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Drilling-Induced Riser Vibration

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Significant riser oscillations were observed during deep-water drilling operations. The riser vibrated at frequencies from below to above the rotation speed of the drill pipe. Laboratory tests of a riser section have been conducted for these riser drilling-induced vibrations. The first test consisted of measuring the fluid forces between the rotating drill pipe and the riser. In the second test, the riser was elastically supported. The riser self-excited about the rotating drill pipe. An analytical model is developed for predicting these drilling-induced riser oscillations. The results show that fluid-coupled riser vibrations can result from the fluid forces generated in the annular fluid between the rotating drill pipe and the riser.

NOMENCLATURE

D_d = drill pipe outside diameter
D_o = riser outside diameter
D_r = riser inside diameter
r = distance from center of riser to center of drill pipe

INTRODUCTION

A deep-water riser assembly in 6,000 ft (2,000 m) of water is shown in Fig. 1. During drilling, fluid flows downward inside the drill pipe and returns upward in the annulus between the drill pipe and the riser. The drill string rotates at 30 to 120 rpm (0.5 to 2 cycles per second). The drill pipe has a 5-inch (12.5-cm) outside diameter, and the riser has an outside diameter of 13 inches (33 cm). A submerged buoy supports the riser weight. The riser tension is set to about 40% higher than the wet weight of the riser, so the riser is always in tension. The drill pipe is also in tension along the riser section; it goes into compression below the mudline where the riser is cemented into the earth.

Remotely operated vehicle (ROV) field measurements are made of the riser motion during drilling with seawater as the drilling fluid. The riser vibrated between the mudline and the buoy at an unsteady range of frequencies between 40 to 60 cycles per minute, 0.6 to 1 Hz. The vibration occurred only during drilling. Peak-to-peak amplitudes of 1 ft (0.3 m) were observed below the buoy, and currents were nominal on the third and final day of drilling when the vibrations caused fatigue failure of the riser at the buoy.

The frequency of oscillations can be above or below or near the drill pipe rotation frequency, as shown in the ROV measurements in Fig. 2. The riser vibration amplitude generally increased with the drill pipe rotation frequency, but the frequency of motion was generally not at the rotation speed of the drill pipe. The difference between the riser frequency and the drilling frequency suggests that the drilling-induced vibration is a fluid-coupled instability rather than a simple driven vibration.

An alternative explanation for the riser vibration is the vortex-induced vibration. The ocean currents may vary from 1.5 knots to less than 1 knot in the thermocline layer that is approximately 1,000 ft (300 m) deep. The evidence against the vortex-induced riser vibration is that the predicted shedding frequency for a velocity $U = 1.5$ knots $= 2.53$ ft/s using the outside riser diameter $D_o = 13.375$ in $= 1.114$ ft and the Strouhal number $S = 0.2$ is $f_s = SU/D_o$ (Hz) $= (0.2 \cdot 2.53$ ft/s$)/1.114$ ft $= 0.444$ Hz, which is below the observed frequencies of 0.83 to 4 Hz (see Fig. 2). Furthermore, riser oscillations occurred only during drilling.

Another possible cause of the observed riser oscillations is an axial flow-induced instability. High-speed internal flow is predicted to produce instability only if the axial flow reaches over 200 ft/s (65 m/s), whereas the actual flow is less than 1/10th of that, 3 ft (1 m) per second in the riser annulus and 22 ft/s (7 m/s) down the drill pipe. The riser is always in tension above the mudline, which eliminates helical buckling.

A fourth alternative is bottom-hole drill-string vibration due to stick-slip and bit-bounce phenomena. However, there is no mention of riser vibration in Bailey's study (Bailey et al., 2008) of these high-frequency drill-string vibrations.

Chang (2007) reported drilling-induced riser vibration in 910 ft of water with a 5.5-inch outside diameter drill pipe and a 9.7-inch

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KEY WORDS: Vibration, riser, drilling, fluid-coupled.