3TU.School for Technological Design

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Automotive Systems Design

Eindhoven University of Technology

PDEng projects 2013

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Automotive Systems Design - PDEng projects 2013


OMCN
TU/e

Prof.dr.ir. M. Steinbuch
Dr. P.S.C. Heuberger

The first ASD trainees

It's with pleasure and pride that we present you the results of the first 7 graduates of the Automotive Systems Design PDEng programme. This programme was started in 2011, motivated by the urgent need of the High Tech automotive industry for system architects, people who are not afraid to go beyond the boundaries of disciplines and who are willing to work together in project teams to achieve desired results in a structural manner.
This two-year programme educates its trainees in-depth in various automotive related disciplines, as well as in personal and professional development. This variation in disciplines is reflected in the 7 projects that lie before you. We see applications and designs in the areas of Mechanical Engineering, Power Electronics, Hybrid Electric Driving, Human Machine Interaction, Vehicle Control, Modelling and Advanced Driving Assistant Systems. The projects are all engineering design type of projects, with a need for a systems' aspect.
One project deals with the noise reduction of automatic transmission systems, another comprises the full design of a new electric hybrid vehicle. With the fast growth of electric driving the need for fast charging becomes a major challenge. In a third project the improvement of these chargers was investigated and developed. The supervisory and dynamic control involved in a new vehicle follow functionality for trucks was completely designed and in a related project the Human Machine Interaction functionality needed for such a new feature was investigated and a prototype created. Another project investigated the new challenges that lie ahead with the development of driver assistance systems and the goal to enable fully automated driving within the next two decades. The safety of the human driver was the key focus of a project, by developing a model for the posture of the driver, which -in combination with advanced vehicle models- will lead to a reduction of the number of casualties in car accidents.
All these final engineering design projects, proposed by the high-tech industry, are diverse, complex and challenging. They require our trainees to deliver products that meet high requirements in a very multidisciplinary setting. We are proud that our trainees live up to the high expectations of the industry.
We wish them all the best and a successful career.

Maarten Steinbuch
Scientific Director

Peter Heuberger
Programme Manager

The Automotive Systems Design PDEng (Professional Doctorate in Engineering) degree programme is an accredited and challenging two-year doctorate-level engineering degree programme. During this programme trainees focus on strengthening their technical and non-technical competencies related to the effective and efficient design and development of technologies and applications for modern high-tech automotive systems. In particular, there is a focus on the multidisciplinary design aspects of project-based research and engineering in high-tech automotive systems, reflected in the key contributions by five TU/e departments.

The programme is organised by the Department of Mathematics and Computer Science of Eindhoven University of Technology in the context of the 3TU.School for Technological Design, Stan Ackermans Institute.

For more information, visit the website: www.3tu.nl/asd.

Challenges

Due to the systems engineering approach followed by this project, the main challenge was to have not only good knowledge in several disciplines of the Automotive Systems Design field (like the V-cycle model, functional architecture, supervisory and dynamic control, real time implementation, etc.), but also to have proper time and resource management skills, together with strong soft-skills like team effort and good communication.

Results

A systems engineering approach (CAFCR) was successfully applied for the design of the Supervisory and Dynamic controller of the Vehicle Follow Control function. The design was successfully implemented by Rapid Control Prototype techniques in a prototype vehicle, allowing the design team to assess this new functionality in reality. It is concluded that the Proof-Of-Concept for the VFC function was achieved.

Benefits

The RCP platform created for this project allows the company to quickly build up experience with this new function; to adapt, adjust and fine tune the initial requirements and to make quick modifications, resulting in an efficient iteration process. Moreover, because the design was carried out using a modular approach, it enables the company to integrate this function with existing and future longitudinal control functions.

Antonio Colin PDEng

Vehicle Follow Control Function: Supervisory and Dynamic Control

Design and Proof-Of-Concept by Rapid Control Prototyping

"Not only did Antonio develop a convincing supervisory control and dynamic control, but also he managed to solve the very challenging system-interaction-puzzle in order to get the Rapid Control Prototype vehicle running. Driving the vehicle and experiencing the Vehicle Follow Control in action was a fantastic experience that definitely proved its value."

Rutger-Jan Kolvoort
DAF Trucks N.V

The Vehicle Follow Control (VFC) is an assistance function that reduces the workload of the driver by automatically following the preceding vehicle. This is particularly useful in congested traffic situations, where the speed has to be constantly adjusted. The VFC function has the potential to improve safety, comfort and fuel efficiency by partly taking over the driving role.

A specific systems engineering approach (CAFCR) was used to transform the customer needs to a set of system requirements. These were used as an input to design the functional and control architecture. The design of the VFC controller consistsof a supervisory logic and a dynamic controller. The Controller was designed using a model-based approach using Matlab/Simulink. The Verification and Validation phase was performed according to the V-cycle model; firstly by a component level, second by an integration level and finally by a function level, where the function was implemented in a prototype vehicle by Rapid Control Prototype (RCP) techniques.

The RCP platform created during this project allows the company to explore more possibilities for longitudinal control and integration with existing functions.

Challenges

The impact of the control algorithm on the various losses across the operating range had to be investigated using simulations. The derivation of loss models that could satisfactorily demonstrate the trends in losses while maintaining reasonable simulation times was a challenge.

Results

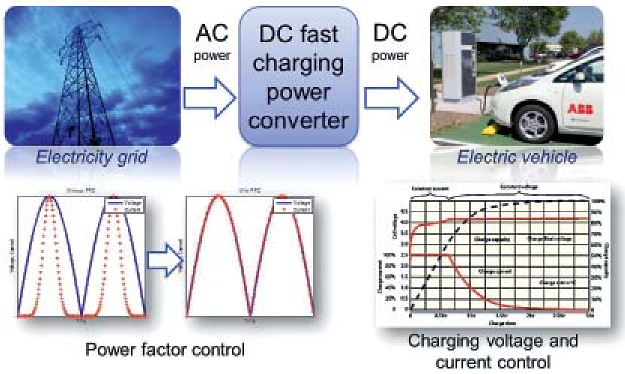
The project resulted in a control algorithm that could be easily integrated into the control architecture of the power converter. The algorithm gave insight into the various losses, input current distortion and power factor. It was also demonstrated that despite the increase in current distortion, the distortion is kept mostly within the stipulated limits.

Benefits

The control algorithm can be incorporated easily into the existing control architecture of the power converter, with minimal changes. The loss models developed can be used to further analyze the effect of variations in the control algorithm on the losses in the system.

Jubin Jacob PDEng

Control algorithm improvements for an electric vehicle DC fast charger



"Jubin investigated all facts thoroughly and the data was well organized. We usually follow a more empirical/ practical approach (simulating, building), but Jubin touched us with the academic approach (reasoning, formulae), which was very insightful for us. He brought these two approaches together in a powerful way. Although the investigation still has points that need continuation, we will definitely proceed with his findings and implement his work."

Gertjan Koolen
ABB B.V. PGEVCI

Electric vehicle DC fast charging systems manufactured by ABB provide a means by which charging can be performed conveniently at public spaces such as shopping malls or highway stops. However, keeping the running cost of these charging systems low would depend on several factors, an important factor being their efficiency. Digital control creates the opportunity to conveniently and economically test several different control algorithms for DC fast charging, that can potentially enhance the charger's operating range and efficiency.

An important requirement was to analyze the effect of control algorithms on various losses taking place in the system, namely the copper losses, magnetic core losses and conduction losses. Apart from these, the impact on other system specifications such as total harmonic distortion and power factor had to be investigated.

Therefore a control algorithm was designed which can easily be incorporated into the existing control architecture of the DC fast charging power converter. It was shown that the algorithm reduces magnetic core losses, which otherwise contribute significantly to the losses in the power converter. Conduction losses remain mostly unaffected. However, the copper losses tend to increase as a consequence of increased current through the power converter. The algorithm also creates more distortion in the input current and causes a reduction in the power factor. However, it has been demonstrated that the amplitude of input current distortion can still be kept within the limits imposed by charging regulations.

Challenges

This project had a very high level of complexity due to several aspects. The number of fields that are used in ADAS is very broad due to the different sensor technologies, the different levels of processing and the different applications that exist. This makes it very difficult to go in depth in all necessary fields to obtain enough information to make an adequate assessment.

To attack this complexity, experts as well as customers were consulted as much as possible. Without these cooperations it would have been impossible to reach the necessary depth in some of the topics like computer vision and radar.

Another big challenge was the uncertainty that is related to the long-term scope of this project. The objective was to look 10-15 years into the future which is very difficult today when technology is changing so drastically. Trends and research papers were used every time it was possible to make the best educated guesses when it came to predictions for systems or applications.

Cooperation is crucial to attack and understand the ADAS field since is very difficult for one single party to possess all the knowledge and the resources that are needed to attack the challenges that have to be passed to reach HAD capabilities.

Results

The main objective of this project was to discover areas of opportunity for NXP in the ADAS market. Some of those opportunities were investigated during this project. These areas of opportunity fall in the area of vehicle networks, radar, cameras and computer vision. Three different project proposals have been submitted already and other ideas are being considered within NXP.

Benefits

With the number of vehicles increasing every year, road traffic accidents will become the fifth cause of death worldwide by 2030. ADAS and HAD are the key elements to attack this growing concern and bring zero accident vehicles to the market.

Hector Montemayor Ayala PDEng

Advanced Driving Assistance Systems for Highly Automated Driving

Hector's warm personality and open communication, professional attitude, and diligent way of working has significantly helped NXP to advance its research objectives in this phase of the project. Therefore from my side I extend my warm thanks to Hector for his very good contribution.

Gerardo Daalderop
NXP Semiconductors N.V.

NXP is one of the leaders in mixed signal electronics. Its industries include automotive, identification and mobile and application areas such as wireless infrastructure, lighting, healthcare, industrial, consumer tech and computing. NXP has operations in more than 25 countries with posted revenue of $4.36 billion in 2012 from which 23% comes from the automotive industry. In automotive, NXP is the world leader in passive keyless entry and immobilizers, in-vehicle networking (CAN, LIN, FlexRay) and car radio. NXP is also present in emerging markets such as LED lighting and telematics.

Advance Driving Assistance Systems (ADAS) are systems that help the driver in the driving process. When designed with a safe Human Machine Interface (HMI), these systems should increase car safety and more generally road safety.
It is the vision of NXP that ADAS with **Highly Automated Driving (HAD)** capabilities will be a commercial reality in 10 to 15 years from today. The vehicle will be capable of sensing its surroundings and interpreting the environment such that **situation awareness** can be obtained. This situation awareness will enable the vehicle to perform driving maneuvers automatically in the same way that an experienced driver does today.

This project has created an understanding of Advanced Driving Assistance Systems and how Highly Automated Driving can be achieved pointing out areas of opportunity in this field for NXP.
Insight has been generated in the different applications that form part of ADAS, identify the trends that the development of these applications have and how HAD could be introduced in the market by the year 2030. Specifications to reach HAD capabilities in a car were generated and the different sensors (cameras, radar, lidar, etc.) that are used to understand the environment around the car were researched and compared. Different areas of opportunity were discovered in the areas of computer vision, were the existing portfolio of NXP was assessed against ADAS and possible new concepts were created including driver monitoring. Other areas of opportunity include vehicle networks and radar technology and are presented in the form of follow up projects that are to be undertaken in the year 2014.

Challenges

To achieve the project goals, it was necessary to introduce a completely new software platform for rapid HMI prototyping and solve all issues that emerged during the integration with the existing systems and processes. Additionally, a proto-truck equipped for rapid control and rapid HMI prototyping needed to be specified and rebuilt with a limited available support.

Results

The main project results include a successful introduction of the HMI toolchain and its integration into a flexible HMI development platform. Furthermore, the toolchain was used for iterative evaluations of the HMI concepts with the user representatives. The main outcome of such user-centered process was an appreciated VFC HMI design concept and the guidelines for its further development.

Benefits

The new tools drastically shortened the time between an HMI idea and a functional prototype, which made elicitation of user evaluations of high-fidelity prototypes possible early in the design process. The HMI platform and the proto-truck were prepared to be ready for use in future projects.

Dino Sepac PDEng

Vehicle Follow Control Function: Human-Machine Interaction

Design and proof-of-concept by rapid prototyping

"Dino was responsible for a VFC HMI design and setting up a whole new toolchain for easy HMI development which can be iteratively used from a desktop environment into a running truck. Setting up the tool chain ended up being a much larger task than anticipated; Dino, however, never gave up."

Alex Uyttendaele
DAF Trucks N.V.

Vehicle Follow Control (VFC) is a driver assistance function that aids a driver of a commercial vehicle by safely and smoothly following its preceding vehicle. Such function increases comfort, safety, and fuel economy by taking over a part of the driver's controlling role. For a driver to trust and like the function, he needs to be able to use it easily and receive clear feedback. Human-machine interaction (HMI) is therefore a very important contributor to the overall user acceptance.

A user-centered design process was followed to achieve a user-friendly HMI. It helped us focus on the users' wants, needs, and limitations by intensively involving users in all stages of the design process. Early in the process, a task analysis provided insight into the truck driving world and user expectations. These insights were translated to high-level HMI requirements and usage models, which were used to steer the conceptual ideas into an actual high-fidelity prototype. The prototype was improved through the iterations according to suggestions received from domain experts and users, leading to a solid VFC HMI and a set of recommendations for improvements in future iterations.

To be able to experience fully functional prototypes in realistic driving situations, it was necessary to introduce a new HMI toolchain for rapid HMI prototyping and build it into a proto truck.

Challenges

A challenge of the project is to measure occupant kinematics with a limited number of sensors. The sensors to be used should be sufficiently accurate and cost-effective. In the concept phase, sensors are allowed to make contact with the occupant; however, it should be possible to replace them by less intrusive types in a later development stage. Another challenge is to find a good accuracy requirement of the estimator. The requirement is currently assigned to some specific points in the occupant body that are expected to be important to describe the occupants posture, and the accuracy of the estimation of these points need to be verified.

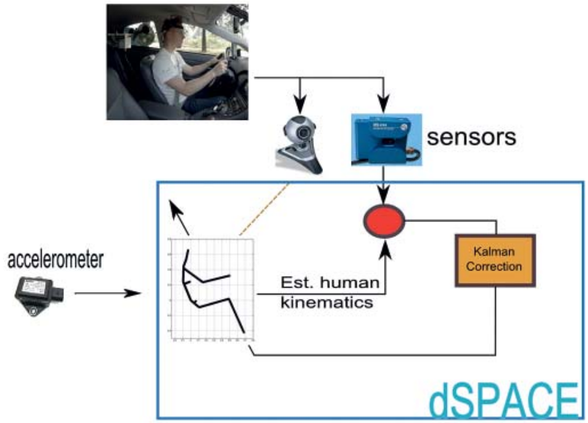
Results

A human state estimator that can identify occupant kinematics in pre-crash braking is implemented in a dSPACE prototyping system. The estimator was developed as a Kalman filter. A simplified human model was adapted from previous work. Two sensors are used to measure the seat belt movement and head displacement. The estimator was tested in a virtual environment and in a real life vehicle environment with an adult male driver.

Benefits

The results demonstrate the feasibility of a real-time kinematic human state estimation concept in pre-crash braking. A complex task has been realized, and the defined requirements has been achieved. Following the project, the estimator can be adapted to other occupants with variations in stature, mass, and awareness level.

Hieu Trinh PDEng



In-vehicle Human State Estimator: Real Time Kinematic Estimation based on a multi-body Human Model

"We knew that the assignment would be very challenging. Especially the translation of a desk-top proof-of-concept into a system functioning in real time in a vehicle environment has been a difficult task. TNO is very satisfied that Hieu has been capable of dealing with that challenge, and that at the end of the assignment, he could demonstrate an in-vehicle system."

Lex van Rooij MSc
TNO

One of TNO's ambitions is to increase traffic safety by introducing innovative safety system concepts. A number of safety systems can benefit from real time information on the position of the occupants in a pre-crash phase within the last few seconds before a possible crash. Moreover, simulation predicts that injury levels of car occupants as the result of a crash can be significantly reduced by optimizing the occupants' postures in the pre-crash phase. In this phase, the crash is no longer avoidable but it does not happen yet. There are still possibilities to bring the occupant into a better position with a lower risk of serious injury during the crash. In addition, the occupants often experience high dynamic movements in the pre-crash phase due to the operation of systems such as autonomous emergency braking. The systems can be controlled such that the movement of the occupant becomes less severe.

This motivates the development of a human state estimator system that can identify the kinematics of an occupant prior to a crash in real time. As a proof of concept, the area of application is currently limited to a typical adult male driver and the state estimator should be capable to deal with pre-crash braking by an AEB system prior to a crash. The occupant awareness level, which is of influence on the occupant's kinematic behavior, is fixed to a pre-set level. The estimated output can be used to control safety systems to make driving safer and more comfortable. The challenge is to implement the system in a real-time car environment and the estimator should run fast enough for the control purpose. Controlling the posture of the occupant based on the estimator however is outside the scope of this assignment.

Challenges

The main challenge in this project was to meet the requirements using the current Punch Powertrain EV technology and the limited design space given by the base vehicle chosen. Other challenges were to get the project recognized within the company and get people involved, as well as keeping track of all the requirements and design decisions in such a way that these are transparent and traceable to their origin.

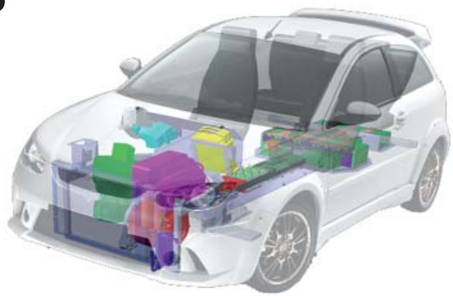
Results

The result was a vehicle architecture and a detailed design (incl. component selection) for most components. It was concluded that the concept is technically feasible, but requires more engineering effort after this project. Especially the top speed requirement is expected to be tough to meet because of the current continuous power and motor speed limitations. Moreover, a novel requirements engineering method was proposed that gives more transparency and better traceability.

Benefits

By striving to use all the lessons learned from previous projects and keeping an open mind, many improvements were made to the EV powertrain products of Punch Powertrain. With the lessons learned from this project it is expected that Punch Powertrain can make another step forward in their EV powertrain development capabilities and product creation processes.

Sebastiaan Voorderhake PDEng



Development of an extended-range electric vehicle: A systems engineering approach

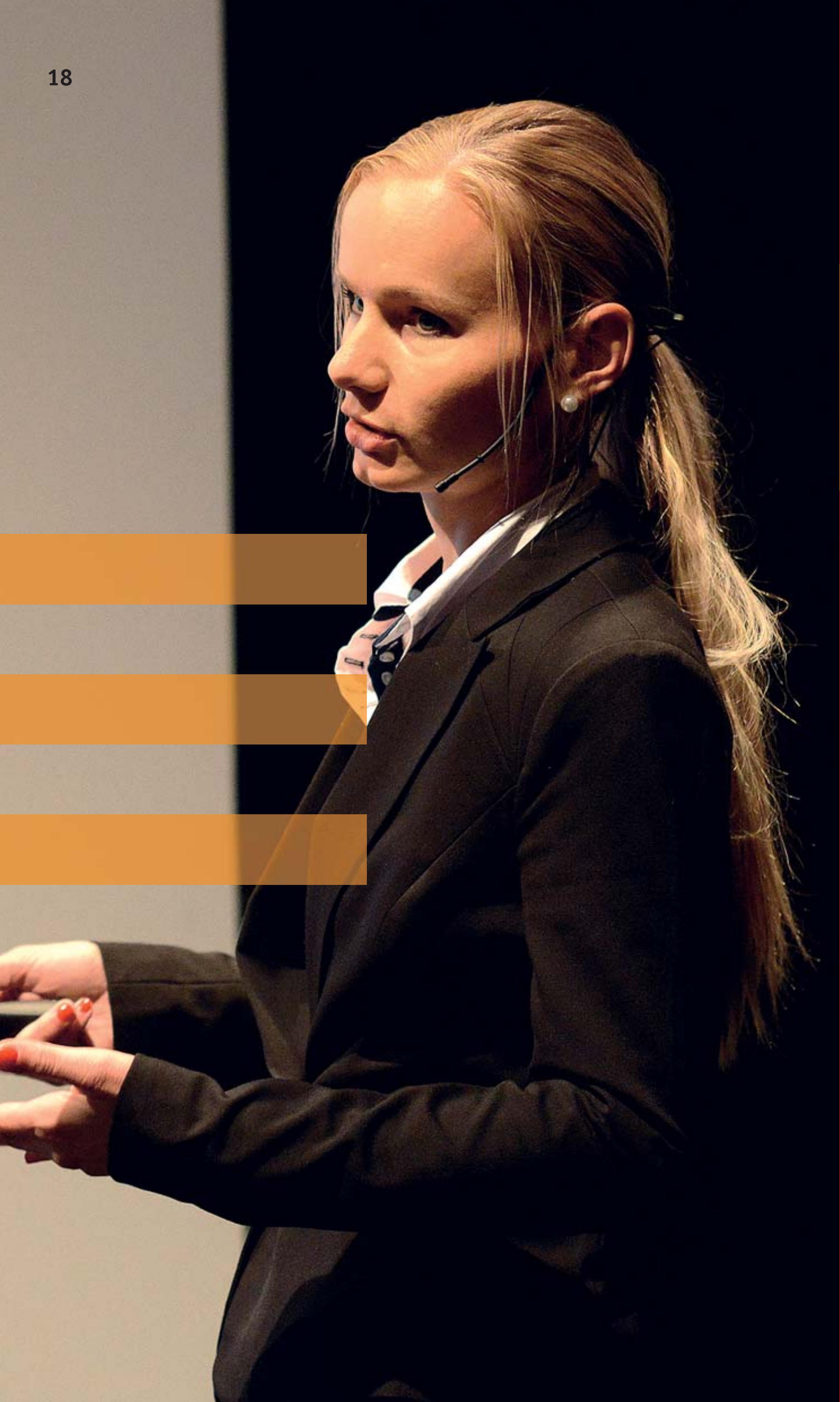
"Throughout the project we have seen Sebastiaan's enthusiasm and skill. While he came in as a motivated PDEng student, he has proven to be a professional systems engineer, ready to up new challenges."

Saphir Faid MSc
Punch Powertrain

Electrification of vehicle powertrains has become one of the key solutions to reduce carbon emissions. Many European automotive OEMs develop their own hybrid electric vehicle (HEV) and electric vehicle (EV) solutions in-house or in a partnership with other OEMs. However, many Asian OEMs and other EV project initiators prefer to buy an off-the-shelf solution. This opportunity was seen by the board of Punch Powertrain in 2006 and started the development of their own switched reluctance motors, motor drive electronics, and battery packs.

Irrespective of the market, range anxiety seems still to be an issue with battery electric vehicles. However, 75% of the Dutch drivers drive less than 75 km per day. Hence, this range anxiety is in most cases not justifiable. Therefore, PPT wanted to investigate the concept of a modular Extended-Range Electric Vehicle (E-REV). Modular, in this case, refers to the option to offer the range extender as an aftermarket product or even as a temporarily installed rental component. From a technical standpoint this meant that the range extender should not be required for vehicle operation and that it is easily removable. Furthermore the vehicle was to have a sporty character (e.g., 0-100 km/h in 8.5 seconds).

Besides demonstrating this concept, Punch Powertrain was also interested in a vehicle that can be used to test and demonstrate newly developed EV powertrain products. This gave extra requirements to the vehicle layout and architecture.



Challenges
The biggest challenge of this project was to bring the system views on the topic at a suitable level of abstraction. The defined design rules had to be explicit, reliable and robust.

Results
The design rules were defined based on the simulations and experiments from the laboratory. All functional and nonfunctional requirements were delivered and verified. The rules can serve the company as an input for further research.

Benefits
The solution brings more insight into the elements arrangement towards the low noise operation of the pushbelt.

Petra Židková PDEng

Design rules for a low noise element sequence of the CVT pushbelt

"We would like to thank Petra for her great contribution to the development of the pushbelt."

Erik van der Noll
Bosch Transmission Technology

Bosch Transmission Technology belongs to one of four business sectors of the Bosch Group, namely the automotive sector. It is the market leader in development and mass production of pushbelts, which is an essential component of continuously variable transmissions. The company started the mass production of this product in 1985. Pushbelt production exceeded 25 million units by 2012. The future prospective is due to the growing demand for more economical cars and lower CO2 promising. The CVT technology from Bosch Transmission Technology brings to the vehicle driver & passengers no torque interruption during gear change, optimal driving comfort, economical driving and option to configure multiple driving modes.

The pushbelt is made from several hundred steel elements and from around 12-30 rings, which string the elements together. The elements are arranged next to each other together with the rings in a circle. Current pushbelts are made from the elements that all have the same thickness. It is realized that applying elements with different thicknesses can change the acoustical behavior of the pushbelt.
The design rules are here the high level architecture of how should be elements arranged in order to fulfill the acoustical requirements. Proposed solution is validated on the simulation and also laboratory level.

Credits

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