# New Technologies for Remanufacturing of Automotive Systems Communicating via CAN Bus

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**Abstract**
The present paper summarizes the recent methodologies, technologies, results and opportunities in the field of analyzing and extending the life cycle of automotive systems by remanufacturing that have been developed within the European research project "CAN REMAN", conducted by Bayreuth University in cooperation with two other universities and eight industrial partners. The aim of this project is to develop appropriate and affordable testing and diagnostics technologies that enable small and medium sized enterprises (SME) to remanufacture mechatronic vehicle components.

**Keywords:**
Remanufacturing; Testing Automotive Components; CAN Bus Communication

## 1 INTRODUCTION

Raising requirements on occupant safety and comfort on the one hand and the introduction of new emission regulations on the other hand, forces the automotive manufacturers to enhance their products continuously. In order to achieve these improvements, electronic systems, based on microcontrollers, have found their way into modern cars and they contributed considerably to many new advantages in terms of safety and comfort such as ESP/ESC (Electronic Stability Program), ABS (Antilock Breaking System), PAS (Parking Assist System), EHPS (Electro Hydraulic Power Steering) or EAS (Electro Assisted Steering). Nevertheless, the new trend of modernization has an immense impact on the remanufacturing business. It can be seen that new branches in electronic remanufacturing arise. In contrast to that, the knowhow of traditional remanufacturing companies has eroded rapidly and even the industrial principle of remanufacturing is at risk. Due to the fact that modern cars incorporate up to 80 of these mechatronic and electronic systems that are communicating with each other e.g. via the vehicle controller area network (CAN), remanufacturing of these automotive systems requires innovative reverse engineering knowhow, methodological innovations and new technologies, especially focussing on the tasks testing and diagnostics of systems and their subassemblies. Since traditional remanufacturing companies do not have much capacity to build up the appropriate knowhow, the Chair of Manufacturing and Remanufacturing Technologies at Bayreuth University assists these companies in reverse engineering, as well as finding new methodologies and technologies for remanufacturing [1] [2].

In the following chapters, recent methodologies and technologies for automotive components will be presented on the example of an electro-hydraulic power steering (EHPS) pump. The results have been obtained within the European research project "CAN REMAN" which is conducted by Bayreuth University, Linköping University (Sweden), the University of Applied Sciences Coburg, Fraunhofer Project Group Process Innovation and eight industrial partners. The target of this project is to enable independent aftermarket (IAM) companies to remanufacture modern automotive mechatronics for multiple life cycles and electronics with innovative reverse engineering skills as well as to develop appropriate and affordable testing and diagnostics technologies.

## 2 REMANUFACTURING TODAY

Remanufacturing is defined and known as the industrial manufacturing of "good as new" products from used and returned products. This means, that remanufacturing is the process of restoring a non-functional, discarded or traded-in part to like-new condition, giving the product a further life. The products, also known as "cores", are brought to a shop floor, where they run through the five steps of remanufacturing [3] [4].

### 2.1 The Remanufacturing Market - A hidden Giant

While early remanufacturing was limited to a hand full of expensive capital (so called "investment") goods, the number and variety of remanufactured products is tremendous nowadays and it is still increasing [5]. Even though the estimations about the current scope of remanufacturing activities vary, two comprehensive studies discovered the impact on the economy in the US. The first study, published in 1996 and updated in 2003 by Lund of Boston University is summarized in Table 1. Lund divided the great variety of currently remanufactured products into six major classes as pointed out by Table 1 [3] [6].

| Categories | Companies [Amount] | Annual Turnover [Mio. $] | Employees [Number] |
|---|---|---|---|
| **Automotive components** | 50.538 | 36.546 | 337.571 |
| **Electrical devices** | 13.231 | 4.633 | 47.280 |
| **Office furniture** | 720 | 1.663 | 12.148 |
| **Machines** | 685 | 1.272 | 10610 |
| **Tires** | 1.390 | 4.308 | 27.907 |
| **Toner cartridges** | 6.501 | 2.475 | 31.872 |
| **Others** | 250 | 2.009 | 14.372 |
| **Summation** | 73.315 | 52.906 | 481.760 |

Table 1: Main remanufacturing categories and their magnitude in USA [6].

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The second and more reliable study, conducted by the OEM Product-Service Institute (OPI), is based on a different methodology to fill in the gaps from the Lund study. The idea was to use the current replacement value (CRV) of actual products as basis for estimating the remanufacturing expenditures. These remanufacturing costs were estimated by experts from each industry as a percentage of the CRV. The benefit of this study, which does not make extensive use of real data, such as in Lund's study, is that a broader range of industries was addressed [7]. The results of the OPI study can be found in Figure 1.

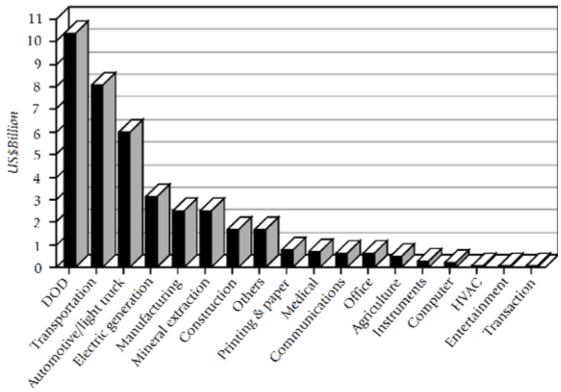


Figure 1: Remanufacturing expenditures by industry [7].

Although the estimates differ to a certain extent, the conclusion given is clear. Remanufacturing offers tremendous untapped opportunities. One of the most beneficial area for remanufacturing is the automotive sector that covers 70 % of all remanufacturing companies and that has an annual turnover of 36 Billion US-$. The background of these companies highly differs. While in some cases OEMs and OEs remanufacture their own products, the plurality of remanufacturers is of smaller subcontractor or "third party" nature. Those smaller companies need to reverse engineer the products themselves.

### 2.2 Remanufacturing in a five-step-process

As stated before, remanufacturing, also referred to as product recycling, is organized in an industrial process, in order to have the same advantages and benefits as series production. Among others, the remanufacturing process in five steps (Figure 2) aims to maintain a constant quality level as well as to formulate a rational and reproducible production process.

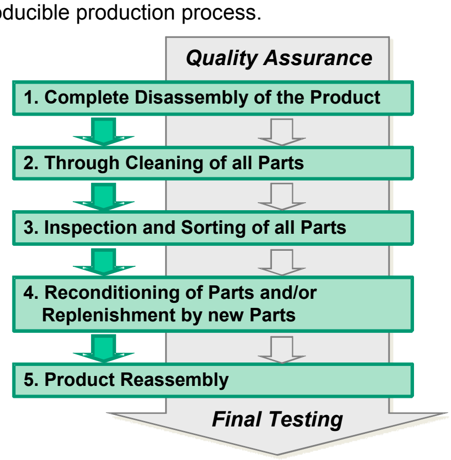


Figure 2: Traditional remanufacturing process chain [4].

In order to reach the same quality level, product reliability, safety and lifetime level, to meet current safety standards and to provide the same warranty like a new product, adequate quality assurance measures are applied in every step [1] [4]. At the end of the process chain, each remanufactured product has to pass a 100 % test which should be seen as an integrated part of the whole process chain rather than as an independent "sixth step" [4]. At the bottom line, all remanufactured products arrive at the customers with the same quality level compared to the factory brand new counterpart, or even better [1].

## 3 AUTOMOTIVE MECHATRONICS CHANGE TODAY'S REMANUFACTURING

The term "mechatronics" was formulated in 1969 in Japan and it is an artifice that describes a system which combines mechanics, electronics and information technologies. A typical mechatronic system gathers data, processes the information and outputs signals that are for instance converted into forces or movements [8].

### 3.1 Technological Change of Vehicles

Automotive parts should not longer be seen as isolated standalone applications with few mechanical and electrical inputs and outputs. Now, they have the capability to communicate to each other and to share the same sensor information. Subsequently, the communication of the different automotive subsystems helps the OEMs to reduce weight and cost by sharing the same sensors and reducing cable doubling (cable length) in modern vehicles. For the driver the network and communication within the car remains invisible and he feels the car behaving like ten years ago despite of some additional comfort functions.

But if we take a closer look, modern vehicles resemble more or less a distributed system. Several embedded computers – often referred to as electronic control units (ECUs) – communicate, share information and verify each other over the vehicle network. One of the commonly used communication networks in vehicles is the CAN-Bus (Controller Area Network). Within this network structure, each control unit has at least one unique identifier (ID) on which it broadcasts messages that again incorporate different signals and information [8]. Easily speaking, in case of a missing or faulty participant in the network, all other controllers will notice the participant as they have a lack of information. The lack of information or errors on the CAN bus force the other systems to operate in a "safe mode". In reverse, a controller not connected to the specific vehicle network stops its operation patterns and falls into "safe mode".

### 3.2 Difficulties for Remanufacturers

As stated before, the introduction of electronic networks into modern cars entails enormous problems for remanufacturers. Modern electronic and mechatronic vehicle components cannot be tested as easily as traditional electrical and mechanical ones. While it was usually sufficient to link electrical systems to the power supply (battery), modern mechatronic and electronic systems gather a lot of information from the vehicle environment and driving conditions using plenty sensors and the CAN bus network of the vehicle. As a consequence, connecting all sensors and the power plug to the device under test (DUT) is insufficient unless the device is connected to the network of a real car or an adequate simulation of the communication in the vehicle.

Following these statements, the key for successful remanufacturing and testing of a certain automotive system lies in the simulation of the complete network communication in the vehicle. Unfortunately, there are no tools available in the market that allow the remanufacturers to simulate a complete car of a specific type and model easily. In each case, the car matrix (CAN database) of the specific vehicle model is required to build a simulation of the CAN communication in a vehicle. However, the OEMs will not release any information on the communication parameters to non-OEs and therefore they will not support the independent remanufacturing business. As a consequence, the independent remanufactures (onto which this paper focuses) have to do a lot of reverse engineering themselves or in cooperation with others in order to design their remanufacturing process chain and to come up with test solutions to ensure the quality of their products. The reverse engineering activities focus on the system, its components, the system behavior in the vehicle and the vehicle CAN bus communication.

### 3.3 The Remanufacturing Process Chain for Automotive Mechatronics

Following the previous aspects, the state-of-the-art process chain for remanufacturing, presented in chapter 2.2., needs to be reconsidered when it comes to mechatronics. Regarding the process steps, disassembly, cleaning and reassembly, great progress has been made, as it can be found in the literature [10] [11] [12]. Primarily, the diagnostics and testing differs to a certain extend from the traditional (final) testing of mechanics, as it has already been discussed before. In addition to this, it was found that a lot of failures of parts and its subassemblies can only be detected or isolated with a test of the completely assembled mechatronic system [1], e.g. by utilization of the onboard-diagnostics and the fault memory of a mechatronic system. This means that the process chain for remanufacturing of mechatronic systems should be extended by an additional first step.

The initial (entrance) diagnostics of the system to be remanufactured imply that the product itself and its communication patterns have been reverse engineered before and the appropriate simulation model of the reference vehicle has been developed so that the tested product “feels” like in its original environment.

## 4 UNDERSTANDING AN AUTOMOTIVE MECHATRONIC SYSTEM BY REVERSE ENGINEERING

The term “reverse engineering” has its origin in the mechanical engineering and describes in the original meaning the analysis of hardware by somebody else than the developer of a certain product and without the benefit of the original documentation or drawings. However, reverse engineering was usually applied to enhance the own products or to analyze the competitor’s products [13].

Chikovsky describes reverse engineering in the context with software development and the software life cycle as an analysis process of a system, in order to identify the system (sub-) components, to investigate their interaction and to represent the system at a higher level of abstraction [13]. In this context, he also clarifies the terms “redocumentation” and “design recovery”.

“Redocumentation” is the generation or revision of a semantically equivalent description at the same abstraction level. That means that the results are an alternative representation form for an existing system description. However, redocumentation is often used in the context of recovering “lost” information [13].

The term “design recovery” defines a subset of reverse engineering that includes domain knowledge, external information (of third parties) and conclusions additionally to the original observations and analyses in order derive meaningful abstractions of the system at a higher level [13].

Overall, reverse engineering of software in the software development focuses on the following six targets [13]:

- Coping with the system complexity
- Generation of alternative views
- Recovery of lost information
- Detection of side effects
- Synthesis of higher abstractions
- Facilitation of reuse

These targets, that have originally been defined for software reverse engineering, can also be transferred to a certain extend to the reverse engineering of automotive mechatronic systems and hence to the remanufacturing of these systems.

First, remanufacturers face the same problem that they usually have to cope with complex mechatronic systems as stated before. “Cope” means in this context, that it must be possible to operate an automotive mechatronic system independently from its original environment (the vehicle).

Second, it is possible to detect universal taxonomies which can then be abstracted and used in order to transfer the gained knowledge to similar mechatronic systems or to other variants of the system. Especially the high degree of variation of similarly looking mechatronic systems and control units makes it difficult for the remanufacturers to cope with the complexity of automotive components that usually differ by a slight detail [14].

Third, recovery of missing information rather than lost is one of the most important aspects for the remanufacturing.

The following chapter demonstrates how a reverse engineering analysis can be conducted for an automotive mechatronic system.

## 5 ANALYZING AN AUTOMOTIVE SYSTEM IN FIVE STEPS

After a reference system for the analysis has been chosen it is necessary to procure at least one, ideally brand-new, system to grant correct functionality, for all following investigations. In order to analyze the system in its normal working environment, the original vehicle, in which the reference system commonly is built in, should be procured as well.

This investment might be unavoidable, because a mechatronic system communicating via CAN, detached from all other vehicle communication will not work anyway, as essential input information, transmitted via CAN, is missing otherwise (refer to chapter 3). In this case it is very difficult to understand the ECU communication and put up the system into operation isolated from the vehicle.

A cheaper way to investigate the communication between vehicle and reference system is to create a CAN trace using a software tool such as “CANoe” from Vector Informatics. This tool allows easily recording of the complete vehicle communication for instance while doing a test drive with a vehicle that may be available only once.

Whatever strategy is chosen, it is essential to figure out which input (CAN data) is required to start, operate and control the system.

### 5.1 Electrical Wiring

After having obtained a reference system, it is essential to know the pinout of all connectors of the system. Therefore, the very first step is to find out which pin belongs to which wire and signal.

First of all, the power connector (ground and positive terminal), including ignition, must be identified. One opportunity to obtain this information is the utilization of wiring diagrams or similar credentials. If such documents are not available, for example a visual inspection of the connectors and wire harness in the vehicle or continuity measurements can be beneficial.

Afterwards, it is indispensible to identify the CAN connection pins. These can easily be recognized by inspection of the cable harness. In most cases two twisted wires indicate a CAN bus connection, but single wire CAN connection is possible, too.

Finally, all connectors for sensors and actuators (auxiliary power and sensor/ actuator signal) must be known as well to go further in the analysis process.

### 5.2 Vehicle Network Topology

The investigation of the structure of all bus systems in the vehicle is placed in front of the proper CAN bus analysis step. It is necessary to determine how many (CAN) bus networks are established and in which network the references system is located. Additionally, the network speed, the presence of a separate diagnosis network (e.g. K-Line), and all ECUs of the specific networks must be found out. Especially those ECUs that provide essential input as mentioned before. Furthermore, possible gateway ECUs should be identified.

A feasible solution to gain this information can be for example a web inquiry, documents from the manufacturer of the vehicle or the system, third party documents or technical journals.

### 5.3 CAN Bus Communication

Having collected all information about the (bus) network structure of the vehicle, detailed knowledge about the received CAN messages and transmitted CAN data is necessary.

In the first step, all ECUs and its associated CAN message IDs must be determined. For this purpose CANoe can be used. First of all, a physical connection to access the CAN bus using CANoe has to be installed in the vehicle, ideally nearby the reference system ECU. With the “trace functionality” of CANoe the bus communication and all CAN messages of all ECUs can be displayed easily.

Beside of the CAN IDs, the cycle time and the length of each message can be analyzed. This information is relevant for a later rest bus simulation of all participating ECUs to ensure correct functionality of the reference system.

The assignment of CAN ID and the associated ECU is more difficult. One possibility to gather this information is, to locate all ECUs which provide relevant data on the CAN bus and to separate the CAN wires out of the cable harness. Afterwards, a kind of software gateway is installed in between the DUT and the other ECUs using CANoe and a simple CAPL (CAN Access Programming Language) program.

Each end of the CAN wires in the vehicle must be connected to a computer via CAN hardware (Figure 3). By this means, it is now possible to detect the messages on the bus as well as the transmit direction – receive or transmit. In addition to this, it is also possible

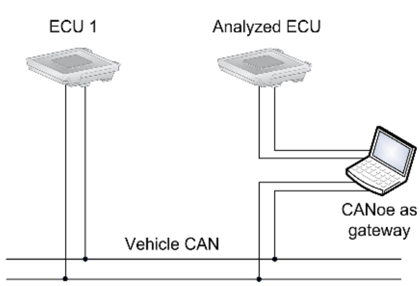


Figure 3: CANoe as software-gateway.

to add some filters to the CAPL program in order to filter out unnecessary messages and hence to reduce data complexity.

This step is repeated for each ECU which provides relevant input data for the reference system.

After having identified the relevant CAN messages, it is inevitable to examine the message data bytes in detail to determine the physical signals. This can be achieved by generating physical inputs manually (e.g. open the throttle, drive, break …) and observe the particular CAN messages as well as its bytes in parallel.

After that, a correlation between a certain CAN message, its CAN data and a physical input value can be established.

Having performed the steps above, it is possible to setup the desired restbus simulation for the reference system.

### 5.4 Sensors

Besides the CAN data, analog inputs of sensors and analog outputs of actuators are important in order to ensure correct functionality of the reference system. Therefore, each sensor and nearly each actuator has to be analyzed and simulated, too.

The sensors can be analyzed using an oscilloscope and a multimeter in order to characterize current consumption, supply voltage and signal transmission. Typically, sensor output signals are analog to:

- Current / voltage, amplitude
- Frequency / cycle time
- Pulse width / duty cycle

Or they are discrete in the following forms:

- Binary
- Multi-staged (different scaled)
- Multi-staged (equidistant) → digital

For the simulation, the measured values must be interpreted and emulated. For example, the internal resistance of a sensor can be calculated from the sensor current consumption. Afterwards, the presence of the sensor can be simulated by a (simple) resistor.

The simulation of the sensor signal can be realized using a waveform generator, an analog circuit, a microcontroller or a combination of them.

### 5.5 Diagnostics

Finally, to test the reference system completely detached from the vehicle, it is necessary to know how the diagnosis communication works in order to check the fault memory and to read internal sensor information of the ECU (e.g. for temperature).

First, the applied protocols for transport and application layer must be identified. Often, standardized communication protocols for ECU diagnostics are used (e.g. ISO TP, KWP2000 or UDS). In some cases OEMs use proprietary self-developed keyword protocols (e.g. KWP1281). Thus, it is more difficult to build up a diagnosis connection to the reference system because the protocol specification is unknown to the remanufacturer. Hence, a detailed analysis of the CAN or K-Line communication during a diagnosis session is essential. Sophisticated reverse engineering capabilities are necessary to analyze, understand and recreate such a diagnosis communication. The message IDs, used for the communication, must be investigated independently by observing the diagnosis communication with CANoe. If the CAN IDs and protocols are known, the diagnose communication can be reproduced for example in CANoe.

After a remanufacturing company has accomplished all mentioned steps for the reference system, it is able to operate this system detached from all analog (sensor signals) or digital (CAN) inputs.

Finally, a test bench can be developed for entrance and final testing in series production scale.

## 6 EXAMPLE: REMANUFACTURING OF AN EHPS

The following six steps describe the reverse engineering process on the basis of an electro-hydraulic power steering (EHPS) pump that is used in a VW Polo.

### 6.1 Physical Analysis and Electrical Wiring of the EHPS

At the beginning, the EHPS has to be perceived as a black box with inputs and outputs. Because of the mechanical design and the general function of a hydraulic power steering, the output can be determined as the flow rate of the fluid. The inputs are composed of an information about the internal combustion engine state (running or not running) and direct or indirect information about the necessary oil flow rate.


Figure 4: Examination of the CAN Reman test vehicle.

To get a first overview about the electrical connections of the device, a reference unit was completely disassembled. Large connector pins were good indicators for the general power supply by reason that the power consumption of the electric motor is supposed to be high. The ground pin of this connector was found by searching for a direct linkage between those pins and the ground plate of the circuit board. The color of the connected cable usually indicates the ground connection (GND). The other cable on the connector is the positive power supply (Vcc). At this point, the connection of the steering angle sensor, which is directly mounted on the steering shaft, was disregarded. The third connector contained three cables. Two of them were twisted in the following cable harness. That was a perfect indication for CAN cables. The CAN-high cable rises from 2.5 V to 3.5 V and the CAN-low cable falls from 2.5 V to 1.5 V during active communication. When operating the vehicle, the last cable was on 12 V level and therefore it was assumed to be the signal for “ignition on”.

At this point the electrical analysis of the device was completed.

### 6.2 Vehicle Network Topology

The most important questions in this step are: “How does the EHPS communicate in the vehicle network? Will the device communicate outside the car?”

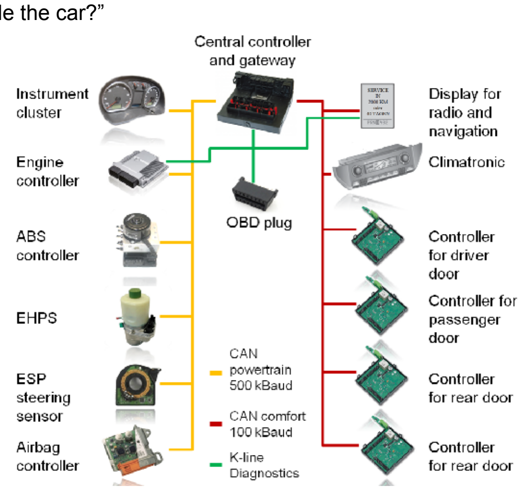


Figure 5: CAN bus topology of the test vehicle.

To get answers for these questions, the reference EHPS, outside the car, was connected to a power supply and an ignition signal. In this configuration, the electric motor of the EHPS was not started by the control unit. By connecting the EHPS via CAN hardware to a computer running CANoe (version 7.2), the message IDs sent by the EHPS were displayed in the trace-window. Usually, selected CAN bus data is also accessible through the vehicle on-board diagnosis (OBD) connector. This data can contain the IDs of the EHPS inside the car and further ECUs. Unfortunately, the CAN bus was not linked to the OBD connection of the test vehicle (Figure 5). Therefore, the CAN wires of the EHPS were disconnected in order to use CANoe as gateway for CAN messages. As a consequence, it was possible to differentiate between received and transmitted messages. This test verified the previous observations on the CAN IDs sent by the EHPS.

### 6.3 CAN Bus Communication Investigations

This step can always be split into two parts. The first one is the analysis of the communication in order to filter out and understand the relevant messages for the EHPS sent by other ECUs. The second one is the simulation of the necessary CAN communication, which is called “restbus” in the following.

First, the start signal, transmitted to the EHPS via CAN bus, must be discovered as described in step 2. Therefore, a recording of the in-car CAN communication was made at a stationary test. After that, the recording was replayed to the test device outside the car and it started its operation. Next, CAN messages were successively filtered out until the motor of the test device stopped. Hence, the last filtered message contained some kind of a start signal. After some tests, this signal was identified to be the RPM signal of the internal combustion engine. In order to eliminate or to find other input parameters, the same test was made with a recording of a real-road test. It was found that the vehicle speed is another input parameter for the EHPS.

Second, the required input parameters were simulated with CANoe. Using a third party diagnosis garage tester (Bosch KTS 650), it was discovered that the fault memory of the external EHPS can only be erased when at least the presence of the missing messages of the in-car communication is simulated, too. This simulation of messages with and without data content is called restbus.

At this point the EHPS can completely be operated outside the car, but with a real steering angle sensor.

### 6.4 Simulation of Sensors

In order to operate the EHPS in a completely simulated environment, the angular velocity sensor had to be simulated.

Analog to step one, Vcc and GND were identified on the sensor terminal using a multimeter. The third cable transferred the information about the angular velocity of the steering wheel. This signal was analyzed with an oscilloscope. A pulse width modulated signal was detected and simulated with a waveform generator. Furthermore, the sensor presence had to be emulated by a simple resistor matching the power consumption of the original sensor.

### 6.5 Diagnostic Functions of the Device

Most devices, including the present EHPS, can be diagnosed over CAN bus with an external diagnosis garage tester. This tester can, as mentioned above, directly communicate with ECUs using a transport and a keyword protocol. The protocols are only partially defined and the communication differs from brand to brand tremendously. Therefore, the most efficient way to understand how e.g. the fault memory can be erased, is to erase the fault memory with one of those testers and to try projecting the sequence onto known standards. In the present case, it were the standards KWP1281 and TP1.6. Even though the understanding of the diagnosis communication was very time-consuming, it was possible to erase and read the fault memory, to read the internal sensor data or duty cycles, to parameterize the device for different car models or even to completely reprogram the software.

Finally, all functions were implemented in CANoe using CAPL which can be controlled by a graphical user interface (GUI).

### 6.6 Operation Range

At last, the correlations between input and output values were determined in detail. For this reason, the input parameters angular velocity, vehicle speed, RPM and the outputted oil flow rate were recorded simultaneously.

In this case the RPM signal only started the EHPS and was disregarded for the measurement. The vehicle speed was found in a particular message on the CAN bus as figured out in step 3. The angular velocity value is part of the sensor data provided by the EHPS in a diagnosis communication session as mentioned in step 5. The resulting oil flow rate was measured by adding an oil flowmeter to the low pressure side of the EHPS in the test vehicle. This flowmeter generates a frequency modulated signal which was converted to a CAN message by a microcontroller and broadcasted to the local in-car CAN network in a separate CAN message. Finally, all necessary input and output values were recorded from the CAN network time simultaneously using CANoe. Figure 6 depicts the flow rate of the steering oil as a result of vehicle speed and angular velocity, measured in a real-road test.

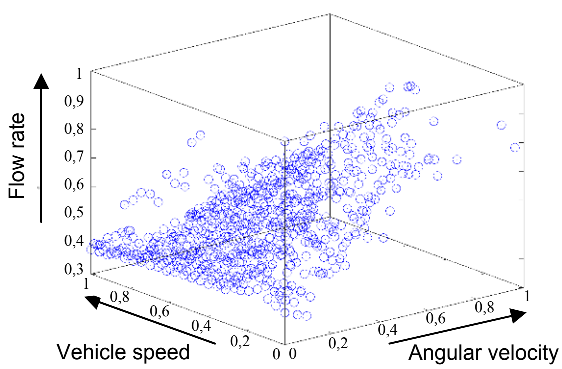


Figure 6: Flow rate as a function of vehicle speed and angular velocity.

## 7 CONCLUSION

A still increasing number of mechatronic and electronic systems is built into today's vehicles. In the future, even more of these systems will be introduced to the cars as a result of increasing demand for comfort, safety and reduced fuel consumption. Remanufacturing of failing mechatronic systems offers a great opportunity for all, the OEMs and OEs which can safe resources; the remanufacturing companies as they can make a growing new business with these systems; and the customers that are benefitting from cheaper, but as good as new, spare parts.

Progress is not possible without its challenges, but it is achievable. Therefore, remanufacturing companies have to build up new reverse engineering knowhow, have to find methodological innovations and they need to develop new technologies, especially focusing on the tasks testing and diagnostics of automotive systems and their subassemblies. The paper outlines challenges, possible solutions and technological progress for the reverse engineering process of mechatronic automotive systems that are communicating via CAN bus. In addition to this, the reverse engineering process is demonstrated on the example of an EHPS which is used in a VW Polo. Obviously, it was possible to completely understand the steering system of the VW Polo by reverse engineering. Even though the reverse engineering effort was time consuming, it is now possible to run and test the mechatronic system outside the car as well as to adopt the results for remanufacturing the system in series production scale. The same principle can also be applied with some effort to further automotive systems, so that everyone wins, regardless of perspective.

## 8 ACKNOWLEDGEMENT

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