IS WAVE ENERGY UNTAPPED POTENTIAL?

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ABSTRACT

Increasing energy demand in the past 50 years and targets to reach net-zero carbon dioxide emissions have led to an increase of electricity production from renewable energy sources. Although, a wide variety of renewable energy sources have been progressively integrated into the world's energy mix, the continuous search for innovative solutions and techniques has attracted attention to marine sources. Ocean waves have the potential to provide a vast amount of green energy, which is currently practically untapped despite a significant research effort. Since the last century, different schemes and devices have been proposed, however most of the systems have either low efficiency and high cost or are not able to withstand the harsh marine environment.

This work attempts to give an overview of the current global status of wave energy technologies in the market and under development. By identifying their design characteristics, performance and the challenges still required to be addressed, the future research paths and market developments have been spotted and presents motivation for future research. A new design concept of wave energy converters (WEC) based on pendula systems is presented, which operate in rotatory motion and convert complex wave excitation into mechanical power. The initial studies carried out by the Centre for Applied Dynamics Research at the University of Aberdeen [1-5] have provided the theoretical underpinning for a new design concept of four rotating mechanical pendulums, which can harvest vibrational energy from a base. The concept is generic and can work across scales and can be applied to devices generating power from mW to MW. The novelty of the new concept relies on its ability to harvest the vibrational energy independently from its frequency, amplitude or wave angle of advancing front.

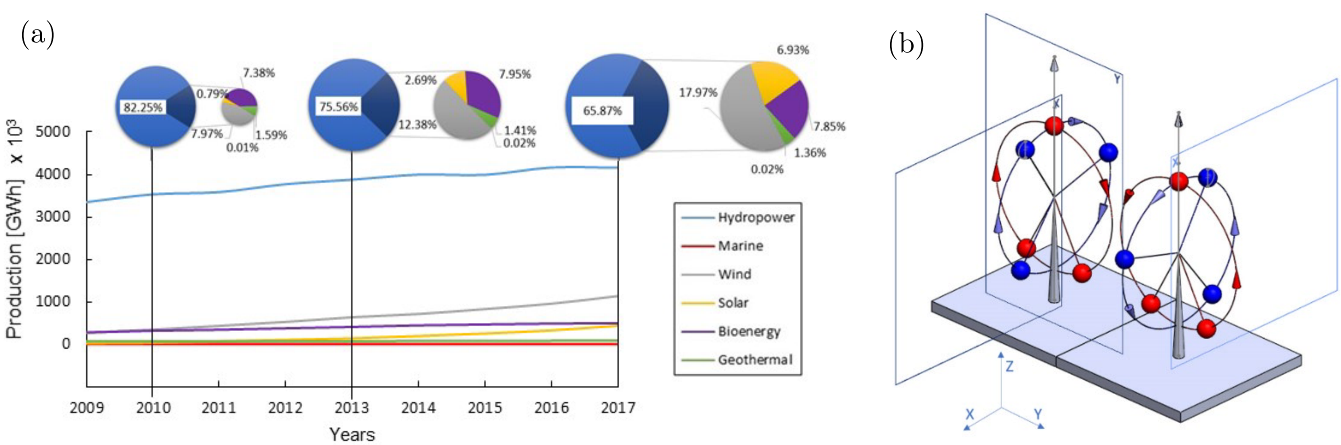

Figure 1: (a) Evolution of renewable energy production in GWh from 2009 to 2017 classified by energy source. (b) New WEC pendula scheme.

Keywords: Renewables; Energy conversion; Wave Energy Converters; Marine energy; Vibration; Pendula systems.

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Application of Resonance Enhanced Drilling to Coring

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ABSTRACT

This paper aims to evaluate the applicability of Resonance Enhanced Drilling (RED) technology to coring operations. A series of coring experiments on sandstone and granite using diamond impregnated and polycrystalline diamond compact bits are carried out on a specially designed vertical laboratory drilling rig. We present a comparison between the efficiency and quality of cores obtained using RED technology against conventional coring. Based on this analysis, improvements in penetration rates of up to 180% compared to conventional coring for the same drilling conditions were achieved. All cores retrieved are in good condition showing consistent diameters, generally smooth core surfaces and no evidence of fracturing or other visible core damage. Our preliminary assessment suggests that the RED coring technology provides significant improvements in Rate Of Penetration (ROP), while maintaining consistent core quality compared to conventional coring.

Keywords: Coring, Drilling, Core quality assessment, Experimental studies

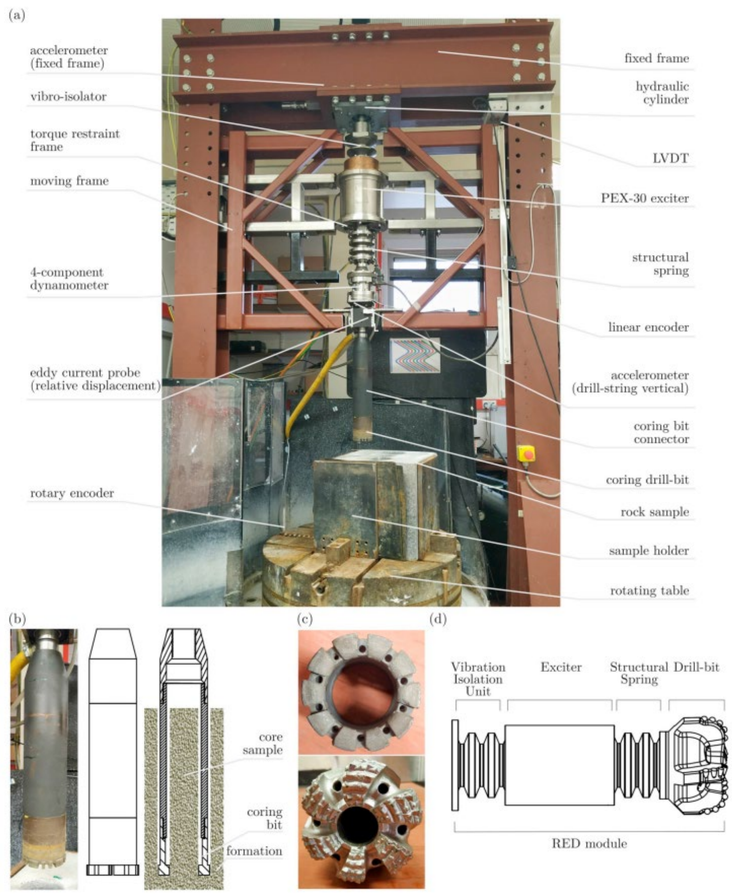

Figure 1: Graphical Abstract

APPLICATION OF HYDROGEOLOGICAL DATA IN SEARCH FOR OIL FIELDS IN WESTERN SIBERIA

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ABSTRACT

Oil and gas hydrogeology in Russia and in Western Siberia in particular is of great importance in both applied and fundamental aspects. The main tasks of oil and gas hydrogeology at the geological study stage are to assess the prospects of petroliferousity, to forecast the zones of oil and gas accumulation (plan and by section), and to make a local forecast of oil and gas deposits [1].

Western Siberia is rich in hydrocarbon deposits. In total, more than 500 oil, gas and gas condensate deposits were discovered in Western Siberia. The study of the West Siberian megabasin with regard to groundwater testing is quite good. The number of hydrogeological tests in prospecting and exploration wells in Western Siberia exceeds 15,000, in Aptian–Cenomanian sediments it exceeds 1,500 (10 %), in Neocomian sediments 8,500 (57 %), in Jurassic sediments 5,000 (33 %) [3]. Thus, we have a statistically significant amount of hydrogeological information for predicting petroliferousity. The essence of the hydrogeological prediction is that halos of the dispersion of organic and inorganic compounds form around oil deposits. The theory of «missed deposits» (V.M. Matusevich) is based on these data. The oil deposit is surrounded by groundwater and, as a result of contact and duffusion mass transfer in the «oil-underground formation» system, groundwater forms the halos of scattering of certain components.

Long-term studies have shown that aromatic and aliphatic hydrocarbons (benzene, toluene, para-meta-ortho-acids, hexane, light hydrocarbons, organic acids) and microelements have the highest predictive significance. Some of these are shown in the table 1.

Table 1

The contents of components in the marginal waters
(according to V. M. Matusevich [2])

Deposits	milligram /l			microgram /l			
	C_6H_6	S	Ba	Ni	Co	Pb	V
Small	0,35	6,4	103	58	11	16	22
Average	0,57	1,8	14	35	8	4	23
Large	0,61	1,4	12	17	7	4	7

An incomplete sample of data from the northern part of the region showed that the prognosis of hydrogeological data was sufficiently robust over the 10-year period since the last assessment. The total number of sample intervals positively assessed and tested was 57. Out of these, 51 are hydrocarbon inflows (oil, gas, gas condensate). The success of the forecast was 89.5%.

The systematic implementation of the hydrogeological method for assessing petroliferousity will undoubtedly make it possible to solve the problems of finding new accumulations of hydrocarbons in a more rational manner. It will also help to critically assess the results of the exploratory and exploration work carried out, and to make timely changes and additions to plans to substantiate the oil and gas potential of the facilities.

Keywords: West Siberian mega-basin, Oil and gas hydrogeology, hydrogeological prediction for oil and gas

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FLUID-STRUCTURE INTERACTION ANALYSIS ON PIPE CONVEYING FLUID USING TURBULENT STOCHASTIC MODELING

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ABSTRACT

Engineering of pipelines has been widely applied for the transportation of fluids, being essential for several industries. These pipes are often subjected to vibrations due to the fluid dynamics, leading to wearing of the supports or failure of pipe walls. In this regard, it is important to analyze the fluid-structure interactions in order to evaluate pipe vibration. Internal fluid flow can be laminar or turbulent which makes this analysis complex. Severe pressure gradients and velocity fluctuations trigger undesired axial pipe vibrations. The idea of this research effort is to analyze fluid-structure interaction using reduced order models. Therefore, a mechanical oscillator is connected to a stochastic equation to predict velocity fluctuations according to a normal Gaussian distribution through the well know Langevin model. The model parameters are calculated as a function of the turbulent kinetic energy and the dissipation of the vortices can be based on the Reynolds number of the flow [1]. A dynamical system is established considering that the pipe behaves as a Bernoulli-Euler beam and the fluid does not have viscoelastic behavior [2]. The flow is modeled in cylindrical coordinates assuming axisymmetric behavior. Galerkin method is employed in order to discretize the equation in space by assuming a selection of basis, as a function of time and space, based on vibration modes [3]. Therefore, governing equations can be considered as a mechanical oscillator coupled to Langevin's equation that represents fluid flow. Results allow a proper description of the pipe vibration, evaluating the lock-in effect, the variation of RMS acceleration, kinetic energy of the system and the average displacement amplitude a function of the average flow velocity.

Keywords: Flow-induced vibration, pipe conveying fluid, inner turbulent flow, Langevin's model, natural frequency, oscillation, crack.

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NONLINEAR YOUNG'S MODULUS OF NEW RED SANDSTONE

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ABSTRACT

Changes of geomechanical characteristics of rocks under static and dynamic loading is a significant fundamental and practical importance. Design engineers must consider the static and dynamic geomechanical characteristics of soils and rocks (e.g. while rock excavation [1]). One of the most important characteristics of mechanical properties of natural and man-made materials used in science and engineering is the Young's modulus, which is not only non-constant for rocks but a nonlinear character [2]. In this study, Young's modulus of a New Red Sandstone was investigated experimentally to gain insight into its nonlinear nature. A large experimental programme was carried out by applying a controllable quasi-static and dynamic uniaxial loading to over 250 dry sandstone samples of four different sizes. The static and dynamics tests similar to those aimed to determine uniaxial compressive strength were conducted using the state-of-the-art experimental facilities at the University of Aberdeen including a custom built small experimental rig for inducing a dynamic uniaxial compressive load via a piezoelectric transducer. The obtained results have confirmed a complex nature of sandstone Young's modulus. The investigated sandstone Young's modulus E_{dyn} under a harmonic dynamic loading shows a strongly nonlinear behaviour, which is hardening and softening with regards to frequency and amplitude of the dynamic loading, respectively (Fig. 1).

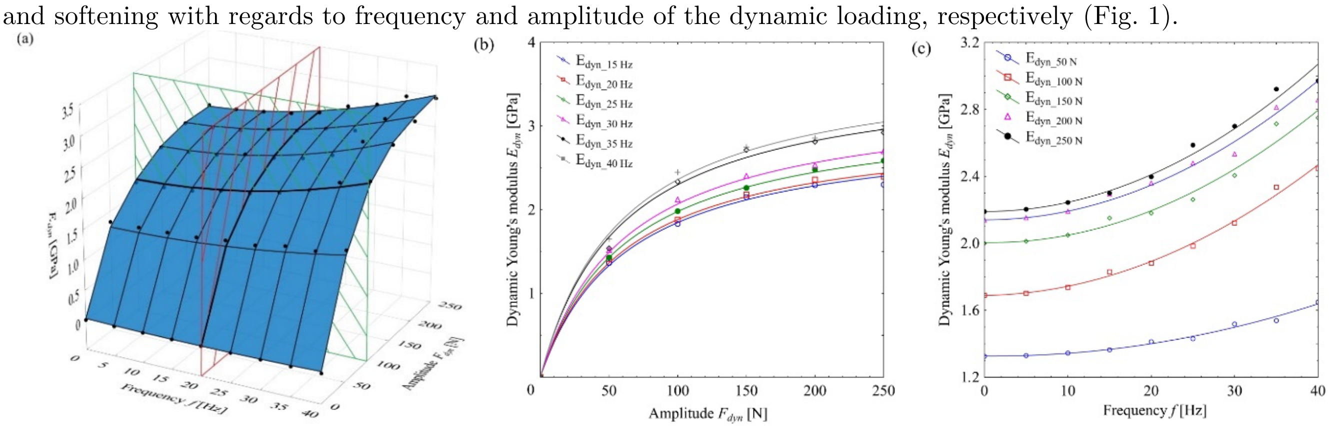

Figure 1: Nonlinear nature of the dynamic Young's modulus E_{dyn} of the New Red Sandstone determined experimentally; (a) 3D surface of E_{dyn} determined using the minimum square error method intersecting the planes of constant amplitude and frequency, (b) and (c) the softening and hardening characteristics of E_{dyn} with respect to the amplitude F_{dyn} and the frequency f of the dynamic loading respectively.

Keywords: Sandstone, Young's modulus, Static and dynamic loading, Experiments, Stress and strain, Nonlinearity.

Acknowledgement

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DYNAMICS OF DRILL-STRING WITH ANTI STICK-SLIP TOOL

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ABSTRACT

A drill-string presents a highly complex dynamical behaviour due to strong geometrical and material nonlinearities occurring during a downhole drilling process. These complexities can be analysed by classifying drill-string dynamic responses into axial, lateral and torsional vibration. Stick-slip phenomenon can cause a severe form of torsional vibrations, which is a self excited vibration mode, happening because of different reasons that is of particular interest to the drilling community, due to its negative effect on drilling efficiency. Stick-slip happens due to different reasons. This might happen when drill-string is not stiff enough to support stable drilling and the drill-bit stalls instead of rotating with a constant speed, also it might happen as a results of nonlinear characteristics of drill-bit and rock interactions [1, 2]. To minimize the negative effects of torsional vibration such as damage to the equipments, fatigue or catastrophic failures and also to maximize the Rate of Penetration (ROP), the stick-slip should be suppressed. Numerous researches have been done to model stick-slip, which are able to capture the dynamics of the system during the stick-slip intervals in order to control torsional vibration. One of them is Anti Stick-slip Tool (AST), designed by TOMAX, which is claimed to eliminate the torsional vibration mechanically. AST is a mechanical tool which should be placed as a part of the Bottom Hole Assembly (BHA) and controls torsional vibration and stick-slip. This mechanical passive tool (no need to be operated) intends to convert the torsional vibration to the axial displacement. Previous researches have been focused on modelling the AST and drill-string together [3], additionally the effect of Anti Stall tool in deviated wells, where the drill-string contacts with the bore-hole [4]. This research focuses on the AST itself by defying the input parameters, which mimics the motion of the drill-string at the top of AST and considers bit rock interactions at the bottom of the tool. The model should be able to capture the AST responses in different conditions and the effect of the tool in the dynamics of the drill-string when the tool is in/out of the activation range. Also the axial and torsional motions of the drill-string are coupled through the AST tool which enables the model to capture the axial motion when the excess torque is being converted to the vertical movement. Additionally, the model considers a pre-loaded spring inside the AST which is based on the advanced generation of AST. The results obtained through the model, show the behaviour of AST in different scenarios.

Keywords: stick-slip, AST, dynamics, drill-string, torsional vibration

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THE EFFECT OF LOW FREQUENCY AND HIGH AMPLITUDE FLUCTUATIONS ON OIL PRODUCTION

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ABSTRACT

In [1], it is noted that when the wells are turned off and on, pressure redistribution waves appear in the formation, pressure drops between individual rock blocks increase, and elastic deformations of rocks occur. When pressure wave are created in several wells simultaneously, each of the waves will cause fluid exchange between blocks, proportional to the magnitude of the depression at a particular point. When creating pressure waves of different, correctly selected, frequencies on the bottom of the wells, it is possible to create oscillations in the formation with the maximum possible depressions at various points in the formation. It has been reported in [2] that such dynamic processes increase oil production. With a change in reservoir pressure, rock deformations can go from an elastic to a plastic region, as a result, reservoir permeability and oil production will decrease.
To create a pressure wave of high efficiency and prevent the occurrence of plastic deformations during sequential operation and shutdown of production and injection wells, criteria for evaluating the time of operation and shutdown of wells are necessary. The mass exchange of fluid between individual rock blocks and fractures with pressure changes was estimated using the Barrenblatt model to determine the optimal cycle frequency ($\boldsymbol{\omega}$) for turning wells on and off. $\boldsymbol{\omega}$ depends on the propagation velocity of elastic waves ($\boldsymbol{\varkappa}$) and the attenuation coefficient (C), the distance between the wells. $\boldsymbol{\varkappa}$ and C depend on the porosity, compressibility of rocks and fluid, dynamic viscosity, permeability, and fragmentation.
A model of the field was created in the Tempest More software package and data was entered on changes in reservoir parameters with changes in reservoir pressures. The operating and shutdown times of production and injection wells were selected. The modeling of work and well shutdown cycles for 10 years has been performed. An increase in cumulative oil production was obtained within 4% during successive shutdown and operation of injection wells and within 10% during sequential shutdown and start-up of injection and production wells. The data obtained indicate the effectiveness of creating a wave of pressure redistribution in a reservoir during oil production.

Keywords: pressure waves, rock, deformation, oil production, permeability, reservoir model

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AN OBSERVER AND MODEL PREDICTIVE CONTROL DESIGN FOR THE SUPPRESSION OF STICK–SLIP OSCILLATIONS IN DRILLING SYSTEMS

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ABSTRACT

The ability to control destructive stick-slip oscillation in drilling operation continues to be a fundamental challenge, since drillstring failures caused by downhole vibrations are a significant cost in the well construction process. This phenomenon results from conditions in the borehole, such as specific rock compositions, a small diameter borehole or high inclination well trajectories. Due to non-linear friction along the wellbore and at the drill bit, constant rotation at the surface results in the period rotation (slip) and stopping (stick) of the drill bit. The release of the drill bit often results with very high rotational speed until the bit stalls once again [1].

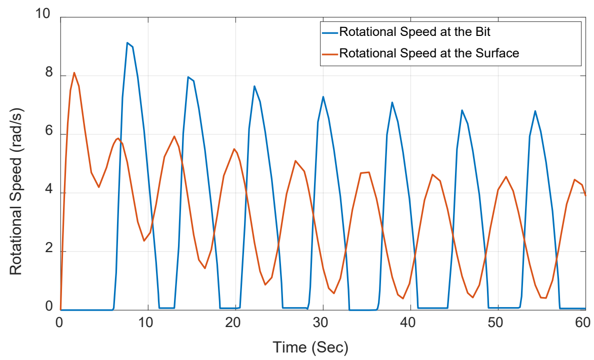

Figure 1: The stick-slip oscillations of a drill-string

The computational performance of a full dynamic model of the drillstring is a function of the drillstring length and spatial resolution, and hence loses performance as the well becomes deeper [2]. Additionally, communication latency from downhole tools increases with depth, so this motivates the development of a computationally efficient model predictive control system. State feedback Robust Model Predictive Control (RMPC) is a control strategy that can may be applied since it offers an online optimization strategy which can handle uncertainty and nonlinearity in a dynamic system with guaranteed robustness. To design a controller to handle these torsional oscillations and reduce rotational speed fluctuations, we must have complete knowledge of the drillstring dynamics system. A drillstring is a complex dynamic system with many unknown parameters, such as friction and damping, that are often estimated using rarely available or expensive downhole data [3]. Thus, we need a system to estimate downhole data, using a construct such as an observer. Since drillstring dynamics system has nonlinearities and disturbances, an observer system with ability to handle them is required.

Consequently, this study presents an observer based RMPC method to handle stick-slip oscillation in a drilling system. The mentioned method is based on combination of a new proposed observer method for nonlinear uncertain systems and proposed nonlinear RMPC method in [4]. Then, the results are verified with recorded surface and downhole field data to examine the accuracy of the observer and the simulate the performance of the controller.

Keywords: Drillstring, Stick-slip, Torsional oscillations, non-linear friction, RMPC, Observer

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