Automation and Robotics in Construction XI
D.A. Chamberlain (Editor)

Driving forces and status of automation and robotics in construction in Europe

W. Poppy

Construction Machinery - Design and Engineering; Berlin University of Technology
Jebensstrasse 1, D-10623 Berlin / Germany

ABSTRACT

Automation and robotics in Europe are concentrated on concrete and asphalt mixing, concrete block and pipe making, precast concrete units and masonry prefabrication, control of mobile construction machinery, tunnelling, and renewing of buildings and sewers. The development has been going at a slow pace, because not all prerequisites to the introduction of these new technologies are fulfilled in the construction industry. Limited need for construction works on one hand, and shortage of skilled workers as well as new demands and tasks on the other hand stimulate the development - performed by manufacturers, construction companies, universities and institutes - in different ways. However, a survey around a lot of European specialists allows to draw a uniform picture of the driving forces and the current status of research, development, and usage of automation and robotics in construction (ARC).

1. INTRODUCTION

The construction technique in Europe is - as in all industrial countries of the world - characterised by a wide range of mechanisation. The transition from manual working methods to mechanical work went off very differently in the individual construction areas so that the prerequisites for automation and use of robots vary considerably, too. While important advance with the automation of concrete and asphalt mixing was already achieved in the sixties, the development of the necessary prerequisites for mobile construction machinery first began with the introduction of microelectronics in the beginning of the eighties.

Most of the countries of Western Europe are members of the European Community. January 1, 1993, a new age began for these countries: the Common Market - without economic borders between the twelve members Belgium, Denmark, France, Germany, Greece, Ireland, Italy, Luxembourg, The Netherlands, United Kingdom, Portugal, and Spain.

In reality the borders are not eliminated completely. So the economical and technical development will be different also in the next years, because the current situation in the various countries is very different.

On one hand there are similar requirements to be fulfilled in all countries. On the other hand the historical growth of the economic and the climatic conditions, especially concerning

all interests of the construction industry and the use of automation and robotics in plants and on sites, are to take into account.

In the following I will make the attempt to analyse the "Driving Forces and the Status of Automation and Robotics in Construction in Europe". It is the result of a survey around a lot of specialists - mainly scientists and researchers - in the field of automation and robotics in construction - not only in the European Community but also in Austria, Switzerland, Finland, and Sweden. The specialists were asked to mark the in their opinion most important points in a questionnaire of 100 issues.

The current status of automation and robotics in Europe can not be quantified exactly on this basis - neither for every country nor for the continent altogether. But independently from economic and technical conditions one can draw a rather uniform picture of the situation in Western Europe.

After these symposia had begun in 1984, we agreed every year on basic arguments for need and benefit of automation and robotics in construction. Most of them seemed to be clear and obvious. But there is a difference between theory and practice.

Scientists and Researchers in all countries have many good ideas how to increase construction techniques by using automation and robots. But often they do not have enough money to translate their ideas into action, and therefore they are often protected from bad experiences. They play their games on abstract playgrounds, for example on computer monitors. One main aim of a couple of scientists is to realise a complete change of the basic design and construction rules and methods. In my opinion this way does not exist. There is no alternative to a development of small steps. We can go only this long way - step by step.

Designers in the construction industry and civil engineers in the construction industry with tasks for practical use eat the hard bread of reality. They must find solutions not for academical ideas but for practical problems that can not be managed differently. The final solution must be good for practical use and for all requirements of effective work and high economy. These people have to fight against new enemies every day. Again and again they learn the proverb: the devil is in the detail!

Fact is that overall automation and robotics in construction do not play a very important role in most of the Western European countries. Main activities are pursued in universities and institutes and neither in the construction machinery industry nor in the construction industry. Experiences of the last years show that Finland, Germany, Sweden, and United Kingdom are the most active countries in Europe.

Activities are not a question of need for automation and robotics in the construction industry or of innovative ideas but first of all they are a question of the availability of money. The world-wide recession reduces research and development in most of the European countries.

Only in Germany extensive need for construction work marks the situation since the unification in 1990. Nevertheless, most of that need is not satisfied with automation and robotics but with conventional construction methods and machinery.

2. MAJOR DRIVING FORCES AND BARRIERS

2.1 Major driving forces

The first point I will look at are the major driving forces for automation and robotics in construction.

For years the personnel, technological and economic conditions for the automation of construction machinery and plants in Europe were characterised by

* an extensive lack of skilled workers and a growing average age of the staff,
* demands for effective humanisation of nearly all construction works,
* increased requirements on the quality of the work execution,
* a need for works in dangerous and inaccessible areas of operations,
* an increase in performance and reduction of costs for improvement in economy, and
* by the competition on international markets of construction machinery.

First of all there are three major driving forces in Europe: increase in performance, reduction of costs, and improvement in economy.

Special fields are the avoidance of work in inaccessible areas, e.g. micro tunnel, and the avoidance of work in uncomfortable, unreasonable, and dangerous areas, e.g., in case of hazardous influence of temperatures, dusts, steams, gases, liquids or radioactivity as well as in case of danger of falling or collapsing. For these problems no alternative solutions exist.

Further general demands are higher quality of the work execution and the optimisation of work processes.

Humanisation of construction works and relief and protection of the operators as well as safe machine operation and simplification of the machines' operation do not belong to the major aims.

In face of the general recession in the European construction industry the shortage of skilled workers is at present not one of the major driving forces for automation and robotics in construction.

Only in Germany we have to consider a growing average age of the staff and lack of young people in the construction industry. Also for years to come the German construction industry will not succeed in covering the need for qualified junior members of the staff for machines operation and maintenance. In the next decades we will have further increase of employees over fifty and a remarkable decrease of employees under thirty.

The European specialists see the following issues without actual importance for research and development: better use of the machines' efficiency, minimisation of power consumption, determination of optimal combinations of machines, just-in-time supply of the machines for the construction site, extensive need for construction work (only in Germany) and the competition on international markets of construction machinery.

2.2 Major barriers

The next point are the major barriers for automation and robotics in construction.

The fact that the development to a higher degree of automation in the construction industry of Europe has been going at a slow pace so far has to be attributed to high costs and shortage of public money for research and development.

Lack of interest in the construction industry, unsolved technical problems, and the special conditions of use in construction plants and sites lead to problems of acceptance in the construction industry.

A problem of former years has been solved: the lack of electronic components and systems and of confidence in the life expectancy of electronic components and systems.

Remarkable self-confidence of the European scientists can be noticed concerning the availability of scientific institutes and their capability in basic scientific knowledge, e.g. modelling and simulation.

In several countries a research infrastructure has grown up, independently from the existence of a large domestic fabrication of construction machinery.

3. STATUS OF RESEARCH AND DEVELOPMENT

What is the status of research and development in European countries?

To find out the current status of research and development (R&D) concerning automation and robotics in construction (ARC) in Europe three question were asked to the European specialists:

- How many *institutions* are working in ARC-R&D?
- How many *manufacturers* of construction machinery and equipment are working in ARC-R&D?
- How many companies of the *construction industry* are working in ARC-R&D?

No specialist was able to supply an exact information. The scope of answers reached from complete helplessness to unsure estimations. It will be an important task for the International Association for Automation and Robotics in Construction (IAARC) and their national subsidiaries respectively to collect exact information about these questions. Identifying a growing number of companies, which are working in research and development on automation and robotics in construction, and establishing fruitful connections between active partners can help stimulate the development for more and faster progress.

We have general fields of research and development on automation and robotics in construction in Europe.

The main general field of research and development is the growing use of electronic systems in construction machinery and equipment.

A daily task of R&D is to choose and test suitable electronic components as a prerequisite for the configuration of reliable control systems, e.g., sensors, actuators, microprocessors, micro controllers, bus systems.

So far electronic controls are mainly brought in selectively in addition to and as a modification of the conventional technology. Fundamental prerequisites for the creation of from top to bottom new conceived flexibly automated machines and systems are not fulfilled yet.

The necessity for 3D-measuring devices is a special task. Application of robots or manipulators on the site demands 3D-measuring devices and 3D-modelling of the building to be built. This 3D thinking and connection of the 3D-model and 3D-measuring is in its infancy at the moment. Control and autonomous navigation of robots in unstructured environment also need 3D-devices.

A general impression is the neglecting of construction engineering and management in all European countries.

Low interest in the study and analysis of kinematics and in modelling and simulation shows serious deficit of basic research. More interest is expanded to Expert Systems and Artificial Intelligence.

Minor interest in Fuzzy Logic and Neural Networks indicates a shortage of basic scientific knowledge. The importance of research and development on robotics as a basement of autonomous robot control systems will soon grow rapidly.

Overall research and development for *automation* is concentrated on fabrication of precast concrete units, bricklaying machines (especially in the United Kingdom and Germany), control and monitoring of mobile construction machinery, computer controlled equipment, and tunnelling and for *robotics* to mobile construction machinery, distribution booms of concrete pumps (Germany), excavators (United Kingdom), renewing of buildings, and micro tunnelling (United Kingdom and Germany) and others with no important weight.

4. STATUS OF USAGE IN PRACTICE

What is the status of usage of automation and robotics in practice?

In terms of automation and robotization, stationary machines and plants on the one hand and mobile machines for the construction-site on the other hand have attained a very different state of the art in Europe.

The status of usage in practice is marked by monitoring, diagnosis, and maintenance, safety aspects as well as operator information and guidance, independently from the kind and type of the machines, but predominantly in the large sizes.

Quality control, and measuring and recording of machine data are not so important until now.

4.1 Fabrication of precast concrete units

A high degree of automation is attained at stationary concrete and asphalt mixing plants and at the series production of standardised concrete blocks and pipes.

The prefabrication of large concrete units went through a changing development in Europe. After a gradual increase of automation up to the early seventies a beginning recession caused a general return to conventional construction techniques. Prefabrication plants with a higher degree of automation had to be closed. Some years ago a new development began and has in individual cases already resulted in computer aided manufacturing (CAM) and in initial stages in computer integrated manufacturing (CIM) of precast concrete units.

4.2 Bricklaying machines

Besides the fabrication of precast concrete units the prefabrication of masonry elements in stationary plants gains growing importance in the United Kingdom and in Germany. The people's preference to bricked residential buildings and the high dependence on weather of this construction method have lead to the development of a number of bricklaying machines. Some of them are already in practical use. In other cases neither a systematic market analysis has been done nor a ripened design principle has been developed. Therefore they are not marketable yet. With bricklaying machines a higher output can be achieved. They facilitate great lightening of work and the saving of workers.

4.3 Control and monitoring of mobile construction machinery

So far mobile machines are characterised less by automation and robotization than by a growing penetration with microelectronic components and systems. The machines of some manufacturers are already equipped with large systems which inform the operator constantly

about the state of the machine, which signal inadmissible changes optically and acoustically and which are able to give instructions to clear faults. Such systems contain control devices to optimise the use of the machines and to suit them to the conditions of use.

4.4 Expert Systems for planning and controlling

An exact choice of construction machinery and planning of work is necessary for their use on sites. Due to many exogenous conditions on construction sites the execution of work is mostly of stochastic nature. To take these conditions completely into account, planning systems have been developed, which make it possible

* to determine optimal combinations of machines,
* to ensure just-in-time machine preparation on the construction site and
* to gain continual and high use of capacity during the whole operation time.

By the aid of Expert Systems the organisation of the construction site can permanently be adapted to changing conditions.

4.5 Computer controlled equipment

So far the working processes of mobile machines have to be controlled by operators. An important decision in every development is to split control tasks between men and technology, especially in case of machines, whose movements of working equipment have to be adapted to a permanently changing working process, e.g. hydraulic excavators, drilling machines, and concrete pumps with distributor boom.

4.6 Tunnelling

For years underground construction methods have been of growing importance in Europe. The shotcrete technology for the lining of tunnels imposes tremendous requirements on the operators. Shotcrete robots have been developed to improve the working conditions, the shotcrete technology, and the quality of work.

In many centres of population it is not possible to do service works with open trenches. Therefore the number of trenchless working laser-controlled machines for micro tunnelling with small cross-sections has increased considerably.

4.7 Renewing of buildings and sewers

The sewerage systems represent a special problem in many German towns. Already in World War II they have suffered excessive damages and now they reach the end of their normal lifetime, too. Urgent need exists both for robots to inspect the sewers and for renewing the damages with trenchless methods. Several robots to coat old pipes, to renew pipes and to point bricked sewers have been developed.

5. A PREDICTION OF FUTURE USAGE

Finally I will make a guess at future usage of automation and robotics in construction in Europe. General aims and tasks of future development and usage are - in the opinion of European specialists:

* the improvement of working conditions and safety in construction,
* the increase of performance and quality,

* the reduction of costs of construction work.

These tasks are abstract and self-evident.

"In addressing automation and robots applications, consideration must be given to the whole subject of "Computer Integrated Construction". Automation of the construction process will be slow unless we consider the use of "robotics" in the design process and as an integral part of complete Information Technology (IT) systems.

Robotics application will be selective and be influenced by economic and practical considerations and, of course, the type and nature of construction. However, in selective operations, such as excavation, the wider application of robotics will be feasible. Equally, Inspection Robots will have a very useful and wide application to many types of structures. On the other hand, the universal introduction of "heavy robot plant to site", will be difficult indeed.

To accelerate the introduction of automation and robotics in the construction process, there is a need for a number of test beds where the integration process of IT, machines and human resources may be demonstrated." - (Dr. Fikry K. Garas, Taylor Woodrow - UK).

For a lot of people in the European construction industry robotics is not a "hot issue". The main issue in automation in the construction industry is not the automation of the construction process itself ("replacing labour"), but the computer-support of design, planning, cost-calculation etc.

A main task of automation in the construction industry is to increase the possibilities of information interchange - not only between locations or companies, but also between computer-applications in one system.

The prerequisites to the development of automation and robotics are not alone fulfilled by the availability of new technologies, especially of microelectronics. The suitability of electronic components for construction machinery is significant. High loads and heavy use of the construction machinery, extreme changes of weather and climate, influence of building materials and dirt as well as poor operating and maintenance require the use of extremely robust automation components, which must be available in low cost/heavy duty-versions.

These components, e.g. sensors, actuators, microprocessors, on-board computers, bus systems, process in- and output units and power modules, must have - considering very different combined machine pools - the feature of machinery components: standardised, with well-known use and quality characteristics, easy to handle and generally available.

On this base the manufacturers can use cheaper series products of component suppliers, and the user of construction machinery can organise a simpler storage of replacement parts and maintenance.

Those tasks require theoretical basics, which make a systematic new design of products and construction processes under integral aspects possible, i.e. with tuned fusion of mechanical, hydraulic, electric and electronic components (mechatronic). That fusion cannot be achieved by an empirical development of machines and systems, where an electronic component is grafted on to an existing product. The development must rather start with a complete system analysis, which includes machines, operation, construction methods, building materials and all conditions of use. Such an integral reflection on the system man-machine-construction technology-site-environment and the consideration of all interactions is as a rule possible by modelling and simulation of all important system parameters only.

General aims and tasks of development and usage of *automation* are - in accordance to the European specialists - safety aspects and quality control.

An often expressed idea concerning the development of *robotics* are multi-functional robots to increase the productivity and multi-functional robots for dangerous jobs.

Special tasks of such robots are to be seen in the substitution of interior works, e.g. multi disciplinary robots to work on interior surfaces of floors and walls (finishing, plastering, and painting), robots for maintenance, inspection, and repair of tall buildings, cooling towers, and oil drilling platforms, multi-functional gripping tools for assembly works of different elements (walls, columns, slabs), and block and brick laying robots.

CONCLUSIONS

The European development in the field of automation and robotics in construction is handicapped by the current recession. Compared with similar branches of the industry the construction technology is characterised by an enormous delay - in spite of several encouraging examples of automation and robots. That delay has to be made up to improve working conditions and safety in construction, to increase performance and quality and to reduce costs.

Representatives of the German construction industry look forward to a special way of using robots. They expect the growing of service companies, which commission a pool of rental robots including skilled operators and all maintenance tasks. It can be a way to guarantee a full and qualified use of the robots' capacity. A comparable example of such service is the combination of ready mixed concrete and mobile concrete pumps.

An important step ahead is the grown confidence in the life expectancy of electronic components and systems, because manufacturers present solutions with a high standard of quality.

The manufacturing of construction machinery in small series and the machine pools of the construction companies with many different kinds and sizes of machines suggest the development of standardised concepts of measurement, control, and automation for mechanised construction processes. On the one hand that will create better conditions for developing a suitable range of components. On the other hand that will simplify the use and the maintenance of construction machinery in the construction companies.

Large need exists for highly sophisticated research in the field of basic knowledge, e.g. Expert Systems, Artificial Intelligence, Fuzzy Logic and Neural Networks. It leads to the needed theoretical basement for practical solutions in the future.
However, actual progress will only be possible in case of commercial interest of the construction industry.