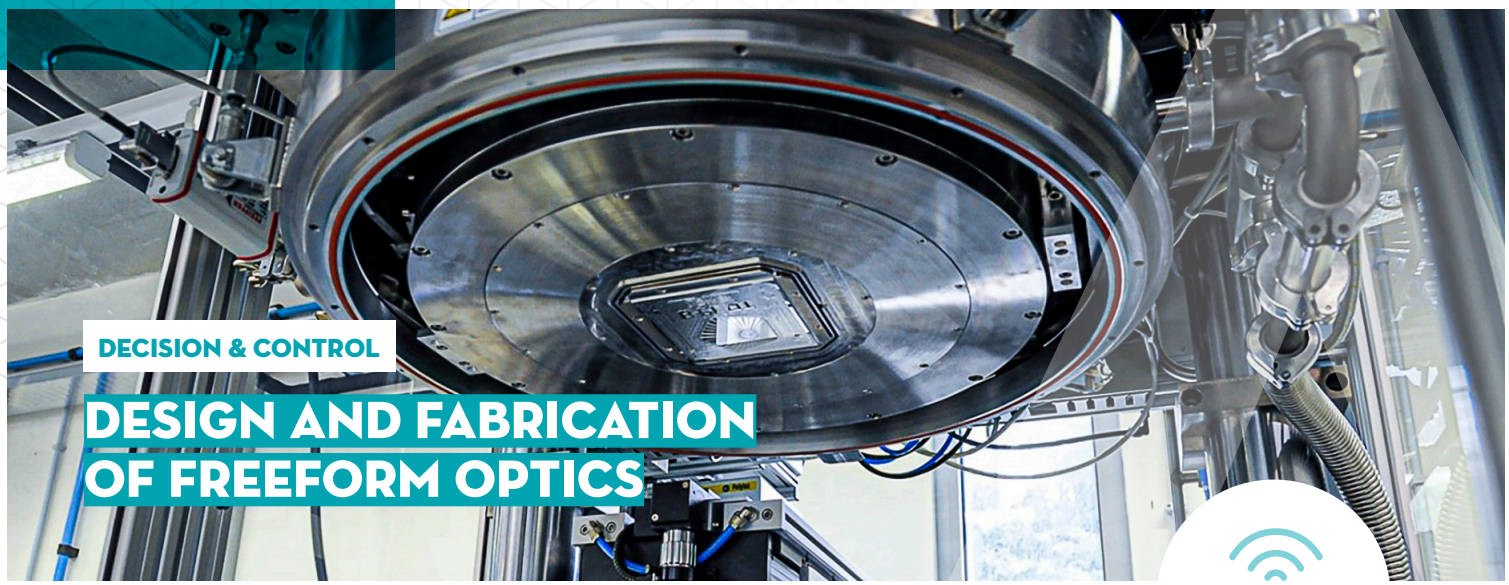


DECISION & CONTROL

DESIGN AND FABRICATION OF FREEFORM OPTICS

Flanders Make offers unique expertise and tools for "first-time-right" freeform optical design. We combine optical design, modelling, prototyping, manufacturing and testing to deliver optimal optical components and systems of random complexity. Leveraging our state-of-the-art machining and metrology equipment, we produce prototypes and replicas in plastic, glass and a selection of specialty optical materials.

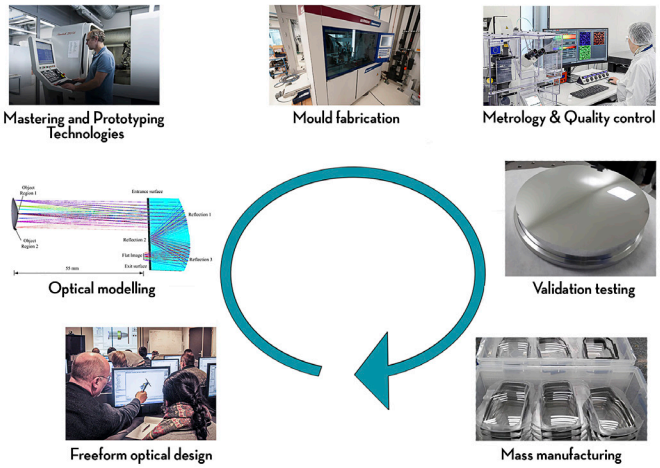
The simplest definition of a freeform optic is an optical component with an optical surface lacking translational or rotational symmetry. Freeform optics have unique advantages for both imaging and non-imaging optical applications as they combine the best optical performance with a small form factor and low weight. We support companies by selecting the best suited, commercially available optics or by designing and fabricating customised freeform optics solutions. With our freeform optics technology platform, we offer:

- freeform optical design;
- modelling;
- prototyping;
- mould fabrication;
- metrology;
- validation testing;
- mass manufacturing.

After choosing or designing the correct optics, we can manufacture batches of diffractive, refractive and hybrid freeform optical components from 10s to 1000s at a pre-commercial level. We offer a wide variety of optical grade materials such as high-end plastics, glass or highly refractive index semiconductors. This allows us to span the entire optical transmission spectrum from UV to Midwave-IR.

In this process, we use various unique software and hardware tools:

- **Design:** state-of-the-art commercial tools (Zemax, ASAP, Code V, Lumerical MODE/FDTD Solutions, OptSim, VirtualLab) combined with proprietary algorithms capable of "first-time-right" freeform optical design.
- **Manufacturing:** freeform optical components in polymers or glass through ultraprecision diamond tooling, ultraprecision grinding and polishing, hot embossing, injection moulding and glass press moulding.
- **Metrology:** state-of-the-art CMM and interferometry in ISO Class 7 cleanrooms.



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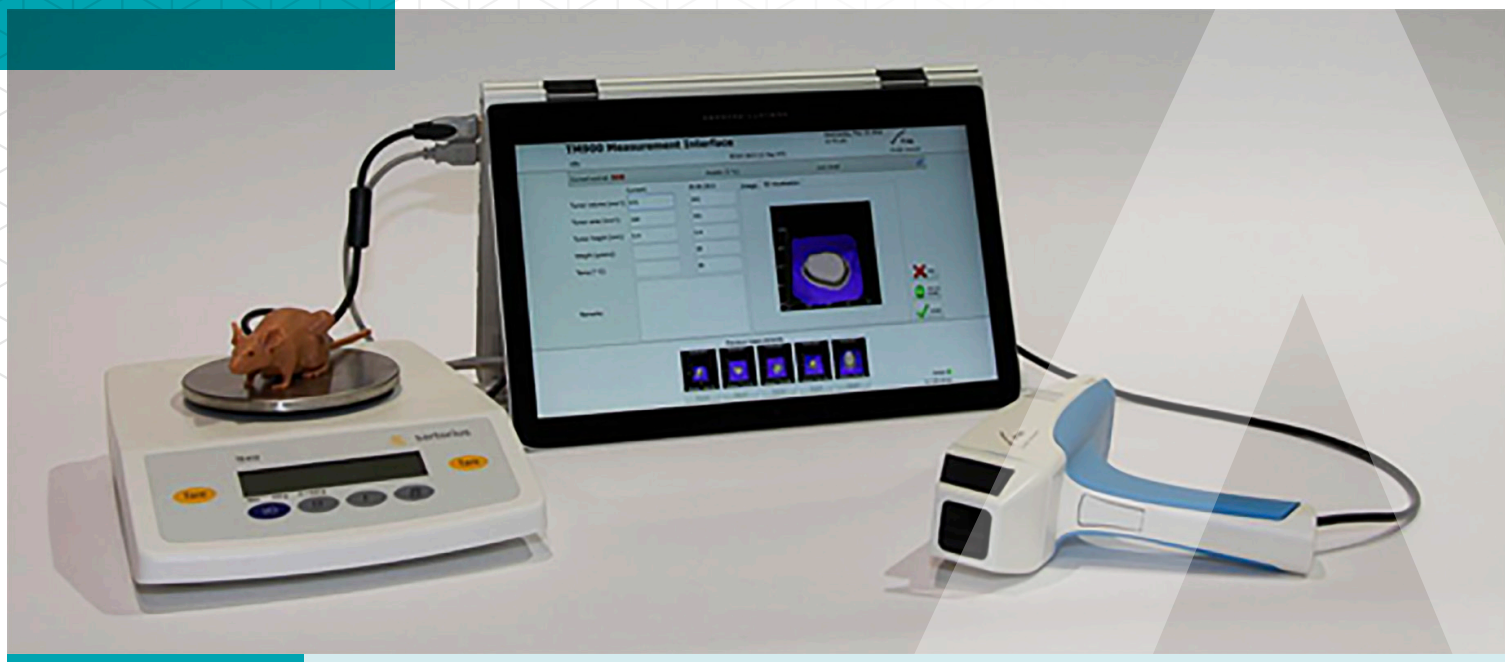


SUCCESS STORY

In a VLAIO Innovation Boosting project with the company Peira, we improved the resolution and imaging quality of a handheld medical diagnostic device, the TM900, which aims at making 3D stereoscopic images of subcutaneously implanted tumours in small rodents.

PROBLEM

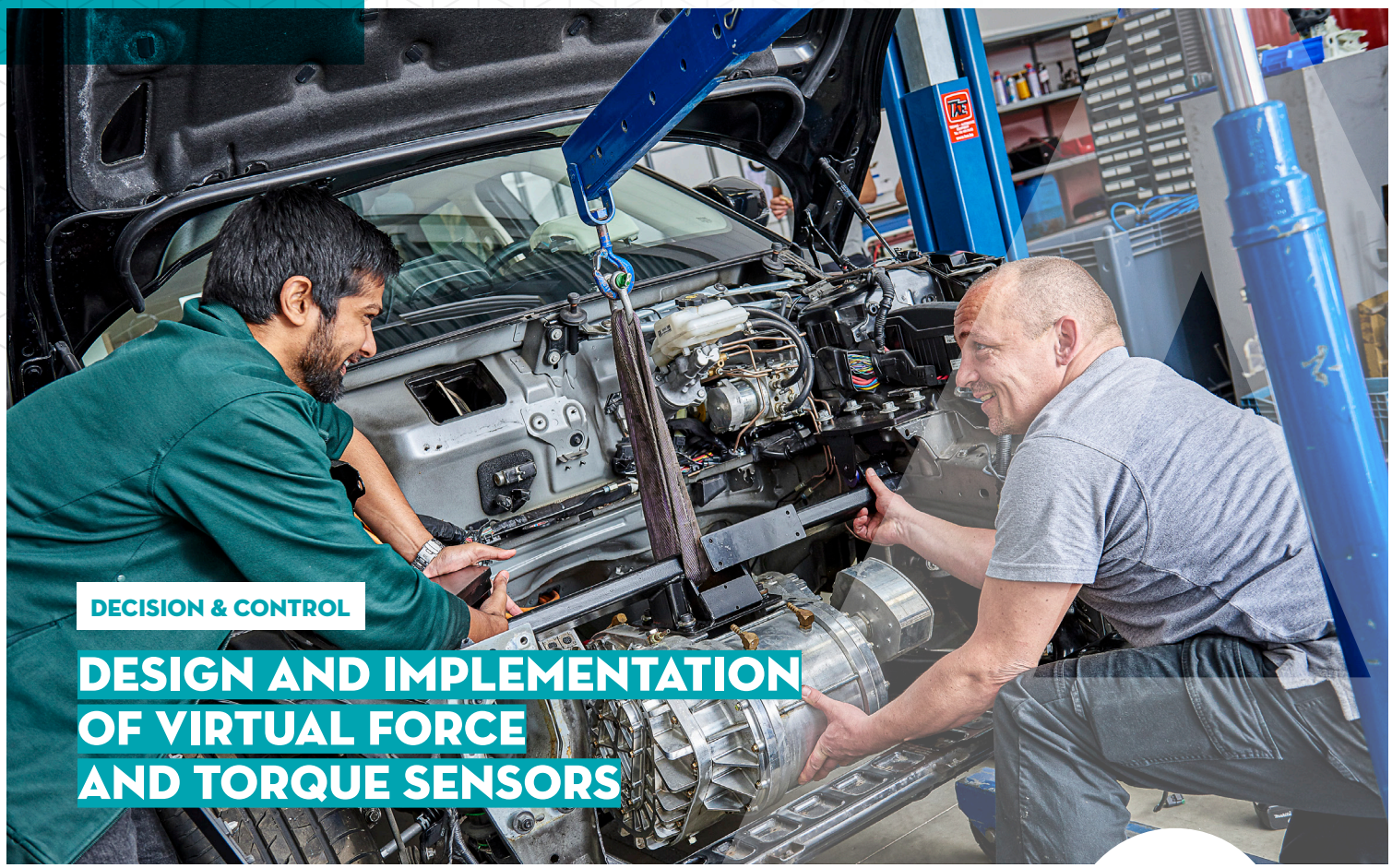
The resolution and image quality of the current instrument was not sufficient.

SOLUTION

Through optical modelling, we proposed a new optical design with lens specifications that allow for improved resolution and image quality. We proposed two solutions, one based on commercial off-the-shelf optics and one based on customised freeform optics.

CUSTOMER VALUE

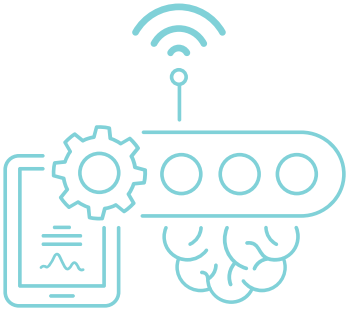
The improved resolution and image quality provides Peira with a unique selling proposition in the sense that the novel device allows to extract the volume of the imaged tumours and, as a result, to track the growth evolution of the tumours in preclinical research on mice.



DECISION & CONTROL

DESIGN AND IMPLEMENTATION OF VIRTUAL FORCE AND TORQUE SENSORS

In the development phase of new machines and vehicles, the drivetrain is often a key subsystem. In order to gain maximum insight in the behaviour of these drivetrains, force and torque measurements are highly valuable. However, direct measuring of force and torque values in modern machines and vehicles is often not possible due to the costs, complexity and intrusiveness of the required sensors. Flanders Make offers a solution involving virtual sensing of force and torque, where cheap and low-intrusive sensors are combined with a model-based approach to indirectly, yet accurately measure these key parameters.



This unique approach leverages the power of our drivetrain knowledge and physical modelling.
We offer:

- affordable solutions for non-intrusive torque measurements in drivetrains;
- methodologies and tools to generically design, calibrate and validate model-based virtual force and torque sensors;
- sensor selection and placement;
- physical modelling of sensed component or system;
- support for online deployment of virtual force and torque sensors in real-time systems;
- design and validation tools for online, real-time virtual force and torque sensors.

We use various unique software and hardware tools in this process:

- We use toolboxes for:
  - model-based force and torque estimation;
  - vehicle dynamics estimation;
  - multi-sensor multifunctional topology optimisation.

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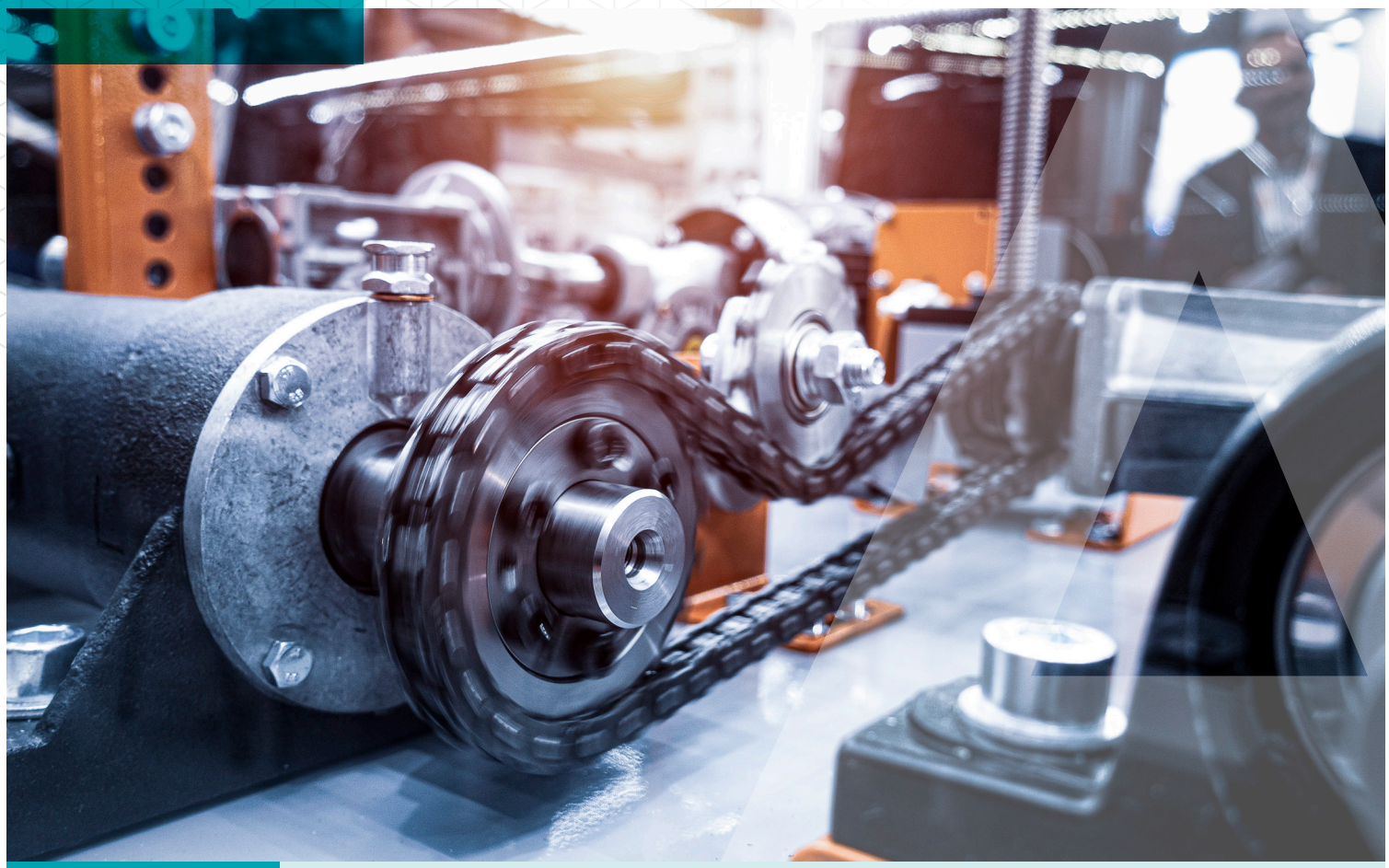


SUCCESS STORY

Torque estimation improvement through periodicity exploitation

PROBLEM

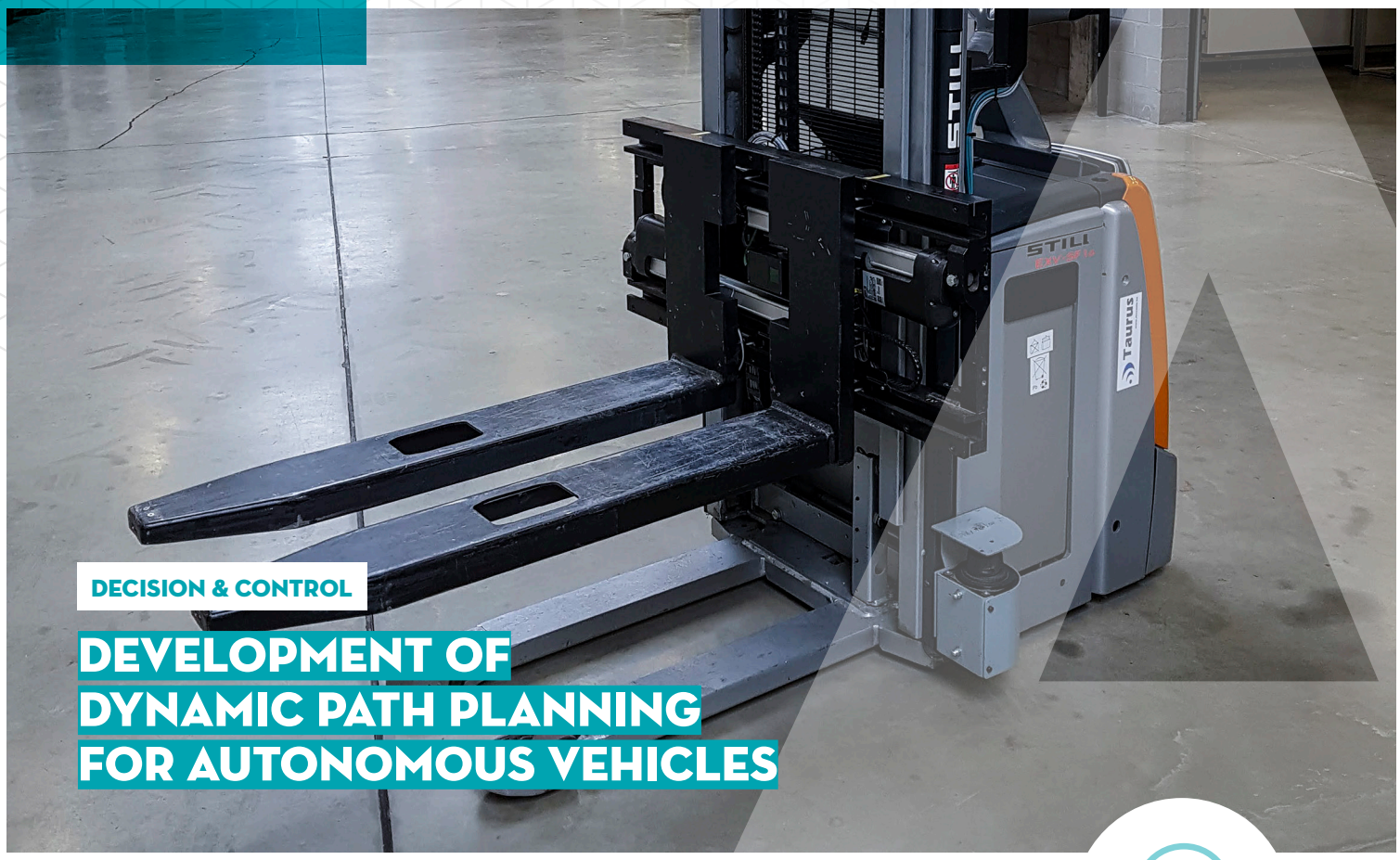
Companies need to know the operational loads (torques) of the drivetrains in machines. However, measuring torques is expensive and intrusive, and often not possible due to geometrical, durability and/or safety constraints.

SOLUTION

Virtual sensing allows to estimate torques using cost-effective sensors, such as encoders, without the need to install torque sensors. Approaches to account for the operating conditions, such as periodicity exploitation, can further improve estimation accuracy up to a factor two.

CUSTOMER VALUE

Accurate torque estimation using low-intrusive, cost-effective sensors



DECISION & CONTROL

DEVELOPMENT OF DYNAMIC PATH PLANNING FOR AUTONOMOUS VEHICLES

Autonomous vehicles are increasingly finding their way to the production floor. Think about AGVs transporting semi-finished products throughout the factory, drones inspecting machinery for preventive maintenance, boats that automatically survey the waterways. Flanders Make provides several tools that enable users to develop environment models, deploy sensor fusion for environment perception and develop dynamic path planning and tracking controllers.

Our toolbox includes:

- global path planning using computational resources for efficient QUAD map representation (see Success Story);
- local path planning that takes the immediate environment and specific vehicle constraints into account;
- LIDAR-based obstacle avoidance;
- autonomous reverse driving whenever the vehicle is obstructed;
- dynamic adaptation of the maximum speed when overtaking obstacles and when recognising pedestrians;
- semi-autonomous vehicle path tracking based on energy-optimal & model-predictive control.

The algorithms can be deployed and validated on real-time embedded controllers.

We use the following unique software in this process:

- Optimal Motion Generation Tools (OMGtools)
- Quad map virtual world toolbox

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SUCCESS STORY

dotOcean deployed the final version of the "Quad map virtual world toolbox" from the SitControl ICON project.

The toolbox can be used to build virtual world models represented as quad maps. A quad map is based on a spatial tree structure with a high resolution in occupied areas and a low resolution in empty areas. These virtual models have a small memory size and can thus be transmitted fast over a cellular network connection with limited bandwidth; they are modular and are easily updatable without having to resend the complete map; furthermore, they can be used together with traditional path planning methods such as A*, allowing to find the fastest route to navigate from A to B with minimal computational resources, starting from a pre-existing occupancy map.

PROBLEM

Autonomous boats need to navigate across harbours and adapt their paths to a dynamic, changing environment (boats, currents, water depth...).

SOLUTION

Quad map-based environment representation that efficiently maps large-scale environments, uses the latest information on radar and ship positions in the harbour and allows for efficient path planning within the available space.

CUSTOMER VALUE

- No need to indicate fixed paths that the autonomous boat must follow.
- Boats are not blocked by fixed obstacles.
- Time-optimal navigation paths increase performance.
- Efficient implementation for constrained computational platforms.

DECISION & CONTROL

DEVELOPMENT OF MODEL-BASED CONTROLLERS FOR INCREASED SYSTEM PERFORMANCE

Flanders Make supports machine builders with tools to efficiently create better performing controllers for their products. Using our experience in combining theory and application insights, we employ model-based technologies. This allows us to leverage our knowledge about the system dynamics to create real-time, optimally performing controllers.

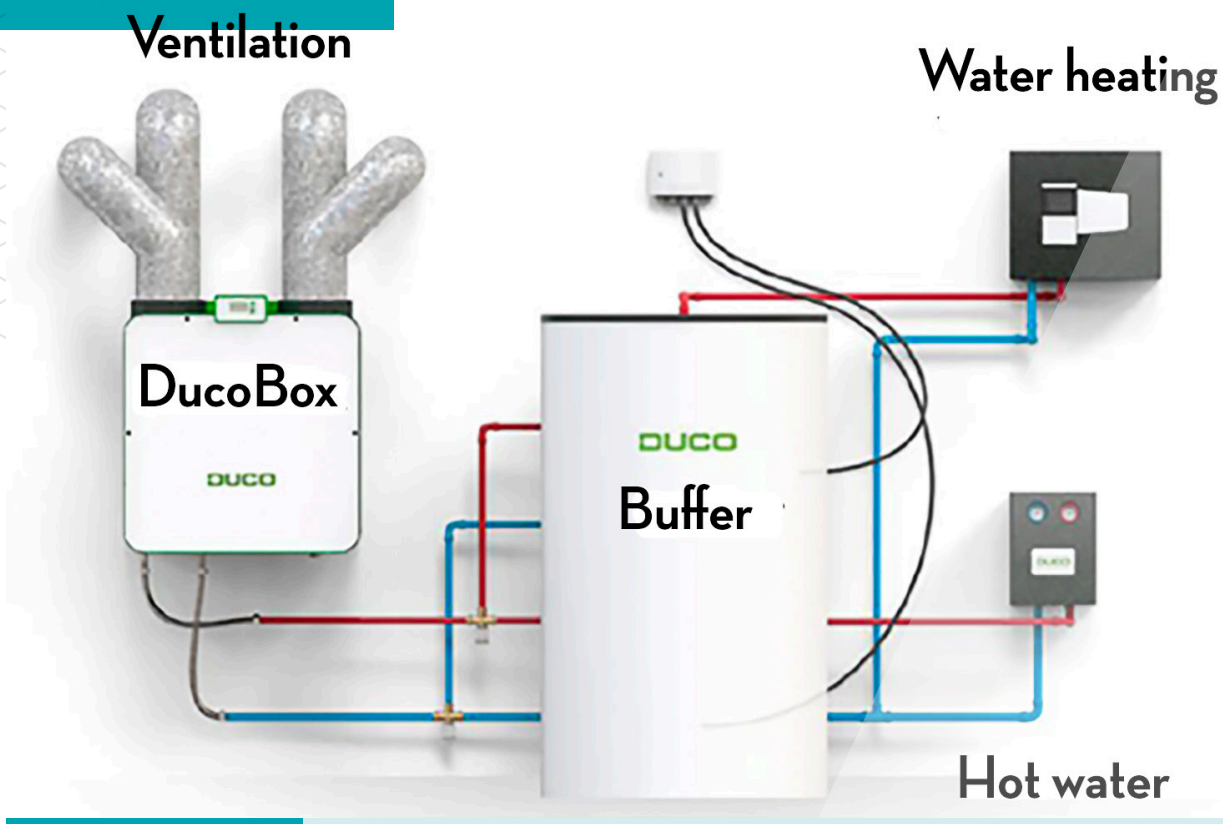
In the quest for lighter, faster, stronger or more energy-efficient products, large-scale optimisation problems arise in different product development stages: e.g. modelling, parameter estimation and optimal control.

Companies that manage to solve these problems efficiently gain an important strategic advantage. We help to accelerate the engineering of a working controller prototype, we give advice to achieve state-of-the-art computational efficiency and assist companies in creating a long-lasting, yet flexible control software solution. Our offer consists of:

- modelling and model identification of drivetrain system dynamics;
- controller type selection;
- model-based controller design and tuning;
- development of a learning or adaptive controller if so required by the application;
- development of an optimal controller;
- accelerated controller testing and validation.

We use various unique software toolboxes in this process:

- Linear control toolbox
- Learning control toolbox
- Context estimation and adaptive control toolbox
- Vibration/noise control toolbox
- Nonlinear optimisation and algorithmic differentiation toolbox
- Optimal drivetrain co-design toolbox
- Optimal cam design toolbox
- Dynamic programming toolbox for optimisation, including discrete variables
- Offline and online optimal path planning for AGV's, drones...
- Controller validation toolbox



SUCCESS STORY

The DUCO energy systems are more efficient thanks to machine learning and advanced control.

PROBLEM

Duco contacted Flanders Make to investigate to what extent their DucoBox Eco could respond better to the comfort wishes of owners and the varying climate conditions in their homes.

SOLUTION

The expertise of Flanders Make was used for the implementation of an advanced control strategy. The new algorithm uses models of the Duco systems, the residents and the house. In this way, we predict the impact of the various control actions on comfort, cost and energy consumption. Expertise in the field of machine learning was also applied to analyse the impact of the residents' energy consumption.

CUSTOMER VALUE

Thanks to this study, Duco can determine how much energy and costs a family can save by installing the DucoBox Eco ventilation heat pump in an All-Electric or Hybrid setup. Corresponding analyses and the new control techniques will also be applied in future Duco systems.

DECISION & CONTROL

IMPLEMENTATION OF MODEL-BASED DATA ANALYTICS

Obtaining actionable insights is difficult for complex manufacturing systems consisting of highly dynamic machinery, integrated robotics and automated processing equipment. Getting a step closer to offering decision support for monitoring, controlling and maintaining these applications requires good models of the physical phenomena that occur. Unfortunately, these models are often incomplete or insufficient. With our model-based data analytics (MODA) approach, we can improve these models by combining physics-based insights with data-driven technology such as machine learning (ML) and artificial intelligence (AI). This unique hybrid approach allows us to create and improve models of physical phenomena, such as energy consumption, product quality and production efficiency.

We help companies to:

- gain a better understanding of the behaviour of their product or production process by implementing model-based data analytics;
- set up a decision support strategy through model-based data analytics;
- adopt our toolchain and integrate it into their software routines.

Data are key to a better understanding of machines and processes, but current data analytics do not inherently incorporate existing expert knowledge of such machines or processes. MODA improves physical, empiric models (white box models) with data-driven information (black box models) of non-modelled components or difficult-to-model physical quantities. The combined information enables new insights into the systems. These insights are subsequently used to update the model in an iterative manner.

We use various unique software and hardware tools in this process:

- Hybrid modelling toolbox
- Deep-hidden physics modelling toolbox
- Lifetime estimation toolset

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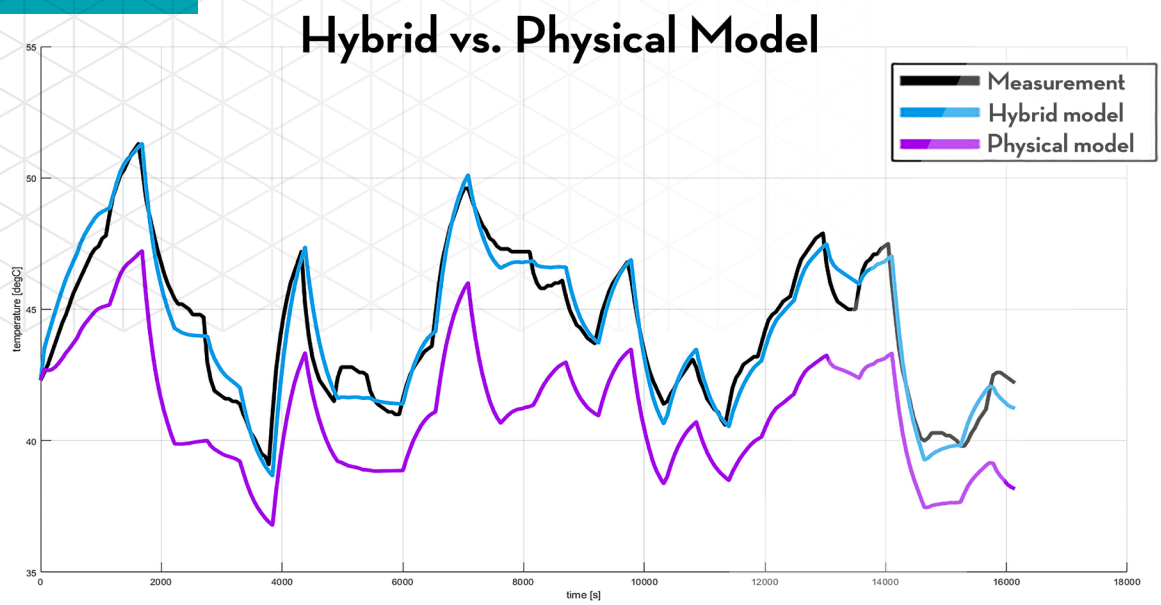


SUCCESS STORY

Improved white box model

PROBLEM

The customer had a product for which it wanted to install a temperature-based condition monitoring system. To accurately predict this temperature (<1°C tolerance), a white box model had been set-up in the past. However, this model was not sufficiently accurate as it did not include the impact of friction.

SOLUTION

The white box model was extended with a state- and input-dependent dynamic friction term, which was captured using AI according to the above-described hybrid modelling principles.

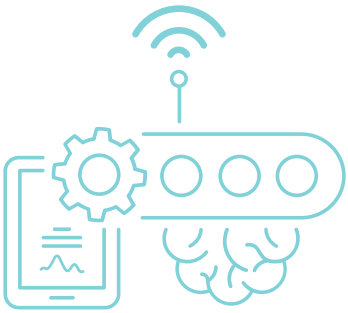
CUSTOMER VALUE

The resulting model had a remaining error of <1°C, making it suitable for condition monitoring; and, equally important, a closed formula for calculating the impact as a function of measurable parameters was extracted to further improve the existing white box model.

DECISION & CONTROL

IMPLEMENTATION OF ROBUST AND RELIABLE LOCALISATION SYSTEMS

Flanders Make creates robust and affordable localisation systems for indoor and outdoor autonomous vehicles based on optimal sensor selection and sensor fusion. For these systems, we achieve high localisation accuracies below 15 cm by selecting the best combination of sensors for your specific environment. Furthermore, we combine, through sensor fusion, our knowledge about vehicle dynamics with sensor models to filter out outliers and improve localisation robustness.



We can help you develop, test and validate the appropriate localisation solution for your specific environment or application. By combining the right sensors, we ensure a cost-effective solution, even for large-scale indoor environments.

To this end, we offer a sensor fusion toolbox for the localisation and mapping of autonomous vehicles, including:

- Simulation environments with:
  - dynamic drone/AGV models.
  - optimisation of UWB sensor placement for single and multi-cell installation.
  - estimation of the localisation accuracy.
- Ultra-Wide Band (UWB) components for 1D-2D-3D localisation:
  - outlier removal for ultra-wide band localisation systems.
  - debugging and analysis tools for ultra-wide band localisation performance.
  - proprietary firmware and PCBs for Decawave UWB hardware.
- Online asynchronous state estimation (OASE) toolbox for easy online implementation of sensor fusion for multi-sensor systems, which automatically deals with measurement delays.

Potential applications include:

- Range estimation devices for monitoring compliance with social distancing rules.
- Industrial AGV localisation system based on sensor fusion of UWB, wheel encoders and vehicle model.
- 3D Drone localisation system for large scale environments based on sensor fusion of UWB, passive visual markers, SLAM, IMU and drone model.

The solution can be extensively tested and validated in our AGV and drone labs.

We use unique software tools in this process:

- OASE: Online Asynchronous State Estimator Toolbox
- UWB auto-calibration methods
- UWB components for 2D (AGV) and 3D (drones) localisation

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SUCCESS STORY

Automated indoor drone navigation

PROBLEM

Due to the lack of an indoor localisation system (no GPS reception), the automated navigation of drones in large-scale indoor environments (e.g. a warehouse) is challenging.

SOLUTION

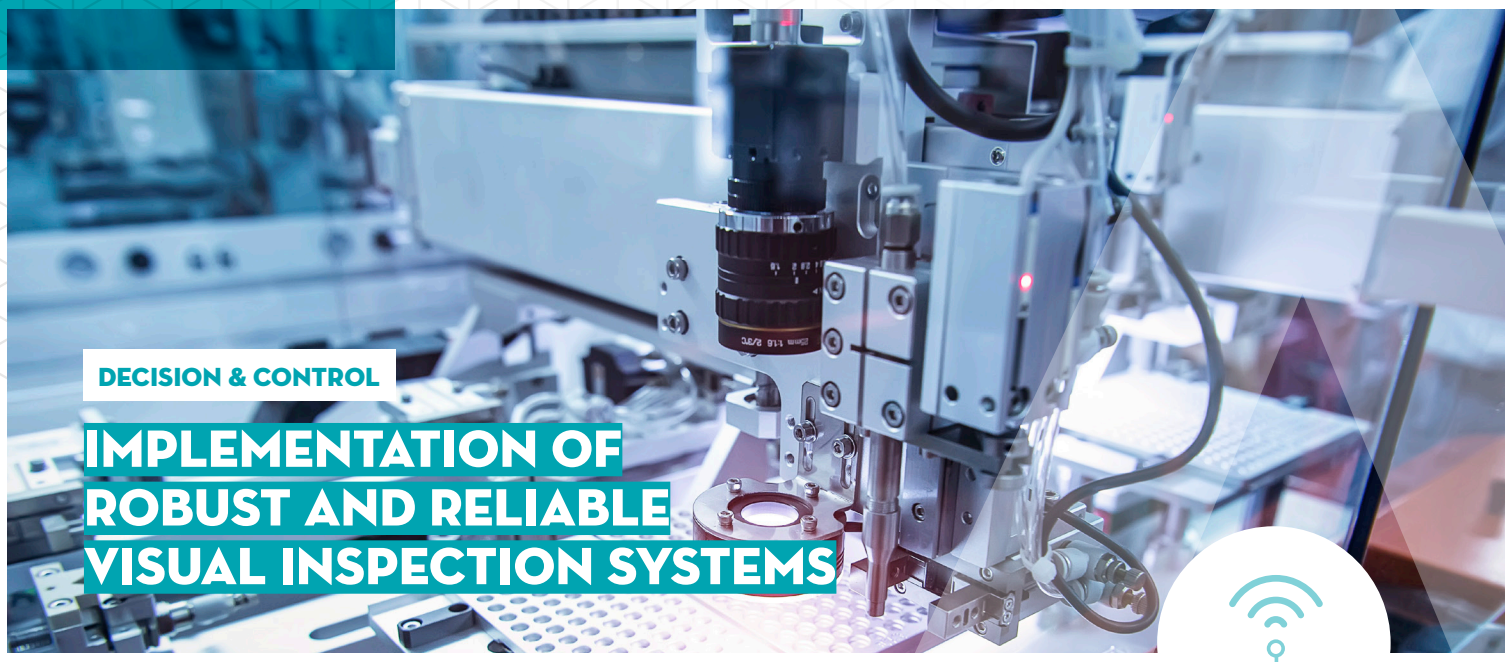
To solve this, we fused UWB (ultra-wide band) sensor measurements, visual marker localisation and visual SLAM with traditional drone sensors (accelerometers, gyroscopes, barometer and lidar for altitude).

CUSTOMER VALUE

By combining the different sensor data we achieved:

- Indoor positioning for indoor drone flights in large-scale environments of over 10,000 m2 with accuracies below 15 cm.
- Robustness in terms of incorrect measurements (e.g. outliers).

By combining multiple technologies and selecting the appropriate combination for different parts of the environment, we were able to optimise the total hardware and installation cost for the customer.



DECISION & CONTROL

IMPLEMENTATION OF ROBUST AND RELIABLE VISUAL INSPECTION SYSTEMS

Flanders Make provides the optimal HW configuration and algorithmic solutions for visual inspection systems in production environments (production line, manufacturing machines, assembly workstation, etc.). We offer robust and easy-to-deploy computer vision algorithms that need little training data.

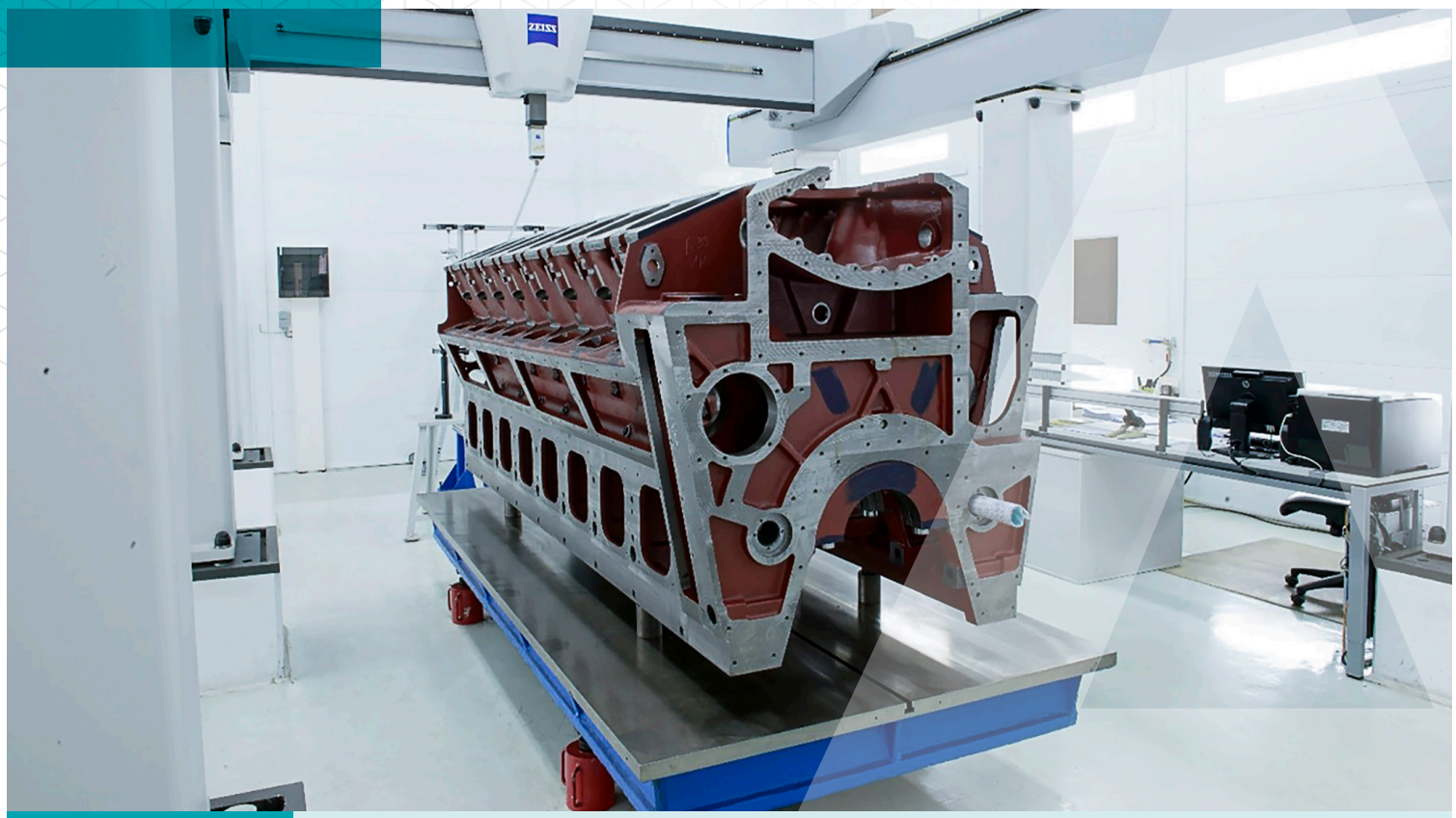
We provide customised solutions for visual inspection in different applications. One of our key areas is the accurate visual detection of anomalies in products with high variability, such as delamination of machined composites, crack detection in 3D printed soles, quality monitoring of medical pills, etc. We provide the optimal HW configuration and algorithmic solutions for visual in-line or end-of-line quality monitoring in production lines. The solutions are based on commercially available 1D, 2D or 3D vision sensors. Our services include:

- In-line quality monitoring in production lines:
  - Estimation and verification of product features (dimensions, profiles, etc.) for stationary and moving objects, even with high motion speeds (up to 100m/s).
  - Accurate visual detection of surface quality anomalies, including low-contrast and tiny defects that are difficult to detect with the naked eye. The solution that we propose only requires a small amount of model images (typically a few good images per anomaly) and leverages on the creation of accurate photorealistic synthetic data. This solution can be implemented in flexible production lines that contain multiple products.
  - Inspection of anomalies within the immediate surroundings of a production system (e.g. mist detection example described below).
- Embedded machine vision for low-cost (starting at ~100€),high-speed monitoring applications (up to 20 kHz).
- 3D scanning for metrology and CAD-based optimisation (e.g. optimal fitting and stitching to highlight precise deviations in geometrical and surface features) using a Flanders Make optimisation framework that allows productivity improvements while ensuring the same accuracy as provided by commercial systems.

We can build vision solutions without proprietary code and offer the full source code of your solution.

We have developed various unique software tools for these applications:

- Low-cost 1D vision system design toolbox
- 1D/2D visual anomaly detection software
- 3D point cloud reconstruction software



SUCCESS STORY

The Anglo Belgian Corporation (ABC) uses a Flanders Make toolbox for automatic mist detection during endurance testing of combustion engines.

PROBLEM

During tests of big diesel engines (typically used in ships and energy plants), leakage may occur in any of the pipes. Due to the complex piping structures and the large surface in which such leak may occur, it is not economically feasible to use classical pressure sensors. A leak, especially when it consists of fuel and/or oil, can lead to dangerous situations.

SOLUTION

We developed the "Robust vision-based anomaly monitoring and detection toolbox". This toolbox works with online visual image streams. It autonomously trains a background model during a calibration period. Afterwards, this model is used for anomaly detection based on a comparison of intelligently grouped pixel deviations. To compensate for variabilities in the ambient and background conditions, an image processing drift compensation is provided for by retraining the model online (auto-calibration). The toolbox is robust against changes within the scene (that are not related to leak anomalies).

CUSTOMER VALUE

The Anglo Belgian Corporation (ABC) uses the toolbox for automatic mist detection during prototype endurance testing of combustion engines at their production plant in Ghent. This vision-based monitoring system runs continuously and sends a warning signal to the safety system of ABC.
By using this solution, ABC can reduce operator effort during testing. Before this technology uptake, an operator had to be present during the tests. Now, the tests can continue with less supervision. The operator only needs a few visits to the test lab and is connected to the safety warning system.

DECISION & CONTROL

MONITORING AND CHARACTERISATION OF WEAR-INDUCED MATERIAL DEGRADATION

Flanders Make detects, characterises and analyses wear patterns on metal surfaces to assess the remaining lifetime of crucial machine components and reduce maintenance.

Tribological phenomena (friction, lubrication and wear) have an important impact on the remaining useful lifetime (RUL) of crucial machine components like bearings, cam rollers or gears. By combining our state-of-the-art test infrastructure with computational tools as well as our expertise, we provide both experimental and computational support extending your maintenance intervals and reducing the corresponding costs.

- **Experimental support:** We test the tribological response of materials (friction, friction stability and wear) in dry or marginally lubricated conditions.
- **Computational support:** Via multi-scale and multi-physics models we perform a numerical analysis, including simulation of fluid- and particle-related tribological issues. Both lubrication modelling (elastic-hydrodynamic lubrication, smart fluids) and erosion/abrasion modelling (cavitation, droplet and solid-particle erosion) are performed, supported by multiple simulation techniques, particle-based methods and numerical optimisation tools.

We use various unique software and hardware tools in this process:

- openFOAM
- STAR-CCM
- Various tools for lubrication and erosion/abrasion modelling, data analysis and interpretation that have been developed in-house.

SUCCESS STORY

Development of a lubricant-free system for the 'Eye of Dubai', the largest Ferris wheel in the world. The expertise of Flanders Make in monitoring and characterising wear patterns in a broad variety of materials was a crucial component in that development.

PROBLEM

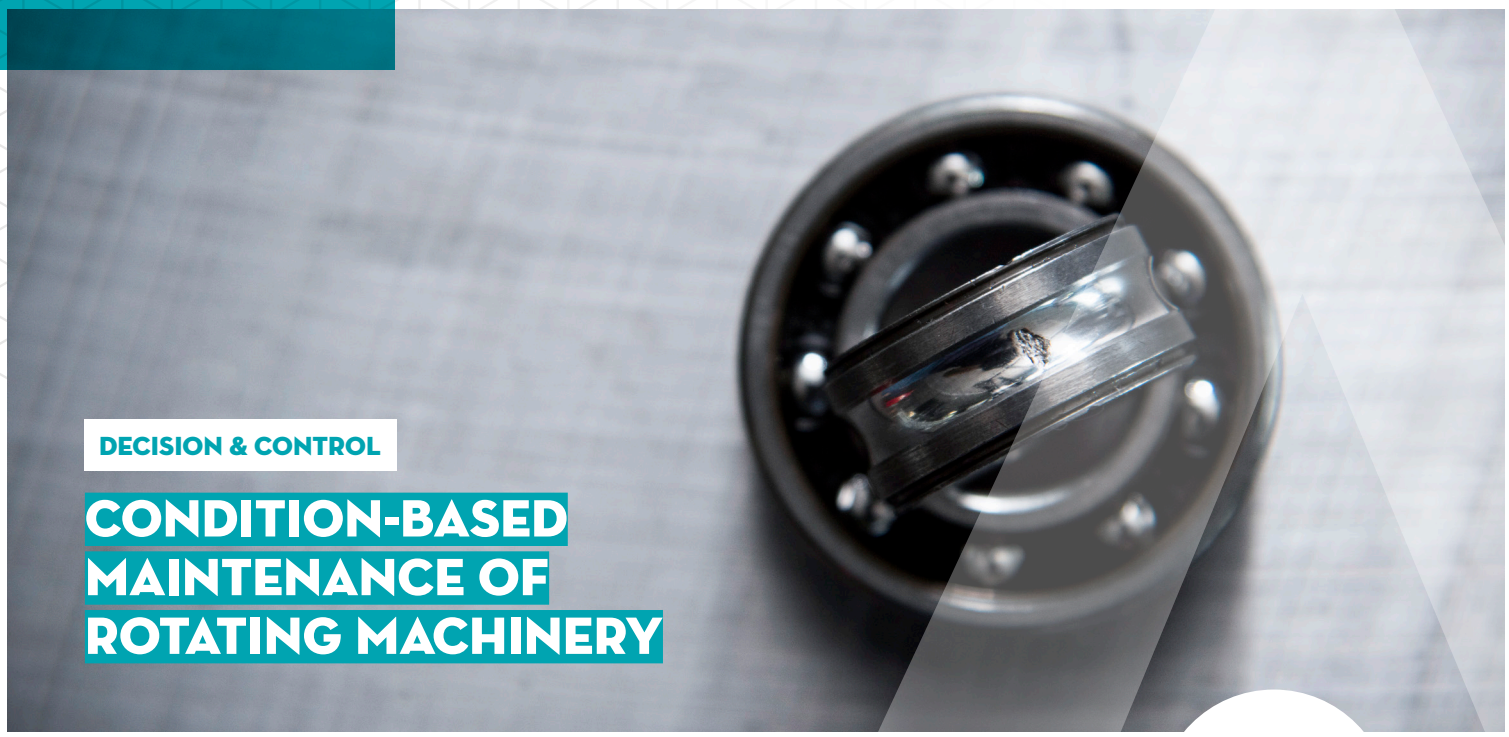
The Eye of Dubai operates in harsh conditions (high temperatures). Moreover, with an axis diameter of 6.25m and weighing 1805 tonnes, a lubricant-free solution was required to ensure smooth operation. Due to the specific requirements, a customised solution had to be developed.

SOLUTION

An international R&D team designed composite bearings based on a polyester matrix, reinforced with polyester fibres and using Teflon powder as lubricant. Flanders Make was responsible for material testing. In particular, large-scale bearing tests and numerical simulations have been performed. Our expertise in wear characterisation and material degradation paid a crucial contribution to the design.

CUSTOMER VALUE

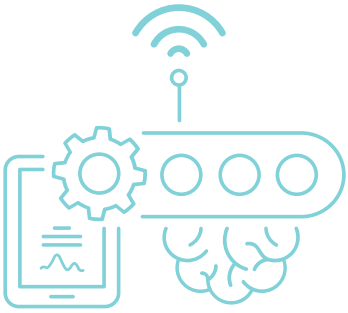
Together with various partners, a customised solution was developed to ensure the smooth operation of the machine to the customer.



DECISION & CONTROL

CONDITION-BASED MAINTENANCE OF ROTATING MACHINERY

When in operation, machines and vehicles produce vibrations. By monitoring the characteristic patterns in these vibrations we know when components, such as bearings or gears, start to show faults, typically as a result of mechanical wear. This knowledge allows us to schedule maintenance well before failure, but only when the system needs it, reducing downtime and optimising the maintenance costs. Flanders Make offers customised monitoring solutions to detect and diagnose faults in machines and vehicles based on sensing technologies for vibrations, acoustics and e-motor currents.



In our Smart Maintenance Lab, we capture the vibration data of vehicles and machines using accelerometers. We connect this information with other available parameters such as temperature, rotational speed, etc. The signals are then processed using smart fault detection and prediction algorithms. Our algorithms can be implemented on embedded hardware to process the data and optionally send the health indicators to a cloud environment for easy monitoring.

If you are looking for a partner to evaluate and demonstrate the feasibility of condition monitoring for your specific machine or vehicle, we can help by installing our portable monitoring system, gather machine data and process them using our algorithms. Secondly, we also offer our proprietary algorithms for robust fault detection and prediction, ready for use with low-cost vibration sensors. Thirdly, our test infrastructure for customised testing of bearings and gears is available for different types of bearing or gear faults. Finally, we can provide well-documented vibration datasets from accelerated life tests on bearings to test, evaluate or benchmark existing condition monitoring solutions.

We use various unique software and hardware tools in this process:

- Robust fault detection and prediction algorithms for faults in bearings, gears, motors, etc.
- A wide range of sensing technologies (e.g. low-cost, MEMS-based accelerometers and microphones, ultrasound sensors, current sensors, etc.).
- Portable condition monitoring system for data acquisition and processing.
- Bearing setups in smart maintenance lab for high-quality datasets.

SUCCESS STORY

Vibration-based condition monitoring of an expander machine

PROBLEM

The current maintenance strategy applied to expander machines is time-based (preventive) maintenance. This manual inspection requires, every week, a lot of manpower. Furthermore, when the machine breaks down, the production comes to a complete standstill.

SOLUTION

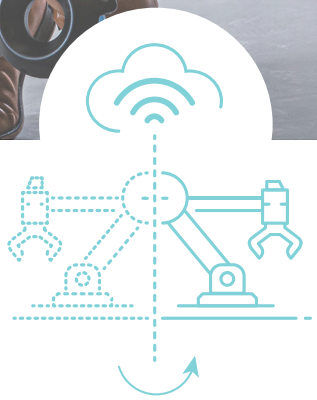
Installing a condition monitoring system using low-cost accelerometers. By adding a software toolbox we can use vibration signals as health indicators to continuously monitor the condition of the expander machine.

CUSTOMER VALUE

- Reduction of manpower:
  - Periodic & manual inspections on expander machines by technicians are no longer required.
- Condition-based instead of time-based maintenance:
  - Maintenance can be planned according to the actual machine condition.
- Minimisation of production loss due to prevention of unexpected machine breakdowns.

DESIGN & OPTIMISATION

COMPUTER-SUPPORTED DESIGN OF ASSEMBLY SYSTEMS



Flanders Make helps you with the design of assembly systems that are customised to your specific needs.

Throughout the years, our researchers have built up expertise on assembly systems in various industry-driven research projects. Now, we use this knowledge to create the right assembly system for your specific needs. We assist your company with:

- selecting the right assembly sequence, taking ease of assembly and assembly feasibility into account in the design phase already;
- cost-efficient allocation of operators and machines;
- optimising the physical location of all cell elements during the assembly process, taking assembly time and ergonomics into account;
- improving the flexibility of your assembly cell in view of new products or different workload allocations;
- capacity studies when product volumes are changing or machines must be replaced.

We use various unique software and hardware tools in this process:

- In-house prototyping tools for assembly cell visualisation
- In-house prototyping tool for optimal layout of hybrid production cell

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SUCCESS STORY

Investment analysis tool for Reynaers Aluminium

PROBLEM

The production environment for windows with a high product mix raises several questions:

- Which machines should we buy?
- How many operators are required?
- Excess/missing capacity?

SOLUTION

We have developed an investment analysis tool:

- to perform an analysis of the current production flow and bottlenecks;
- to compute the (cost-)optimal production capacity.

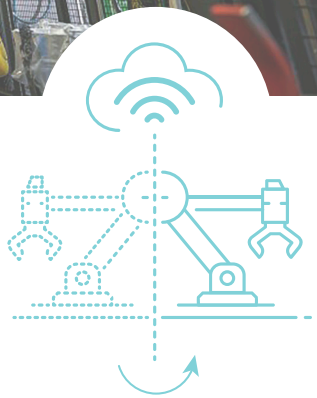
CUSTOMER VALUE

With this tool, the end user gets immediate results regarding the ideal amount of machines and operators.
Our tool allows the customer to:

- support investment decisions taking into account:
  - return on Investment (RoI)
  - lead time
  - production time/shifts
- make prognoses in view of future and timely investments:
  - investments in stages vs single but larger acquisitions.

DESIGN & OPTIMISATION

COMPUTER-SUPPORTED DESIGN OF MECHATRONICS PRODUCTS



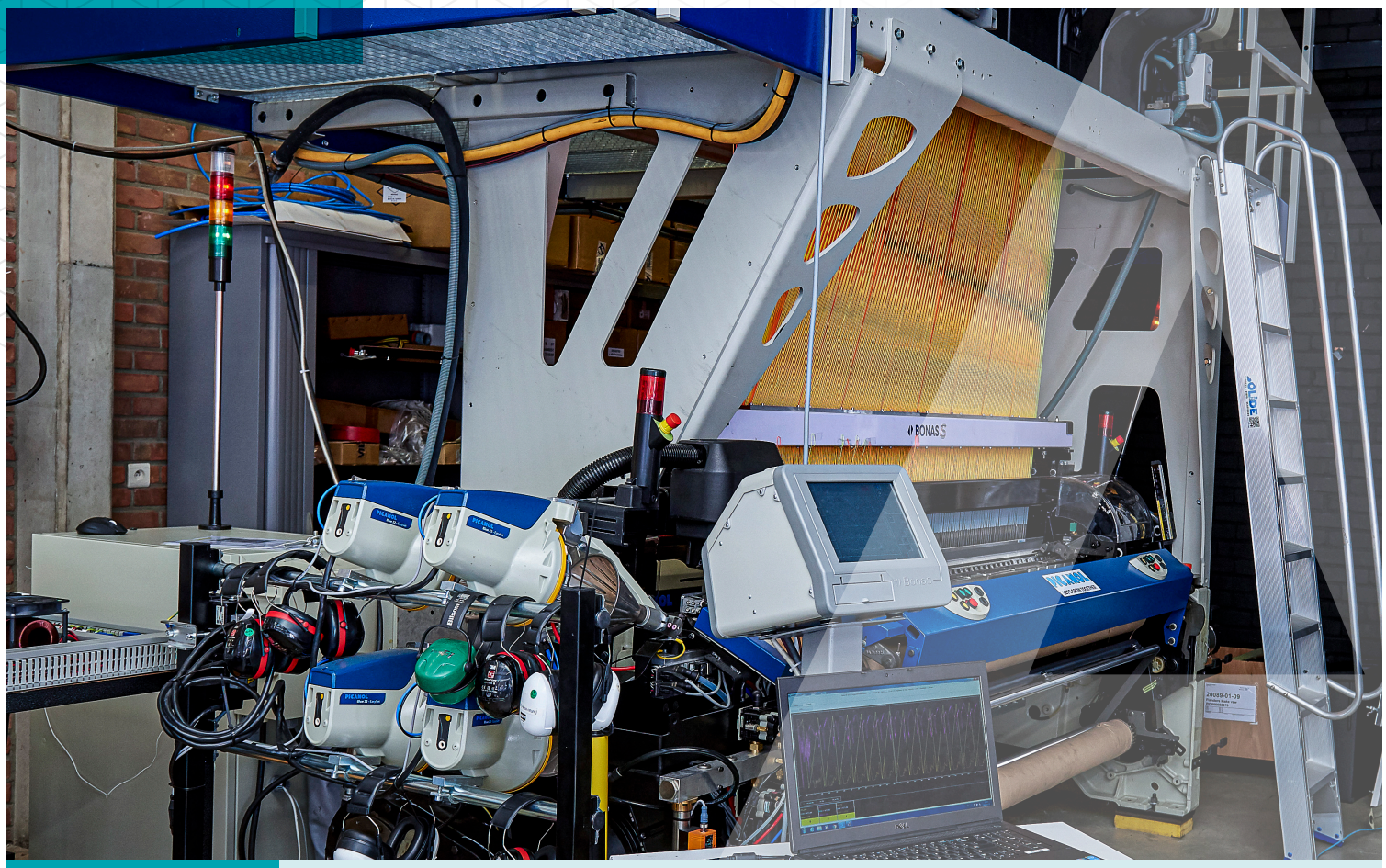
Due to the increased complexity of mechatronic products (more components, functions, technologies, etc.), using models for designing these products has become inevitable. Without supporting tools, designing and analysing product concepts would be difficult and very time-consuming. Flanders Make offers computer-supported design tools that generate various design concepts and adapt and optimise them to meet your specific requirements.

Using our comprehensive expertise in computational design synthesis, we define and set up parameterised dynamic performance models. A key point here is to select the correct model structure in such a way that the necessary design features can be included. In addition, we speed up the conceptual design phase by generating and evaluating design candidates. Through targeted model approaches, we enable the analysis of energy consumption, component loads and NVH performance.

A model-driven design approach benefits both system-level integrators as well as companies designing components. It helps to solve large-scale optimisation problems that arise when designing mechatronic products. The dynamic performance assessment is front-loaded to the pre-prototype stage and companies gain insight in their design 'hotspots'.

We use various unique software tools in this process:

- In-house modelling and simulation tools
- In-house optimisation toolboxes



SUCCESS STORY

In the VLAIO Baekeland project in collaboration with Picanol, we assisted in improving the design of high-speed weaving looms and succeeded in reaching higher operational velocities with a reduced risk of failure.

PROBLEM

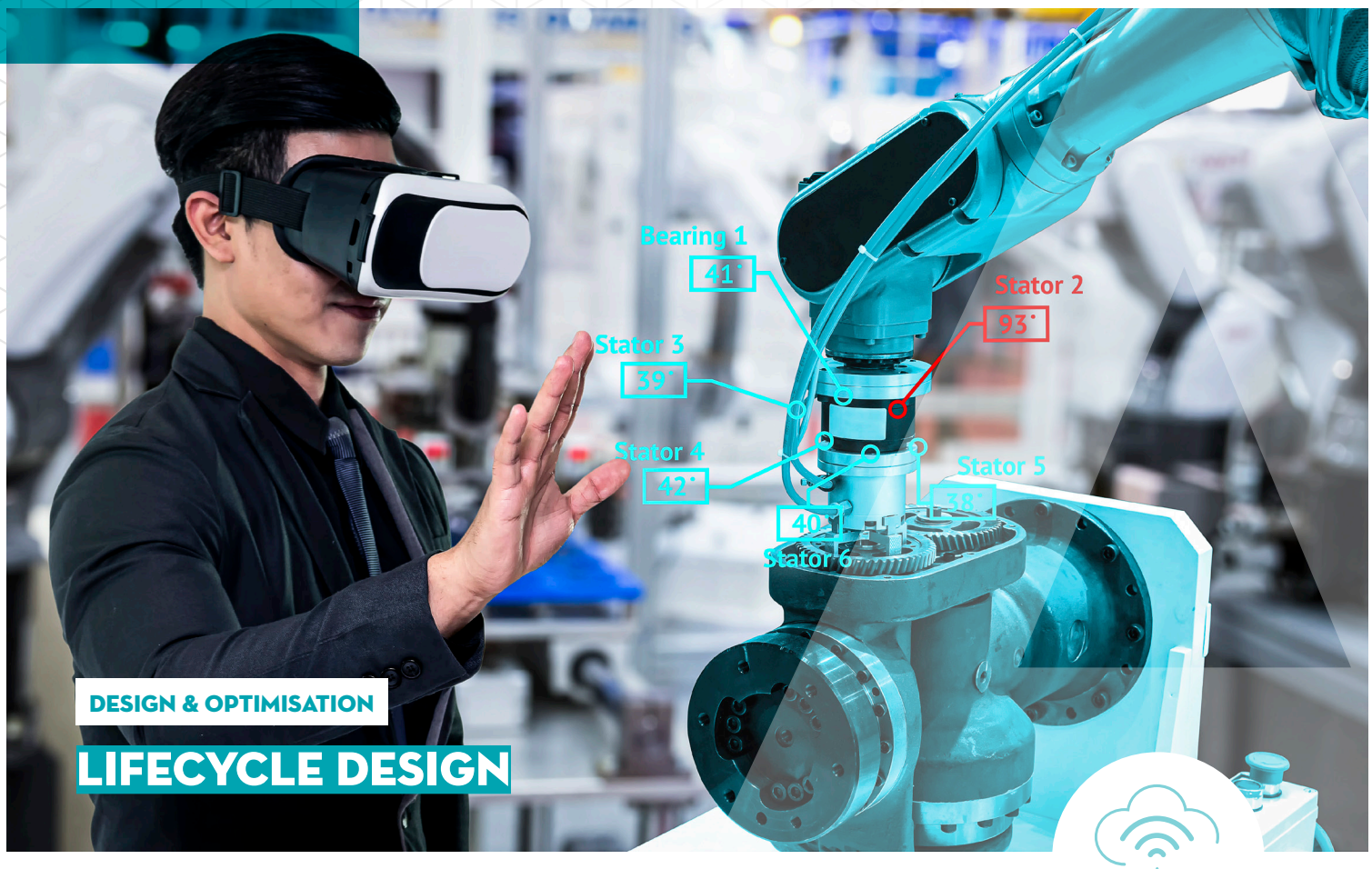
Some structural components were not optimal in terms of their operating conditions within the overall system, therefore limiting the overall performance.

SOLUTION

Through a combination of flexible multi-body simulation and topology optimisation, we were able to improve the design. Using our in-house toolboxes, we were able to set up a state-of-the-art framework enabling structural topology optimisation of a component with an accurate description of its operational loads.

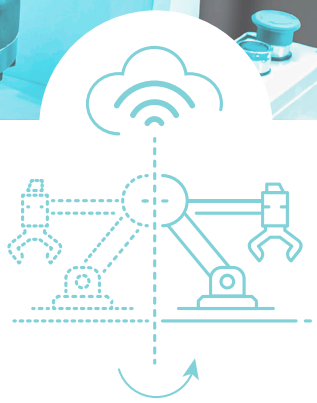
CUSTOMER VALUE

The toolchain that we developed provides Picanol with a unique approach to improve the design of their components in a market where a few grams here and there make all the difference in building the best performing machines in the industry.



DESIGN & OPTIMISATION

LIFECYCLE DESIGN



Flanders Make offers a reduction of design uncertainties by translating data from the manufacturing, validation or operational phase into useful design information. With our unique approach, we capture these hard-to-measure data through data-driven digital twins enriched with physics-inspired models.

To improve future designs of your machines and components, we take the different phases of the product life cycle into account. Knowledge and information of manufacturing rules and consequences, assembly processes and the impact on product performance are objectified and used in the product design.
This allows us to:

- optimise the product design by considering different lifecycle aspects such as manufacturability and assembly;
- optimise production process parameters in terms of performance requirements;
- consider information that is captured in design rules when optimising a design. These insights can come from human experience, simulations or digital twins.

We use various unique software and hardware tools in this process:

- In-house developed research codes in Matlab to model (non-linear) finite elements, (flexible) multi-body systems and gear dynamics.
- In-house developed method for process performance optimisation and design for assembly.

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FLANDERS MAKE

SUCCESS STORY

In a recent collaboration with CNHi, we assisted in the development of an improved design process to ensure an accurate assessment of the durability of mechanical components in high-cycle mechanisms.

PROBLEM

In pre-prototype phases, obtaining realistic load conditions for assessing the durability of mechanical components is quite difficult.

SOLUTION

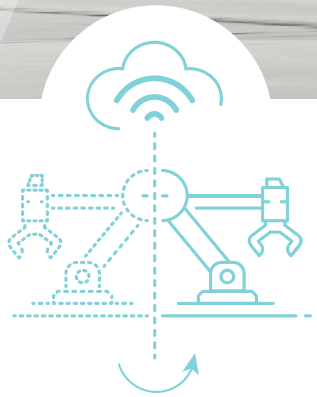
Using a full-system flexible multi-body model as well as advanced technology for efficient deformation and stress extraction, representative component loads for new designs can be obtained efficiently. Starting from concept developments using our in-house toolboxes, we assisted in setting up a process that uses commercial software that can be integrated in the day-to-day engineering practice.

CUSTOMER VALUE

The approaches and toolchains we developed enable CNHi to effectively assess component durability in a pre-prototyping stage and to optimise the design of novel components for improved durability. By using a model-based framework, late design-stage iterations can be avoided and development cost and time can be reduced.

DESIGN & OPTIMISATION

FUNCTIONAL SAFETY ANALYSIS



Functional safety aims to avoid risks, damage or physical injuries when working with a piece of equipment. By implementing various (functional) safety measures, we protect the (end) user when handling the product. Flanders Make offers expertise in understanding the impact of safety standards on the product design and support in developing safety-critical systems.

Companies must often submit safety evidence as part of a certification process, for instance in the automotive, agricultural or machinery industry. We help you to understand and implement functional safety measures. More specifically, we provide:

- maturity assessment of functional safety processes;
- training:
  - standard-based general functional safety approach
  - technical safety analysis (HARA, FMEA, FTA, RBD)
- product design guidance:
  - risk analysis
  - specification of functional safety requirements
  - specification of architectural functional safety solutions
- evaluation:
  - ISO2626 HW metrics evaluation
  - quantitative FTA & FMEA
  - estimation of reliability failure over time

We use various unique software tools in this process:

- **FLAME:** in-house process tool to guide the engineer in the design of safety-critical products
- **Enterprise architect:** functional safety system engineering modelling
- **Dedicated HARA tool:** cross-domain hazard analysis and risk assessment

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FLANDERS MAKE

BLUWAYS JABIL inalfa roof systems Melexis INSPIRED ENGINEERING

SUCCESS STORY

Flanders Make Functional Safety Academy

PROBLEM

Customers request evidence of the safety integrity of their products:

- Do their functional safety processes comply with the current state of the art?
- Is the product demonstrating functionally safe behaviour?

SOLUTION

Flanders Make created the Flanders Make Functional Safety Academy (Flanders Make-FSA), with the following objectives:

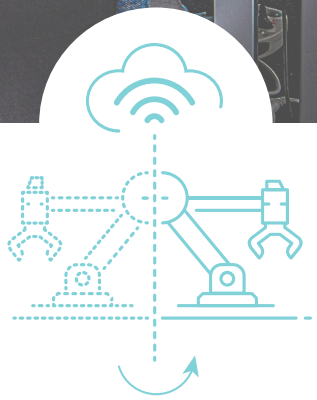
- Supporting the industry with FuSa engineering
- Developing methods and approaches to comply with FuSa
- Grouping experts in view of sharing knowhow

CUSTOMER VALUE

- Fast introduction into domain-related FuSa processes & implementation into product development processes
- Design of functional safety mechanism:
  - Specification of FuSa mechanisms for electric powertrain, BMS, fault-tolerant lateral controller, autonomous control system within automotive industry and agriculture, etc.
- Technical Safety Analysis:
  - Hazard Analysis and Risk Assessment
  - FMEA and FTA to assess the safety integrity level
  - Reliable Failure Analysis

DESIGN & OPTIMISATION

MECHANICAL DESIGN AND STRUCTURAL OPTIMISATION FOR MECHATRONIC SYSTEMS



Flanders Make assists companies in taking design decisions in the conceptual phase of a mechatronic product design process. This results in a better initial design within a shorter period of time, fewer design iterations and shorter development times.

We provide workflows to perform structural topology optimisation of components in modern machinery, accounting for their interaction with other components and their dynamic performance. The results of these approaches serve as an effective starting point for the final human design iterations, including verification of the structural integrity of components and systems as well as the optimisation of mechanical structures:

- optimisation of weight, NVH, strength, stiffness and cost;
- evaluation and comparison of design concepts;
- decision support in connection with material and geometrical parameter choices.

We use various unique software and hardware tools in this process:

- Simulation and concept evaluation tools: from lumped parameter to 3D distributed parameter analysis and co-simulation
- Robust pattern search optimisers
- Structural topology and parametrical optimisation tools
- Materials database (Granta CES Selector)

SUCCESS STORY

Design optimisation of Thule bike carriers

PROBLEM

Thule, manufacturer of bike carriers, was confronted with consumers changing from normal bikes to electrical bikes, which are considerably heavier. Therefore, they aimed to strengthen their aluminium bike carriers using steel reinforcements.

SOLUTION

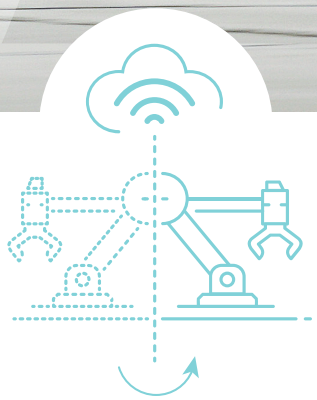
Flanders Make optimised their design in such a way that it could remain all-aluminium to ensure the same mechanical performance in terms of strength and stiffness.

CUSTOMER VALUE

The assembly procedure was simplified, the weight and cost decreased by 3% and the risk of corrosion was eliminated.

DESIGN & OPTIMISATION

NOISE REDUCTION THROUGH LIGHTWEIGHT VIBRO-ACOUSTIC METAMATERIALS



Flanders Make has developed a patented metamaterials* technology combining excellent noise and vibration behaviour with a low weight and compact volume. With this technology, we assist companies in achieving excellent NVH-performance.

We assist companies that are in search of quieter products by:

- analysing the current noise and vibration status;
- evaluating the potential of a metamaterials solution, based on the relevant transmission paths and the frequency spectra of the NVH-signals;
- designing and validating a prototype of the identified solution.

Our patented metamaterials technology offers a solution not only to OEMs in the machinery, equipment, transportation or construction industry, but also to companies specialised in retrofitting machinery – for example ductwork for AC.

**A metamaterial (from the Greek word meta, meaning "beyond" and the Latin word materia, meaning "matter" or "material") is any material engineered to have a property that is not found in naturally occurring materials. They are made from assemblies of multiple elements fashioned from composite materials such as metals and plastics. The materials are usually arranged in repeating patterns, at scales that are smaller than the wavelengths of the phenomena they influence.*

We use various unique software and hardware tools in this process:

- A wide range of sensors and exciters to perform vibro-acoustic evaluations
- In-house developed software tool to optimise the design/geometry of the resonators so as to create the stopband at the aimed at frequency

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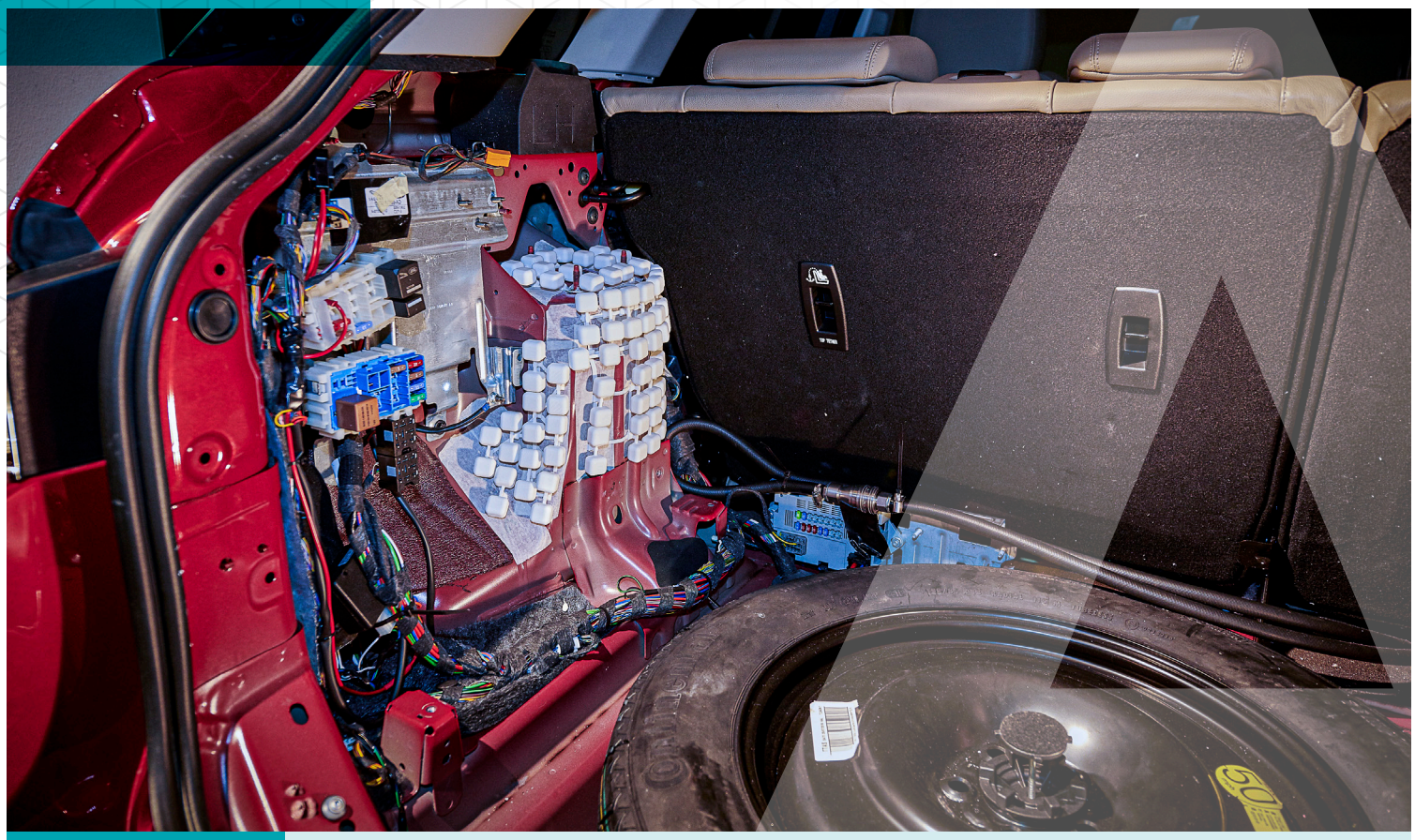


SUCCESS STORY

Lightweight vibro-acoustic insulation in a Range Rover Evoque

PROBLEM

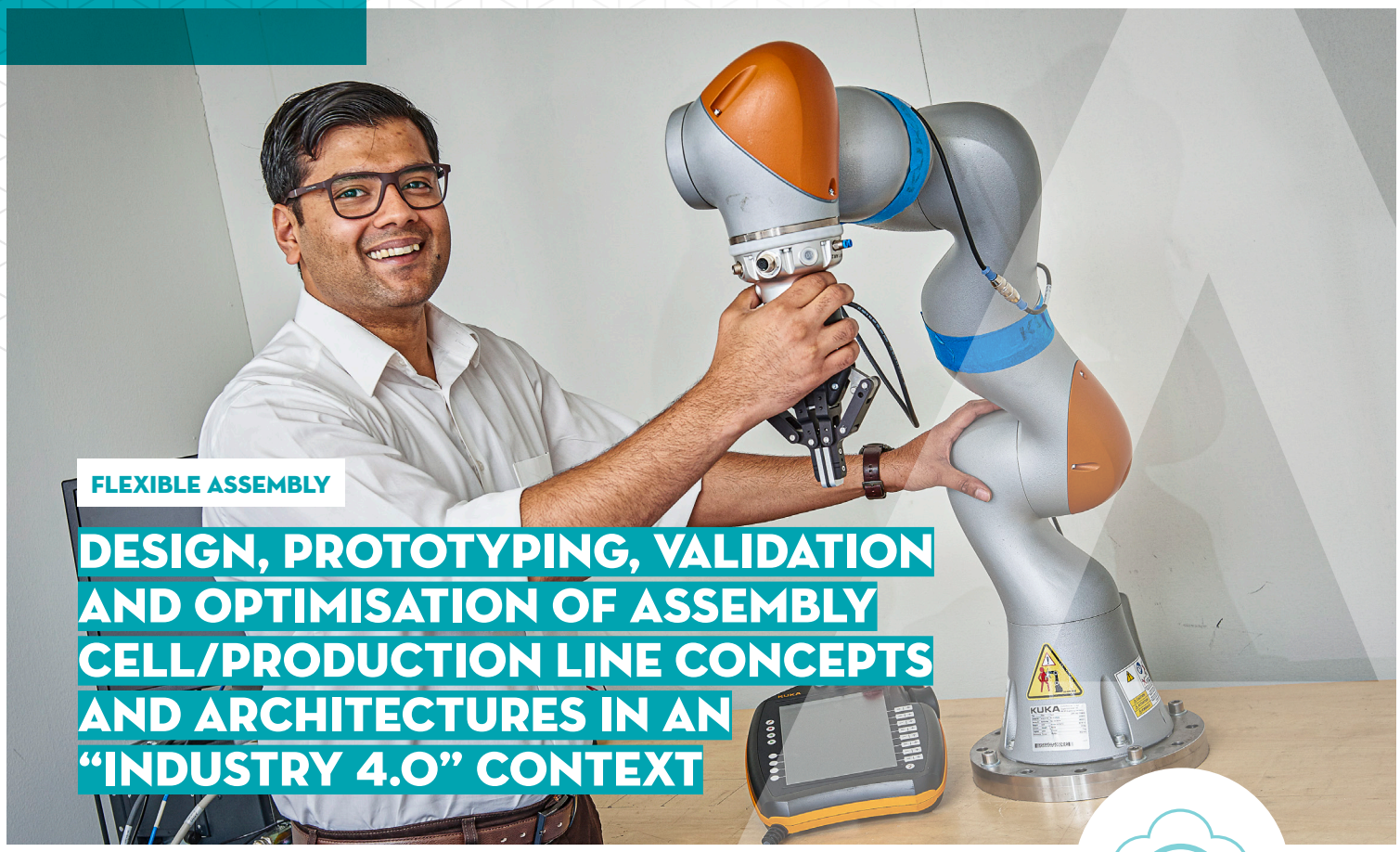
As product designers are looking for lighter materials to increase performance or reduce energy consumption, conventional (heavy) noise and vibration solutions do not suffice anymore.

SOLUTION

In a Range Rover Evoque, we installed insulation using lightweight vibro-acoustic materials on the inside of the trunk and above the wheel and shock absorber.

CUSTOMER VALUE

The use of metamaterials strongly reduces noise and/or vibration levels in machines or motion equipment. This vibro-acoustic insulation has proven to be equally efficient in vibration reduction as traditional insulation but weighs 50% less.



FLEXIBLE ASSEMBLY

DESIGN, PROTOTYPING, VALIDATION AND OPTIMISATION OF ASSEMBLY CELL/PRODUCTION LINE CONCEPTS AND ARCHITECTURES IN AN "INDUSTRY 4.0" CONTEXT

Flanders Make offers concept and feasibility studies for flexible manual and (semi-)automated assembly and production systems. We combine new innovative insights with state-of-the-art design technology and with optimisations at both workstation and system level.

As a supplier-independent solution provider, we support companies with:

- design of flexible assembly/production system architectures (for one-piece flows);
- benchmarking of commercial off-the-shelf assembly technologies;
- development of manufacturing process lay-outs, scheduling strategies, balancing & sequencing, buffer sizes etc.;
- strategies for process monitoring of flows, quality & machine condition;
- virtual commissioning;
- validation in a (near) real-life production environment in our own labs or in virtual reality.

We use a unique combination of software and hardware tools in this process:

- In-house discrete event simulation and mathematical system models
- Visual components
- FlexSim: Simulation
- Siemens Plant Simulation
- Siemens MCD: Validation of automation concepts and virtual commissioning
- Development of customised VR environments on a Unity platform
- Image-based 3D scans of objects
- AR/VR/MR visualisations and interactions

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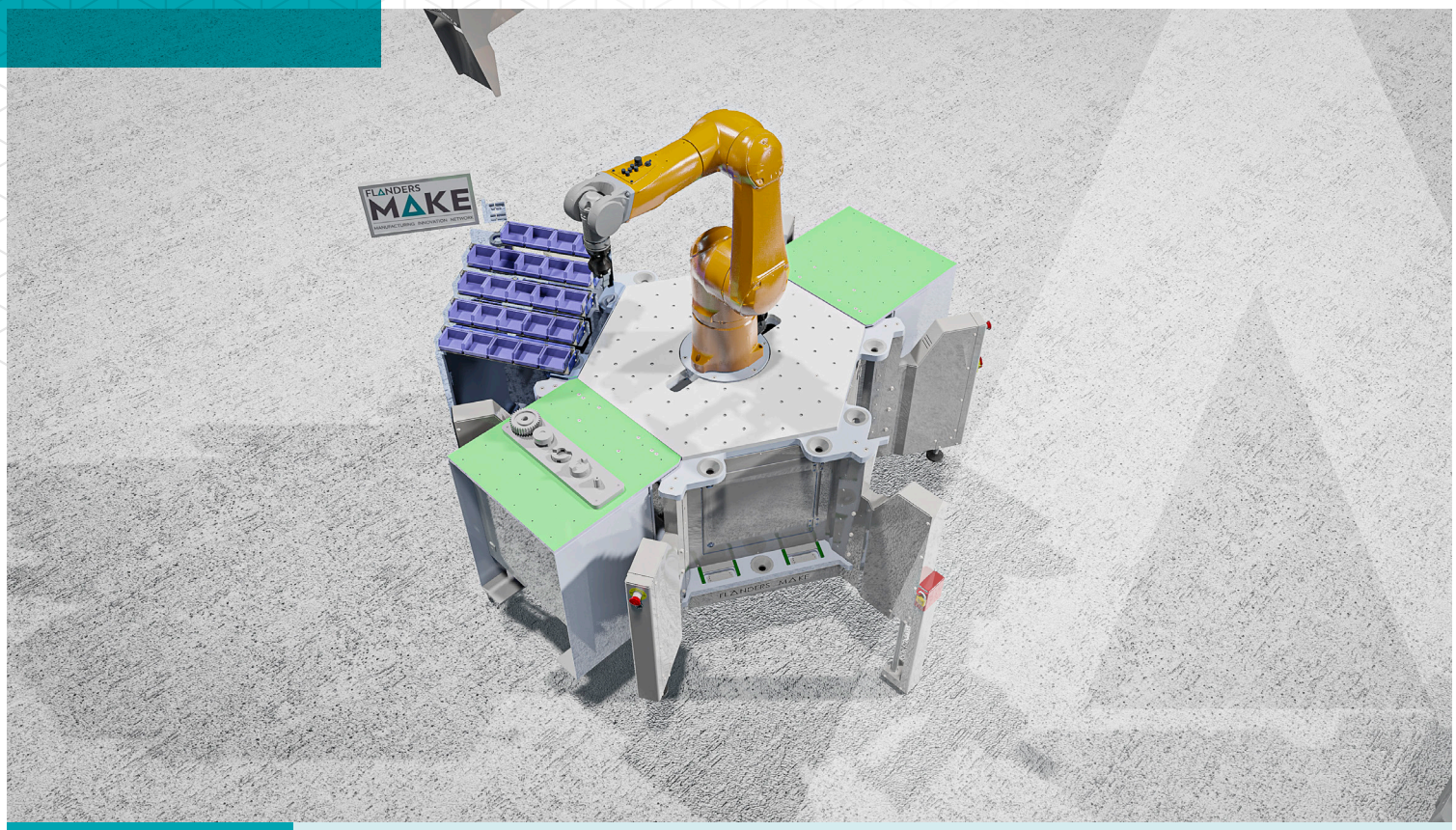

SUCCESS STORY

Open architecture of multiple reconfigurable work cells for flexible assembly

PROBLEM

The Flemish manufacturing industry is increasingly confronted with markets demanding highly customised products that must be built to order and assembled quickly and reliably. Obviously, their production systems, which are currently organised to build larger batches of the same products, need a major rethinking and reworking.

SOLUTION

Our infraflex environment consists of an open architecture of multiple reconfigurable work cells for various assembly tasks, end-effectors and quality controls, allowing to assemble and disassemble multiple customised products in a flexible and reliable way with short reconfiguration times and achieving an optimal single-piece flow. The infrastructure also includes extensive monitoring equipment, which allows to collect valuable production data and evaluate advanced data-driven and model-based assembly process optimisation techniques.

CUSTOMER VALUE

Infraflex is an infrastructure that allows testing, validating and demonstrating new concepts aimed at enhancing the flexibility and robustness of the assembly process. The infrastructure is easy to reconfigure so that different configurations and architectures can be validated. The main advantage is that customer can make experimental setups and validate different assembly scenarios in a flexible way under industrial conditions while the whole process is continuously being monitored and optimised.

FLEXIBLE ASSEMBLY

HUMAN-ROBOT COLLABORATION

Flanders Make combines engineering expertise from robotics and artificial intelligence with sociology and human sciences to improve the productivity and reduce the cognitive and physical stress of factory workers.

Collaborative workcells, where robots work side-by-side with their (human) operators, is one of the ways to achieve mass customisation of complex products. This technology is highly suited when human flexibility and adaptability are key in some critical parts of the manufacturing process. However, this kind of collaboration comes with several challenges, such as:

- communication between operator and robot;
- task-specific robot programming;
- design of layout of ergonomic collaborative work cells;
- balancing productivity with safety.

By offering proof-of-concept demonstrators, we allow you to gauge feasibility, validate the cost-benefit analysis and ensure technology acceptance. We build on an extensive range of cobots to support state-of-the-art technology development and high-TRL validation:

- Methods and algorithms for dynamic multi-objective task allocation, based on CAD-controlled task breakdown and optimally distributing assembly subtasks between humans and cobots.
- Methods for easy, fast, skills-based and intuitive robot programming.
- Constraint-based robot programming for complex robot tasks.
- Controlling robots with AI algorithms for flexibility and learning capabilities.
- Architectures for flexible multi-variant grippers
- Virtual validation of cobot work cells.

Next to testing the functionality, we can also test physical and mental fatigue in industrial settings, think of ergonomics, cognitive load & stress, etc. Additionally, we provide exoskeletons to physically support operators in situations where ergonomics cannot be improved by optimising the work cell design or through cobot integration. You can test these exoskeletons in a specific use case, both on an ergonomics and technology acceptance level.

We use various unique software and hardware tools in this process:

- Custom-developed software:
  - eTaSL: Our custom-developed task specification language for reactive control of robotic systems
  - Web-based environment for skills-based programming
  - Robot skills for programming by demonstration
  - Virtual world implementation
- Native Robot operating systems (Universal Robots, Kuka, ABB, Staubli, Fanuc...)
- Generic skills-based control framework based on ROS, DDS
- AI-based control framework
- Motion planning: convergent IT: Automappps
- Cobots, robots, AGV's, exoskeletons from several suppliers

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SUCCESS STORY

Improving the gluing process on an Audi car door

PROBLEM

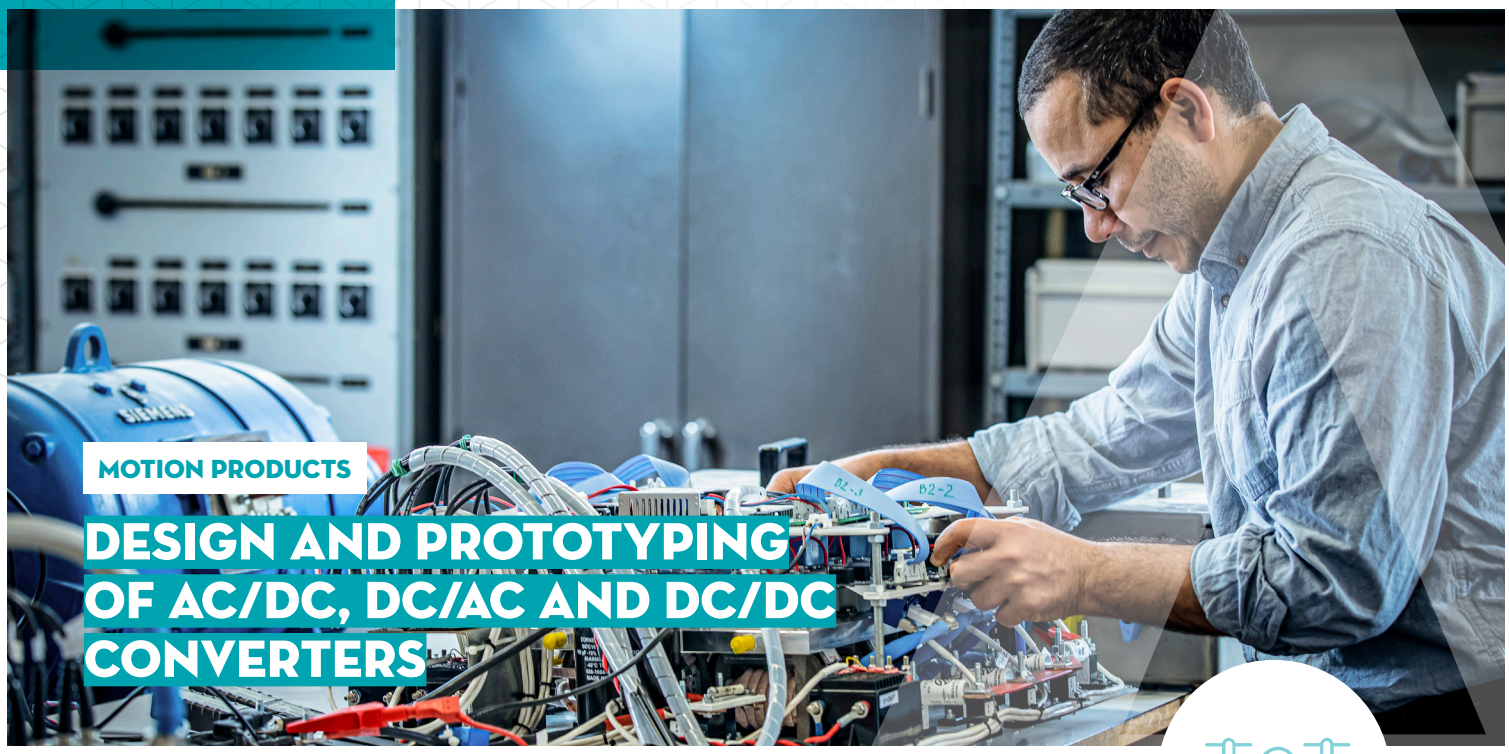
Audi wanted to improve the speed and accuracy of the quality control for a gluing process on car doors.
The process was carried out manually and operators could only check a few points. The quality control was therefore sub-optimal so that a door had to be destructively investigated on a regular basis to guarantee the quality of the gluing process.

SOLUTION

A cobot is positioned above the door. The robot gripper has a built-in sensor that can guarantee the quality of the glue. An operator shows the cobot where the door is and then the cobot can automatically follow the door contours and verify the quality of the adhesive process.

CUSTOMER VALUE

The solution achieved by Flanders Make in an ICON project ensures that the gluing process can now be monitored with a cobot over the entire door contour. The process is faster, more accurate and more ergonomic for operators. It saves the company +/-€5000/week, reduces CO_2 emissions and results in an immediate quality control.



MOTION PRODUCTS

DESIGN AND PROTOTYPING OF AC/DC, DC/AC AND DC/DC CONVERTERS

To improve the power density and reduce the total cost of ownership of machine and vehicle drivetrains, Flanders Make offers customised design and prototyping of AC/DC, DC/AC and DC/DC converters based on our uniquely comprehensive experience in novel converter architectures, wide bandgap (WBG) semiconductors and advanced cooling concepts.

Our services range from the design and prototyping phase up to the testing and validation of your customised power conversion systems:

- Designing, dimensioning, integrating, benchmarking and prototyping novel concepts, including:
  - novel topology exploration (e.g. multiport converter) & selection;
  - technology selection (Si, SiC, or GaN) and sizing of optimisation;
  - advanced (air & liquid) cooling concepts and thermal management control systems;
  - multi-level Matlab modelling (based on proprietary Matlab models) and control design, including interactions between electrical, thermal, mechanical and control domains.
- Design, modelling and control design of power electronics and control systems with a co-design approach (integrated sizing & control).
- Testing of:
  - power electronics with a wide operating range up to 350kW/600V and up to 160kW/1kV;
  - automotive charging and charging infrastructure in G2V and V2G modes;
  - conformance of charging systems (incl. standard testing and analysis communication protocol (PWM, PLC));
  - complete performance assessment of power electronics converters under controlled ambient conditions through highly accurate multi-channel data acquisition;
  - high-accuracy measurement methods, developed especially for analysis of electrical signals described in IEC 61851-1;
  - testing and validation of control system units (CSU's) and energy management systems (EMS's) for vehicle drivetrains.

MULTIPORT CONVERTER FOR HYBRID ENERGY STORAGE SYSTEM

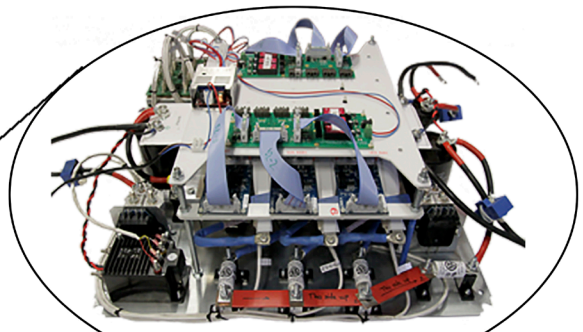


Figure 1

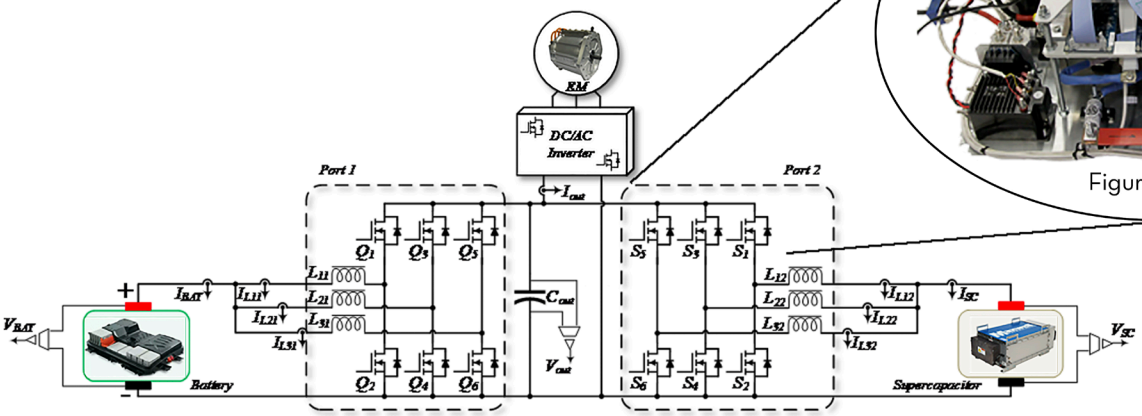


Figure 2

Figure 1. 60 kW liquid cooling SiC-based multiport converter (configurable to AC-DC, back-to-back converter)
Figure 2. Hybrid energy storage system multiport system of Figure 1.

SUCCESS STORY

Scalable, flexible multiport converter system up to 200 kW and voltage levels of 800 V

PROBLEM

Hybrid energy systems in electric drivetrain applications suffer from low efficiency rates, typically limited to about 93%, and large converter volumes.

SOLUTION

- The introduction of Wide Band Gap (SiC) technology for high-power and high-voltage applications allows to increase the operational switching frequency from <20 kHz to 100 kHz, resulting in less converter losses and improved dynamic performances.
- System design optimisation, including control and thermal performance, with passive components and a downsizing of the cooling system.

CUSTOMER VALUE

- Our solutions achieved a 98% efficiency at high operating powers.
- Even at low operating powers, we achieved a significant efficiency improvement.
- Reduced size of passive components.
- Reduced size of cooling system.
- Bi-directional power flow, configurable for multiple applications, including hybrid energy storage systems in electric drivetrains, grid-connected back-to-back inverters and charging systems.

MOTION PRODUCTS

DESIGN AND PROTOTYPING OF AUTONOMOUS WORKING VEHICLES

Flanders Make designs and prototypes autonomous working vehicles to increase productivity and flexibility, whilst guaranteeing safety and reducing hardware costs.

Autonomous working vehicles combine autonomous driving capabilities with autonomous operating functions. Our services for designing and prototyping autonomous working vehicles include:

- architectural design of autonomous mobile systems such as agricultural vehicles, mobile robots and drones;
- implementation of a proof-of-concept for both software and hardware;
- virtual and semi-virtual (Hardware-in-the-Loop) validation of autonomous driving and working functions;
- performance evaluation of self-driving algorithms.

We have a unique position in designing and prototyping these vehicles as we are well-connected with, a/o, the agricultural, manufacturing, logistics and automotive sector.

We use various software and hardware tools in this process. Our unique infrastructure includes:

- Mobile perception & control platform
- Several perception implementations on Nvidia platforms (object detection and classification algorithms and sensor fusion algorithms)
- Several control implementations on RCP or computer platforms
- Virtual validation framework for performance evaluation of autonomous work/drive systems or their components.

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FLANDERS MAKE

SUCCESS STORY

Autonomation of agricultural vehicle together with CNHi

PROBLEM

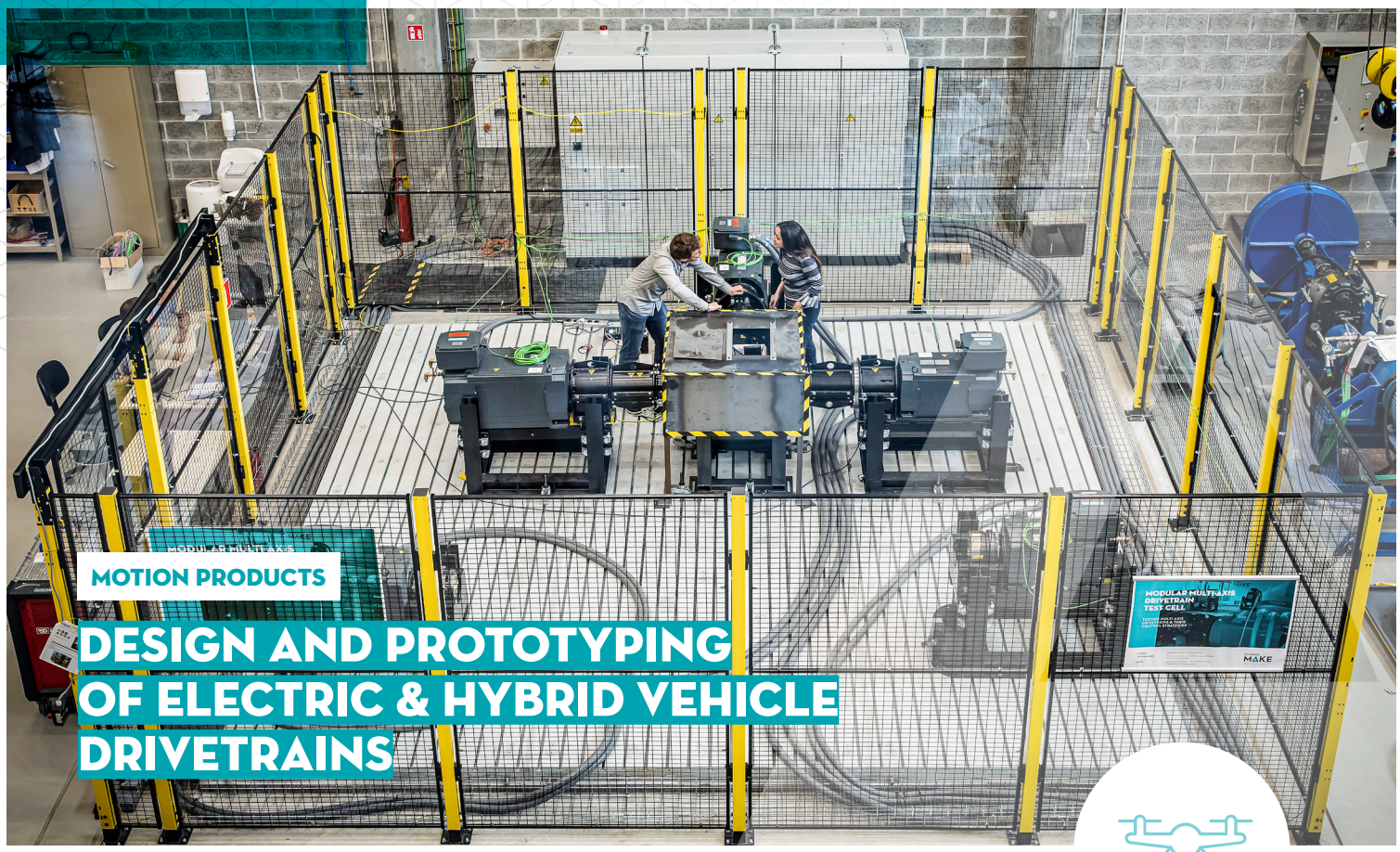
CNHi wants to autonomate its machines and therefore had to expand its knowledge on the architectural design of autonomous systems and the integration of perception and control algorithms.

SOLUTION

We developed a research platform and investigated and developed essential technology components (perception, control and integration).

CUSTOMER VALUE

With this research platform, CNHi is able to acquire field data and demonstrate the feasibility of performing autonomous agricultural operations. In addition to providing basic technology components, knowledge and expertise, this project is also one of the information sources for CNHi to determine its roadmap towards autonomous operations for all its machines.



MOTION PRODUCTS

DESIGN AND PROTOTYPING OF ELECTRIC & HYBRID VEHICLE DRIVETRAINS

Flanders Make designs and prototypes electric and hybrid vehicle drivetrains in terms of energy consumption, lifetime, costs and comfort. Using our simulation platform, we optimise the design and control architecture of these drivetrains. Furthermore, we integrate proof-of-concepts for validation on test vehicles in lab and road environments.

Manufacturers of electric and hybrid vehicle drivetrains and their components are constantly looking for ways to improve performance, energy efficiency, reliability and/or compactness. Our simulation platforms facilitate a top-down and bottom-up approach for the architectural design, modelling and integration of electric and hybrid drivetrains and their components for a wide variety of applications:

- hybridisation & electrification;
- vehicle dynamics control strategies for torque vectoring and (active) suspension;
- impact of increased autonomy and functional safety levels on vehicle drivetrains;
- advanced ECO energy management systems (charging, driving, routing and comfort).

We support your entire process: from application requirements over architecture, conceptual evaluation, (co-)design and building proof-of-concepts, including software implementation, up to validation.

We use various unique software tools in this process:

- Virtual simulation and optimisation platform, developed in-house in MatLab, for energy management strategies for hybrid electric vehicle, hybrid energy storage system and powertrain sizing
- Static, hybrid and dynamic models and parameterised finite element (FE) models, e.g. electric variable transmissions (EVT), in Matlab/Simulink
- Validated vehicle models for vehicle dynamics applications

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FLANDERS MAKE

SUCCESS STORY

Full electric drivetrain range optimisation

PROBLEM

Power consumption is the main challenge in electric vehicles. How can we maximize the driving range without compromising on the vehicle's performance?

SOLUTION

We use software algorithms that manage the control of every wheel independently. We apply torque vectoring (TV) and at the same time optimise e-drivetrain losses.

CUSTOMER VALUE

The vehicle's efficiency and range significantly improved after implementing these developments. By characterising component losses through software development, we were able to lower the e-consumption by 4.6%. When combining this software development with torque vectoring, validation tests on proving grounds displayed a decrease of e-consumption by 11.4%.

MOTION PRODUCTS

DESIGN AND PROTOTYPING OF ELECTRICAL AND MECHANICAL ENERGY STORAGE

Energy storage is an important topic in modern machine and vehicle design. To improve the energy and power density as well as the total cost of ownership (TCO), Flanders Make designs, dimensions, integrates, benchmarks, selects and prototypes various energy storage solutions such as batteries, (magnetic) springs, inertias and capacitors.

Our services include:

- electrical, mechanical, thermal, structural and control design for energy storage components and their integration in a system;
- modular battery and energy management and balancing systems for mobile and stationary applications;
- optimisation of advanced thermal management.

We use various unique software and hardware tools in this process:

- In-house developed SoX (State of charge, health, power...) software for batteries and (real-time) models in MatLab, SimuLink and Simscape
- Patented magnetic spring with variable stiffness

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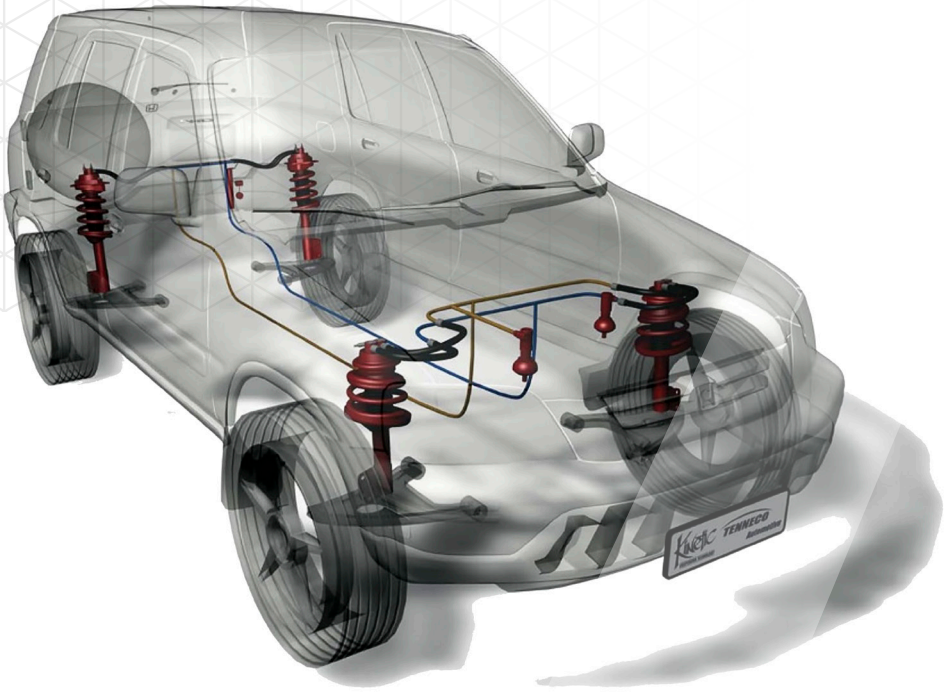


SUCCESS STORY

Shock absorber with integrated energy storage

PROBLEM

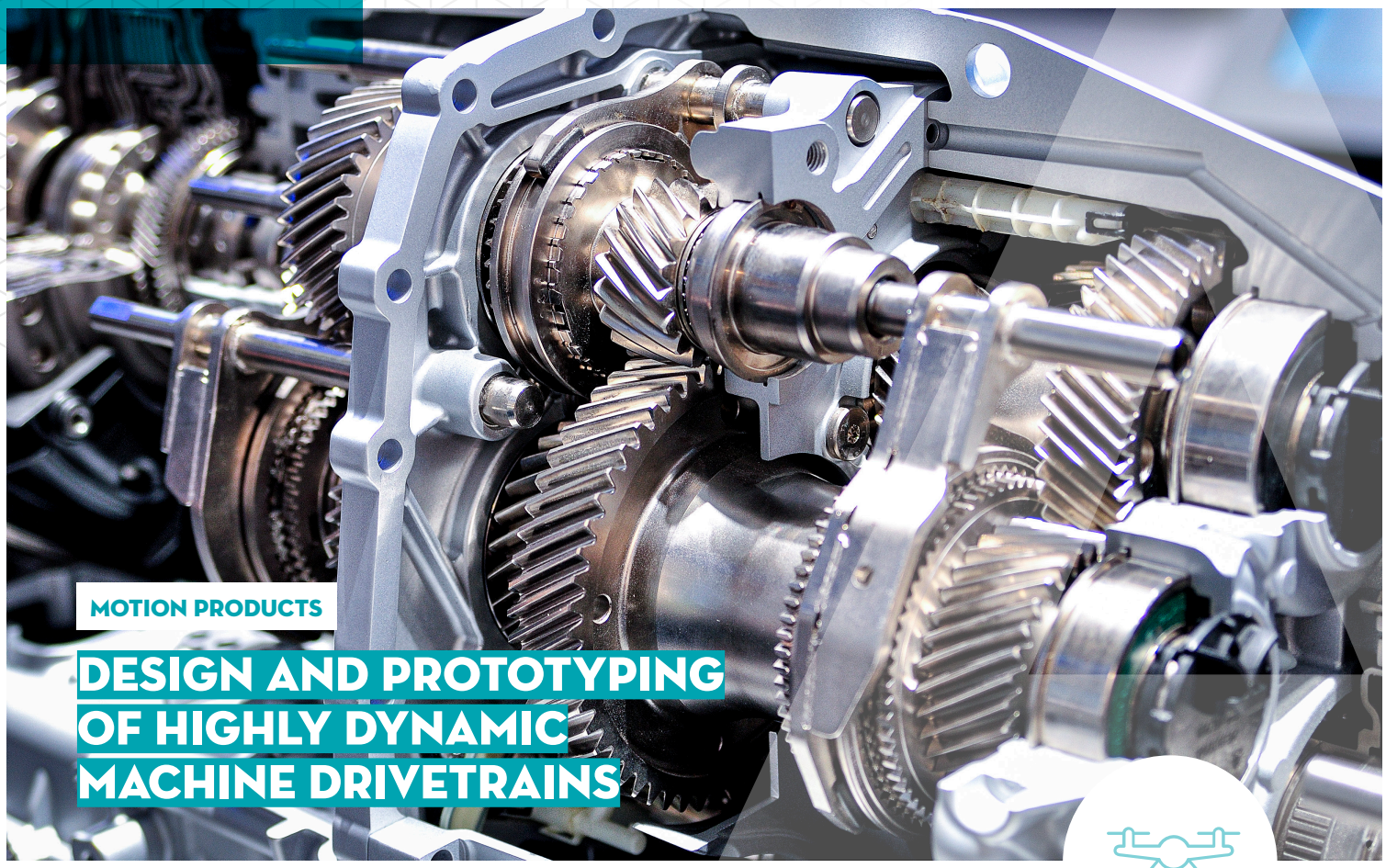
The energy from the suspension motion of a vehicle is currently dissipating/wasted.

SOLUTION

We developed an energy harvester for a vehicle's suspension system. We also designed the innovative architecture with optimal storage sizing and controller design for this system.

CUSTOMER VALUE

Our prototype harvested energy up to 5W, while we were able to increase the efficiency of the energy conversion up to 48%. The harvested energy can be used to make the (semi-)active suspension self-supplying and thereby reduce wiring costs (material, labour). The comfort level inside the car remained unchanged.



MOTION PRODUCTS

DESIGN AND PROTOTYPING OF HIGHLY DYNAMIC MACHINE DRIVETRAINS

Energy efficiency, compactness, reliability and costs are keywords when designing machine drivetrains. Flanders Make offers a model-based design approach for the physical and control design of smart machines with highly dynamic (single- & multi-motion) drivetrains.

For companies designing and manufacturing highly dynamic machines, drivetrains and drivetrain components we offer:

- guidance in choosing the right drivetrain architecture for your application;
- physics-based modelling of highly dynamic machine drivetrains (based on available CAD models);
- integration of mechanical, magnetic and electrical energy storage in drivetrains and drivetrain components to speed up the dynamics and energy efficiency;
- optimisation of motion profiles;
- development & prototyping of power supply electronics;
- design & prototyping of auxiliary systems such as cooling and lubrication;
- virtual testing of drivetrain systems.

We use various unique software tools in this process:

- Proprietary CAD-based drivetrain design toolchain using motion simulators
- Co-design tool for optimisation of physical and control parameters of drivetrains
- Design tool for TCO-optimisation of drivetrains with fast and slow energy storage
- Active and passive front-end design tool

www.flandersmake.be

For more information, please contact
services@flandersmake.be

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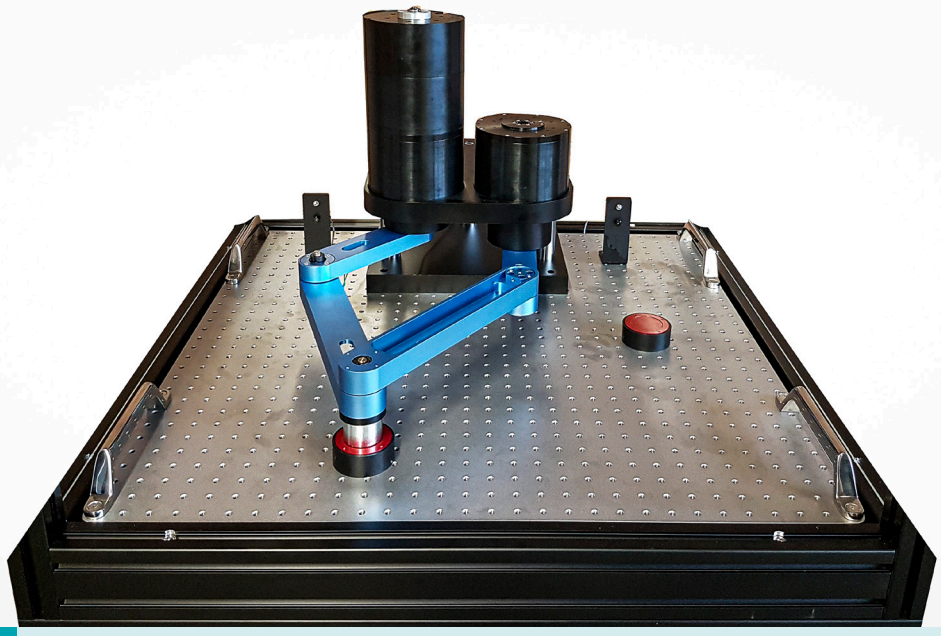


SUCCESS STORY

Magnetic spring assisted pick-and-place robot

PROBLEM

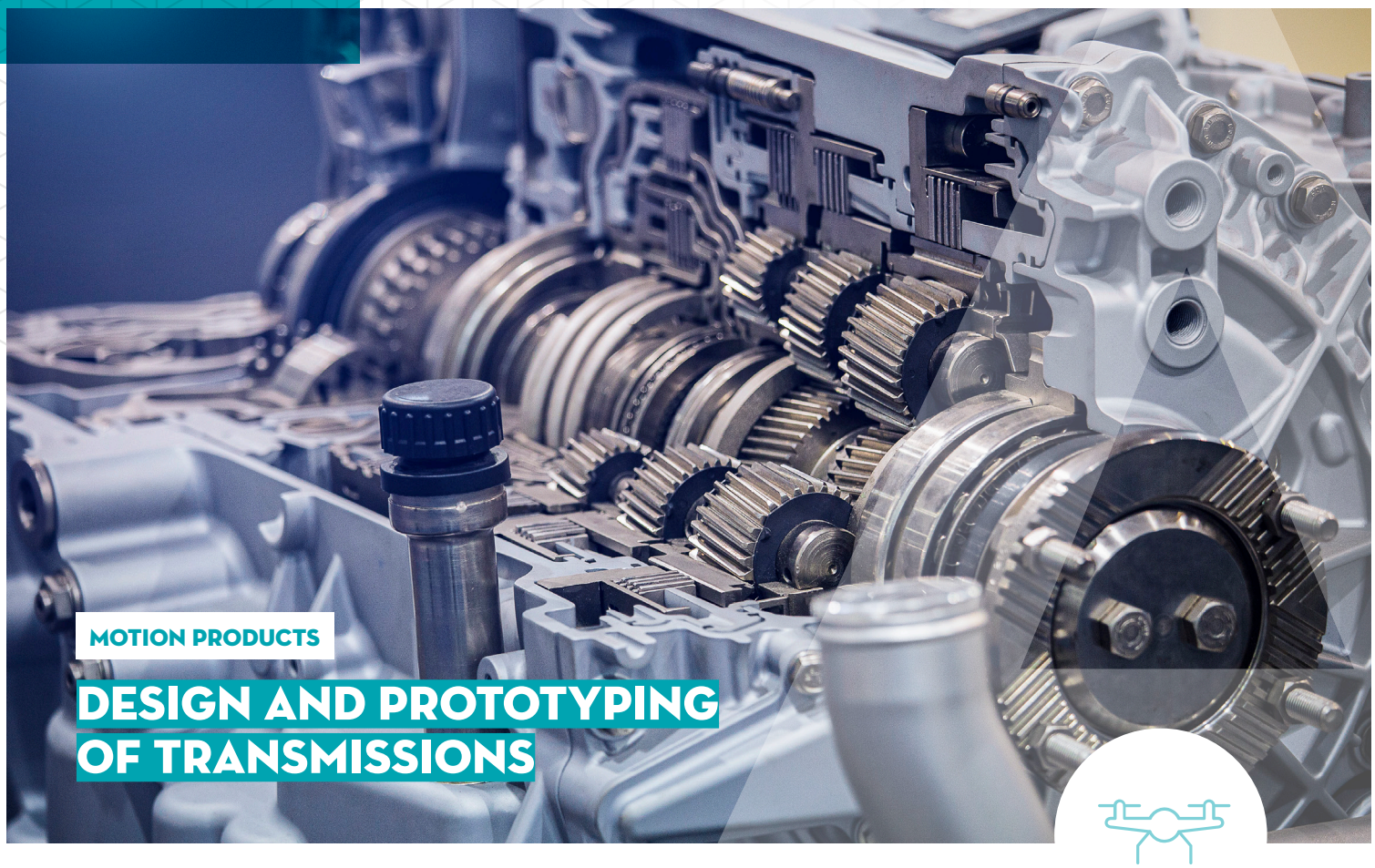
High-speed reciprocating motions, as found in pick-and-place robots, feature high torque pulses leading to oversized actuators and low energy efficiency.

SOLUTION

A magnetic spring assists the electric motor in generating the required torque pulses.

CUSTOMER VALUE

By using a magnetic spring in a pick-and-place robot, we enable the use of smaller and less expensive motors (35% lower motor peak power) and achieve lower losses (30% lower energy consumption), thus reducing the total cost of ownership (TCO)



MOTION PRODUCTS

DESIGN AND PROTOTYPING OF TRANSMISSIONS

Flanders Make supports companies with the optimisation, characterisation and integration of drivetrain transmissions to improve their performance.

Thanks to our winning combination of modelling expertise and a unique validation setup (multi-load drivetrain test cell), we can offer modelling, simulation and experimental validation of (prototype) transmissions through:

- detailed characterisation and validation measurements of transmission components, including vision-based teeth monitoring, loss models, efficiency maps etc.;
- numerical and experimental modelling and characterisation of tribological effects (e.g. friction, lubrication, wear) in transmissions, incl. CFD and fluid-structure interaction methods;
- system level modelling of mechanical transmissions, incl. Continuous Variable (toroidal and belt) Transmissions (CVT), Electric Variable Transmissions (EVT), planetary gears, belt and differential transmissions, hydraulic transmissions;
- sizing optimisation of components (gears and clutches) of gear boxes;
- optimisation of clutch actuation control.

We use various unique software and hardware tools in this process:

- In-house developed parametrised transmission models in MatLab/Simulink;
- In-house developed tools for lubrication and erosion/abrasion modelling;
- Tango Toolbox combining ABAQUS and ANSYS Fluent for fluid structure interaction;

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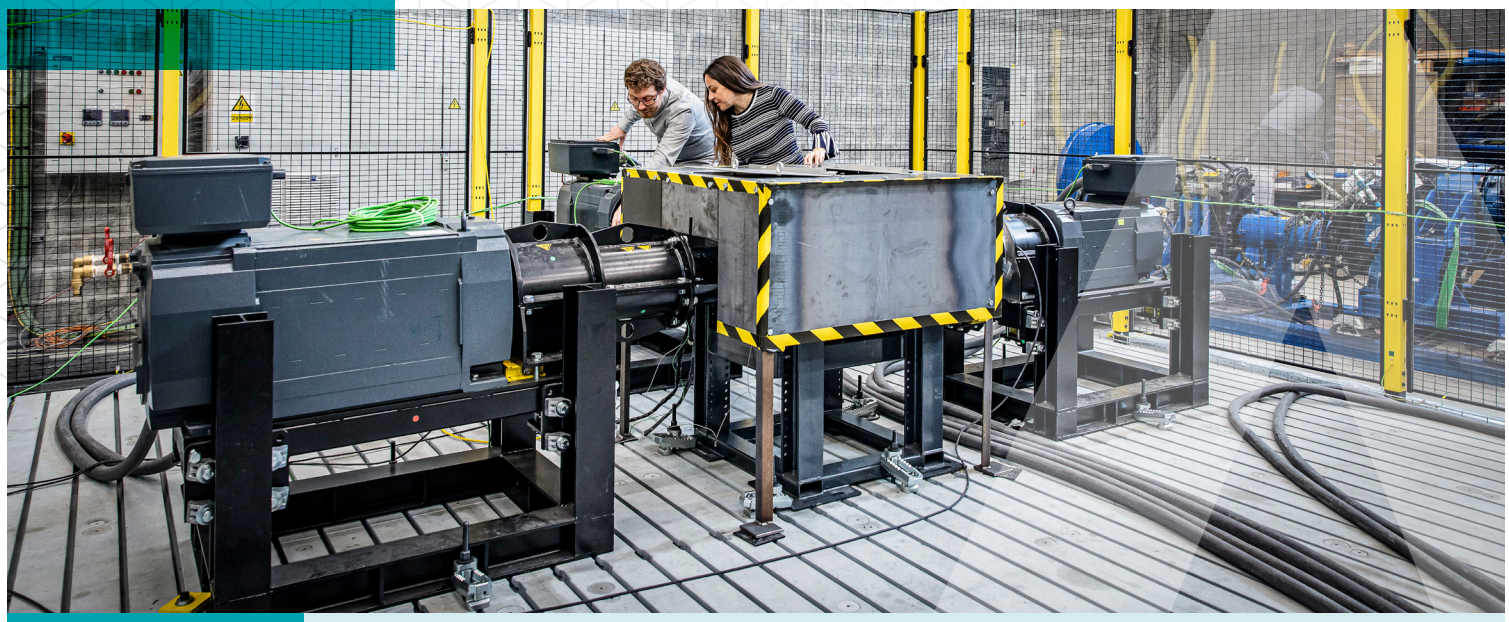

SUCCESS STORY

Physical design tool for optimisation of drivetrain and gearbox

PROBLEM

The design process of hybrid drivetrains is becoming ever more complex

SOLUTION

A computational design method consisting of 3 steps:

- Modelling components and expert knowledge
- Automatic generation and evaluation of concepts with automatically sized components
- Providing designers with a set of new driveline components or systems that can be used as a basis for the final design.

CUSTOMER VALUE

- Decreased design effort
- Faster time-to-market
- Transmission design knowledge captured in models
- Reduced Total-Cost-of-Ownership (TCO)