CANOPEN FOR MOBILE CONSTRUCTION MACHINES - AN OPEN COMMUNICATION NETWORK FOR CONTROL AND AUTOMATION

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Abstract: Information technology and communication technology offer increasingly improved possibilities for automation and robotisation in mobile construction machines. Apart from the electronic systems the intelligent connection of subsystems by a network plays a crucial role. The preconditions for the connection within mobile construction machines were created with the research project "Standardisation of Open Communication in Mobile Construction Machines". For a full automation in mobile construction machines a management system should be used, in order to connect the subsystems in the future.

Keywords: mobile construction machines; electronic systems; CANopen-network; automation; robotisation; management system

1. PREFACE

In contrast to the stationary prefabrication, automation and robotisation on the construction site is still a problem. Earthmoving and road construction machines partly have a high automation potential, because there is a large number of repeatable work functions with high complexity degree at the same time [1]. Not only for monotonous work (e.g. planing large surfaces), but also for applications under less favourable conditions (e.g. mining, contaminated areas) there are advantages by automation and robotisation. Aim is, to increase the economy of the machines and to relieve the driver of the various control and monitoring functions.

Although mobile construction machines are equipped increasingly with electronic systems and some of these systems already enables a part-automation, there are obviously obstacles with automation and robotisation. The unfavourable operating conditions for electronic components, high development costs and the limited possibilities for the networking of electronic systems play a substantial role.

The construction-machine-efficiency of electronic components was improved in the last years substantially. Therefore, this argument is of importance no longer.

The rapid development in the information and communication technology offers increasingly better possibilities for automation and robotisation in mobile construction machines.

The effective and safe data communication between the individual electronic components and systems is very important (**Figure 1**).

For the data communication within the mobile area the closed serial field bus system CAN (Controller Area Network) is established and used internationally. However, the data exchange between controllers of different suppliers is possible only in a limited way, because of the used protocol. So far there are a few CAN-applications only, because of the high costs for development as well as the extensive arrangements between the manufacturer of construction machines and its suppliers (diesel engines, transmission gears, hydraulic components). The result are manufacturer-specific networks, which makes the inclusion of new network participants more difficult.

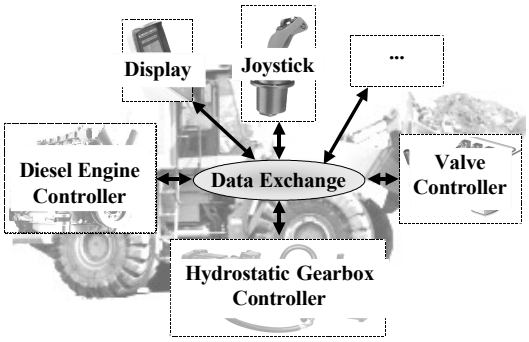


Figure 1: Data exchange between components and systems is necessary

The user does not want to pay the higher costs [2].

The data exchange via a so called open communication system (e. g. CANopen) allows a manufacturer-independent inclusion of all network particpants and offers comprehensive safety.

CANopen is based on CAN. It offers higher flexibility as well as extensive safety and control mechanisms.

2. RESEARCH PROJECT

In the context of a research project at the University of Magdeburg the preconditions for the use of open communication in mobile construction machines were created.

The manufacturer-independent data exchange between electronic components and systems forms better conditions for future developments to the automation and robotisation of mobile construction machines. The available possibilities of the data communication must be used however optimally.

A precondition for the structure of a CANopen network are standardised device profiles, which describe all parameters necessary for communication via CAN in detail. Aim of the research project was, to develop and standardise construction-machine-typical device profiles on the basis of the CANopen-standard.

The device profiles for diesel engine, automatic gearbox, hydrostatic drive, proportional valve and joystick were defined according to the CANopen network protocol.

These drafts of device profiles were discussed in cooperation with industry partners. The standardisation committee „CAN in Automation International Users and Manufacturers Group“ (CiA) accepted these device profiles as proposals for the standardisation and founded the Special Interest Group „Off-Highway Vehicles“.

In order to prove the function and to document the strategy in principle, a 14-t-excavator was equipped with a CANopen network. The necessary electronic components and controllers were installed.

Now the controllers of the diesel engine, the hydraulic pumps and the valves as well as the display with keybord, the joysticks and the pedal for driving are able to exchange data over the CANopen-network (**Figure 2**). Additionally the individual controllers can be configured over the display. That is a precondition, in order to adapt the modules and systems to the respective operating conditions optimally.

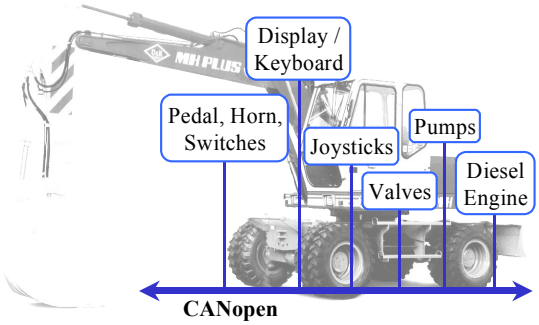


Figure 2: Excavator with CANopen-network

3. MEANING OF THE RESULTS

The defined CANopen profiles and the practical realisation at a mobile excavator are important preconditions for the advancement of the mobile construction machines.

In the future the manufacturers of construction machines can connect the electronic components and systems of different suppliers in the same network. The machines can be equipped and configured by the manufacturers, according to the customer's requests. Previous development-barriers will be abolished, and there are new possibilities for the creativity of the developers. As a result of the simplified connection of sensors, of actuators and of electronic systems, new possibilities arise for automation and robotisation in the construction machines.

The operators of mobile construction machines profit from the improved possibilities of the data capture, diagnosis and the driver information. Shorter downtimes and shorter times for maintenance increase the capacity and the availability of the machines.

4. APPROACHES FOR FUTURE DEVELOPMENTS

Which trends can be detected for the development in the area of mobile construction machines?

If one compares the past development of electronics in automobiles with their introduction into the mobile construction machines, parallels show themselves. For future developments it is useful, to orient at the automotive engineering.

For years, automobiles play a role of the pioneer with the application of the possibilities of the information-technology and the communication-technology. Aim is, to improve safety, reliability and comfort crucially.

Time-critical and safety-relevant electronic systems, like engine control, automatic gearbox, ABS and ASC are already standard and are connected via CAN. Further systems without real time requirements have partly their own bus system and are integrated by gateways into the total network. That are mainly comfort functions, like for example climatic regulation, locking mechanism and seat adjustment.

The investment into the telematics is increased also. Dynamic navigation systems, breakdown assistance, automatic emergency call and telediagnosis were already shown on the IAA (international motor show) in 1999 in Frankfurt. Furthermore there are development activities for the drive-by-wire and break-by-wire technology. One advantage is that the position of the driver and the arrangement of the control elements can be selected freely. Additionally the developers think already about the fact that only one control stick (Daimler-Chrysler-Stick) is sufficient for steering, brake and acceleration. In the future software will bring more functionality into the electronic systems, without intervening on the hardware side. The simple conformance to different areas of application and styles of driving becomes possible thereby.

There are similar trends for electronic systems in mobile construction machines. First developments of automatic steering for tractors, which are based on the steer-by-wire technology are showing this [3].

Further important systems for automation and robotisation are in the development stage or are already available at the market [4, 5, 6]:

- navigation systems for orientation on the construction site,
- teleservice systems for remote operation and telediagnosis
- systems for automation of motion controlling.

The construction machine manufacturer is the system integrator and bears the responsibility for the total system. From the multiplicity of the offered subsystems the construction machine manufacturer must select the appropriate systems for the respective machine. The operating conditions and the requests of the customer must be respected.

An effective and economic automation within mobile construction machines becomes however only possible by the appropriate linkage of the electronic modules and systems in a total network (**Figure 3**).

But only an open communication system such as CANopen permits such a connection of the subsystems in a main network.

In order to use this potential optimally, all presently used electronic components and in the future available components should be analysed regarding their communication requirement.

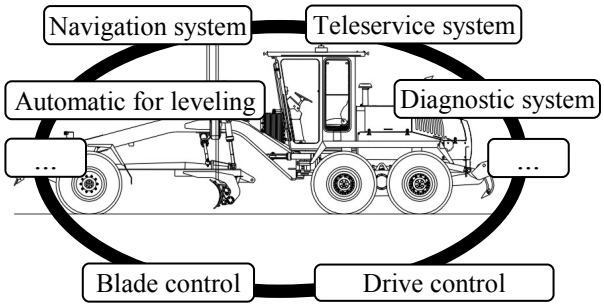


Figure 3: Automation by connection of subsystems

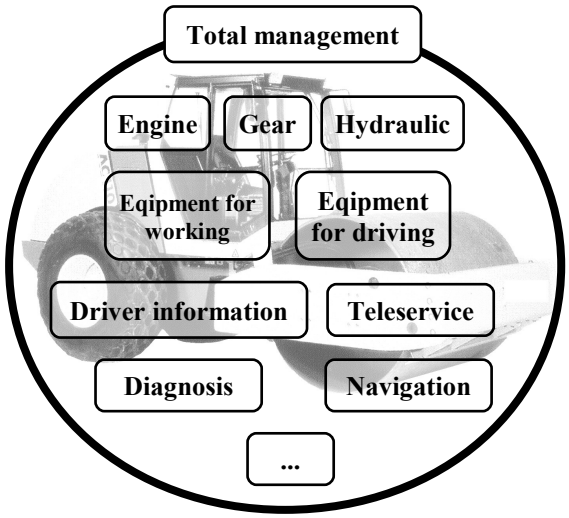
For the structure of the main network the following questions are crucial:

- Which sensors and actuators are used?
- Which real time requirements of data communication are available?

It must be decided whether the subsystems are closed or open. So for example the diesel engine control can be called in itself closed. Also in future the desired values and actual value are exchanged between the diesel engine controller, the sensors at the engine and the injection pump not over a main network, because of the quantity of data and the real time requirements. Data from other subsystems or from the driver as well as configuration data can be transmitted over the main network.

Open subsystems can also use the main network for the transfer of real time critical data. That is particularly attractive for systems, which must access data of different subsystems. For example an automatic drive system needs data of the diesel engine, of the hydraulic drive and from the navigation system.

For an optimal total system the intelligent connection of the subsystems is crucially. Because of



the complexity of the total system the development of a management system is necessary [7] (**Figure 4**).

Bild 4: Managementsystem for a Mobile Construction Machine

The total management system should enable or optimally support the following functions:

- Configuration of the participants of the main network, e.g. controllers for engine, transmission gear and hydraulics.
- Selection of different optimisation aims, e.g. minimum fuel consumption, max. hydraulic power.

The mobile construction machines can be adapted to the respective customer needs and operating conditions, with the help of the total management system.

A full automation of the mobile construction machines becomes possible by the linkage and monitoring of the subsystems for part automation.

5. CONCLUSIONS

Automation and robotisation of mobile construction machines get substantial impulses by the variety of new possibilities of information and communication technology. The original handicaps lose meaning more and more.

Particularly the construction machine manufacturers are requested to use the new possibilities in co-operation with the building contractors. The unfavourable conditions of work on the construction site can be improved, the productivity and the quality can be increased by automation and robotisation. A contribution for the image improvement of the building industry will be made.

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