MOBILE ROBOTS - A NEW GENERATION OF PRODUCTION TASKS FOR ROBOTS

Detlef Spee, Head of Department of Handling Systems
Fraunhofer Institute for Transport
Engineering and Physical Distribution

Emil-Figge-Straße 75
D-4600 Dortmund 50
West Germany

ABSTRACT

Mobile robots - a wide range of tasks await them - but what forms can this type of tool take? The design of the robot tools is determined by the most important functions, i.e. transporting in order to move the robot, and handling. Depending on the combination of these components mobile robots are designed for various applications and have various characteristics. The four most important combinations

- robots on rails
- robots on monorail
- robots on a S/R-machine
- robots on AGVs

are discussed on the basis of experience gained during the realization process. The specific characteristics of the mobile robots are presented on the basis of their fields of application.

The special constructional features of the systems are discussed on the basis of the solutions arrived at for the particular system in question.

Finally, a handling tool currently being developed for use on building sites is presented: A tool for the transfer of hollow concrete blocks which is currently undergoing the transformation from manipulator to automaton.

1. ROBOTS - HOW CAN THEY BE RENDERED MOBILE?

Mobile robots are production tools of the future and will be used to perform an increasing number of operations in the modern factory.

They are not, however, a vision of the future but already exist today. Some prototypes have already been built and the realization of individual robots for use in industry has taken place. The majority of these robots, however, have been designed for special operations, such as production in clean rooms. They are rarely used for "normal" operations.

How can a mobile robot be characterized? What makes a robot mobile? These questions must be asked when thinking about the special features of mobile robots. Well, a generally accepted definition has not been arrived at, so please allow me to attempt to clarify what is discussed below using my own definition:

The working area of mobile robots can be increased considerably without making constructional changes to the robots themselves by integrating them into transfer systems.

This defintion shows that a mobile robot is created by combining transfer and handling technology.

At the moment, this combining process is not yet at the stage where it is possible to speak of the "mobile robot" as a unit. As a rule, a mobile robot can be reduced to the following four main components from the point of view of the technical construction:

- robot drive module
- robot machine construction
- control systems and sensors
- energy supply.

In this connection, the robot drive module and the machine construction are the two components which make the nature of the functions to be shared patently obvious.

If the system of function sharing is examined, it can be seen that there are many ways of mobilizing a robot.

At the Fraunhofer Institute (ITW) some of these possibilities have been realized:

- The rail-guided robot ROMEO
- the Materials Flow Handling System (MHS), a robot on a monorail
- the mobile order-picking system, a robot on a S/R-machine
- a robot on an AGV, called "HERMES"

I should like to explain the characteristics of these four mobile robots below.

1.1 "ROMEO" - A Rail-guided Robot

Uses - systems with line-drive capability

"ROMEO" was developed at the ITW as early as 1984. The operation envisaged was the order-picking of square filled packages. In order to have access to a sufficient number of articles, it became necessary to mobilize "ROMEO".

The order-picking storage system is formed by pallets of articles arranged in two lines. "ROMEO" moves along between these lines, picks up the articles and deposits them on the order picking pallet which it transports with it (Fig. 1).

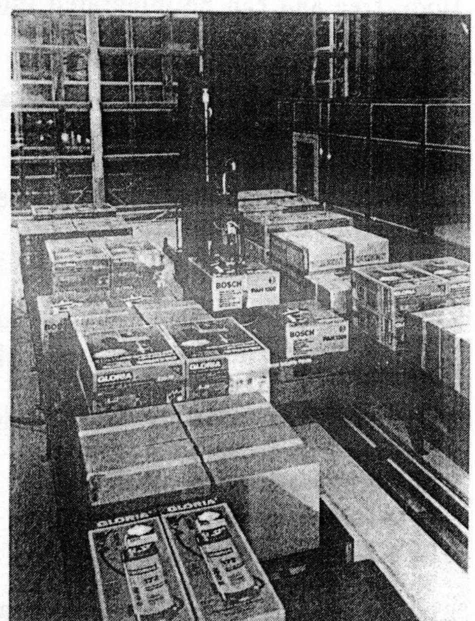


Fig.1: ROMEO-the rail guided robot

When realizing handling systems with "ROMEO", an additional mobile application became clear - the multi-palletizing of sacks. "ROMEO" drives to the roller conveyor, removes the sacks and deposits them on the pallet available.

1.1.1 The Kinematic Construction - Adapted To The Operations Required

A major requirement for the kinematic construction of "ROMEO" was to enable it to drive in storage aisles and remove articles from the pallets. The aisle constitutes the robot's area of movement. "ROMEO" need only be capable of linear movement to satisfy this parameter.

The combination of rails and travelling gear is thus ideal for a robot drive module. The robot can be positioned accurately and it can be supplied with energy and information via a solid link using cable chains.
The kinematics of the robot have been constructed to enable it to drive into the "gripper window" created in the storage rack and remove the articles from the available pallet. This ist designed for short cycle times and for areas where there is a low risk of collision. In addition to the drive axis, "ROMEO" has the following axes construction:

CZY as main axes, i.e.

- a rotational axis around Z (350°)
- a lifting axis (1,850 mm as a standard construction)
- a radial telscopic axis

With this construction, the robot can operate in a stationary working area with a diemeter of 2,600 mm. This means that Euro-pallets which have been stored lengthwise on both sides of the rail path can be reached.

In contrast to "ROMEO" with its limited mobile area, a system was subsequently developed which not only has an almost unlimited working area but also operates floor-free and can be integrated into existing infrastructures.

1.2 The Materials Flow Handling System (MHS) Floor-free Transport And Handling Technology

Uses: can be integrated into existing monorail systems.

The MHS consists of the basic components monorail and handling device.

It is possible to couple various handling axes with modified travelling gear, resulting in a very wide-ranging number of possible uses.

The MHS which comprises the basic components

- travelling gear
- lockable suspension gear
- diverse handling tools

can operate in conventional monorail systems (Fig. 2).

The following are typical characteristics of the system:

- floor-free transport and handling technology at the second factory level
- info sheet
- functional separation of robots and factory, which has considerable advantages in terms of safety as the handling device is only active in the work station area and need only be specially protected here.

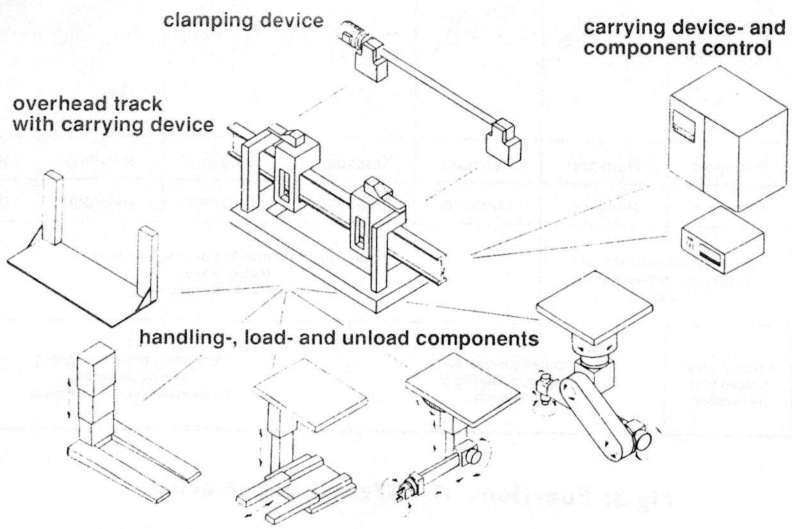


Fig.2: Robot on monorail

1.2.1 The Constructional Design Of The MHS

1.2.1.1 The Travelling Gear - The Transport Unit

The travelling gear corresponds to the conventional travelling gear used in monorails where no special demands are placed on positional accuracy.

1.2.1.2 The Suspension Gear - The Coupling Element Overhead Track/Robot

An neither monorail nor rails and rail suspensions are designed for anything other than vertical forces, other strains are only permissible at low levels.
The strains occuring with handling processes must therefore be taken up by other elements. A clamping device which is supported on reinforced rails located at the work points was developed for this (patent pending).

1.2.2 The Robot - Can Be Configured According To The Operation Required

Various robots can be flanged onto the travelling gear and the suspension gear. The nature of the robot is determined by the operation required (Fig. 3).

Two types have been realized at the ITW. The first of these involves a conventional 6-axes Manutec robot (Fig. 4). Subsequently, the supply vehicle with the active load handling devices was developed as a handling tool.

The positioning gear is a further important component of the robot. As the vehicle

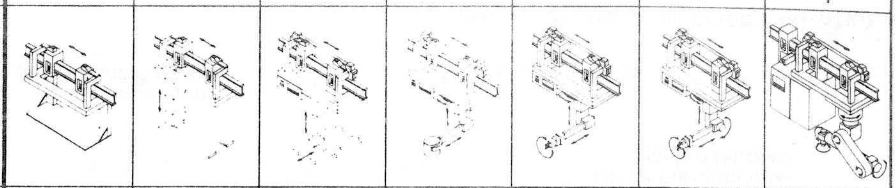
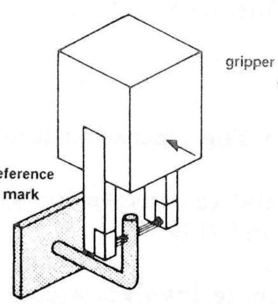
type	1	2		3			
degrees of freedoom	1	2	3	4	5	6	7
example							
major function	Transport	Transport	Transport	Transport	Handling	Handling	Handling
minor function	———	Handling	Handling	Handling	Transport	Transport	Transport
characteristics	like a conventional monorail In general clamping device required		Integration of handling devices with more than one axis clamping device required				
	external load/ unload tool necessary	handling device for loading/unloading of unit loads		Performing handling tasks at several locations, no transportation of unit loads			

Fig.3: Functions of different components

can only be positioned along the rail with the accuracy of an conventional monorail.travelling gear, i.e. to within a centimeter, the robot is referred to points in its environment

The exact robot position is determined by passing a glass fibre light barrier located in the robot gripper across a reference mark at the work station (Fig. 5). The light barrier signal is passed to an interrupt input in the control system. The robot programmes are corrected using this method of positioning measurement. In this way, it was possible to achieve a positioning accuracy of +/- 0,5 mm with the first prototype.



Interruption by means of optical switch

Fig.5: Positioning-device

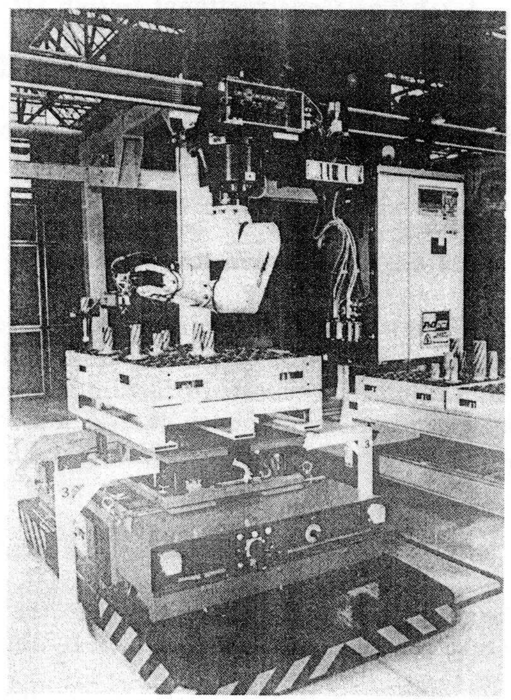


Fig.4: 6-axes Manutec-robot

1.3 The Mobile Order Picking System (MKS) - A Robot Used In Storage And Retrieval

1.3.1 Uses

There is already a mobile storage robot in use in storage systems today. It is a portal robot mounted on a S/R-machine (Fig. 6). The tool developed is designed for handling 16 hardware containers which are stored behind and beside each other on a pallet. This made it possible for the first time to open up a third dimension (storage depth) in a container storage system. Now access to the random stored containers is available without having to retrieve the entire pallet and transport it to the order picking zone.

The pallet, on which the containers to be order-picked are located, is retrieved by the S/R machine using a telescopic fork. Thus, the object to be handled is in the direct reference system of the robot. The problems connected with positioning were solved in two stages. Firstly, the complete system comprising the robot and the S/R machine must be positioned relative to the pallet. This is state-of-the-art. As the pallet can be mechanically positioned exactly on the S/R-machine, there are no special demands on the robot positioning gear.

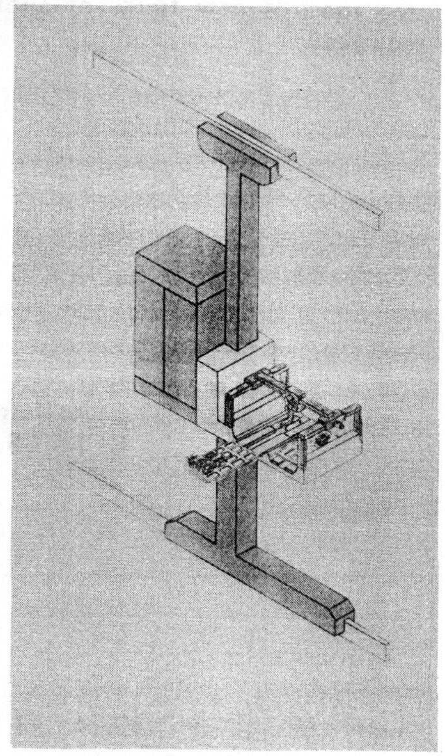


Fig.6: Portal-robot on a S/R-machine

1.3.2 Construction

In the first realization, twelve robots were required. For this reason, the principal ordered an extremely inexpensive robot. This aspect was given due consideration in the development stage. The manufacturing costs for a portal robot with a working area measuring 900 x 500 x 80 mm are under DM 50.000,--.

The following constituted important factors in achieving this goal:

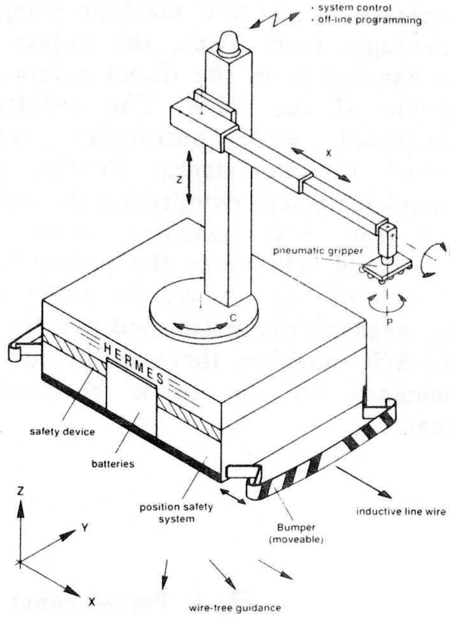
- step motors were used in the drive system
- a conventional programmable controller (PC)
- the axes were positioned using intelligent step motor cards

1.4 Omnidirectional Robots

1.4.1 HERMES - Prototype Of A Mobile Robot Using An AGV As A Base

By combining AGV and robot, "HERMES" can be moved in any direction.
The AGV is guided by wire over long distances and wire-free in restricted areas.
The orientation and data transfer are implemented using infrared technology.
The "HERMES" guidance system facilitates the adaptation of the robot to changing working area
NiCd batteries are used for energy supply. They make it possible to operate uninterrupted round the clock.
Fig. 7 shows the robot with the essential system components.
This system concept permits a high flexibility when using mobile robots. This is a step towards new fields of application where a higher degree of independence is required.

Fig.7: The mobile robot HERMES



1.4.2 A New Development - On The Way To Robot Which Can Be Used In Block Wall Laying

The mobile robots presented so far are all intended for use indoor. In co-operation with Kesting, a small firm of builders and contracters, the ITW has also taken the first steps towards using mobile robots outside closed workshops. Kesting have developed a system of building using hollow concrete blocks. As these blocks measuring 100 x 65 cm can no longer be laid manually, a manipulator with manual controls was developed (Fig. 8). The manipulator can set up to 4 blocks on top of each other. Its lifting mast is telescopic to enable it to go through door openings. Energy is currently supplied via a trailing cable.

The aim is not to develop a 100 % fully automated robot but to arrive at a flexible handling tool which can perform the simple functions automatically, functions which take up 75 % of the guidance operations. The complicated functions, e.g. joining, will be completed with worker assistance.
The work sequence is as follows:

1. Collection of a block (manually assisted)
2. Lifting the block
3. Driving to the block-laying location
4. Raising the block to the correct laying height
5. Revolving the robot mast
6. Telescoping the arm
7. Placing the block (manually assisted)

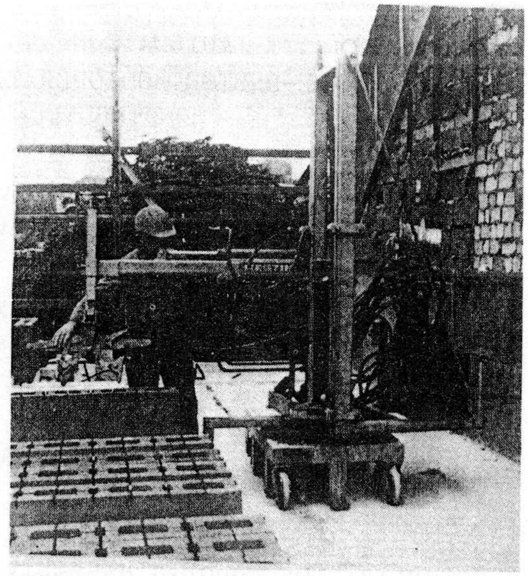


Fig.8: Manipulator for block laying

This progressive handling system requires the following functions among others (Fig. 9):

- Pre-selection of the block-laying height
- Clearance sensors for orientation at the wall
- Clearance sensors to determine where the block has to be laid
- Protection of the working area

These are only the most important points to show that there is still a lot of development work to be done until the tool becomes a "mobile robot at the building site".

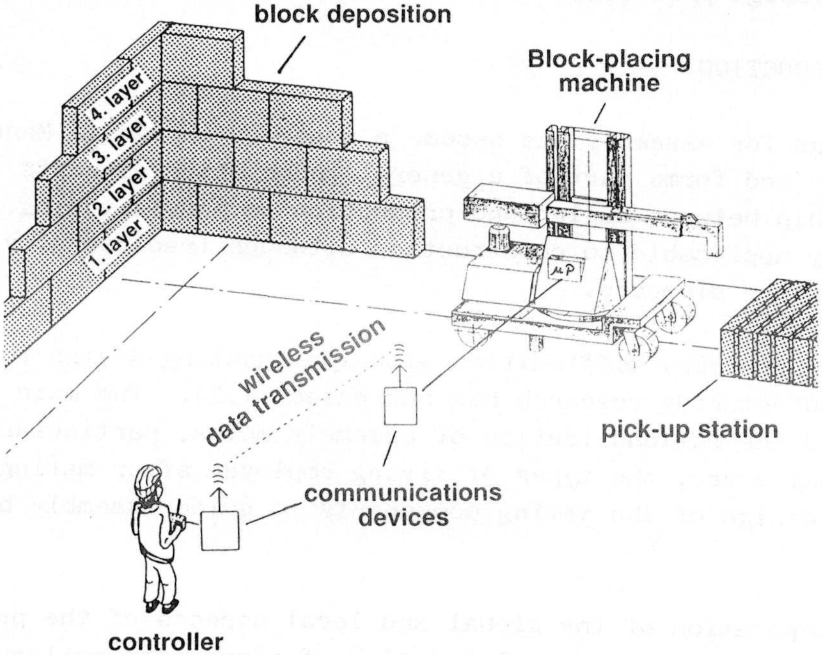


Fig.9: The manipulator at the site