Implementation of online predictive maintenance in the car production and in the service

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Abstract: The rapid development of the electrical architecture of road vehicles opens up new avenues for online diagnostics and servicing. This is facilitated by the rapid development of the mobile telecommunication networks and the data transfer rate and offered bandwidth. The increasing complexity of vehicle systems is moving vehicle diagnostics more and more from the workshop to the manufacturer in certain special cases. Failures of complex and thus more expensive systems increase vehicle repairs and maintenance costs (TCO: total costs of ownership). A preventive maintenance can reduce these costs and if all this is done online, the customer does not have to visit the service even for a vehicle condition check-up. In the following, it will be discussed about current and especially future applications of online preventive maintenance of road vehicles.

1. The beginning of online predictive maintenance systems

AIRBUS and BOEING have been using the ACARS system for online communication of aircraft and ground handling since the late seventies. (Fig. 1.) The communication way was initially radio, but later satellite. It helps to transfer also diagnostic and maintenance date to the ground backend.

Who does not remember the disappearance of Malaysia Airlines Flight 370 on March 8, 2014? This case was (also) clarified with the help of ACARS, since for hours after the plane disappeared from radars, the system's maintenance module still sent the engine data to the ground control center.

The function of this module is to monitor the condition of the engine using various sensors and to transmit this data to the airline's maintenance department for evaluation. Thus, the previous strictly operating hour-based planned preventive maintenance system has been replaced by a more flexible predictive system for monitoring the actual technical condition of the aircraft, offering fewer unnecessary breakdowns under given operating parameters and reducing aircraft downtime by anticipating more serious technical failures, reducing its operating costs.

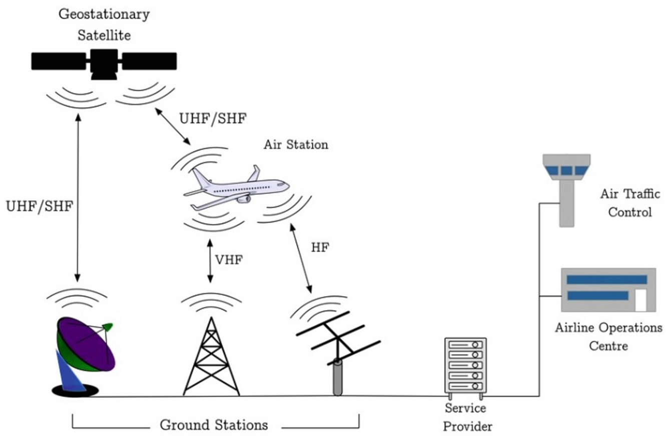

Fig. 1. schema of ACARS: aircraft communication and reporting system [1]

Online: ISBN 978-963-88875-7-3

2. Online diagnostics in the automotive industry

2.1 Schema of online data transfer between road vehicles and backend infrastructure for service in the future

With the increase in complexity and costs, supported through the development of telecommunication networks, the automotive industry is gradually taking over from the aerospace industry the online vehicle diagnostics and the preventive repair / maintenance philosophy based on the collected data from vehicles.

Previously, the vehicle's control units themselves have collected and stored various measurement data e.g. freeze frame data of DTC's (diagnostics trouble code) and measured values too.

The increase in online bandwidth through 4G and 5G networks allows this data to be transmitted in real time to the manufacturer for further analysis, without the need for the customer to go to a dealership. Currently, only a few premium cars are capable of this, but in the future this method is likely to become fully widespread.

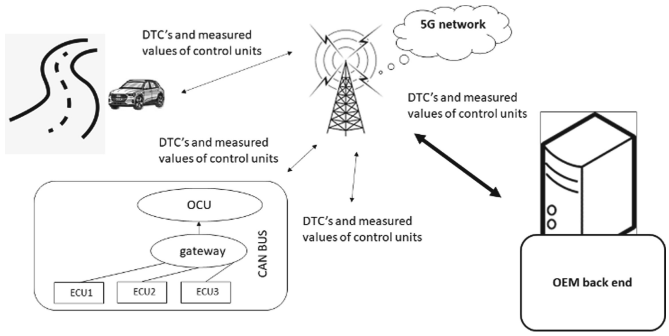

Fig. 2. way of communication between vehicle and backend

(OEM: original equipment manufacturer – "car maker")

This vehicle gateway is connected to all control units and can also store data.

The communication with the backend through 4G or 5G network is based of a SIM-card or integrated e-SIM supported by OCU = online communication unit or connected gateway in the case of after sales. [2]

2.2 Data transfer between vehicle and backend in the meantime – in the car manufacturing

In the past the vehicles needed to be connected through cable to the diagnostic scan tool.

As next step the cable has been replaced by local WIFI network in the production or test track area and the vehicles used an OBD socket – wi-fi interface.

The actual way of improvement could be an implementation of a local 5G network covering all the production and test areas while using of an OBD socket – 5G interface in the vehicle (see Fig. 3.)

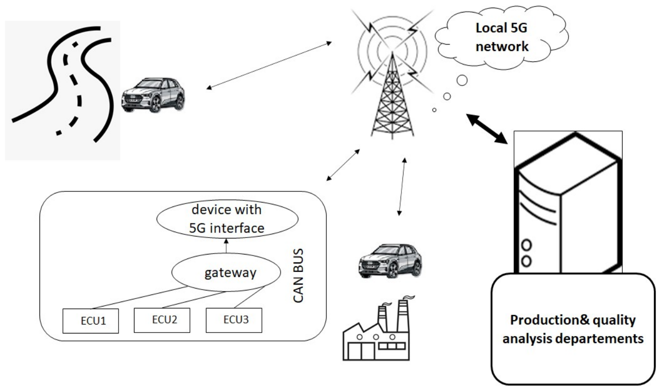

Fig. 3. way of communication between vehicle and backend in the car factory area [3]

With that technology it is possible to transfer DTC's and different kind of measured values from vehicle's control units through its gateway unit supported by online connection units based of a local 5G network to the back end.

A very important benefit is also to be able to realise a real time diagnostics connection between vehicles and users PC's.

All this open a lot of new opportunities to reduce quality costs during vehicle production but also in field.

3. **Principle of online predictive maintenance**

Predictive maintenance systems follow the principle to prevent of subsequent serious technical failures to save quality and warranty costs and to achieve a better customer's satisfaction.

The method is, to collect and to evaluate of different measured values and to find abnormalities which show a beginning failure mechanism.

The system sends alerts to the users or customers or service so give the chance to repair the vehicle before getting a real claim.

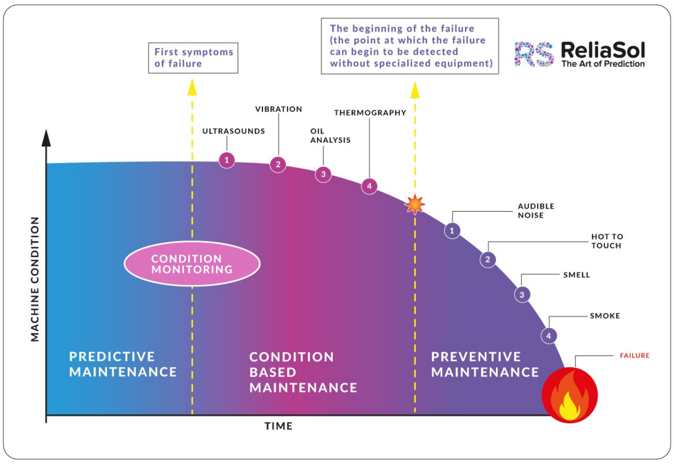

Fig. 4. Principle of preventive/predictive maintenance [4]

4. Examples for predictive maintenances / repairs in the vehicle production

4.1. Leakage of aluminium air condition pipe

Porosity in material or soldering issues can also lead to a very small leakage of vehicle's air condition system and it's not 100% testable during system test and filling procedure.

In worst case the system pressure will reduce only later in field under a critical level caused a warranty claim.

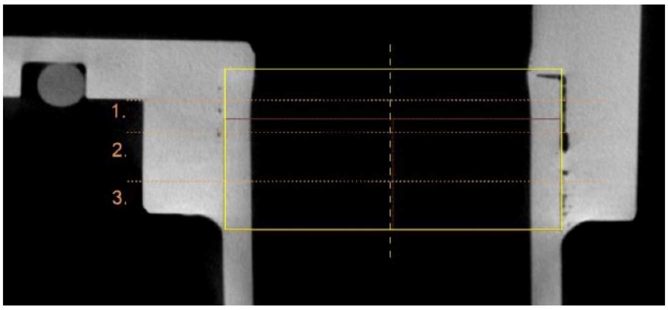

Fig. 5. NOK soldering of A/C pipe (porosity and filling)

Supported by online vehicle diagnostics (see Fig. 6.) it would be possible to monitor/check the gas pressure of A/C system stored vehicles on yard before shipping

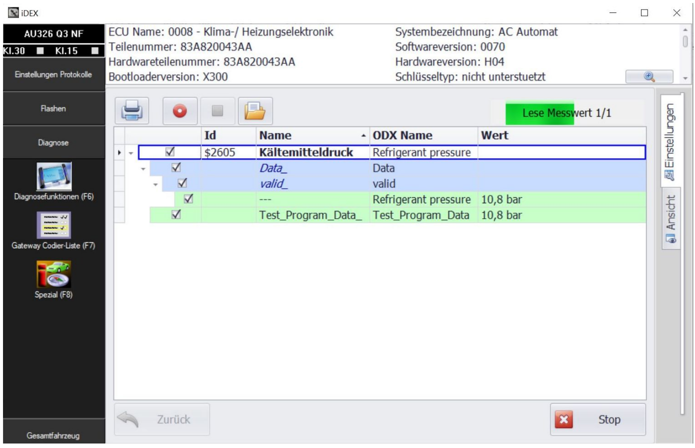

Fig. 6. Example for A/C system pressure measured value performed trough OBD II and IDEX scan tool [5]

4.2. State of charge monitoring of stored vehicle's batteries

In the meantime – e.g. due to microchip shortage situation or other issues (Ukraine war) – frequently sold vehicles, stored on factory area / yard / harbour are waiting for parts.

With the time their batteries can reach an SoC-level (state of charge) which requires a recharging or worst case a replacing.

In field it is recommended to use an SoC-monitoring but in the factory, because of the very new battery condition so a few basis for calculation of SoC we use a charging balance (basically a difference of charging and discharging electrical energy of all performed cycles).

It is possible, to get all vehicle's SoC-level and to determine the VIN's (vehicle identification number) needed a rework. (see Fig. 2. and 3.)

With online monitoring of SoC values it is no longer needed to check the condition of the batteries of the stored vehicles manually.

A PDI (pre delivery inspection) claim at dealership afterwards can be also avoided.

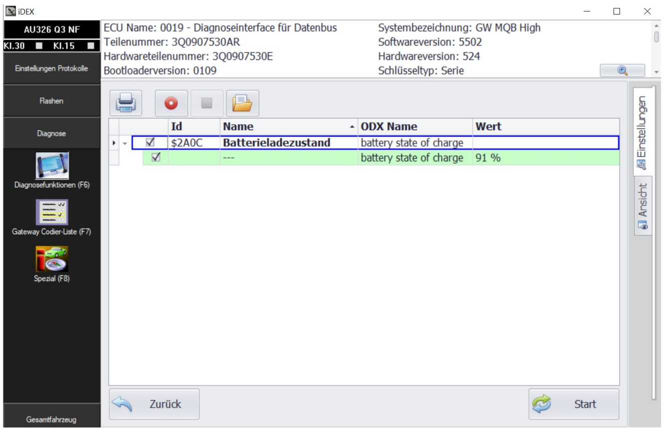

Fig. 7. Example for measured battery SoC value performed trough OBD II and IDEX scan tool [6]

4.3. Oil temperature monitoring of vehicles during internal test drive on test track

Eventual manufacturing issues of internal combustion engines (machining, screwing) can lead in worst case to very expansive total engine damages.

Using of online, real time vehicle diagnostics during testing procedure on roller test bench or on test track can help to detect abnormal temperatures on time and through immediately stopping of engine also to avoid serious defect with high rework potential. (See Fig. 2. and 3.)

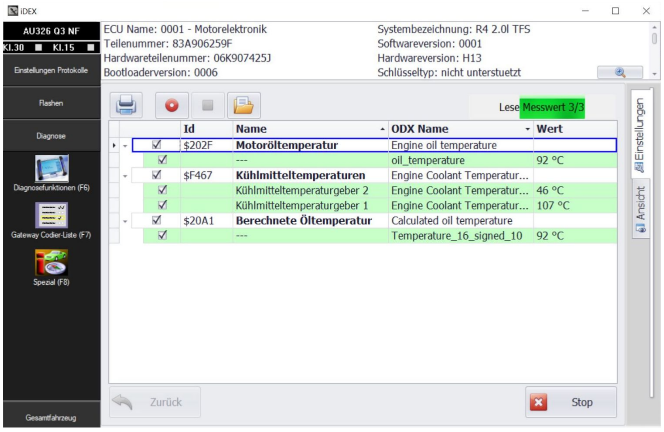

Fig. 8. Example for measured oil temperature performed trough OBD II and IDEX scan tool [7]

Online: ISBN 978-963-88875-7-3
Editor: Dr. Péter Tamás

5. **Examples for predictive maintenances / repairs in the field (service)**

5.1. Monitoring of SoH and module's condition of BEV high voltage batteries

Since batterie is the most expansive part of an electric vehicle and it has also a huge impact on durability, reliability and safety of the car it is important to observe its lifetime condition in field.

Beginning abnormalities of battery modules can lead to overheating and to dangerous "thermal runaways" and also "just" to damages of cells and so vehicle tow in cases but to "simple" capacity loosing (potential warranty claim) too.

In order to avoid such as issues the temperature and the voltage difference of HV-battery modules can be monitored and also the SoH-level (state of health) shows the current condition of the energy source system.

(SoH is a difference of charging and discharging electrical energy of all performed cycles). See Fig. 2.

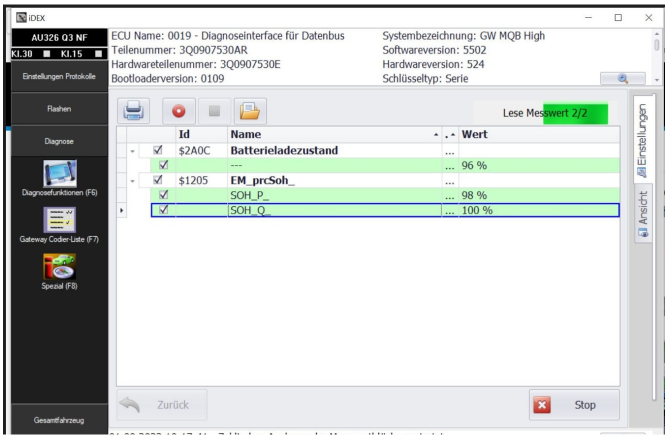

Fig. 9. Example for measured SoH values performed trough OBD II and IDEX scan tool [8]

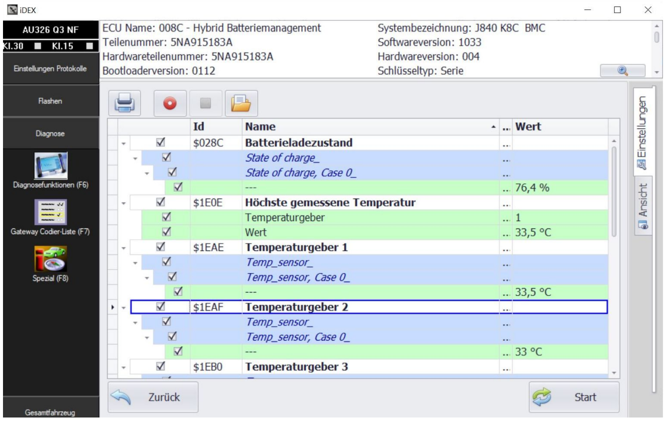

Fig. 10. Example for measured oil temperature performed trough OBD II and IDEX scan tool [9]

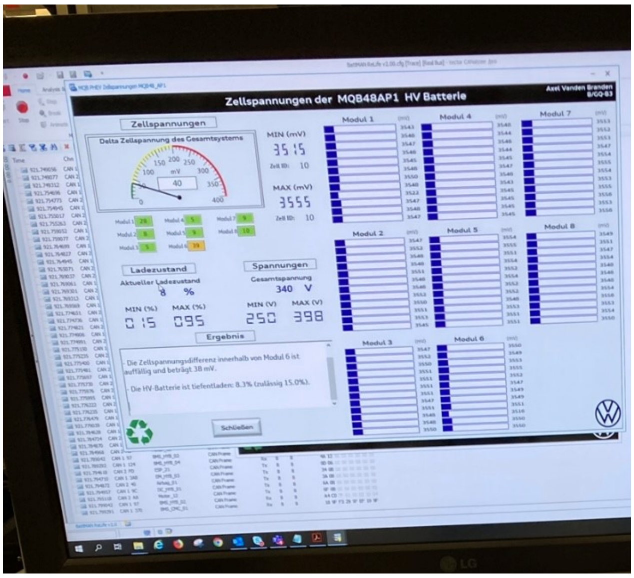

Fig. 11. Example for measured voltage differences between cell modules performed trough "BATMAN" scan tool [10]

5.2. Monitoring of electric drive motor's coolant leakage

The electric motors of high performance BEV's can be cooled with water too. A certain level above also its rotor has to be cooled. In this case there is an axial sealing for the rotor axle which is very important from system reliability perspective. It is a normal leak to observe. This very small volume of coolant leak is collected in a reservoir. An abnormal leak can lead to a rapidly filling of this canister and cause an electrical short circuit in the electric motor which means a total damage.

In order to avoid this issue (tow in vehicle, high warranty cost, customer unsatisfaction) the level of gathered coolant could be measured and also online monitored. A certain level per defined milage above could trigger an alarm.

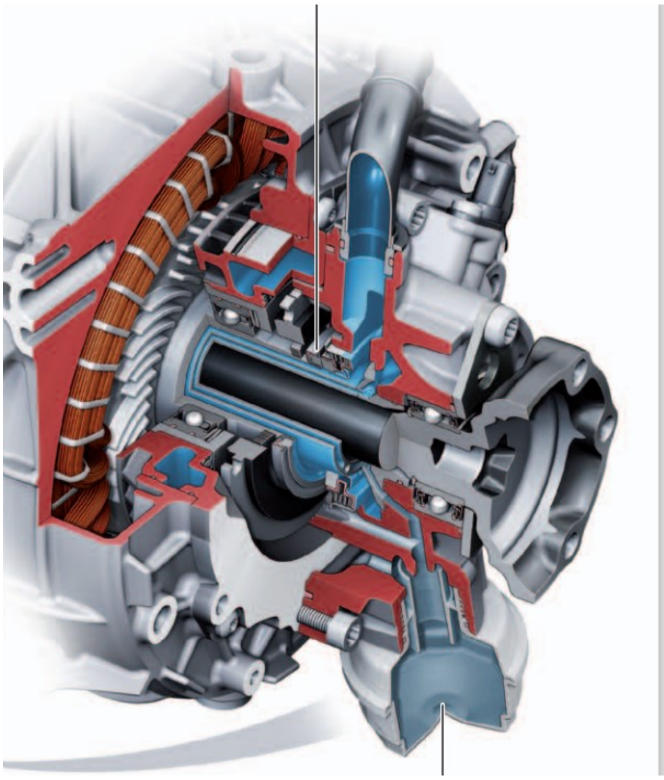

Fig. 12. Rear axle rotor cooled electric motor of Audi e-tron (95/165 kW) with leak reservoir bottom right [11]

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