issues will also cross our path, such as cultural differences and intellectual property issues. We have to work on those if we want to let precision engineering grow as an important export product of the Netherlands. The DSPE Conference provides the showcase.

Keeping our discipline booming is an important goal for DSPE.

I want to thank all the people who are actively participating in DSPE and wish all the participants a very enriching and enjoyable DSPE Conference.

Hans Krikhaar
President of DSPE
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DEBURRING, THE FINISHING TOUCH OF ACCURATE MACHINING

Burrs: manufacturers of precision machining equipment usually deny their existence. But even laser machining, wire erosion and precision punching cause burrs, however tiny they may be, making some form of deburring indispensable. Timesavers International in Goes, the Netherlands, is specialised in such deburring equipment, achieving rounding-off radii from nearly 0 to 2 mm. Another precision challenge addressed by Timesavers has been the design of a huge machine for calibrating metal sheets.

FRANS ZUURVEEN

The Timesavers 81 series sheet calibration machines can handle titanium, stainless steel, aluminium and other metal sheets up to 7,500 mm long and 2,100 mm wide (see Figure 1). By grinding the upper and lower surfaces three times in a row, and with the sheet upside-down during the second time, a thickness accuracy tolerance of 25 μm is attainable, making this calibration process real precision technology. The main application area of such calibrated sheets is the aircraft industry.

1 *A Timesavers 8100 belt grinding machine for the accurate calibration of sheet metal up to 7,500 mm long.*

AUTHOR'S NOTE

Frans Zuurveen is a freelance text writer who lives in Vlissingen, the Netherlands.

Belt grinding versus stone grinding

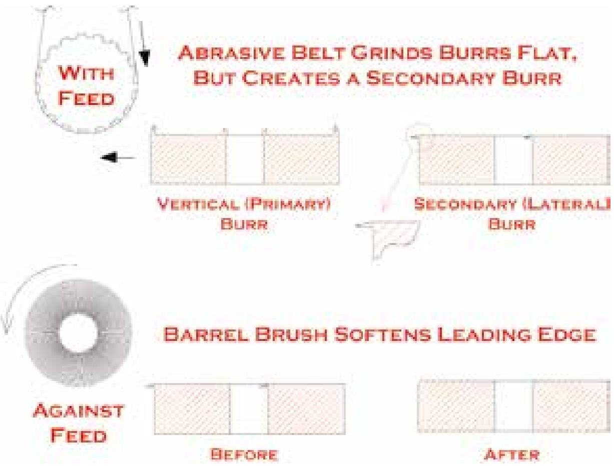
The 81 series sheet calibration machines, which will be dealt with further on in this article, may be regarded as a successful spin-off of Timesaver's deburring expertise with grinding belts. In the precision engineering world, stone grinding is mostly preferred to belt grinding because stone grinding has the ability to machine 3D-curved surfaces. On the other hand, belt grinding is limited to the machining of flat surfaces, although cylindrical forms can be handled too.

Hermes Abrasives in Hamburg, Germany, is an important supplier of grinding and sanding materials. They claim some important advantages for the application of their belts: long lifetime, high cutting rates and dry as well as wet application. Base materials for grinding belts are paper, cloth or webrax, a non-woven cloth with a polyester web. A surprising property is the regular arrangement of abrasive grains – aluminium oxide, zirconium oxide, silicon carbide or special ceramic – on the base material. Because of the identical orientation of each abrasive grain, Hermes states that their grinding particles nearly always show the same cutting and clearance angles. This is contrary to the stochastic orientation of grains in stone grinding discs. And Timesavers claims that changing a grinding belt requires much less time than changing and adjusting a stone grinding disc.

Deburring technology

Timesavers has more than seventy years of experience in the field of deburring technology, with its roots in the development and sales of wood machining equipment. Gradually, its expertise evolved from the rather rough removal of unwanted machining remnants to a sophisticated technology for applying the finishing touch to precision parts from sheet metal. This evolution originated from the understanding of primary and secondary burr formation.

Figure 2 shows how a so-called primary burr can be removed by making a grinding belt move in 'with feed' mode. The primary burr disappears, but a secondary burr occurs inside the hole due to plastic deformation of the primary burr. [If the belt was moving in 'against feed' mode, a secondary burr would occur at the other side of the hole.]



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The lower part of Figure 2 shows the solution to this problem: using a barrel brush. This is a rotating brush with slabs of grinding cloth, which tend to protrude outwards thanks to centrifugal forces. Those slabs penetrate into holes and remove the secondary burrs. Depending on parameters such as rotational speed, slab stiffness, type of abrasive, product material, etc., the edge of the hole is rounded off with a radius between nearly 0 and about 2 mm.

Grinding tool configurations

Deburring is very often an indispensable operation, but the customer-specified rounding-off radius is subject to variation. Electronic workpieces need a rather large radius because of the risk of damaging wires at sharp edges. Rounded-off workpieces are also preferred in the food industry and for parts that have to be powder-coated. Products for the aircraft industry need some rounding-off as well, because sharp edges may damage the rubber cushions applied in large presses for aluminium sheet parts. On the other hand, high-precision parts must often have well-defined sharp edges. Needless to say, the deburring process for precision sheet parts should reduce the product thickness as little as possible. These varying customer wishes require a thorough knowledge of deburring processes.

Some decades ago, Timesavers' deburring processes comprised the simple application of Scotch-Brite rotational discs. Such discs consist of non-woven polyamide mesh containing glue to which the abrasive grains are applied. These simple deburring processes sufficed to remove primary burrs.

Over time, customers and Timesavers specialists became aware of the existence of secondary burrs and the necessity to remove them. Figure 2 illustrates that barrel brushes, shown in Figure 3, are able to accomplish this. The only disadvantage is that secondary burrs with about the same direction as the circumferential brush motion do not vanish. This insight inspired Timesavers to invent several configurations of grinding belts and barrel brushes in gradually advancing deburring machinery, with the main objective of confronting every part of the product with a correct direction and speed of the brush and belt. Figure 4 is an example of this evolution and Figure 5 shows the configuration in practice.

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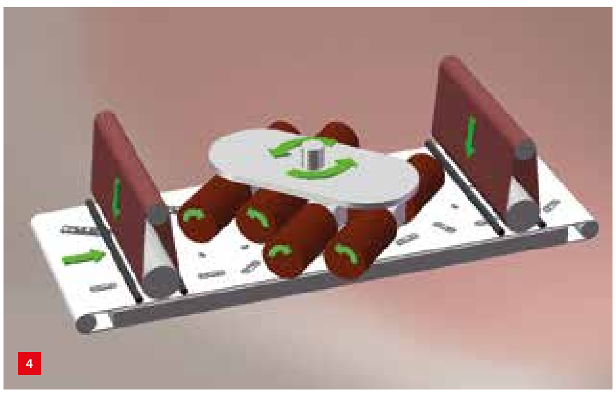

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2 *Upper part: removing a primary burr with a grinding belt, with the unwanted creation of a secondary burr inside a hole. Lower part: removing a secondary burr with a barrel brush. (Published in The Fabricator magazine, www.thefabricator.com, May 2012)*

3 *An arrangement of four barrel brushes, the two left ones as well as the two right ones mutually rotating in opposite direction.*

4 *An advanced configuration of two grinding belts and four barrel brushes, resulting in the removal of primary as well as secondary burrs.*

5 *The arrangement of Figure 4 in a Timesavers 42 series deburring machine.*

6 *The main grinding head of an 81 series sheet calibration machine with opened front panel. The (dark) vertical bars along which the grinding head moves vertically are clearly visible below.*

The 8100 calibration machine

Timesavers offers an extensive range of deburring machines, each developed according to specific customer wishes. The Timesaver 8100 sheet metal calibration machine may serve as an interesting example of applied precision engineering. The huge machine shown in Figure 1 contains a stationary main grinding head with a moving slide supporting the metal sheet to be calibrated. In comparison, a configuration with a moving grinding head and stationary sheet would only require nearly half the machine length, but has the disadvantage that all grinding head connections must be flexible. These connections include the electric wiring of course, but also the cooling fluid supply and grinding waste removal. Moreover, the stationary head configuration guarantees a high sheet thickness accuracy, as this accuracy only depends on the position of the grinding belt with respect to the slide moving underneath.

For extra precision, the temperature of the cooling fluid – water – is thermostatically maintained at 20 °C with a tolerance of some tenths of a degree. The fluid can recirculate thanks to a filter that removes grinding waste. The workpiece, up to 7.5 m long, is clamped on the movable slide with atmospheric pressure, thanks to 'vacuum' suction below. The complete main grinding head has to be accurately adjustable in a vertical direction to meet the nominal sheet thickness and to compensate for grinding belt wear. Sheets with a thickness as low as 0.18 mm can be calibrated.

The engineering of the complete machine comprises rather well-known precision engineering design principles. The nearly 15 m long base frame consists of a stiff welded construction supporting stone-ground prismatic guideways on which recirculating ball units run. A rack-and-pinion unit with a pre-tensioned gearwheel drives the table.

The main grinding head, with separate display and control unit, is movable vertically thanks to four round precision bars on which ball bushings run (two on each bar, see Figure 6). Four ball circulating nuts running on carefully machined lead screws support the complete unit. The lead screws are positioned in-line with the four round bars. Driving the nuts synchronously makes the complete unit move.

Thanks to compensation of grinding belt wear during a machining operation, an ultimate tolerance field (over the full sheet area) of 25 µm results when processing a sheet of stainless steel, titanium, zirconium, aluminium or any other metal. Given the very large dimensions of a sheet, achieving this precision is quite a challenge.

To conclude

Sheet metal deburring and calibration are the fields where the expertise of Timesavers is applied. Curiously, deburring is often being ignored by precision engineers. But the foregoing illustrates that awareness of the existence of burrs and careful sheet calibration both help to improve the performance of the sheet machining industry. ■

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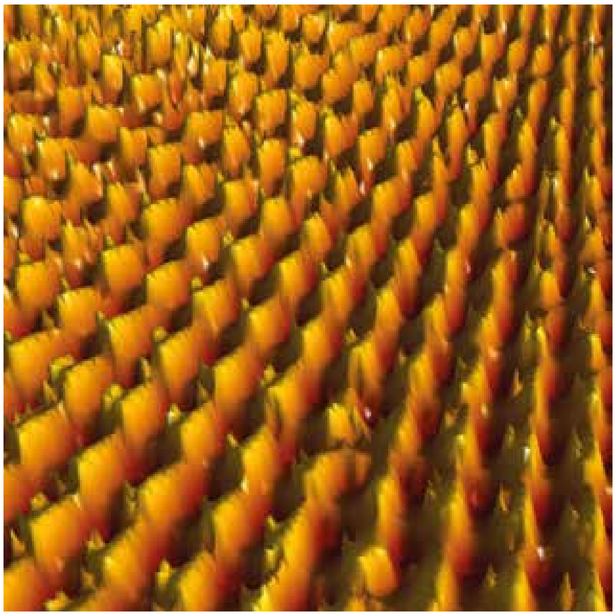
PUSHING THE LIMITS

As the European Society for Precision Engineering and Nanotechnology (euspen) prepares itself to host a Special Interest Group meeting on the subject of Structured and Freeform Surfaces on 9-10 November 2016 at the Technical University of Denmark in Copenhagen, this article looks at this niche of precision engineering, and touches on the key issues and opportunities that exist for manufacturers.

CHRIS YOUNG



Basics

When analysing structured and freeform surfaces, what we are looking at in broad terms is the manipulation of surface features and shapes on a micro- and nanoscale to add functionality to products and components. As with any 'new' concept in any line of science and technology, there is a huge amount of debate centred around definition, equally as much in fact as is centred around the possibilities, opportunities, and pitfalls that surround technological advancements.

When looking at 'structured' surfaces, definition is relatively simple and generally agreed upon. Regularly structured surfaces are usually characterised by small-scale features, which are repeated with a specific periodic pattern on the surface of interest.

The definition of a freeform surface is a little more complicated. For some people, a standard aspheric lens surface is seen as a freeform surface. But for others, a freeform surface is one that is impossible to create by sweeping a 2D curve around an axis or sweeping it along a straight line. The argument goes that 'swept' surfaces have been possible through the use of processes such as diamond turning for a long time before the term 'freeform' was even invented.

It seems as if the term 'freeform' was introduced to describe surfaces that couldn't be created by such techniques. A freefrom surface therefore is one that is significantly more difficult to design because it has more degrees of freedom than a swept or rotated 2D curve, and that requires modern manufacturing methods rather than conventional ones to fabricate.

Either way, unlike conventional surfaces, freeform surfaces have no axes of rotation, and in the future could almost have any designed shape. Their geometry cannot be described by a single universal equation (as is the case for example with aspheric surfaces), but only by a myriad of equations.

Freeform in nature

Much of the more accessible news surrounding freeform surfaces centres around attempts to copy naturally occurring surface features in order to enhance the functionality of products, often referred to as biomimetics. The surface of many plants and the skins of animals have intricate microscale surface features that give rise to properties such as directed water repellency and adhesion, camouflage, etc. Here are a few examples.

Sharkskin-inspired swimsuits were much in the news in 2008 during the summer olympics, since when they have

AUTHOR'S NOTE

Chris Young, Managing Director & CEO of UK-based Micro PR & Marketing, is media partner of euspen.

been banned as they give unfair advantage to competitors. Magnified, sharkskin is made up of numerous overlapping scales called 'dermal denticles' which have grooves running down their length in line with water flow. These grooves disrupt the formation of eddies, or turbulent swirls of slower water, making the water pass by faster. The rough shape also discourages parasitic growth such as algae and barnacles.

It is now possible to replicate dermal denticles on swimsuits and also for the bottom of boats. When commercial cargo boats can save even a tiny amount in terms of efficiency, less oil is burned, and therefore they become more efficient and less polluting. Researchers have also adapted this technique to create surfaces in hospitals that resist bacteria growth – the bacteria being unable to stick on the rough surface.

Next is the lotus flower, which has a micro-rough surface that repels dust and dirt particles, keeping its petals clean (Figure 1). Close up, a host of protuberances can be seen that can fend off specks of dust. When water rolls over a lotus leaf, it collects anything on the surface, leaving it clean. A paint has now been developed with similar properties. The micro-rough surface of the paint repels dust and dirt, diminishing the need to wash the surface that has been painted.

Another example is associated with the Stenocara beetle's water collection attributes. The beetle lives in a dry desert environment, and is able to survive due to the unique design of its shell. The Stenocara's back is covered in small, smooth bumps that serve as collection points for condensed water. The entire shell is covered in a slick, Teflon-like wax and is channelled so that condensed water from morning fog is funnelled into the beetle's mouth. Scientists have been able to build on a concept inspired by the Stenocara's shell and have crafted a material that collects water from the air more efficiently than existing designs.

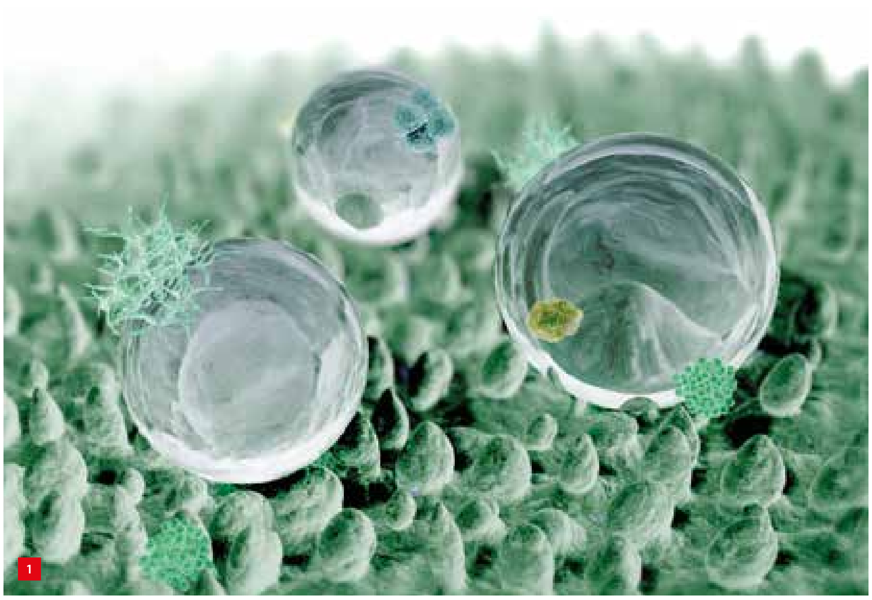
Altering product functionality

With the above examples of freeform surfaces inspired by nature, and all other freeform and structured surfaces, the ability to deterministically alter the topographic structure of a surface can have a profound effect on how that surface functions. Whilst much of the work in this area is at the research stage, the number of products that include some form of surface structure control is growing rapidly.

Structured and freeform surfaces have numerous applications ranging from optics to automotive, from aerospace to biomedical, and from micro-fluidics to power generation. The key feature that determines a structured or a freeform surface is that its topography is not just an artifact of the process used to generate the surface – on the contrary, it has been engineered for a specific function.

Thus, for a structured surface, typical parameters such as R_a do not adequately characterise its properties. A freeform surface can have a topography that significantly departs from a standard geometric element and thus conventional metrology methods tend not to be adequate. For these reasons, such surfaces are a challenge to manufacture and to measure. However, their function is by definition profoundly affected by their geometrical characteristics.

A nice example of an optical application is shown in Figure 2. This is a replica of an array of about 2,800 (57x49) hexagonal cubic retroreflector elements. The size of the array is about 10 mm x 10 mm and it was replicated by injection moulding in a polymer; the whole part/plate is about 50 mm x 50 mm large. The mould for this was machined by diamond micro-chisseling in nickel silver; the diameter (wrench size) of each of the cubic retro-reflector is 200 µm.



1 *Computer graphic of a lotus leaf surface. (By William Thielicke, en.wikipedia.org/wiki/Lotus_effect)*

2 *An array of hexagonal cubic retroreflector elements made using a mould machined by diamond micro-chisseling in nickel silver. See text for further explanation. (Photo courtesy of LFM Laboratory for Precision Machining, University of Bremen, Germany)*

Metrology concerns

In the world of precision, micro-, and nanomanufacturing, there is one homily that underlies everything that designers, researchers and manufacturers do: "If you can't measure it, you can't make it!"

Making microparts and components – or larger parts with micro- and nanofeatures –, the pressure is constantly on sophisticated metrology technologies to keep up. Nowhere is this more the case than in the area of structured and freeform surfaces. Over recent years, there has been a paradigm shift in the discipline of surface metrology, driven in large part by the growth in nanotechnology and the dawn of the next generation of ultra-precision surfaces.

Advances in nanotechnology have brought into clear focus the issues of the ability to measure and qualify commercial micrometer- and nanometer-scale manufactured components. As the dimensions of a product become smaller, the importance of the surface and its properties become the dominant factor in the successful functionality of that product. Measurement of surface texture is becoming increasingly critical because of its direct link to part functionality. Manufactured items such as micro- and nanoscale transistors, micro-electro mechanical systems (MEMS), and nano-electro mechanical systems, optics, and structured surface products are clear evidence of products where the surface plays the dominant role.

The next generation of ultra-precision surfaces will not only be very smooth, but will also have the specification of surface form at levels approaching atomic magnitude. These surfaces will relate to a wide range of devices and components, including micro-electronic devices (where semiconductor surfaces have to be extremely flat in order to pack more and more transistors and other microscopic components into the same area), and optics in ground- and space-based telescopes, in defence and satellite-based imaging systems, and in large laser facilities, where smooth surfaces with complex optical shapes with exceptional precision are required. Similar accuracy is also required in implantable medical devices such as hip and knee joints, where micrometer form and nanometer roughness requirements are specified in order to reduce the generation of wear debris.

When it comes to freeform surfaces made by one or a combination of ultra-precision multi-axis freeform machining techniques a very real difficulty is how to measure such surfaces with the required sub-micrometer form accuracy and sub-nanometer surface texture resolution.

As a consequence of the geometrical complexities of freeform surfaces, the ability to achieve a good freeform surface depends to a great extent on the prowess of machine operators and trial & error. However, there are measurement and characterisation techniques for freeform surfaces constantly under development, although there is still no mature traceable measurement methodology for the complete range of complex geometric surfaces. Instead, traditional measurement techniques ranging from contact to non-contact and from points to areal measurement are partially used for freeform surface measurement.

Fabricating processes

Various replication processes exist that are used in the manufacture of structured and freeform surfaces such as imprinting and embossing, and an area of very productive research is centred around the use of additive manufacturing techniques.

Imprinting processes have attracted increasing attention for their potential as manufacturing techniques for micro- to nanoscale features especially in polymers. Such processes include hot micro-embossing, nano-imprint lithography, UV-embossing, and others. Broadly, these processes involve the use of a tool to replicate micro- to nanoscale features in a substrate.

Replication fidelity is often high, so the geometry, surface texture, and other characteristics of the finished part are largely determined by the tool. Tooling is a critical factor for the overall success of imprinting processes, not only in terms of the quality of individual parts, but also for realising the potential of imprinting as a mass-manufacturing technique. Each tooling material and production technique has unique fundamental limits in terms of minimum feature size, aspect ratio, surface finish, and other attributes. These limits place additional constraints on production quality and tool durability. In many cases, however, these constraints are not yet known.

Imprinting techniques have demonstrated potential for manufacturing of polymer-based devices with features at the micro-/nanoscale. In order to achieve this potential on a mass scale, fundamental issues such as production rate and quality must be considered. Imprint tooling strongly influences the characteristics of the final product, and the production and quality of tooling is a vital concern for micro- and nanomanufacturing.

In the area of additive manufacturing, selective laser melting (SLM) is a technique that potentially enables new, complex-shaped geometries. It allows for the building of prototypes of freeform products from polymer-based materials with functional surfaces to which coatings can then be applied.

Alternatively, SLM can create aluminium-based prototypes that do not require coating. Both reduce the manufacturing time and the carbon footprint of complex-shaped components.

SLM has been found to be an efficient method for the fabrication of optical components, with a carbon footprint that compares favourably with that of conventional fabrication techniques. Although SLM makes it relatively easy to generate a rigid structure that serves as a mounting base for additional parts, the requirement for a high reflection grade is a serious challenge.

In the area of microfluidics – as another example – the search for economically viable microfabrication technologies to replace the more commonly used glass etching or injection moulding processes is moving on apace. Roll-to-roll production as a high-volume process has become the emerging fabrication technology for integrated, complex high-technology products recently. Differently functionalised polymer films enable researchers to create a new generation of lab-on-a-chip devices by combining electronic, microfluidic and optical functions in multilayer architecture. For replication of microfluidic and optical functions via roll-to-roll production processes competitive approaches are available (Figure 4). One of them is to imprint fluidic channels and optical structures of micro- or nanoscale from embossing rollers into UV-curable lacquers on polymer substrates.

Figure 3 shows as an example an ultra-precision drum roller being employed within the reel-to-reel platform of the EPSRC Centre for Innovative Manufacturing in Ultra Precision at Cranfield University, UK. This drum has undergone fabrication, heat treatment, machining, coating, balancing and ultra-precision diamond machining, each drum representing a major investment for a reel-to-reel production system.

SIG meeting

The scale of both the challenge and the opportunity provided by structured and freeform surfaces makes it a fertile area for discussion and research, hence euspen runs a Special Interest Group (SIG) on this topic, covering all the key areas of research and development in the area of metrology and replication processes associated with complex surfaces. The next SIG meeting will be held 9-11 November 2016 in Copenhagen, Denmark.

Topics:

- Replication Techniques (incl. Embossing, Imprinting, ...)
- Structured Surfaces to Effect Function
- Precision Freeform Surfaces
- Large Scale Surface Structuring (incl. R2R & Printed Electronics)
- Surfaces for Nanomanufacturing and their Metrology

3 *An ultra-precision drum roller being employed within a reel-to-reel platform. See text for further explanation. (Photo courtesy of Cranfield University)*

INFORMATION
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FOCUS ON GRIPPERS

In the high-tech industry (small product series with high variety and high complexity) and in the healthcare sector there is a rapidly increasing demand for adaptive robotics. Within this broad domain, Avans University of Applied Sciences focuses on industrial binpicking applications (using robots and 3D vision), force feedback gripping and twisted-cord actuators for underactuated grippers. The research supports regional companies with the implementation of systems engineering and trains students in this multidisciplinary art.

JOS GUNSING, FONS GIJSELHART, NYKE HAGEMANS, HANS JONKERS, ERIC KIVITS, PETER KLIJN, BART KAPTEIJNS, DIEDERICH KROESKE, HANS LANGEN, BART OERLEMANS, JAN OOSTINDIE AND JOOST VAN STUIJVENBERG

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This paper was presented at the International Congress on Design Engineering and Science (ICDES) 2016, which was held on 27-29 February at the University of Malaya in Kuala Lumpur, Malaysia. See also the report in the April issue of Mikroniek.

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Context

Avans University of Applied Sciences is situated in a highly industrialised part of the Netherlands. There is a shortage of highly skilled technical people, so production automation and robotics is an important theme. Many SMEs are active in this industry, not involved with mass production but with the building of highly complex machines in small series, characterised by high logistic flexibility and a large variety of products to be handled. Following consultation with industry, Avans decided to focus on robot gripper technology in combination with adaptive robotics.

As a university of applied sciences, Avans aims to make new technologies applicable in new innovative products and systems, in cooperation with universities and companies. Most of the projects are carried out in close cooperation with other universities of applied sciences, with additional funding from the Dutch Innovation Alliance Foundation, SIA. The selection of the projects is based upon the business and product roadmaps of the companies involved, combined with the useful European technology roadmap plus research agenda from euRobotics [1, 2].

In the research projects, teachers, students and companies work together. Because of the increased system complexity and the increased multidisciplinarity, a lot of educational effort is put in systems engineering, as an umbrella under which many systematic design approaches can be applied, such as V-model, scrum/agile, etc.

Projects

With a focus on industrial systems, Avans also carries out design studies of those types of healthcare gripper technologies which are also applicable in industry for handling purposes. The project roadmap aims for a gradual increase in robot complexity, especially in terms of robot-human cooperation. Based on a systematic approach using requirement analysis, function selection and modular design, several applications were selected for study. Recently, communication & multimedia design people have been involved in the research on robot-human interaction. They can help to define the right functionality and design a robot with which people are really comfortable.

Avans has already been working on binpicking applications for several years. In its region many companies work with metal or plastic components. Picking unsorted and non-oriented components out of a bin is a challenging job especially when a very short learning time is required for the robot/vision/gripper system when trying to handle a new component. To produce a robustly working system, the aim is to reduce learning time from weeks to one hour.

A new project is concerned with a robot buddy for a mechatronic systems assembly engineer, who will teach his robot buddy to take over part of the more routine-like jobs. In a healthcare robotics project a robot is being developed which is intended to help elderly people pick up objects which are on the floor or have fallen. The focus is on the hand gripper function. Healthcare technology students studied the hand functions very thoroughly and produced a set of user requirements including use cases, which form the basis for further development and engineering. The healthcare technology department at Avans will help to review the gripper design and test the gripper and robot system with the target user group.

Systems engineering

Several systems engineering design approaches are being applied during the entire process from user requirement/use case set-up to concept generation/modelling, design, engineering and experimental validation. At Avans, this is considered to be the backbone of the educational programme, especially for mechatronics engineers. Companies struggle with the implementation of systems engineering, but they are very well aware that it will help them to work successfully in multidisciplinary teams, to collaborate with other companies, to design modular product families, to transform from an engineering-to-order to a configure-to-order company, et cetera.

The research is partly based on the CAFCR method [3], (Customer Objectives, Application, Functional, Conceptual and Realisation views with respect to the product or system to be developed) in order to obtain the most suitable requirement-product concept combination. Gripper design features the complete set of mechatronic technologies as found in a robot:

- gripper design;
- force and slip sensing plus control;
- actuation/transmission;
- 3D vision including data transfer.

In cooperation with its partners in industry and (applied) sciences, Avans is currently gradually combining all the developed technologies into a complete gripper and robot system.

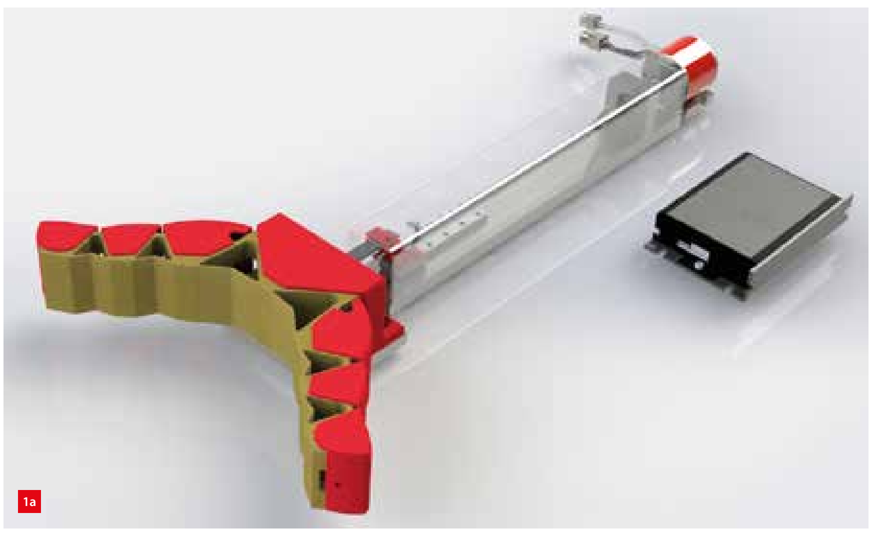
Gripper design

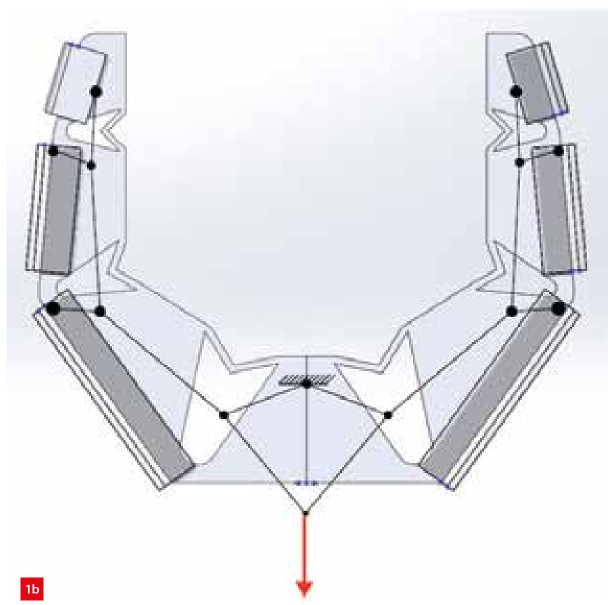
Many alternatives have been considered as a gripper concept. They had to fulfil at least the following requirements (in the case of a healthcare robot for picking up items from the floor):

- two-finger grippers to satisfy the required jobs/use cases;
- underactuated gripper design for the sake of simplicity;
- easy manufacture/low product cost/easy exchangeability.

The design that proved to be the best proposition (Figure 1) has the following (unique combination of) features:

- all moving parts manufactured in one piece, waterjet cutting plus milling from polyurethane;
- simple design with the use of elastic hinges having relatively low hysteresis;
- external actuation possible, in this case with twisted cord plus electrical motor (described below);
- moving parts covered with 3D-printed covers.





1 *Underactuated gripper. (a) Realisation. (b) Cross-sectional view of the design with elastic hinges.*

The first test results are promising, but extensive test work including validation tests with potential users still has to be carried out.

Force and slip sensing/control

Work on measuring and controlling the force in the gripper revealed that it would be most appropriate to also measure and control slip when holding objects between the fingers. A slip-sensing concept developed by the UEC Shimojo Laboratory (University of Tokyo, Japan) was used, based on a conductive rubber placed on top of an electrode. In a pressurised condition, the conductivity changes and a force-dependent signal can be measured. Just before slip occurs a high-frequency signal can be observed [4].

At the moment, a test rig is up and running and the first promising indications of slip sensing, i.e. high-frequency signals, have been seen. The test rig set-up has been designed for very low hysteresis in the gripper finger force, both in holding and slipping direction. A test gripper with very low friction/hysteresis has also been designed (Figure 2). After evaluation of the results on the test rig the force and slip sensor can be put on the gripper described above, which is much more robust but also has a higher hysteresis due to the polyurethane material choice.


2a


2b

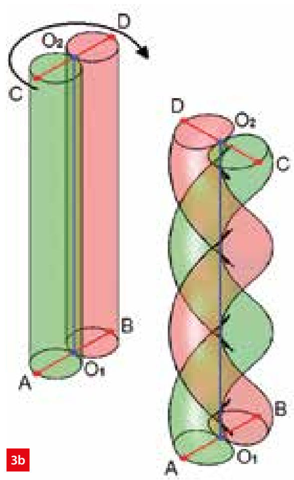
2 *Low-hysteresis gripper design for laboratory test, development and validation of force and slip sensor.*
(a) Assembly.
(b) Exploded view.

Actuation/transmission

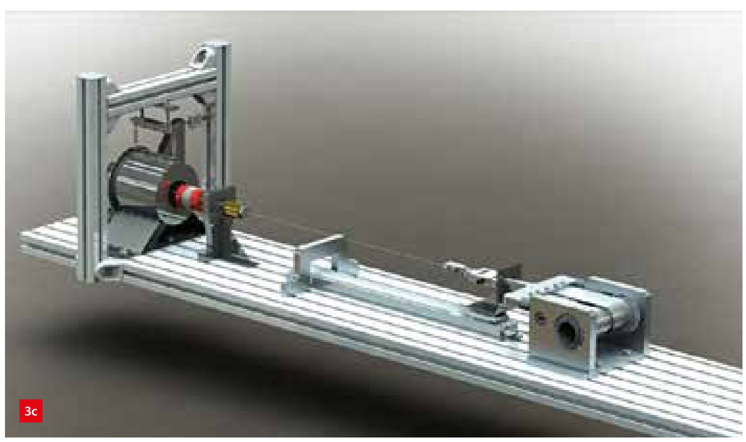
The choice for a combination of a twisted cord and electrical motor was not based on extensive studies; it appeared to be an actuator/transmission which was not quite known yet and few papers were available at that time. A twisted cord consists of two or more cords twisted together; one end is fixed, the other end is directly attached to a motor shaft. When the motor turns, the total length of the cord becomes shorter and it can exercise a longitudinal force, which can be applied to one or more gripper fingers.

This actuator has advantages when it is used to move the fingers in a gripper. The electrical motor can be installed in the arm of a robot at some distance, keeping the gripper compact and the inertia low when moving the gripper together with the arm. A high-torque motor is not necessary for moving the fingers. In order to become more acquainted with the characteristics of a twisted cord, a theoretical model was set-up and a test rig was also designed and built for predicting and measuring the relation between the force/torque and the shortening of the twisted cord/number of motor revolutions (Figure 3).


3a



3b


3c

3 *Twisted-cord actuator/ transmission.*
(a) Example.
(b) Model.
(c) Performance test rig.

Vision inclusion data handling

No robot and gripper system without a vision system. Since the start of its robot investigations Avans has acquired experience with vision systems based on several types of sensors:

- laser triangulation sensor;
- time-of-flight camera;
- stereo vision (two cameras).

A lot of effort also went into setting up Avans' own FPGA-based data handling system. This yielded a lot of inside knowledge of this system, but an off-the-shelf system will be used for the time being and the focus will be on the stereovision system integration with the robot and gripper system including actuation force and slip sensing system. Data handling remains important however. Since robots tend to work (partially) autonomously, there are two options:

- data transformation to information is carried out directly on the robot, preferably close to the camera;
- data are transmitted by wifi to an operator dashboard or data storage depending on the application.

Conclusion

Avans will soon have working gripper & robot systems available. Meanwhile, the research into increased levels of adaptive cooperative behaviour and of robots will be continued. Application of know-how from artificial intelligence, behavioural sciences and communication & multimedia design will help to further expand adaptive robotics applications. Projects integrating these disciplines with engineering are now being set up as an eye opener for all those interested in robots and humans working more closely together.

Working with students in applied research helps them to develop an innovation-minded attitude while being very critical about their own way of working. Systems engineering helps to align their process thinking and provides them with tools for further development of their skills and mindset. ■

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2. "Robotics 2020 Multi-Annual Roadmap for Robotics in Europe", Call 1 ICT23-Horizon 2020, Initial Release B 15/01/2014, www.eu-robotics.net
3. G. Muller, "A Multi View Method for Embedded Systems Architecting, Balancing Genericity and Specificity", Ph.D. thesis, 2004, ISBN 90-5639-120-2, www.gaudisite.nl
4. S. Teshigawara, T. Tsutsumi, S. Shimizu, Y. Suzuki, A. Ming, M. Ishikawa, and M. Shimojo, "Highly Sensitive Sensor for Detection of Initial Slip and Its Application in a Multi-fingered Robot Hand", *2011 IEEE International Conference on Robotics and Automation*, pp.1097-1102, 2011.

UPCOMING **EVENTS**

22 September 2016, Son (NL)
Precision-in-Business day
Organised by DSPE and YPN at Tegema, under the motto of "Stretching the boundaries for high-precision assembly". See also the announcement on page 49.

WWW.DSPE.NL/CENTRAAL/EVENTS/PIB-VISITS-TEGEMA

27 September 2016, Eindhoven (NL)
Photonic Integration Conference
Second edition of conference that covers the integration of photonics with microelectronics, cases in a variety of application areas, business models, and new (nano) materials.

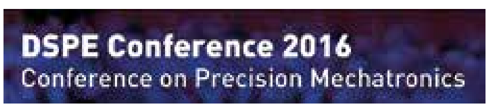
WWW.PHICONFERENCE.COM

28 September 2016, Den Bosch (NL)
Bits&Chips Smart Systems 2016
Third edition of the annual event on embedded systems and software, focused on networked technical and information systems, from smart lighting to sophisticated diagnostic equipment.

WWW.BC-SMARTSYSTEMS.NL

4-5 October 2016, Sint-Michielsgestel (NL)
DSPE Conference on Precision Mechatronics
Third edition of conference on precision mechatronics, organised by DSPE. See the programme on page 24 ff.

WWW.DSPE-CONFERENCE.NL



4-7 October 2016, Utrecht (NL)
World Of Technology & Science 2016
Four 'worlds' (Automation, Laboratory, Motion & Drives and Electronics) will be exhibiting in the Jaarbeurs Utrecht.

WWW.WOTS.NL

12 October 2016, Bussum (NL)
14th National Cleanroom Day
Event for cleanroom technology users and suppliers in the fields of micro/nano electronics, healthcare, pharma and food, organised by the Dutch Contamination Control Society, VCCN.

WWW.VCCN.NL

23-28 October 2016, Portland (OR, USA)
31th ASPE Annual Meeting
Meeting of the American Society for Precision Engineering, introducing new concepts, processes, equipment, and products while highlighting recent advances in precision measurement, design, control, and fabrication.

ASPE.NET

26 October 2016, London (UK)
The Future of Precision Engineering
The last outreach meeting of the EPSRC Centre in Ultra Precision. The activities over the past five years will be briefly reviewed and the majority of the event will focus on where precision and ultraprecision manufacturing is heading.

WWW.ULTRAPRECISION.ORG/NEWS/EVENTS

7-11 November 2016, Leiden (NL)
LiS Academy Summer School Manufacturability
Summer school targeted at young professional engineers with a limited knowledge of and experiences with manufacturing technologies and associated manufacturability aspects.

WWW.LISACADEMY.NL

9-10 November 2016, Copenhagen (DK)
Special Interest Group: Structured & Freeform Surfaces
Meeting of the euspen SIG Structured & Freeform Surfaces. Read the article on page 9 ff.

WWW.EUSPEN.EU

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

WWW.PRECISIEBEURS.NL

Precision Fair

18 november 2016, Eindhoven (NL)
HTSC Consortium Day
The Eindhoven-based TU/e High Tech Systems Center organises this day with the goal of setting up a number of research consortia, each having one or two OEMs on board, a number of suppliers and one or more knowledge institutes. Other universities, such as Delft, Twente, Wageningen and Leuven, are invited to participate. The research areas include Beyond rigid body, Contamination Control, AgroFood/HighTech, IoX for High Tech Systems and Manufacturing, System Design, Material on Demand, Complex Software, and Design for Total Cost of Ownerschip. See also the News item on page 43.

WWW.TUE.NL/HTSC

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

WWW.LINKMAGAZINE.NL

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

WWW.MICRONANOCONFERENCE.ORG

27 March 2017, Düsseldorf (GE)
Gas Bearing Workshop
Second edition of the initiative of VDE/VDI GMM, DSPE and the Dutch Consulate-General in Düsseldorf (Germany).

WWW.DSPE.NL/CENTRAAL/EVENTS/GAS-BEARING-WORKSHOP

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

WWW.AWK-AACHEN.DE

ENGINEERS, NOT RESEARCHERS, BUILT THE FIRST WAFER STEPPER

In a few weeks the book "Natlab – Kraamkamer van ASML, NXP en de cd" will be published, the Dutch title meaning "Natlab – Breeding ground for ASML, NXP and the CD". This book provides, among other things, a detailed description of the chip lithography history at Philips' famous Natlab (Natuurkundig Laboratorium, or Physics Laboratory) and the transfer of the wafer stepper to Philips Science & Industry. Mikroniek publishes a sneak preview.

RENÉ RAAIJMAKERS AND PAUL VAN GERVEN

Following their trip to the US in January 1971, it became quite clear to [Natlab employees] Gijs Bouwhuis and Herman van Heek that non-contact patterning on silicon was the Holy Grail for the semiconductor industry. They had learned that Perkin-Elmer and Ultratech wanted to tackle the problem with one-on-one exposure of the wafer, but also that Perkin-Elmer's first attempt had not survived its market launch.

Most Americans said they no longer believed in optics; they pinned their hopes on electron beams, which can write very small details directly on semiconductor wafers. Nevertheless, Bouwhuis and Van Heek stuck to an optical reduction projector. Bouwhuis still worked on a one-on-one projection system, however. He knew such a system did not distort the image, something that was often a major problem with reduction. But Bouwhuis and Van Heek realised that if they succeeded in directly reducing optically on silicon, they would have a superior technology. All problems with damaged contact masks would be a thing of the past. Furthermore, non-contact contraction would

AUTHORS' NOTE

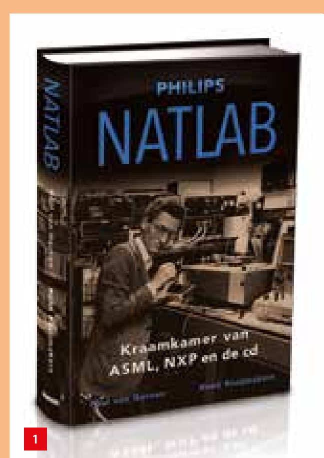
René Raaijmakers and Paul van Gerven are the authors of "Natlab – Kraamkamer van ASML, NXP en de cd". As publisher and editor, respectively, they are associated with Bits&Chips, leading newsmagazine for the high-tech industry in the Netherlands.

"Natlab – kraamkamer van ASML, NXP en de cd"

The machine with which ASML eventually became market leader in chip production equipment was conceived at the Philips Physics Laboratory. The chip technology from NXP also has its roots in this research laboratory, together with the compact disc, Philips' most successful product. But there were also serious failures. Natlab staff and their colleagues from the manufacturing world, for example, did not succeed in breathing new life into the cathode-ray tube.

Technology journalists Paul van Gerven and René Raaijmakers focus on the wafer stepper, chips, compact disc and screens in their outline of the Natlab. The way in which Philips dealt with the ingenuity of its legendary lab has never before been described in such detail and with so much colour, so the publisher claims. The authors explain in concrete terms a research world that has been closed for decades, and its impact on business. In the process, they dispel some persistent myths, such as the frequently acclaimed freedom in the lab.

For this book the authors spoke to people who were the driving force behind both failures and mega-successes.



1 *"Natlab – Kraamkamer van ASML, NXP en de cd" will be published on 28 September 2016. More than 400 pages, price €39.50, ISBN 978-90-825798-0-2.*

WWW.BITS-CHIPS.NL/NATLAB

greatly reduce errors and dust particles on the mask. What errors and dust particles would be left, would be so small on the silicon that they could cause no more damage, generally – and that would massively improve output.

In retrospect the concept seems simple, but an optical solution to pattern chips was hardly considered viable in 1971. After all, electron beam lithography was already very successful. Writing with electrons went slow, but the belief prevailed that the pace could easily be increased. Anyway, in those days electron beam lithography was significantly more accurate than optical imaging.

Bouwhuis had little knowledge of electrons, but all the jubilant American stories about electron beam patterning caused him to have serious doubts. He seriously wondered whether it was still worthwhile getting started with a complicated optical device for chip production. Along with Van Heek, he concluded that such a machine could only compete with electron writers if it worked much faster. Otherwise, the instrument would be simply too expensive and the e-beam would most certainly outflank it.

With this in mind Bouwhuis and Van Heek exchanged ideas and thoughts for months. In May 1971, together with Ad Bouwer, they explained in their technical report "Technical Note 105/71" why they opted for reduced optical projection with steps and repeats in preference to exposing an entire silicon wafer one-on-one. Among their considerations, they wrote that 250 thousand guilders would be required for a prototype: 150 thousand guilders for the optics and the rest for the electronics and mechanics. "The Natlab optical group prefers a repeater to a 1:1 projection system", according to them. "The crucial difference between the two systems is the possibility of meeting future needs."

The name was quickly devised. A few years earlier at the Natlab, Frits Klostermann had built a machine for producing contact masks photographically, the Philips Photorepeater. That machine flashed repeated patterns on glass negatives. The system of Bouwhuis and Van Heek projected these patterns directly onto silicon, so they called their machine the Silicon Repeater.

Bouwer, Bouwhuis and Van Heek proposed a structure that combined the principles that Klostermann had developed previously for the Photorepeater and the Opthycograph. They wrote that the movement was 'stop and go'. In their Silicon Repeater there was no flash but a thousand-watt mercury lamp. The light would fall on the wafer by means of a mirror concentrator, mask and lens. A shutter mechanism would precisely dose the flash.

Just like Klostermann, Bouwhuis and Van Heek were outsiders at the Natlab. They did not behave like researchers, but more like engineers who wanted to solve a practical problem, namely how to quickly display many patterns with details of a few microns on silicon slices. Van Heek was the architect and system engineer, Bouwhuis the opticist. The principle of non-contact optical projecting was actually more or less obvious, but this problem proved so difficult to solve that for a long time they did not want to consider it as a feasible route for serial production. It was like landing on the moon: they knew it was doable, but it was also rather daunting to really get started.

For example, there were the sky-high demands on the lens. To project the exposures precisely on top of each other for ten or more layers, the lens should not distort. But everything started literally and figuratively with the alignment of mask and wafer, one of the most difficult tasks. Before the system could flash an entire semiconductor wafer with patterns, it first had to know exactly where that wafer was. It then had to bring the coordinates of the wafer exactly into line with those of the photomask. This adjustment is called alignment, and had to be in fractions of microns. It was impossible to do this by hand, as it would take far too much time.

Precise alignment was just the first step. If the machine knew exactly where the wafer was and knew the coordinates of every previous exposure, it had to automatically fully flash the photoresist on the silicon wafer. This meant that the Silicon Repeater had to position the table with the wafer prior to each exposure with an accuracy of a few tenths of a micron.

In those days, Van Heek managed a small factory at the Natlab in order to make the grid measuring heads for the Photorepeater. These heads read out a code of 4-micrometer dashes on the basis of optical polarisation and phase contrast. The principle was devised within the group of Hendrik de Lang and was refined by Bouwhuis. It was fiddly work making the measuring heads. Van Heek's assistant produced just one a week.

Bouwhuis and Van Heek quickly saw the solution to their alignment problem in the polarisation principle. In fact, they did nothing else but build measuring heads that rendered these height differences visible by means of the phase contrast principle. It was a piece of cake. If they could put a barcode on wafer and mask and could align everything with a laser, then in principle they had a solution to their problem. Therefore, they didn't hesitate for one moment and began to experiment with etched stripe patterns on the wafer and similar patterns on the mask.

Coarse control was first required to bring the alignment marker within the capture range of the laser beam. Then the machine had to align the markers on wafer and mask with great precision. When the system had finished aligning, it knew exactly where the slice was. It could then fully flash the silicon with the required patterns. Bouwhuis and Van Heek discussed the implementation and the details for months – initially also with their group leader Piet Kramer, who dropped in occasionally to ask how things were going.

Apart from the markers, the discussion focused on the optical path, the route the laser had to take between the markers on mask and wafer. Bouwhuis and Van Heek came up with the brilliant idea of having the positioning laser run through the projection lens. Individual light channels for projection and alignment was a solution that all competitors chose in the 1970s, but this was much less accurate. Errors would always creep in. The two separate lenses also had to be firmly anchored together. The idea of sending the laser through the imaging optics was as groundbreaking as it was simple.

It was Bouwhuis who elaborated the idea and who later on claimed the patent for through-the-lens alignment. The choice of combining this with phase gratings was no less revolutionary. The discovery was one of the crown jewels that Philips transferred in 1984 to ASM Lithography, its lithography joint venture with ASM International. The principle was actually so advanced and robust that ASML, where alignment was concerned, still had a technological lead over its competitors at the end of the 1980s.

Together with the linear motor – also an invention from the Natlab – the phase gratings with the through-the-lens alignment represented the most important elements underlying ASML's success from a technological point of view. Partly as a result of these discoveries, ASML conquered the world market and after 2000 grew to become by far the largest supplier of lithographic processes for chips. ■

2 *The operation of the Silicon Repeater I is explained to group leader Leo Tummers (foreground) by Theo Lamboo, who was responsible for alignment under Herman van Heek. The small screen shows the alignment marker. ASML later based its logo on this marker. The photo was taken in late 1973.*

Bronkhorst – Specialist in low-flow fluidics handling technology

Bronkhorst High-Tech stands for quality, market orientation, innovation and sustainability within the world of measurement and control. The company, founded in 1981, is located in the town of Ruurlo, the Netherlands. In addition to headquarters, based in a modern factory, Bronkhorst has ten sales and service branches in Europe, Asia and America. Worldwide, Bronkhorst employs around 420 staff and enjoys an excellent reputation within the field of flow and pressure measurement and control.

Coriolis flow meter/ controller for very low flow rates.

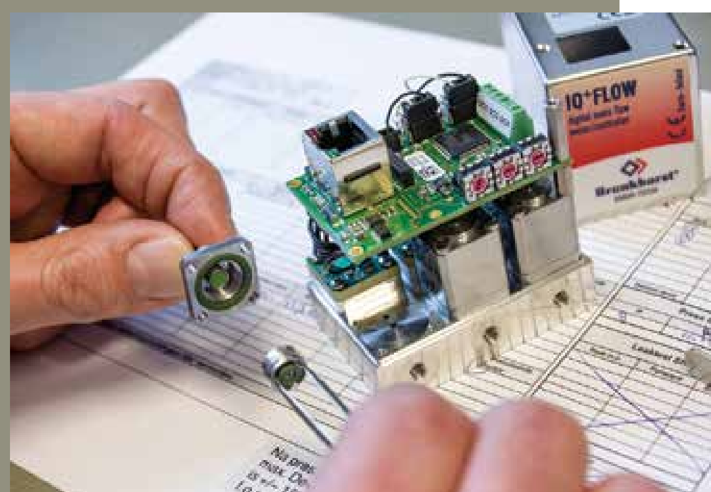
Bronkhorst offers an extensive product range of thermal and Coriolis mass flow meters and controllers for low flow rates. Numerous styles of both standard and bespoke instruments can be offered for applications in laboratory, machinery, industrial and hazardous areas. The full-scale measuring range can be selected between 0-0.7 ml_n/min and 0-10,000 m^3_n/h for gases and 0-75 mg/h up to 0-600 kg/h for liquids. The newly developed mini CORI-FLOW series of Coriolis mass flow meters and controllers feature smallest physical dimensions and lowest internal volume. Coriolis mass flow controllers are ideal for fast, repetitive dosing and filling processes for precursors, additives, solvents, etc.

Furthermore, Bronkhorst offers pressure transducers and controllers with a minimum range of 0-100 mbar and a maximum range of 0-400 bar. Bronkhorst's product group Solutions closely cooperates with OEM customers regarding customer-specific designs, e.g. of multi-functional, pretested modules for fluid delivery or dosing systems. The vapour delivery solutions can be applied for humidification, coating or analytical applications, generating between 100 ml_n/min and 10 l_n/min of saturated gas flow.

Customer satisfaction and quality of product and service have been important cornerstones of Bronkhorst's success. The organisation has been certified to both ISO 9001 and ISO 14001. In addition, the Bronkhorst Calibration Centre – also focused on low flow rates – was awarded ISO/IEC 17025:2005, guaranteeing the accuracy of every gas flow calibration performed by the calibration laboratory.

Bronkhorst's wide range of instruments can be applied in innumerable ways to a large number of different markets. A considerable number of instruments are included in production machines and systems. The most important markets are:

- (Petro)chemical
- Energy
- Environmental / Analytical
- Food and beverages
- Medical / Pharmaceutical
- Semiconductor / LEDs
- Surface treatment ■



Assembly of microfluidic multi-channel mass flow meter.

"Farmers, Pioneers and Precision Engineers"

The third edition of the DSPE Conference on Precision Mechatronics will be held in conference hotel De Ruwenberg in Sint Michielsgestel, the Netherlands, on 4-5 October 2016. This year's theme is "Farmers, Pioneers and Precision Engineers", inspired by the discussion about sustainable business and prosperity generated from precision engineering know-how and the role that (new) application areas play.

1 *Once again, the DSPE Conference will be held at the inspiring location of conference hotel De Ruwenberg in Sint Michielsgestel.*

The Dutch precision engineering community's success depends on maintaining and deepening existing knowledge (farming) and exploring new knowledge (pioneering). Therefore, it is essential to continue working in the current application areas, while also developing and investing in new ones. Maintaining the current success and simultaneously developing new knowledge and application areas is an exciting challenge for the community.

Here, cooperation and communication play a crucial role. To continue sharing the available expertise and experience in the field of precision and control engineering, DSPE decided after the first two successful editions, in 2012 and 2014, to organise a third DSPE Conference on Precision Mechatronics. The target group includes technologists, designers and architects in precision mechatronics, who, through their respective organisations, are connected to DSPE, the mechatronics contact groups MCG and MSKE, or selected companies and research/educational institutes.

In addition to paper and poster presentations and demos, the conference will provide the ideal setting for networking, technical discussion and sharing the enthusiasm of working in this challenging field. The programme is outlined on the next page and the following pages feature the abstracts of the papers and an overview of the posters and demos.

2 *Participants of the successful 2014 conference.*

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Tuesday 4 October 2016

Invited speakers

Exponential technologies to solve humanities great challenges
Maarten den Braber (Singularity University Netherlands)

How to measure a gravitational wave from a binary black hole merger
Prof. dr Jo van den Brand (National Institute for subatomic Physics, Nikhef)

SESSION 1: SYSTEM DESIGN 1

System design of the next generation wafer tables for the die-sorter machine of NXP
Thijs Kniknie, et al. (NXP Semiconductors)

Large dynamic range atomic force microscope development
Stefan Kuiper, et al. (TNO Technical Sciences)

Wafer feeder capability in iX Hybrid
Rik van der Burg, et al. (Kulicke & Soffa Eindhoven, Sioux CCM)

SESSION 2: BIG SCIENCE

Cryogenic mechanisms for infrared astronomical instrumentation
Gabby Aitink-Kroes, et al. (NOVA Optical Infrared Instrumentation Group)

Development of automated assembly machines for the particle tracking system of the ALICE detector upgrade at CERN
Ivo Widdershoven, et al. (IBS Precision Engineering)

Actuator concept to align 4,000 quadrupole magnets in the Compact Linear Collider
David Tshilumba, et al. (CERN, TU Delft)

SESSION 3: ADVANCED APPLICATIONS

High-Density Optical Fibre-to-Chip Interface
Roy Derks, et al. (MA3 Solutions)

XY360 – Planar Positioning Stage with a PSD sensor and ferrofluid bearings
Stefan Lampaert, et al. (TU Delft)

Multibody-based topology synthesis method for large-stroke flexure hinges
Mark Naves, et al. (University of Twente)

Wednesday 5 October 2016

Invited speaker

Sanjeev Pandya (Executive Vice President for Global Business Development of Advanced Oncotherapy)

SESSION 4: PIONEERING NEW APPLICATIONS

High-volume harvesting machine for white asparagus
Ad Vermeer (Cerescon)

Precision engineering in a seismic environment: the design of an electro-magnetic vibrator
Björn Bukkems, et al. (MI-Partners, Seismic Mechatronics, Magnetic Innovations)

Transformation of a planar Maglev system to new application areas
René Boerhof (Philips Innovation Services)

SESSION 5: SPECIAL TOPICS

Advanced Feedforward and Learning Control for Mechatronic Systems
Lennart Blanken, et al. (TU/e, Océ-Technologies)

Reliable nanoscale measurements in the production line
Richard Koops, et al. (VSL Dutch Metrology Institute)

Large signal non-linear analysis and validation of the suspension of a transport tool
Araz Abbasi, et al. (NTS Systems Development)

SESSION 6: VIBRATION CONTROL

Vibration Damping for 2D Image Quality
Rob Gielen, et al. (Philips Healthcare - Image Guided Therapy Systems)

Vibration Isolation applied to Coriolis Mass-Flow Meters
Bert van de Ridder, et al. (Demcon advanced mechatronics, UT)

Enabling overlay/focus improvement via passive damping in ASML motion stages
Stan van der Meulen, et al. (ASML Research Mechatronics & Control)

SESSION 7: SYSTEM DESIGN 2

Mechatronics of a sub-milliNewton tribometer
Sander Paalvast, et al. (Janssen Precision Engineering)

Slicer module for large-volume reconstruction workflow
Ron van den Boogaard, et al. (FEI)

Large flat surfaces in a high-temperature and low-pressure environment
Rob Boereboom, et al. (VDL ETG - T&D)

Both days

POSTER SESSIONS AND DEMONSTRATIONS

DSPE CONFERENCE – PAPERS (abstracts)

SESSION 1: SYSTEM DESIGN 1 - 1

System design of the next generation wafer tables for the die-sorter machine of NXP

Thijs Kniknie, Luc van den Broek, Ralph Huybers, Tom Kampschreur, Dennis van Raaij, Abhishek Bareja, Mark Otto, Joep Stokkermans (NXP Semiconductors)

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Constantly striving for quality and the lowest DFPC (die free package cost), the ITEC (Industrial Technology & Engineering Center) department of NXP develops state-of-the-art equipment for testing, die bonding and taping discrete components and integrated circuits. ITEC's Automatic Die ATtach (ADAT3) platform already has a capability of handling 6" (150 mm) and 8" (200 mm) wafers at extremely high production speeds. The next step in the equipment roadmap is to enable 12" (300 mm) wafer handling and increase the production speed significantly. Since package miniaturisation is ever ongoing, the product placement also requires improved accuracy.

The Wafer Table project started in 2013 with an exploratory concept study. In 2014 the concept had to be made in slightly more detail to estimate the volume claim of the frame design. At the end of 2014 the first prototype development was started. An additional design cycle was used to implement changes that followed from the prototype tests and to improve serviceability and reliability. In the complete project timeline, MI-Partners was involved to support in architecture and concept design and prototype development. The software application development and integration on ITEC's dedicated FlexDMC motion platform was done by ITEC.

The Long Stroke / Short Stroke stage concept was successfully introduced on ITEC's ADAT3-XF platform. The experience of MI-Partners with MIMO planar stage technology and the experience of NXP ITEC with system integration and industrialisation were combined to develop an industry-ready module starting from concept design without large setbacks. In the third quarter of 2016 the first 300mm-capable ADAT3-XF machine was shipped to one of NXP's assembly plants. ■

SESSION 1: SYSTEM DESIGN 1 - 2

Large dynamic range atomic force microscope development

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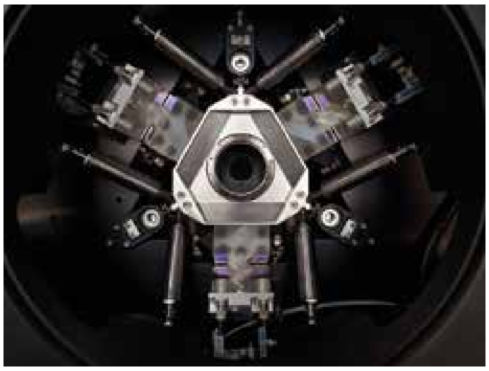
Semiconductor and nano-manufacturing demands for metrological tools that allow accurate measurements of both the nanometer-scale dimensional properties of individual features and the distance between individual features. For instance, in semiconductor manufacturing accurate characterisation of both the shape of the alignment markers, as well as their distance with respect to the functional product features would allow significant improvement of the overall overlay performance.

The major advantages of Atomic Force Microscopy (AFM) are its direct imaging method, high resolution and the fact that it is non-destructive. However, AFM systems are mostly used as pure imaging tools and they are not suitable for high-accuracy metrology tasks. Moreover, most AFM systems have a positioning range of 10 to100 microns, which is not sufficient here. Therefore, TNO is developing a metrological AFM system with an extremely large measurement range of several millimeters.



Top view of hexapod used for positioning the AFM head with respect to the wafer.

The major challenge is posed by the huge dynamic range requirements, requiring subnanometer measurement uncertainty over a range of several millimeters. On top of that, large substrates such as 300mm wafers or reticles result in a relatively large metrology loop, which poses additional stability challenges. ■

SESSION 1: SYSTEM DESIGN 1 - 3

Wafer feeder capability in iX Hybrid

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With the strategic acquisition of Assembléon by Kulicke & Soffa, market leader in wire bonders used in the back-end industry, the K&S product portfolio has been expanded to meet the new industry requirements for back-end applications. Production technologies like FOWLP (Fan Out Wafer Level Packaging) have been introduced recently. With FOWLP traditional wire bonding is replaced by an alternative bonding technology. Another important application is SIP (System in Package), where dies and passives are combined in one package. The Assembléon iX Hybrid machine offers these possibilities in a single machine.

The potential benefits of FOWLP are numerous. It provides the smallest possible form factor for packaging small, high-I/O chips. The device-to-board connections through thick copper routing layers and large solder balls offer excellent electrical properties and performance. When hitting acceptable cost and yield targets, FOWLP can potentially displace other forms of packaging, such as flip-chip or wire-bond ball-grid arrays (BGAs). Finally, FOWLP enables the connection of two or more chips in the fan-out routing layer, facilitating multi-chip and SIP applications.

The Assembléon pick & place machines contain the basic functionality to accurately place dies with high output and low cost on a variety of substrates. After the acquisition a development programme has been started to add missing functionality and improve the existing machines. Improved placement accuracy (5 µm) and picking dies directly from a wafer are examples of the new requirements.

A wafer feeder for the iX Hybrid has been developed. Bare dies can directly be picked and placed on a diversity of substrates. The iX Hybrid is ready to enter new markets to cover back-end applications like FOWLP. Re-use of existing technology available within the K&S organisation (hardware, software and bare die handling processes) and co-development with Sioux CCM helped to reach demanding time-to-market goals. ■

SESSION 2: BIG SCIENCE 1

Cryogenic Mechanisms for Infrared Astronomical Instrumentation 2.0

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NOVA, the Netherlands Research School for Astronomy, is involved in the development and realisation of various optical astronomical instruments for ground-based as well as space telescopes, with a focus on near- and mid-infrared instrumentation.

The performance of infrared instruments strongly depends on the minimisation of instrumental thermal background radiation, hence IR instruments are cooled to cryogenic temperatures. Because of the properties of Planck's radiation law the instrumental background requirements are most demanding for mid-IR instruments, resulting in instrument temperatures below 30 K.

The use of mechanisms is inevitable. The cryogenic operating environment poses several challenges: vacuum and thus limited use of lubrication; high feature density; limited space; and most significantly the physical property variation of materials, such as CTE, heat capacity, E-moduli, refractive indices, etc. Various materials change differently and in a non-linear fashion during cooling.

Several solutions have been developed for high-accuracy, backlash-free and repeatable motion under these demanding circumstances. For fine alignment special flexure-based mechanisms have been developed. For selection purposes two concepts of selection mechanisms can be distinguished based on the same design principles: linear selection mechanisms (sliders) and rotating selection mechanisms (wheels). The design and realisation of a number of these mechanisms will be discussed. ■

Alignment tip/tilt mirror mechanism.

SESSION 2: BIG SCIENCE 2

Development of automated assembly machines for the particle tracking system of the ALICE detector upgrade at CERN

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As part of the upgrade of the ALICE detector at CERN, IBS Precision Engineering is currently realising a series of machines for automated assembly of sensor modules. ALICE (A Large Ion Collider Experiment) is one of the four detectors of the Large Hadron Collider (LHC), the well-known flagship of CERN. ALICE studies the quark-gluon plasma, a state of matter thought to have formed just after the Big Bang.

CERN will upgrade the ALICE Inner Tracking System (ITS) with a new low-material and high-resolution tracker in order to greatly improve features like spatial resolution, tracking efficiency and read-out rate capabilities. The new ITS consists of seven concentric layers of pixel detectors. Each pixel sensor element is a chip consisting of a single silicon die of 15 mm by 30 mm, which incorporates a matrix of charge collection diodes (pixels, with a pitch of the order of 30 μm).

The key element of the new ITS detectors is the Hybrid Integrated Circuit (HIC), designed to have minimal material budget and high accuracy of chip positions. It is a structure consisting of a flexible printed circuit of about 150 μm thickness and an array of pixel chips. It is for the assembly of these HICs that IBS Precision Engineering was tasked with the development and realisation of seven automated assembly machines. Together, these machines will enable the assembly of over 30.000 chips.

The main assembly requirement is the positioning accuracy of the chips to within 5 μm with respect to external reference features. The design of the machine has been shown to meet this and all other critical requirements. In May 2016, the first assembly machine was delivered to CERN and extensive process testing was started. By the end of the year, six additional machines will be realised and delivered to institutes around the world. ■

SESSION 2: BIG SCIENCE 3

Actuator concept to align 4,000 quadrupole magnets in the Compact Linear Collider

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The Compact Linear Collider (CLIC) is a European project for the next-generation particle collider under study at CERN. The overall dimension of the machine is foreseen to be 48 km long, with two straight sections of 24 km facing each other. The accelerator will consist of about 41,520 modules.

The accelerator will produce collisions of electrons (e^-) and positrons (e^+), operating at 3 TeV. Unlike circular machines, linear colliders do not suffer from the synchrotron radiation. CLIC will operate beams of nanometric size (1 nm x 40 nm) and produce a high density of collisions at the interaction cross section ($2 \cdot 10^{34}$ hits/(cm^{2}s)). To guarantee this high density of events two major challenges must be addressed: the tight alignment tolerance of the critical components of the accelerator (up to 10 μm along 200m-long sliding windows) and the motion control of the quadrupole magnets. The objective of the PACMAN project is to tackle these challenges.

The motion control challenge involves the design of a stiff and sub-nanometer-resolution positioning system providing a stroke in the millimeter range for 4,000 quadrupole magnets. Stiffness can be provided either by the actuator directly (direct approach) or by a leveraged mechanism actuated by a softer actuator (leveraged approach). Analytical calculation and finite-element analysis of a flexible lever arm rotating around a compliant rotation joint have shown the influence of the flexibility of the pivot and the lever arm on the effective stiffness amplification ratio. As a conclusion any compact stiffness amplification mechanism based on inverted lever arms can be used for moderate input stiffness (< 1 N/μm) and small stiffness amplification factors.

Because of the order of magnitude of the required stiffness (400 N/μm) the direct approach is more appropriate. To achieve the millimeter range, a possible approach consists of including a stepping capability to the positioning system. The focus of study will be on the treatment of the transient phenomena during the stepping cycle in order to optimise the speed and repeatability of the system. ■

SESSION 3: ADVANCED APPLICATIONS 1

High-Density Optical Fibre-to-Chip Interface

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Ahe miniaturisation of integrated optics is going through a similar evolution as that of electronics: by scaling down the component size, reduced power consumption and increased signal bandwidths are achieved. Up to now, photonics research has been mainly focusing on the integration of new and miniaturised functionalities on-chip. However, the interface technology of coupling the photonic integrated circuits (PICs, on-chip) to the outside world (optical fibres) is generally far behind in development.

First of all, the large-scale difference between the core of an optical fibre (~10 µm) and the width/height of an on-chip waveguide (~400 nm) challenges the creation of a low-loss connection. Several in-plane taper-based mode field expanding solutions have been evaluated. However, planar tapers are only capable of expanding the mode field in one direction (1D) and result in high losses, where 3D or staircase tapers achieve lower losses but are very difficult to produce in standard fabrication technologies used for photonic chips.

As a second challenge, due to the increased functionalities on-chip, the number of fibre-to-chip connections needs to scale up equally. Most common coupling technologies are in-plane, and only have limited space to connect fibres. Interfacing out-of-plane can be done using grating couplers implemented on a Silicon-on-Insulator (SOI) chip, which use diffraction to direct the light perpendicular to the waveguide. This is nowadays a popular and promising technology that enables the required high number of fibre-to-chip connections, from the top surface of the optical chip, with efficient signal transmission. The fibres to be connected to a chip with grating couplers need a two-dimensional (2D) arrangement, which is up to now a bottleneck in photonic applications. Fibre-per-fibre alignment is very labour-intensive and has a very low yield.

A novel method for the out-of-plane coupling of optical fibres is proposed, by the development of a highly accurate 2D fibre array for SOI photonic chip interfacing, together with the development of associated 6-DoF fibre-to-chip alignment technologies. ■

SESSION 3: ADVANCED APPLICATIONS 2

XY360 – Planar Positioning Stage with a PSD sensor and ferrofluid bearings

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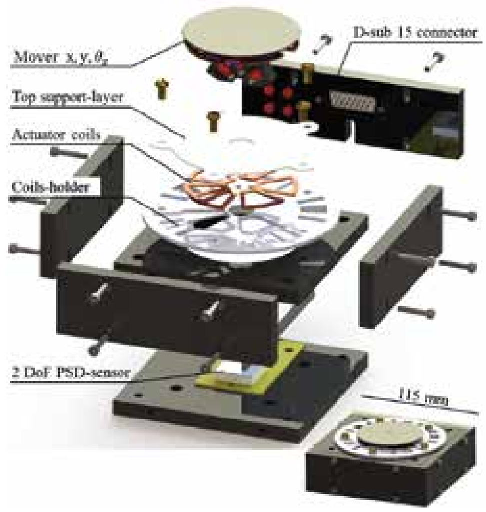
Two earlier concepts of planar stages, realised in Delft, demonstrated that ferrofluid bearings are very promising when a simple and low-cost solution for high-precision positioning is required. The first concept is a 1-DoF (degree of freedom) motion stage. The second is a so-called (2+4)-DoF positioning system to demonstrate nanometer-range accuracy. The next effort was to reduce the complexity and cost of all components of the system. The result was a compact XY stage with two optical mouse sensors and an Arduino controller with PWM drivers for three simple in-plane Lorentz (voice-coil) actuators. Now the next step in the ferrofluid micro-stage research is presented, in which a large-stroke in-plane rotation DoF has been added. This DoF was constrained actively in the previous systems. The result is a novel and simple 3-DoF positioning system that can make 9mm translations in-plane and a full rotation, a so-called XY360 planar positioning system; it has an integrated 3-DoF sensor system, actuator system and and bearing system. A possible application is in light microscopy enabling 3D imaging and stitching.

The planar position and orientation are measured by sequentially modulating three light beams on the surface of one optical 2-DoF position-sensitive device (PSD). A switched Lorentz actuator, similar to the ones used in hard disc drives, actuates the XY360 stage. The magnetic field of the actuator magnets is used both for the Lorentz actuation and the ferrofluid bearing system. ■



Overview of the symmetrical bearing and actuation system of the XY360 planar positioning system.

SESSION 3: ADVANCED APPLICATIONS 3

Multibody-based topology synthesis method for large-stroke flexure hinges

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In high-precision manipulators flexure-based mechanisms are often used for their deterministic behaviour due to the absence of friction, hysteresis and backlash. However, when designing flexure hinges, designers face a trade-off between flexibility for motion in certain desired directions and stiffness to constrain motion for guiding in the remaining directions. Typical flexure hinges have a range of about 10°, beyond which the guiding stiffness and load bearing capacity decrease dramatically. By using a topology optimisation suited for large deflections, guiding stiffness can be greatly increased for flexure hinges vastly exceeding the 10° range of motion.

Typical structural topology optimisations are based on density distribution or level set-functions. These methods show good results for small deformations. However, when more complex three-dimensional topologies are considered, the design domain becomes very large and topological optimisations can become computationally intensive. Furthermore, geometrical nonlinearities are mostly disregarded as they significantly increase computation load and often iterative solvers are required which have the potential to fail to converge. This makes finite-element modeling currently impractical for optimising three-dimensional large-stroke flexure mechanisms including the required non-linear effects.

A new multibody-based topology synthesis method has been developed which combines a building-block-based layout variation strategy with a shape optimisation method to obtain the optimal topology. This method shows good results for optimising flexure hinges vastly exceeding the 10° range of motion and is capable of obtaining optimised solutions in a matter of hours.

The proposed method was used to design two flexure hinges for two selected applications which both resulted in a flexure design with unmatched performance. An optimisation case aimed at maximising support stiffness showed an increase of a factor eight with respect to the customary three-flexure cross-hinge. For a second case, a flexure hinge was optimised to maximise parasitic frequency, which resulted in a tenfold increase in performance. ■

SESSION 4: PIONEERING NEW APPLICATIONS 1

High-volume harvesting machine for white asparagus

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Agriculture was limited by manpower until the combine harvester revolutionised work by using one machine to mow, thresh, and clean grain all in one pass over the field. After the invention of the first combine harvester, designed for corn, many comparable machines have been realised for almost every type of crop. But not yet for white asparagus, which to date are still harvested manually, causing labour issues and quality problems (violet colouring due to exposure to sunlight).

Start-up company Cerescon is now developing a machine for automated asparagus harvesting. Two innovations, both requiring challenging mechatronics, are vital for success: sub-surface asparagus detection and a high-volume multi-row machine concept. With subsurface detection violet colouring can be eliminated. Also, the harvesting frequency can be reduced from daily to every three days, practically tripling the machine productivity. The 3-row machine concept at a challenging 0.5 m/s drive speed has led to a 2.5 acre/hr capacity. Combined with operation in two shifts, these features lead to a system that replaces the manual work of 75 labourers.

The alpha version of the asparagus harvester. (Photo: Bart van Overbeeke)

The presentation will focus on the technical highlights in the context of the start-up business story.

Feasibility has been proven in 2015 and an alpha version of the system with all functions integrated was successfully tested in the 2016 season, proving the machine concept. A beta version is planned for next year, market introduction will follow prior to the 2018 season. ■

SESSION 4: PIONEERING NEW APPLICATIONS 2

Precision engineering in a seismic environment: the design of an electro-magnetic vibrator

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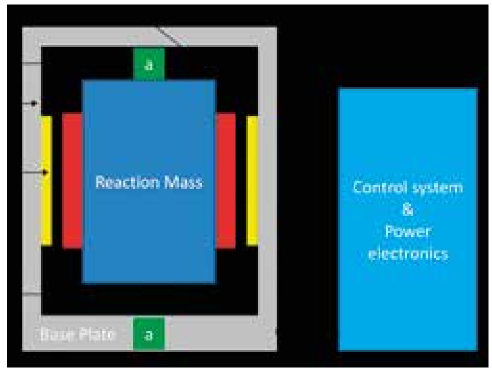
For seismic monitoring and exploration surveys, frequently used in the mining, oil and gas industry, and for geothermal research, it is required to actively excite the ground, which is most often done with a vibrator. The transmissibility of the ground is measured using a combination of sensors attached to the vibrator and geophones on the ground. Especially for monitoring purposes, the vibrator's excitation signals must be highly reproducible to detect any changes in the ground. Commercially available systems use hydraulics to create the required forces.

To overcome the performance limitation of hydraulic vibrators at low frequencies, the use of electro-magnetic (EM) linear motor technology has been investigated. This has led to the establishement of Seismic Mechatronics, a spin-off company from MI-Partners and Magnetic Innovations that has the ambition to industrialise EM-vibrator technology. The current portfolio consists of two prototypes, 'Lightning' and 'Storm', that generate 1 kN and 7 kN of excitation force, respectively.

It has been shown that the application of precision engineering design principles, yielding 'clean' mechanics, and linear actuation technology can be used to obtain reproducible ground forces with very low distortion levels. In a surface wave field test the EM vibrator proved to be capable of injecting high-quality signals into the ground such that the low-frequency part of the frequency-velocity diagram could be accurately fitted, whereas this could not be done using conventional hydraulic vibrators. ■



Schematic representation of the 'Storm' vibrator.

SESSION 4: PIONEERING NEW APPLICATIONS 3

Transformation of a planar Maglev system to new application areas

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6-DoF contactless electromagnetically levitated planar motion systems have already been around for some time, in an increasing variety of configurations, ranging from moving coil to moving magnet, all kinds of coil topologies and even to vertically suspended upside-down systems. However, the (commercially) successful application of this technology is still very much limited to high-end and in general highly customised and costly systems within very customer/user-specific application areas.

The wireless moving magnet configuration, however, could be particularly suitable for many different application areas where environmental conditions such as (particle) contamination, cleanability, vacuum and/or hazardous environments are critical. When combined with its inherent possibilities of multiple independent moving bodies and flexible modular layouts it might be argued that the future pioneering of planar 'Maglev' technology is less about the traditional (ultra-)high-precision positioning applications and more about a transformation towards flexible mid-range (µm) accuracy (product-) transportation and positioning and pick-and-place applications.

One of the main challenges for this transformation is the transition from high-end custom components in a rigid system topology towards low-cost off-the-shelf components in a highly flexible modular topology. This is where traditional linear amplifiers and high-end nanometer measurement systems need to be replaced by low-cost PWM (chip) amplifiers and (e.g. Hall) sensor arrays integrated in modular local smart electronic boards governed by a flexible overall master system.

Some of the thoughts, concepts, results and challenges of such a transformation will be addressed, partially based on an internal Competence Development effort (paper study) and partially based on a customer project to realise a functional model for several aspects of such a system. This includes a completely new and challenging functional requirement to rotate 180° in-plane (Rz) in addition to the traditional 'virtually unlimited' in-plane translational range (XY). ■

SESSION 5: SPECIAL TOPICS 1

Advanced Feedforward and Learning Control for Mechatronic Systems

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Feedback and feedforward control are key components in mechatronic systems. Regarding feedback control, PID controllers are often used because of their intuitive tuning, disturbance suppression capabilities and robustness for variations in the system dynamics. By including a feedforward controller, a significant performance increase can be obtained, often at least a factor of ten for motion control applications. This increase is achieved due to the fact that feedforward can essentially compensate for known 'disturbances' before these affect the system. For instance, the reference signal is known beforehand and its scaled velocity, acceleration, jerk, and snap profiles enable a straightforward feedforward tuning.

Iterative learning control (ILC) enables a possible further significant performance increase over common feedback and feedforward approaches. The main idea is to combine the advantages of feedback and feedforward: by learning from feeding back the error of a previous experiment, a new feedforward signal is generated that potentially compensates all repeating components of the error signal. Thus, in addition to known disturbances such as reference signals, it can also compensate for repeating disturbances such as friction and parasitic actuator forces.

Although the theory underlying ILC is reasonably mature and several design frameworks have been developed, its full potential for mechatronic applications is still largely unexploited. Some of the shortcomings of traditional ILC and related approaches will be identified and an overview is provided of recent developments that are particularly tailored towards successful implementation in an industrial mechatronic environment. In the near future, it is expected that the unified framework will be further extended and will have a significant impact on mechatronic system performance in a broad range of applications. ■

SESSION 5: SPECIAL TOPICS 2

Reliable nanoscale measurements in the production line

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Currently, product features and characteristics are entering the nanoscale domain and require increasingly accurate measurement instrumentation to inspect and validate product quality. Nanostructured surfaces to control wetting, self-cleaning, glare and even colour are just a few examples.

Within the European project aim4np (automated in-line metrology for nanoscale production) a novel approach is implemented to realise accurate nanoscale measurements on products that are still in the production line. This will enable quality assessment and improved process control in the earliest possible stages of production. A metrology platform will be dynamically positioned over the product with a robot arm and actively stabilised to minimise effects from vibrations in the production environment. One of the instruments on the platform is a dedicated high-speed atomic force microscope (AFM) that will be used to perform highly accurate measurements on preselected very small areas on the product surface.

The methods will be presented for ensuring the traceability of the instrument, so that the measurement results are indeed real nanometers, linked to the primary standard of length. A special calibration method employing virtual standards has been developed. These standards are both flexible and robust and thus ideally suited for use in an industrial setting where there is significant risk of damaging or contaminating delicate physical standards. Normally this would entail a cost in terms of the accuracy that can be achieved, but this is not the case. For this reason, the virtual standards are also an attractive alternative to traditional artifact-based calibration methods for lab-based AFMs or other high-resolution microscopes.

Virtual standards based on highly linear piezo actuators have been accurately calibrated and applied to calibrate AFM settings where conventional standards fail or standards are not available. ■

SESSION 5: SPECIAL TOPICS 3

Large signal non-linear analysis and validation of the suspension of a transport tool

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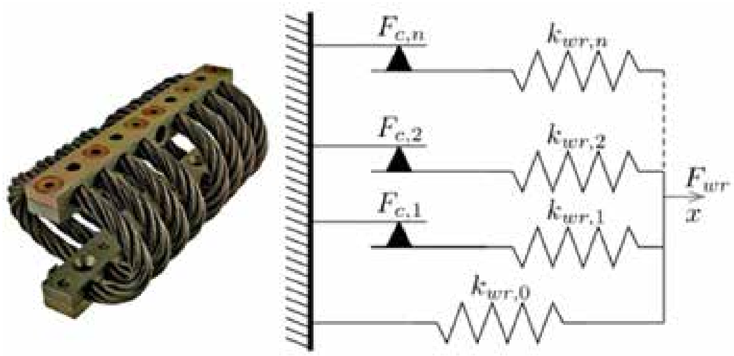
The design of ultra-high precision positioning equipment is mainly focused on the process performance of the equipment under operating conditions. External disturbance sources like floor vibrations, temperature fluctuations, particle pollution, air pressure variations and acoustic excitation, etc., have a significant influence on process quality. The magnitude of these error sources, however, often is relatively small and one may realistically assume linear behaviour of the system.

A completely different set of operating conditions is encountered during transport of the system or its modules from the manufacturing site to the customer site. Due to the large magnitudes of external disturbances linear system behaviour often is a fiction. Therefore, pioneering in the field of nonlinear system design is required. Take vibrational input from the floor, representing the mean of transportation, e.g. a truck or airplane: floor vibrations have to be isolated and shocks have to be absorbed.

Wire rope springs are great for absorbing shocks (due to their highly nonlinear behaviour) but they act as a rigid connection for small random vibration input. Elastomer isolators are able to provide reasonable damping for those vibrations but they do not provide the same amount of damping during large deflection shocks. A series connection is proposed of a wire rope spring and an elastomer isolator resulting in a hybrid damper. Such a well-designed passive isolation system combines and optimally uses the properties of these separate components. ■



Wire rope spring and model.

SESSION 6: VIBRATION CONTROL 1

Vibration Damping for 2D Image Quality

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The mechatronic factors that contribute to 2D image quality (2D-IQ) for X-ray imaging systems will be discussed. Most relevant in this context is image blur. Three factors contribute to image blur: the image detector, the X-ray source and mechanical vibrations. Their effect can be expressed using the modulation transfer function, which is the magnitude of the Fourier transform of the imaging system's response to an infinitesimal point or line.

Based on modulation transfer functions it was decided that vibrations are allowed to deteriorate the performance of the imaging system by no more than 20%. From this specification a budget for mechanical vibrations has been derived, including a maximum vibration amplitude in combination with a measurement window (determined by the X-ray exposure time). Mechanical vibrations are mainly injected via two sources; floor vibrations and setpoint disturbances. Both can be accurately modeled based on simple mass-spring-damper systems.

For floor vibrations, this model makes insightful the trade-off between the floor specification (which is a cost driver for the hospital) and the damping of the low-frequent eigenmodes of the system. However, when this model is applied to analyse the effect of floor vibrations, complying with the IGT (image-guided therapy) spec, it is found that most IGT systems do not meet the admissible vibration level specification.

For the setpoint disturbances a somewhat different model shows how different setpoints give rise to different vibration profiles. This is used to determine optimal setpoints in view of factors such as different system poses, movement speeds and distances. More specifically, a setpoint profile can be translated into a disturbance force on the system. Several improvements have been investigated and the most succesful one by far is to change the setpoint profile. The original design turned out to be very poorly tuned given the system's first eigenmode. The improved design is currently being tuned for robustness to obtain the optimal system's response. ■

SESSION 6: VIBRATION CONTROL 2

Vibration Isolation applied to Coriolis Mass-Flow Meters

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Accurate measurements of small flows are becoming more and more important in process technology.

Upcoming is the Coriolis mass-flow meter (CMFM). The sensor is based on the Coriolis force principle, for direct mass-flow measurements independent of fluid properties. The sensor contains a fluid conveying tube that is actuated to oscillate in resonance with a low amplitude around the twist-axis. A fluid flow in the vibrating tube induces Coriolis forces, which affect the mode shape by a rotation around the swing-axis

Measuring the tube displacements allows measuring the mass-flow. For sensors with a nominal flow of less than 1 kg/h the actuation displacement is sub-millimeter, while the Coriolis-force-induced displacement corresponding to the flow resolution is sub-nanometer. A successful CMFM design for measuring small flows, using contactless actuation and sensing, has been proposed earlier. The gas and liquid mass-flow measurements have an accuracy of 0.01% of the nominal flow. This accuracy is limited by many factors, such as drift, external disturbances and tube asymmetries.

The mechanical behaviour of the considered CMFM has been analysed extensively using a finite-element model. Its vibration sensitivity can be reduced considerably by passive and active vibration isolation. Careful design of the passive stage is needed to reduce the number of sensitive directions and to prevent self-excitation. Active vibration isolation (AVI) can be added to reduce the vibration sensitivity even more. The use of low-cost sensors that measure the base motion is enabled by a feedforward AVI control strategy. The tube displacement sensors, already present for the flow measurement, can be used to damp the resonance motion of the stage support and to adapt the feedforward control parameters. ■

SESSION 6: VIBRATION CONTROL 3

Enabling overlay/focus improvement via passive damping in ASML motion stages

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In a positioning system, the servo bandwidth (BW) determines the extent to which external (low-frequency) disturbances are suppressed. This is directly related to the achievable positioning accuracy, which determines the overlay/focus performance. In general, the higher this servo BW, the better. For wafer-stage short-stroke (WSSS) designs, this servo BW is limited by the plant dynamics. Specifically, the lightly damped resonant behaviour in a wide frequency range hampers the feedback control design. Two solution directions to improve the plant dynamics via the introduction of passive damping are investigated.

The first solution direction concerns the modification of the actuator suspension by using elastomer material in parallel to the existing (leaf-spring) interconnection between the actuator body and the structure, i.e., a damped actuator suspension. The leaf-spring dominates at low frequencies, which eliminates possible undesired side-effects of the elastomer material, such as drift, hysteresis, and creep. The problematic flexible modes at high frequencies are influenced by the elastomer material, which reduces the resonant behaviour over a wide frequency range. This enables a substantial servo BW increase and a corresponding positioning accuracy improvement for WSSS designs. Notice that besides the actuator body also other masses, either already in place or to be designed, are (possibly) suited for this approach.

The second solution direction concerns the addition of small add-on devices. Specifically, robust mass dampers (RMDs) on the basis of a high-viscosity fluid damping principle have been designed. The moving part undergoes a relative motion with respect to the static part, which shears the fluid in a narrow clearance between the parts and, consequently, introduces damping. This solution is characterised by: 1) a low mass contribution to the positioning system (~2%); 2) a substantial robustness with respect to parameter variations of both the RMD and the positioning system; and 3) a substantial damping increase over a broad frequency range. ■

SESSION 7: SYSTEM DESIGN 2 - 1

Mechatronics of a sub-milliNewton tribometer

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Mechatronic challenges have been encountered during the development and realisation of a sub-milliNewton tribometer operating in both ambient and vacuum. In state-of-the-art equipment working with thin substrates, these handling interfaces typically have a surface area of less than 1 mm^2 and are flat to the nanometer level. Designers of such interfaces cannot rely on data generated by classic pin-on-disc experiments because small surface asperities can significantly change the friction force for example at normal loads in the milliNewton range where adhesion plays a role.

The goal of the system is to measure with normal loads starting at two Newton and going down to one milliNewton. Especially the lower normal load range is challenging because small offsets in the force sensor signal have a relative large impact on accuracy. Furthermore, at these low loads the contact stiffness could still be as high as $2 \cdot 10^6$ N/m, requiring a measurement system capable of accurately measuring sub-nanometer deformations.

A tribometer to measure the coefficients of friction, both static and dynamic, and contact stiffness of ultra-precise mechanical contacts has been developed and realised. Exact replication of contact geometry and conditions typically found in precision applications adds considerable complexity to an already challenging measurement system. Flexure mechanisms are used to constrain and guide degrees of freedom of the samples to guarantee reproducibility of the (parasitic) forces and motions.

Before the actual measurement, the samples are brought into contact with low velocity (down to 1 µm/s) to avoid (sub)surface damage when the samples first touch. After the contact is established a feedback loop is enabled to accurately control the applied forces, corrected for sample geometry, in the presence of drift and varying lateral loads during the experiments. Currently, the impact of vibration is larger than expected, but can probably be attenuated to the required level by adding damping to the force cells. ■

SESSION 7: SYSTEM DESIGN 2 - 2

Slicer module for large-volume reconstruction workflow

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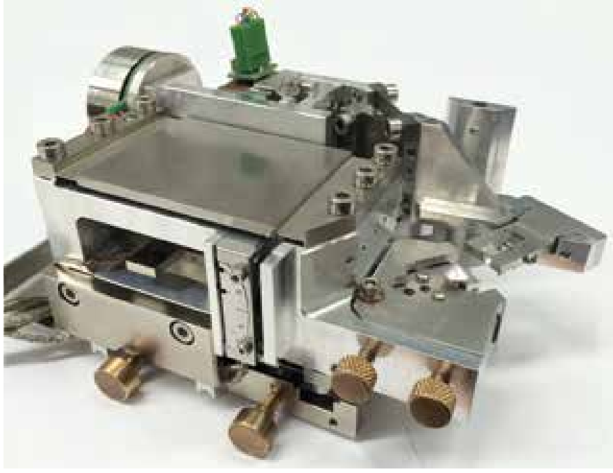
The value of FEI is to offer complete workflows to enable customers to innovate in their science, technology or production. One of these workflows is large-volume reconstruction by using serial block-face scanning electron microscopy. In short, this technique requires that sequentially slices of the sample are removed, while imaging the top face of the sample between cuts. By combining the images, a large-volume reconstruction of the sample can be obtained. The application of the workflow is within the Life Science business unit, with typical samples like brain or muscle tissue.

The slicer module has been developed and productised by the mechatronics department of FEI. The high-level requirements on slice thickness are 30-100 nm with a typical time in-between cuts of 1-10 minutes. With this in mind requirements on e.g. stiffness, repeatability and stability have been determined. Several concepts have been evaluated and one concept with optimal stacking for high stiffness and thermal stability was selected.



The concept consists of two motorised axes; the first one being a sample feed axis, with a high-resolution encoder and a piezoelectric drive for high accuracy. The second axis is the cutting action driving the knife. Both axes are guided by flexure hinges to avoid friction and obtain high stability and robustness. The serial block-face SEM workflow and the design of the slicer module will be discussed. ■

SESSION 7: SYSTEM DESIGN 2 - 3

Large flat surfaces in a high-temperature and low-pressure environment

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OLED TV flat-panel display production systems can use the Organic Vapour Phase Deposition (OVPD®) process to cover substrate areas – typically 5.5 m^2 (Generation 8) to 9 m^2 (Gen10) – with organic material. The organic vapour is supplied via a large number of small nozzles in a closed coupled showerhead (CCS®) plate.
A constant distance between the showerhead and the substrate is the parameter for a uniform film deposition and high material utilisation. The process is running at a temperature regime of 200-450 °C in a low-pressure environment. The temperature homogeneity of the showerhead is another important process parameter and should stay within 10 degrees. VDL's combined manufacturing and system knowledge resulted in a feasible concept, basically comprising a heated showerhead suspended to a stable cold frame. The frame acts as a reference to which the showerhead can be adjusted.

Suspension and adjustment is accomplished by 56 flexible rods. Each rod is separately connected to an adjustment mechanism on the reference frame while the other end of each rod is mounted to the heated nozzle-plate. High temperature, mechanical strength and in-plane flexibility of the rod allow only certain materials to be applied. Stability of the frame is guaranteed by thermally shielding the frame from the heated environment. The welded sheet-metal honeycomb structure allows a stiff frame with a low mass.

After assembly of the total system the nozzle-plate flatness has been measured. Correction values for each rod have been calculated to adjust this flatness to within ± 0.2 mm. The system has been running for over a year at the customer site and is still within this specification. ■

The 56 flexible rods.

DSPE CONFERENCE – POSTERS AND DEMOS

- **Decreasing Laser Grooving product change-over time by introduction of an 8-DOE manipulator**
  Ralf Noijen (ALSI)
- **SAW sensors for industrial temperature measurements**
  Mihai Patrascu (ASML)
- **Cost of goods reduction of a cooled electronics box by Additive Manufacturing**
  Denis Loncke (ASML)
- **Infrared Laser Alignment Tool**
  Bas van Dorp (ASML)
- **Improving positioning performance via advanced feedforward design with position-dependent compliance identification**
  Wouter Aangenent (ASML)
- **Silicon Carbide on the right spot**
  Tim van Kampen (Ceratec)
- **Polymer Damper Technology for improved system dynamics**
  Pieter Wullms (MI-Partners)
- **Generic Trajectory And Setpoint Control In Medical Robotics**
  Wil Baaten (Philips Healthcare IGT)
- **Model-based support to flatbed printer development**
  Patrick Smulders (Segula)
- **High-resolution magnetic field position sensors**
  Uwe Stock (Sensitec)
- **Challenges in high pressure engineering for high vacuum applications**
  Kevin van Dijck (Settels Savenije van Amelsvoort)
- **Control performance predictions for a mechatronic system design**
  Gert Witvoet (TNO)
- **Modelling and design principles of planar ferrofluid bearings**
  Stefan Lampaert (Delft University of Technology)
- **Beyond Traditional Sampling Strategies for Enhanced Performance and Cost-Effectiveness**
  Jurgen van Zundert (Eindhoven University of Technology (TU/e))
- **Designing a tool for the diagnostics of atmospheric pressure proximity plasmas for spatial Atomic Layer Deposition**
  Nikita Skornyakov (TU/e)
- **Position-Dependent Modeling for Next-Generation Motion Control of a Wafer Stage**
  Robin de Rozario (TU/e)
- **Effects of overconstrained design of an elementary flexure hinge**
  Marijn Nijenhuis (University of Twente)
- **AM Flexures for Optical Components**
  Rob Boereboom (VDL ETG)

Products made of silicium carbide.
(From the poster by Tim van Kampen (Ceratec), "Silicon Carbide on the right spot")

ECP² COURSE CALENDAR

COURSE (content partner)	ECP² points	Provider	Starting date (location, if not Eindhoven, NL)
FOUNDATION			
Mechatronics System Design - part 1 (MA)	5	HTI	10 October 2016
Mechatronics System Design - part 2 (MA)	5	HTI	31 October 2016
Design Principles	3	MC	26 September 2016
System Architecting (Sioux)	5	HTI	14 November 2016
Design Principles Basic (SSvA)	5	HTI	22 November 2016
Motion Control Tuning (MA)	6	HTI	30 November 2016
ADVANCED			
Metrology and Calibration of Mechatronic Systems (MA)	3	HTI	22 November 2016
Actuation and Power Electronics (MA)	3	HTI	11 October 2016
Thermal Effects in Mechatronic Systems (MA)	3	HTI	28 November 2016
Summer school Opto-Mechatronics (DSPE/MA)	5	HTI	to be planned
Dynamics and Modelling (MA)	3	HTI	12 December 2016
Summer School Manufacturability	5	LiS	7 November 2016
Green Belt Design for Six Sigma	4	HI	28 September 2016 5 October 2016 (Enschede, NL)
RF1 Life Data Analysis and Reliability Testing	3	HI	14 November 2016
SPECIFIC			
Applied Optics (T2Prof)	6.5	HTI	1 November 2016
Applied Optics	6.5	MC	15 September 2016
Machine Vision for Mechatronic Systems (MA)	2	HTI	29 September 2016
Electronics for Non-Electronic Engineers – Basics Electricity and Analog Electronics (T2Prof)	6	HTI	10 October 2016
Electronics for Non-Electronic Engineers – Basics Digital Electronics (T2Prof)	4	HTI	to be planned
Modern Optics for Optical Designers (T2Prof)	10	HTI	to be planned
Tribology	4	MC	1 November 2016 (Utrecht, NL) 14 March 2017
Design Principles for Ultra Clean Vacuum Applications (SSvA)	4	HTI	3 October 2016
Experimental Techniques in Mechatronics (MA)	3	HTI	to be planned
Advanced Motion Control (MA)	5	HTI	7 November 2016
Advanced Feedforward Control (MA)	2	HTI	14 November 2016
Advanced Mechatronic System Design (MA)	6	HTI	to be planned
Finite Element Method	5	ENG	in-company only
Design for Manufacturing – Design Decision Method	3	SCHOUT	in-company

ECP² program powered by euspen

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

ECP2EU.WPENGINE.COM

Course providers

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

Content partners

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

Oude Reimer – offering a complete processing chain for the metalworking industry

Oude Reimer, based in Hilversum, the Netherlands, was established almost 60 years ago and now is an innovative and successful supplier of a complete programme for the metalworking industry, emphasising precision, productivity and efficiency.

Machines

In the early years, a balanced combination of machine tools and cutting tools was Oude Reimer's core business. Nowadays the company represents innovative brands like Chiron and Heller for machining centres, and WFL (Millturn), Star (Swiss-type), Emag and Benzinger lathes and multi-axis machines, combining precision with productivity in the Netherlands/Benelux. The programme includes machinery for the tube and wire industry.

The Benzinger GoFuture B3 machine with counter spindle (below in close-up).

Cutting tools

The customers of Oude Reimer can rely on the know-how of experienced sales people, and team up to achieve the extra speed and precision the rapidly changing market demands. The mostly Swiss and German innovative manufacturers of cutting tools, tool holders and shrinking and balancing machines use the most advanced technologies, which allow Oude Reimer customers to stay ahead of the competition.

Fluid management and cleanliness

Oude Reimer also represents Motorex Oil of Switzerland, the benchmark in cutting oils and coolants for spindle, cutting and grinding applications, thus completely satisfying the needs of the metal-cutting industry.

A complete line of high-end cutting fluids makes it possible to achieve the required results, without worrying about spotting, corrosion or roughness. As a specialist in industrial oils and lubricants, Oude Reimer takes care of the total fluid management of its Motorex customers.

If oil is used, Roll Part Cleaning Systems from Germany offers a wide range of cleaning solutions. This company is the right partner for a water-based, solvent-based or combined solution for cleaning products. Its machine range starts with the Petit, for small parts, requiring only 1 m^2 of floor space. Giant products, up to 6,000 mm in length, can also be cleaned. Eighty percent of the solutions produced by Roll Part Cleaning Systems are customised.

Vibration insulation

Customers demand greater accuracy, but every vibration can ruin a production run or a measurement. Bilz manufactures products and solutions for the insulation of equipment from vibration and sound. Due to the consistent progress, especially in the field of air spring technology, Bilz can consolidate its position as market leader in Europe. The Bilz products are used in a very wide range of applications, from simple elastomer springs all the way to active pneumatic vibration damping systems.

In cooperation with Bilz, Oude Reimer is a system supplier, from the project-planning phase through to installation, supplying everything from one source. For example, Bilz Vibration Technology was awarded the contract for the implementation and installation of the air spring isolation systems in the new precision laboratory of the Max Planck Institute for Solid State Research in Stuttgart, Germany. ■

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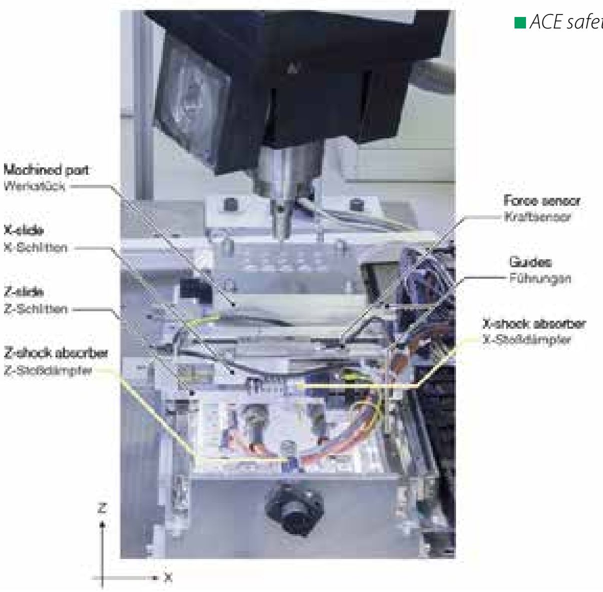
WWW.OUDEREIMER.NL

Innovation with safety

Four safety shock absorbers by ACE protect the end positions of a directly powered planar motor, which was developed at the Institute for Production Technology and Tool Machines (Institut für Fertigungstechnik und Werkzeugmaschinen - IFW) in the production technology centre of Leibniz University Hanover, Germany. The innovative concept is very interesting for highly dynamic machines and, amongst others, can improve the productivity of tool machines.

The Hanover project, which has been sponsored by the German Research Association DFG since 2010, serves the fundamental research of a biaxial, directly powered multi-coordinate system, which can be used in tool machines in particular. As well as intensively working on the motor, one aspect the IFW team focused on was protecting the end positions of their system. Using an online tool offered by ACE (www.ace-ace.de/de/berechnungen.html) the practicability was tested of new concepts regarding the dimensioning of built-in safety shock absorbers.



■ *The planar motor, with shock absorbers visible, used in a machine tool.*

The decision was made to install four safety shock absorbers of type SCS33-50 EUD, characterised by their unique damping technology, a strengthened guide bearing and continuous thread. This shock absorber family by ACE is designed especially for non-stop operation and can be used flexibly in sizes M33 x 1.5 to M64 x 2 because of the compact design, such as in conveyor systems or automatic placement machines. The designs used for the planar motor are able to absorb 620 Nm/stroke at a maximum stroke of 50 mm without fixed stop. The high thrust force of the planar motor is special, as it is based on the principle of permanently magnetically charged synchronised linear motors, which makes this solution superior to all previous planar drive concepts. These are usually based on the magnetic reluctance principle for producing (relatively low) thrust forces on one level. The motor developed in the IFW also features an innovative cross-winding technology. The coils are stacked vertically for the individual thrust directions. The use of standardised axis controllers is made possible as both coil systems can only minimally affect each other. Using permanent magnets lined up in a chessboard pattern allows the planar motor to achieve great power consistency and therefore it can be deployed for highly dynamic tool machines.

■ *ACE safety shock absorber, with explanation in German.*

The motor was also optimised in view of the disturbing forces typical of direct linear drives. Latching forces and thrust force fluctuations have been significantly reduced due to a method for calculating the optimum geometry of the motor. On top of that, an increase of the thrust force was achieved. Because additional dynamic forces affect the drive during the processing of a tool, the IFW investigated the performance of circular courses and pockets in aluminium tools when being milled and, with this, the impact of forces on the positioning during a working process. This gave the option of a process-near analysis of drive performance affected by changes during the manufacturing process.

Activities are now focused on the transfer of the findings to further design sizes. A larger planar motor built of 16 prototype modules has been designed and constructed. The developed modularity of the motor allows the realisation of different construction sizes according to the relevant industrial requirements. The new planar motor is to have top forces up to 4,800 N and nominal forces of about 2,400 N per axle. Together with the permanent magnetic field, individual travel ranges can be achieved independent of the size of the planar motor.

Possible applications for turning, milling and grinding technologies are the same as in handling technology or in positioning drives. Use in specialised as well as processing machinery with high dynamics and positioning precision also comes into consideration.

(contribution by Jonathan Fuchs, head of the department for components and monitoring systems at the IFW institute, and Robert Timmerberg, journalist and co-owner of the plus2 press and advertising agency in Wermelskirchen, Germany)

WWW.IFW.UNI-HANNOVER.DE
WWW.PZH.UNI-HANNOVER.DE
WWW.ACE-ACE.COM

i-Botics: cooperation on interaction robotics

The Netherlands organisation for applied scientific research TNO and the University of Twente have joined forces in the field of robotics in the open innovation center i-Botics. Within the center, TNO and the UT will work together with industrial partners on a widely supported development programme, which is now under construction.

The research lines will most likely be centred around exoskeletons and telerobotics (particularly within inspection and maintenance application). Stefano Stramigioli, professor of Advanced Robotics at the University of Twente, will be responsible for the scientific content: "With robotics, there are numerous possibilities to ensure a safer working environment in several industries. But also, physically demanding jobs might profit from clever robotic applications. There are some great examples of situations in which robotics and machinery can support people in creating safer and more pleasurable jobs with better end results."

In addition to a collaboration on content, TNO and UT will work together in improving research facilities in which robots can be tested. Arjen de Jong, Senior Business Developer at TNO, is in the lead for the business development: "Preferably, robots are being deployed for dangerous and complicated tasks. But before they are ready for use on the working floor, tests need to be executed in a controlled and realistic environment. For several industries, these testing facilities are not available yet. By improving these, the market implementation process can be smoothened."

WWW.I-BOTICS.COM

Patent tutorial

Quite often, the success of a business depends on the ability to innovate. Knowing that others may wish to benefit from that innovation power, it is key to protect innovations using the available intellectual property rights in order to stay ahead of the competitors. In case of technical developments patents may have to be filed. Drafting patent applications, and in particular drafting claims, is a specialist skill requiring a high level of technical and legal knowledge. Such work is generally carried out by patent attorneys. A patent application must comprise enough details to optimise the chance of grant, and to provide an acceptable scope of protection over the 20 year lifetime of the patent.

For 'outsiders' dealing with patents, it can be difficult to understand these legal documents, and to judge the quality and scope of protection. Furthermore, it may be difficult to navigate through the many conflicting requirements and recommendations. Therefore, DeltaPatents, a patent attorney firm based in Eindhoven, the Netherlands, is offering a 3-day patent tutorial. The objective of this course is to give the participants tools to better understand patents and to improve the patent drafting process, when communicating with patent attorneys in their daily work. This is achieved by first putting the patent law within the broader context of intellectual property rights, whereafter it is illustrated, using hands-on exercises, what a patent is, what it is used for and how each element in the patent can help or hinder its use. Also, the patent system and the possible patent routes will be explained in more detail.

All materials and tuition will be in English. The tutorial will be given on 21-23 November 2016 in Eindhoven. DeltaPatents also offers the possibility of in-house training.

WWW.DELTAPATENTS.COM

Microscope-objective piezo nanopositioner

Aerotech presents the QFOCUS™ QF-46 piezo nanopositioning stage series that enables microscope objective and optics positioning at high speeds with nanometer-level performance. The stages are available in closed-loop travels of 100 µm and 250 µm, and open-loop travels of 120 µm and 300 µm. The QF-46 is guided by precision flexures that have been optimised using finite-element analysis to ensure high stiffness and long device life.

QF-46 piezo stages have the option of closed-loop feedback using a unique capacitive sensor design that results in sub-nanometer resolution and high linearity. The capacitive sensors measure the output of the positioning carriage directly, enabling superior accuracy and repeatability. When coupled with Aerotech's Q-series controllers and drives, the QF-46 demonstrates sub-nanometer positioning resolution (0.30 nm closed loop and 0.15 nm open loop), in-position stability (jitter), and high positioning bandwidth.

WWW.AEROTECH.COM

Compact system for parts cleaning and corrosion protection

With the EcoCCompact, Dürr Ecoclean has developed a versatile full-vacuum system for parts cleaning and corrosion protection with non-halogenated hydrocarbons and modified alcohols. It offers a wide range of options, from rapid degreasing right through to sophisticated cleaning tasks conforming to exacting cleanliness specifications. Innovative technologies guarantee maximum cleaning efficiency and a targeted reduction in per-unit costs.

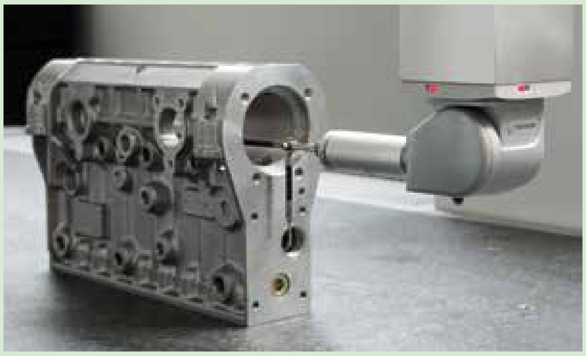
The new EcoCCompact is extremely compact and easy to operate, as well as easy to adapt to a company's specific requirements, for example, from degreasing through pre-washing and intermediate washing right up to fine-cleaning. With a footprint of just 4,000 x 1,600 x 2,700 mm (*l* x *w* x *h*), the space-saving housing can hold one, two or three fluid tanks for cleaning and corrosion protection processes. Furthermore, the EcoCCompact can be adapted to different batch sizes. The work chamber is designed to hold batches up to 530 x 320 x 200 mm in size. Alternatively, with the same footprint, a larger work chamber can be installed to hold part containers with a height of 250 mm.

WWW.DURR-ECOCLEAN.COM

Upgrade of scanning sensor range

Hexagon Manufacturing Intelligence has released new versions of its HP-S-X1 series of compact probes for tactile scanning. As well as featuring a new bearing system for better joint repeatability, HP-S-X1 range probes now accept longer horizontal styli for improved flexibility – with no need to change modules.

Featuring small external dimensions and supporting stylus lengths of up to 225 mm, HP-S-X1 probes enable coordinate measuring machines (CMMs) to take measurements of features deep inside a workpiece. Magnetic interfaces allow automated stylus changes, and they support all standard inspection modes including single-point contact measurement, self-centring measurement and continuous high-speed scanning, providing quick and precise data acquisition for all kinds of surface contours.



WWW.HEXAGONMI.COM

Substantial growth NTS with acquisition of Norma

First-tier systems suppliers NTS-Group and Norma have signed an agreement for Norma to become part of the NTS-Group. With this acquisition NTS becomes a group of high-tech industry suppliers with globally 1,500 employees and an annual revenue of over 210 million Euros. NTS, with headquarters in Eindhoven, the Netherlands, will continue to develop, produce, assemble and test complex (opto)mechatronic systems and mechanical modules for large, high-tech machine manufacturers (OEMs).

Marc Hendrikse, CEO of the NTS-Group comments: "Norma's core competences in the area of precision machining perfectly complement those of NTS. What's more, the companies' cultures are a great fit. All in all, together with Norma, we represent a powerful and ambitious first-tier supplier to high-tech industry machine builders, whom we are able to serve optimally thanks to our scope, international position and complete portfolio of knowledge and expertise. The acquisition of Norma perfectly fits our growth strategy to support our customers on a higher level by developing, producing and assembling systems, modules and components."

As a high-tech supplier of mechatronic systems, Norma (400 employees) has a wealth of knowledge and experience in (ultra-)precision machining and the assembly of ultra-precise modules. Norma also boasts key knowledge in the field of value engineering. The company operates out of three Dutch sites: Hengelo (Ov), Drachten and Doetinchem. Norma CEO Frank Biemans comments: "Joining forces with NTS – in regard to both production and engineering – will enable us to meet the needs of a great number of customers. These customers are looking to do business with larger suppliers, capable of a higher level of support and taking on bigger projects."

The transaction is expected to close in the third quarter of 2016, subject to fulfilment of customary conditions.

WWW.NTS-GROUP.NL
WWW.NORMABV.NL

R&D workgroup Mechatronics links HTSC to industry

The Dutch national R&D workgroup Mechatronics originated from the PfHTS (Programme for High Tech Systems), which was set up in 2007 to strengthen the Dutch position as 'knowledge economy' via close collaboration between OEMs, suppliers and knowledge institutes. Suppliers were more actively involved in innovations to allow OEMs to focus on marketing and development of new products. The workgroup, chaired by Jan van Eijk, former CTO of Mechatronics at Philips Applied Technologies and Emeritus Professor of Advanced Mechatronics in Delft, targeted to set up and maintain a long-term Mechatronics roadmap and define new consortia, successfully stimulated by government funding.

After discontinuation of Dutch government funded programmes in 2012, the R&D workgroup, chaired by Hans Vermeulen (ASML) in the meantime, started exploring a new format where academic research was collaboratively funded by industry via consortia. It took a significant amount of time to get a contract in place, but eventually the first industrially funded consortia on Advanced Thermal Control (ATC) and Flow-Induced Vibrations (FIV) got started.

Since early 2015, the R&D workgroup Mechatronics is connected to the High Tech Systems Center (HTSC), which stepped in as linking pin between academia and industry in the field of applied research. Members are OEMs (ASML, Bosch Rexroth, FEI, Océ, Philips, VDL ETG), SMEs (Adinsyde, CCM-Sioux, Demcon, IBS Precision Engineering, Imotec, JPE, Mecal, MI-Partners, Nobleo, Roosen, Segula, TMC, Vision Dynamics), academia (TUD, TU/e, UT), and other knowledge institutes (Fontys, FMTC, TNO) in the Netherlands and surrounding countries.

Via bi-monthly meetings at the HTSC and industrial sites in turn, the R&D workgroup pursues to:

- Increase synergy between R&D of partners in the High Tech Systems and Materials (HTSM) area via fundamental and applied research in consortia.
- Build a strong network between industry and academia to address critical challenges in various sectors, in particular High Tech and Agro & Food.
- Drive the long-term Mechatronics roadmap by creating new concepts for future systems.

Together with the HTSC, multiple themes for new consortia are currently being explored and detailed out by the workgroup, among others on system design, robotics, plant-wide control, beyond rigid body control, contamination control, and material on demand. These will be presented at a Consortium Day organised by the HTSC on 18 November 2016, to which interested parties are invited.

HTSC@TUE.NL
WWW.TUE.NL/HTSC

High-load piezo stage for vertical positioning

Nanopositioning of high loads, such as detectors or cameras can be a difficult task. In addition, many applications require large travel ranges, but have limited installation space available. Attocube's new ECSz5050 piezo drive has been especially developed to meet these demands: it offers an orientation-independent force of 8 N over a travel range of 8 mm, without adding to the small footprint of the ECS5050 series (50 mm x 50 mm).

The ECSz5050 is suited for lateral motion set-ups, and can be easily combined with the whole range of rotators, goniometers and linear positioners of attocube's Industrial Line portfolio.

The Industrial Line series of positioners, so attocube states, combines highest precision piezo-drive technology with extremely rugged yet cost-effective design, for operation at ambient temperature and at pressures ranging from atmospheric to UHV. This drive series is precisely engineered for applications where space is frequently constrained while load and torque applied to the positioning units may be significant. This powerful performance is supplemented by the ECC100 drive electronics which enables open and closed-loop positioning with 1 nm/1 μ° position resolution.

WWW.ATTOCUBE.COM

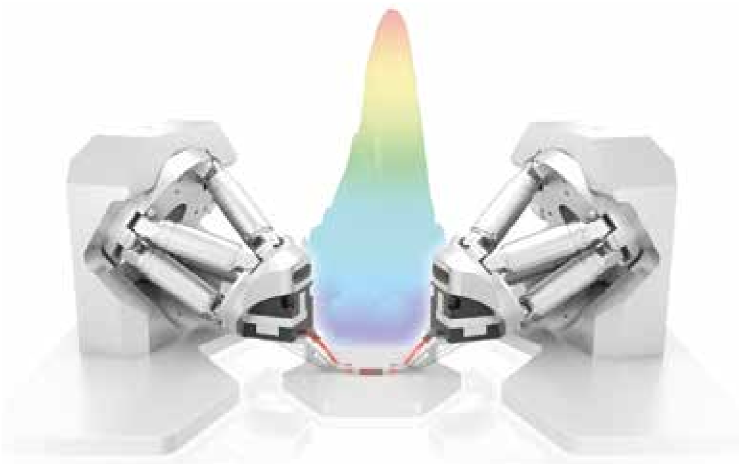
Automatic testing of photonics components

Silicon photonics (SiP) sets the pace on the fibre-optic data highway. However, a number of challenges must be overcome for production and testing of the latest generation of SiP wafers. For example, it is critical to introduce wafer-level testing of each circuit before dicing and packaging. Optical inputs and outputs must be tested. Maximum precision during handling, positioning and adjusting is just as necessary as the highest possible speed.

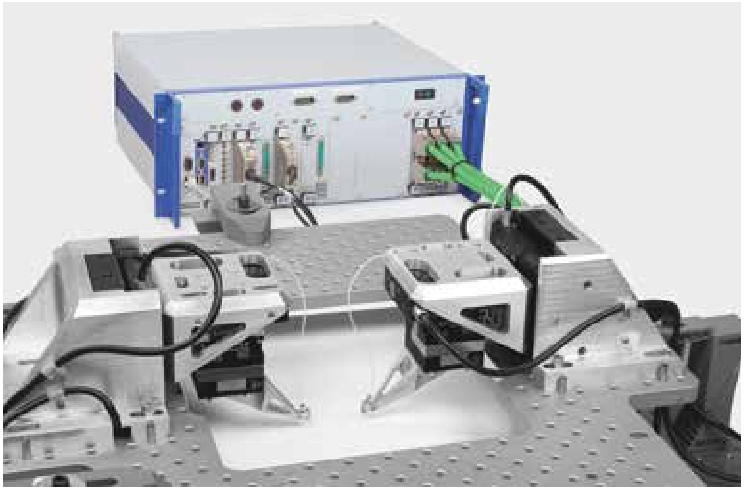
The required precision is several orders of magnitude higher than is possible with traditional electrical wafer probing equipment. Inputs and outputs need to be aligned precisely to the optical fibres connected to the test equipment. That is definitely not a trivial matter, because optical waveguides in silicon wafers normally have a core diameter of only 150 to 200 nm, and to avoid losses, alignment equipment must have at least a ten times higher resolution.

PI (Physik Instrumente) from Karlsruhe, Germany, developed a new complete system for fast fibre alignment, which can align, test, and optimise the light input and output at each coupling point in less than one second. This guarantees fast data throughput rates during industrial production. The system consists of two compact identical positioning units with a small footprint of 100 x 100 mm. The heart of the system is the application-specific controller with a variety of built-in alignment and tracking algorithms required for optical alignment; this lightens the burden on the higher level control.

Positioning is done in two phases. A three-axis positioning stage driven by closed-loop DC motors takes care of the initial task of coarse adjustment; it travels to the respective coupling point over travel ranges of several tens of millimeters with an accuracy of up to 50 nm. An additional three-axis positioning unit is then responsible for fine positioning of the fibres. The system is driven by piezo actuators and achieves resolutions of 1 nm with response times in the microsecond range and travel ranges of 100 x 100 x 100 µm. The high-performance piezo actuators are integrated into guiding systems with finite-element-analysis-optimised flexure joints and are free of both friction and backlash.



Wafer level alignment with a two-side 6-axis hexapod and a piezo scanning stage for fine alignment



Industry-suited complete systems for wafer probing in silicon photonics.

More axes are required when, for example, the fibres need to be positioned at different angles or tilting angular errors need to be compensated. Serial stacking of additional axes on the positioning stage is basically possible, but the limitations outweigh the advantages. The accuracy would suffer because additional guiding errors would reduce the overall precision. Instead, a more elegant and performant solution is to combine the above-described fine positioner with a hexapod parallel-kinematic positioning system. Because, in contrast to serial kinematics, all actuators in parallel-kinematic systems act directly on the same platform and, therefore, it is not possible for guiding errors to accumulate as is the case with 'stacked' systems and this increases the accuracy considerably. Moreover, hexapods – due to their low moving mass – provide much higher dynamics.

PI's compact H-811 hexapod, for example, offers linear travel ranges up to 34 mm and rotational travel up to 42°. The piezo-based fine positioner integrates with the hexapod platform. It provides minimum incremental motion of 0.1 µm / 2 µrad, and velocities of 10 µm/s to 10 mm/s.

WWW.PI.WS

Value engineering

Celebrating its fifth anniversary, The High Tech Institute, based in Eindhoven, the Netherlands, has launched a new training, Value Engineering. This is a comprehensive training for those who work in multi-disciplinary product design teams that aim to timely launch winning products to the market and/or improve profitability of existing products. The training presents the value engineering way-of-working and methods as means to translate customer requirements to solutions that have an optimal value-to-cost ratio for both customer and manufacturer. The method is in this respect a valuable add-on to systems architecting and systems engineering.

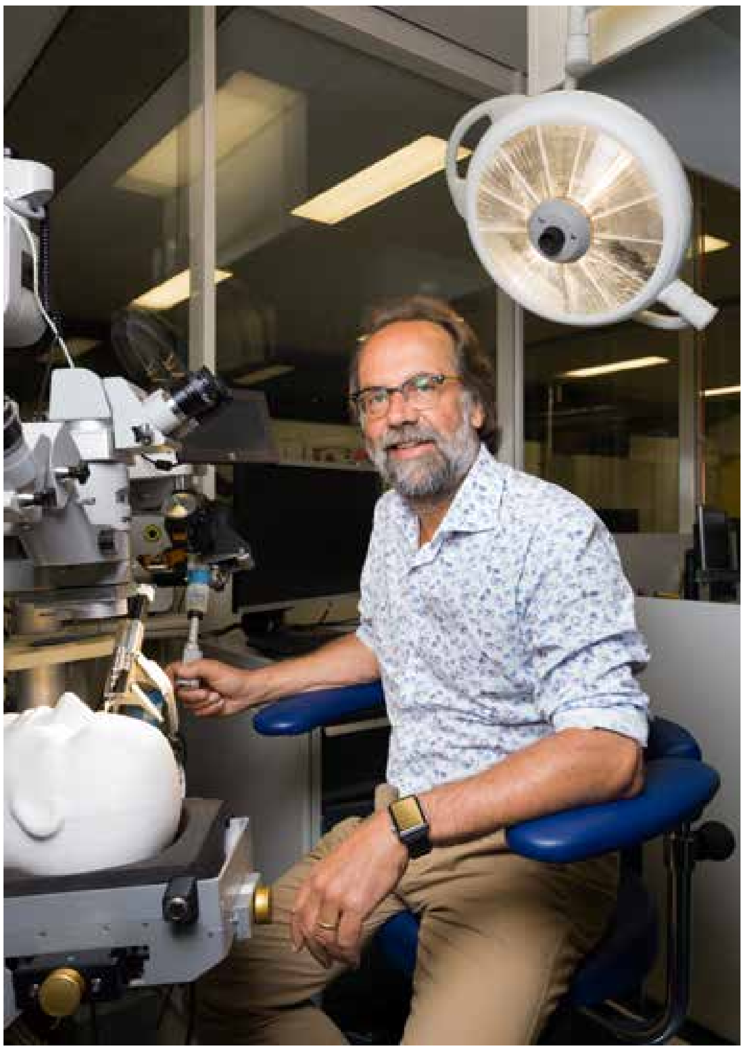
WWW.HIGHTECHINSTITUTE.NL

NEWS

Maarten Steinbuch awarded honorary title of Simon Stevin Master 2016

Professor Maarten Steinbuch will be the Simon Stevin Master this year, the highest distinction for technical sciences in the Netherlands. It is an honorary title, bestowed by the STW Technology Foundation, and it comes with half a million euros to spend on research. "I feel very honored", said Steinbuch in reaction to the announcement. "The award underlines the importance of the connection that science has to make with society and industry. That is something I champion. That I am now receiving this award is encouragement for this approach."

Maarten Steinbuch is professor of Control Systems Technology at Eindhoven University of Technology (TU/e) and the work that he and his group do in the field of advanced motion control – the control of advanced engineering systems where extreme precision and speed are crucial – enjoys a considerable international reputation. Examples of this field include machines that produce micro-electronics and nuclear fusion reactors. His group also develops sophisticated surgical robots that are now getting to the market via spin-off companies.



Maarten Steinbuch. (Photo: Ivo van der Bent)

STW praises the way that Steinbuch creates a bridge between science and industry, and their cooperation in solving societal challenges. In his research, Steinbuch works with leading companies like ASML, Philips, TNO and Océ as well as with many SMEs. It is due in part to Steinbuch that the Netherlands has become a hot spot for developments centring on electric driving, precision systems control and microsurgery.

In view of his services as a professor, in 2013 TU/e gave Steinbuch the honorary title of Distinguished Professor. He is also scientific director of the TU/e High Tech Systems Center and of the 3TU High Tech Systems Research Center as well as a member of the AutomotiveNL sector organisation.

Simon Stevin (1548-1620) was a Flemish mathematician, physicist and military engineer. He was active in a great many areas of science and engineering.

WWW.STW.NL
WWW.TUE.NL

NEWS

Hembrug introduces the Mikroturn 100 XLS

During the AMB exhibition, on 13-17 September 2017 in Stuttgart, Germany, precision machine builder Hembrug Tools will introduce its newest development, the Mikroturn® 100 XLS. It is a larger spin-off from the well-known Mikroturn 100 hardturning machine. The 100 XLS has been designed for the precision machining of hardened shafts up to 1,000 mm length. This asked for the enlargement of the machine frame and the base, made from highly stable natural stone. The machine has also been provided with larger lead screws, ball-circulating nuts and linear slide drives. For a better product support the machine also got two steady rests. The Mikroturn 100 XLS can handle workpieces up to a diameter of 420 mm.

Hembrug Machine Tools is specialised in the development and manufacture of precision cutting machines with a stable natural granite base, an everlasting hydrostatic main spindle and hydrostatic slides. Thanks to the high thermal, static and dynamic stability and stiffness the Mikroturn machines succeed in attaining extremely high machining accuracies. For example, the 100 XLS specifies for hardened steel up to 68 Rockwell in serial production: form accuracy better than 1 µm, surface quality between 0.1 and 0.4 µm and overall dimensional accuracy up to 2 µm. Thanks to the hydrostatic bearings the accuracy of Hembrug Machines remains stable for 25 years or even more. The large lead screws with ball-circulating nuts enable short-time accelerations and slowing-downs, with shorter cycle times as a favourable result.

Hembrug has extended its well-known Mikroturn 100 machine for the precision machining of hardened shafts up to 1,000 mm product length. The inset shows a customer product – a lead screw – being machined on the new 100 XLS. Both steady rests are clearly visible.

Accenture to invest in RoboValley

Accenture and RoboValley, an innovation hub for robotics located at Delft University of Technology in the Netherlands, have announced a five-year collaboration designed to advance on the development of the next generation of robotic technology. Accenture will invest €500,000 to facilitate international robotics research and development and knowledge sharing, becoming RoboValley's Crown Partner.

To support Accenture's Artificial Intelligence business, Accenture and RoboValley will conduct joint robotics research that will establish industry best practices for incorporating robotics into large enterprises, including developing proof-of-concepts and cutting-edge industry use cases. Together they will host innovation workshops for clients to explore new opportunities to use robotics to augment their current workforce and create new opportunities to grow their businesses.

"We strongly believe in the concept of RoboValley, with research, entrepreneurs and start-ups all in one place, as part of our commitment to open innovation", said Frank Rennings, Managing Director and Technology Lead at Accenture Netherlands. "Our collaboration will help us speed innovation and bring new applications to market faster. In addition, we can now take our clients to RoboValley, so that they can experience for themselves the latest developments and, above all, be inspired by them."

"RoboValley helps robotics companies and start-ups create the new generation robots and bring them to market. Through Accenture's international network, RoboValley will have direct access to a large number of companies faced with robotisation issues", said Arthur de Crook, Business Development Manager at RoboValley. "The collaboration also enables us to increase our visibility as an international knowledge centre. Together with Accenture and our 170 robotics researchers, we will be publishing global reports on the latest developments in robotics."

WWW.ROBOVALLEY.COM
WWW.ACCENTURE.COM

Printed electronics

Printed and flexible electronics open up a plethora of possibilities in a myriad of markets, from logistics to healthcare and from retail to solar cells. The Printed Electronics side event of Bits&Chips Smart Systems, on 28 September 2016 in Den Bosch, the Netherlands, showcases the state of the art in this emerging technology.

Speakers include Joanne Wilson (Holst Centre) on flexible OLED lighting, Hans van de Mortel (Metafas) on printing of smart blisters and other electronics products, Robert Abbel (Holst Centre) on smart materials sensing touch and responding with luminescence, and Jeroen op ten Berg (GBO Design) on printed electronis and product design.

WWW.BC-SMARTSYSTEMS.NL

Ultra-small with exceptional power density

With its new Gold Bee series, Elmo Motion Control continues to develop innovative high-power and high-intelligence-density servo drives for extreme environments. Available with full support from Heason Technology, Elmo Motion's UK distribution partner, the ultra-small PCB mount package, measuring just 35 x 30 x 14.4 mm, can deliver up to 4, 000 W of power with current ratings to 50 A at 100 V_{DC}.

As part of Elmo Motion's ExtrIQ Gold servo drive range the diminutive Gold Bee is built for extreme environment conditions with wide current control and a current loop dynamic range of 2,000:1 for high bandwidth servo performance. It can be used with brushed and brushless servo motors and is configured for a predetermined DC Voltage and current range.

Elmo Motion also offers 'no peak current' versions where continuous current is up to 50 A. Such current control is made possible with Elmo's thermal management drive design that realises safe and reliable high-power density and cutting-edge performance. The Gold Bee is specifically built for extreme environments with temperature ratings of –40 °C to +70 °C and vibration up to 14 G_{rms}.

The drive features dual feedback inputs with provision for absolute serial encoders, incremental encoders, digital and analogue halls as well as resolvers – making the choice of feedback very flexible to suit a wide range of servo motor technologies. Servo loop sampling times are as fast as 50 microseconds for current, velocity and position.

WWW.ELMOMC.COM
WWW.HEASON.COM

OBITUARY JAAP VERKERK (1943-2016)

Jaap Verkerk. (Photo: Evert Landré)

On 11 July 2016, Jaap Verkerk passed away. He studied Mechanical Engineering at the HTS in Utrecht (now University of Applied Sciences Utrecht) and Production Engineering at TU Delft (Delft University of Technology). In 1976, he obtained a Ph.D. in Delft on the topic of 'Wheel Wear in Grinding'. Throughout his career he worked as a publisher and editor for various publications (including Mikroniek, 1990-2001). In 1980 he became head of the science workshop (*Instrumentele Groep Fysica*) of the Faculty of Physics and Astronomy at Utrecht University. There he was in charge of the innovation and development of scientific instruments and special add-ons for microscopes, telescopes and vacuum systems with extremely high accuracy. He modernised the workshop and implemented a quality management system. In 2007 he retired from his post at the university.

I was shocked to hear that Jaap had passed away. In 1996, Jaap came to visit me and asked me if I would take over the chairmanship of the NVPT (*Nederlandse Vereniging voor Precisie Technologie*, Dutch Society for Precision Engineering). For 11 years, Jaap had the leadership of the NVPT, during which he brought Mikroniek to a high level. Also, the *PT Jaarboek* (Precision Technology Year Book) was his and was very popular.
It has been my honour to be his successor.
I learned that Jaap had great integrity, wisdom and vision. In the years following, he continued supporting the NVPT, whose name was internationalised to DSPE. Jaap's contribution to the NVPT created the building blocks we needed to construct DSPE. We are very grateful to Jaap and personally I will miss the warm chats we had about our DSPE.

Hans Krikhaar, President of DSPE

Precision-in-Business day at Tegema

On Thursday 22 September, DSPE and YPN (Young Precision Network) organise a Precision-in-Business (PiB) day at Tegema in Son, near Eindhoven, the Netherlands. The primary target group of the event comprises DSPE and YPN members.

As a full-service development partner, Tegema develops, innovates and realises products, processes and systems, from idea to a functional model, prototype or pre-production series. Tegema can take care of production, assembly, tooling, test equipment, realisation and commissioning. The areas of expertise include high-tech systems, medical technology, factory automation, automotive systems and maritime applications.

The PiB day motto is "Stretching the boundaries for high precision assembly" and the programme features three presentations by Tegema system architects:

- Ralph van Oorschot, "A journey to the smallest droplet"
- Theo Bookelmann , "Process machines & motion"
- Merijn Wijnen, "Exploring the boundaries of high-end optics"

A tour of the Tegema premises and drinks afterwards will conclude the PiB day.

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