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Robotized Mould Milling and Precast Concrete Polishing

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Abstract

A robotized cell consisting of a standard industrial robot, trackmotions, necessary tools and power sources, is applied to precast Architectural Concrete in mould milling and polishing of façade elements. Tests performed in an industrial environment, clearly show that, milling and polishing with a standard industrial robot is possible, robotization increase productivity, and the robot enables flexible automation.

1. INTRODUCTION

In rich developed countries, the construction industry is facing shortage of (skilled) labour, on site works in particular. This results in high salaries, high costs and in a risk of falling behind of tight schedules.

This situation is caused by the working environment and conditions prevailing on construction sites and in many factories as well. This syndrome is characterised by three attributes, which can be called 3 Ds (synonymous with the famous Japanese 3 Ks (5Ks) for Kitanai, Kitsui and Kiken) ie Dirty, Difficult (also Dull) and Dangerous.

Industrialised building construction and automation is the answer to this predicament. Three alternatives are put forward below (see figure 1).

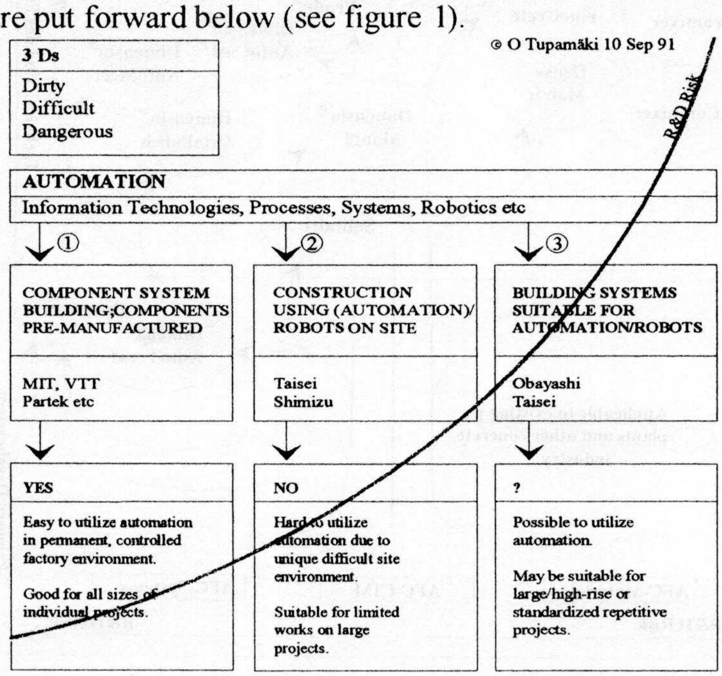

Figure 1. Three Alternatives for Automation and Robotics in Construction [1].

2. PARTEK CONCRETE - LEADER IN PRE-CAST CONCRETE TECHNOLOGIES

Partek is an international industrial group, which develops, manufactures and markets products and services intended primarily for construction and building material industry. Majority of its turnover of 1.3 billion USD is made outside Finland, mainly in the Baltic region, Western Europe and North America.

The largest business sector, precast concrete elements ie Partek Concrete Ltd, is today a leading player in the whole world on the precast concrete business. We have factories in operation in eight countries (Finland, Norway, Germany, The Netherlands, Belgium, France, Singapore and Malaysia), and our precast concrete technology and machinery, under the brand name Elematic, has been delivered to almost 50 countries.

In the end of 1990 Partek Concrete Ltd. launched an ambitious, medium range, development program called Automated Factory Concept (AFC), aiming at a leap ahead in precast concrete material (concrete), systems (machinery) and information technologies (see figure 2).

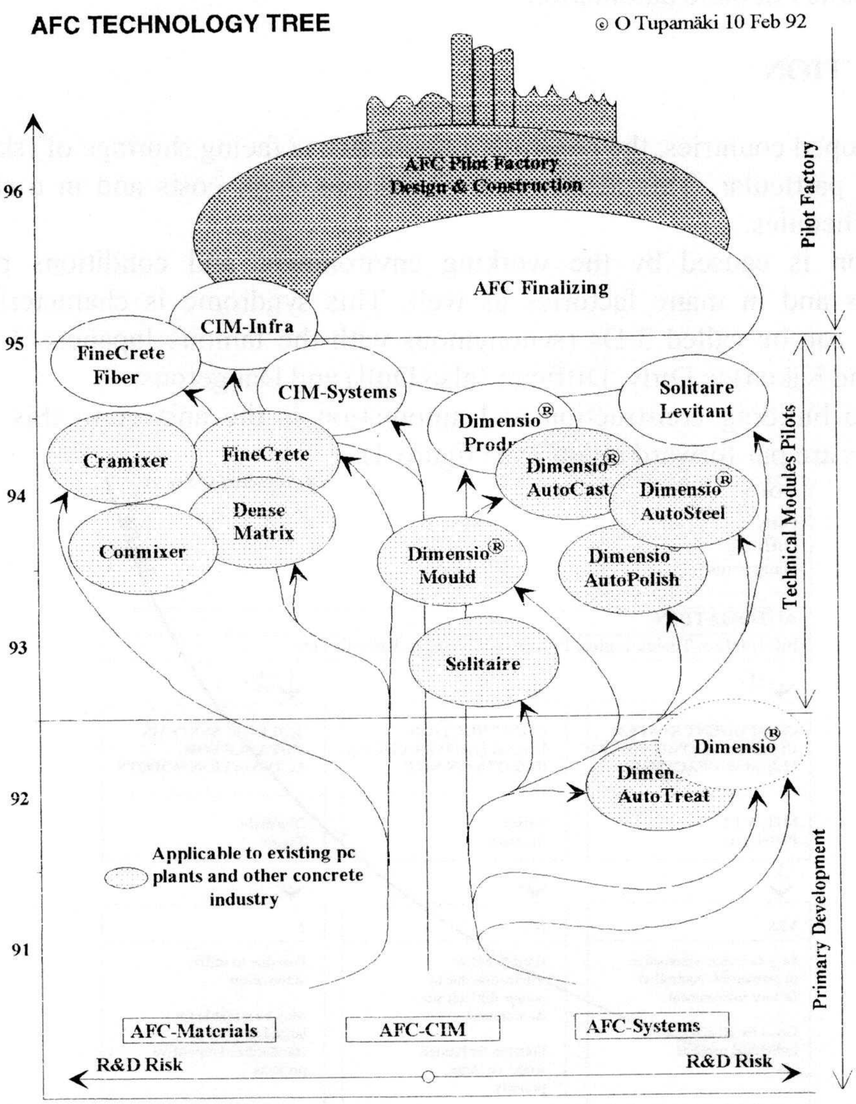

Figure 2. AFC Technology Tree [2].

AFC results in highly automated and robotized precast architectural concrete factory, in which production in short series is made possible.

Some pilot applications have already been released and tested in our factories. One of such is robotized mould milling and precast concrete polishing -pilot (Dimensio® Mould and Dimensio® AutoPolish respectively) at Partek Ergon NV in Lier, Belgium.

3. THE PILOT CELL

3.1 Lay-out

The pilot cell consists of a standard industrial robot (six degrees of freedom), a 7-meter transverse trackmotion (integrated seventh axis) and 19-meter longitudinal track (external eight axis). Thus the robot can cover a work envelope of 7 x 19 x 2 m3. Large work envelope is needed for two reasons as follows; firstly final products ie moulds and elements are large in size and secondly during polish there is a requirement for interim manual workphase, which is porehole filling with concrete slurry.

An operator room is located in the end of the eight axis, facing to the robot (not shown in the illustration).

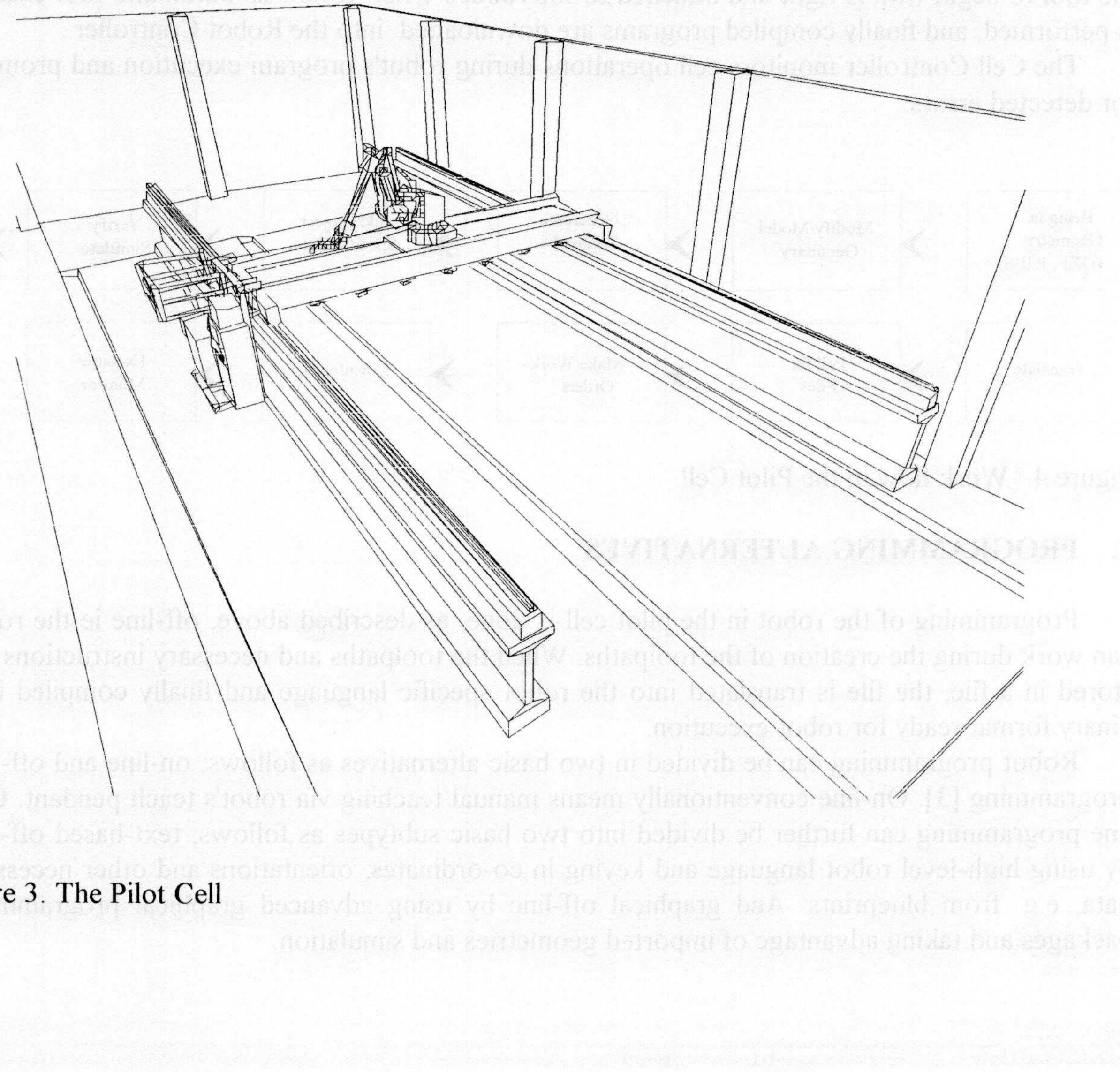

Figure 3. The Pilot Cell

3.2 Work flow Description

A typical procedure (see figure 4) to program and operate the pilot cell is discussed here. Some other programming alternatives, which are under testing, are put forward later in this paper.

Geometric CAD models of the elements and/or moulds are transferred into the robot programming system via DXF or IGES translators. In some cases geometries are totally modelled in the programming system. Some modifications have almost always to be done to the transferred geometry.

Toolpaths are created on the surfaces either in CAD/CAM environment or in graphical off-line environment and stored as a program file. A program file typically includes robot home location and necessary via points, e.g. engage and retract points, work points, tool specification and necessary data for later identification of program, workpiece and project.

Generated toolpaths are verified by simulating and, if necessary, by collision checking (for gouge free path) and translated into a robot specific language and finally compiled into the binary format.

Specially developed Cell Controller software polls for translated programs and, after having found one, lets the operator make milling/polishing orders from Cell Controller Production window. When necessary data has been keyed in and approved, checks the Cell Controller that the tool to begin with is right and attached to the robot's wrist. If not, an automatic tool change is performed, and finally compiled programs are downloaded into the Robot Controller.

The Cell Controller monitors cell operations during robot's program execution and prompts for detected errors.

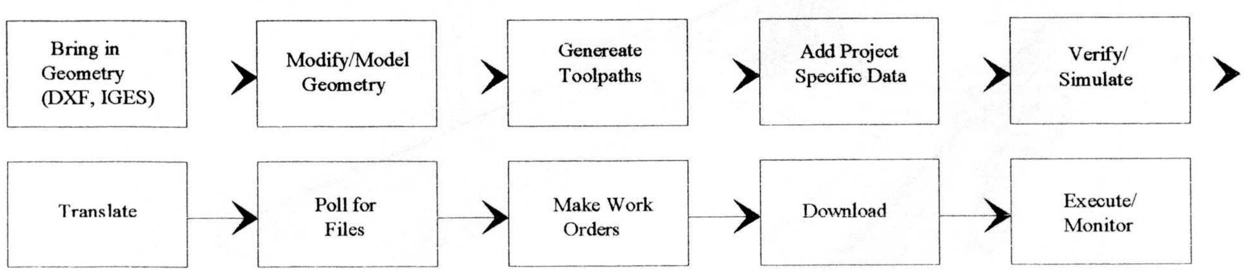

Figure 4. Work flow in the Pilot Cell.

4. PROGRAMMING ALTERNATIVES

Programming of the robot in the pilot cell is done, as described above, off-line ie the robot can work during the creation of the toolpaths. When the toolpaths and necessary instructions are stored in a file, the file is translated into the robot specific language and finally compiled into binary format ready for robot execution.

Robot programming can be divided in two basic alternatives as follows; on-line and off-line programming [3]. On-line conventionally means manual teaching via robot's teach pendant. Off-line programming can further be divided into two basic subtypes as follows; text-based off-line by using high-level robot language and keying in co-ordinates, orientations and other necessary data, e.g. from blueprints. And graphical off-line by using advanced graphical programming packages and taking advantage of imported geometries and simulation.

Technology development has enabled some new techniques to be introduced into the above mentioned categories; 1) advanced text-based high level language tools are under development [3], 2) machine vision can be used for digitisation of geometries, position/orientation determination and toolpath creation and 3) some other sensor-based techniques like force sensing can be used for on-line teaching or off-line real-time motion control.

5. MILLING MOULDS AND POLISHING CONCRETE SURFACES

The pilot cell has been in operation about a year now and we have gained plenty of experience both on the robotized mould milling ie Dimensio® Mould and on the concrete surface polishing ie Dimensio® AutoPolish projects.

Milling operations in mould making are analogous to those found in other fields of industry, but accuracy requirements are not very high typically we are speaking about rather 1 mm than 1/10 or 1/100 mm. Lower requirement enables usage of an industrial robot as long as blank material is wood or alike in terms of milling forces. When speaking about so called difficult shapes (for carpenters) like ruled surfaces or doubly curved surfaces, milling with a robot reduces throughput time considerably.

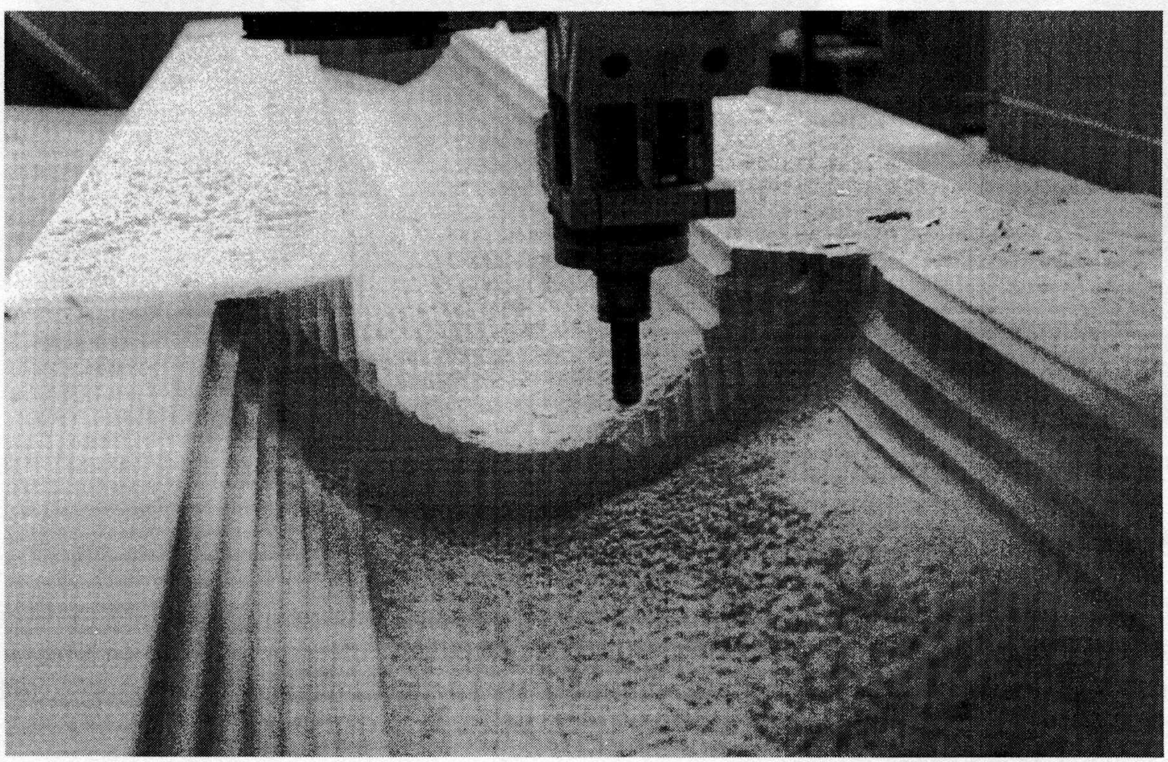

Figure 5. Milling of the Mould for Pilaster Elements.

Polishing is tedious and time consuming if it has to be done by hand. Existing machines enable almost only flat surface polishing, but require a lot of time and effort to level elements according to the plane of the machine spindle. Typically only one surface can be polished with such an inflexible machine and the rest manually to avoid turning of the elements. A few new generation polishing machines enable limited planar angles.

Polishing with a robot provides tireless "worker" with constant polishing pressure against the surface and automatic tool change. Unmanned shift is made possible supposing that enough elements can be placed within the robot's work envelope.

Interim workphase, the porehole filling with cement slurry, has been arranged by dividing the work-area into two equal parts. While robot is working on the other area, another part can be entered without occurrance of safety stop.

Changeover from the milling application to the polishing or other surface treatment application takes only a few minutes.

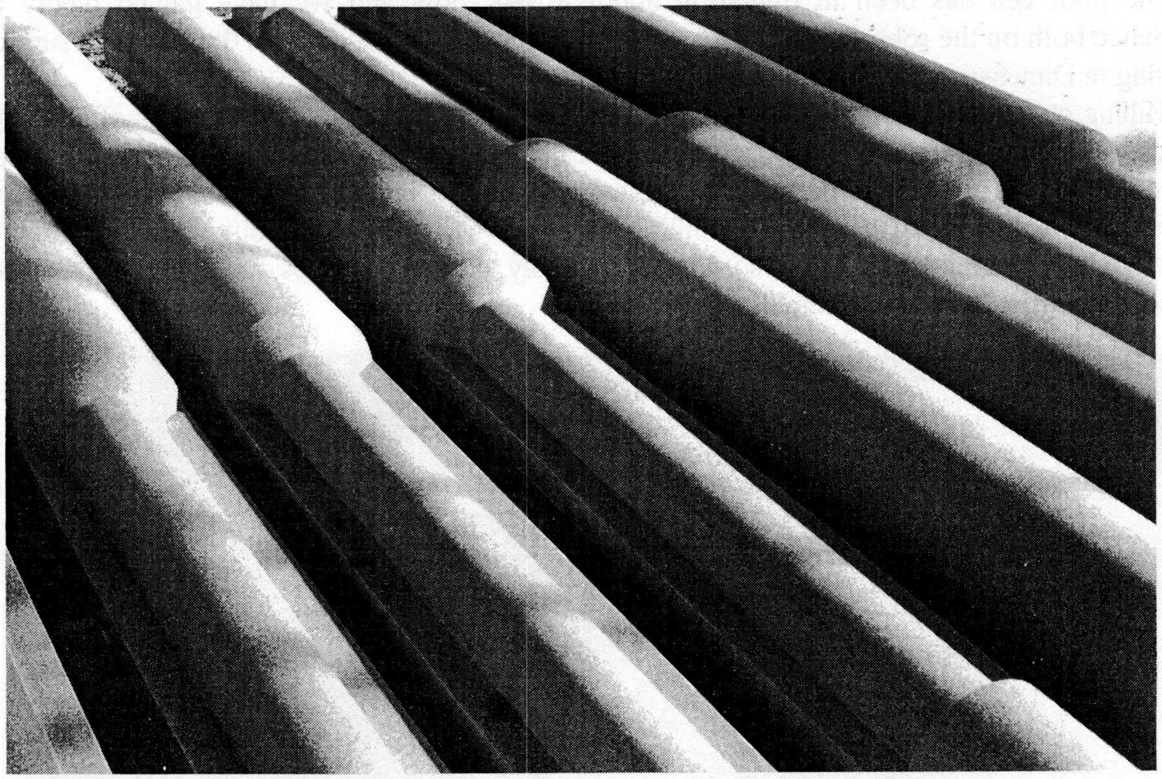

Figure 6. Polished Pilaster Elements.

6. CONCLUSION

Our tests have clearly shown that an industrial robot equipped with appropriate tools and accessories can be used for mould milling in wood or alike material and for architectural concrete polishing. It was also shown, that considerable cost and throughput time savings can be achieved and that the robot enables flexible automation, and so is applicable to various tasks in precast concrete industry.

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