This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 860243

MARIE CURIE ACTIONS

# LIVE-I ITSW6

## May 15th – 17th 2023

Organised and hosted by TU Darmstadt, Compredict GmbH, Fraunhofer LBF and VDMA, Germany

The *Lightning and Innovating transmission for Improving Vehicle Environmental Impacts* or LIVE-I is a European Cooperation project between multiple universities and industrial partners that is funded by the European Union's Horizon 2020 research and innovation programme. The main objective of the project is to achieve breakthrough technological progress in the design of lightweight transmission systems and build an innovative training network.

The LIVE-I project aims to demonstrate a significant weight reduction of gearboxes using advanced modelling tools together with advanced materials and systems. The objectives of the project however, are not limited to just weight reduction, but also extend to introducing efficiency improvements through new paradigms in the design of components and developing smart concepts in accordance with vibroacoustic comfort.

It is our pleasure to invite you to the 6th LIVE-I International Training Seminar and Workshop Event. A three-day event consisting of Seminars from industrial and academic experts in addition to dissemination of the research outcomes of the LIVE-I project. With your presence, we hope to bring forth engaging and productive scientific dialog and interaction.

The event would be held over three days in Darmstadt and Frankfurt. The schedule of the event can be found in the following pages.

The event would be held in person, however, if you are unable to make it in presence, you can also join the even online. For any queries, please feel free to contact us. Our contact details are provided on the last page.

We look forward to hosting you in Darmstadt.

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# Day 1: 15th May 2023

**Venue:** Room 113, L1|10 Gerhard Pahl-Zentrum (Lehrzentrum Maschinenbau) Jovanka-Bontschits-Straße 7, TU Darmstadt, 64287

**Online Meeting Room:** https://ec-lyon-fr.zoom.us/j/99830889629

**Arrival Instructions**:

- Tram Number 2: From Darmstadt Hbf or Luisenplatz (city centre) to TU-Lichtwiese
- Bus L: Luisenplatz (city centre) to TU-Lichtwiese

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| Schedule: 15.05.2023 | |
|---|---|
| 0900 to 0915 | Opening Ceremony |
| 0915 to 1000 | 'From PhD results to company founding, funding and scaling: Why not you?' by Dr. -Ing. Stéphane Foulard, Compredict GmbH |
| 1000 to 1045 | Mohamed Shalaby, Sono Motors GmbH |
| 1045 to 1100 | Refreshment Break |
| 1100 to 1145 | Dr. -Ing. Hendrik Schaede, Adaptive Balancing Power GmbH |
| 1145 to 1315 | Lunch Break |
| 1315 to 1400 | Adel Turić, IMS, TU Darmstadt |
| 1400 to 1500 | Prof. Dr. Christian Beidl, VKM, TU Darmstadt |
| 1500 to 1530 | Refreshment Break |
| 1530 to 1615 | Dr.-Ing. Christian Adams, SAM, TU Darmstadt |
| 1615 to 1645 | 'Reliability of printed circuit boards in automobiles: Analyse and Optimize' by Moritz Hülsebrock, Fraunhofer LBF |
| 1700 to 1730 | IMS Lab Tour |
| 1900 to 2200 | Dinner: Restaurant Sitte, Darmstadt |

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# Day 2: 16th May 2023

**Venue:** VDMA, Lyoner Str. 18, 60528 Frankfurt am Main, Frankfurt.

**Online Meeting Room:** Click Here
Meeting-ID: 392 215 387 278; Passcode: nVQtkX

**Arrival Instructions:** For those travelling from Darmstadt, we meet at Darmstadt Hbf and take the RB67 at 0830 to Frankfurt Hbf followed by S9 to Frankfurt Niederrad. Other travel options include:

By car

- Coming from the South: Take the A5 motorway, cross the "Frankfurter Kreuz" motorway interchange and then take the "Frankfurt-Niederrad (Bürostadt)" exit.
- Coming from the North: Take the A5 motorway and exit "F-Niederrad/Uniklinik".
- Coming from the West or East: At the "Frankfurter Kreuz" motorway interchange take the A5 towards Kassel. Then take the first exit - "Frankfurt-Niederrad (Bürostadt)".

By train

- From Frankfurt Airport Railway Station (Flughafen Regionalbahnhof) Take the S8 or S9 S-Bahn (suburban train) line towards Hanau and Frankfurt Central, getting off at "Niederrad".
- From "Niederrad" S-Bahn station: Walk from the Niederrad station to the VDMA. This takes roughly 10 minutes.

By plane

Fly into Frankfurt am Main airport

- Continuing by tax
  Journey takes roughly 10 – 15 minutes, costs approx. € 20
- Continuing by public transport
  Take S-Bahn (suburban railway) line S8 or S9 from "Regionalbahnhof" in Terminal 1, level 1, towards Hanau and Frankfurt Central, getting off at "Niederrad" (train every 15 minutes, journey time roughly 5 minutes).
- From "Niederrad" S-Bahn station see "By train" instructions.

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| Schedule: 16.05.2023 | |
|---|---|
| 1015 - 1030 | Opening |
| **Session 1: Digital Twins and Manufacturing Tolerances** | |
| 1030 – 1100 | **Enhancing Vibroacoustic Design through Digital Twins Enabled by Machine Learning and Transfer Learning**<br>*Barbara Zaparoli Cunha, Christophe Droz, Abdel-Malek Zine, Stéphane Foulard, Mohamed Ichchou*<br>*University: Ecole Centrale de Lyon, France*<br>*Industrial Partner: Compredict, Germany*<br>This study focuses on creating Machine Learning (ML)-enabled Digital Twins (DT) for vibroacoustic products to detect and resolve design issues before production. However, challenges arise from the lack of interpretability of ML, the non-smooth nature of vibroacoustic problems, and data scarcity at early product development stages. To overcome these issues, this work explores appropriate ML techniques, sensitivity analysis, and physics-guided features. A transfer learning-based approach is also proposed to improve data efficiency and accuracy by leveraging knowledge from previous product generations. Ultimately, the methodology will be applied to construct a DT used in the NVH optimization of gear transmissions. |
| 1100 – 1130 | **Manufacturing margins and robustness of NVH prediction**<br>*Ranim Najib, Jessica Neufond, Giuseppe Petrone, Francesco Franco, Sergio de Rosa*<br>*University: Universita degli Studi di Napoli Federico II*<br>*Industrial Partner: Vibratec SA, France*<br>A numerical scheme is developed to rank gear design parameters based on the Morris method, which determines the effect of these parameters on the peak-to-peak static transmission errors for helical and spur gears under different torque values. Different evolutionary algorithms are tested, and the particle swarm optimization problem is integrated to correct gear geometry and reduce vibroacoustic response at the source. The optimized gears are assessed for robustness, and experimental investigations are conducted to evaluate the impact of mounting and manufacturing errors, including lead slope and profile slope errors. Ten gear configurations are tested under various operating conditions, and the results are compared with a predictive tool based on statistical computations. Meshing excitations resulting from gear uncertainties also cause notable fluctuations in the studied dynamic responses. |
| 1130 -1200 | Refreshment Break |

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## Session 2: Weight reduction of transmission systems

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| | **Geometry and mounting optimization of lightweight gearbox components**<br>Firas Bejar, Joel-Perret Liaudet, Olivier Bareille, Mohamed Ichchou, Mauro Fontana<br>*University: Ecole Centrale de Lyon, France*<br>*Industrial Partner: Powerflex SRL, Italy* |
| 1200 - 1230 | The research optimizes gearboxes using lightweight gears and evaluates their dynamic behaviour. Random pattern gears are implemented to reduce modulation effects compared to conventional holed configurations and are more stable to boundary conditions compared to topologically optimized gears. Different gear contact analysis software packages were tested to compare their modelling capabilities for lightweight gear simulation and identify limitations that may impact the outcome of the study. A random gear blank generator was built to vary gear geometries and identify the most influential pattern parameters for optimization, based on collected excitation and dynamic response data |
| | **Material optimisation of lightweight gear transmission components**<br>*Jessica Neufond, Giuseppe Petrone, Francesco Franco, Sergio De Rosa*<br>*University: Universita degli Studi di Napoli Federico II, Italy*<br>*Industrial Partner: Vibratec SA, France* |
| 1230 - 1300 | The study investigates the development of lightweight gear transmission systems by employing composite materials in metal-composite gear designs. It optimizes the balance between Static Transmission Error (STE) response and mass reduction through a robust nonlinear finite element (FE) method for gear contact. The study includes static and dynamic analyses of hybrid metal-composite spur and helical gears, comparing their vibroacoustic performance to standard steel gears and highlighting the potential advantages of these innovative hybrid systems. |
| | ***Lightweight gearbox housing using novel housing architecture and materials***<br>*Daniel Amaral, Mohamed Ichchou, Pascal Fossat, Michelle Salvia*<br>*University: Ecole Centrale de Lyon, France*<br>*Industrial Partner: Adaptronica Sp. z o.o., Poland* |
| 1300 - 1330 | The presentation will explore two approaches to improving gearbox housing design to reduce its mass and improve its performance. The first approach centres on reducing the amount of metallic material in the housing while simultaneously improving its NVH characteristics by introducing locally resonant metamaterials (LRMs). The second approach delves into the use of composite materials in gearbox housings to reduce their mass. |
| 1330 - 1430 | Lunch Break |

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## Session 3: Vibration Control

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| | **Semi-active vibration control approaches**<br>*Sina Soleimanian, Giuseppe Petrone, Francesco Franco, Sergio De Rosa, Przemysław Kołakowski*<br>*University: Universita degli Studi di Napoli Federico II, Italy*<br>*Industrial Partner: Adaptronica Sp. z o.o., Poland* |
| 1430 – 1500 | This research consists of two phases, (A) and (B). Phase (A) proposes a computational approach on semi-active noise mitigation using the virtual acoustic black hole (ABH) effect by designing a shunt circuit. Phase (B) proposes an optimal semi-active vibration control technique for mechanical transmission systems using metal rubber (MR) whose adaptive stiffness and damping properties were proved recently by literature. To apply the control scheme, initially, the National Instruments hardware and software are employed. Subsequently, the control scheme is deployed using Raspberry Pi programmed with Python, as a software-embedded and cost-effective solution. The highlighted wide-band vibration attenuation effect of the MR-based semi-active solution makes it an intriguing issue for further investigation. |
| | **Improvement of NVH behaviour of a gearbox using the traction motor**<br>*Sidharth Dave, Jessica Neufond, Rainer Nordmann, Stephan Rinderknecht*<br>*University: TU Darmstadt, Germany*<br>*Industrial Partner: Vibratec SA, France* |
| 1500 – 1530 | Gear trains are plagued by self-excited vibrations that are concentrated at the mesh frequency and its harmonics due to their varying mesh stiffness and deviations from the ideal involute profile. This behaviour is more pronounced in electrified vehicles due to reduced masking by the combustion engine. However, the presence of a traction motor offers the advantage of having a potential actuator for actively countering these vibrations without adding any additional weight or packaging constraints, in addition to being cost effective. This research explores an approach of countering these vibrations through control strategies that utilise the traction motor as the actuator. |
| 1530 -1600 | Refreshment Break |

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## Session 3: Vibration Control

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|---|---|
| 1600 - 1630 | **Development of Actuator-Amplifier Systems for the Active Vibration Control of Gearboxes**<br>*Sherif Okda, Sven Herold, Rainer Nordmann, Tobias Melz*<br>*University: TU Darmstadt, Germany*<br>*Industrial Partner: Powerflex SRL, Italy*<br>The research focuses on developing an active vibration control system to control the vibrations of a transmission system housing. Through developing powerful and efficient actuators and power electronics. Simulations are established to tackle this optimization. In addition, a mock-up system with a simplified automotive transmission system is constructed to demonstrate the efficiency of the active vibration control system. An inertial mass actuator has been manufactured and tested to control the housing. The vibrations on the gearbox housing are reduced significantly. Yet other concepts are being investigated, which are more integrated in the system. In addition, a more dedicated power amplifier is under development. |
| 1630 - 1700 | **Development of system for active vibration reduction**<br>*Sneha Nampally, Mauro Fontana, Rainer Nordmann, Stephan Rinderknecht*<br>*University: TU Darmstadt, Germany*<br>*Industrial Partner: Powerflex SRL, Italy*<br>The research deals with a design of an active vibration control system to suppress unwanted vibration caused by gear mesh at high frequencies in the range up to 5000 Hz. Actuators, vibration sensors and a control algorithm are chosen and evaluated specifically for the gearbox housing structure. The main advantage of the projected system consists of the opportunity to further reduce weight of the passive solutions and to loosen the manufacturing tolerances of the gears and thus reduce cost of production. The research focuses on selection of a suitable control approach with optimization of actuator positions, number of actuators, sensor positions, number of sensors, and system integration, in the presence of uncertainties and complicated gearbox geometries |
| 1700 - 2200 | Frankfurt city tour and Dinner (Restaurant Dauth-Schneider, Frankfurt) |

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# Day 3: 17.05.2023

**Venue:** Fraunhofer Institute for Structural Durability and System Reliability, Bartningstraße 47, 64289 Darmstadt

**Online Meeting Room:** https://ec-lyon-fr.zoom.us/j/99830889629

**Arrival Instructions**: We meet at Luisenplatz (city centre) at 0800 hrs and take Bus 5E upto Kranichstein Institutszentrum, Darmstadt.

| Schedule: 17.05.2023 | |
|---|---|
| 0900 to 1000 | LIVE-I General Assembly |
| 1000 to 1015 | Refreshment Break |
| 1015 to 1100 | Seminar on Vibration Control by Jonathan Millitzer |
| 1100 to 1145 | Seminar on Metamaterials by Sebastian Rieß |
| 1145 to 1300 | Lunch |
| 1300 to 1500 | Lab Tour |
| 1500 to 1510 | Closing Ceremony |

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# Contact Details

If you have any questions, please feel free to contact us.

**Sidharth Dave**, IMS, TU Darmstadt
Email: sidharth.dave@tu-darmstadt.de

**Sneha Rupa Nampally**, IMS, TU Darmstadt
Email: sneha_rupa.nampally@tu-darmstadt.de

**Sherif Okda**, SAM, TU Darmstadt
Email: sherif.okda@sam.tu-darmstadt.de