NATIONAL ACADEMIES Sciences Engineering Medicine

2017: Safer Offshore Energy Systems 3 Final Report

GULF RESEARCH PROGRAM

Project Title: Hydrocarbon Influx Behavior within a Deepwater Marine Riser – Implications for Design and Operations
Award Amount: $1,185,963
Awardee: University of Houston
Award Start Date: December 1, 2017
Award End Date: November 30, 2020
NAS Grant ID: 2000008864

Project Director: Ramanan Krishnamoorti
Affiliation: University of Houston

Project Key Personnel:

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I. PROJECT SUMMARY (from proposal)

The dynamic effects of free-bubble gas formation within deepwater marine drilling risers are a major issue for the offshore industry and recently emphasized in the CSB Macondo report. This project will take a holistic approach to the issue of riser gas unloading with the objective to:

- Undertake a comprehensive assessment of the risks and consequences of influx of hydrocarbons entering the drilling riser;
- Develop a new computational model describing the response of hydrocarbons in the riser under different hydrocarbon influx situations, operating conditions and response procedures;
- Implement the model in a computational code;
- Calibrate computational models through a supporting experimental program;
- Evaluate new technologies which can improve hydrocarbon detection;
- Provide a comprehensive physical and practical understanding of events that can occur when hydrocarbons are introduced into an offshore drilling riser.

The project will characterize a range of potential mixtures of formation fluids and drilling fluids within a drilling riser such that any potential safety issues can be identified and potential mitigations constructed.

Two particular focus areas are noted for this work – these are potential gaps in understanding and capability:

- Rapid expansion of gas near the top of the marine riser

• Lack of riser instrumentation to detect/quantify hydrocarbons in the riserThere are significant limitations in the ability of existing models to represent the specific conditions in the upper marine riser and this project will focus on improved computational methods to model the physical processes occurring within a riser. The project will describe how varying amounts of hydrocarbons may be handled, if at all, by existing drilling rigs and by comparison with those rigs equipped with a Riser Gas Handler (RGH) or Managed Pressure Drilling System (MPD). The project will also assess instrumentation that could be installed at the base of the riser to detect and quantify any hydrocarbon that enters the drilling riser.

The project outputs will include:

• Improved modelling capability, compared to current commercial software, specifically for varying hydrocarbon conditions in a marine riser;

• A comprehensive physical and practical understanding of events that can occur when hydrocarbons are introduced into an offshore drilling riser;

• Identification of new and existing technologies that can be applied to deepwater drilling operations to significantly reduce future risks;

• Communication with the drilling community so that they can better comprehend potential hazardous situations and devise mitigations.

This project represents a strong collaboration between the academic research within the Subsea Systems Institute's partners and industry specialists with experience in both drilling operations and technology development. The team has both the academic expertise and the operational and well control experience to conduct the complex physical analysis of the real wellbore fluid mixtures and to ensure the validity of the results and the applicability of these results to the real world.

Finally, the project may suggest the classification of deepwater wells into those which require additional equipment and those which do not. The outcome from this project will provide quantitative results to provide the direction for the design and operations of future deepwater drilling programs.

II. PROJECT SUMMARY (from final report)

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III. PROJECT RESULTS

Accomplishments

All objectives and outputs outlined above were achieved.

The project elucidated the reason for the destructive potential and seemingly sudden nature of gas kick events and developed a new fast and sensitive detection method. Experimental demonstration was carried out and guidelines for implementation were developed. Further, the project was presented widely to the drilling community.

A new computational model to describe the response of hydrocarbons in the riser was developed and implemented in a computational code.

We updated the conclusions of our earlier study on the violent expansion of the Taylor bubble which, were sufficient for water-based muds, to the case of oil-based muds. Since oil-based muds exhibit non-Newtonian behavior, we improved our previous model by including non-Newtonian effects.

Development of flow loop program: We improved the performance of the new riser-tube apparatus. The generation of the large air bubble involved opening a valve in the pressurized bottom section of the tube. This action created 2 challenges of (a) inducing lateral oscillations of the riser-tube apparatus, and (b) creating a pressure surge that disrupted the formation of a clean air bubble and induced propagating pressure waves along the column of fluids. These complications affected the pressure data and complicated the interpretations of bubble velocity and expansion. We strengthened the riser-tube supporting frame with braces to increase its structural rigidity. Placing the valve in a horizontal section upstream and away from the vertical tube reduced the pressure surge. The opaque gel, slurry, and mud obscured the movements of the air bubble. Non-optical sensors were employed to complement the pressure sensors. The work produced several papers and in 2021 was highlighted at Society of Petroleum Engineers, NASGRP and at the Offshore Technology Conference.

Implications

The clarification of the mechanisms by which a gas kick can result in damage to the drilling rig and environmental pollution highlights the necessity of early and timely detection of such an event. The methods currently in use in the industry are insufficient for the purpose as they are too slow (10-15 minutes) to deal with a process that can last just seconds. Our work has also led to the proposal of a novel, minimally invasive procedure for the detection of gas kicks which might greatly benefit the industry and protect the environment.

Our work shows that a NIR-based sensor could be developed to report a kick in real-time. Installed with the lower marine riser package possibly the blow-out preventer, the sensor works on the principle of near-infrared (NIR) absorbance but would require innovative methods of deployment such as porous hydrophobic coatings to prevent signal attenuation. Due to the difference in NIR absorbance, the sensor would report an influx of hydrocarbons, and our results also suggest that the composition of the fluids entering the wellbore may be identified.

Coupling this approach with a pressure-based sensor would provide two lines of evidence for early kick detection in real-time. The detailed information provided to rig personnel would enable them to take the necessary steps to avert the dangers of a blowout and thus save lives and resources.

Education and Training

Number of students, postdoctoral scholars, or educational components involved in the project:

- K-12 students: 0
- Undergraduate students: 0
- Graduate students: 7
- Postdoctoral scholars: 1
- Citizen Scientists: 0
- Other Trainees: 0

IV. DATA AND INFORMATION PRODUCTS

This project produced data and information products of the following types:

- Data
- Information Products

DATA

Data Management Report:
As described in the data management plan, project data was managed and secured through a project sharepoint site. The sharepoint site was used for the storage and exchange of all project data and documents between the project participants. Access to the site was controlled and restricted to the key project personnel and their staff. The project Director and Program Manager were responsible for the management and security of all data and communications on this site.

Relationships Between Data Sets:
The data generated by this project include the numbers necessary to draw the figures in the papers.

Additional Documentation Produced to Describe Data:
None

Other Activities to Make Data Discoverable:
None

Sensitive, Confidential, or Proprietary Data:
N/A

INFORMATION PRODUCTS

Information Products Report:
[If there is an Information Management Reporting document, then "See attached Information Products Report." and Information Management Reporting document gets attached as a PDF to end of final PDF version of this document. If there is not an Information Management Reporting document, then "N/A".]

Citations for Project Publications, Reports and Monographs, and Workshop and Conference Proceedings:
Scholarly publications and models or simulations

Additional Documentation Produced to Describe Information Products:
N/A

Other Activities to Make Information Products Accessible and Discoverable:
N/A

Confidential, Proprietary, Specially Licensed Information Products:
No

V. PUBLIC INTEREST AND COMMUNICATIONS

Most Exciting or Surprising Thing Learned During the Project

As a large gas bubble ("gas kick") ascends in the riser, it expands due to the falling pressure. This expansion pushes liquid out of the riser onto the rotary table (drill floor). The key issue that has emerged from this work to date is the extremely short time frame - order of seconds - over which the amount of this liquid spill goes from a fraction of a cubic inch per second to many gallons per second. Such a short time frame is insufficient for drill crew reaction and closure of a well control device. This will be a key element of future discussions with the drilling community.

Outcomes Achieved During the Project

The major outcome of this project has been a clear physical understanding of the mechanisms by which undetected gas kicks can result in catastrophic damage. This insight has been supported by computational and laboratory simulations and has successfully underwent the peer-review process.

Communications, Outreach, and Dissemination Activities of Project

SSI Newsletter - https://uh.edu/uh-energy/research/ssi-newsletter/january-2021/
SSI Website – www.subseasystems.institute
Shared findings and paper with Regional Director Mike Celata of BOEM
Presentation to SPE
https://webevents.spe.org/p/210413
Presentation at Offshore Technology Conference, Advances in Drilling Technology Panel
https://2021.otcnet.org/technical-program?&searchTerm=prosperetti&searchgroup=52161AC5-technicalprogram-2021