DETERMINING PHYSICAL AND CHEMICAL BEHAVIOR OF CEMENT BARRIERS USED IN ULTRA-DEEPWATER SYSTEMS

BACKGROUND

Because cement stability is critical to ensure that gas (hydrocarbons) will not break out of the slurry, cement must be tested under conditions that simulate placement in the well and situations that exist in post placement.

Researchers at the U.S. Department of Energy's National Energy Technology Laboratory (NETL) are focused on improving the science base for wellbore integrity as it relates to the near-term and long-term efficacy of lightweight cements. Lightweight cements are used in many wells. However, these cements are increasingly used in deepwater wells and are the system of choice for high stress environments and shallow flow conditions such as those prevalent in the Gulf of Mexico (GOM). Currently, there is little, if any, information regarding the stability of lightweight cement systems under wellbore conditions. Operators and regulators do not have the information to predict or understand the properties of lightweight cement as it is placed in the well and at bottom hole conditions. In addition, the state of knowledge about the integrity and longevity of wellbore cements over decades is poor, with little or no data or tools available for researching the situation. As wells are increasingly repurposed for secondary and tertiary purposes, ensuring that cement remains a barrier to subsurface flow is key. Research in this project seeks to address these challenges.

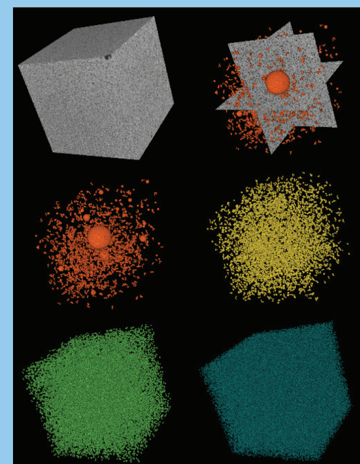

Figure 1. 3-D renderings of a 10.4 mm3 digital subsection of 10% foam quality cement sample. (A) Opaque grayscale cement cube. (B) Orthoslices of solid cube with largest bubbles. (C) Largest bubbles in data set that sum to 10% of the total void space in the sample. (D) The next largest bubbles, summing again to 10% of the total void volume. (E) The mean bubbles, between the largest and the smallest in the sample set. (F) The smallest half of the bubbles.

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PROJECT GOAL

The goal of this project is to determine lightweight cement stability at various depths in the well and correlate those test results with current atmospheric testing as outlined in the American Petroleum Institute (API) Recommended Practice (RP).

PROJECT DESCRIPTION

NETL is researching the physical and chemical behavior of typical wellbore cements to better understand how various cement formulations perform, with emphasis on potential failure pathways and remediation technologies. Currently, there is no information on how foam cements, commonly used in extreme offshore settings, perform and persist under in situ conditions.

NETL researchers initiated laboratory characterization studies of commonly used industry standard formulations of foam cements and have obtained the first computed tomography (CT) images of foamed cement systems. The CT characterization of the samples allows quantitative analysis of physical properties and structures within the cement (particularly bubble sizes and distributions). NETL researchers have also developed a reliable methodology to probe the microstructure of foamed

R&D207, February 2019

cements under in situ conditions. The team will use this methodology to determine stability of foamed cement systems at various "depths" in the subsurface and correlate those properties with the current method of atmospheric testing. Phase 1 findings from this project were released in the document, "An Assessment of Research Needs Related to Improving Primary Cement Isolation of Formations in Deep Offshore Wells." Initial results from this study's atmospheric foamed cement experiments are summarized in the publication, "Computed Tomography and Statistical Analysis of Bubble Size Distributions in Atmospheric-Generated Foamed Cement."

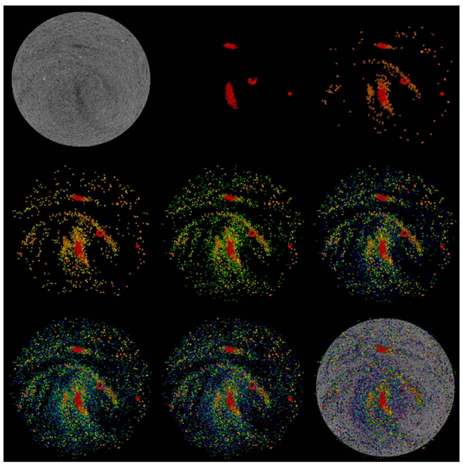

Figure 2. The upper left image is a grayscale rendering of a cement sample. In the other images of the same sample, the red dots are the largest gas bubbles that make up 10% of the volume followed by sequentially smaller yellow, green, blue, indigo, and violet bubbles.

NETL CAPABILITIES

Researchers use CT scanners at NETL's Geological Services Laboratory in Morgantown, WV, to characterize the micro-structure of the foamed cement. The lab has three CT scanners: (1) a medical CT scanner; (2) an industrial CT scanner; and (3) a micro CT scanner. The medical scanner is useful for observations of sub-core bulk properties; the industrial scanner can portray pore networks; and the micro scanner analyzes pore surfaces.

NETL's Geomechanics and Flow Laboratory is a multi-functional, state-of-the-art facility that performs a wide spectrum of studies and provides an experimental basis for measuring foamed cement behavioral properties. The laboratory has a wide range of tools and instruments to ensure a complete cycle of scientific studies, from preparation of representative samples, through the preliminary measurements of basic properties, to the advanced investigation of the processes of interest under simulated subsurface conditions.

BENEFITS

The use of CT imaging and statistical analysis is an effective method of characterizing the microstructure of foamed cement. Commonly held assumptions that foamed cements with higher foam qualities (entrained-nitrogen fractions) have higher bubble connectivity, higher permeability, lower foam stability, and lower compressive strength were confirmed and published. Research to evaluate and implement improved laboratory methods to generate foamed cement under pressure, or with greater shear rate, will improve the correlation between current API RP 10B-4 (2015) test methods and foamed cements generated with field cementing equipment.

ACCOMPLISHMENTS

The atmospheric foamed cement generation method [as outlined in API RP 10B-4 (2015)] and the current foamed generation methods used in industrial-scale foamed cementing equipment do not provide similar bubble size distributions (BSD) in foamed cements of similar foam qualities. When comparing samples of a similar foam qualities, the atmospheric foamed cement generation method in API RP 10B-4 (2015) creates an average bubble size considerably larger than field foamed cementing equipment. Foam cement samples generated with field equipment display higher foamed stability and lower permeability compared to samples generated at atmospheric conditions in the laboratory.

Results of the analytical data generated with atmospherically generated foamed cement samples confirmed the current industry guideline of limiting the in situ target design of foamed cement nitrogen fraction to 30 to 35 percent. Above this level, atmospherically generated foamed cements display significantly increased permeability and decreased foamed stability. The measured mechanical properties of both field-generated and atmospherically-generated foamed cements designed within current industry guidelines of a maximum 30 to 35 percent nitrogen fraction are suitable for applications to isolate subsurface formations in oil and gas well cementing operations.

For additional information, we invite you to visit https://edx.netl.doe.gov/offshore

Research Partners

Carnegie Mellon University | University of Pittsburgh | BP | Shell | Schlumberger | Baker Hughes | Halliburton | Benge Consulting | API cement subcommittee 10c

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