Science@ifpen
Issue 8 - December 2011

The Science@ifpen newsletter provides the scientific community with access to a selection of results obtained by our researchers and published in world-class journals. A few years ago, in order to enhance its scientific excellence, IFP Energies nouvelles (IFPEN) created an R&D expertise network that now brings together around fifteen Experts and Expert Directors. Our aim is to publish regular issues of Science@ifpen, primarily focusing on the work of our expert community.

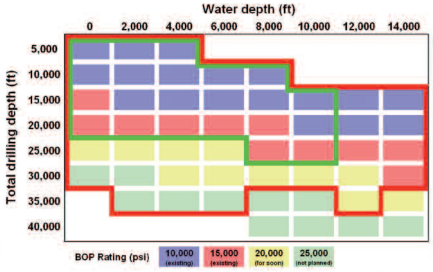
In issue 8, for example, readers will discover a broad range of topics, including how modeling can provide a clearer understanding of foothill zone behavior, the results of eco-driving techniques applied to electric vehicles or the development of innovative methods for monitoring corrosion. We are delighted to be able to offer you a glimpse of this diversity and hope you enjoy reading our newsletter.

Xavier Montagne,
Deputy Director, Scientific Management

Diving deep into the world of risers

Risers are a key component of offshore drilling systems, linking the floating platform to the subsea wellhead. A riser is composed of a bundle of tubes with a main pipe extending the well and 5 safety and service lines, integrated into 23 m joints and assembled to one another. This system has demonstrated its efficacy to depths of up to 3,000 m of water. Risers are either connected to the wellhead, during drilling operation, or disconnected during running and retrieval. However, these two situations are antagonistic and dimensioning of the riser needs to take them into account. It has been shown, in fact, that the weight required by the riser to guarantee its dynamic stability when it is disconnected becomes a major handicap when it is connected.This difficulty can be overcome by integrating the peripheral lines hyperstatically, i.e. by rigidly connecting their ends to the main pipe. The resulting sharing of loads between the tubes makes it possible to significantly reduce the weight of the overall system and gives the riser a high level of axial stiffness, which is beneficial to its dynamic behavior.

A parametric study has quantified these effects and enabled extension of the riser's operational range, in terms of water and drilling depths, to be evaluated. In particular, it is estimated that the new concept may allow water depths of 4,200 m to be reached. Load sharing riser technology, which is patented by IFPEN, is currently being developed. Detailed conceptual and design studies were performed according to a particular specification and a qualification testing program is planned, including static and fatigue testing of prototypes.



Increase in the operational scope of risers using load sharing technology. The range of conventional risers is indicated in green and that of hyperstatic ones in red.

E. Persent, J. Guesnon, S. Heitz** and **D. Averbuch, New Riser Design and Technologies for Greater Water Depth and Deeper Drilling Operations, *Paper SPE/IADC 119519 (2009)*

***J. Guesnon,** C. Gaillard,* Method of dimensionning a drilling riser, *US Patent 7,630,866 (2009)*

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Foothill zones give up their secrets

2D and 3D seismic reflection data acquisition and processing methods are today helping to optimize imaging, previously a major obstacle to exploration of foothill zones.

For the last twenty or so years, IFPEN has been developing petroleum system simulation tools in tectonically complex zones. 2D kinematic modeling tools (Thrustpack and Ceres) have been developed to simulate the gradual formation of a tectonic prism. 2D incorporation of hydrocarbon compaction, expulsion and migration processes by Ceres is now helping us to understand the distribution of excess pressures and predict hydrocarbon charge on regional transects as complex as the Albanides *(see figure)*.

However, the inversion of organic matter maturity data (T_{max} and Ro) is insufficient here, since it does not enable simultaneous resolution of uncertainties related to the thickness of eroded series and paleo-heat flux values. Several analytical methods can be used to reduce these uncertainties and, in particular, the use of paleo-thermo-barometers, such as fluid inclusions, with the co-existence of aqueous inclusions and hydrocarbon inclusions in the same diagenetic cement enabling the paleo-temperature and paleo-burial (paleo-pressure) of reference points to be obtained.

Although the complexity of their structures will limit the use of the 3D tools currently being developed, foothills zones are still under-explored and likely to provide new hydrocarbon reservoirs. They will thus represent a natural laboratory ideal for studying the hydrodynamic properties of faults and validating new reactive transport tools for a long time to come.

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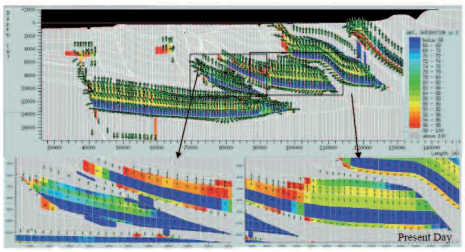
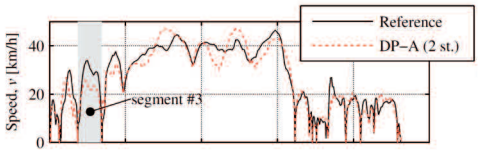


Ceres modeling of the Albanides, demonstrating partitioning of fluids within the various tectonic units. The size of the arrows is proportional to the migration speeds, which range from 0.04 to 4.5 m per million years (Vilasi et al., 2009).

N. Vilasi, J. Malandain, L. Barrier, ***J.P. Callot,*** *N. Guilhaumou, O. Lacombe, K. Muska,* ***F. Roure*** *and R. Swennen,* From outcrop and petrographic studies to basin-scale fluid flow modeling: the use of the Albanian natural laboratory for carbonate reservoir characterization, *Tectonophysics, 474 (1-2), 367-392. DOI: 10.1016/j.tecto. 2009.01.033*

F. Roure, *P. Andriessen,* ***J.P. Callot,*** *H. Ferket, E. Gonzales, N. Guilhaumou, N. Hardebol, O. Lacombe, J. Malandain,* ***P. Mougin,*** *K. Muska, S. Ortuño,* ***W. Sassi,*** *R. Swennen and N. Vilasi,* The use of paleo-thermo-barometers and coupled thermal, fluid flow and pore fluid pressure modelling for hydrocarbon and reservoir prediction in fold and thrust belts, *In G.P. Goffey, J. Craig, T. Needham and R. Scott., eds.,* Hydrocarbons in contractional belts, *Geological Society, London, Spec. Pub., 348, 87-114. DOI: 10.1144/SP348.6 (2010)*

Eco-driving for electric vehicles



Real speed profile measured and optimized with the same distance and speed constraints.

Eco-driving is an integral component in the reduction of a vehicle's energy consumption. Tools are emerging to help motorists drive safely and use relatively little energy. These tools range from relatively intuitive driver assistance devices (aimed at reducing driving aggressiveness) to tools based on information and communication technologies (GPS, sensors that detect other vehicles, communication with a centralized facility, etc.).

Having access to this information makes it possible to estimate the journey to be made in the immediate future and the associated constraints (distance, average and maximum speed, traffic, etc.). Calculation of the driving profile that minimizes energy consumption in these conditions is then systematically possible using optimal control methods.

With respect to the first existing applications, IFPEN is rather interested in employing this optimized approach in real urban use. To do this, IFPEN is working with VULog, a specialist in onboard algorithmics and electronics for car-sharing. The VME *(Ville, Mobilité, Énergie* or Town, Mobility, Energy) project, funded by Ademe, involves a fleet of self-service electric vehicles in Rueil-Malmaison and Nice. The vehicles are fitted with an Onboard Energy Supervisor, which supplies the driver with energy-efficient driving advice based on GPS location, detailed maps of the town and online optimization calculations.

A preliminary study conducted with the support of VULog, demonstrated that the range of the vehicles can be 20% more than that measured in real driving conditions. These results are calculated by formalizing the problem in mathematical terms and using an optimal control technique: dynamic programming. The optimized approach is currently being validated on the Rueil fleet.

A. Sciarretta, L. Guzzella, *at-Automatisierungstechnik 53 (2005), 244–250*

E. Hellström, M. Ivarsson, J. Aslund, L. Nielsen, *Control Engineering Practice, 17 (2009), 245-254*

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Gaining a better understanding of the properties of heavy products

Heavy crudes and oil residues produced by successive distillations have the specific characteristic of containing a high concentration of heavy, aromatic substances called asphaltenes. Their aggregation properties are the source of their high viscosity and low mobility in catalytic networks. Hierarchized aggregation mechanisms govern the combination of asphaltene molecules. A detailed description of these mechanisms — on a nanometric scale, in particular — would help to improve our understanding of the transport and refining steps.

To this end, IFPEN is using radiation small-angle scattering (neutrons, SANS and X-rays, SAXS), enabling observation of colloidal systems over a broad range of scales, from the nanometric scale to the micron scale. In addition, each type of radiation "sees" matter differently, making the methods complementary. Hence, combination of SANS and SAXS measurements on large instruments (LLB, ILL, ESRF), combined with variation of experimental conditions, led to identification of a fine organization of matter over regions with distinct chemical compositions.These asphaltene nanoaggregates are best depicted by a disc structure composed of a dense, aromatic core, surrounded by an aliphatic ring. The average size is around 32 Å radius, and the aggregate resembles a small pile of 3 aromatic molecules.

Knowledge of the small-scale structure of these materials is the basis for description and modeling of their functions. On the basis of this characterization, the mechanisms governing viscosity, behavior to temperature and diffusion properties can be explained.

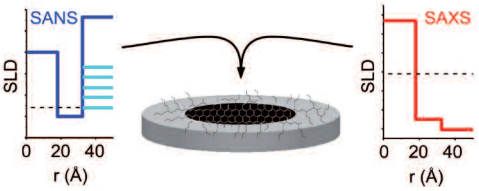

Diagram depicting an asphaltene nanoaggregate described by SANS contrast variation and SAXS.

L. Barre, S. Simon, T. Palermo, Solution properties of asphaltenes, *Langmuir, 24 (2008), p.3709–3717. DOI: 10.1021/la702611s*

J. Eyssautier, P. Levitz, D. Espinat, J. Jestin, J. Gummel, I. Grillo, L. Barré, Insight into Asphaltene Nanoaggregate Structure Inferred by Small Angle Neutron and X-ray Scattering, *J. Phys. Chem. B, 115 (2011), p.6827–6837. DOI: 10.1021/jp111468d*

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The kinetics of colloidal deposits in porous media

Colloidal fluids are very common in natural and industrial systems. In particular, they are present at different stages in the petroleum system. Generated *in situ*, or added for production purposes, they lead to significant reductions in permeability and alter the flow properties of fluids. Controlling the behavior of these systems in porous media is therefore a major challenge for the oil industry and is an integral component of Improved Oil Recovery (IOR).

The process adopted by IFPEN is based on the "colloidal" approach, combined with adimensional analysis. This strategy has led to identification of deposit regimes and determination of kinetic laws for these, such as scale laws, with exponents that are universal and system-independent since they are dictated by the colloidal character common to colloids. Hence, in a convection/diffusion regime, deposits take place within a diffusion layer δ_D according to a first-order reaction with a constant k. The kinetic law of the deposit is therefore expressed as follows:

$$\eta = \frac{1}{UC_0}\frac{\partial \Gamma}{\partial t} = Cte.\frac{Da}{1+Da}P_{eg}^{-2/3}$$

With two adimensional numbers:

$$D_a = \left(k.\delta_D / D_\infty\right) \text{ and } P_{eg} = \left(U.d_g / D_\infty\right)$$

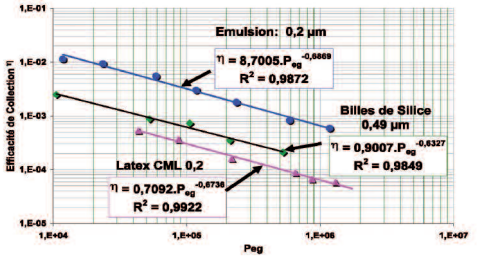
D_a: Damkohler (reaction/diffusion) and P_{eg}: Peclet grain (convection/diffusion) where Γ: density of the deposit (mg/m²), U: fluid speed, d_g: grain size and D_∞: diffusion coefficient.

Two limit regimes can be distinguished:

D_a	s (P_{eg}^{-s})	Limit regim
→ ∞	2/3	DLD (Diffusion)
→ 0	1	RLD (Reaction)

The figure illustrates the validity of this law for solids and emulsions in the DLD regime (s~0.66).

Hence, this colloidal approach combined with adimensional analysis enables development of a unified vision, using adimensional numbers to model the deposit kinetics of colloids in porous media.



Deposit kinetics for different colloids.

L. Nabzar and M.E. Aguiléra, OGST- Rev. IFP Energies nouvelles, Vol. 63 (2008), 21-35. DOI: 10.251/ogst/2007083

S. Buret, L. Nabzar, and A. Jada, SPE J., 15 (2), June 2010: 557-568. DOI: 10.2118/122060-PA

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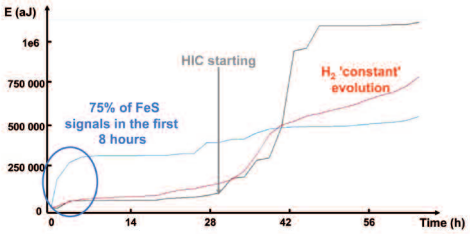
Listening steels during their corrosion

To improve the reliability of equipment, *in situ* monitoring of the degradation of metallic materials has led to an important step forward. A variety of technologies have been developed for this purpose, including the use of electrochemical phenomena, electrical conductivity and acoustic emissions. The latter is based on the emission of acoustic signals as a result of active corrosion, the waves of which differ in terms of type (volumetric, surface, Lamb) and frequencies (50 Hz – 1.5 MHz). Thanks to the use of suitable sensors, waveguides and amplifiers, it is possible to non-intrusively and continuously monitor active corrosion.

The main obstacle to the development of this method concerns identification of the specific signals linked to the corrosion phenomena studied. Research work has been conducted at IFPEN, with the collaboration of Total and Insa in Lyon (MATEIS Laboratory), to study the embrittlement of steels by hydrogen in aqueous media containing H_2S. In media of these types, the high level of atomic hydrogen penetration into the steel can cause the formation of internal blisters and cracks, and even premature rupture. A specific study methodology has been developed in the laboratory enabling specific areas of damage to be located using appropriate sensors and the acoustic signature linked to the different possible mechanisms of hydrogen-induced embrittlement to be identified. As the figure illustrates, signals specifically linked to Hydrogen Induced Cracking (HIC) have been differentiated from other signals triggered, firstly, by surface corrosion associated with the formation of iron sulfides and, secondly, *via* the release of hydrogen gas into the liquid medium where this corrosion occurs.

Quantitative monitoring of HIC mode could therefore be performed in a non-destructive, non-intrusive manner. Important information, such as latency time before formation of the first cracks, then estimation of their propagation rate, is also accessible.



Discrimination on the basis of their energy of acoustic emission signals according to the different damage mechanisms for a carbon steel immersed in aqueous medium with 1 bar of H_2S at 20°C.

***V. Smanio,** M. Fregonese, **J. Kittel,** T. Cassagne, **F. Ropital,** B. Normand,* Wet Hydrogen Sulfide Cracking (HSC) monitoring by Acoustic Emission: discrimination of AE sources, *Journal of Materials Science, 45 (2010), 5534-5542. DOI: 10.1007/s10853-010-4613-2*

***V. Smanio,** M. Fregonese, **J. Kittel,** T. Cassagne, **F. Ropital,** B. Normand,* Acoustic emission monitoring of H_2S cracking of linepipe steels: application to HIC and SOHIC, *Corrosion, 67 (2010) 6, 065001-12. DOI: 10.5006/1.3595097*

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Upcoming scientific events

• *IFP Energies nouvelles' "Rencontres scientifiques" event* ***– Multiscale Approaches for Process Innovation –*** *25-27 January 2012, IFPEN Lyon.*

• *IFP Energies nouvelles' "Rencontres scientifiques" event* ***– Colloids and Complex Fluids –*** *17-19 October 2012, IFPEN Rueil-Malmaison.*

• *IFP Energies nouvelles' "Rencontres scientifiques" event* ***– IFAC Workshop on Engine and Powertrain Control, Simulation and Modeling, E-COSM'12 –*** *23-25 October 2012, IFPEN Rueil-Malmaison.*

• *IFP Energies nouvelles' "Rencontres scientifiques" event* ***– LES for Internal Combustion Engine Flows (LES4ICE) –*** *29-30 November 2012, IFPEN Rueil-Malmaison.*

Nomination

• **Sébastien Candel,** *professor at the* École centrale Paris, *head of the Mechanics, Aeronautics and Space option and leader of the Combustion team at the EM2C Laboratory, member of the French Academy of Sciences, has been appointed Chairman of IFPEN Scientific Board, taking over from Bruno Chaudret (1 July 2011).*

Accreditations to direct research (HDR)

• **Jean-Marc Schweitzer,** *HDR at* Université Claude Bernard Lyon 1: *"Chemical reactors: from extrapolation to thermal stability" (24 March 2011).*

• **Bernard Bourbiaux,** *HDR at the* Institut national polytechnique de Toulouse (INPT): *"Dynamics of double media" (10 May 2011).*

INDEED winner of IEED call for projects

The Institute for the factory of the future, INDEED (French national institute for the development of eco-technologies and low-carbon energies), which is actively supported by IFPEN, was selected on 1 June 2011 within the context of the IEED (Excellence institutes initiatives in the field of low-carbon energies) call for projects in the Investments for the Future government-backed spending program. It strives to build up a position as international leader in the field of eco-efficient processes, particularly in the energy, chemistry and recycling sectors.

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