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Dynamics and Control of a hydraulically driven Boring Plant

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In civil and underground engineering very large boring plants are used for drilling holes into the ground having a size of up to 30 m in depth and .5 m in diameter. Today such machines possess hydraulically driven cable winches, which control both, the lifting and the lowering of the heavy drilling tools (Fig. 1).One problem of controlling the machine consists in an interaction of the hydraulic control and the mechanical system dynamics generating sometimes self-excited oscillations with large amplitudes. Another problem is connected with the groundwater contact when the drilling tool comes down rather fast. Both phenomena may lead to slack cables, which must be avoided at all costs.

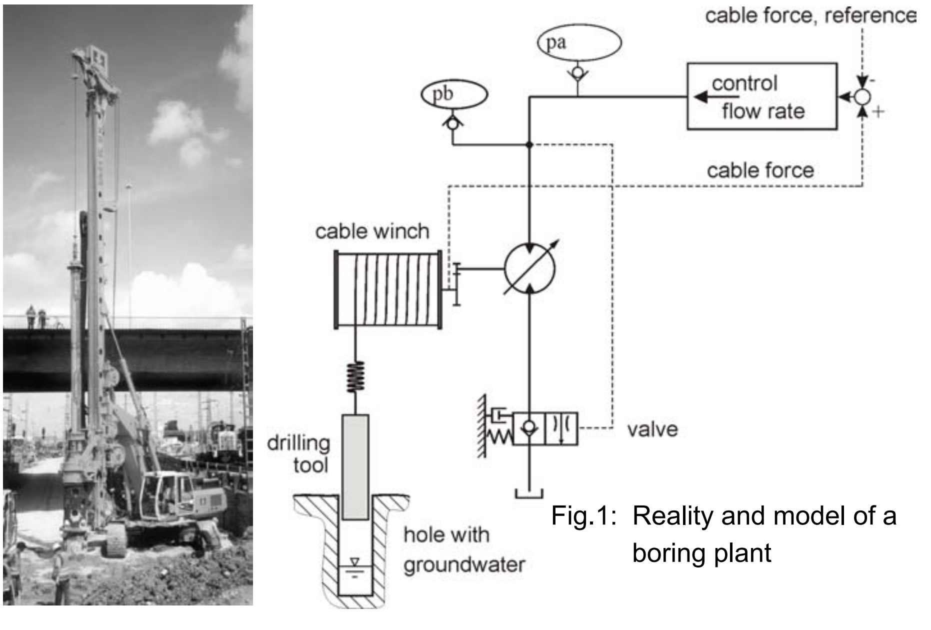

Fig.1: Reality and model of a boring plant

The first step for solving these problems consisted in considering the hydraulic and mechanical model of Fig. 1 and in deriving the corresponding equations of motion /1,2/. For this we must take into account the hydraulic and the mechanical degrees of freedom together with the appropriate bilateral and unilateral constraints as given by the configuration itself as well as by hydraulic or mechanical non-smooth features. We come out with a typical set of equations of motion for non-smooth systems containing the differential equations, some equality constraints, for example Kirchhoff´s equations, and some set-valued force-laws in the form of complementarity conditions /3/. On the numerical side we use the one-step-method Runge-Kutta-3/4 in combination with a solver of the complementarity problem (LCP) according to Lemke /1/. All non-smooth events are interpolated and then the integration started anew. A solution of these equations demonstrates the problems as discussed above, namely large amplitude nonlinear vibrations and the impact of the drilling tool with the groundwater /1/.

The requirements with respect to a control system solving these problems are the following:

- Stability of the tool moving in the air or in the groundwater, which means significant reduction of all types of possible vibrations.
- Very fast control reactions with respect to impacts on the surface of the groundwater or on the ground itself.
- Large tool velocities for all phases of operation.

The basic structure of the control is PID, but with the control matrices adapted to the three phases, motion in the air, impact on the water surface, motion in the water /4/. All problems as discussed above could be removed. Figure 2 stands for quite a lot of simulations and experiments, which all confirm the taken measures. It depicts the effectiveness of an adaptive control structure for all phases of the motion: large cable forces in the air and small ones in the groundwater, an impact at the water surface and excellent control in the adaptive case, bad control with a controller possessing constant coefficients. The new control system has been implemented into the process control unit of the boring plant, existing machines have been modified correspondingly, all newly produced machines (by a Bavarian company) have it as standard. Since then problems of the above type did not occur any further.

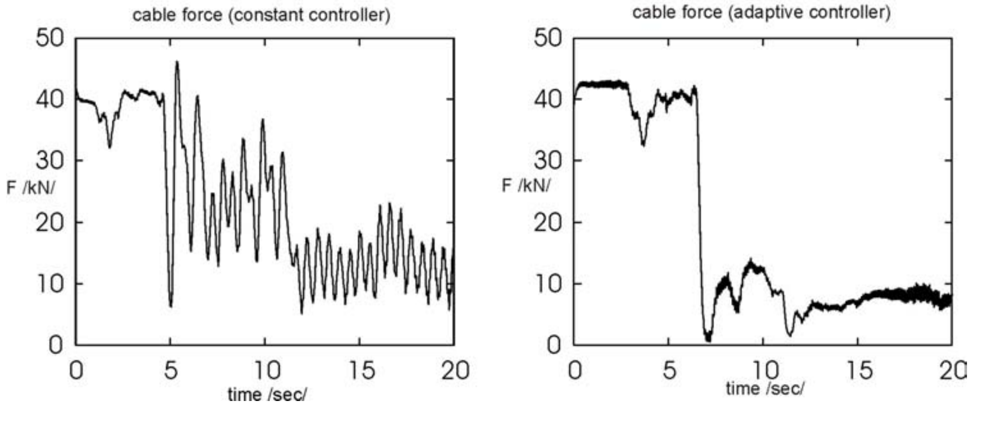

Fig. 2: Measurements without and with adaptive control

Literature

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