NORTH AMERICAN OUTLOOK
- Midyear revision shows the depth of the downturn
- Land rigs may have bottomed
- US coalbed methane dives

NORTH SEA REGIONAL REPORT
- Licensing remains strong

SAND MANAGEMENT
A systematic approach to sand management

Sand production has plagued producers for decades. And for decades many have been satisfied to treat the symptoms instead of seeking the cure. A sand solution exists, if we only look for it.

Yousef Gherryo and Mohamed Shatwan, AGOCO; Kaibin Qiu, Rob Marsden, Joe Alexander and Albertus Retnanto, Schlumberger

Sanding is one of the most pervasive, and damaging, conditions affecting production. Historically, sanding has been handled much the same way we handle the various ailments that affect us during our lives. We treat the symptoms, gain some measure of relief, and go on about our business, relegating the experience to an unpleasant, but fast-fading memory—until it strikes again.

The reason we treat sanding the way we do is a reflection of human nature. Just as not all people catch pneumonia, not all wells make sand. Even those wells that do make sand do not do so immediately upon completion. Since many wells are drilled and completed in sequence, those wells that ultimately make sand do so over time.

Piecemeal problems call for piecemeal solutions, and so over the years the sanding problem has been treated like a disease, through remediation, usually performed on an ad hoc basis. The approach can be likened to the cure-all prescription—if you have an itch, scratch it. But remediation efforts proved to be costly and very difficult to implement successfully. Even after heroic efforts to stem the onslaught of sand production, wells were lost.

SAND CONTROL—PROACTIVE THINKING

The word control is reactive, like disease control or fire control. First the problem must manifest itself before controls are implemented. Gradually, engineers came around to the idea that a proactive approach would be more effective. They postulated that if they could find a way to understand completely the conditions and mechanisms that result in sand production, perhaps they could predict its likelihood and apply preventative measures as needed. They reasoned that sand could be made to stay in place if well conditions were properly managed. Eventually, a four-step sand management solution was developed.

Prediction and planning. Reservoir measurements are used to predict if and when sanding might occur. The predictions are used to determine the best completion techniques needed to protect against sand production for the life of the well.

Prevention. Designs are implemented from the prediction and planning stage. This involves achieving the optimum balance between sanding prevention and production optimization, thus eliminating the heavy-handed approaches of the past. Prevention steps are only taken to the degree necessary based upon the calculated risk using reasonable projections of the dynamic conditions expected during the productive life of the well.

Monitoring. Flowrates and drawdown pressures are monitored and controlled during reservoir depletion to prevent mechanical failure that could initiate sand production. Sand production is monitored regularly to detect early warning signs that sanding potential is increasing.

Remediation. Early treatment is implemented to control sanding after initial production is detected. Appropriate techniques are implemented based on a thorough understanding of the well’s dynamic and geomechanical condition, rather than a “shotgun” solution.

TREATING THE DISEASE, NOT THE SYMPTOMS

While everyone agrees that sand production in conventional wells is unacceptable and almost always leads to unwanted consequences, the proponents of sand management techniques recognize that precautionary, but unnecessary, sand prevention will mean unwarranted reduction in productivity and added costs. By adopting a systematic approach, engineers hope to identify reservoir segments that have a high sanding potential, thoroughly understand their sanding mechanisms and take proactive preventative measures.

Finding and identifying sanding-prone formations is fairly straightforward, as is identifying formations with low sanding potential. The difficult part is identifying formations that are not sanding now, but that have a high likelihood of sanding in the future as reservoir conditions change.

For many years, conventional wisdom held that sanding was directly caused by applying too much drawdown to a producing interval. The fix was easy—choke back on the drawdown and the problem would go away. However, experience proved that drawdown was only a part of the problem, and simply choking back production did not mitigate all sanding, but it certainly did cut back on profits.

The first clues that there was more to sanding than high drawdown started to emerge with the introduction of Electrical Submersible Pumps (ESPs), following field pressure depletion. ESPs were very susceptible to damage from sand in the flowstream and suddenly, field maintenance costs skyrocketed, as did production downtime. As a result, the search for a practical solution to sand production gained momentum.

ACHIEVING SANDING PREDICTION ACCURACY

The first step in effective sand manage-
ment is accurately predicting a formation’s sanding potential. The huge oil fields of Libya’s Sirte Basin provided a perfect scenario. The basin’s giant fields consisted of hundreds of wells, production had been continuous for decades, considerable oil remained to be produced, reservoir pressures had declined to the point where ESPs were being deployed, and, most importantly, the fields experienced sanding problems on some wells, but not others.

The final condition encouraged the engineers. If they could understand why some wells sand, but not others, they believed they could discover the root cause of sand production, and thus develop a solution.

Two of the largest fields in the Sirte Basin are operated by AGOCO—Messla Field and Sarir Field, Fig. 1. The former was chosen as the “lab” and, if a successful cure evolved, the latter would be the case study to validate the team’s findings.

Original oil in place at Messla was estimated at 3 billion bbl with a recovery factor of about 50%. The field produces from numerous wells, so finding candidate wells to study would not pose a problem. Moreover, some wells in the field had experienced massive sanding while others had not. Accordingly, an extensive geomechanics study was initiated in 2005 to investigate the reasons for the well-to-well variation in sanding, evaluate the sanding risk in other wells, and provide the information and interpretation necessary to design appropriate completions, maximize economical production and optimize future reservoir management.

Using all available information, including logs, cores, drilling and production data, a Mechanical Earth Model (MEM) was developed. The MEM allowed integration of a simple linear elastic analysis with rock failure, plasticity effects and scale effects. All factors deemed significant to sand production were considered, including stresses, rock strength, drawdown and depletion, as well as completion type and geometry. Fig. 2. The objective was to develop a practical, realistic analysis technique that could be made fit-for-purpose for any well scenario. The areas of uncertainty were reduced as much as possible.

Invaluable contribution to the project came from new technology, specifically the dipole shear sonic log and the full-bore formation microimager log. Significant factors started to emerge. These included rock elastic properties, rock strength data and the magnitude and orientation of principle geostresses. Considerable emphasis was placed on determining sand particle size, which was found to vary from well to well, as well as from level to level within the wells. Laboratory analysis was used on cores and on actual sand bailings from sanded wells or from production separators. A key validation technique was to apply geomechanical analysis and predictive modeling to a sanded well, then compare the resulting prediction with the actual result.

A COMPLEX PROBLEM

It soon became obvious to the team that sanding was driven by different parameters such as rock strength, in situ stresses, production drawdown and depletion—that drawdown was only one factor—and as a result, one or two parameters were insufficient to reliably predict sanding potential. Four basic approaches were considered: an empirical approach using field data, laboratory simulation, numerical methods and analytical calculations.

The field engineers agreed upon a methodology that was simple, yet versatile enough to be run over the entire completion interval in each well. It had to be reliable and require easily obtainable input parameters. The system had to be transferable across different geological and geomechanical settings, across different well configurations, and even different fields. A fit-for-purpose evaluation was wanted that had some independent method of calibration, and one that offered accuracy, multiple realizations, sensitivity studies and alternate completion choices. Most of all, the solution had to be able to achieve these goals in a timely manner, without excessive computational effort and at reasonable cost. The field’s demands appeared to be achievable through the integration of field observations, laboratory experiments and theoretical modeling.

The most demanding requirement was for an evergreen solution—one that could be applied over the life of the well or reservoir, regardless of the well’s status or stage of depletion. AGOCO had qualified many techniques on previous wells in some of its other properties. An advantage of the MEM approach is that many of the input parameters can be validated by acquiring them using complementary techniques. The ability to cross-check data from different sources takes a major bite out of uncertainty and results in a robust procedure that is both accurate and consistent.

All data must be indexed to time of acquisition and related to dynamic parameters such as reservoir pressure, rock stress patterns, flowrates, drawdown and fluid properties. By extending the analysis to a broad field view, rather than focusing only on those wells producing sand,
the major and potential sand-producing wells were identified and their potential sanding risks determined. Nevertheless, the sanding wells provided a valuable way to match prediction accuracy with actual observations. Lab measurements allowed engineers to calibrate calculated results with measurable facts. These techniques allowed a program to be implemented that is expected to perform over the remaining life of the reservoir both for its existing wells and for any future wells that may be drilled.

SARIR

Lying 7 mi southeast of Messla Field, Sarir Field is believed to be the largest oil field in Libya with more than 16 billion bbl of reserves. Boasting more than 400 wells, Sarir first experienced significant sanding with the introduction of ESPs in the late 1980s. The combination of production cutbacks to forestall the onset of sanding and the cost to replace and repair ESPs led to a major economic problem for AGOCO.

Besides the damage to ESPs, problems at Sarir included erosion of completion hardware and surface equipment, flowline blockages, and casing failure or borehole collapse. In 1992, the first gravel-pack completion was installed in an attempt to prevent sanding. However, it was a reactive approach and did little to address the root cause of the problem.

Following the successful development of a systematic sand management program at Messla Field, steps were taken to acquire the necessary information to implement a complete sand management system covering the entire Sarir complex. First, a geomechanics study involving seven wells was completed. The study indicated the source and severity of the sanding problem, linking it to the occurrence of thin beds. In October 2005, a further study was done on 25 Sarir wells deemed representative of the entire field. The 25-well study aimed to complete reservoir characterization, review sanding history and optimize completion options.

As with Messla Field, an MEM was built. Existing data were used as much as possible during the initial stages, with any observed gaps to be filled in as needed.

The team depended heavily on the dipole shear sonic and full-bore formation microimager logs. Logs provide a continuous record of the wellbore, whereas cores only provide spot data. Nevertheless, core analysis is valuable to cross-check and ‘calibrate’ log results. Caliper log data were used to calibrate borehole failure predictions. Basic stress parameters were established for the field, including minimum and maximum horizontal stress (magnitude and orientation) and overburden (vertical) stress. A wellbore stability log can be constructed from these data that combines a complete formation stress analysis with a point-by-point critical mud weight/failure mode analysis and compares it with actual caliper log data, Fig. 3.

SANDING PREDICTION

Using a proven sand prediction model, the plasticity effects that modify the rock strength behavior surrounding openhole completions and perforations during drawdown and production were considered. A unique feature of the technique is its ability to account for the scale effects imposed by different borehole and perforation diameters and sand grain sizes. It was noted that even when perforating the same type of sandstone using the same perforating charges, the perforation diameter and penetration length can change with the rock’s uniaxial compressive strength. In addition, sand grain diameter was factored in, because large sand grains tend to form stable bridges around a cavity, thus preventing a failure zone from expanding. The sanding prediction study concluded that the reservoir was comprised of alternating layers of competent and friable sandstone with the thin friable layers representing the sand source.

A key finding altered the conventional wisdom that for decades had blamed excessive drawdown for most sanding problems. The original reservoir pressure at Sarir was 3,900 psi at a vertical sub-sea level depth of 8,200 ft. Three different units were studied; the most depleted unit was down 1,300 psi, the least depleted was down 900 psi and the third unit fell in between, which reflected its geographi-
cal position relative to the other two units. Critical drawdown profiles were calculated for each unit. These showed that reservoir depletion had a significant influence on sanding. Moreover, the studies showed that the weak, friable levels would sand at virtually any drawdown. Further analysis revealed a direct correlation between critical drawdown pressure and depletion percentage, providing a way to predict the onset of sanding at any time in the future of the reservoir’s production life, and adjust drawdown to forestall it.

Another application of critical drawdown profiles is identifying potential sanding zones behind pipe. Sand production can create dangerous cavities behind pipe that can lead to casing deformation and eventual collapse, Fig. 4.

Fig. 4. Sand competence is directly related to depletion percent and critical drawdown pressure. Cavities can even be created behind casing away from perforated zones.

The Good News

Sand management techniques were able to identify the zones with the highest potential to sand. The key was the presence of thin, weak beds that were concentrated in one particular area of the field. Failure prediction in that area averaged 10 times more than in any of the other areas tested. As a result, geomechanical engineers, working in conjunction with reservoir, completion and production engineers, were able to select the most suitable completion strategies as well as the least potentially sand-productive zones to complete. These completion strategies applied to existing wells as well as new wells planned for the development of the reservoir, Fig. 5.

By thoroughly understanding the root causes of sand production, engineers were able to access a wide range of well completion options never before considered, including openhole horizontal completions and screenless completions. Many of these options offered the same or better protection from sanding at a fraction of the cost. Most importantly, these completion solutions brought an end to the unnecessary precautions of the past, where prevention techniques were applied to zones that actually had little to no sanding potential.

Acknowledgements

The authors gratefully acknowledge the Society of Petroleum Engineers for granting permission to reference SPE 100944 and 112904, on which this article was based.
THE AUTHORS

Yousef S. Gherryo is Manager of the Reservoir Engineering Department in AGOCO, Libya. He has over 25 years of experience in reservoir engineering/management and reservoir simulation. He has a BS in petroleum engineering from the University of Southern California.

Mohamed Shatwan is Superintendent of Reservoir Engineering in AGOCO, Libya. He has spent more than 20 years in the petroleum industry, and held various roles such as Coordinator of Reservoir Engineering, Petroleum Production Engineer and Sarir Reservoir Engineers Group Head before his current position. He received his BS degree in petroleum engineering from Elfateh University in Tripoli, Libya.

Kaibin Qiu is Geomechanics Product Champion for Schlumberger Data and Consulting Services (DCS) located in the Schlumberger R&D center in Beijing. A Senior Geomechanics Specialist with 12 years of experience in rock mechanics and civil engineering, Kaibin has expertise in geomechanics applied to drilling, completion and reservoir management. He holds an MS in geotechnical engineering from Tsinghua University in Beijing. Kaibin has authored over 10 technical papers and is currently Technical Editor on the SPE Drilling & Completion Journal Editorial Committee.

Rob Marsden is Schlumberger’s Reservoir Geomechanics Advisor and Geomechanics Manager for Europe, Africa and the CIS. Prior to joining Schlumberger in 2000, he spent 10 years teaching, researching and heading the Rock Mechanics Labs and Wellbore Mechanics Research Group at Imperial College, London. A Chartered Engineer with a first degree in civil engineering and an MSc and a DIC in engineering rock mechanics, Rob has coauthored over 60 papers, has over 25 years of experience in rock mechanics consulting, research, teaching and field work related the petroleum, mining and civil engineering industries.

Joe Alexander is a Principal Engineer for Sand Management and Production Enhancement currently based in India and has been with Schlumberger for the past 28 years in various operational and technical positions in Asia, the Middle East, the UK and the US. Joe has a degree in mechanical engineering from the University of Loughborough.

Albertus Retnanto is Principal Production Engineer and Engineering Team Lead, with North Sea—Schlumberger Data and Consulting Services and has 12 years’ experience in production optimization and enhancement. He started his career as Production Engineer and since then has held technical and lead positions in Latin America, Libya and Indonesia. He holds a PhD degree in petroleum engineering from Texas A&M University.