Open Communication in Mobile Construction Machinery

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CANopen Device Profiles for Mobile Construction Machines

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Abstract: The paper describes the research project „Standardisation of the Open Communication in mobile Construction Machines“. The project created the bases for the use of CANopen in mobile construction machines. Specific device profiles for construction machines were defined and suggested for standardisation. A mobile excavator was equipped with CANopen, so that various devices are able to exchange data.

1 Preface

Mobile construction machines which were developed exclusively by mechanical engineering, do not correspond to the current increasing requirements. We are pleased to see that applications of electronic controls were intensified in mobile construction machines. However, the electronic control is no warrenty for a higher machine power and for more reliability.

Especially mobile construction machines require a reliable data transfer because of the extreme vibrations, the variations in temperature as well as the dirty environment. The data exchange via a serial field bus is able to solve this problem.

The serial field bus CAN (Controller Area Network) proved effective for mobile applications under such conditions internationally. This data exchange diminishes the effort of cabling and allows the employment of complex controllers.

The manufacturers of diesel engines, transmission gears and hydraulic components equip their controllers with CAN interface since about 6 years. Nevertheless there are so far only some specific applications in mobile construction machines. The cause for it is that the network protocol is suitable for data exchange between specific applications of different manufacturers only in a different way (closed communication). In the case of closed communication the full performance cannot be used. For this purpose enormous efforts for development and extensive arrangements between the manufacturers of the mobile construction machines and their suppliers are necessary. The users would not like to pay the higher costs.

To solve this problem an open communication system like CANopen can be utilised. The data exchange via CANopen allows a manufacturer-independent inclusion of all network participants and offers comprehensive safety.

CANopen is based on CAN-standard ISO 11898 and is favoured from many manufacturers of mobile machines. The data exchange between several controllers via CANopen requires a standardised device profile.

There are already standardised device profiles for following devices:

- Human Machine Interfaces
- IEC1131 Programmable Devices
- Drives and Motion Control
- Encoder
- I/O Modules [1].

Especially small companies can not use the open communication technology because there are no standardised device profiles for typical applications in mobile construction machines.

2 Aims of the Project

In the context of a research project at the University of Magdeburg the preconditions for the use of open communication via CANopen in mobile construction machines were created. Both between the controllers of individual modules (e. g. diesel engine, display, pedal for driving) and manufacturer-specific systems (e. g. hydrostatic drives) data exchange should be possible.

Aim was the definition of construction-machine-typical CANopen device profiles. In close co-operation with construction machine manufacturers and suppliers as well as the standardisation committee CiA (CAN in Automation Internationally Users and Manufacturers Group e. V.) the standardisation of the device profiles should be forced.

Special value is put on the practical realisation in order to facilitate the introduction into open communication particularly for small and medium-sized enterprises and suppliers. A mobile construction machine should be equipped with a CANopen-network. So the advantages can be clarified and the fundamental strategy can be documented.

3 Strategy

The aims of research should be achieved by the following steps:

- Analysis of mobile construction machines
- Analysis of communication requirements
- Definition of device profiles
- Programming of controllers
- Equipping of a mobile excavator with controllers
- Configuration and optimisation of the network.

3.1 Analysis of mobile construction machines

The complete functions and the functionality of single components must be analysed. The fundamental structure (main drive, drive of construction machines equipment, drive of chassis), the fundamental functions (working and driving functions) and the controllers (mechanic, hydraulic, electronic) should be considered [2].

3.2 Analysis of communication requirements

For the analysis of the communication requirements in mobile construction machines, a complete registration was striven by current and future information to be expected.

It had to be respected that both, conventional components without own CAN interface and components with CAN or CANopen interface must exchange data via the network. The data exchange between following specific devices of mobile construction machines was analysed:

- diesel engine,
- automatic gear,
- hydrostatic gear,
- proportional valve,
- joystick,
- display and
- slope sensor.

3.3 Definition of device profiles

The device profiles were defined with the help of an analysis of the communication requirements. These profiles describe all needed parameters of the CAN communication in detail.

Physical variables and device parameters (objects) must be selected for each device and component and they must be integrated into one object group. For each object the attributes must be defined (measure, resolution, data coding, lower limit, upper limit, default value etc.).

The defined device profiles were discussed in cooperation with the industry partners. The profiles were handed over as a discussion basis for standardisation to the CiA.

3.4 Programming of controllers

The programming effort of controllers depends substantially on the specific device suppositions. The CANopen network protocol (transmit, receive etc.) is downloaded by a „Source code library“. The application-specific part is programmed with „C".

The components must be connected to the network as follows:

- **Diesel engine:**

A separately controller must be used because the memory cell of the diesel engine controller is too small. The CANopen protocol and the device profile must be programmed into this controller. This controller is also used as a gateway for CANopen because the diesel engine controller used the CAN SAE J1939-protocol.

- **Hydrostatic pumps**, **display:**

No separately controller is needed. The CANopen protocol and the device profile can be programmed directly into the respective controller.

- **Valves and joysticks:**

They can be connected directly because the CANopen protocol was downloaded already by the manufacturer. Only the modified device profiles must be programmed.

- **Pedal and switch for driving:**

The pedal and the switch for driving are conventional components (analog, digital). A separately controller is needed in order to transmit the signals via bus. The CANopen protocol and the device profile must be integrated into the separately controller.

3.5 Equipping of an excavator

For the practical realisation a 14-t-excavator was used (**Figure 1**).

Figure 1: Mobile excavator for practical realisation

Several changes at the mobile excavator were necessary (sensors, actuators, valves). The programmed controllers were installed at the same time.

The diesel engine was equipped with an electronic engine controller.

The hydraulic control of the pumps and of the valve block could be replaced by an electrohydraulical control.

Additionally a display with keyboard, two joysticks and a electrical pedal for driving were attached.

3.6 Configuration and optimisation of the network

The programmed controllers were integrated into the network step by step. The network functions are checked via a separately CANopen bus-monitor.

The complete network tests and the monitoring by bus-monitor will be needed for the data exchange optimisation.

4 Results

4.1 Device profiles

The following device profiles were defined according to the CANopen network protocol:

- Diesel Engine,
- Automatic Gear,
- Hydrostatic Machine,
- Proportional Valve,
- Joystick and
- Slope Sensor.

It is important that both real-time-requiring values and configuration values can be transmitted.

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“.

Profile „Diesel Engine” and profile „Automatic Gear”

For the communication between the controllers of the power train the protocol SAE J-1939 is widely-used. Therefore CANopen objects for diesel engine and automatic gear were selected following the SAE J-1939-standard. Meanwhile a working group is preparing the standardisation of a Truck-Gateway for SAE J-1939 and CANopen.

Profile „Hydrostatic Machine”

Suppliers of hydraulic components are interested to sell complete systems. The hydraulic for driving as well as the hydraulic for working consists of pumps, motors and the appropriate electronics. Therefore pump and motor are not implemented separately into the network, but as a hydrostatic gearbox. The controller of the hydrostatic gear contains the interface to the CANopen network (**Figure 2**).

In close co-operation with the suppliers, CANopen objects for speed, torque, power, flow volume, pressure and temperature were defined. Apart from the desired values and actual values, ramps, limits, standardisation factors and command variables were considered.

Profile „Proportional Valve”

Basis for the CANopen-device-profile „Proportional Valve“ was the field-bus-independent device profile „Fluidtechnik“, which was defined by the Society „Verband Deutscher Maschinen- und Anlagenbau e. V. (VDMA)“ [3].

This CANopen profile is specified furthest. It is already available as Draft Standard Proposal (DSP-408).

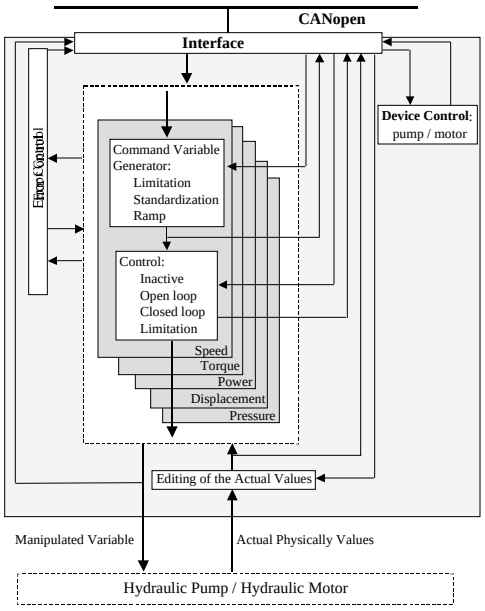

Figure 2: Profile “Hydrostatic Gear” - device architecture

Profile „Joystick” and „Slope Sensor”

These two profiles were likewise defined in close co-operation with suppliers. The Special Interest Group „Off-Highway Vehicles" checks whether both profiles can be replaced by the already standardised CANopen profile „I/O Modules". That would mean a substantial simplification.

4.2 Practical Realisation

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, joysticks and pedal for driving are able to exchange data over the CANopen network (**Figure 3**).

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.

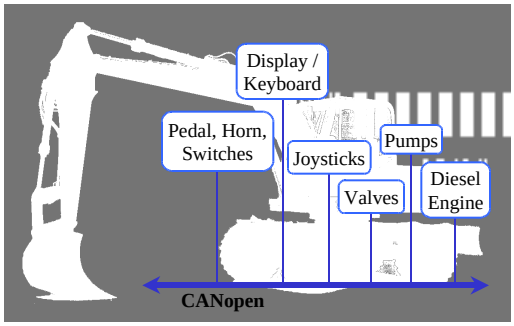

Figure 3: Excavator with CANopen-network

The configuration, the optimisation and the tests of the CANopen network have shown the advantages and possibilities for mobile construction machines.

5 Conclusions

The bases for the use of open communication in mobile construction machines were created.

Modules and systems of diverse manufacturers are able to exchange data within the construction machine.

In the future manufacturers of construction machines can use electronic components of different suppliers and combine these as they choose.

Additionally new components can be integrated easily into existing systems.

The costs of the development can be reduced and the flexibility can be increased.

The utilisation and the maintenance of the mobile construction machines will be simplified for the users.

Better opportunities for data capture, diagnosis and information for the driver exist now.

Shorter downtimes and shorter times for maintenance increase the availability of the machines.

Device Profiles

The device profiles with the CANopen facilities are corresponding currently and future requirements.

At this stage it is not effective to connect all components. In order to keep the development effort and the hardware costs into limits the controllers of several manufacturer specific systems should be used (diesel engine controller, drive controller etc.).

For future applications the number of network participants will be raised.

In the future manufacturers will use several networks, in order to connect the respective communication levels.

The definition of new network components would not be a problem. That is one advantage of the open communication. The definition of new device profiles can be oriented by the existing profiles.

A further advantage is that the use of the defined device profiles is not limited for applications of mobile construction machines because the components and their requirements can be used also in other mobile machines (forest, farming, mining).

Practical Realisation

With the help of the practical implementation the fundamental strategy for equipping a mobile excavator with a CANopen network could be documented. It also points the way for the equipment for future applications in mobile machines.

To demonstrate the CANopen advantages for mobile construction machines, the practical realisation was oriented at the possibilities of the manufacturers of components and/or of machines. On account of the closely cooperation with the industry partners, the mobile excavator was reconstructed with predominantly standard components in an adequate time.

References

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