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Controlling torsional vibrations of drill strings via decomposition of traveling waves. (English)

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Summary: Torsional vibrations in drill strings, especially stick-slip vibrations, are detrimental to the drilling process as they slow down the rate of penetration and may lead to failure of the drilling equipment. We present a method for controlling these vibrations by exactly decomposing the drill string dynamics into two traveling waves traveling in the direction of the top drive and in the direction of the drill bit. The decomposition is derived from the wave equation governing the string vibrations and is achieved with only two sensors that can be placed directly at the top drive and at a short distance below the top drive (e.g., 5 m). Therefore, downhole measurements along the string and at the bit are not necessary, which is a major advantage compared to other control concepts for drill string dynamics. The velocity of the top drive is then controlled in order to absorb the wave traveling in the direction of the top drive, thus achieving a reflection coefficient of zero for the frequency range of the undesired torsional vibrations. The proposed algorithm is implemented for both a numerical example and an experimental setup; results show that the control concept works very effectively.

MSC:

74H45 Vibrations in dynamical problems in solid mechanics
74M05 Control, switches and devices ("smart materials") in solid mechanics
74K05 Strings

Keywords:

stick-slip vibrations; drill string; decomposition of traveling waves; control

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