NOISE AIDED CONTROL OF ROTOR-STATOR SYSTEM DYNAMICS

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Summary In the current study, the authors propose a novel control scheme to control contact between a rotor and stator system. In the experimental arrangement, the control scheme is implemented by adding noise to the motor driving signal, and consequently, the drive torque that is applied to a rotor-stator arrangement, wherein the rotor is connected to the motor through a slender string that is able to undergo torsional and lateral deformations. To complement the experimental investigations, numerical investigations are conducted with a reduced-order model of the system.

INTRODUCTION

Contact between a rotor and stator accounts for a large number of failures in rotating machinery and equipment. If the run-up operation passes through a resonance, the rotor may come in contact with the stator. Under certain conditions, the rotor will stay in continuous contact even while at the operating speed [1, 2, 3]. In the current study, the authors explore the use of noise, which is superimposed onto the driving signal and input into the motor, as a method to break contact between the rotor and the stator. This break of contact can allow for the rotor to move to the center of the stator. The exploitation of noise in this nonlinear system, inhibits the continuous contact between the rotor and stator without having to stop the machinery. Additionally, the system considered in this study is able to undergo large torsional deformations as well as lateral displacements. One such application of a rotor-stator system with torsional vibrations arise in drill-string dynamics. Drill strings are long, tubular structures that are used to bore holes in the Earth. An illustration is provided in Fig. 1. Efforts that aim to suppress harmful stick-slip oscillations of drill strings using active control strategies include those of [4, 5]. Similarly, a work in which the control of torsional vibrations of a rotor subject to discontinuous friction is studied is the study [6].

EXPERIMENTAL ARRANGEMENT

Photographs of the experimental arrangement are shown in Fig. 2(a)-(c). The rotating string of interest is made of aluminum and has a diameter of 3.2 mm and spans a length of approximately 2.0 m. The top of the string is secured to a three-jaw self centering chuck that is rotated by a stiff drive shaft and motor. This assembly can be seen in Fig. 2(b). Additionally, a slip ring placed along the drive shaft allows for strain gages to be secured to the string. The strain due to bending and torsional vibrations may be measured depending upon the configuration of strain gages. A camera located

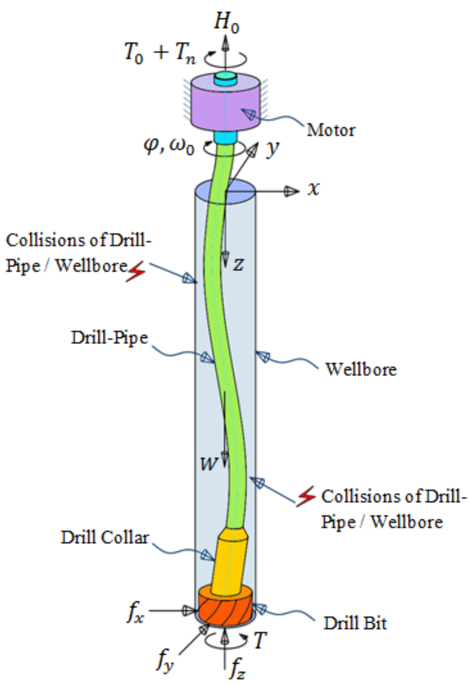

Figure 1. A graphic of a drill string used to bore wells for retrieving resources.

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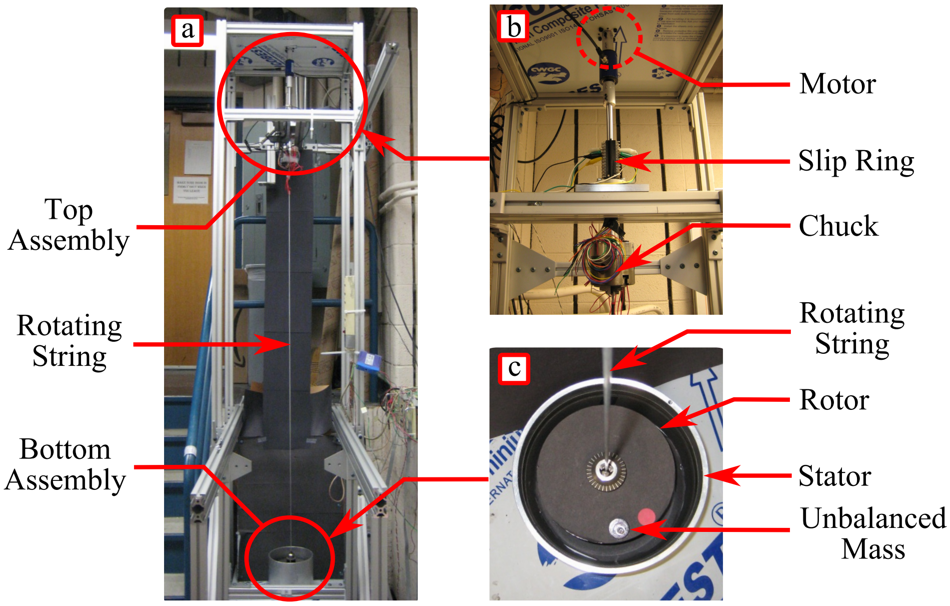

Figure 2. The experimental arrangement used to study the effects of noise on a nonlinear rotor-stator system.(a) A photograph of the entire experimental arrangement. (b) A detailed view of the top assembly used to drive the system. (c) A detailed view of the bottom assembly used to examine contact between the rotor and the stator.

above the rotor is able to capture the rotor time histories within the stator. The base of the string is attached to a rotor with a diameter of 15.2 cm, and this rotor is enclosed within a circular stator with an inner diameter of 20.3 cm. A mass is secured to the rotor in order to create imbalance and eccentricity of the string-rotor system. When the lateral displacements are large, the rotor collides with the shell and a variety of phenomena may ensue. The rotor may undergo impacting motions, return back to the center of the stator, or it may stay in continuous contact with the stator. The rotor is said to exhibit *synchronous whirling* or *slipping* when contact between the rotor and stator is maintained and the rotor whirls in the direction of shaft rotation. The rotor may also whirl in the opposite direction of rotation, referred to as *dry-friction whirling* or *backward whirling* [1]. In the current work, the authors propose a scheme to disrupt these two steady state motions by adding noise into the driving signal of the motor.

MODELING AND NUMERICAL WORK

The system at hand is nonlinear in nature due to geometric and inertial nonlinearities and due to the discontinuous forces acting on the rotor that arise from contact with the stator. A reduced-order model that accounts for lateral and torsional vibrations is used to explore the dynamics seen in the experimental arrangement and understand the effects of noise on this dynamics [2, 3]. The equations of motion are solved numerically by using an Euler-Maruyama integration scheme which is suitable to handle stochastic differential equations [7].

CONCLUDING REMARKS

The novel control scheme based on the use of noise to break rotor-stator contact will be studied using the experimental arrangement and the reduced-order models of drill-string structures. The findings of this study may have applications in specific fields of rotordynamics, including well drilling operations.

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