HANDLING SYSTEMS IN THE HARDCOAL INDUSTRY

Dr. Jürgen Czwalinna
AdB Dieter Sonnenschein
RUHRKOHLE AG
Shamrockring 1
Herne, Germany

Introduction

As this event shows handling systems are widely distributed and they are used for manifold tasks.

This also applies to the mining industry. There are, however, significant differences compared to other branches of industry with regard to application and design resulting from the particular spatial, organizational and environmental conditions in the coal industry. These particularities and their impact on the state of the art and the future perspectives of manipulator technology in the underground mining industry will be the topic of my presentation today.

Conditions of use and requirements in the hardcoal industry

Compared to other industrial enterprises a mine is characterized by tow features:

1. By a large transport volume with regard to numbers, weights, variety as well as transport distances in all three dimensions. So every day some 300 transport units with 3 m length and 0.6 m width are transported from

the surface into the mine where they are distributed in concessions covering up to 200 km^2.

2. Another particularity of the mining industry is the mobility of the actual production workings. To mine coal the working face with its entire infrastructure has to continuously advance through the deposit. To this end roadways have to be driven and supported in advance. Having mined one part of the deposit the entire production workings have to move to another part of this deposit.

As a result of these particularities handling systems in the coal industry are, in addition to special tasks, mainly used for:

- materials handling and
- assembly and disassembly.

In this context different equipment types ranging from sensitive electronic units to heavy 20 t supports have to be transported.

Design and controls of handling systems have to meet the following mining-specific requirements:

- The manipulators have to be mobile, i.e. either automobile or easy to carry, due to the non-stationary character of the coal-producing workings.

- A high degree of flexibility is required to adapt to manifold tasks.

- Uses in confined space have to be considered with regard to kinematics.

- Drive, transmission and control technology have to meet the general safety requirements for the hardcoal industry, e.g. flameproof protection, fire protection and non-flammability.

- When selecting and designing mechanical and electronical units dust, dirt and large temperature differences have to be given consideration.

As you will see in the following the restrictions and conflicts are reflected by the fact that the handling systems are, with only a few exceptions, designed for very special applications.

Nevertheless handling systems are systematically used by the mines and will also find ever wider distribution in future. The main reason for this is the special suitability of handling systems to fill mechanization gaps. In addition to economic advantages handling systems may, by reducing manual work, help to avoid accidents, to reduce strain and to add attractiveness to the work places.

Due to the very advanced handling technology in the other sectors of industry the hardcoal mining industry may often take recourse to existing basic technology. Given the special conditions of use you will, however, be astonished that generally a considerable adaptation is still required which may by all means be very challenging and results in the design of completely new equipment in some cases.

Handling systems in use

In the hardcoal industry numerous handling systems are used, starting from simple force manipulators up to robots. Within this paper I cannot refer to all types but I will concentrate on some significant examples. First of all I will present handling systems which are in use already, then I will talk about our devlopment projects in this field.

At the mines of Ruhrkohle AG more than 250 km of roadways with corss-sections of approx. 15 - 25 m^2 are driven each year. These roadways need to be supported with steel arches set in distances of 0.5 to 1 m. The steel arches consist of 3 or 4 segments, each weighing approx. 100 - 150 kg. The transportation and positioning of these support segments constitutes a considerable physical strain if it is carried out manually.

For this reason support setting devices are used either as independent mobile equipment in connection with support platforms or in connection with the roadheading machines. For arch support a roof consisting of 3-5 preassembled support segment pairs is transported to the point of use and positioned there so that afterwards the lower segments may be connected manually under the protecting canopy roof.

The canopy roof must be kept in a horizontal position when lifting it because the individual components are placed only loosely in the intended assembly points.

This is achieved by a parallelogram-type rod assembly or a hydraulic parallel control with a universal joint and two control rams.

In addition to a height adjustment a movement in transverse direction to the roadway and a lateral slewing is possible by means of a revolute joint. The electrohydraulic drive unit is operated via direct control, hydraulic remote control or infrared remote control.

The support setting devices are offered by several companies and are already state of the art today.

To support the canopy roof and to secure the roadway sides, called "walls", the lower support segments, the "side sections" are installed. To mechanize this process Deilmann-Haniel developed a support manipulator which is installed together with the support setting device on the same undercarriage. It is a telescopic boom with 6 axes which are directly controlled via hydraulic valves. Each of the three control levers is assigned to two functions.

A supplementary support method is the use of shotcrete which is often applied even befor setting the steel support arches to avoid roof falls. To this end a concrete spray manipulator on a crawler-mounted carriage is offered by Putzmeister. The main objective is the remote control of a nozzle to protect the operators against rock and coal fall as well as against rebouncing shotcrete and dust.

The variable boom has 6 motion axes to this end. The crawler-mounted carriage and the shotcrete arm are controlled separately via separate manual valves.

Ruhr university in Bochum carries out promising research work aiming at an automation of the shotcrete process to achieve a constantly high work quality irrespectively of the experience and skill of the operator in this way. Professor Meidel already reported on this on Monday.

There are only low requirements to the control technology of the following manipulator for pipe laying. That the development of a pipe laying manipulator pays off can be seen in the fact that within Ruhrkohle AG several hundreds of kilometers of pipeline are laid underground every year. By means of the manipulator presented here the installation of pipes is made safer with reduced strain and improved economic efficiency. It consists of a combination of a mobile assembly platform and the actual manipulator. At the end of the boom a positive connecting gripper with 2 pairs of jaws is installed which may be hydraulically slewed by 90°. It may be used to pick up the pipes from the floor and to position them.

The next example does not refer to installation but to disassembly with the objective of recycling. If roadways are not used any longer, the steel support is recovered wherever possible. It is obvious that this type of work called "salvaging" by the miner is at least as tedious and accident-prone as the installation of the support. The support is under pressure and often deformed by rock pressure during the utilisation of the roadway. Therefore it cannot be disassembled easily. Moreover the roof is allowed to collapse once the support has been removed.

Therefore a "salvaging manipulator" was developed for this purpose, i.e. the salvaging of the roadway support units, by Ruhrkohle AG in cooperation with Hebben-Fischbach, the Nuclear Research Center in Karlsruhe and the Fraunhofer-Institute for Production Technology and Automation. First test uses have been promising.

The two main units are installed on a crawler-mounted undercarriage, i.e. a staking frame used to stake the rock pressurized support arch to be disassembled and the second unit which is the actual manipulator with 6° of freedom. It may hold both an impact screw driver to loosen the screw connections at the support and gripping pliers to disassembly and salvage the four support segments after detensioning the frame. The whole procedure is, of course, remote controlled from a safe distance.

This case clearly illustrates two important experiences for the use of manipulators in the underground mining industry:

1. The operator's distance from the end effector mainly desired for safety reasons contrasts the necessity to monitor the individual actions as good as possible as a prerequisite for optimal operation. Of course, this applies particularly to the confined space and the limited visibility underground.

2. With a manipulator having 6° of freedom - including two rolling functions - the practicability limits of the joy stick controls used in this case are reached. Later I will come back to the conclusions this has on future manipulator developments.

Handling systems in the development phase

Despite the described successful developments in the mining industry and the fact that coalmining is already 100 % mechanized and semi-automated there are still mechanization gaps in the underground operations field so that the development of handling systems continues to be a key research aspect of Ruhrkohle AG.

The research projects in this field are supported by the Federal Ministry for Research and Technology under the programms "Energy Research" and "Energy Technologies" and "Labour and Technology" as well as the "Ergonomics Program" of the European Community.

Let me first of all present a technology intended to improve the numerous transport and handling tasks connected with roadheading. Generally, the materials required for roadheading operations are transported by a monorail as close as possible to the actual roadhead. It has, however, to stop at a distance of 30 to 50 m ahead of the actual "heading face" as support, heading and loading machines are in the way. For this reason transportation tasks in this road section are handled either manually or with simple rope or chain haulage devices in most instances.

A so-called "monorail bound"-manipulator, i.e. a manipulator which can be moved along a suspended monorail track, is to improve the situation and to overcome the system-inherent drawback of the monorail that the lifting and delivery of loads is possible only below the actual track.

The manipulator, which is developed by Wupper, is equipped with a 2.5 m boom to lift up, transport and manipulate over the entire roadway width materials like transport units or unit loads delivered by a Diesel-powered monorail to the rear roadway section. Every action outside the track axis is, of course, only possible in standstill. The momentum is adsorbed by a hydraulic supporting system which uses the standing support as abutment. The manipulator can be used to handle loads of up to 150 kg unit load. According to a special investigation into this field more than 90 % of all units existing in that area can be handled. Quite consciously a more powerful design was dispensed with because this would have impaired the sensibility and flexibility of the handling system.

Another mobile manipulator, which is developed by Wupper and Hebben-Fischbach, is mounted on an undercarriage with crawlers in contrast to the one described before. This so-called "floor-bound manipulator" has a similar design. It is intended to use it mainly for assembly and disassembly tasks which are conventionally accomplished by means of several compressed air-operated hoisting gears, a method of operation with a high latent accident risk.

The manipulator has an electrohydraulic drive. Also in this case the gripping aids can be interchanged by means of a quick change adaptor.

It is planned to equip the monorail- and the floor-bound manipulator with identical controls. The controls are computer-assisted so that in connection with a quick change automatics an automatic tool change will be possible. In addition to that an automatic control of the respective axes is planned for horizontal and vertical movements so that the operator has to push a lever only forward or upwards for the horizontal and vertical movement of the end effector.

For the same reason as for the monorail-bound manipulator also in this case the bearing capacity had to be limited to 600 kg. When equipping new face workings this weight restriction is sufficient for more than 90 % of the individual unit weights.

Because of its restricted mobility - particularly in the case of the floor-bound unit - the use of these manipulators pays off only where handling assembly or disassembly work concentrates. Within a mine there are, however, numerous other applications for which the manipulators, though not in permanent use, may reduce the work load and the accident risk. For these cases a universal portable handling system is being developed by the Fraunhofer-Institute for Production Technology and Automation in cooperation with Hebben-Fischbach. The device includes a manipulator boom to which identical end effectors may be attached at both ends.

In a first step is planned to develop a device for roadway supporting tasks. In this case the two end effectors are identical because the device is to use gripping pliers to clamp onto the existing support whilst the others are used to pickup and position a prepared support segment. The device has 6 axes and can even "climp up" and move at the support. Of course, it is not possible to move a support segment over larger distances.

An operational model could already be tested successfully. It remains to be seen whether the development objectives of portability and simple controllability can be reached.

As you see the stationary use of manipulators is an exception in the mining industry. In these situations, however, it also provides for full automation. The best example for this is the fully automatic coupling and decoupling of mine cars required underground at the interface between shaft winding and locomotive haulage and transport. Conventionally this work is, even today, done manually from the so-called "coupling pit" because the stirdy mining-specific shackle-type couplings still in use in different versions obstructed mechanized or even automated coupling so far. The workplace of the mine car coupling personnel is inevitably located in confined space between the tracks continuously exposing the workers to high noise and dust concentrations and cold air currents. Reasons enough to automate this work.

The main difficulty consists in finding a suitable sensor system able to detect the different coupling types. This is done by means of inductive fields requiring an accurate positioning of the coupling unit given a range of approx. 5 mm. By using a divided sensor block it is tried to achieve larger tolerances for the detection and error-free decoupling of mine car couplings.

The development carried out by Jansen has not yet been terminated. So far only a laboratory sample has been produced.

Let me finally present the development of a manipulator with particularly high requirements to the controls. This is the so-called "sorting manipulator".

Some 300 transport units with returned material leave the mine every day. The returned material comes from workings in which operations have ceased and it is planned to send them underground to the new workings again, if necessary after carrying out repairs.

Though the material is presorted underground, a transport container with standardized dimensions of 3 m length and 0.6 m width often contains very different materials which need to be sorted by tedious manual work on the sorting yard at the surface.

It is planned to develop a mobile manipulator for these tasks. It shall be used to carefully grasp, lift and store individual parts. Such a task can only be accomplished according to the present state of the art by means of a master slave control with force reflection.

Controls of this type are known. The particularity of this task is, however, the fact that at a projection of the manipulator boom of 3 m unit weights of up to 150 kg have to be moved. The corresponding forces can only be produced by hydraulic drives.

However, today there are no master slave manipulators with hydraulic drives. Therefore the development work centered on the adaptation of the master slave technology to the particularities of hydraulic drives like compressibility, vibration and control behaviour as well as temperature sensitivity. Under these conditions it is a completely new and challenging task to implement force reflection.

At present Biltz and E+PK work on the control technology and on the design of the drives for 6° of freedom per boom. According to the schedule a first prototype will be available in about one year's time.

Should the master slave control fulfill the requirements a number of further applications can be forecast also outside the hardcoal industry.

This last example shows that the special requirements in the mining industry can only be met by cooperating with several different scientific and industrial partners. At the same time it shows that the high requirements open up scope for approaches which are applicable also in other branches of industry.

In this sense I hope that my information incites an exchange of ideas beneficial for all parties involved.