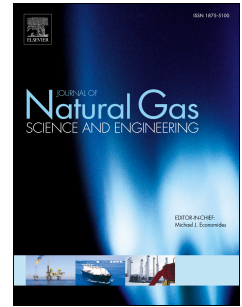


Accepted Manuscript

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PII: S1875-5100(17)30329-3

DOI: [10.1016/j.jngse.2017.08.020](https://doi.org/10.1016/j.jngse.2017.08.020)

Reference: JNGSE 2287

To appear in: *Journal of Natural Gas Science and Engineering*

Received Date: 29 March 2017

Revised Date: 14 August 2017

Accepted Date: 15 August 2017

Please cite this article as: Fei, Y., Pokalai, K., Johnson Jr., , R., Gonzalez, M., Haghghi, M., Experimental and simulation study of foam stability and the effects on hydraulic fracture proppant placement, *Journal of Natural Gas Science & Engineering* (2017), doi: 10.1016/j.jngse.2017.08.020.

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1 Experimental and simulation study of foam stability and the effects on 2 hydraulic fracture proppant placement

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5 Abstract

6 Foam has previously been used as fracturing fluid; however, there have not been enough study on
7 foam stability and its effectiveness on proppant placement during hydraulic fracturing. In this paper,
8 an experimental study was performed using free drainage method at 90°C. Then, the rheological
9 characterisation of foam was produced based on dynamic foam quality change during foam drainage
10 experiments and also based on viscosity breakdown by disproportionation. Subsequently, a 3-D
11 hydraulically fracturing simulation was developed to evaluate the foam performance as a fracturing
12 fluid using different vertical well scenarios. The results show that foam stability is dependent not
13 only on the overall treatment time but also to fracture closure on proppant. For example, longer
14 closure time accelerate proppant settling and accumulation at the bottom of the fracture, lowering
15 propped area, and reducing productivity. The simulation results indicate that this lower productivity
16 can be attributed to the final propped area, proppant distribution confirming the relationship
17 between foam stability, foam rheology, proppant transport and fracture effectiveness.

18 **Keywords:** *Foam stability, Hydraulic Fracturing, Proppant Placement, Drainage*

20 Introduction

21 Foams were introduced as fracturing fluid in the early-1980s, and they have been extensively used
22 in various liquid sensitive and depleted reservoirs where water-based fluids were less effective (Craft
23 et al., 1992; Goelitz and Evertz, 1982; Wamock et al., 1985). It has been commonly reported that
24 foams can achieve faster clean-up, low leak-off and less formation damage than conventional water-
25 based fracturing fluids (Burke et al., 2011; Garbis and Taylor, 1986; Goelitz and Evertz, 1982; Harris,
26 1985; Toney and Mack, 1991). Other reported benefits include lower water consumption and
27 reduced swabbing (Blauer and Kohlhaas, 1974; Gaydos and Harris, 1980). Increasing transportation
28 costs in remote locations, storage costs and high surface pumping requirement have been identified
29 as limitation of field application (Wanniarachchi et al., 2015). However, the main issue of using foam
30 in hydraulic fracture treatments is foam stability, particularly in high temperature conditions that
31 foam becomes more unstable (Fei et al., 2017). Because the ability of a foam to induce fracture and
32 carry proppant, it is essential to maintain foam stability at high shear rates while pumping and low
33 shear rates while fracture is closing. The failure of maintaining foam stability results in proppant
34 screen-out either in the fracture or at the wellbore or inadequate proppant distribution in the
35 targeted interval at fracture closure, based on inadequate foam stability and proppant redistribution
36 during closure (Johnson, 1995).

37 In this paper, the workflow of different tasks is discussed in the next section. Then, different
38 mechanisms of foam stability are reviewed followed by the details of the experimental procedure
39 and results. Furthermore, foam characterization and rheological modelling are discussed followed by
40 the results of 3-D simulation. Finally some conclusive remarks are presented.

41 Methodology

42 This study involved 3 major tasks; 1- Foam stability experiments; 2- Foam rheological
43 characterization and 3- 3D hydraulically fracture simulation. The details of the workflow are shown

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