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A test rig and numerical model for investigating truck mounted concrete pumps

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ABSTRACT

Concrete pump booms are subjected to vibrations that increase mechanical stress and shorten their lifespan. This paper aims to study the problem by considering the two subsystems, the boom and the concrete pump, that have the greatest effect on the phenomenon. The authors supply numerical and experimental tools that can analyze the problem in depth in all its complexity. First, the systems were investigated independently, to identify their individual aspects. Then a mathematical model was created to reproduce the behavior of the whole system and the interaction between boom and pump. The result was a new powerful tool for investigating passive and active solutions for suppressing vibration.

1. Introduction

In recent years construction machinery has undergone considerable development, in terms of increasing dimensions and reduced weight. This trend can be clearly seen in, for example, concrete pump booms. The need for weight reduction, to improve the performance of the systems, makes for structures characterized by high flexibility and low damping. These characteristics, coupled with the dynamic loads due to the large motion of the structure and the flow of the concrete, produce considerable mechanical stress on the material. These structures suffer from fatigue and instability issues, with several negative implications for safety. To reduce the spreading of cracks and increase the booms' working life, it is necessary to reduce the stress by suppressing vibrations of the entire system. Traditional external passive control methods are generally more invasive, since they involve introducing mass on to the structure, and are less effective in a large range of frequencies. On the other hand, active control is an attractive solution, especially considering the rapid development of computer hardware and the consequent reduction of costs. In both cases, a numerical tool that can reproduce the dynamics of the entire system is very useful for identifying the best solution for each specific model and specific application.

Some contributions can be found in the literature. For example, Khulief [1] used an FEM model of a flexible boom to define a control logic for suppressing vibration. Other authors created boom models for tip trajectory synthesis (Wang [2]) or the automation of the pouring process (Zhou [3]) and pump models for enhanced component design (Worthington [4]). Finally the papers on innovative long span machines by Kronenberg [5] [6], specifically relating to the Putzmeister AG company, should be mentioned, though they contain no analysis of possible control laws.

The aim of this paper is to investigate and reproduce the dynamics of the entire system, which have been little investigated in the scientific literature, creating a numerical and experimental development environment for investigating solutions aimed at increasing the performance of the system in terms of pumping capacity, vibration and safety, highlighting the most critical aspects of the system as a whole. The complexity of the system led us first to consider the boom and the pump independently. Two test rigs were built to reproduce in the laboratory the characteristics of the systems and permit an intensive series of experiments. The results of these experiments were the starting point for defining the mathematical models. For the boom, a non-linear flexible multibody (MB) model was created, while the pumping group numerical model was used to solve the oil and concrete continuity equations and the equations of motion of the hydraulic pistons. Then, in the second stage, the forces coming from the pump model were used as the input for the boom model, that, on the other side, returns the system configuration.

2. The truck mounted pump

Concrete pump booms are complex dynamic systems with a variable number of links linked together by kinematic joints and moved by hydraulic actuators. In this way the end-activator, i.e. the boom tip housing the device for placing the concrete, may be very far from the pump (Fig. 1-a) or in very high place (Fig. 1-b). In general these systems have high flexibility and, as a result, very low natural frequencies. Therefore, because of the very low damping associated with these frequencies, there will be high amplitudes of vibration and severe mechanical stresses on the structure.

Moreover, it is important to underline that the possibility of changing the configuration of the system spreads the natural frequencies over a wide range. This range can be only estimated in the design

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