MANIPULATORSYSTEM FOR THE REDEVELOPMENT OF GAPS IN BRICKS SEWERS

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SUMMARY

In the very moment only small sewers can automatically be renewed. Large brick sewers as we can find in nearly every big town are up to now repaired manually.

Therefore the company HOCHTIEF and the Fraunhofergesellschaft have developed a remote controlled manipulator system.

This machine is a hydraulic driven robot with 5 d.o.f for the automatically cutting and filling of the brick sewers. Three CCD-cameras inform the operator about the redevelopment process. Two cameras are integrated in the wrist axes and look to the tool. A third camera is mounted on the vehicle and gives the operator an overview about the working area.

The operator defines via the TV-image the edge points of the brick sewers which has to be redevelopped. This teaching process is mostly computer-aided. The task of the operator is reduced to the monitoring of the the robot movement and the correction of the computed robot path with a joystick. At first the gaps are cutted free by a finger milling cutter. In the next operation mortar is pressed into the gap and smoothed. The robot can be taken into pieces and therefore it can be transported through drains with a diameter of 610 mm. The actual version was designed for oval sewers with a height of 1400 mm and a width of 850 mm.

For the movement with in the sewer the robot is mounted on a walking gear.

In a container outside of the sewer control instruments and monitors inform the operator about the state of the machine and the state of the workprocess.

1. INTRODUCTION

According to a study of the German Ministry of Research the length of the official sewer system is of about 285.000 km and the length of the private one is of about 600.000 km. Today most parts of it have to be renewed or to be redeveloped.

This is of high interest for special companies regarding this area as a lucrative market. The costs for the reconstruction are estimated of several billion Marks. Therefore, it is very important to use machines working efficiently and producing a high quality result. The combination of microelectronics and modern manipulatortechnics are the essential.

For the optical diagnostic of sewers and for their repair several systems are available.

Typical features of these systems are:

- diagnostic and handling tasks are done by seperated devices,
- only simple working tasks can be done.

This state of the art sometimes is not sufficient, especially for the redevelopment of brick lined sewers with an elliptic intersection.

The regular pattern of the bricks leads to a system which was developed by the German building company HOCHTIEF together with our institute.

2. PROBLEM

The first modern sewer system was built after the large fire in Hamburg. It is estimated that still 20.000 km of these old brick lined sewers are part of the sewer system of big German towns and that 50% of it are damaged. Damaged means that the brick commis-sure of joint got leak and the sewers partly lost their mechan-ical stability during the ages whereas the used bricks are highly resistant against the climatic conditions in the sewers.

Nowadays the sewers are regularly inspected and if necessary local parts are arduosly repaired manually.

The aim of the development presented in this paper was a system which enables an operator to renew the sewer from a save working place outside of the sewer. The task separates itself in the cutting of the old mortar and the following refilling with a special developed epoxy resin mortar.

The sewers have an elliptic cross section which has an extension from 0,80m to 2,20m (Figure 1). The prototype being described in this paper is fitted to a sewer with a height of 1,20m. But it can be fitted to the other measurement without any problem as well. The sewers were brick lined on stencils and even today they have only small divergence from the design data. An additional important measurement is the diameter of the manhole. All components of the subterranean renewing system have to be constructed in a way that it is possible to transport the parts through the manhole with the diameter of 625mm and fit them together on the ground.

Before we start with the automatic task some manual operations have to be done. First, the sewers have to be cleaned with high pressure water and then drapped-out bricks have to be manuallly replaced. During the whole renewing procedure the sewer is watertight. Only water from private connections can flow into the actual renewing area.

3. SPECIFICATIONS

Based on the above described problems the requirements for the robot system were developed.

- Frame conditions for the robot action

Before the gaps are renewed, voids behind the sewer have to be detected and refilled. The parts of the reconstruction system standing outside of the sewers do not have to exceed the width of a normal street lane (2,50m) and the manhole with a diameter of 625mm does not have to be extended.

- Surrounding conditions

  All subterranean parts have to work under high humidity. Water from a sudden rain shower must not harm any electronic parts of the robot as well.

- Assembly of the system

  All components inside of the sewer have to be easily assembled and disassembled. In case of power failure it must be possible to pull the robot out of the sewer with a manual driven salvage device. Therefore, all robot arms need an automatic mode as well as a manual one.

- Handling task for the robot

  Walking capability over obstacles on the ground. Payload of the end effector (25kg). The repeatability accuracy has to be better than ±2mm. The robot controller must be open for an interaction with another computer for the adaption to a special task.

- Handling task of the end effector

  Cutting out of the old mortar with a width from 10 to 15mm (depends of the gap) and a depth of 20mm. The cutting velocity is 20 mm/sec. Especially wet bricks have to be dried.

- Mortar

  The used mortar has to be highly resistant against biogenic sulphuric acid corrosion. It must bond on wet bricks. The pumpability must be given. That means, stop and go of the pump must not case segregation and the mortar must not loose its plasticity under pressure. The mortar pump system has to be flexible enough so that several mortars can be pumped.

4. TRANSLATION OF THE SYSTEM CONCEPT.

The whole system can be separated into mechanical system, controller and peripheral equipment.

4.1. MECHANICAL SYSTEM

Figure 2 shows the prototype as it existed in November 1989 on the first presentation at a fair in Hamburg. At that time it was only a model without any automatic function.

The main components are:

- A walking gear which is fitted to the elliptic cross section

  of the sewer. It consists of two pillars which are connected by a hydraulic telescope. By extending the telescope, tense and release of the tension of the two pillars the robot moves through the sewer. An additional advantage of the two pillars is that they tight the robot in the sewer being very important for several repeatability functions of the robot.

- A five degree of freedom manipulator with direct driven arms and resolvers for angle measuring.

- On the first trailer the hydraulic components can be found (servo valves, manual valves), the pneumatic components (valves and distributers) and the water junctions are mounted. A second trailor carries a hydraulic cylinder which presses the two mortar components through the pipe.

The system works with hydraulic and pneumatic energy. Only the valves and the sensors need 24 V. The subterranean parts of the redevelopment system can be separated into five pieces which fit through a manhole and which can be mounted in a relatively easy way in the sewer.

4.2. CONTROLLER

Two in the endeffector integrated cameras inform the operator about the path of the cutter. A third camera which is mounted on a pan-and-tilt-head gives the operator an overall view. The controller concept must enable the operator to switch between automatic mode and semiautomatic mode.

During the automatic mode a precomputed path is driven by the robot whereas in the halfautomatic mode a desired path can be driven by operation of a joystick.

The five manipulator axes are coordinated by a seperat controller.

4.2.1 EXAMPLE OPERATION

The renewing of the sewer is done with the above defined controller.

The sewers have an elliptic intersection which is constructed by several circles. Therefore, it is possible to precompute the path of the manipulator and to simplify in such a way the task for the operator.

In the automatic mode the manipulator drives along the longitudinal joints for a combined cutting and teaching. During that movement the operator can influence the manipulator path in a special coordinate frame (tangential to the joint). Corners of the transversal joints are teached during the longitudinal movement.

The teached corner points are sorted on the PC by a special algorithm and the path program for the transversal joints is generated. The operator has got the ability of changing the pass velocity between 0% and 100%. In case of emergency like crash of the cutter the operator can interrupt the halfautomatic mode and drive the manipulator manually in an assembly position. After repairing the automatic program will be started at the point of interruption.

The refilling of the joints is done nearly automatically. The operator can only influence the flow rate of the mortar.

4.2.2 SYNTHETIC REPRESENTATION

In this application we use a 2D representation with front view and side view. It gives a useful support to the operator and it can be implemented on a low cost PC.

On the two views the operator can see the manipulator as well as the working surrounding. We use the real joint-coordinates of the manipulator to actualize the graphic continually.

Additionally, the operator gets important informations about the state of the machine.

4.3 PERIPERAL COMPONENTS

The whole system must be totally independent from external energy resources. Therefore, two diesel engines producing the necessary pneumatic and hydraulic pressure and the electric energy are mounted on a trailer. In a container we have integrated an operating place, a cable and tube drum and a trolley jib for the transport of the system in the sewer. All components do not exceed the width of a normal street lane.

5. CONCLUSION

An essential problem of the kinematic design was the reduced working and mounting surrounding. Figure 3 shows the manipulator kinematic in an early state of development. The figure was made with a special program system for the three-dimensional design of manipulators. The aim was to get an optimum relation between a long working area and short manipulator arms.

At the very moment we are testing the features of the machine in our laboratory. The next step will be to work in a sewer model under realistic conditions.

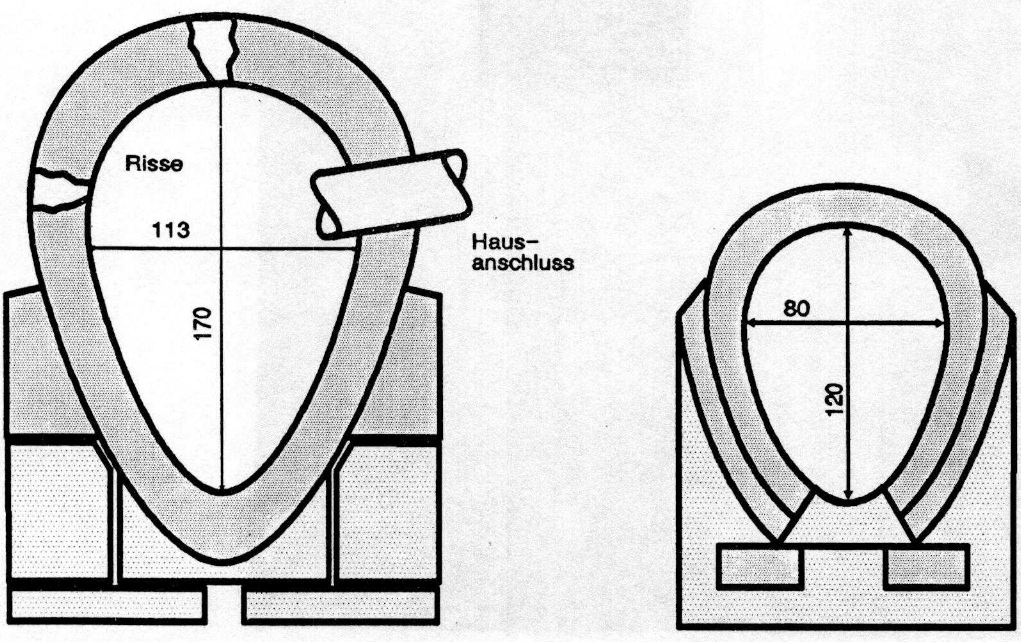

Figure 1: Typical German brick lined sewers

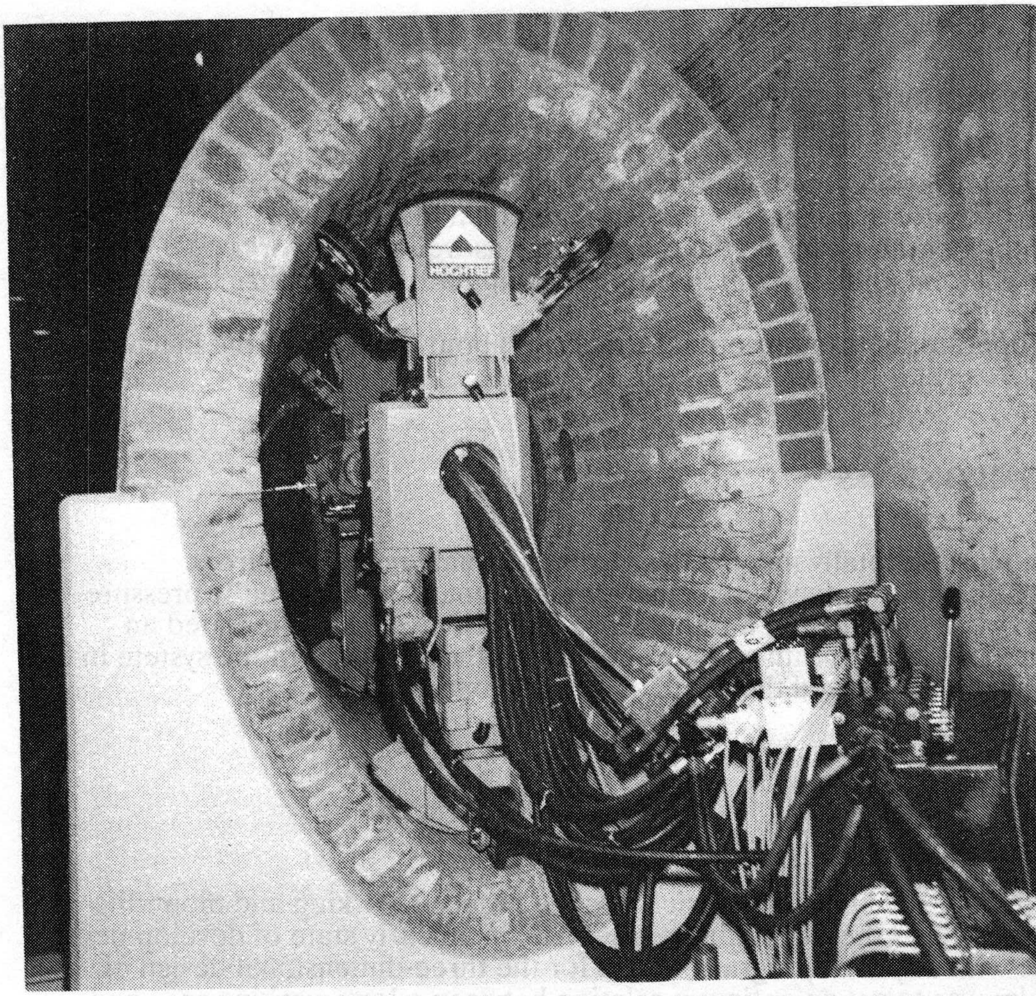

Figure 2: Prototype of the manipulator

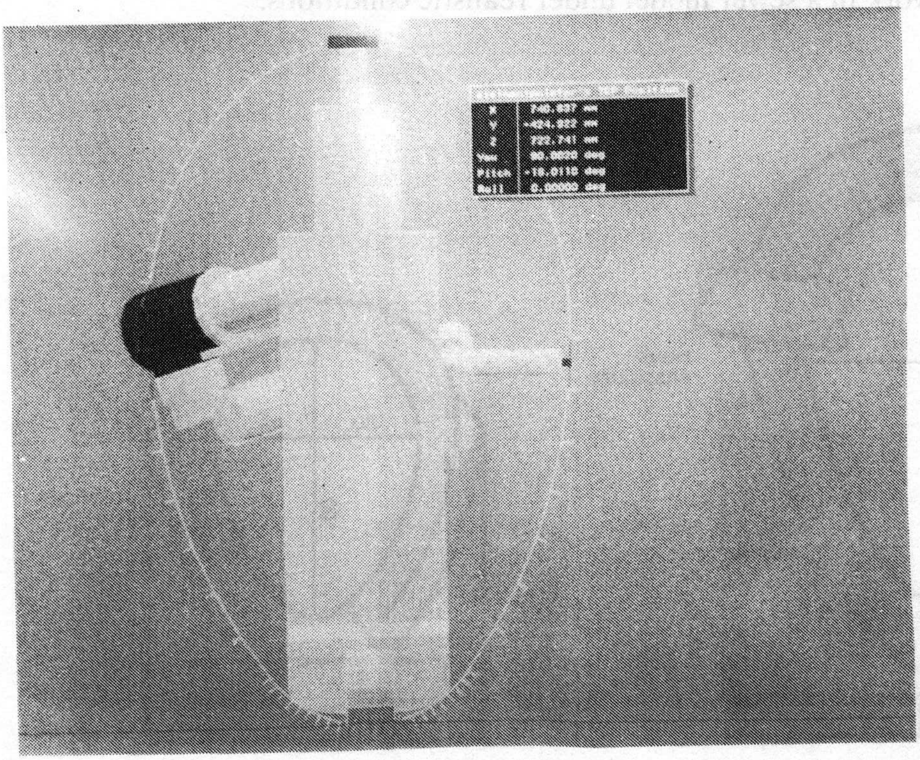

Figure 3: Optimization of the manipulator kinematic with solid modelling