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A Dynamic Model for High-Rate Acid Stimulation of Very Long Horizontal Wells

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Abstract

In 1999, Mærsk Olie og Gas AS introduced the Controlled Acid Jet (CAJ) completion and stimulation technique and over the last 7 years more than 300 km of reservoir sections have been implemented mainly in the Danish chalk fields (see SPE paper 78318 for a description of the concept). This method allows cost effective single operation acid stimulation of ultra long horizontal wells (15,000+ ft) in carbonate reservoirs. Successful implementation of the CAJ technique requires numerical modelling of the dynamics of the entire stimulation process to ensure equal distribution of the acid, effective control of the wormhole growth rate in all sections of the well, displacement of mud along the entire reservoir section, handling of significant (1,000+ psi) formation pressure gradients along the reservoir section etc. Especially the analysis of the mud displacement process along the horizontal sections has proven to be critical for optimising the completion design.

The key to the successful field developments has been the gradual improvement of the CAJ technique which has been achieved by modelling the effect of a range of parameters prior to the full field trial to optimise the design of the completions.

This paper describes the building blocks of the newly developed modelling algorithm* that captures the physics of the stimulation process and the numerical solution methods required to apply the CAJ technique in ultra long horizontal wells.

The model has been matched to actual stimulation data and modelling is now widely used resulting in more effective stimulation and an extensive application of the CAJ technique for the development of marginal fields.

*Patent Pending

Introduction

Horizontal wells with continuous reservoir sections exceeding 15,000 ft are being used for the development of the laterally extensive low permeability chalk in the Dan and Halfdan oil fields as well as on a number of other fields located in the Danish part of the North Sea (Figure 1).

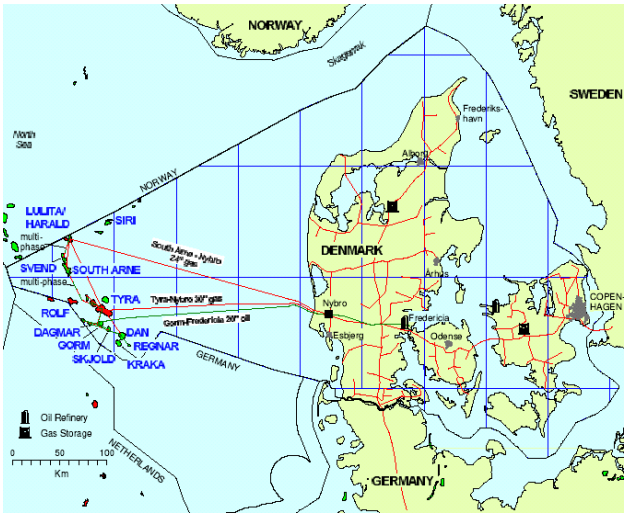

Figure 1: Danish North Sea Sector

The recently patented Controlled Acid Jet (CAJ) technique was originally developed in 1998 to stimulate very long horizontal well sections in a single operation (Hansen, 2005). The CAJ concept is based on a non-cemented liner with a limited number of unevenly spaced holes of different size (perforations) which ensure efficient acid stimulation of the complete reservoir section, provided the acid is pumped at sufficiently high rates to enable complete displacement of the mud phase. Hansen and Nederveen (2002) described the CAJ concept in greater detail. CAJ can be applied in combination with traditional cemented liners or cover the entire reservoir interval.

The CAJ technique has, in several ways, set new standards for the completion and stimulation of long horizontal wells. The most significant achievement with the CAJ technique is the remarkably effective acid coverage resulting from stimulation of long reservoir sections in a single operation. A typical CAJ liner length represents some 20-40 times the interval length covered during matrix acid stimulation in a traditional