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- FROM DESIGN TO **SERIAL PRODUCTION**
- FIRST DSPE **'OPTO'** SYMPOSIUM
- **JPE PRECISION POINT** LAUNCHED
- FREE-FORM **CONTACTLESS** MEASURING

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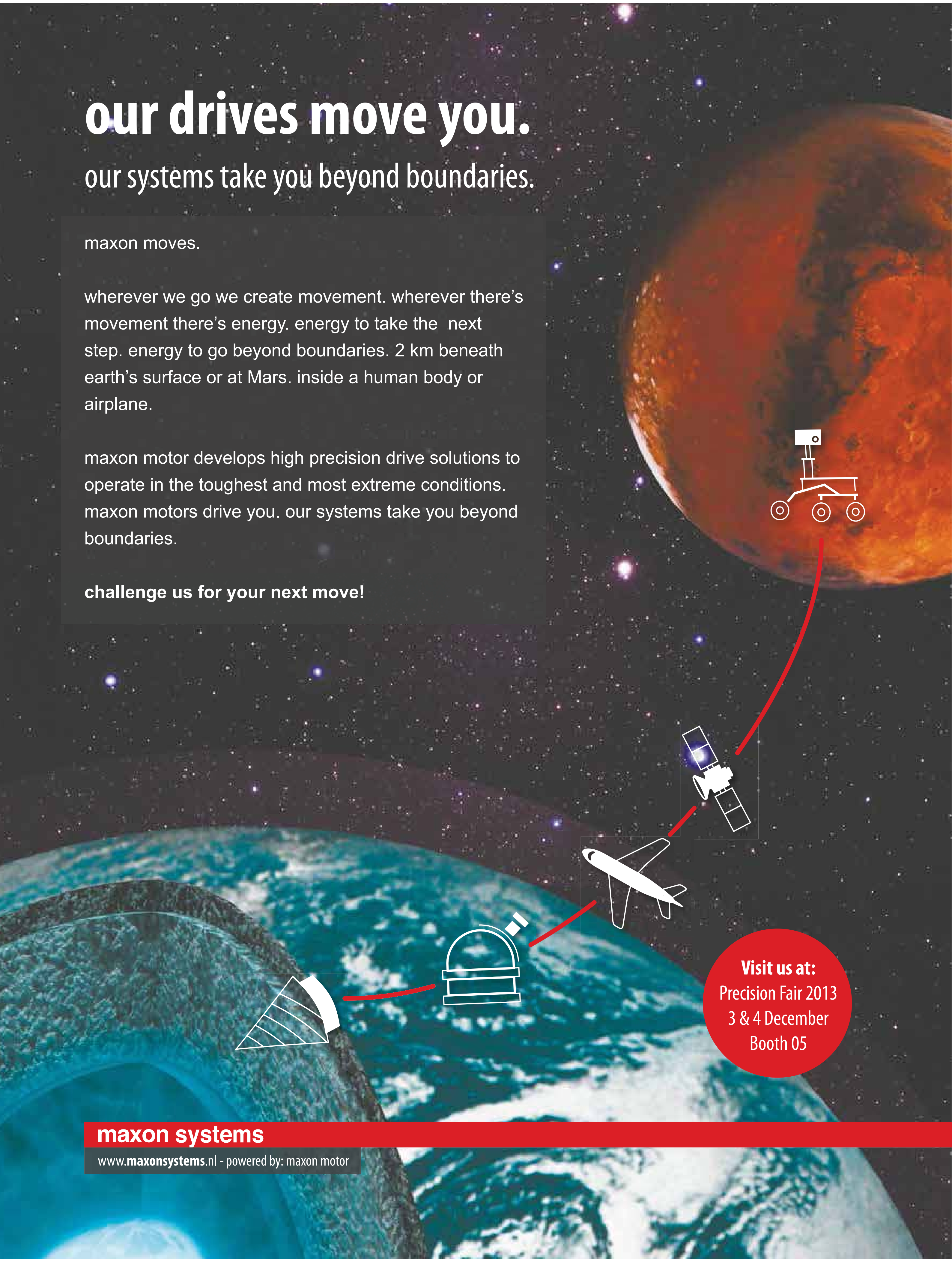
DSPE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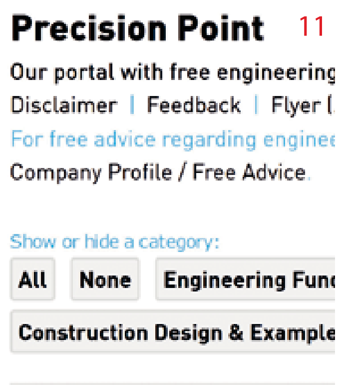

FEATURES

PUBLICATIONINFORMATION

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

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DSPE LAUNCHES SPECIAL INTEREST GROUP AND WEBSITE ON THERMO-MECHANICS

The DSPE Optics & Optomechatronics Special Interest Group (SIG) was successfully launched during a recent symposium at the High Tech Campus Eindhoven (read the report elsewhere in this issue). At the Precision Fair, DSPE will launch a second SIG, one concerned with thermo-mechanics.

In our sector, everything is moving with great precision and sometimes things have to stand still with even greater precision. Whether an interferometer with sub-nanometer precision in a conditioned room or a heavily thermally loaded sensor module in space, this technology is invariably subject to either expansion or shrink because of temperature fluctuations. Accurately predicting the effects of radiation, convection or conduction and the ensuing mechanical behaviour, a-thermal design or accurate measurements after realisation are necessary time and again to be able to get your head around such an intangible phenomenon.

With a symposium, the Optics & Optomechatronics SIG started off big. The Thermo-Mechanics SIG did the exact opposite, however. As a group of colleagues, we started off small over two years ago with the development of a website on thermo-mechanics. The website was set up with two things in mind: DSPE's traditional objective that, as a branche association, it aims to encourage knowledge sharing among colleagues, and the modern fact that the internet has become the largest reference work for polytechnics ever.

Today's engineers can find everything on the internet – an unparalleled revolution that brings engineers from different disciplines closer together than ever before. As an association, this is a trend that we applaud, as also reflected by our own, well-visited website where some 2,000 technical articles and many volumes of Mikroniek issues can be consulted and searched. However, even on the internet, information about a subject as specialised as thermo-mechanics is limited. As such, we have developed a website that begins where Wikipedia stops. The site has about 50 pages of content and features a number of calculators. We will be presenting the site on 3 December in the Koningshof in Veldhoven, where the Precision Fair 2013 will be held. This will also be the official start of the Thermo-Mechanics SIG.
Obviously, our ambitions as a SIG go further than developing a website. Early next year, we will team up with Mikrocentrum to help them organise their next Thermo-Mechanics theme day, plus we will publish a special issue of Mikroniek dedicated to thermo-mechanics. Of course, the site is not yet finished and we plan to expand it. Everyone interested is invited to sign up, contribute and come up with new ideas.

Although perhaps not entirely appropriate for an editorial, I'd like to finish by thanking thermal specialists Erik de Jong of Mapper Lithography, Evert Hooijkamp of Delft University of Technology, Ronald Lamers of MI-Partners, Martin Lemmen of TNO and our webmasters Peter Giesen and Jasper Winters, both of TNO. It took them over two years, more than 40 Monday evenings of meetings in conference room Oost at Hittech Multin, 250 pizzas and a lot of passion for thermo-mechanics in precision applications to develop a unique, first-rate site that DSPE can be proud of.

Pieter Kappelhof
Vice President DSPE, in charge of the Thermo-Mechanics SIG, and Manager Development at Hittech Multin

LET THE ROBOT-MOUNTED WHITE-LIGHT SENSOR MOVE FREELY

In the past, an optical 3D measurement platform was developed to measure the geometry of small products. As this platform is now being used heavily in a wide range of applications it has clearly proven its raison d'être. To broaden the system's field of application, a new platform is being developed, as part of which the white-light sensor used in the current platform will be able to move freely in space. The challenge here is to determine the spatial position of the sensor, mounted on a multi-axis robot, with an accuracy matching that of the sensor.

JAN REINDER FRANSENS

AUTHOR'S NOTE

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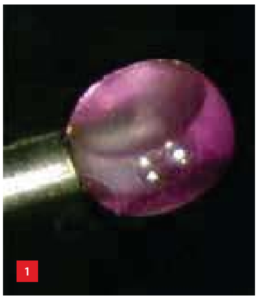
Introduction and objectives

There are a number of techniques available for measuring the 3D shape of objects with micrometer accuracy, each with their own set of advantages and disadvantages. About eight years ago, Irmato moved from taking tactile measurements using a stylus (Figure 1) to contactless measurements using white-light sensors. This enabled faster measurements that did not damage or change the shape of sensitive products. Using the platform that has been developed (Figure 2), the geometrical shapes of small products can be determined with sub-micron accuracy. Meanwhile, the field of application is very broad, ranging from contact lenses, small PECM (Precision Electro Chemical Machining) and EDM (Electric Discharge Machining) processed metal products to parts for the automotive industry.

However, to expand the field of application, an additional development step was needed. It would be great to be able to use the high resolution of the white-light sensor in 3D free-form measurements, as this would allow larger and highly curved objects to be measured. An obvious way to achieve this would be to mount the sensor on a multi-axis robot. However, the absolute accuracy of industrial robots is far from the required micron accuracy. This prompted the next development, which is outlined below.

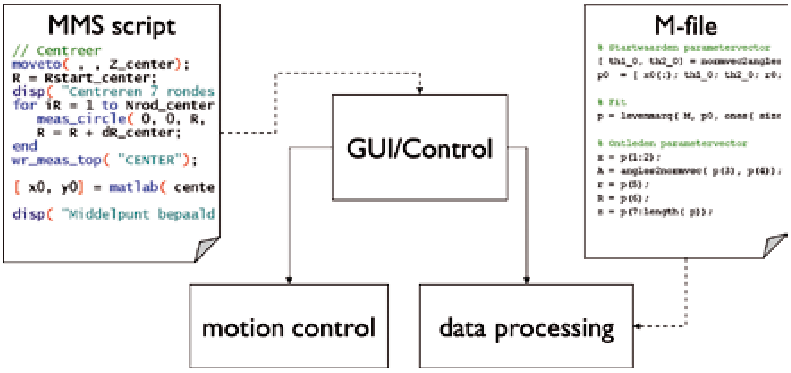
Current system

The current system as shown in Figure 2 uses an accurate X-Y table. Two white-light sensors have been mounted on Z stages above and below this table. Products are mounted on the table and can be scanned with a user-defined pattern and scan rate. A camera image is used to simplify the definition of the area to be measured. When designing the



1 *Stylus for tactile measurements.*

2 *Detail of the current measurement system.*



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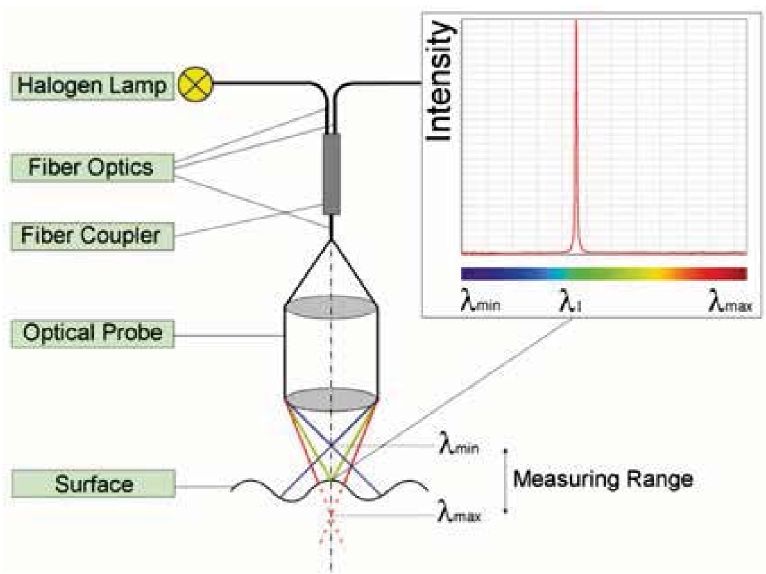

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3 *Software control of the system.*
4 *3D-Dash picture.*
5 *Measurement principle of a white-light sensor. The wavelength of the received light is a direct measure of the distance measured.*

system, the influence of yaw, pitch and roll of the stages, thermal influences, disturbance suppression, etc., on system accuracy was taken into account. To improve this accuracy even further, the sensor data was synchronised with the position of the stages. This resulted in a system accuracy of 0.2 µm for objects up to 100 x 100 mm^2.

Operating software

To operate the system, a layered software structure was developed. Extensive measurements can be defined using a proprietary scripting language. The measured data is saved in files for further processing. Various product-specific Matlab fitting routines are used to translate the data to quality parameters (CTQs). This process is shown in the schematic of Figure 3. To visualise the data (point cloud with X, Y and Z positions), a very flexible 3D viewer (3D-Dash) was developed. Raw data can be shown together with processed data. An example is shown in Figure 4.

White-light sensor

The principle of the white-light sensor is relatively simple (see Figure 5). The light from a polychromatic light source is concentrated on the surface of the object surface. The focal point depends on the wavelength. The reflected light is guided to a spectrometer via a spatial filter, resulting in a monochromatic image. There is a well-defined and calibrated relationship between the wavelength detected and the distance measured. This principle is applied by a number of companies including Precitec [1]. This company has a wide range of white-light sensors that fit our application. Table 1 lists a number of the parameters of their sensors. Some of the systems provide two different measuring procedures, enabling thickness measurement of transparent objects (i.e. glass).

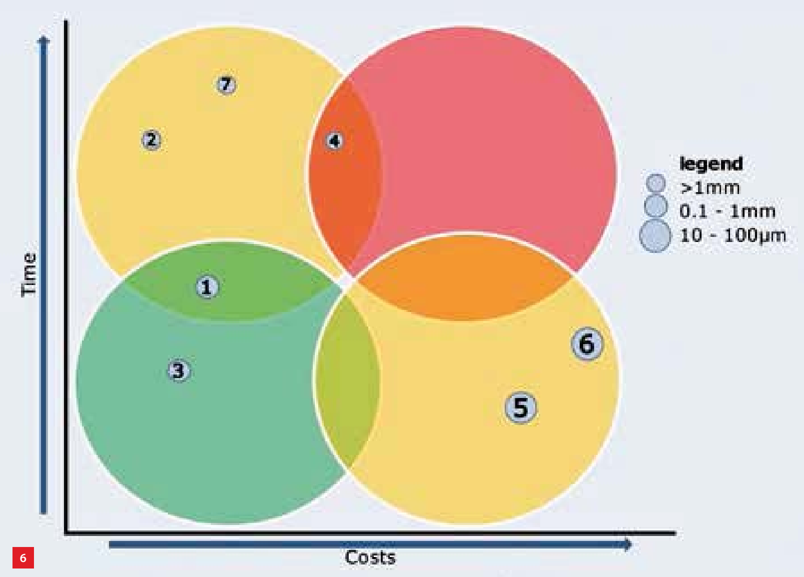
Table 1. *Parameters of Precitec's range of white-light sensors.*

Parameter	Value
Measurement range	100 µm - 25 mm (depending on sensor)
Resolution	10^{-7} · maximum measuring range
Reproducibility	10^{-4} · maximum measuring range
Linearity error	< $3.3 \cdot 10^{-4}$ · maximum measuring range
Lateral resolution	1.8 - 15 µm (depending on sensor)
Opening angle	up to 45°
Measurement speed	up to 70,000 samples/s

The accuracy challenge

The idea sounds simple. Just mount a sensor on top of a robot, extend the available software to handle the multiple axes and synchronisation, and off you go. However, although the repeatability of industrial robots might be relatively good, the absolute position accuracy is far from what is needed. Nubiola and Boney [2] managed to improve

During the second phase, an external sensor system is to be implemented to determine the exact position of the TCP. A number of possible solutions are under investigation. The best solution depends on the specific requirements (accuracy, range, measurement environment, etc.). Table 2 lists a number of methods to determine the actual TCP. Figure 6 depicts the costs versus implementation time of the different methods. The circles indicate the achievable accuracy.



6 *Costs versus implementation time of the different methods to determine the TCP. The size of the circles indicates the achievable accuracy (larger is better).*

Table 2. *Methods for determining the actual tool centre point (TCP).*

1.	Use two cameras and an accurate grid as background to determine the TCP.
2.	Use cables on the robot to determine the joint positions; calculate the TCP.
3.	Use three cameras to determine the TCP position (3D vision).
4.	Determine the joints with laser distance measurement; calculate the TCP.
5.	Use an optical laser system with spatial artefacts to determine the TCP.
6.	Use a laser tracker system with retro-reflector to determine the TCP [3].
7.	Use a precision trigonometric method with cables to determine the TCP.

the absolute accuracy of an ABB IRB 1600 robot by a factor of three using an extensive calibration routine. This resulted in a mean position error of the end-effector of 0.36 mm. Great research, but still not good enough for our applications. The biggest challenge, therefore, is to determine the sensor position in space with an accuracy matching that of the sensor.

Conventional machining uses tool centre point control (TCPC) to position the point of the tool relative to the surface of the workpiece. The final goal is to achieve a TCPC (the tool being the sensor) with a precision in the order of microns. This goal can be achieved by taking the following steps:

1. Use the robot position and accept the absolute position errors.
2. Measure the position of the robot end-effector (TCP) and use this to correct the measurement.
3. Take the measured end-effector position and use a feedback control loop to correct the robot position.

During the first phase of robot position control, the sensor system and the control software are to be integrated. First, the thickness of an object is measured with a simple line-scan. At the end of phase one, the system is able to scan a curved surface and measure the thickness and shape. To measure the thickness accurately, the sensor should be aligned perpendicular to the surface. Two possible ways to achieve this are under investigation: a) use CAD data of the workpiece as a first estimation to control the sensor position, and b) use a sensor system to align the robot end-effector.

3D vision is probably the cheapest way to measure the TCP. Three high-resolution CCD cameras are used to determine the position of a number of well-defined markers (i.e. white balls) mounted on the TCP. Depending on the camera resolution and the field of view, a resolution in the order of 0.1 to 1 mm can be achieved. Laser tracker systems can achieve an accuracy in the micron range. However, these systems are less suited to real time measurements since an uninterrupted image of the required retro-reflectors is needed. Furthermore, the systems are expensive.
The TCP position measured will be combined with the sensor data collected, in order to improve the accuracy of the measurement. This is already a major improvement compared to the results from the system without TCP position feedback.

In the third phase, the measured TCP position will be used to correct the robot position in real time. In his thesis, Hakvoort presents the feasibility of feedback control to improve robot position accuracy [4]. A practical application of this technique is used in the Arc-Eye system, which improves the quality of robotic arc welding [5]. In this system, a laser sensor is used to track the welding seam and to correct the TCP. With this system, accuracy is in the micron range.

Both cases show that it is possible to measure and correct the TCP position with micron accuracy. By combining a

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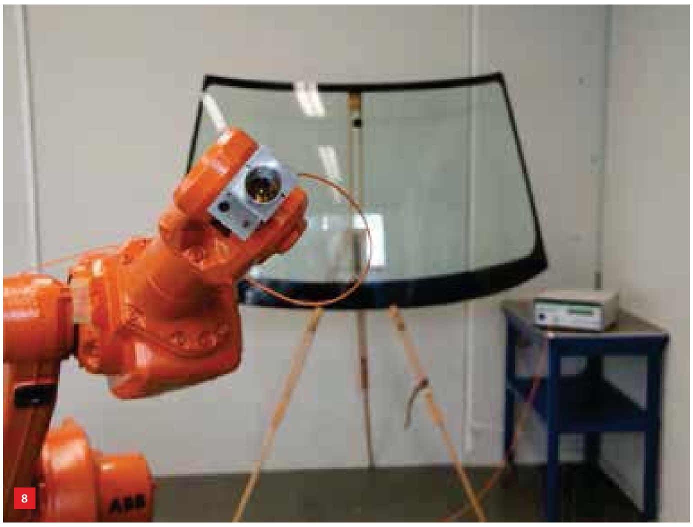

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7 *White-light sensor system from Precitec.*
8 *White-light sensor mounted on an industrial robot.*

dedicated external sensor system with robot TCP feedback, any errors the robot subsequently makes will be very small. Using this technique will significantly improve the accuracy of 3D free-form measurements.

Future

At the Precision Fair [6], Irmato will demonstrate the principle described above. Using a Precitec CHRocodile sensor (see Figure 7) mounted on an ABB IRB 1600/1.45 robot [7], the thickness of a car front window will be measured. Figure 8 shows how this will be set up. The results will be visualised in the 3D-Dash software.

Irmato is continuously improving the flexibility and accuracy of the system. The final goal is clear: a free-form measurement system with micron accuracy. We like challenges, but far more important, customers are already asking what is possible. ■

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[1] www.precitec.de
[2] A. Nubiola, I.A. Bonev, "Absolute calibration of an ABB IRB 1600 robot using a laser tracker", *Robotics and Computer-Integrated Manufacturing*, Vol. 29(1), pp. 236-245, 2013.
[3] See, for instance, www.faro.com
[4] W.B.J. Hakvoort, "Iterative Learning Control for LTV Systems with Applications to an Industrial Robot", Ph.D. thesis, University of Twente, the Netherlands, ISBN 978-90-77172-44-5, 2009.
[5] See www.arc-eye.com
[6] Precision Fair, 3-4 December 2013, Veldhoven, the Netherlands, www.precisiebeurs.nl
[7] See www.abb.com

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PRECISION POINT LAUNCHED

Janssen Precision Engineering (JPE) has launched Precision Point, a portal on which JPE shares the high-tech knowledge it has acquired since 1991, when the company was founded. This knowledge comes in convenient one-page summaries along with in-depth calculation files.

MAARTEN DEKKER AND HUUB JANSSEN

AUTHORS' NOTE

Maarten Dekker has worked as a mechanical engineer at Janssen Precision Engineering (JPE) for several years now and is leading the Precision Point initiative. Huub Janssen is the founder and owner of JPE, based in Maastricht-Airport, the Netherlands, which is renowned for precision engineering and mechatronic solutions in ambient, vacuum and cryogenic environments.

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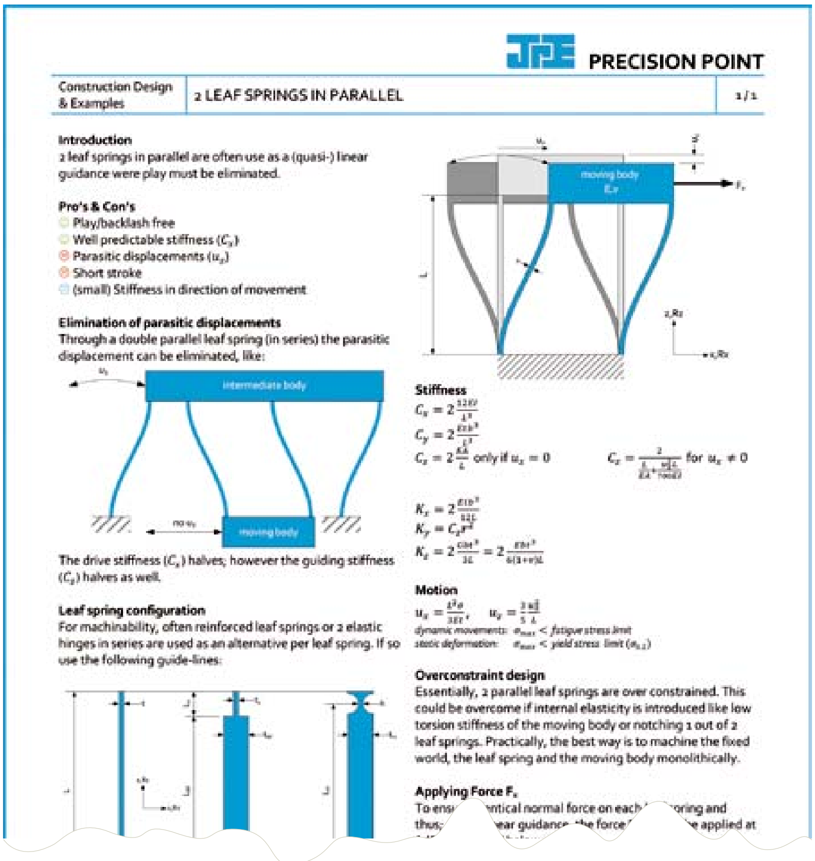
High-tech challenges

Janssen Precision Engineering's core business – precision engineering and mechatronics – often faces high-tech challenges. The ever-increasing demands for better performance, i.e. better resolutions, higher accuracy, faster operation, higher loads and smaller volume claims increase these challenges even more. On top of this, the projects JPE carries out and the products it designs are often intended for special environments such as vacuum (up to UHV) and cryogenic (down to the mK range). These environments involve non-trivial physical phenomena that can cause additional problems affecting the possible solutions. As such, these should be taken into account as well.

Precision Point's roots

In general, solutions arise from theoretical knowledge combined with a pragmatic approach. The JPE team then either remembers these by heart or writes them down for personal use. The Precision Point initiative is seeing this intrinsic knowledge now being collected and summarised on one-page sheets like the one shown in Figure 1. Each sheet elaborates a specific subject and can be read separately from the others. Although greatly summarised, the sheets can be used as background knowledge, a possible concept or even as the basis for a brainstorming session. The sheets can be easily printed on A4 paper and are ideal reminders.


PRECISION POINT

Construction Design & Examples | 2 LEAF SPRINGS IN PARALLEL | 1/1

Introduction
2 leaf springs in parallel are often use as a (quasi-) linear guidance were play must be eliminated.

Pro's & Con's
- Play/backlash free
- Well predictable stiffness (C_y)
- Parasitic displacements (u_z)
- Short stroke
- (small) Stiffness in direction of movement

Elimination of parasitic displacements
Through a double parallel leaf spring (in series) the parasitic displacement can be eliminated, like:

The drive stiffness (C_x) halves; however the guiding stiffness (C_z) halves as well.

Leaf spring configuration
For machinability, often reinforced leaf springs or 2 elastic hinges in series are used as an alternative per leaf spring. If so use the following guide-lines:

Stiffness

Motion

dynamic movements: σ_{max} < fatigue stress limit
static deformation: σ_{max} < yield stress limit

Overconstraint design
Essentially, 2 parallel leaf springs are over constrained. This could be overcome if internal elasticity is introduced like low torsion stiffness of the moving body or notching 1 out of 2 leaf springs. Practically, the best way is to machine the fixed world, the leaf spring and the moving body monolithically.

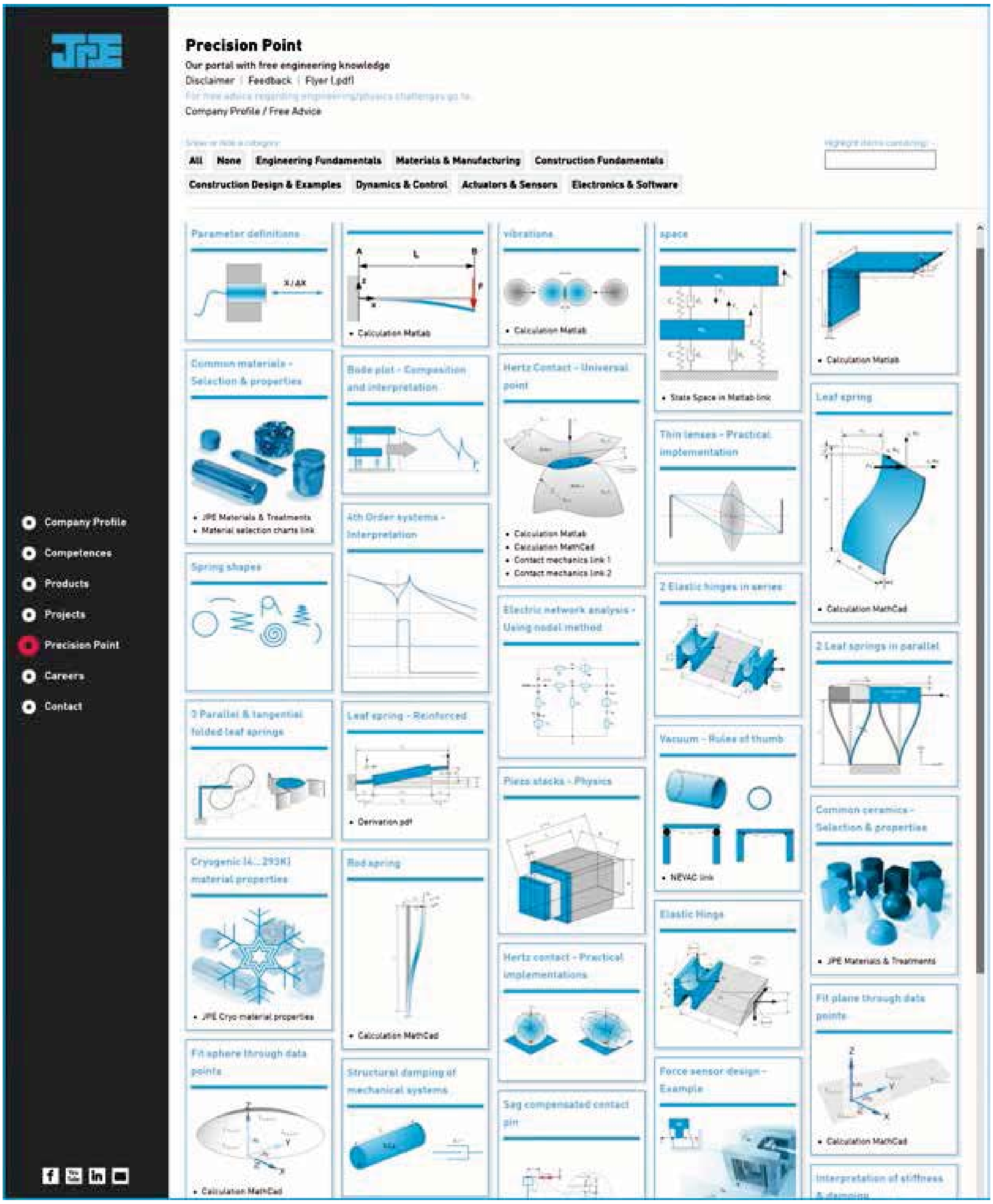
Applying Force F_x

1 *A Precision Point sheet. Every sheet has a similar layout. This sheet clarifies some of the issues regarding the use of a linear guidance through two parallel leaf springs.*

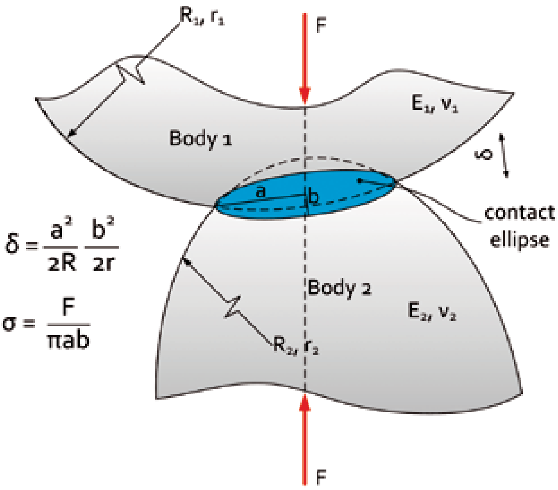
Portal

The sheets are freely available and can be downloaded from www.jpe.nl/precisionpoint (see Figure 2); no registration is required. The portal has been set up with the utmost care to ensure that users find exactly the right sheet. Users cannot search for exact solutions or design ideas; they have to find them. To aid this, the portal has seven categories, which can be (de)selected. It's easy to do a quick scan of the entire collection in the portal because each sheet is represented by an icon, indicating content, as can be seen in Figure 2. The seven categories are:

- Engineering Fundamentals
- Construction Fundamentals
- Construction Design & Examples
- Actuators & Sensors
- Dynamics & Control
- Materials & Manufacturing
- Electronics & Software



2 *The Precision Point portal on www.jpe.nl/precisionpoint. Each sheet is represented by an icon and comes with detailed information and/or computation files.*



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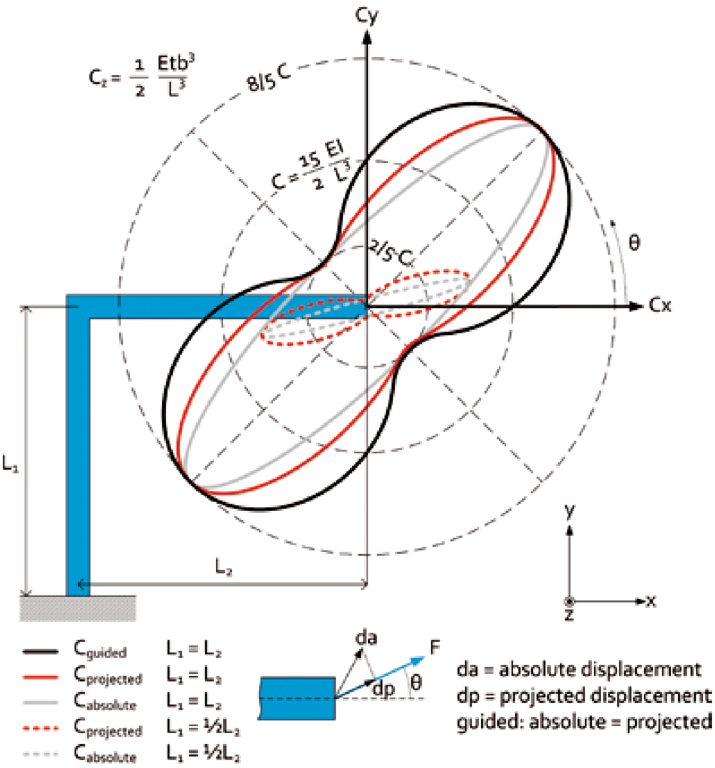

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Moreover, a search engine has been added, so users can apply keywords to search for the right sheet across the categories, which can be selected at the top.

The portal supports users in other ways as well. A whole host of web links is provided below the representative figures. Some of these link to other websites, while others link to such things as Matlab® files with computational codes or PDFs containing detailed information.

So, you may be asking yourself what JPE gets out of all this. The answer is simple. Helping professionals and students from companies and institutes will introduce people to JPE and the company's website. With Precision Point, users will recognise JPE's skills and competences, which may then lead to work and collaborations.

The following sections will clarify the seven Precision Point categories in more detail and provide some examples.

Category 1 – Engineering Fundamentals

This category comprises information such as Hertz contact formulas, beam theory and e.g. thin-lens equations. These fundamentals can be found in many other resources as well. However, this is exactly a main issue; although they can be found anywhere, this information is generic for more expertise fields, not complete or overcomplete. The subjects of this category are intended for precision engineering and/or mechatronics. Figure 3 shows a part of the sheet that elaborates on Hertz contact stiffness. If two (double-) curved bodies are pressed together with a certain force F, an ellipse-shaped contact will occur. The sheet shows the equations of the approach of the bodies, the contact stiffness and the occurring stresses.

3 A part of an Engineering Fundamental sheet, "Hertz Contact: Universal point"; for more equations go to the portal. The next category Construction Fundamentals includes a sheet which explains the practical implementation of such Hertz contacts. There it will become clear that only Hertz contact points are practical, whereas line contacts are overconstrained.

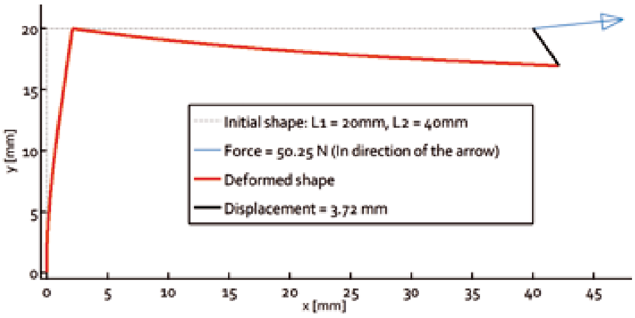
4 A Construction Fundamental: The parasitic x-y stiffness of a folded leaf spring, dependent on load orientation and definition of displacement.

Category 2 – Construction Fundamentals

Construction Fundamentals generally concern Engineering Fundamentals and their practical application. For example, an individual folded leaf spring is regarded as a Construction Fundamental; such a folded leaf spring is known for its high stiffness in one direction (along the 'fold') and is often used in (monolithic) structures combined with other construction elements to statically determine six degrees of freedom (DoFs) of, e.g., a platform. The stiffness along the fold (z-direction) of such a folded leaf spring is (see Figure 4):

$$C_z = \frac{1}{2}\frac{Etb^3}{L^3}$$

However, the parasitic stiffness (in x and y) of a folded leaf spring is often overlooked. An individual folded leaf spring that is not guided at all, or in other words not combined with other construction elements, will comprise an 'absolute' displacement that is not necessary in the same direction as that of the applied force, see Figure 4. Thus, a specific definition for the stiffness is required. Especially because on top of this, the stiffness is dependent on the dimensions of the folded leaf spring and on the orientation of the applied force (θ) as well. A Construction Fundamental sheet is dedicated to this phenomenon and



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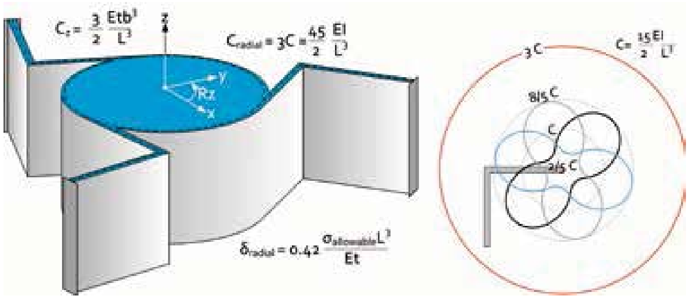

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the parasitic x-y stiffness according to different definitions and different force orientations is shown in Figure 4. The sheet is accompanied by a Matlab file for computing the deformation of the entire folded leaf spring as a result of an applied force, shown in Figure 5.

Category 3 – Construction Design & Examples

This category describes how to use the Construction Fundamentals in practical solutions. For example; Figure 6 shows a construction of a platform of which the stiffness and range of motion (RoM) are clarified on one Precision Point sheet. The shown construction example is able to fix three DoFs: z, Rx and Ry. This is achieved through three parallel and tangentially placed folded leaf springs. So x, y and Rz, for example, are free to be actuated.

A major advantage of such a system over a platform that is fixed with e.g. three vertical rods, is that the parasitic motion in z, due to a motion in x, y or Rz, is negligible. To be able to predict the forces necessary to move this platform in x and y, the x-y stiffness of these combined folded leaf springs has to be known. On top of this, the RoM is also limited through the combination of the individual RoMs of the folded leaf springs; it is typically not desirable that a movement will cause such a high (bending) stress that the (often monolithic) structure will exceed its yield stress. The radial stiffness of the platform and the radial RoM are elaborated in this Precision Point sheet.

Category 4 – Actuators & Sensors

This next category is on the design of actuators and sensors, which is within the JPE expertise. Amongst other actuators, the PiezoKnob is a noteworthy product, see Figure 7. Its actuation principle is based on inertia combined with stick-slip, see Figure 8: the objective is to reposition the moving mass from p_0 to p_2. In the initial condition, a steady-state voltage is applied to the piezo and a normal force *F* is applied to the moving mass to generate friction.

5 *The plotted deformation of an unguided folded leaf spring resulting from an applied force as one of the outcomes from the accompanying Matlab file. As can be observed, the displacement and force are not equidirectional.*

6 *A platform guided with three folded leaf springs as described on a Precision Point sheet. The theory of one folded leaf spring (a Construction Fundamental sheet) is used as a base for this.*

7 *The PiezoKnob, an actuator developed by JPE.*

Secondly, slowly decreasing the voltage shortens the piezo and the inertial mass is 'pulled' to position x_1. The moving mass remains at its initial position ($p_1 = p_0$) due to the friction. After this, the voltage is rapidly increased to expand the piezo to its original length. This rapid expansion accelerates the inertial mass and the resulting force on the moving mass overcomes the friction, causing it to shift to position p_2. Because the inertial mass is larger (more inertia), it will move less backwards than the moving mass shifts forward. After this the system is in steady state again, at position p_2, ready for the next 'step'.

Furthermore, this category comprises e.g. sensor parameter definition sheets. Evaluating sensor specifications can be confusing due to ambiguous parameter definitions that vary between mechanical and electrical engineers and from manufacturer to manufacturer. The Precision Point sheets define extensive sets of sensor parameters, such as resolution, accuracy, reproducibility, (non-)linearity,

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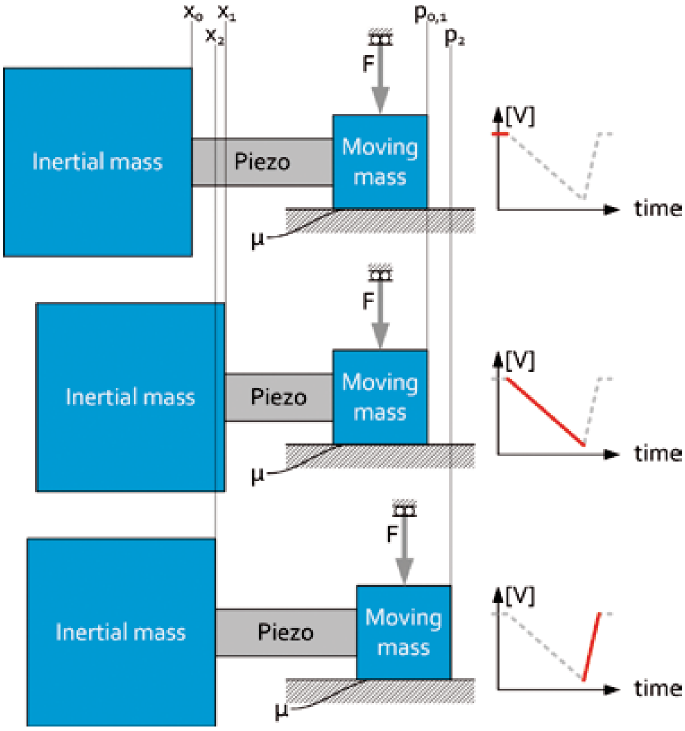

Step 1: Friction holds the position of the moving mass with respect to the fixed world.
Step 2: Slow shortening of the piezo moves the inertial mass towards the moving mass.
Step 3: Fast expansion of the piezo ensures a force that will overcome the friction force, causing the moving mass to shift, while the inertia mass will shift back less due to the fact that its inertia is larger than that of the moving mass.

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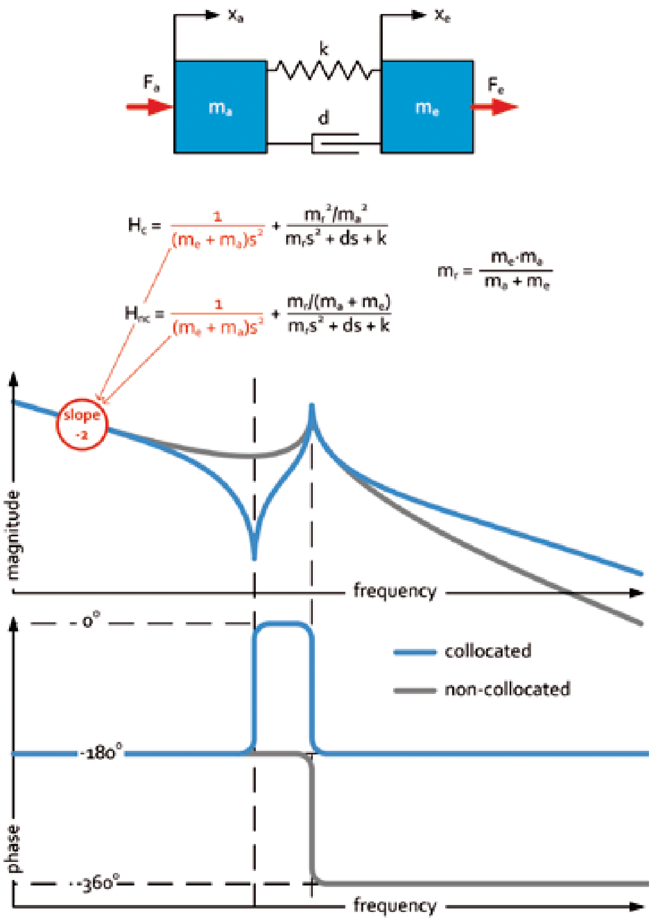

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8 *Actuation concept based on inertia & stick-slip, described on the Precision Point sheet about the PiezoKnob.*

9 *Equivalent masses of the actuator (a) and end-effector (e) and drive stiffness and damping. Two transfers can be thought of: collocated and non-collocated; of which the essentials are described in the Precision Point sheet: "4th Order systems – Interpretation".*

hysteresis, stability, bandwidth, latency and more, for several types of sensors.

Category 5 – Dynamics & Control

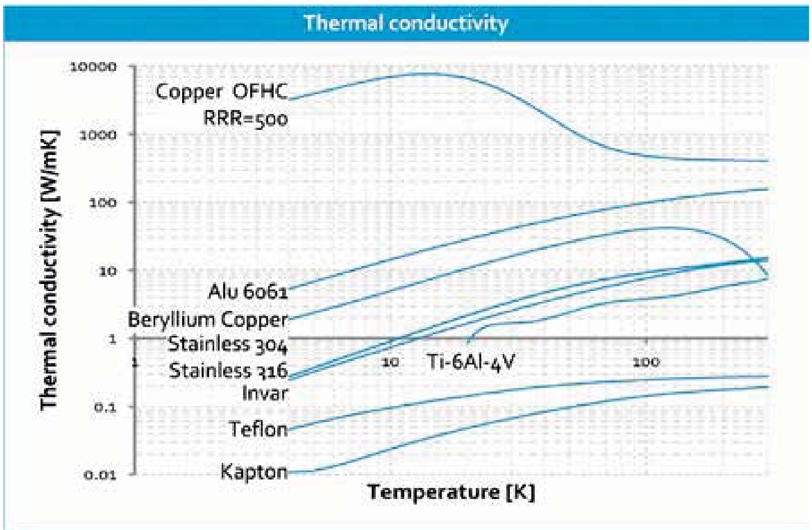
Multiple sheets regarding Dynamics & Control are provided in this section. For example the derivation of a state-space model from a linear lumped-mass model, damping factors and their interpretation, the composition of a bode-plot and loop-shaping rules of thumb. The following example is about the interpretation of fourth-order systems or, in other words, typical motion systems.

Due to limited stiffness, mechanical systems are characterised by internal resonances, which limit dynamical performance, both open-loop and closed-loop. To study the impact of this behaviour, a simplified model, known as the '4th-order system' or '2-mass-spring-damper system', is often used. This lumped-mass model is often a good representation for the low-frequency behaviour of practical motion systems. Figure 9 shows a scheme of such a system: It consists of two masses, connected with a spring and a damper.

In analogy with a real motion system, the first mass m_a is connected to the actuator of the system (a), and the second mass m_e represents the end-effector (e), the functional part of the system. The flexibility between both parts can represent a monolithic interconnection to a complex drive train. The transfer from a motor force to the motor body position x_a, known as collocated transfer, is of importance for feedback control design if the position sensor is located on the actuator side. The transfer from motor force to end-effector position x_e is referred to as non-collocated. The typical transfers are shown in Figure 9.

Category 6 - Materials & Manufacturing

As is the case with the Engineering Fundamentals, material data can be found in many resources. Nevertheless, this category on Precision Point is specifically intended for



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10 *An example from The Precision Point sheet, "Cryo (4K...293K) material properties": the thermal conductivity with respect to the temperature (≥ 3 K). The sheet is accompanied with an Excel file in which hard data is provided and computing is prepared.*

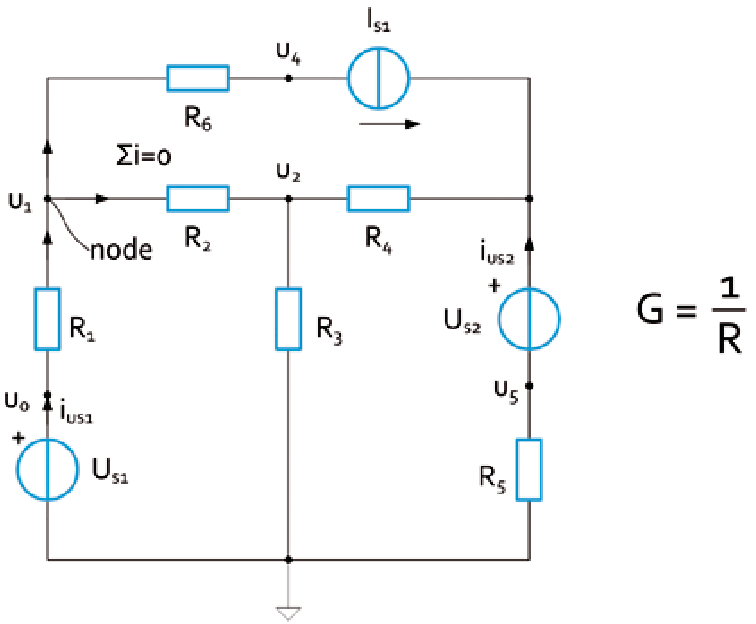
11 *Nodal analysis of electrical networks according to a Precision Point sheet.*

precision engineering and/or mechatronics. For example let's regard allowable material stresses. Mechanical designs often imply that the construction's materials only use their elastic range. In this case, the maximum yield stress is of importance. Occasionally, the material is intended to go beyond the yield limit once, e.g. for (local) reinforcement of the construction. The maximum allowable stress is now of interest. A third limit is the fatigue stress; when the construction material is repeatedly elastically deformed.

These three limits and other useful engineering material properties, such as thermal expansion and conduction, heat capacity and of course the Young's modulus and density, are provided. This is very useful data for ambient design. However, throughout the years, JPE has gained knowledge about engineering in vacuum and cryogenic environments. Consequently, cryogenic material data is also provided in this category, of which an example is shown in Figure 10. Material treatments, use of adhesives, EDM rules of thumb and more are 'under construction'.

Category 7 - Electronics & Software

Electronics in precision engineering are increasingly integrated in the mechanical designs. Therefore, it is imperative that mechanical engineers comprehend electronics or at least realise what issues are to be dealt with. This category provides such information. For example, the sheet represented in Figure 11 describes the basics of electrical network analysis. The description focuses on the modeling of a circuit for static or dynamic analysis using nodal analysis. A network of passive elements (such as resistance and/or reactance) can be analysed on current and



$$\begin{bmatrix} G1 & -G1 & 0 & 0 & 0 & 0 & 1 & 0 \\ -G1 & G1+G2+G6 & -G2 & 0 & -G6 & 0 & 0 & 0 \\ 0 & -G2 & G2+G3+G4 & -G4 & 0 & 0 & 0 & 0 \\ 0 & 0 & -G4 & G4 & 0 & 0 & 0 & 1 \\ 0 & -G6 & 0 & 0 & G6 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & G5 & 0 & -1 \\ 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & -1 & 0 & 0 \end{bmatrix} \begin{bmatrix} U0 \\ U1 \\ U2 \\ U3 \\ U4 \\ U5 \\ iUS1 \\ iUS1 \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ 0 \\ is1 \\ -is1 \\ 0 \\ US1 \\ US2 \end{bmatrix}$$

11

voltage in each circuit node, as a result of the parameters used, such as voltage and current sources. Ohm's law can be used:

$$G = \frac{1}{R} = \frac{i}{u}$$

When combined with the knowledge that the sum of currents in each node is zero, the resulting equation is:

$$\begin{bmatrix} \boldsymbol{G} & \boldsymbol{Q} \\ \boldsymbol{P} & \boldsymbol{0} \end{bmatrix} \begin{bmatrix} \overline{u} \\ \overline{i} \end{bmatrix} = \begin{bmatrix} i_s \\ u_s \end{bmatrix}$$

This equation can be set up according to this Precision Point sheet for several types of further analysis.

Conclusion

The number of sheets continues to grow as tried and trusted solutions have to be collected and elaborated, while new solutions to problems, old and new, are yet to come. From student to professional in the industry, Precision Point can aid in obtaining a solution for a certain high-tech challenge. ■

INFORMATION
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"WITH A NOD TO PERFECTION"

On 1 October 2013, Ter Hoek Vonkerosie in Rijssen, the Netherlands, held a seminar on micro precision manufacturing using techniques such as (spark) erosion. Speakers included representatives of IMS, Ceratizit, GF AgieCharmilles and Mitutoyo. A tour of the Ter Hoek production facilities gave participants an insight into the possibilities and challenges of precision manufacturing.

Bert Lauwers, professor in Mechanical Engineering at K.U.Leuven University in Belgium, acted as chairman of the day. He introduced the seminar programme after first outlining some of the work he is doing in Leuven in the field of advanced manufacturing processes.

EDITOR'S NOTE
This report was contributed by Ter Hoek Vonkerosie.

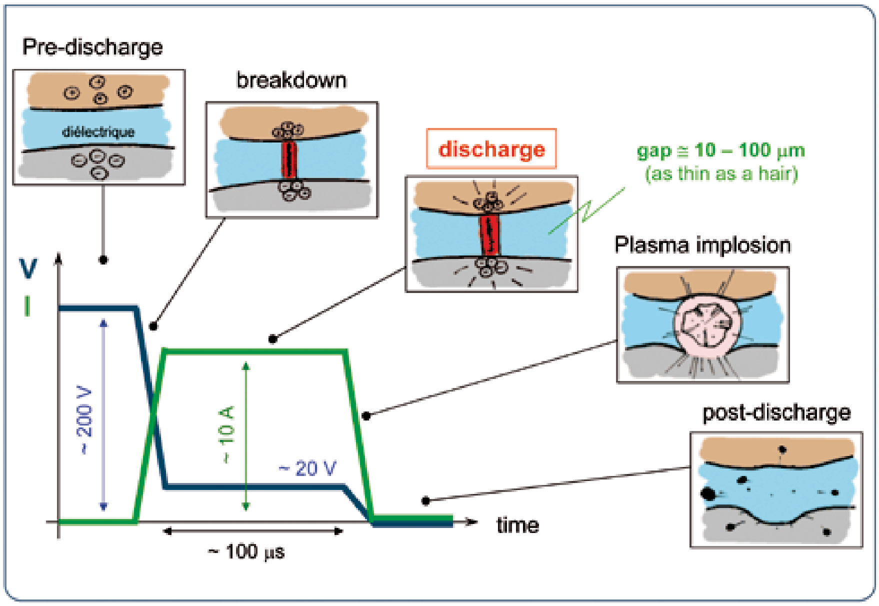
Kees Hoftijzer of IMS in Almelo gave the first presentation. IMS designs and builds manufacturing solutions for assembling small, intricately composed products such as mobile phone parts and medical tools. Hoftijzer introduced the product that would serve as a recurring theme during the seminar: a membrane in which a drop is placed that changes position as soon as it is subjected to an electrical charge. A so-called pixel room ensures that the drop remains invisible when not charged. Once charged, the drop comes out of its housing and becomes visible. The drop is available in different colours, which ultimately reflects the colour of the pixel in question.

The dimensions of the membrane are approximately 7 x 10 mm (see Figure 1), with a thickness of 40 μm; the membranes are used in large billboards. Given the narrow tolerance range, IMS approached Ter Hoek to produce the die for the manufacture of this membrane. The discussion after Hoftijzer's presentation focused on the division of roles between Ter Hoek, IMS and its client, the delivery time for a die such as this, and the choice of material.

Hard-material products

The second presentation came from Henri Bertrand and Jan van Goudswaard of Ceratizit, a supplier of innovative hard-material products. This presentation looked at how to determine the quality of a hard metal and how to handle this material if you want to process it using erosion. Key factors include cleaning (no chlorine) and damp.
Professor Lauwers said that, if required, he would be happy to provide further information on the influence of water or oil on the processed die, or on the special guidelines on how to handle hard metal that has been in contact with water. In that case, the hard metal has to be dried in an oven because there is a major risk of micro cracks occurring if water remains on the surface.
The final part of the Ceratizit presentation dealt with the influence of the roughness and corner radius on the tensile strength of the hard metal: a high level of roughness and a small corner radius result in a lower tensile strength.

1 *The die, approximately 7 x 10 mm, which was the focal point of the seminar. (Courtesy of IMS)*



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precision of this machine can in part be attributed to the cooling of the frame and the fact that the heads move rather than the entire water tank. During the tour, a range of the practical aspects of EDM were addressed, for instance the types of wire used, the smallest possible radius and the associated wire diameter. The spark gap was also explained, as were the material supplements necessary in the case of multiple cuts and the relationship between spark precision, required roughness and price. Besides (cutting) dies, wire-EDM can be used for a whole range of other purposes, including extrusion dies and key ways.

In the measurement room, Mitutoyo representatives explained how to measure contours using light (white-light interference). They had put together a special programme to show what the dies for IMS used to look like (see Figure 5).

Erosion techniques

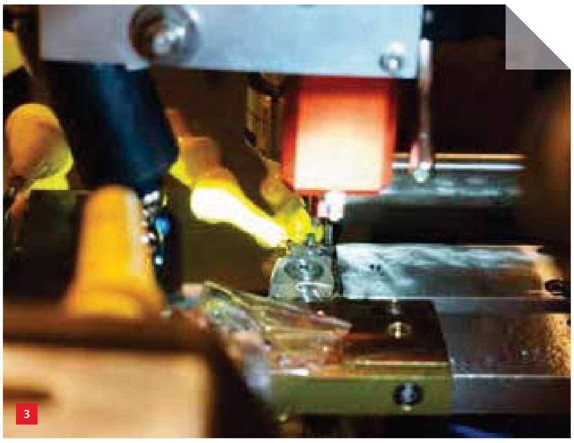
Roberto Perez from GF AgieCharmilles was flown in from Switzerland especially for this seminar. He introduced the technique of eroding, which uses pulses to build up a spark (see Figure 2). Using a charge on a workpiece and electrode, an ionising channel is built up. The voltage goes up to approximately 200 V and is then reduced to ~ 5 V. At the same time, the generator provides an electrical current of up to ~ 10 A. This takes approximately 100 ns. The current then declines, causing an implosion which removes material from the workpiece. A constant flow of water on the product ensures that the material removed is washed away. Varying the pulses affects the material removal, the roughness and the heat-affected zone on the material.

Tour

After lunch, a tour of the factory was given. In the micro department, the thin wire-EDM was demonstrated, the thinnest wire being Ø 0.03 mm. This requires a machine that has an incredibly stable construction and wire run. This makes smooth spark erosion possible, up to a roughness (R_a) of only 0.05 µm. This was followed by a demonstration on small-hole drilling, Ø 65 µm, using a so-called wire-dress device (see Figure 3).

Ter Hoek's largest wire-EDM machine is the Makino U86, which has a range of 800 x 600 x 500 mm (see Figure 4). At the maximum product height of 500 mm, a tolerance of 0.02 mm and a roughness of 0.75 µm are feasible. The

2 The principle of spark erosion. (Courtesy of GF AgieCharmilles)
3 Close-up of the wire-dress device on Ter Hoek's micro-drilling machine. (Courtesy of Ter Hoek Vonkerosie)
4 Ter Hoek Vonkerosie's largest wire-EDM machine, the Makino U86, which has a range of 800 x 600 x 500 mm. (Courtesy of Ter Hoek)



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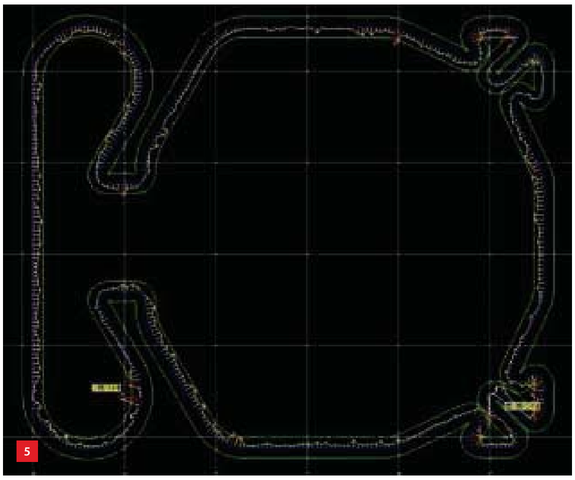

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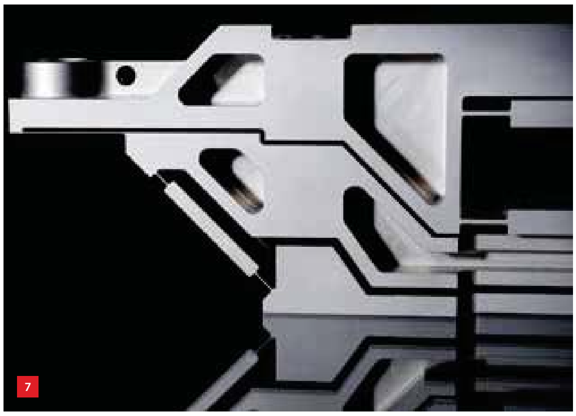

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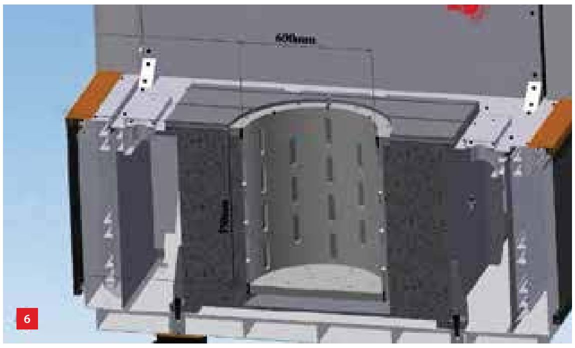

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5 *By measuring the contour, one can determine whether the required profile precision has been met. (Courtesy of Mitutoyo)*

6 *GF AgieCharmilles's Form 400 has a large hole of no less than Ø 600 mm, which is 750 mm deep in the bed of the machine. This presents new opportunities for zinc EDM. (Courtesy of GF AgieCharmilles)*

7 *Wire-EDM allows machining within 0.01 mm accuracy of contours that are not feasible with other technologies. (Courtesy of Ter Hoek Vonkerosie)*

Ter Hoek Vonkerosie's latest acquisition was found in the zinc EDM department: GF AgieCharmilles's Form 400 (see Figure 6). The huge Ø 600 mm hole that is 750 mm deep in the bed of the machine has expanded the range of options, e.g. vertical processing of a workpiece.

The tour ended with EDM drilling. This technique is mainly used for drilling starting holes for wire-EDM, but it can also be used for making cooling holes and extracting a broken off tap by sparking. There is an increasing demand for high-quality holes, presenting a major challenge for this EDM technique.

The EDM process

After that, host Gerrit ter Hoek, director of Ter Hoek Vonkerosie, gave a brief introduction on EDM: the process, the applications (Figure 7), the advantages compared to other machining techniques and the challenges (e.g. the rinsing issues when dealing with a product of varying heights). In terms of what makes Ter Hoek successful, he mentioned the company's understanding of their client's demands and their knowledge of how their clients' products work. This makes it easier to collaborate with clients and consider their product requirements; the thickness of the workpiece, rinsing conditions and choice of material all have a direct influence on the dimensional accuracy of the product.

Measuring technology

The last presentation came from Ruud Bloemen of Mitutoyo, a supplier of geometric measurement tools. He explored the importance of measuring techniques, using the product described earlier. There are a lot of uncertainties in terms of this product's measurements, and accurately checking these using a measuring machine is difficult. Bloemen underlined the importance of calibrating measuring machines to ensure sound and reliable measurements. In all cases, you should use common sense when considering the measurement results, bearing in mind the specific manufacturing issues a product may have.

Conclusion

The seminar concluded that manufacturing down to a precision of 1 micron is a complex undertaking. The ideal conditions, right machines and experienced employees have to be available to achieve that. The seminar contributed to this by providing a platform to share knowledge at a high level. Ter Hoek Vonkerosie's courage to show people what's going on behind the scenes at their company in this way was much appreciated by participants. More companies should do so, on their own or in collaboration with others. ■

INFORMATION

WWW.TERHOEKVONKEROSIE.NL
WWW.MECH.KULEUVEN.BE
WWW.CERATIZIT.COM
WWW.GFAC.COM
WW.MITUTOYO.COM

QUICK AND PRECISE TRANSITION FROM DESIGN TO SERIAL PRODUCTION

For many years the high-tech systems industry has relied on companies like IBS Precision Engineering for the design and prototyping of ultra-precision modules. Nowadays, IBS can also quickly and reliably enable the transfer of modules to serial production.

Precision Engineering solutions typically require input from multiple disciplines; at IBS, leading mechanical design, system and software architecture capability is combined with a foundation in metrology. Bringing their skills in product design together with long experience in measurement, test and tooling, IBS now helps companies better manage the complex route to volume production. In fact, IBS has established itself as a key partner in bridging the gap from specialist design to volume manufacture.

(Pilot) production

IBS has taken up the challenge of bridging the gap by keeping the process between design and serial production in-house. This means that after developing the prototype, it can also produce a first series. For production of components, they can rely on a network of suppliers who can respond to questions quickly and flexibly; which is imperative as adjustments are often needed in the early production phase. IBS does the assembly and testing, documenting critical knowledge on how best to produce its design. Direct transfer to the volume supplier can be made on behalf of OEMs, with full training ensuring an optimised final production process.

Precision dampers

A showcase of this approach is the design process for a critical suspension structure within the measuring system of a precision production machine. For the customer, eliminating external disturbances and vibrations was essential to ensure precise and reliable performance. As part of the overall design task, IBS designed and constructed solutions for isolating and damping vibrations. In this case, the system had a statically determined suspension and was thermally decoupled from the metrology frame, but its dynamic performance was not optimal.

Ivo Widdershoven, systems architect at IBS, explains: "Stronger damping of the high-frequency vibrations was needed, but the system as a whole needed to remain thermally decoupled. We looked for the optimal damping principle and settled on hydraulic damping. Having extrapolated the classic formulas into this regime, the outcomes were a surprisingly good match with the experiments we did. Based on that we designed two hydraulic dampers; one with very strong damping characteristics and the other with a high stiffness, to meet the required specifications. The vibrations in the system have a very small amplitude, in the order of nanometers; to measure this, we had to rely heavily on our expertise in precision measurement technology."

EDITOR'S NOTE

This article was contributed by IBS Precision Engineering, based in Eindhoven, the Netherlands.

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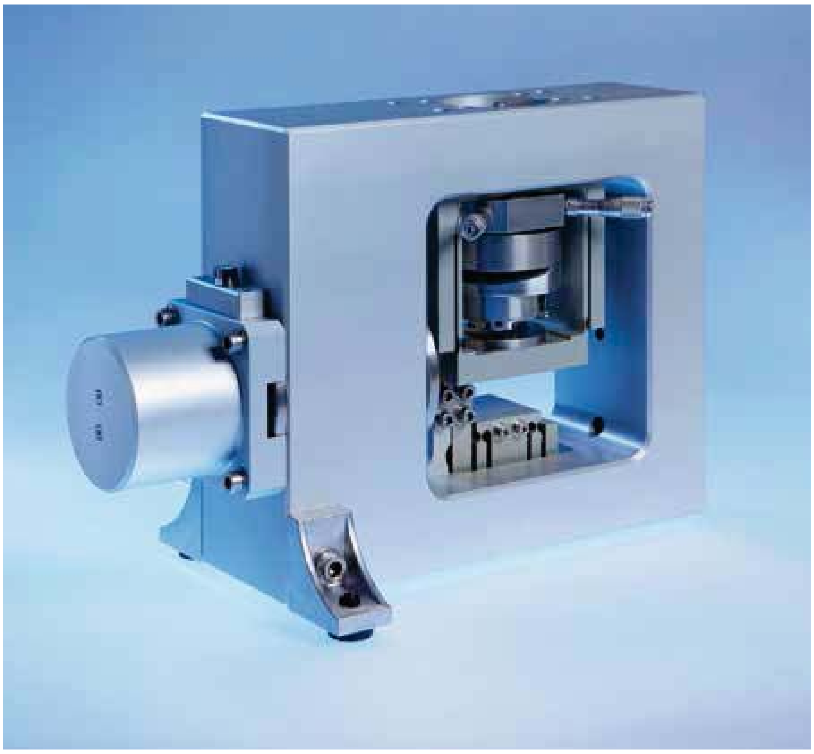

Damper and qualification tool, both designed and realised by IBS Precision Engineering.

Transferring production

The dampers were developed, built and tested in-house. "We wanted to do the testing ourselves to guarantee that the strict dynamic specifications were met. We then designed test equipment for the contract manufacturer, allowing them to determine the dynamic characteristics of all dampers to ensure a 100% verification of their performance." Thanks to its production expertise, IBS was able to quickly supply the client with the first dampers for their testing machines.

IBS has since produced hundreds of these dampers and subsequently transferred the entire production, including the testing, to the contract manufacturer without a hitch. "We helped them optimise production and made sure that no gap emerged between the prototype and serial production. The client then decided to make their specifications even stricter", Ivo Widdershoven explains.

"We helped them to develop the next generation of dampers. The new dampers have now been tested and delivered to the client. We will be transferring production to the contract manufacturer soon."

Smart mirror suspension

Another module that IBS has designed and will bring into production involves a laser mirror unit. This module is currently in the prototype phase. Vibrations from the machine's surroundings have a negative impact on its output, Hugo van der Weijden, lead mechanical designer at IBS, explains. "Currently, the mirrors have a rigid suspension. For the module, we have designed a suspension combining a passive damper and an ingenious spring construction. The required damping coefficient was relatively low, so in this case we were able to apply eddy current damping. Together with the client, we developed a simple damper without the drawbacks of conventional rubber-based damping solutions, such as sensitivity to temperature and moisture, ageing and static stiffness. We had the springs made by a specialist in wire-EDM (Electrical Discharge Machining, ed. note), as their construction is crucial to the mirror's dynamic behaviour and requires very high production accuracy."

Quick

Thanks to its network of suppliers, IBS was able to quickly build a functional model. "Our strength is that we can get things done, and to tight deadlines, with the support of our suppliers. We have extensively tested the new suspension and we will now do the initial production in-house. So this too is a project where IBS keeps up the pace", Hugo van der Weijden comments. "We have already had discussions with the prospective contract manufacturer."

Design to manufacture

The ability to take an idea or prototype and transform it into a manufacturable product is one of the most essential steps in the innovation process. IBS has established itself as a key partner in the very early stages of product manufacture where volumes are uneven and engineering may still be on-going, helping clients to bring a mature product to market quickly and with high quality. ■

SHARED INTEREST IN ‘OPTO’ DISCIPLINES

On 7 October 2013, the first DSPE Optics & Optomechatronics Symposium took place in the conference centre of the High Tech Campus Eindhoven (HTCE). Topics included the design and manufacturing of optics as well as optomechanics, and their implementation in optomechatronic systems. With top-class speakers from the world’s leading companies, over 110 delegates and an exhibition hosting seven companies, the inaugural edition of this DSPE initiative was a great success.

JASPER WINTERS

AUTHOR’S NOTE

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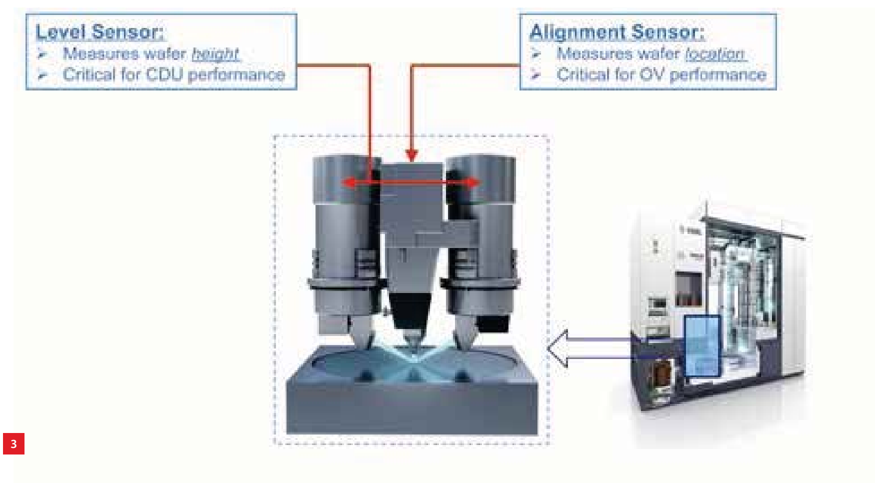
To start, DSPE President Hans Krikhaar explained to the delegates (Figure 1) how the initiative for the symposium had come about. “Precision engineering is bridging the gap between disciplines. Over the last few decades, more and more disciplines have become separate entities, and there has been less and less interaction. Now, however, there is a need again to bring the disciplines together; this symposium was organised to improve interaction and knowledge sharing across all disciplines related to optics. Working together, but also having your own opinions is something that is typically Dutch. When collaboration across the disciplines increases, this leads to great work, good products and healthy economics.”

Acting as chairman of the day, Jan Willem Martens, VP of System Engineering at ASML, opened the symposium by saying that given that 2013 was the Huygens Year, the theme of bringing disciplines in mechanics and optics together was very apt. This, too, is an important topic at ASML, where there is a growing need for a broader understanding in addition to expertise. Systems have become so advanced, that knowing a single discipline is not enough to be able to solve today’s challenges. We now need to combine disciplines. “We’re only just starting to do this at ASML, but at least we’re moving in the right direction.” After these encouraging words, the podium was handed over to the speakers.

1 *Delegates in deep concentration at the symposium. (Photos, unless otherwise indicated: Jan Pasmans)*



2 *Wilhelm Ulrich, Sr. Director of Optical Design at Carl Zeiss, presented the history and current use of free-form optics, and also looked to the future.*

3 *The two critical wafer metrology sensors of a lithography tool. (Illustration courtesy of ASML)*

From sphere to free form

The first speaker, Wilhelm Ulrich, Sr. Director of Optical Design at Carl Zeiss (Figure 2), presented the history and current use of free-form optics, and also looked to the future. The optical design of Zeiss has evolved through the development and use of different optics, from sphere to asphere to free form. Free-form optics have been used for a long time (e.g. sx-70 Polaroid camera). However, despite them being a great invention, they are still not being used for many applications.

So, are free-form optics just a hype? No, the number of publications on their use is growing rapidly, so they are here to stay. New applications can be found in very small cameras and head-mounted devices. What we need in order to apply the benefits of free-form optics to current designs, is the "efficient integration of free form into mathematical solvers". The conclusion being that free-form optics are a great tool to simplify and optimise the design and cut costs. They improve performance in many applications and even act as an enabling technology. However, tools have to be developed for design as well as aberration and tolerance management. Free form gives a lot of freedom in design, but as with all good design, keep it simple.

Optical metrology in lithography

Arie den Boef (a fellow at ASML) provided a good insight into how optical systems are an integral part of wafer metrology systems. Level sensors and alignment sensors were discussed (see Figure 3). These sensors are used to characterise the wafer before exposure. The level sensor measures the wafer height map, which is critical for Critical Dimension Uniformity (CDU) performance. The alignment sensor measures the wafer location, which is critical in realising overlay (OV) performance. They, of course, need to be accurate and fast, but they also need to be flexible for coping with different layer materials, and to be robust against such things as layer thickness variations.

'Process robustness' is a common challenge that can be solved by integral optomechatronic design. For the level sensor, a solution was found "using broadband light for process-robust levelling". Further process robustness was achieved by "using UV light for wafer height measurement." For the alignment sensor, a solution was found in the interferometric alignment sensor ('SMASH'), which uses up to four different wavelengths and diffraction optics. This makes the sensor less sensitive to signal loss when more (up to 40) layers are stacked.

Lithography system stability

The second speaker from ASML was Bert van der Pasch (also a fellow at ASML). To get good quality patterning results, a wafer scanner has to stay accurate over time. This presents the challenge of keeping the optics stable to a sub-nm level, while components like the wafer stage and reticle stage exert accelerations in the order of 3g and 10g respectively. To resolve the instability, all relevant position measurements should be related to a maximum stable position reference and adjusted for instabilities at the relevant time scales (per wafer/batch/day/week). One measure that can be taken is to move the actual lens

4 *Optics for a 360° camera module, showcased by exhibitor VDL ETG Research. In the hole in the bottom a camera points towards a little metal mirror, which receives the image from the large metal mirror . This large mirror 'observes' the surroundings through the PMMA housing. Software processes the image so that it can be 'read' by the human observer.*

5 *KLA-Tencor's Teron 610 reticle inspection machine. (Photo courtesy of KLA-Tencor)*

positions to adjust for image size and location. Stability is important due to loss of yield and productivity. As a rule of thumb, the following steps should be taken to design a stable system. Make a maximum-stable reference, use low-hysteresis sub-modules, use software to make adjustments per wafer and use constant sequence timing to enhance reproducibility.

A course in lens design

After a short break, with intriguing objects (Figure 4) and lively discussions in the exhibition area, Chris Velzel presented his upcoming book "A course in lens design". At the age of 58, Chris left Philips after 30 years to start his own company. He has trained many of those working in the optics field today. His book aims to teach people starting in the optics field a practical way of designing optics in less than 400 pages by "learning lens design step by step". Although Chris is a very experienced engineer, he had to start at the very beginning when it came to optical design. In particular, the practical component was a topic he had to learn.
This practical basis is exactly what the book starts with. The key is to really understand the optical design rather than optimising it with computer algorithms. The book covers the following: geometrical optics, optical instruments, aberrations, lens design processes, design strategies and design examples. The last chapter of the book is by far the most extensive. The book is still just a manuscript, and although the exact publication date is not known yet, the aim is to publish it in the second or third quarter of 2014.

Free-form surfaces in optical microsystems

Stefan Sinzinger, Head of Technical Optics, at TU Ilmenau, elaborated on the many different activities of TU Ilmenau, with a focus on free-form optics and the science behind them. The design, surface representation and optimisation were discussed first. Stefan explained how differential mathematics is used to link the image plane to the object plane, while NURBS (Non-uniform rational B-splines) are used to optimise the elements locally. Again, free-form optics are not simple to design, but they do enable revolutionary new designs.

The manufacture of optical microsystems was also addressed. Manufacturing techniques such as micro-milling, laser ablation, interference lithography and fly-cutting were mentioned as techniques that TU Ilmenau uses to produce free-form optics. Characterisation remains a challenging topic that continues to be worked on. Applications of free-form optics are foreseen in visual aids, compact optical systems and optical microsystems (e.g. active optical systems, hyperspectral imaging, optofluidic fluorescence detectors and nanowire-based gas sensors).

High-performance microscope objectives

Wolfgang Vollrath, Chief Scientist at KLA-Tencor, explained the optical inspection activities of his company and its involvement in lithography. A rather extreme example is the 'Teron 610' reticle inspection machine (see Figure 5), which consists of over 1,000 optical surfaces. "It's like finding a single defect the size of a pinhead on an area the size of Manhattan while going over it at Mach 15."

One of the challenges here is the microscope objective design, with key specifications being: diffraction-limited image performance, telecentricity and parfocality (i.e. the equal distance from focal plane to mounting flange for all objectives on a microscope turret). Examples were presented magnified up to 250x. A Strehl Ratio (SR, measure of quality of optical image formation) higher than 0.95 is not uncommon. These objectives are limited by such things as mechanical tolerances (air gaps < 50 µm with an error < 5 µm) and call for superior design performance. After assembly, the wavefront distortion of each objective is measured. Some cleverly placed elements can then be manipulated to adjust it for optimal Strehl Ratio.

6 *The exhibition encouraged lively interaction.*

7 *The Newtonian telescope in the Dr. A.F. Philips Observatory. Its concave parabolic primary mirror is 40 centimeters in diameter. The telescope is focused manually, with a special motor helping to keep the viewer focused on the object. The viewer magnifies up to 400 times and can detect distant objects down to magnitude 14. (Photo courtesy of Dr. A.F. Philips Observatory, sterrenwacht.dse.nl)*

Performance of E-ELT mirror segments

After looking at lithography and nanometer-level inspection, Jan Nijenhuis, Senior System Engineer at TNO, presented the primary mirror support for the E-ELT (European Extremely Large Telescope). This is a mirror 39 m in diameter, consisting of 798 hexagonal segments of 1.4 m each. Most segments are different but require the same support mechanics. Also, each mirror is actuated in piston, tip and tilt by three voice-coil actuators and spindles, and even internally deformed by nine more to compensate for gravitational effects when rotating the telescope. A typical position accuracy of 1.7 nm rms and a wavefront error in the order of 10 nm rms are required. To achieve these results, whiffle trees were used to create a statically determined support with 27 connections to the mirror segment. Also, motor positions were chosen that prove the best match for the Zernike optical deformations. Three demonstrators were built by TNO and tested by ESO.

The E-ELT case shows integral optomechatronic design on a massive scale. All cases presented here demonstrate that the optomechatronic field covers a wide variety of applications, from the creation and inspection of nanometer-scale structures to the survey of faraway galaxies.

Evening programme

After drinks and the last exhibition session (Figure 6) concluded the day programme, delegates were given the option to join the evening programme. Dinner was served at Hotel Parkzicht in Eindhoven, after which the Dr. A.F. Philips Observatory was visited. Unfortunately, it was quite cloudy, but a tour of the building, visit to the telescope (Figure 7) and viewing footage of the amateur astronomers made up for it. It is astonishing what can be realised when optics and mechatronics are combined and used by skilled and passionate people.

Conclusion

What was good about the symposium was that there was a general shared interest in understanding each other's disciplines. People with an optics background were enthusiastic about mechanics and mechatronics, while people with a background in those fields really enjoyed the presentations on optics. This contributed to the main objective, i.e. to connect people and companies and improve the level of knowledge. Driven by the success of this first symposium, the plan is to repeat the event every two years. ■

PRECISION TECHNOLOGISTS GET TOGETHER

Building sophisticated high-precision equipment requires co-operation between specialists in different disciplines. But how can you encourage such co-operation? The Campus Industry Connection provides ample opportunity for specialists to share information on their individual skills.

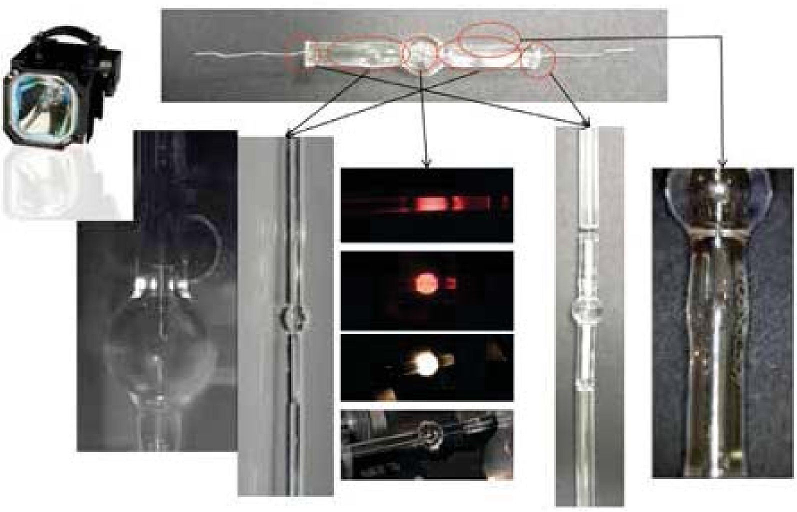
FRANS ZUURVEEN

AUTHOR'S NOTE

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

The Campus Industry Connection (CIC) is situated at the High Tech Campus in Eindhoven, the Netherlands, historically the home of Philips Research Laboratories. CIC provides a meeting platform for specialists working in product research and development in the fields of materials technology, micro-system technology, biotechnology, health technology, solar technology and precision technology. CIC focuses on three key activities: networking meetings, specific company visits and hosting a permanent internet Campus Industry Connection community forum.

During the recent CIC meeting on 16 October, Gert Vanvuchelen of Philips Innovation Services first informed the delegates how he and his colleagues solved many difficult laser welding problems, most of which concerned Philips Lighting products. Xander Janssen of the VDL Enabling Technologies Group then explained how his group's discipline of ultra-precision machining helped to produce Big-Science components for CERN and other parties. The meeting then gave delegates ample opportunity to share their specialist information.

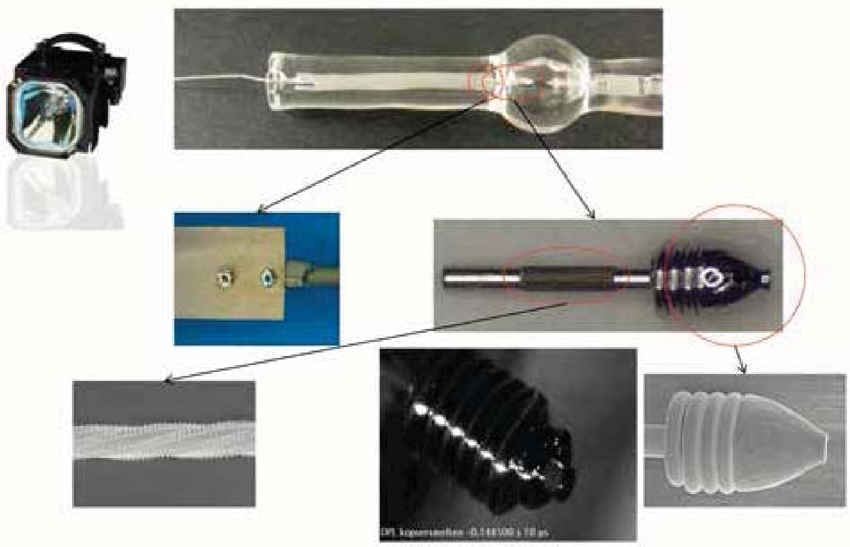


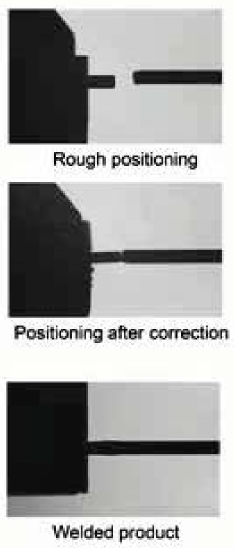
1 *Creating a bulb in a small quartz tube for a DPL beamer lamp using a CO_2 laser.*

Optimising laser applications

The disciplines of the Philips Innovation Services group include concept creation support, product and process development, industrialisation and quality and reliability. In his presentation, Vanvuchelen highlighted the aspects of industrialisation, especially laser welding, being applied at the Philips Lighting factory in Turnhout, Belgium, which are also available as a service to customers inside and outside Philips. The Turnhout site, the High Tech Campus in Eindhoven and other locations in Europe are home to more than one thousand engineers, specialists and consultants working for the group. Approximately 50% of the activities that Philips Innovation Services does are for Philips Electronics, with the rest of their work being done for third parties.

Vanvuchelen illustrated his group's laser application activities with some examples, including the creation (using a CO_2 laser) of a bulb in a small quartz tube as part of the manufacturing process of a DPL beamer lamp (Digital Projection Lighting); see Figure 1. This kind of laser is also being used to melt the quartz around the metal interior. To connect the metal parts of the interior, a YAG laser is activated (see Figure 2).





2 *Welding the metal components of the bulb in Figure 1 using a YAG laser.*

3 *Visual inspection and correction of two tungsten wires before welding.*

Control and process optimisation are of vital importance when trying to achieve the ultimate goal: zero-defect production. Vanvuchelen distinguished four levels of inspection: basic control, correction, identifying trends, and real-time in-process optimisation. An example of the second level, correction, is the visual inspection and correction of two tungsten wires before welding (see Figure 3). An example of the fourth inspection level is a chip manufacturing project, developed in collaboration with K.U.Leuven University (Belgium). The challenge was to control and monitor a selective laser melting process in real time. The solution was the continuous visual inspection of the melt pool. Detection of an aberration results in correction of the laser position and on-the-fly adjustment of the scanner speed and laser power.

Machining Big-Science components

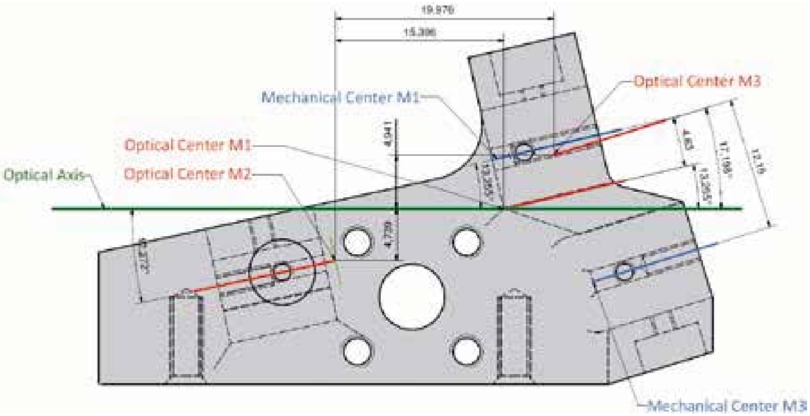
The VDL Enabling Technologies Group is a continuation of the former Philips Machine Factories. The VDL ETG disciplines Xander Janssen referred to in his presentation were ultra-high precision machining and metrology. The machining processes used to achieve ultra-high precision are single-point diamond turning and milling. The form accuracies attainable with turning are better than 0.1 µm, with milling better than 1 µm. The surface finishes (R_a) are better than 5 and 25 nm respectively. Relative accuracies up to 1:40,000 have been attained.

In contrast to the small products Vanvuchelen talked about, the precision components Janssen dealt with are large, e.g. telescope mirrors and accelerator parts. These components are normally used on earth, but ETG also builds them for projects like satellites in space: ESA CubeSats, miniaturised cost-effective satellites. Figure 4 shows a 'breadboard' supporting complex aspherical mirrors, whereas Table 1 lists specified and achieved dimensional demands. VDL was responsible for the design, manufacture, dimensional inspection and assembly of this component. The table clearly shows that all specified tolerance limits were met, e.g. a surface finish of 3 nm instead of 5 nm.

Table 1. *Specification of demands and results of a mirror support (see Figure 4) for the ESA CubeSat miniaturised satellite.*

		Specified results			Achieved results		
		M1	M2	M3	M1	M2	M3
Form	RMS [nm]	25	15	25	18	6	17
	PV [nm]	125	65	125	95	36	84
	Surface finish [nm]	5	5	5	3.1	3	4.7
Offset	X [µm]	21	22	20	0.7	0.1	0.1
	Y [µm]	31	22	16	1.0	2.3	2.3
	Z [µm]	34	16	27	0.8	1.1	1.1
Tilt	X [°]	0.028	0.200	0.025	0.004	0.006	0.004
	Y [°]	0.016	0.300	0.020	0.009	0.016	0.011
	Z [°]	0.068	0.500	0.090	0.001	0.022	0.001

ETG carries out other high-precision tasks for PSI, the Swiss Paul Scherrer Institute. PSI is building an X-ray free-electron laser called SwissFEL. This linear accelerator consists of an array of RF (radio frequency) modules. A 50 MW klystron in each module feeds a pulse compressor, which converts a 3 µs pulse into a 330 ns pulse, after which the compressed energy is guided to the accelerating structures.



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6

VDL ETG has produced a prototype of this pulse compressor (see Figure 5). This product, which is about 500 mm in diameter, is an assembly of two separate components from OFE-Cu and stainless steel 316 LN, brazed together as a result of product optimisation achieved by VDL ETG and PSI. Part of the manufacturing process is leak testing down to 2.5 $\cdot 10^{-8}$ Pa. The overall accuracy of the pulse compressor amounts to 5 µm at an inner surface roughness better than 50 nm.

Another challenging task for ETG was making prototype parts for the future linear accelerator to be installed by CERN, the CLIC (Compact Linear Collider). Despite having the word ‘compact’ in its name, it will be 48 km long. This huge device will become the successor of the already existing CERN circular accelerator, in which the Higgs particle was recently discovered. In the linear accelerator, two electron beams with opposing speed will collide. VDL ETG was involved in the development of components for the accelerator structures (AS). These RF structures will be built up from separate discs with an outside diameter of 80 mm and an accumulated structure length of 300 mm (see Figure 6). The form accuracy achieved is 2 µm, with 5 µm specified, at an inner surface roughness of 5 nm, with 25 nm specified. When actually installing the CLIC, about 150,000 of these structures must be manufactured, each consisting of many discs.

4 *Mirror support for the ESA CubeSat miniaturised satellite.*

5 *A pulse compressor optimised and manufactured by VDL ETG for the Paul Scherrer Institute with an accuracy of 5 µm and inner surface roughness better than 50 nm.*

6 *Prototype of an AS disk (Accelerator Structure) made by VDL ETG for CLIC, the CERN Compact Linear Collider.*

To conclude

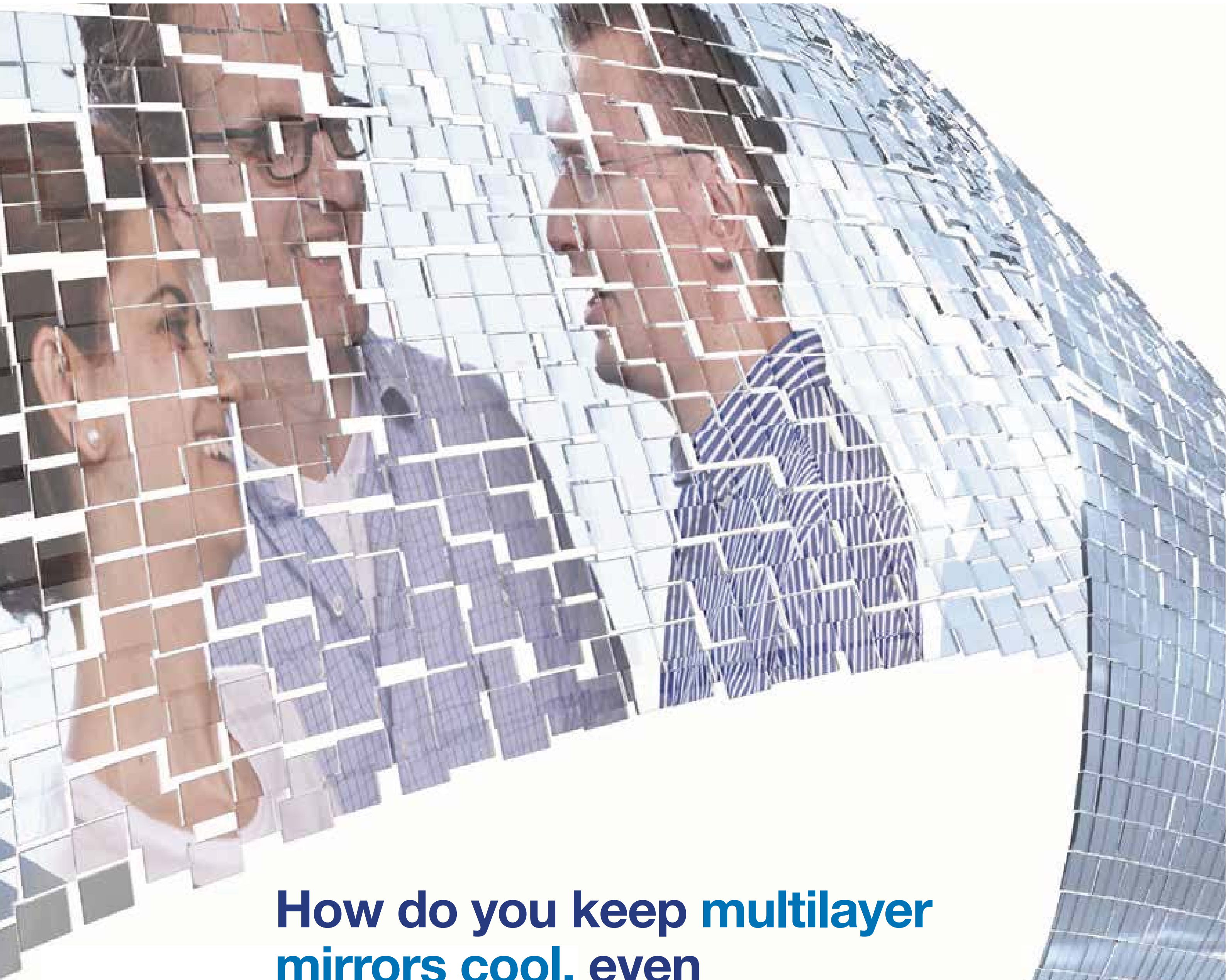
The world is now a global village! That’s what Marshall McLuhan postulated in 1962 when making his predictions of a futuristic high-tech society. Indeed, high-tech achievements such as the massive accelerators in Switzerland on the one hand and the nearly invisible laser joints in Belgium on the other have become a reality thanks to the global co-operation between high-precision specialists. They work together just as productively as the blacksmith and the mechanic in their village did one century ago.

INFORMATION

WWW.CAMPUSINDUSTRYCONNECTION.NL

WWW.INNOVATIONSERVICES.PHILIPS.COM

WWW.VDLETG.COM



A CELEBRATION OF ALL THINGS HIGH TECH: EVENT TO BUILD ON SUCCESSFUL 2013 LAUNCH

High-Tech Systems 2013 – a conference, exhibition and network event targeting the international advanced high-tech systems development sector – was a very successful international 'celebration' of the high-tech sector. This year's inaugural event featured complex mechanical development, advanced co-engineering and co-development as well as mechatronics technology, all in an international event format. High-Tech Systems 2014 will both continue and extend this successful format.

JOOST BACKUS

The High-Tech Systems 2013 event on 24 and 25 April was a great success. The two-day event had excellent in-depth presentations combined with company exhibits, an integrated business matchmaking activity, recruitment pitches as well as three 'tech side' events. Over 10% of the visitors were from abroad, and there were German exhibitors from Hessen, Saxony and North Rhine-Westphalia.

Company tours

For international and selected Dutch guests, the event kicked off one day before the start of the main event, with company tours to renowned high-tech stakeholders such as ASML, NXP, Philips Innovation Services, Imec, TNO, Frencken, NTS-Group and VDL ETG. The international guests participating in the tour were all delighted with the hands-on insights given into the high-tech ecosystem around Eindhoven, the Netherlands.

Cooperation and partnering

The 'Klokgebouw', part of the Philips industrial heritage in Eindhoven, was the main venue for High-Tech Systems 2013. The conference programme featured presentations on themes such as cooperative systems development, automotive, medical systems, semiconductor technology and agro-food. Cooperation and partnering in the high-tech systems arena was an important theme in 2013 and will continue to be a theme in 2014. This year, the event featured lectures from industry-leading partnerships such as ASML / Zeiss, Philips Innovation Services / Süss Microtec and Mapper Lithography / Leti, focusing on their co-development and co-engineering opportunities, strategies and cases for high-tech systems development.

Buzz

Business and buzz were clearly evident at High-Tech Systems 2013: over 2,200 visitors (> 10% international), 12 countries represented, over 100 companies exhibiting, 44 high-quality presentations in five tracks, a great Enterprise Europe Network (EEN) Business matchmaking event, a recruitment plaza and a number of very successful side and network events. Most parties promised to come back in 2014. High-Tech Systems has proved its worth in 2013; the format works and industry leaders have committed themselves for 2014.

Robotics

The main themes for the 2014 edition will be design and modelling, semiconductor equipment, system architecture,

AUTHOR'S NOTE

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Impressions of the High-Tech Systems 2013 event. (Photos courtesy of Bart van Overbeeke/ Techwatch)

robotics, and value engineering. Company tours for international visitors will be organised once more. The EEN matchmaking event will also be a regular feature at High-Tech Systems. The call for proposals for 2014 is open and all researchers, industrial professionals and other stakeholders in mechatronics and high-end engineering are invited to submit proposals for presentations.

Fast pace

Up first in 2014 will be the fast-paced conference for technical management and decision-makers, which will offer concise, inspiring pitches about additive manufacturing, Industry 4.0, co-development in the Eindhoven-Louvain-Aachen (ELA) triangle, and international business experiences.

A must in 2014

High-Tech Systems 2014 is a must for every high-tech professional. The organisers, which include DSPE, Brainport Industries, Flanders Mechatronics Technology Centre, Syntens and Techwatch, are joining forces once again. On 7 & 8 May 2014, they will host another truly inspiring celebration of all things high tech in the Southern Netherlands. Venue will be 1931 Congrescentrum Brabanthallen in Den Bosch (30 km from Eindhoven).

INFORMATION

WWW.HIGHTECHSYSTEMS.EU

WWW.HIGHTECHSYSTEMS.NL/EN/PROGRAMME/CALL-FOR-PROPOSALS.HTML

BRAINPORT PICKS UP WHERE THINGS LEFT OFF

Over twenty years ago, robot football kicked off in Japan. The first World Cup (RoboCup) followed in 1997 and two years later Philips CFT entered with a team that started developing and building football robots. One year after the team had reached the final, Philips pulled the funding. Recently, former teammates became interested again and took the initiative to set up a new industrial RoboCup team, Robot Sports. Technical challenges include sensors and integrating artificial intelligence into an industrial platform.

TON PEIJNENBURG

RoboCup is mostly a student affair. Every year, teams from universities and universities of applied sciences from all over the world compete with each other in various leagues. Last summer, RoboCup was held in Eindhoven, the Netherlands. Mikroniek covered the event in issue no. 4. Even before then, during the Dutch Open in 2012, former Philips teammates were itching to start again. They felt that the Brainport region should not only have a university team (Tech United, from Eindhoven University of Technology, the 2012 RoboCup Middle Size League champion and 2013 runner-up) but also one representing the industry. This team has since started, under the name Robot Sports.

Control

The new team wants to incorporate developments in artificial intelligence into an industrial robotics platform. After all, industrial robots also need to be able to operate autonomously to a certain degree. Just like robots in a hospital or a living room, for example, they need to be able to function in an unpredictable environment. In that case, the current design paradigm for technical systems operating under full control in a completely defined environment no longer applies.

A key challenge is building a system that comprises multiple agents and, moreover, does not follow a nominal business scenario. Machine builders are used to building a machine that carries out a nominal scenario and to then making them immune to disruptions that jeopardise the conclusion of the nominal process. A team of football robots displays behaviour that emerges as the sum total of the behaviour of all robots. These are difficult concepts in a traditional approach to machine building. Behaviour is chiefly determined by the control of the robot, which means that the key challenges lie in the software design. Other challenges come from the fact that practically all sensors are far less ideal than when used in 'normal' high-tech machines.

Spin-off

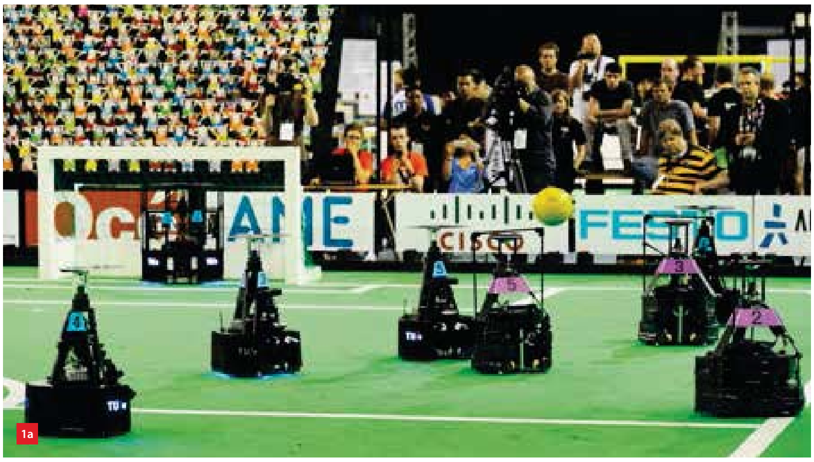
Besides the robot's control, attention is also given to the robot's hardware for ball handling, for example, and to newer types of control cards with less of a proven track record – things that tend to be disregarded in daily practice, but which ultimately may result in a spin-off for the business of the companies in question. This is what Philips had in mind more than ten years ago: RoboCup team developments could be interesting in other applications. It was a nice model that allowed people to set to work in their own time using their employer's assets – an exercise in multidisciplinary collaboration. That approach worked: in the end the team reached the final. But one year later Philips cut off funding.

AUTHOR'S NOTE

Ton Peijnenburg is Manager Advanced Developments at VDL ETG and previously worked for companies such as Philips CFT (currently Philips Innovation Services). He is the co-founder of the new Robot Sports team, and a DSPE board member.

Industrial character

Now in 2013, practically all the new teammates are designers with an industrial background. Their day-to-day work is mainly about delivering results on time, which leaves little time for exploring new technologies or related fields. It is both inspiring and encouraging to have the opportunity to check out what is happening in other areas and to pursue personal technical interests in a less rigid



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environment. The fact that RoboCup presents a competitive challenge only makes it more interesting.

CyberValley

The initiative for the new Robot Sports team was taken by VDL ETG, backed by Bosch Rexroth and maxon motor benelux. There are teammates as well from ASML, Philips, TNO, Vanderlande Industries, and other companies. On the list are names of about 35 people, 15 of whom are really active. Anyone can enter. The team's activities fall under the CyberValley foundation, whose aim is to promote technology. The ambition is to end up in the top three of the Middle Size League, the most prestigious RoboCup league.

Meetings

Meetings are held at least once week, usually on a Wednesday evening, and Thursday evening has recently been scheduled as well. The team has some space on the High Tech Campus Eindhoven, with facilities for simple electronic and mechanical work. They are, however, looking for more space, with a mechanical workshop and space to do electronic work. The team is also looking for a practice pitch the size of a RoboCup Middle Size League field (12x18 m). The meetings are used to work on software, electronics, mechanics, integration, experiments, website maintenance and publicity.

Invitation

Mikroniek readers who would like to contribute as a participant, sponsor or otherwise are invited to contact the RoboCup team. One of the charming aspects of the Robot Sports team is that people from different companies can work together towards a common goal, without being bothered by purchase orders, contracts and other standard aspects of doing business.

2

1 RoboCup 2013 impressions: robots functioning in an unpredictable environment, without nominal scenario. (Photos courtesy of Bart van Overbeeke/ RoboCup)

2 Get-together of the Robot Sports team.

Open innovation

Collaboration in the Robot Sports team may be called a form of open innovation: it is open (as in: everyone can join) and it is innovation (as in: learning new things). Other teams, such as Tech United, are close enough to be able to have frequent practice games. After all, real progress is only made in the period immediately before and during the real matches and competition. In short, the Robot Sports team contributes to the innovative strength of the Brainport region.

INFORMATION

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WWW.ROBOTSPORTS.NL

"REVOLUTIONARY TEMPERATURE CONTROL SYSTEM"

Controlling temperature starts by removing waste heat from the application involved. The use of solid-state thermoelectric modules (TEMs or Peltier elements) mounted to a metal heat sink is often enough for a modest amount of heat. When a larger amount of heat is involved and temperature needs to be controlled to within a few hundredths of a degree, TEMs are still the way to go, but only when utilised in a Top-Cool Technology (TCT®) module and with a flowing liquid, according to Qill Industrial and Top-Cool Products.

Sudden and uncontrolled changes in temperature are critical in many industrial applications. When it comes to accuracy and consistency of temperature control, it is essential that temperature fluctuations are instantly detected at the heat spot and that there is a rapid response to any changes. This requires the use of state-of-the-art NTCs (Negative Thermal Coefficient thermistors) and high-performance AD converters, connected to an aggressive and precise PID filter. Unfortunately, in traditional thermoelectric systems, a barrier of thermally resistant material between TEMs and the cooling liquid limits the efficiency and speed of such systems. With TCT however, Top-Cool Products and Qill Industrial remove this limitation from the equation.

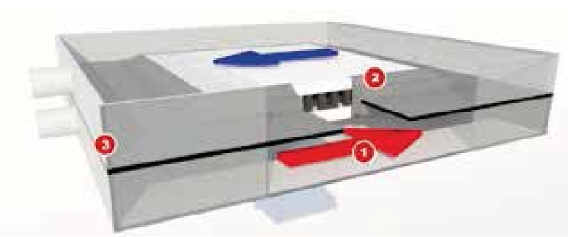
In TCT, Peltier elements are sandwiched in a plastic carrier in such a way that a flowing liquid directly touches the ceramic plates on each side. The absence of a metal heat sink leads to a revolutionary, precise and consistent temperature control system. TCT allows a liquid to be cooled directly, with no thermal barrier in between, maximising the effective contact surface of the TEMs and responding to temperature changes more rapidly, while preserving a constant temperature (max. ΔT = 5 mK). ■

EDITOR'S NOTE

This article was contributed by Qill Industrial.

INFORMATION

WWW.QILL-INDUSTRIAL.COM



Schematic of a TCT system: the excess heat is pumped directly from one liquid to another by forcing separate warm and cold flows to touch the ceramic sides of the TEM.

DSPE/MIKRONIEK FOCUS ON THERMO-MECHANICS

Thermo-mechanics is becoming a key DSPE topic. The Special Interest Group Thermo-Mechanics will be launched at the Precision Fair in Veldhoven, the Netherlands, in early December (see pages 4 and 43). Next year, Mikroniek will be publishing a special issue on thermo-mechanics; contributions on (the control of) thermal effects in mechatronic systems as well as heating and cooling technologies for high-tech systems are welcome. For example, the special issue will outline the TCT system described here, and its underlying principles, in more detail.

WWW.DSPE.NL

EMPLOYEE TRAINING IS WORTH THE INVESTMENT

Employee training does cost money; still it should not be seen as an expense but rather as an investment. Since it is an investment, it makes sense to talk about "Training Return On Investment (ROI)" and many people look at Don Kirkpatrick's work from as early as 1959 as the beginning of ROI in learning and development.

Kirkpatrick distinguishes four levels, being:

1. Reaction: to what degree participants react favourably to the training.
2. Learning: to what degree participants acquire the intended knowledge and skills based on their participation in a training event.
3. Behaviour: to what degree participants apply what they learned during training when they are back on the job.
4. Results: to what degree targeted outcomes occur as a result of the training event and subsequent reinforcement.

Shortage of qualified staff

In concept, Kirkpatrick's levels seem valuable. After all, what business wouldn't want to have training programmes that impact the performance of an organisation? However, the difficulty starts as one tries to quantify these results and get meaningful results. So, instead of trying to do too much number crunching, let's follow the well-known economist J.M. Keynes, who once said "It's better to be roughly right than precisely wrong", and look at the topic from a qualitative point of view, realising that in the high-tech systems arena there is a shortage of qualified staff. While government and industry are doing their best to stimulate technical education in order to increase the inflow of new talent and companies are also working on the inflow by recruiting staff from all over the world, there is ample reason to also invest heavily in the current staff.

At the end of the day, it's the employee that lays the golden eggs.

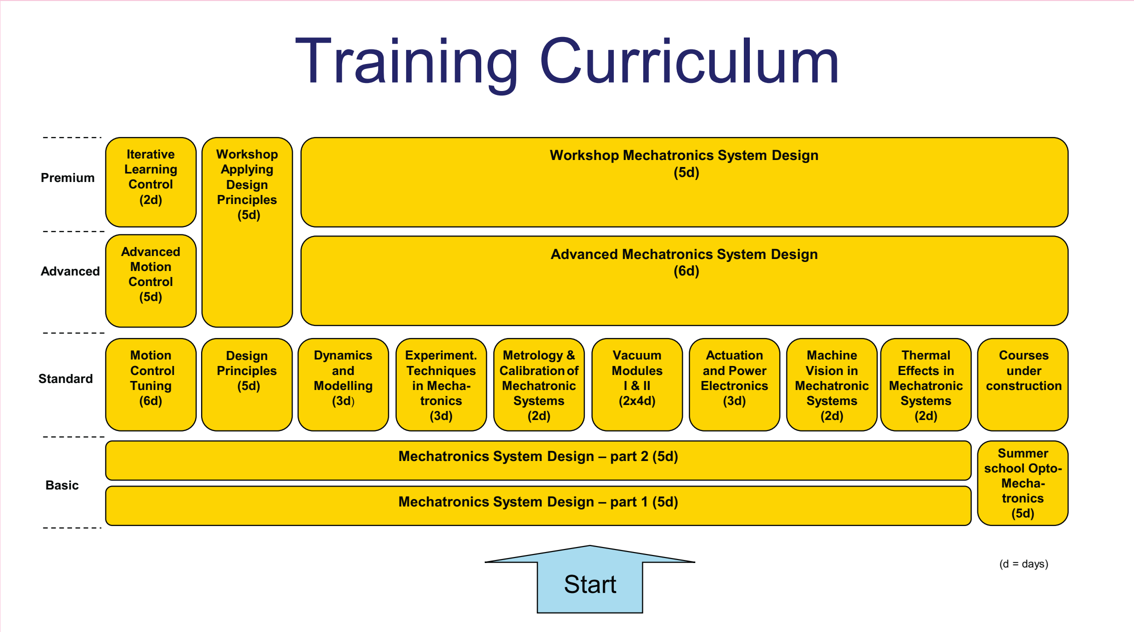
Payback

Despite the initial monetary costs, staff training pays back the investment. Here are just some of the reasons to take on development initiatives:

- Training helps to speed up the learning curve of newcomers by sharing the knowledge and lessons learned from more experienced seniors.
- Training does not only make an individual employee better, it also helps to make teams much more effective. Especially in the case of complex technology projects, requiring many team members from different disciplines, an individual improvement of say 2% for each team member easily results in a double-digit improvement of overall team efficiency and output.
- Training is a recruiting tool. Today's young workers want more than a monthly paycheck. They are looking for employment that allows them to learn and develop their professional skills. Employers are more likely to attract and keep good employees if they can offer development opportunities.
- Training promotes job satisfaction. Nurturing employees to develop more rounded skill sets will help them contribute to the company. The more engaged and involved they are in working for success, the better the employer's rewards.
- Training is a retention tool, instilling loyalty and commitment from good workers. Staff looking for the next challenge will be more likely to stay if they are offered ways to learn and grow on the job while at the company. Don't give them a reason to move on by letting them stagnate.

At the end of the day, it's the employee that lays the golden eggs, by producing solutions to technical challenges, fixing customer issues, coming with innovative ideas and generating IP that helps to stay in front of competition. So, learning and upgrading their skills makes business sense. ■

INFORMATION
WWW.KIRKPATRICKPARTNERS.COM



Mechatronics Academy

Early this year, after a period of informal cooperation, Maarten Steinbuch (professor of Control Systems Technology in Eindhoven), Jan van Eijk (professor emeritus of Advanced Mechatronics in Delft) and Adrian Rankers (former manager Mechatronics Technologies at Philips) have taken the step to a formal cooperation in the field of Mechatronics courses by founding the Mechatronics Academy. The purpose of the Mechatronics Academy is to ensure the continuity of the mechatronics-related courses that arose within Philips, and to update and expand the entire training portfolio in cooperation with top experts from industry and academia in order to permanently provide quality training services to the high-tech landscape.

For the open trainings an exclusive collaboration with The High Tech Institute has been established. This step also fits in the growth scenario of The High Tech Institute, which focusses on marketing, communications and back-office, while cooperating with a growing number of leading content partners for the different domains.

The three Mechatronics Academy initiators, from left to right: Adrian Rankers, Jan van Eijk and Maarten Steinbuch.

The Mechatronics portfolio currently consists of sixteen trainings, arranged in a consistent training framework. In line with needs from the high-tech community, three new trainings have been developed and were successfully launched in 2013. These are "Thermal Effects in Mechatronics", "Actuation & Power Electronics", and very recently "Metrology & Calibration of Mechatronic Systems". For next year, the new training "Advanced Mechatronic System Design" has been scheduled. All trainings of the Mechatronics Academy are part of the CPE framework of DSPE (www.dspe.nl/certification).

WWW.MECHATRONICS-ACADEMY.NL

DUTCH SOCIETY FOR PRECISION ENGINEERING

DSPE
YOUR PRECISION PORTAL

DSPE Conference 2014
Conference on Precision Mechatronics



Conference Hotel De Ruwenberg, Sint Michielsgestel
2-3 september 2014

CALL FOR ABSTRACTS

Conference by & for technologists, designers and architects in precision mechatronics. This conference is targeted at companies and professionals that are member of:

- Dutch Society for Precision Engineering
- Brainport Industries
- Mechatronics contact groups MCG and MSKE
- Selected companies/academia

Revolution vs. Evolution
This year's theme is 'Revolution vs. Evolution', because progress is always a mix of evolution (optimization) and revolution (disruptive technologies). Therefore it is crucial to learn from each others evolutionary steps, but also to discuss the revolutionary steps in requirements, material science, manufacturing science, computer intelligence, design approaches, ... we are facing today and tomorrow.

Be part of the inspiring community
"Informal, inspiring, enjoyable, relaxed, pleasant, open atmosphere, reunion, amazing community, a warm bath of exchanging interesting technical knowledge and networking, fun, good mix of people from different companies" were some of the remarks of the successful 2012 edition.

Important dates

February 1, 2014	**Deadline for short abstract submission**
April 1, 2014	Notification of acceptance & provisional program ready
May 15, 2014	Deadline Early Registration Bonus
July 1, 2014	Deadline for submission final papers / extended abstracts
Sept 2-3, 2012	Second DSPE conference on precision mechatronics

Conferencepartner

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Presentations
Discussions and networking
Sharing ideas and experiences
Posters and demonstrations
Meeting peers in precision mechatronics

Invitation
December 3, 4

Visit our stand 253 at the Precisiebeurs (near the coffee corner and the lectures halls), Koningshof Veldhoven

www.dspe-conference.nl

DSPE CONFERENCE 2014: CALL FOR ABSTRACTS

On 2 & 3 September 2014, the second DSPE Conference on precision mechatronics will be held.

The first conference, in 2012, an initiative of DSPE, Brainport Industries and the mechatronics contact groups MCG/MSKE, was a huge success, with about 150 delegates and nearly sixty presentations, posters and demonstrations. The 2014 conference will be held in Conference Centre De Ruwenberg in Sint-Michielsgestel. The target is 250 attendees. Next year's theme is 'Revolution vs. Evolution', because progress is always a mix of evolution (optimisation) and revolution (disruptive technologies). See the call for abstracts on the left page.

Areas of interest include (but are not limited to) picometer stability, disruptive technologies & approaches, additive manufacturing, topology optimisation, new materials, design principles, sensors, actuators, metrology, imaging technology, thermal design, vacuum & contamination, motion control, dynamics & acoustics, reliability, energy efficiency, machine specs vs. user needs, new business, value creation, and open innovation.

WWW.DSPE-CONFERENCE.NL

Thermo-mechanics in the spotlight

On 3 December 2013, DSPE will present the Special Interest Group (SIG) Thermo-Mechanics and the special website developed by the SIG. The presentation will be in Room 19 at the Koningshof in Veldhoven, the Netherlands, where the Precision Fair 2013 will be held. The happening starts at 12.05 h and will last half an hour. An overview of the SIG's ambitions and programme and a tour of the Thermo-Mechanics website will be presented. Afterwards, SIG members can be contacted in the DSPE stand on the Precision Fair.

Training

TOLERANCE ANALYSIS

Teaching Objectives

- ✓ The ability to solve tolerance-related problems structurally
- ✓ The ability to make complex tolerance studies understandable for others
- ✓ The ability to set up a design process where the tolerance aspects are concerned
- ✓ The ability to assess a design from the point of view of tolerance management

Format

The workshop is of an interactive nature. Short theoretical lessons alternate with exercises and case studies (sometimes from the participants' own professional practice). Individual experiences, questions and practical examples submitted by the participants will receive ample attention in this course.

Course Programme Tolerance Analysis

- ✓ Introduction, fundamental concepts and tolerance model
- ✓ Tolerance table
- ✓ Exceptional situations
- ✓ Tolerance diagram
- ✓ Risk analysis, theory
- ✓ Risk analysis, continued: practical machine construction
- ✓ The generation of alternatives
- ✓ Budgeting
- ✓ Balancing the costs within a tolerance chain

Target Group

All employees wishing to get a better understanding of tolerance effects and to communicate about them, like designers, constructors, product or production managers as well as purchasers.

Entry Level

Higher Professional Education (HBO).

Duration

Three full-day sessions (9.00 till 16.30).

Training

GEOMETRIC DIMENSIONING AND TOLERANCING

Teaching Objectives

- ✓ The ability to apply tolerances in shape and position functionally when formulating product specifications and making design drawings
- ✓ The ability to interpret tolerances in shape and position correctly

Interpretations and Applications

- ✓ Inaccuracy of shape in products
- ✓ Elements and symbols to represent tolerances in shape and position
- ✓ The shape of the tolerance field
- ✓ References and reference systems for tolerances in shape and position and their indications
- ✓ Fundamental tolerance principles: the envelopment and the independence principle
- ✓ The significance of tolerances of shape and position

Deviations in Shape

straightness • roundness • flatness • cilindricity • profile accuracy of lines • profile accuracy of surfaces

Deviations in Orientation

parallelism • parallelism of broken surfaces • squareness • accuracy of angles

Deviations in Position

position accuracy • coaxiality and concentricity • symmetry

Run-out

circular run-out • total run-out • maximum material principle • minimum material principle • projected tolerance zone

Target Group

Constructors and technical draughtsmen, work planners and skilled workers, metrological employees.

Entry Level

Secondary Professional with work experience, Higher Professional.

Duration

Three full-day sessions (9.00 till 16.30).

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UPCOMING **EVENTS**

27-28 November 2013, Karlsruhe (DE)

Micro/nano manufacturing workshop

Micro/nano manufacturing is recognised as a key element in bridging the gap between the nano and macro worlds. Relevant industrial sectors include automotive, medical, sensors and actuators, etc. Euspen brings together leading expertise from around the globe to an open forum for focused presentations and discussions on micro/nano manufacturing.

WWW.MICRONANOWORKSHOP2013.EUSPEN.EU

3-4 December 2013, Veldhoven (NL)

Precision Fair 2013

Thirteenth edition of the Benelux premier trade fair and conference on precision engineering. Some 275 specialised companies and knowledge institutions will be exhibiting in a wide array of fields, including optics, photonics, calibration, linear technology, materials, measuring equipment, micro-assembly, micro-connection, motion control, surface treatment, packaging, piezo technology, precision tools, precision processing, sensor technology, software and vision systems. The conference features over 50 lectures on measurement, micro-processing, motion control and engineering. The Precision Fair is organised by Mikrocentrum. See also the News pages.

WWW.PRECISIEBEURS.NL

6 December 2013, Eindhoven (NL)

Innovation & Technology Conference

The impact and results of the work of the Centres of Excellence of the 3TU Federation (the three Dutch universities of technology) will be presented to partners in industry, government and academia. Central themes are High Tech & Health and Energy & Mobility.

WWW.3TU.NL

11-12 December 2013, Ede (NL)

Netherlands MicroNanoConference '13

Conference on academic and industrial collaboration in research and application of microsystems and nanotechnology. This is the ninth edition of the conference.

WWW.MICRONANOCONFERENCE.NL

26-27 February 2014, Veldhoven (NL)

RapidPro 2014

The annual event for the total additive manufacturing, rapid prototyping and rapid tooling chain.

WWW.RAPIDPRO.NL

11-14 March 2014, Utrecht (NL)

ESEF 2014

The largest and most important exhibition in the Benelux area in the field of supply, subcontracting and engineering.

WWW.ESEF.NL

19-20 March 2014, Zürich (CH)

Special Interest Group Meeting: Thermal Issues

Thermal effects are major contributor to errors on machine tools, on measuring equipment and on workpieces. Euspen's SIG meeting addresses thermal issues regarding machine tools, micro-manufacturing, and semicon equipment.

WWW.EUSPEN.EU

7-8 May 2014, Den Bosch (NL)

High-Tech Systems 2014

The second edition of this event focuses on the high-tech systems industry in all European areas with significant high-tech roadmaps. It entails advanced system engineering and architecture, precision engineering, mechatronics, high-tech components system design as well as advanced original equipment manufacturing (OEM). See also the article on pp. 34.

HIGH-TECH SYSTEMS

WWW.HIGHTECHSYSTEMS.EU

22-23 May 2014, Aachen (DE)

28th Aachen Machine Tool Colloquium

The Aachen Machine Tool Colloquium (Aachener Werkzeugmaschinen-Kolloquium, AWK) has established itself as an important platform for exchanging future perspectives for production technology. The general topic of AWK 2013 is 'Industry 4.0 – The Aachen Approach', focusing on the potential as well as risks of implementing a cross-linked, intelligent production and demonstrating the technical realisation by means of case studies.

WWW.AWK-AACHEN.DE

2-6 June 2014, Dubrovnik (Croatia)

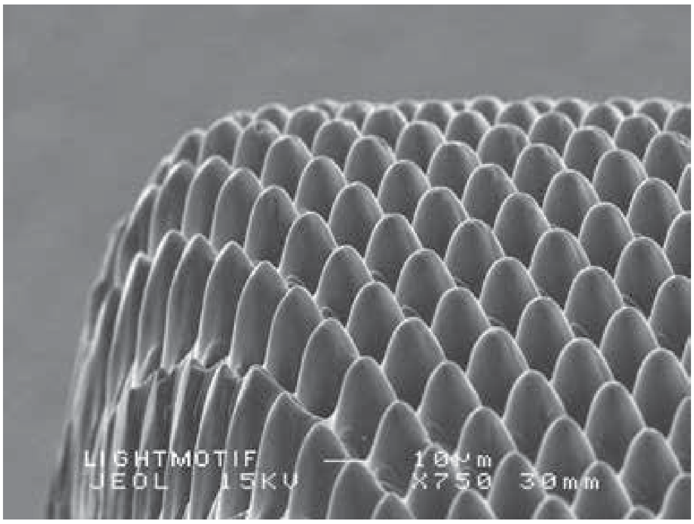
Euspen's 14th International Conference & Exhibition 2014

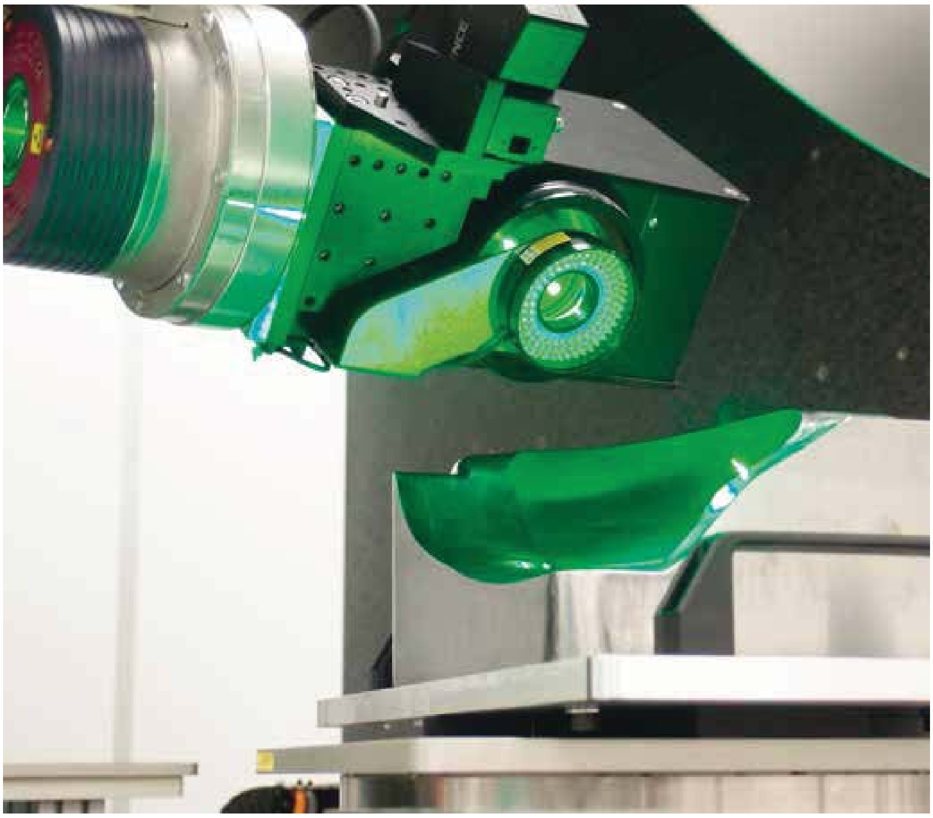
- Renewable Energy Technologies
- Precision Engineering for Medical Products
- Additive Manufacturing for Precision Engineering
- Nano & Micro Metrology
- Ultra Precision Machines
- Ultra Precision Manufacturing & Assembly Processes
- Important/Novel Advances in Precision Engineering & Nano Technologies
- Motion Control in Precision Systems, Nano & Micro Manufacturing

WWW.EUSPEN.EU

Lightmotif sells first production machine

Earlier this year, Lightmotif sold and installed its first production machine to a Dutch customer. Starting in 2008 as a spin-off from the University of Twente and the M2i institute, Lightmotif develops solutions for micromachining using ultrashort-pulse lasers. This innovative technology offers new possibilities for precise micromachining in various industrial sectors such as high-tech systems or consumer electronics. Machining methods such as drilling, milling, cutting and structuring can be applied to every material with micrometer precision. This technology can also be used for surface texturing to create functional surfaces.





5-axis machine developed by Lightmotif for surface texturing. Here, an injection mold is textured so that it can be used to produce plastic products with functional surface structures. The upper photo shows the SEM image of a micro-textured steel surface; textures like these can reduce skin friction or change adhesion properties, amongst other things.

The recently installed machine was purchased by a Dutch high-tech company that is using it to replace an existing micromachining method. Lightmotif was able to prove that the new technology is more accurate, more reliable and easier to automate. The customer is now able to make better products at a lower cost. The machine developed by Lightmotif is highly integrated and uses several sensor systems to measure and automatically compensate for process deviations. This results in a production tool that is both easy to operate and incredibly accurate.

Lightmotif started developing its own processes, machines and control software in 2008, resulting in a combination of expertise that can help clients move from feasibility studies into production. In 2014, Lightmotif will launch a standardised micromachining system for ultrashort-pulse laser processing. This flexible 3-axis system will be equipped with control software specifically designed for laser micromachining, offering flexibility to users. The system will make it possible to specify large and complex jobs, while defining a simple experiment will be quick and easy. The high level of integration ensures that processes are reliable, while automatic calibrations of several machine characteristics will ensure accurate and reproducible results.

WWW.LIGHTMOTIF.NL

Frencken Europe takes over engineering firm All MEPP

Frencken Europe, the high-tech supplier and manufacturer of high-quality components and systems, is taking over engineering firm All MEPP. All MEPP, which stands for All Mechatronical Engineering Projects & Prototyping, develops and builds machines, appliances, tooling and test equipment for manufacturing companies, OEMs, laboratories and research institutes. The projects range from assembly tools and specialised machines to high-tech production lines delivered on site. All three All MEPP shareholders and the full staff complement will be going to Frencken Europe. For the time being, activities will continue at the current All MEPP site in Eindhoven, the Netherlands. The company will be renamed Frencken Allmepp Projects.

This takeover means that, in addition to product development, Frencken will now be able to offer its clients one-off projects and to build specials and production tools. It will also acquire the intellectual property of a number of systems developed by All MEPP for the medical market, such as a machine which fits catheters with a protective coating.

Henk Tappel, Managing Director of Frencken Europe, sees another advantage: "As part of this acquisition, a number of experienced senior mechanical designers will be joining our team, a resource that is in scarce supply in this region. The knowledge and experience that the All MEPP staff bring are a welcome addition to our activities. I particularly appreciate their extensive expertise in developing production tools and manufacturing very small series. Their knowledge of the medical market is also very interesting to us."

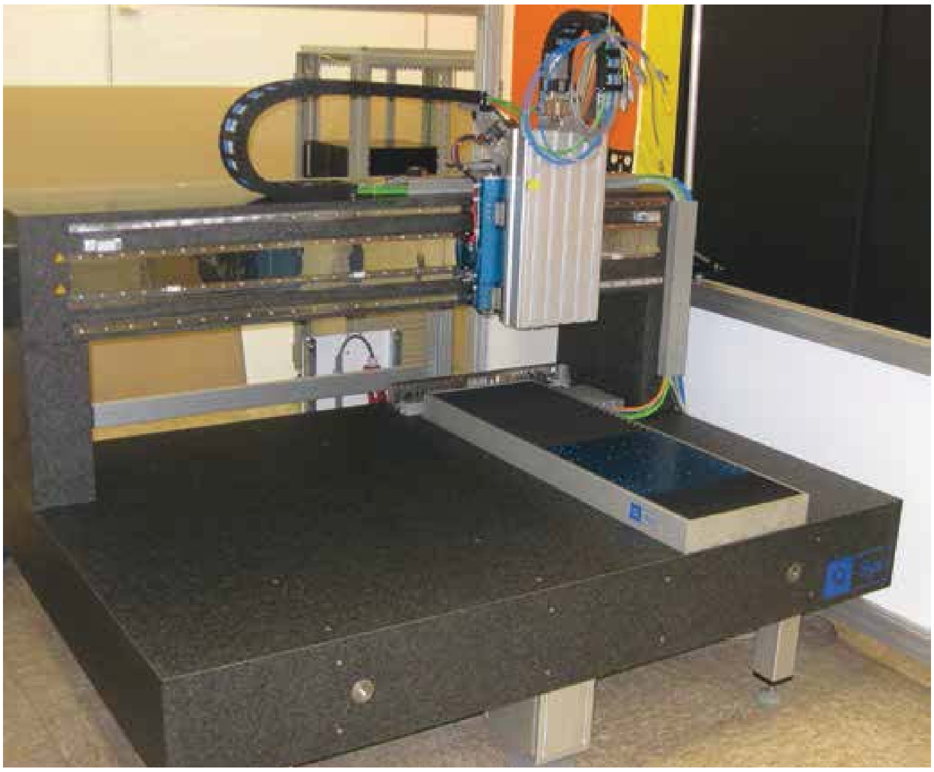
As a supplier to international OEMs, Frencken Europe has already been operating in the field of medical, semiconductor and analytical systems for 65 years. In addition to the manufacture, assembly and testing of complex and advanced components, modules or even complete products based on fine mechanics, electronics and software, the company is also involved in product development. This allows clients in Europe, Asia and the US to accelerate their innovation, simplify their processes and concentrate solely on their core business. Frencken Europe is responsible for all business development, marketing, sales, development and engineering activities in the global Frencken Group, which has production sites in China, Malaysia, the Netherlands, Singapore and the United States.

WWW.FRENCKEN.NL

3-axis platform for laser machining

Q-Sys has delivered a 3-axis motion platform for integration into a laser machining system. The finished system will be used to explore various laser processes including solar cell production. Designed to meet the customer's specific requirements, the system has travels of 600 mm on the base, 1,300 mm along the bridge and 200 mm in the vertical direction. The base plate design also incorporates the facility to add reel-to-reel hardware at a later stage. The axes have positioning repeatability of better than 1 micron and absolute accuracies of 3.5 microns. Flatness and straightness of X and Y are 5 and 6 microns, respectively.

WWW.Q-SYS.EU



European Robotics Week 2013

This year, the European Robotics Week will be held from 25 November to 1 December. The European Robotics Week offers one week of various robotics-related activities across Europe for the general public, highlighting the growing importance of robotics in a wide variety of application areas. The Week aims at inspiring technology education in students of all ages to pursue careers in STEM-related fields, i.e. science, technology, engineering and math.

There is a lot going on in Europe during the European Robotics Week: school visits with lectures on robotics, guided tours for pupils, open labs, exhibitions, challenges, robots in action on public squares, etc. The participating companies, universities and research centres come up with interesting programmes to bring their robots and organisations to the attention of the public educating them on how robotics impacts society, both now and in the future.

Events are organised locally (by scientists, labs, teachers, schools, robotics engineers, robot makers etc.), but centrally listed and co-promoted. The euRobotics aisbl (a Brussels-based international non-profit association for all stakeholders in European robotics) is acting as the central coordinator. They are supported through national coordinators who are promoting the idea among their national networks and communities. The national coordinator of the Netherlands is RoboNED.

WWW.ROBOTICS-WEEK.EU

WWW.ROBONED.NL

Fast installation makes robotics affordable for small companies

The European Union funded project Factory-in-a-Day (part of the Seventh Framework Programme 'Factory of the Future') aims at developing a robotic system that can be set up and made operational in 24 hours and is flexible, leasable and cheap. The international project consortium comprises sixteen partners and is coordinated by Delft University of Technology. The project started last month with a formal kick-off meeting in Delft.

Currently, setting up a robotic system for complex tasks such as packing and quality checking of fruit, the polishing of steel moulds or the filling of a spray-painting machine, can take months and the costs involved are prohibitive. SMEs usually only have small production batches due to seasonal on-off production, which means these large investments rarely pay off. State-of-the-art systems do not provide the flexibility they need to stay competitive in a global market. For these reasons SMEs in Europe hardly use advanced robot technology.

The Factory-in-a-Day-project will provide a solution to these problems: a robot that can be set up and made operational in 24 hours. SME companies can use the robot for a specific job and their staff can learn how to work closely together with the robot and thus optimise their production. "With the technological and organisational innovations of the Factory-in-a-Day project, we hope to fundamentally change the ways in which robots are used in the manufacturing world", says project coordinator Martijn Wisse, Associate Professor in Delft.

First, before a robot is actually taken to the SME premises, a system integrator analyses which steps in the process can be taken over by the robot. In most cases the repetitive work is done by the robot while the human worker carries out the more flexible, accurate tasks and deals with problem-solving. Customer-specific hardware components are 3D-printed and installed on the grippers of the robot. The robot is then brought to the factory and set up, and any auxiliary components such as cameras are also set up in the unaltered production facilities. The robot will be connected to the machinery software through a brand-independent software system.

After that, the robot is taught how to perform his set of tasks, for example how to grasp an object. This requires the operator to physically interact with the robot. A set of predefined skills will be available, rather like apps for smart phones. Finally, the robot is operational and the human co-workers receive their training – all in just 24 hours. As the robot will be operating without safety fences, which is not the rule in most industrial applications, a number of safety-related precautions will be developed.

WWW.ROBOTICS.TUDELFT.NL

New hardturning machine for large and heavy workpieces

At the EMO 2013 fair in Hannover (Germany) this September, hardturning specialist Hembrug Machine Tools introduced their new Mikroturn® 500XL hardturning machine. The two-axis ultra-precision horizontal lathe is designed for workpieces of up to 500 mm in diameter and 300 kg in weight. With this new machine, Hembrug allows new and existing customers to produce large, heavy components up to 68 HRC on a horizontal Mikroturn turning machine and to achieve micron tolerances without having to invest in a much more costly vertical turning machine.

The Mikroturn 500 XL is equipped with an in-house developed hydrostatic torque motor spindle having 1,200 or 2,000 rpm. Hembrug implements spindles of this range in the vertical machine tool programme because they meet the required stability needed to perform sub-micron finish hardturning operations in large and heavy workpieces.

This new hydrostatic main spindle has an integrated spindle motor that offers both a high torque of 249 Nm as well as a very accurate run out of < 0.2 μm. High-speed linear motors are integrated in the fully hydrostatic X- and Z-slides having a 4 m/s² acceleration and a 30 m/min rapid traverse rate. The slides have a repeatability of ± 0.1 μm.

WWW.HEMBRUG.COM

0.05 μm minimum incremental vertical motion

Aerotech has introduced a new compact vertical translation stage offering 0.05 μm minimum incremental motion. The MPS-SV series lift stages provide high-performance elevation motion in a compact design. These lift stages are engineered for applications ranging from laboratory research to high-reliability production processes and are offered in two sizes. Adapter brackets and mounting compatibility inherent in all MPS stages permit easy assembly of multi-axis configurations using linear, rotary and lift MPS stages.

MPS-SV stages utilise a precision-ground ball screw and preloaded crossed-roller bearings for smooth and accurate geometric performance, high accuracy and repeatability, and 0.05 μm minimum incremental motion. Unlike competitive products that use belts and other high-wear-rate components, all drive-train mechanics are designed with high reliability and service life in mind. Motor options include a DC servomotor with rotary encoder and a stepper motor. A precision-machined wedge design and lateral constraint system result in high stiffness and load capacity, while at the same time providing constraint of lateral motions. The stages are available with vacuum preparation.

WWW.AEROTECH.COM

Dynamic Precision

At the EMO 2013 fair in Hannover (Germany) this September, HEIDENHAIN presented the 'Dynamic Efficiency' and 'Dynamic Precision' concepts. These comprise functions for its TNC machine controls with which milling and turning operations can be made even faster and more exact. 'Dynamic Efficiency' can be used for improving efficiency in heavy machining, to optimise the machining time, and to increase the metal removal rates.

'Dynamic Precision' helps to more effectively exploit the accuracy potential of a TNC-controlled machine tool, enabling high production rates of precisely machined workpieces with better surfaces, increased workpiece accuracy and reduced machining times. The concept features compensation of acceleration-dependent position errors, active damping of drive-train and machine set-up vibrations, and position-/load-/motion-dependent adaptation of control parameters.

WWW.HEIDENHAIN.DE

Linear motors into vacuum

Growing amounts of high-tech applications require vacuum solutions to minimise the risk of unwanted chemical reactions or pollution of the process or surrounding equipment. Motion is one of the main challenges within a vacuum environment and many applications involve linear motors. Tecnotion, based in Almelo, the Netherlands, has grown to become the specialist for vacuum linear motors. Twenty years of experience is used in designing and building vacuum coils and magnets for semiconductor applications such as lithography and inspection machines, with demanding vacuum requirements.

Linear vacuum-rated motors have no moving parts and are frictionless, which make the motors maintenance-free. Additionally, the linear motors can be placed into vacuum as a whole and therefore do not require a feed trough, which saves costs and eliminates the risk of leakage. Tecnotion currently offers three types of vacuum-rated linear motors: ironless linear motors; linear motor transport systems using iron-core or ironless motors; and customized linear actuators.

WWW.TECNOTION.COM

■ *A Technotion ironless vacuum motor.*

■ *All vacuum-rated products are designed, produced, quality-inspected and packed in Tecnocation's cleanroom facilities in the Netherlands.*

ASML and imec launch Advanced Patterning Center

Last month, Veldhoven-based lithography machine manufacturer ASML and research centre imec announced the next major step in their extensive collaboration, with the launch of the Advanced Patterning Center. Together they plan to tackle upcoming scaling challenges due to the chip industry's move towards single-digit nanometer dimensions. The Center will be located at the imec campus in Leuven (Belgium) and is expected to grow to close to 100 engineers over the next couple of years.

To guarantee critical dimension uniformity and overlay control, soon to be measured in fractions of one nanometer, imec and ASML will collaborate to investigate the practical interaction between all the different steps in the chip patterning process. The Advanced Patterning Center will use actual devices to analyse and optimise process steps as well as materials and device architecture choices, while applying integrated metrology.

Imec will bring to the partnership its world leading clean room infrastructure (full 300 mm pilot line with extension to 450 mm) through which it supports a unique partner network of material and equipment suppliers, integrated device manufacturers, foundries and fabless companies. ASML will support the Advanced Patterning Center by making available its most advanced scanners, metrology systems and holistic lithography solutions, and by using the Center's resources to optimise its offerings for the fab environment.

WWW.ASML.COM

WWW.IMEC.BE

Precision Fair 2013: platform for chain collaboration, open innovation, and awards

On Tuesday 3 and Wednesday 4 December, Mikrocentrum organises the 13th edition of the Precision Fair. The free-entry event will be held in the Koningshof in Veldhoven, the Netherlands.

This year, some 275 exhibitors – companies and organisations in the field of high- and ultra-precision engineering, predominantly from the Netherlands, Belgium and Germany – are expected. The event is focused on component and system system suppliers, engineering firms, research institutes and universities in the high-tech systems sector.

The lecture programme features four keynote tracks. The first one is dedicated to CERN, the European Organization for Nuclear Research, and the Instrumentation roadmap of the Dutch economic top sector High Tech Systems and Materials. More Big Science in the second track, including ESS and ESRF, research centres for the world's most powerful neutron source and synchroton radiation, respectively. The second day of the event features several international speakers, for instance in the euspen track (European Society for Precision Engineering and Nanotechnology). Another lecture theme is Additive Manufacturing, and exhibitors will deliver over 40 lectures on topics such as micro-machining, engineering, motion control and metrology.

Under the auspices of DSPE, two award ceremonies will be held. With the Prof. M.P. Koster award, DSPE wants to highlight the importance of designing for the precision industry. M.P. (Rien) Koster has contributed to this discipline as a group leader at Philips CFT (Centre for Industrial Technology), as a professor at the University of Twente, and as the author of the 'bible for mechanical designers', "Construction principles for precision movement and positioning".

The biennial Prof. M.P. Koster Award is for deserving mechanical engineers/designers in the field of mechatronics and precision technology. The award is sponsored by the High Tech Institute.

The Wim van der Hoek Award – also known as the Constructor's Award – was named after the Dutch doyen of construction principles, Wim van der Hoek. It is awarded annually for the best graduation project in the field of construction in mechanical engineering at the three universities of technology, and is sponsored by the 3TU Centre of Competence High Tech Systems.

WWW.PRECISIEBEURS.NL

CPE COURSE CALENDAR

COURSE	CPE points	Provider	Starting date (location, if not Eindhoven)
BASIC			
Mechatronic System Design (parts 1 + 2)	10	HTI	27 January 2014 (part 1) 7 April 2014 (part 2)
Construction Principles	3	MC	1 April 2014 (Utrecht)
System Architecting	5	HTI	17 March 2014
Design Principles Basic	5	HTI	to be planned
Motion Control Tuning	6	HTI	2 April 2014
DEEPENING			
Metrology and Calibration of Mechatronic Systems	2	HTI	to be planned
Actuation and Power Electronics	3	HTI	22 September 2014
Thermal Effects in Mechatronic Systems	2	HTI	10 March 2014
Summer school Opto-Mechatronics	5	DSPE + HTI	16 June 2014
Dynamics and Modelling	3	HTI	25 November 2013
SPECIFIC			
Applied Optics	6.5 6.5	MC HTI	6 March 2014 26 February 2014
Machine Vision for Mechatronic Systems	2	HTI	20 March 2014
Electronics for Non-Electronic Engineers	10	HTI	7 January 2014
Modern Optics for Optical Designers	10	HTI	to be planned
Tribology	4	MC	12 March 2014 (Utrecht) 27 November 2013
Introduction in Ultra High and Ultra Clean Vacuum	4	HTI	to be planned
Experimental Techniques in Mechatronics	3	HTI	15 April 2014
Design for Ultra High and Ultra Clean Vacuum	4	HTI	25 November 2013
Advanced Motion Control	5	HTI	6 October 2014
Iterative Learning Control	2	HTI	12 March 2014
Advanced Mechatronic System Design	6	HTI	5 February 2014

DSPE Certification Program

Precision engineers with a Bachelor's or Master's degree and with 2-10 years of work experience can earn certification points by following selected courses. Once participants have earned a total of 45 points (one point per course day) within a period of five years, they will be certified. The CPE certificate (Certified Precision Engineer) is an industrial standard for professional recognition and acknowledgement of precision engineering-related knowledge and skills. The certificate holder's details will be entered into the international Register of Certified Precision Engineers.

WWW.DSPEREGISTRATION.NL/LIST-OF-CERTIFIED-COURSES

Course providers

- The High Tech Institute (HTI)
  WWW.HIGHTECHINSTITUTE.NL
- Mikrocentrum (MC)
  WWW.MIKROCENTRUM.NL
- Dutch Society for Precision Engineering (DSPE)
  WWW.DSPE.NL

Bearing and Linear Technology

Schaeffler Nederland B.V.

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Development

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

member DSPE

Development and Engineering

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ACE has developed into a leading engineering and consultancy firm with a strong focus on mechanics and mechatronics. Services include conceptualization, development, engineering and prototyping.

member DSPE

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Education

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The LiS is founded in 1901 by the famous scientist prof. Kamerlingh Onnes. Nowadays the LiS is a modern school for vocational training on level 4 MBO-BOL. The school encourages establishing projects in close cooperation with contractors and scientific institutes, allowing for high level "real life" work.

member DSPE

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Laser 2000 Benelux considers it her mission to offer customers the latest photonics technologies available.
Their areas of expertise are:
- Lasers and laser systems for industry and research
- Light metrology instruments for LED and luminaire industry
- Piezo- and stepper motion products for nano- and micro-positioning
- LED illumination and high speed inspection in machine vision applications

Laser Systems

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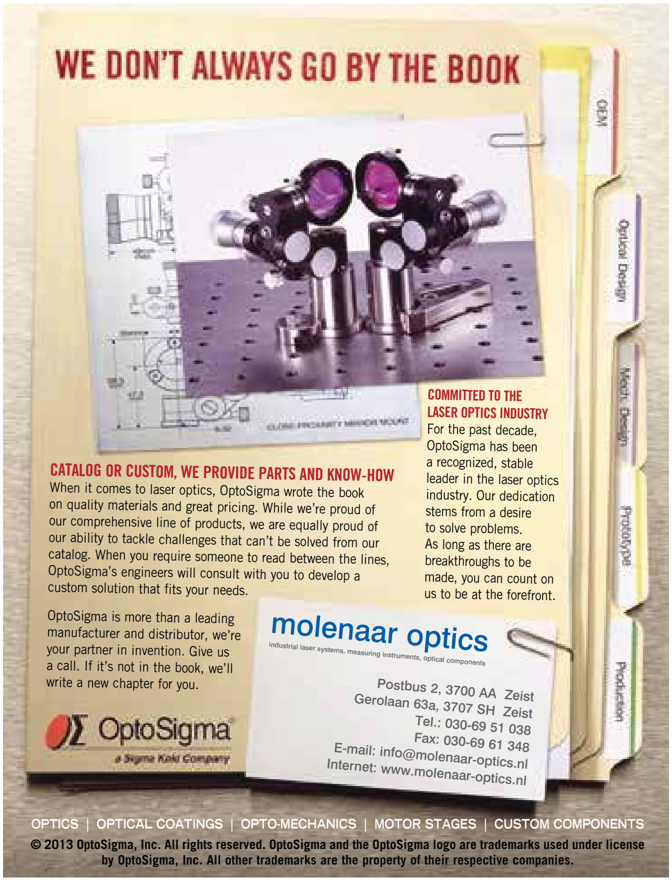

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