ISAPP symposium

11 & 12 November 2015

Venue:
Lecture room G - Faculty of Civil Engineering and Geosciences - Delft University of Technology

Wednesday 11 November 2015

09:00	***09:30***	***Registration and coffee/tea***			
09:30	09:40	Hegen	Dries	TNO	Welcome and short ISAPP status overview
09:40	10:00	Jansen	Jan Dirk	TUD	ISAPP and recovery factory technical status overview
10:00	10:25	Kahrobaei	Siavash	TUD	Identification of flow-relevant structural features in history matching
10:25	10:55	Vink	Jeroen	Shell	Why Bayesian style history matching doesn't (always) work
10:55	***11:25***	***Coffee/tea break***			
11:25	11:50	Fonseca	Rahul	TUD	Recent improvements in ensemble optimization with and without geological uncertainty
11:50	12:20	Codas	Andres	NTNU	Output constraints handling and computational parallelization applied to reservoir control optimization
12:20	12:50	Hanea Hustoft	Remus Lars	Statoil	Decision maturation based on robust optimization under geological uncertainties
12:50	***13:35***	***Lunch***			
13:35	14:00	Moraes	Rafael	TUD	Multiscale reservoir management
14:00	14:30	Stordal	Andreas	IRIS	Generalized randomized maximum likelihood for improved Bayesian history matching
14:30	15:00	Egberts	Paul	TNO	Salt precipitation in gas reservoirs; modeling and optimization
15:00	15:25	Schutte	Koen	TUD	Asphaltene agglomeration and deposition in turbulent channel and pipe flow: Towards closure in one dimensional models
15:25	***15:55***	***Coffee/tea break***			
15:55	16:20	Barros	Eduardo	TUD	Value of multiple production measurements and water front tracking in closed-loop reservoir management
16:20	16:50	Gelderblom	Paul	Shell	A direct method for stratigraphically consistent assisted history matching of object-based geomodels – algorithm and field application
16:50	17:20	Zhang	Yanhui	TNO	Ensemble-based reservoir history matching for complex geology and seismic data
17:20	17:45	Popa	Tudor	TUD	An engineering localization approach for the assisted history matching of the Norne field
18:30		***Dinner***			

Thursday 12 November 2015

09:00	***09:30***	***Registration and coffee/tea***			
09:30	09:55	Diaz Cortes	Gabriela	TUD	Physics-based preconditioners for large-scale subsurface flow simulation
09:55	10:20	Meer, van der	Jakolien	TUD	Temporal oscillations in foam enhanced oil recovery simulation
10:20	10:50	Verlaan	Martin	Deltares	Data-assimilation with constraints with application to hydrodynamic models
10:50	***11:20***	***Coffee/tea break***			
11:20	11:45	Insuasty	Edwin	TUE	Flow characterization of the Brugge field: A tensor approach
11:45	12:15	Moraes	Rafael	Petrobras	Advances in optimization-based techniques for reservoir management studies
12:15	12:40	Foss	Bjarne	NTNU	Daily production optimization – surrogate modelling based on B-splines
12:40	***13:25***	***Lunch***			
13:25	13:55	Siraj	Mohsin	TUE	Risk management in oil reservoirs water-flooding optimization
13:55	14:20	Fatemi	Amin	TUD	Discerning in situ performance of an EOR agent in the midst of geological uncertainty using Bayesian statistics
14:20	14:40	Jansen	Jan Dirk	TUD	Closing
14:40		***Drinks***			
15:30		***Steering committee meeting***			

ISAPP Symposium 11 and 12 November 2015

Programme Wednesday 11 November

09:30 - 09:40 **Dries Hegen (TNO)**
Welcome and short ISAPP status overview

09:40 - 10:00 **Jan Dirk Jansen (TUD)**
ISAPP and recovery factory technical status overview

10:00 - 10:25 **Siavash Kahrobaei (TUD), Mehdi Mansoori (TUD), Gerard Joosten (Shell), Paul Van Den Hof (TUE) & Jan Dirk Jansen (TUD)**
Identification of flow-relevant structural features in history matching

Geo-modeling is the process of populating a reservoir model with properties such as permeabilities, porosities etc., which is a highly uncertain procedure. The uncertainty arises from a lack of knowledge about the reservoir and many times, more importantly, from interpretations of uncertain data sources such as seismic, well logs, core data, etc. Interpretation of any data source is always subject to uncertainty and creativity which can lead to significant bias in the model descriptions. This uncertainty is propagated through a set of models used during the development phase of an oil field. Thus unexpected flow-relevant features that are not captured in the reservoir model may be present in reality. This is known as 'under-modeling'. In such scenarios penalizing deviations from a prior model can be undesirable since it leads to solutions that stay close to the prior. Therefore if a feature is missing in the prior there is almost no chance to capture it since the updated parameters are constrained by incorrect prior knowledge that usually originates from interpretation errors of geological data. On the other hand, attempts to estimate all uncertain parameters from production data without regularization typically lead to very high or low parameter values that have little or no geological realism. Although, these unrealistic solutions can, sometimes, help us to improve our understanding about the reservoir by identifying problematic areas in the reservoir models or be seen as a way to correct for incorrect interpretations of geological data. In this study we focus on the application of different parameter estimation formulations in finding 'unknown unknowns' in different conditions and investigating the theoretical aspects of such an unrealistic parameter updates.

10:25 - 10:55 **Jeroen Vink (Shell)**
Why Bayesian style history matching doesn't (always) work

Current theoretical formulations of assisted history matching (AHM) problems within the Bayesian framework are typically based on the assumption that optimally tuned simulation models can accurately reproduce field data within the measurement error. However, this assumption does not hold for AHM problems of real assets. This paper critically investigates the impact of using realistic, inaccurate simulation models. In particular it demonstrates the risk of underestimating uncertainty, when conditioning real-life models to large numbers of field data. Even though it is well-known, that model error and under-modeling impacts Bayesian methods, the practical effect that uncertainty may be severely underestimated, simply by using all available data is not well appreciated. Besides highlighting this effect, also a mitigation strategy to counteract this problem will be proposed and shown to be effective for the analytical toy model as well as for the real field case used as tests in this paper.

10:55 - 11:25 ***Coffee/tea break***

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11:25 - 11:50 **Rahul Fonseca (TUD, TNO), Olwijn Leeuwenburgh (TNO), Ernesto Della Rossa (ENI), Paul Van den Hof (TUE), Al Reynolds (Univ. of Texas) & Jan Dirk Jansen (TUD)**

Recent improvements in ensemble optimization with and without geological uncertainty

In this talk we provide an overview of a few recent developments which illustrate the applicability of approximate gradient methods, specifically EnOpt, for model-based oil recovery optimization incorporating geological uncertainty. Based on a series of numerical experiments and recent theoretical insights we show that the recently proposed modified robust formulation performs significantly better than the original formulation and comparably to the adjoint method in an optimization context. We will also highlight the impact of gradient quality on an optimization experiment and illustrate the need to achieve high quality gradients for different cases. Additionally, we will also talk about an improvement to the gradient quality through an iterative updating of the covariance matrix used to generate the ensemble of controls. The results of the CMA-EnOpt algorithm that highlights the benefit of 'learning' about the objective function search space during the optimization will be illustrated on a synthetic water flooding test case. Finally we have used some of the proposed modifications in EnOpt for optimization applied to an ensemble of realistic reservoir sector models inspired from a real field case. We aim to show that ensemble based optimization workflows can be used to produce reservoir management strategies of significant practical value.

11:50 - 12:20 **Andres Codas (NTNU)**

Output constraints handling and computational parallelization applied to reservoir control optimization

The presentation will introduce the Multiple Shooting (MS) formulation for optimization of reservoir flooding control. In contrast to the traditional Single Shooting (SS) formulation, MS divides the time horizon in several independent time frames, thus it promotes simulation parallelization and broader constraint handling by means of the independent state variables. The independent prediction time frames are synchronized by a tailored Non-linear Programming (NLP) algorithm based on a reduced Sequential Quadratic Programming approach (rSQP). Although, this method was initially proposed for deterministic water-flooding optimization, it will be presented its extension to problems involving fluids in the gas phase and its extension to handle risk measures under uncertainty.

12:20 - 12:50 **Remus Hanea & Lars Hustoft (NGRMM group, Statoil & TNO)**

Decision maturation based on robust optimization under geological uncertainties

The logical step is to use the updated models obtained from the history matching as input to a production-optimization process, in the larger framework of a field development or redevelopment plan. The combination of model-based optimization and assisted history matching is called "closed-loop reservoir management" and was introduced by Jansen et al, 2008. During the production-optimization phase one tries to identify the best possible drilling strategy, as well as a configuration of controls, that maximizes the production from the reservoir. Formulating the process as an optimization problem, the goal is to maximize an objective function that may represent, e.g. the net present value or total hydrocarbon recovery. Chen et al. (2008) introduced an ensemble-based optimization method (EnOpt) and obtained good results in their application. An EnOpt implementation, where we are using the information from the updated ensemble (obtained by the AHM process) to estimate the gradients, is used for the optimization in this work. In Hanea et al. 2015 (RSS paper) it was shown how FMU can be used in combination with robust optimization for well planning (targets, infill wells, drilling priority, rate control). We introduced a new approach where the drilling of wells, timing and type of wells are optimized under geological uncertainty using an ensemble of models. Results are presented for two field cases.

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12:50 - 13.35 ***Lunch in the Exhibition room***

13:35 - 14:00 **Rafael Moraes, Jan Dirk Jansen & Hadi Hajibeygi (TUD)**
Multiscale reservoir management

Closed-loop Reservoir Management (CLRM) is a workflow that allows the continuous update of reservoir models based on data from different sources. It relies on computationally demanding optimization algorithms (for the assimilation of the data and well control optimization) which require multiple simulations of the reservoir model. One important aspect for the successful application of the CLRM workflow is the definition of a model that can both be run multiple times in a reasonable timespan and accurately enough represent the physics of the problem. Techniques such as Reduced-Order Modeling (ROM) and Upscaling are often employed and can meet the computational efficiency criteria, but at the expense of (excessive) simplification/neglection of the physics. Multiscale (MS) methods, a reservoir simulation technique, however, solves a coarser simulation model, thus increasing the computational speed up, while still utilizing the fine scale representation of the reservoir. In addition, the MS approach to reservoir simulation may be of benefit in the data assimilation step of CLRM, because various types of data are naturally linked to different spatial scales. In this work we investigate the utilization of MS techniques as an efficient and accurate simulation alternative, and in this presentation we will address MS simulation concepts in the context of a reservoir simulator development that will be utilized in CLRM studies.

14:00 - 14:30 **Andreas Stordal & Geir Naevdal (IRIS)**
Generalized randomized maximum likelihood for improved Bayesian history matching

Minimization of a stochastic quadratic objective function for Bayesian data assimilation is known as Randomized maximum likelihood in the petroleum reservoir community. The algorithm is well established and has shown promising results in several application. For linear models the algorithm samples the posterior density. To improve the sampling for nonlinear models we introduce a generalized version in its simplest form by reweighting the prior. The weight term is motivated by a sufficiency condition on the expected gradient of the objective function.
Recently an ensemble version of the algorithm was proposed which can be implemented with any commercial simulator. Unfortunately, the method has some practical implementation issues due to computation of low rank pseudo inverse matrices and in practice only the data mismatch part of the objective function is maintained. Here we take advantage of the fact that the measurement space is often much smaller than the parameter space and project the prior uncertainty from the parameter space to the measurement space to avoid overfitting of data. The proposed algorithms are tested on synthetic models including a 2D reservoir

Programme Wednesday 11 November

14:30 - 15:00 **Paul Egberts, Rohith Nair & Aris Twerda (TNO)**
Salt precipitation in gas reservoirs; modeling and optimization

Many gas producing wells in the North-Sea suffer from significant production decline due to salt precipitation near the wellbore. The evaporation of water can result in the increase in in-situ brine salinity up to its solubility limit, at which salt will start to precipitate. This will reduce the rock porosity and subsequently permeability, possibly up to a level that a well becomes clogged. The well's productivity is often in practice restored by a downhole fresh water treatment, a process that needs to be repeated leading to numerous costly production and washing cycles. A challenge for operators is to find well production and washing strategies to maximize production.
We will present a near wellbore model for the salt precipitation phenomena built using DumuX, an open source simulator for multi-phase flow in porous media, developed by the University of Stuttgart. Modification of the simulator to make it suitable for our problem will be addressed. Sensitivity of model to parameters such as pressure drawdown and initial liquid saturation will be shown and interpreted.
Finally, the near well bore simulations results are incorporated in a large scale semi-analytic model to study the long term cyclic production and washing strategy and the scope of optimization.

15:00 – 15:25 **Koen Schutte (TUD), Aris Twerda (TUD, TNO) & Ruud Henkes (TUD)**
Asphaltene agglomeration and deposition in turbulent channel and pipe flows: Towards closure in one-dimensional models

Asphaltenes deposition is a major concern in crude oil production, as it leads to fouling of production equipment and thereby diminishes the oil production rate. In this project, we aim at acquiring a better understanding of the influence of flow on agglomeration of asphaltenes, as well as on its subsequent deposition. To this end, we use a primary-particle based numerical model that was implemented on top of an existing channel flow solver, that has been extended with a novel approach to account for the deposition of particles at the confinements of the flow domain. Our model now can simulate deposition both in channel and pipe geometries.
In this presentation, we will show our latest results. Our main focus will be on those results that can be used to provide closure relations for one-dimensional engineering models. Also, we highlight the main differences that are found between pipe and channel flows, and show how agglomeration and deposition of the dispersed phase affect the turbulent flow itself.

15:25 - 15:55 ***Coffee/tea break***

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15:55 - 16:20 **Eduardo Barros (TUD), Olwijn Leeuwenburgh (TNO), Paul Van den Hof (TUE) & Jan Dirk Jansen (TUD)**

Value of multiple production measurements and water front tracking in closed-loop reservoir management

In this presentation, we address the extension of previous work on value of information (VOI) assessment in closed-loop reservoir management (CLRM) to estimate the added value of performing multiple measurements along the producing life of the reservoir. The new procedure is based on the workflow from our previous paper which allows to quantify the VOI of a single observation under geological uncertainty. Here we show that, by modifying that workflow slightly, it is possible to assess the value of a series of measurements without a prohibitive increase in computational costs. The approach is illustrated with two cases based on a simple water flooding problem in a two-dimensional five-spot reservoir: the first one, in which we assess the value of a series of production measurements, and the second one, in which we estimate the additional value of water front positions tracked by an interpreted time-lapse seismic survey. The results show that the proposed methodology is able to generate valuable insight to support decisions on reservoir surveillance. To end the talk, we take a look back on the progress over the last year and we show an outlook of the activities for the final year of my PhD.

Programme Wednesday 11 November

16:20 - 16:50 **Faruk Alpak, James Jennings & Paul Gelderblom (Shell)**
A direct method for stratigraphically consistent assisted history matching of object-based geomodels – algorithm and field application

Object-based static models are typically constructed for stratigraphically complex reservoirs. In this approach, the stratigraphic architecture is represented by use of distinct objects with specific geometric attributes and petrophysical characteristics. It is a major challenge to condition such models to production data while simultaneously maintaining the geologic realism and static conditioning. A novel workflow is developed for the assisted history matching (AHM) of object-based geomodels where the uncertain object locations and attributes are directly modified in the model without resorting to (post-geomodeling) reparameterization techniques. An object modeling algorithm capable of modeling channels and levees is constructed such that the pre-raster geomodeling parameters for individual object locations and attributes are directly built into the blueprint of the algorithm. Through these parameters, object locations and attributes are gradually modified subject to physical constraints to achieve a history match. A "Big Loop" paradigm is employed in this process that automatically couples the static modeling algorithm with the reservoir simulator. The resulting workflow is moderated by a massively parallel and highly efficient iterative data-integration algorithm. In the AHM workflow, static and dynamic conditioning operations are respectively driven by separate objective functions, and are performed at the iteration level in a sequential fashion. Static conditioning operations are permitted to adaptively add and remove objects in the geomodel potentially changing the number of active AHM parameters over the course of the iterative search. The data-integration algorithm is purpose-designed to handle such operations with minimal impact on the robustness of the search.
A potential application of the direct AHM workflow for object-based geomodels is the identification of locations and attributes of channels in deepwater turbidite reservoirs, where the channels are typically below the resolution of the seismic data, the well spacing is typically larger than the characteristic object dimension, yet, the production data exhibits strong sensitivity to channel connectivity. The concept of gradually adjusting the channel locations by using the information in the production data (while maintaining static conditioning) is demonstrated on a real dataset for a deepwater channelized-turbidite reservoir. The model proposed by the new AHM workflow not only improves the difficult-to-history-match injected-gas breakthrough profiles with reasonable accuracy, but also provides a geologically based explanation for them taking into account the channel connectivity. The proposed AHM workflow ensures consistency across static and dynamic models by integrating multi-disciplinary data with an easily auditable and replicable capability.

Programme Wednesday 11 November

16:50 - 17:20 **Yanhui Zhang (TNO), Dean Oliver (Uni CIPR-Norway), Olwijn Leeuwenburgh (TNO) & Philippe Steeghs (TNO)**
Ensemble-based reservoir history matching for complex geology and seismic data

Ensemble-based data-assimilation methods have gained fast growth since the ensemble Kalman filter (EnKF) was introduced into petroleum engineering. This talk is focused on the updating of geologic facies models and the assimilation of seismic data within the framework of ensemble-based reservoir history matching. A post-processing approach for updating the distribution of geologic facies is introduced, in which model parameters are first conditioned to production data using EnKF-like methods without regard to their categorical nature, and then projected back to prior discrete model space in an optimization step. Because the optimization step is non-iterative and independent for each ensemble member, the proposed method is quite efficient. In addition, 4D seismic data provide valuable information on the dynamics of fluids in a reservoir. However, how to make better use of 4D seismic data in a quantitative way is still challenging. The ongoing project at TNO as part of the Norwegian IOR Centre Research program is targeted to perform innovative and applied research on the conditioning of reservoir models to 4D seismic data using ensemble-based methods. In order to achieve these objectives the research puts an emphasis on exploring the efficiency and effectiveness while performing seismic history matching at field scale. A brief overview of this project is also presented here.

17:20 - 17:45 **Tudor Popa (TUD), Martin Verlaan (Deltares), Remus Hanea (Statoil) & Arnold Heemink (TUD)**
An engineering localization approach for the assisted history matching of the Norne field

In reservoir characterization, modern reservoir modelling and history matching aim at delivering integrated models with quantified uncertainty, constrained on all available data. In this work the quantification and propagation of the uncertainties is done by using an ensemble based algorithm: the Ensemble Kalman Smoother (ES).
Ensemble size is critical to the efficiency and performance of the ensemble based methods. A consequence of the finite dimension of the ensemble is sampling errors. These can severely degrade the reliability of estimates of conditional means and uncertainty quantification obtained by the ES.
The work presented here introduces a new localization based on region based localization (engineering approach) which will ensure that the dynamics, the physical process and the influence of the structure of the reservoir are not violated. The definition of these regions is based on the understanding of the physics/dynamic of the problem. The permeability in the cells surrounding a well (versus those far away) has a higher impact on observed production in the well. Similarly, wells in a fault block have more information about the Oil Water Contact (OWC) in that fault block. The model is broken down into regions based on many parameters, e.g geology(layers), structure(fault blocks), fluids(oil vs gas). Within each region the relevant observation data and parameters are selected. All other correlations are neglected (treated as spurious). The new methodology is implemented using the ERT (Ensemble Reservoir Tool) from Statoil and it is applied to the Norne field case. The localization is applied over the faulted region of the E sector of the field.

18:30 ***Dinner***
't Postkantoor, Hippolytusbuurt 14, 2611 HN Delft, 015-7503243
www.postkantoordelft.nl

Programme Thursday 12 November

09:30 - 09:55 **Gabriela Diaz Cortes, Kees Vuik & Jan Dirk Jansen (TUD)**
Physics-based preconditioners for large-scale subsurface flow simulation

We develop efficient preconditioners for the solution of large systems of linear equations. We focus on the pressure equation resulting from multi-phase flow in porous media. Proper Orthogonal Decomposition (POD) of many snapshots are used to capture the system's behaviour and to accelerate the convergence of the iterative solution of the linear system. This acceleration is achieved using a combination of preconditioning and deflation techniques.

09:55 - 10:20 **Jakolien van der Meer (TUD), Matthias Möller (TUD), Hans Kraaijevanger (Shell), Johan Romate (Shell), Hans Groot (Shell), & Jan Dirk Jansen (TUD)**
Temporal oscillations in foam enhanced oil recovery simulation

If hydrocarbon recovery methods fail because of viscous fingering and gravity override one can turn to enhanced oil recovery methods, like foam injection. Foam generation can be described by a set of strongly nonlinear partial differential equations. Forward simulation methods lead to temporal oscillations, due to discretization artifacts. The heat equation with discontinuous thermal diffusivity shows similar oscillations. By applying a new discretization scheme we solve this problem. We apply the same technique to the foam model, and show why this reduces the oscillations, but does not remove them.

10:20 – 10:50 **Martin Verlaan (Deltares)**
Data-assimilation with constraints with application to hydrodynamic models

State variables and parameters to be estimated frequently are limited by rigid constraints, eg concentrations cannot become negative. This in contradiction with the assumption that a random variable follows a Gaussian distribution. Here we will follow a pragmatic approach that adds hard constraints to some familiar methods.
For example the total waterdepth in a hydrodynamic model should remain positive as well as the friction coefficient for the sea-bed. We estimated these parameters with an iterative least-squares estimator (DUD by Ralston and Jennrich 1978) was applied to assimilate satellite observations of sea-level as well as coastal tide-gauges. To constrain the values of the parameters, the available DUD algorithm in OpenDA was extended with the option for hard constraints in a manner similar to Quadratic Programming (Janjic et. al. 2014).

10:50 – 11:20 ***Coffee/tea break***

Programme Thursday 12 November

11:20 - 11:45 **Edwin Insuasty, Paul Van den Hof, Siep Weiland (TUE), Jan Dirk Jansen (TUD) & Tzu-hao Yeh (Shell)**
Flow characterization of the Brugge field: A tensor approach

Understanding the dynamical similarities between reservoir realizations is crucial for the quantification of flow-relevant geology. In this work, we exploit the spatial-temporal nature of the reservoir flow patterns for defining a flow-relevant dissimilarity measure useful for flow characterization. To this end, a spatial-temporal representation of the reservoir flow patterns is used through tensor representations, which allow for reduced order formulations of the dominating patterns and simple computation of a flow-induced dissimilarity measure between models. The proposed workflow for flow characterization is applied to generate a smaller set of flow-relevant realizations for the Brugge field.

11:45 - 12:15 **Marco Antonio Cardoso, Alexandre Emerick, Manuel Fragoso, Rafael Moraes, Diego Oliveira & Régis Romeu (Petrobras)**
Advances in optimization-based techniques for reservoir management studies

The decision making process intrinsic to the management of a petroleum field is particularly challenging due to, in great extent (but not exclusively), the high level of uncertainty associated with the knowledge about the reservoir. However, the advances in technologies regarding the acquisition of data resulting from the reservoir exploitation, e.g. permanent seismic sensors, down-hole pressure gauges and flow meters for real time measurements, provide a valuable set of information that can support the decision making process. Moreover, advances in the hardware for controlling the reservoir production, e.g. smart wells equipped with inflow control valves (ICV's), allow for more pro-active and flexible strategies to maximize production. Nonetheless, the massive amount of data and countless possible production settings require the employment of robust and efficient computational techniques for taking the best advantage of the technologies, thus enabling the choice of the best production strategy. This talk will give an overview of Petrobras' most recent advances in R&D regarding reservoir management studies involving optimization techniques, such as life-cycle production optimization considering ensemble-based geological uncertainty description, simultaneous optimization of placement, trajectory, and length of wells, optimization of ICV's settings and maximization of the value of operation flexibility. Application of such techniques in real fields will also be presented.

12:15 - 12:40 **Bjarne Foss (NTNU)**
Daily production optimization - surrogate modelling based on B-splines

This presentation considers daily production optimization. To obtain meaningful operating advice in real time, the predictive capabilities of an advanced process simulator is combined with state-of-the-art optimization software via surrogate modelling. B-splines provide modelling flexibility and accuracy required in surrogate modelling for production optimization. A new spatial branch-and-bound method has been implemented in the MINLP solver named CENSO, which is publicly available. It solves nonconvex mixed-integer nonlinear programming (MINLP) problems with spline constraints to global optimality. CENSO is applied to solve several realistic production optimization cases in cooperation with BP. The value of using surrogate models in the problem formulation - allowing an algebraic formulation with explicit derivatives - and a state-of-the-art MINLP solver is demonstrated.

12:40 - 13:25 ***Lunch in the Exhibition room***

Programme Thursday 12 November

13:25 – 13:55 **Mohsin Siraj (TUE), Paul Van den Hof (TUE) & Jan Dirk Jansen (TUD)**
Risk management in oil reservoirs water-flooding optimization

Model-based economic optimization of the water-flooding process in oil reservoirs suffers from high levels of uncertainty. The achievable economic objective is highly uncertain due to the limited knowledge of the reservoir model parameters and the varying economic conditions. For improving robustness, different approaches, e.g., mean or mean-variance optimization have been proposed. One of the drawbacks of the mean-variance approach is the symmetric nature of the variance and hence the reduction of the best cases. In this work, we focus only on the lower tail, i.e., the worst case(s) and aims to maximize the lower tail of the economic objective function without heavily compromising the best cases. Concepts from the theory of risk (worst-case, CVaR and semi variance) are considered to offer an asymmetric shaping of the objective function distribution with respect to the given uncertainty. A scenario-based approach is used, where an ensemble of geological model realizations and the oil price scenarios characterize the geological and economic uncertainty respectively.

13:55 - 14:20 **Amin Fatemi, Jan Dirk Jansen & Bill Rossen (TUD)**
Discerning in situ performance of an EOR agent in the midst of geological uncertainty using Bayesian statistics

It is important to verify the properties of the enhanced-oil-recovery (EOR) agent in situ while seeking other goals in an EOR pilot such as making money (if possible), demonstrating oil recovery, and providing the information needed for scale-up to an economic process. Given the complexity of EOR processes and the inherent uncertainty in the reservoir description, it is a challenge to discern the properties of the EOR agent in situ in the midst of geological uncertainty. In this study, we propose the "modified Egg Model" case study to illustrate this challenge: a polymer EOR process designed for a 3D fluvial-deposit water-oil reservoir. The analysis is performed using Shell's in-house simulator MoReS as the numerical simulator for the polymer flood and a code was written in MATLAB to run the different simulations and do the signal analysis. The polymer is designed to have a viscosity of 20 cp in situ. We start with 100 realizations of this 3D reservoir to reflect the possible range of geological structures honoring the statistics of the initial geological uncertainties. For a population of reservoirs representing reduced geological uncertainty after five years of waterflooding, we select three groups of 10 cases out of 100 with similar water breakthrough dates at the four production wells. We then simulate five years of polymer injection. We allow that the polymer process might fail in situ and viscosity could be half that intended. We test whether the signals of this difference at injection and production wells would be statistically significant in the midst of the geological uncertainty using the Bayesian probability approach which offers a framework to deal with both sources of uncertainty.

14:20 - 14:40 **Jan Dirk Jansen (TUD)**
Closing

14:40 ***Drinks in the Exhibition room***

15:30 ***Steering Committee Meeting***