ArchitectECA2030

SC 2 Demo 2.3 Key Card

Health monitoring system for electric motors

Main aim	
When operating motors, a variety of problems, such as mechanical and thermal imbalances, misalignment, housing deformation, aging and wear, etc., can lead to mechanical vibrations of rotating parts. These can also be measured on non-rotating parts, such as the motor housing. Combining measurement results from other sources, such as the controlling inverter, with results from measurements directly on the motor can improve the accuracy of the fault diagnosis.	
Partner	*TU Dresden / ILK (TUDR), Brno University of Technology (BUT)*
ECS value chain	*Research / Tier 1*

State-of-the-art	**Beyond SotA / Innovation**	**Targeted TRL**
• *Motor monitoring using external sensors* • *Evaluation of machine vibration by measurements on non-rotating parts* • *Vibration condition monitoring*	• *Motor monitoring using structural integrated sensors* • *Usage of 3 strain gauge sensors in addition to a 3-axis accelerator*	*TRL3 - TRL4*

Link to project objectives

Objective	***Addressed (Y/N)***	***How***
O1 – Continuous robust design optimization for each part in the ECS value chain	*N*	
O2 – Framework for safety validation of ECS value chain	*N*	
O3 – Identification & management of residual risks over the entire ECS value chain	*N*	
O4 – End-user acceptance by trustworthy ECS value chain	*Y*	*Accurate fault diagnoses and measurements of actual wear and tear during the operating life of the electric drive motor, give the user more safety and confidence and can thus lead to greater acceptance of the technology in automated vehicles.*
O5 – Zero emissions, zero crashes, zero congestions by ECA2030-car	*Y*	*Measurements during the operating life make it possible to consider the actual health state of the drive motor in the motor control system and to replace worn components before they fail and can become the cause of an accident.*

Joint demonstrator (JDEM SC2)

Demo 2.1	***Demo 2.2***	***Demo 2.3***
SC	*SC*	*SC*

Linked supply chains (Y/N)

SC1	*N*
SC2	*Y*
SC3	*N*
SC4	*Y*

Considered MonDev layers

System (S)	*N*
Subsystem (SS)	*N*
Component (C)	*N*
Subcomponent (SC)	*Y*

Setup

***TUDR** will carry out the measurements on the motor model using sensors integrated into the end shield of the motor (Figures 1 and 2). The measurements shall also be used to characterize the sensors. In addition, the **TUDR** will simulate the influence of unbalances of the rotor. At **BUT** measurements on the real motor are carried out.*

Mechanical faults of a motor may lead to a changed electrical drive power and can thus be detected by monitoring the electrical output parameters of the inverter if relevant motor parameters, such as the winding inductance, are known. However, since motor faults are not the only factors influencing the output parameters of the inverter, the detection of fault conditions can be improved in practice by further monitoring measures, such as the detection of mechanical vibrations directly at the motor.

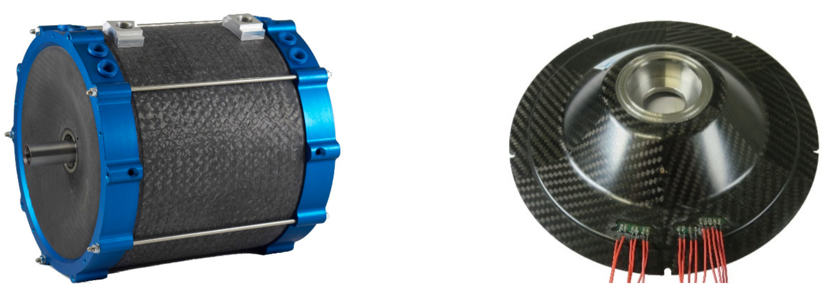

Figure 1: Leight-weight electric motor and end shield with structurally integrated sensors

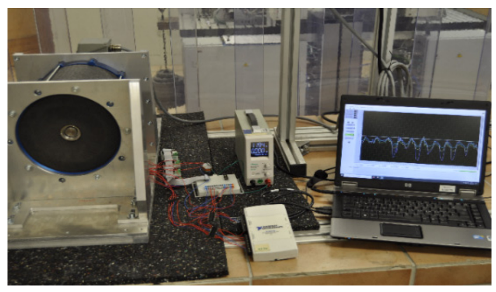

Figure 2: Test bed for practical measurements on the motor

Benchmark scenario/mission/etc.

In the context of the demonstrator, the focus is on mechanical vibrations caused by imbalances in the rotor, since imperfections in the rotor and shaft often lead to a change in the mass distribution or to a shift in the axis of rotation and thus to imbalances. In addition, vibrations caused by the normal load on the motor are measured. For the measurement of mechanical vibrations, three strain gauges and a 3-axis accelerometer were integrated directly in the end shield of the motor. This allows the measurement quantities vibration displacement and vibration acceleration listed in ISO 20816-1 to be recorded indirectly and directly, respectively.

For long-term operation of machines, ISO 20816-1 proposes the definition of two limit values – alarm and trip. Applying these operational limits to a drive motor for electric vehicles, a warning and a recommendation for predictive maintenance could be issued to the user if the alarm value is exceeded. In addition, the motor controller could take into account the current state of the drive motor and, if appropriate, initiate actions such as limiting the maximum speed. When the trip value is exceeded, the motor can then either be throttled back or stopped.

KPIs (related to requirements)	**Baseline**
• *Degree of* differentiation (How well can different influences be differentiated in the measurement signals?*)*	• Output signal of the measurement unit with vibrations • Output signal of the measurement unit when the motor is idling
• *Degree of robustness* (How reliably can the vibrations be determined from the measurement signals?*)*	• *Distinguishability of vibrations generated by different sources*
• *Degree of sensitivity* *(How well does the specific sensor type detect the vibrations?)*	• *Output signal of the sensor with vibrations* • *Output offset signal of the sensor without vibrations*

Evaluation

The measurements allow reliable identification based on the frequency and amplitude of the measured vibrations (Figure 3). The frequency of the measured vibrations allows a clear assignment to their source (load or unbalance). As the individual frequency ranges in which the vibrations occur partly overlap, it is also necessary to know the nominal speed of the motor for an exact analysis. An assessment of the measurement results in accordance with the ISO 20816-1 standard has provided practical and comprehensible decision criteria.

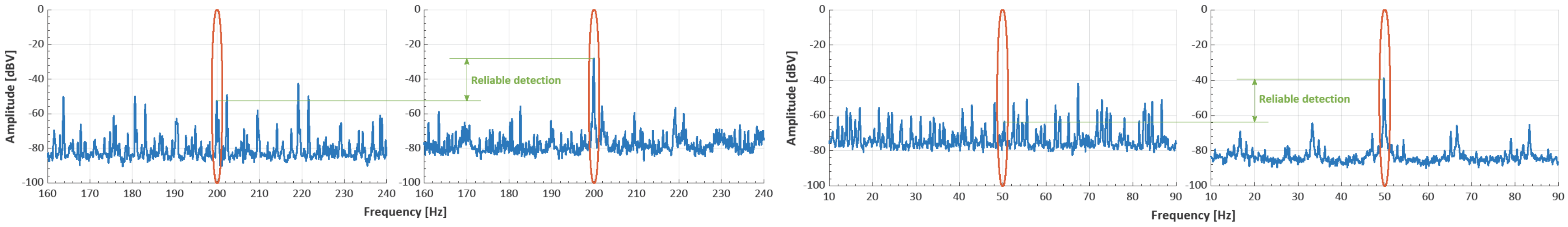

*Figure 3: Measured vibration signals (frequency spectra) at 3000 rpm — (**left**) Real motor without and with a load of 40 Nm (values of a strain gauge) (**right**) Real motor without imbalance and motor model with imbalance of 2152.1 g mm (values of the acceleration sensor)*

Final status / Highlights

- *Simulations and practical measurements on a motor model and a real motor were carried out*
- *The experimental results were evaluated and assessed according to current standards*
- *The general appropriateness of the structurally integrated sensors has been proven*
- *Future research areas for the practical use of this technology have been identified*

Impact

- *Monitoring of the drive motor during the entire service life*
- *Avoidance of motor failures through early maintenance recommendations*
- *Improvement of behavior diagnosis by combining results of direct measurements on the motor and measurements inside the inverter*

Used standards

- *ISO 10816-3:2017-08*
- *ISO 13373-1:2002-02*
- *ISO 13373-2:2016-01*
- *ISO 13373-3:2015-09*
- *ISO 20816-1:2016-11*
- *ISO 21940-1:2019-02*
- *ISO 21940-11:2016-11*
- *ISO 21940-31:2013-08*
- *ISO 26262:2018-12*

Future standardization potentials

- *Not perceived yet*

ArchitectECA2030 has been accepted for funding within the Electronic Components and Systems For European Leadership Joint Undertaking in collaboration with the European Union's H2020 Framework Programme (H2020/2014-2020) and National Authorities, under grant agreement n° 877539.

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