Bruno Cesar Cayres Andrade

Numerical and experimental analysis of nonlinear torsional dynamics of a drilling system

DISSERTAÇÃO DE MESTRADO

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do Rio de Janeiro

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Dissertação de Mestrado

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Advisor : Prof. Hans Ingo Weber
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To my parents and my sister, my family, and Bárbara Lavôr,
with love.

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Abstract

Andrade, Bruno Cesar Cayres; Weber, Hans Ingo (Advisor); Aguiar, Romulo Reis (Co-adivisor). **Numerical and experimental analysis of nonlinear torsional dynamics of a drilling system**. Rio de Janeiro, 2013. 88p. MSc. Dissertation — Departamento de Engenharia Mecânica, Pontifícia Universidade Católica do Rio de Janeiro.

A successful oil and gas prospecting requires many efforts to overcome the encountered challenges, some of these challenges include drill string axial, lateral and torsional vibrations. These phenomena may cause premature component failures of the drilling system, dysfunction of measurement equipments, and increase time and costs of the prospecting process. Torsional vibrations are present in most drilling processes and may reach a severe state: stick-slip. An improved understanding about the stick-slip phenomenon provides tools to avoid the increase of prospecting time and costs, assuring the investment and success of the drilling process. Firstly, a numerical analysis of the drill string is performed with different friction models. These models are proposed in order to get familiar with the drill string dynamics. Also, it is described the experimental procedure with a nonlinear friction aiming to induce stick-slip and is performed a simple analytical modeling of the problem. The friction model is based on dry friction imposed by a break device. The nonlinear behavior of the experimental apparatus is analyzed and the numerical model is validated comparing experimental and numerical bifurcation diagrams.

Keywords

Oil well drilling; torsional vibration; dynamic drill string; stick-slip phenomenon; nonlinear dynamics.

Resumo

Andrade, Bruno Cesar Cayres; Weber, Hans Ingo; Aguiar, Romulo Reis. **Análise Numérica e experimental da dinânica não linear torsional de um sistema de perfuração**. Rio de Janeiro, 2013. 88p. Dissertação de Mestrado — Departamento de Engenharia Mecânica, Pontifícia Universidade Católica do Rio de Janeiro.

Uma prospecção bem sucedida de petróleo e gás requer muitos esforços para se sobrepor os desafios encontrados, tais como vibrações axiais, laterais e torcionais. Estes fenômenos podem causar a falha prematura de componentes do sistema de perfuração, disfunção nos equipamentos de medição e aumento no tempo e custo no processo de perfuração. Em particular, vibrações torcionais estão presentes em grande parte dos processos de perfuração e podem alcançar um estado crítico: *stick-slip*. Um melhor entendimento sobre este fenômeno proporciona ferramentas para evitar o aumento do tempo e do custo da prospecção, assegurando o investimento e sucesso do processo de perfuração. Neste trabalho, é descrito um procedimento experimental com um atrito não linear objetivando induzir *stick-slip* e é feito uma modelagem analítica simples do problema. O modelo de atrito é baseado em um atrito seco imposto por um dispositivo de freio desenvolvido. O comportamento não linear da bancada experimental é analisada e o modelo numérico é validado comparando diagramas de bifurcações numérica e experimentais.

Palavras–chave

Poços de perfuração; dinâmica de coluna de perfuração; vibração torcional; fenômeno de stick-slip; dinâmica não linear .

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Nomenclature

δ	Logarithm decrement
μ	Friction coefficient
ν	Poisson ratio
ω_d	Damped frequency
ω_n	Natural frequency
Ω	Vector of velocities
ρ_{BHA}	Density of the Bottom Hole Assembly
ρ_{DP}	Density of the Drill Pipe
φ	Vector of displacements
ξ	Damping factor
BHA	Bottom hole assembly
C	Matrix of damping
DOF	Degree of freedom
DP	Drill Pipe
DP	Drill pipe
Dr	Damping factor of the mud per length unit
$DRPM$	Downhole rotation per minute
E	Young modulus
G	Shear modulus
I	Area moment of inertia
IC	Initial conditions
ID	Inner diameter
J	Matrix of inertia
K	Stiffness coefficient or Stiffness matrix
K	Stiffness of test rig
K_{BHA}	Stiffness of Bottom Hole Assembly
L_{BHA}	Length of Bottom Hole Assembly
L_{DP}	Length of Drill Pipe

MCF	Modified Coulomb Friction
$NDOF$	Number of Degree of Freedom
OD	Outer diameter
P_f	Proportional factor
PDF	Probability density function
RPM	Rotation per minute
$SRPM$	Surface rotation per minute
SSS	Severity criteria
$STOR$	Surface Torque
T	Period
T_1	Torque at bottom end
T_2	Torque at surface end
TOB	Torque on bit
WOB	Weight on bit

Try not to become a man of success but rather to become a man of value.

Albert Einstein, .