Automation and Robotics in Construction XII
E.Budny, A.McCrea, K.Szymanski (Editors)

A DIGITAL CONTROL SYSTEM FOR HYDRAULIC EXCAVATOR FIXTURES

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Abstract

The cutting tool trajectory of a hydraulic excavator during working with traditional machine results from experience and intuition of an operator. To allow the excavator for an automatic execution of planned trajectories, the machine should be provided with control system of fixtures motion. Such a digital control system for single bucket excavator, which has been built in the Kielce Branch of the Institute of Fundamental Technological Research of Polish Academy of Sciences, is presented in this paper.

1. DESCRIPTION OF THE SYSTEM AND THE TESTING STATION

The determination of tool coordinates in assumed coordinate system in real time is necessary for execution of tool motion along the assumed path. For machines of an excavator type it can be made indirectly by measuring of the cylinder position or the angular orientation of fixtures. Such an idea was used to built in IFTR the model control system for excavators, where signals from position sensors of cylinders or angular sensors of fixtures are used as feedback signals for regulators. The system is based on PC/486 computer provided with analog-to-digital and digital-to-analog converters with control procedures built on the basis of interruption system with minimal possible sampling period of 5ms. The system called DIGDIGG (Digital Digger) allows [1,2,4] for:

- manual control with stabilization of fixtures position,
- real time animation of fixtures on monitor display,
- regulation of cylinders position or fixtures angular positions by means of PID controllers or state controllers, also with state observers,
- identification of control plants and selection of optimum parameters for digital controllers,
- various methods for planning of the cutting tool trajectory,
- modification of the trajectory during motion, what allows for obviating of obstacles,
- optimization of the cutting tool trajectory,
- measurement of forces acting on cutting tool of excavator,
- observation of an experiment and documentation of its results.

The special testing rig was built for examination of the mentioned-above system [4]. Its working part consists of fixtures for single bucket hydraulic back digger with bucket capacity of 0,5 m (Fig.1a). Inductive position sensors have been installed on cylinders for measuring cylinders positions and resolver type sensors have been installed in axes of rotation of fixture parts for measuring their angular positions.

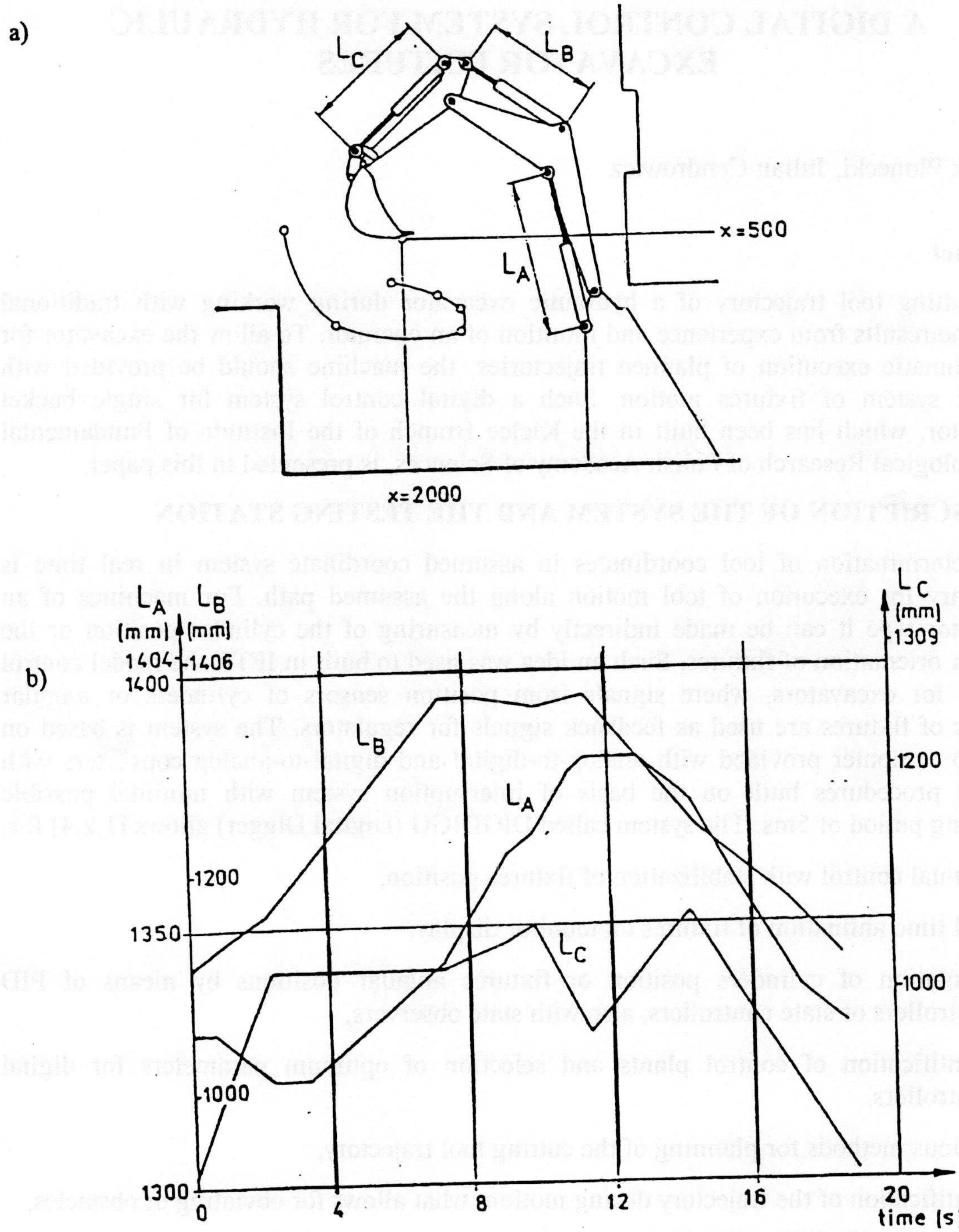


Fig.1 a) Planned path of cutting tool with linear interpolation, b) Control signals for control systems of cylinders positions in the case of linear interpolation

Forces acting on the excavator cutting tool were measured through the loading cells (transducers ones) built in cylinder ears.

The hydraulic feeding of the rig is realized through variable delivery multi-piston pomp which allows for continuous change of the feeder output. The hydraulic control of fixtures of cylinders is performed by means of proportional valves with internal feedback from the slider position.

The system contains also a set of amplifiers for hydraulic valves, pumps and sensors as well as the console for manual control.

2. CUTTING TOOL TRAJECTORY PLANNING

The control of the excavator working motions in the described system is performed by means of regulations of cylinders positions or fixtures angular positions.

Planning of cutting tool trajectory is executed in the stages as follows:

- determination of the tool trajectory in assumed coordinate system,
- parameterization against time of the fixtures trajectory,
- saving the trajectory in the form of control signals for regulators used in the fixtures control system.

The trajectory planning can be made in Cartesian coordinate system i.e. in the working space of fixtures or in configuration space using generalized coordinates. The most frequent way of tool path description is determination of its initial and final point and sufficient number of intermediate points. Values describing this points are introduced into the system where interpolation procedures perform calculations for other points of the path. The system uses linear interpolation (Fig.1) or third degree polynomial interpolation (Fig.2). Control signals for cylinder positions, for two different motion paths, are presented in Fig.1a and Fig.2a in the case of above-mentioned two kinds of interpolation.

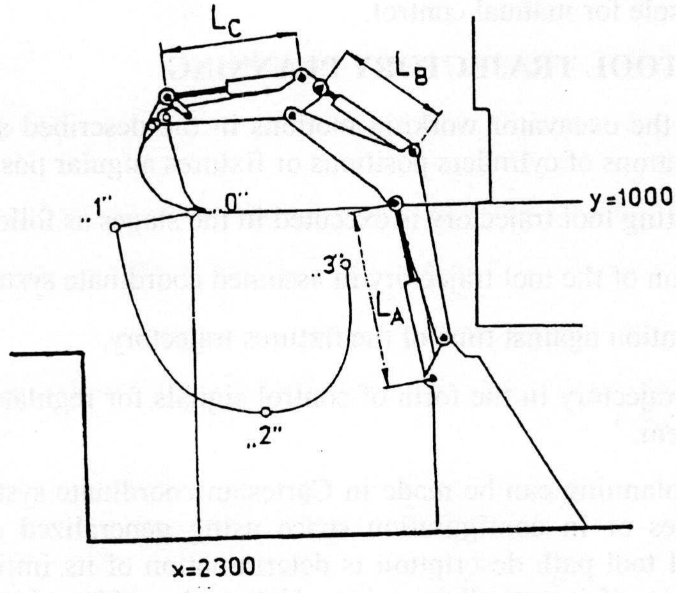
Because of ambiguous inverse kinematics problem occurring for excavator fixtures, the path points are given by two coordinates and the cutting angle determined against tangent to the path. When planning the trajectory in working space of the machine, a shape of path results directly from the assumed method of interpolation. The coordinates of path model points results from the solution of the inverse kinematics problem and are converted into sets of generalized coordinate values. If linear interpolation is applied for configuration space, the path of tool in working space consists of curvilinear segments as a result of geometric nonlinearity of fixtures.

Parameterization against time of the cutting tool trajectory can be performed in two ways. In the first one, motion time along assumed path is determined. For each nodal point the vector of apparent velocity should be assigned, which is used to divide the total time of motion between individual path segments. In the second one, the control system determine transit time between consecutive model points on the basis of assumed hydraulic feeder output.

As the result of parameterization against time of cutting tool trajectory we obtain time trajectories of generalized coordinates which are used as control signals for regulators.

Values of regulators command signals in consecutive time instants can be recorded in tables, with time synchronization of signals for outrigger (boom), arm and bucket. The main disadvantage of this method is size of tables necessary for recording trajectories.

a)



b)

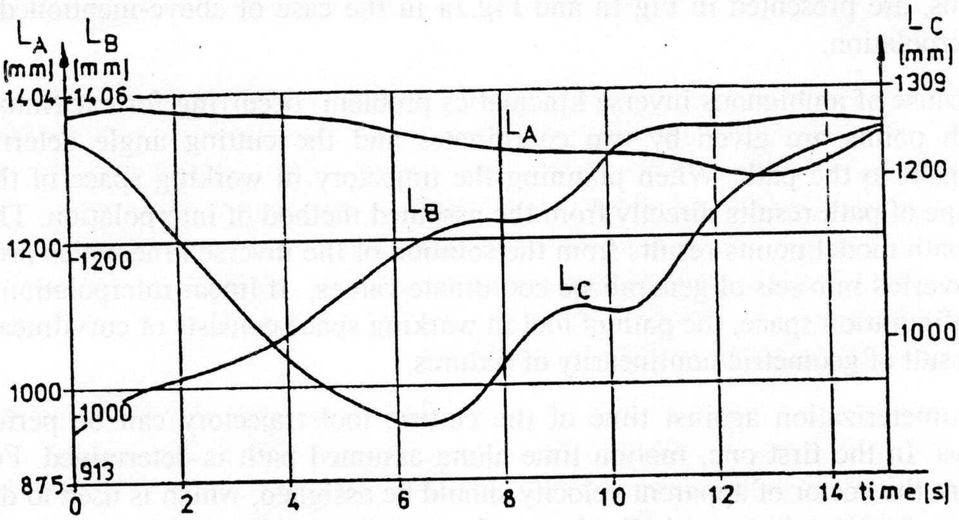


Fig.2 a) Planned path of cutting tool with third degree polynomial interpolation, b) Control signals for control systems of cylinders position in the case of third degree polynomial interpolation.

It is also possible to record in tables values determining nodal points of trajectory and then calculate "on line" values of command signals in consecutive time instants. In such a case, quite fast computer is necessary.

The discussed system contains both methods of trajectory recording.

Modification of used trajectory is sometimes necessary. It is the case when the tool encounters obstacle which shall be obviated or when the decrease of medium resistance allows to withdraw the tool along slip line. The DIGDIGG system provides such possibility and the force acting on tool is used as actuating signal for trajectory modification procedures.

It was found that the best quality of control is obtained using state controllers with integral action [1] and that using control systems of cylinder position is more advantageous for ensuring proper quality of control.

Experimental results confirms full applicability of the presented excavator control system to execute prescribed tools trajectories with sufficient accuracy and repeatability.

LITERATURE

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