Conference Paper

Automating Continuous Demulsifier Injection (CDI) for Oil Well Treatment

Rami Esbai[1] and Mohamed Khalifa[2]

[1]Production Engineering Department, Tatweer Petroleum
[2]Information Technology Department, Tatweer Petroleum

Corresponding Author:
Rami Esbai

Received: 18 September 2018
Accepted: 10 October 2018
Published: 15 October 2018

Publishing services provided by Knowledge E

Selection and Peer-review under the responsibility of the Sustainability and Resilience Conference Committee.

Abstract

An emulsion is a condition in which produced oil and water are intermixed to such a level that they cannot be separated easily. These mixtures are highly viscous, and as a result limit the productivity of oil wells. While some emulsions can be treated by pumping chemicals downhole in batch treatments, many wells in the Bahrain Field need continuous chemical injection for effective treatment. The pay-out for efficient treatment is very high as an average of 20 Barrels of Oil Per Day (BOPD) to be gained from most wells at negligible cost. However, efficient optimization and injection depends on several dynamic variables. In order to best optimize this process, automated optimization workflows were created to maximize production gain without the need for constant surveillance and human intervention. This article covers the entire process from emulsion detection and treatment design to optimization and surveillance, giving an overall picture of where the oil industry is headed with development to SCADA system utilization and automation.

Keywords: Automation, Emulsion, Oil Well Surveillance, Optimization

1. Introduction

The Bahrain field (“Bahrain Field” or “Field”) is the oldest oil field in the GCC region. Starting production back in the early 1930’s, the Field consists of sixteen (16) stacked individual layers forming a complex range of reservoirs with different characteristics. Ranging from thick, heavy oil at its shallowest, to gassy reservoirs with light oil at its deepest, the Bahrain Field presents a wide range of ever-changing challenges.

When a field such as the Bahrain Field is produced for such a long time, it is often referred to as a “brown” field. Brown fields differ from newer ones in that they typically present more complex oil production challenges; declining pressure, increasing undesirable water production, and bacterial corrosion are just a few of the difficulties that brown fields face.

In December 2009, Tatweer Petroleum ("Tatweer") was founded as a joint venture between Nogaholding, Occidental Petroleum, and Mubadalah to bring together the latest technologies and increase investment in the Field to revitalize production and be better able to face the challenges associated with brown fields. Large emphasis was placed on full-field automation, research and development, and improving Bahraini workforce capabilities. One such example of how these values were combined with sustainable and resilient production solutions is with the treatment of emulsion.

An emulsion is a condition in which oil and water are intermixed at a molecular level to an extent that they do not separate easily. This may either be oil-in-water, water-in-oil, or a combination of both. These mixtures pertain a substantially increased viscosity which makes them far more difficult to flow and produce. As such, it is extremely undesirable to have emulsions in oil wells since they harm productivity. Notably, emulsions contain stabilizing agents that resist the natural separation associated with oil and gas mixtures. Some of these agents include:

- Salts
- Gas
- Sand
- Wax
- Asphaltenes
- Incompatible chemicals
- Temperature

Emulsion stability is also highly impacted by shearing forces, where flow velocity and even gas may intermix and entrain the fluids into one another. In the case of temperature, higher temperatures weaken emulsions and lower ones strengthen them. The latter is notable due to the fact that it is this behavior which is used to identify the existence of emulsions in oil wells.

2. Detecting Emulsion

There are currently over 500 naturally flowing and gas lifted wells at Tatweer with surface pressure and temperature transmitters used to monitor flow.

As is the case that emulsions worsen with increasing temperature, it has been noted that this phenomenon is presented in the pressure and temperature readings as a fluctuation between day and night. Fluid from wells with emulsion flow with a higher

Figure 1: Standard wellhead configuration with transmitters.

viscosity (lower productivity) at night than they do in the day since the fluid is cooler and thicker at night. This may be seen in Figure 2:

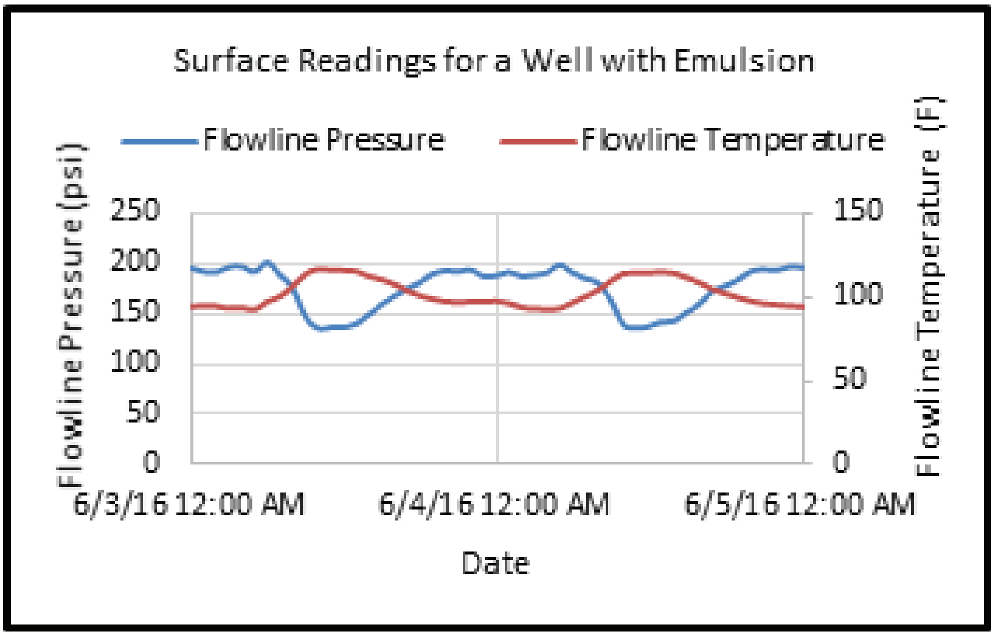

Figure 2: Emulsion signature found in surface readings.

In order to identify this mathematically, the correlation coefficient between the two values is calculated, where a negative value indicates a direct and opposite relationship between the well temperature and pressure. This discovery by the authors has allowed for the existence of a live and continuous metric to be used to continuously track whether the well has emulsion or not. The purpose of this paper is to show the applications of this metric and how it was expanded to be used as a Key Performance Indicator ("KPI") for Tatweer's Continuous Demulsifier Injection ("CDI") units.

Equation *1*: correlation coefficient used to detect emulsion

$$r = r_{xy} = \frac{\sum x_i y_i - n\bar{x}\bar{y}}{\sqrt{\left(\sum x_i^2 - n\bar{x}^2\right)}\sqrt{\left(\sum y_i^2 - n\bar{y}^2\right)}}$$

3. Literature Review

The study of emulsions is not a new one as there have been publications on the matter since the 1920's. However, emulsions are typically analyzed through laboratory testing, with each well condition being considered on a case-by-case basis with individual treatment needs. The use of the correlation coefficient is a world-first discovery that has a unique importance particularly to the application of continuous injection. The purpose is to immediately identify emulsion formations in wells.

4. Study and Findings

Emulsions are substantially harmful to oil well revenues as in some cases production may be reduced by over 70%. As such, treatment is carried out by either injecting chemicals on a batch basis down-hole for reservoir treatment, or through continuous pumping into the well through an injector at the surface. Depending on whether the emulsion is formed in the reservoir or only at the surface where the fluids are much cooler, the type of treatment is determined.

Continuous Demulsifier Injection, or CDI for short, is a useful and highly economical technique for production improvement. Injection skids consist of a tank and pump which pumps chemicals, driven by gas, into the casing of a well and is then forced into the tubing and flow path of the fluids.

As with any type of chemical treatment, it is always desirable to be injected at the optimal rate. Low rates would not break the emulsions completely and overly high rates would be costly and could also worsen emulsions. Considering the fact that the behavior of any well may be dynamic with time, and that Tatweer engineers must monitor over 500 wells of this type each day, the challenge of having a continuously optimized chemical treatment program appears.

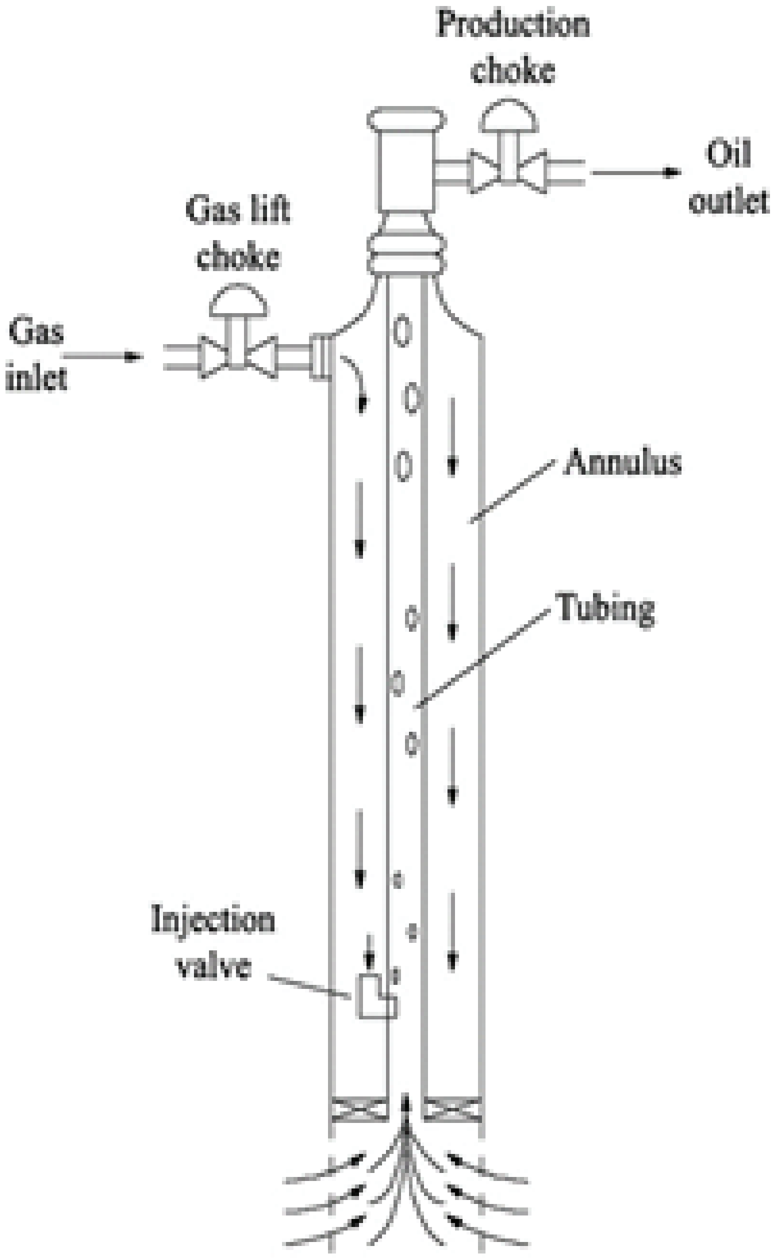

Figure 3: Typical flow path for gas-lifted wells (Jahanshahi, 2009).

4.1. Chemical injection system

Chemical flow assurance and oil recovery are the main objectives of Tatweer chemical skid. It was designed for one specific chemical type to be pumped into a single well injection-point either continuously or intermittently. The skid was fabricated to accommodate a 130 gallon chemical storage tank, pressure safety valves, tubing, a calibration point, its own controller and other auxiliaries. The system is operated as a stand-alone with its own solar power supply.

4.2. Components of chemical injection system

4.2.1. Tank

The chemical tank is a polyethylene vertical 130 gallon storage tank. In order to not cause the tank to fail and to take in to account the temperature at which the chemical is stored, the specific gravity was selected to be suitable for oil application. A large tank was also selected in order to minimize the frequency at which it would need to be refilled.

4.2.2. Pump

A solar-powered, positive displacement injection pump was used. This pump is capable of handling relatively modest volume (20Liter/Day) but can withstand very high pressure (1000 psi). It has a constant-speed with a maximum discharge pressure of 2500 psi. Efficiency is achieved by running the pump is an on-off mode with maximum RPM.

4.2.3. Valves

Safety relief pressure valve is used to protect the closed loop in the event of overpressure or system malfunction.

4.2.4. Instrumentation

Positive displacement flow meter measures a relatively good accuracy with low flow rate. This volumetric flow measure is ideal for an on-off or pulse operation because each pulse is proportional to the actual flow rate. The pressure transmitter is explosion proof and CSA approved for use in hazardous areas. The tank level sensor is required to provide an instantaneous level reading back to the SCADA system and to ensure pump operations

4.2.5. Controller and power

The flow meter, pressure transducer and pump motor are wired back to controller. All control and monitoring actions can be performed locally at the controller as well as remotely from the Tatweer's Central Control Facility (CCF). The skid power is fed from two 135W solar panels. The charge regulator provides 12 VDC back to power the skid controller and feeds the battery enclosure.

4.2.6. Communication panel

The communication back to the CCF are either over radio or fiber network based on the geological location of the well and its proximity to Tatweer fiber optic. This consist of Stahlin communication box and Earthing Bit to provide the grounding for the skid and radio pole.

4.3. Automated skid operation

Information and Communication Technology (ICT) has become the lifeblood of Tatweer's operations and played a significant role in its achievements. Some of the unique characteristics of the ICT program at Tatweer includes the speed, scale and engineering of deployment in addition to utilization of its backbone infrastructure. To meet its field development goals and obligations, Tatweer embarked on installing fiber optic and a wireless digital network to transmit real time data from chemical injection system wells in order to aid in the surveillance, monitoring, and control of wells operations and activities. The selection of the communication media was based on many factors including the proximity to the over 300 KM fiber optic network spanning over Bahrain Field or line of sight transmission path to Tatweer radio base stations.

The CCF operator maintains the communication with the skid controller in order to ensure accurate injection volume per well. Over-injection can have an impact on the crude properties as well as the supply chain inventories, whereas under-injection affects the well oil production rates. The skid controller is equipped with tank level, pump settings and daily target volumes. The controller protects the pump against low flow and low chemical by disabling the pump output. In case the skid trips, it can be started locally or remotely from the Central Control Facility.

The chemical skid calculates the volume pumped out based on the total number of pump strokes. Even though this is accepted in the short time, the injection rate will drift in the long term because it does not take in to account the well downstream pressure and the temperature variation which will affect the fluid viscosity. So the indicated the injection rate by the positive displacement flow meter may not represent the actual injection rate by the skid. Additionally, the maintenance and skid downtime is higher with this type of flow meter because of its moving parts.

The skid pump achieves the lower flow rate by operating in the start/stop mode rather than continuous/variable speed. Frequent start and stop of the pump which currently set at 1,440 per day (one (1) minute interval) may affect the pump in the long term. Also throttling is quite challenging to achieve with PD pumps continuous run because their characteristics curve are very steep. As soon as the flow decreases, the pressure increases and efficiency drops significantly. Analysis of well chemical injection data from well tests and practical operation experienced gained indicated that the need to consider the temperature in real time. In standard chemical skid, the operator monitors and changes the injection rate every four (4) hours to compensate for the temperature variation. One way Tatweer can identify the emulsion issues in real time is by automatic well testing.

4.4. Optimizing injection

In 2014, Tatweer has replaced its manual two phase test separators with automatic three phase test separators. A Process Logic Controller (PLC) is also provided at the facility to facilitate controlling the pressures, levels, rates, as well as remote well testing. Human-Machine Interface (HMI) screens were kept in place to provide an identical interface of the local panel screen available at the three phase separator skid, in order for the field operators to adapt to remote testing easily. The optimum chemical injection rates can be calculated in real time based on the water oil separation process.

Finally, the following logic process was set in place to optimize injection:

Firstly, the well is tested to measure current baseline production. Chemical injection rates are then started at an arbitrary figure and the well is tested again. If the production increases but the correlation coefficient is still negative, chemical rates are increased until production is at its maximum. Chemical rates are then gradually reduced with time to ensure minimal cost for the maximum production gain.

5. Outcome

Tatweer currently operates eleven CDI skids, with three being of the automated type. As such, the advantages of these three can be gauged and compared with the simpler skids: Firstly, the automated skids require far less follow up with regards to chemicals management. It was initially assumed that the manual skids could also be easily checked on a weekly basis to ensure chemical levels do not run out, however mechanical issues found in the simpler pumps make it more difficult to understand pump conditions. As such, on a week-by-week basis it is often quite tedious to ensure and optimize the injection process.

Automated skids also allow for the accurate monitoring of current injection rates. Many issues have been identified almost immediately and were rectified with minimal downtime. When considering that a malfunctioning pump could cost tens of barrels per day, the difference between rectifying an issue between today and next week is quite substantial. Finally, a few lessons were learnt purely by observing the transmitter data as it was found that air bubbles trapped in the level gauges could block injection and were fixed easily by bleeding.

6. Conclusion

The importance of continuously developing automating systems for well optimization cannot be stated enough. Increasingly aging oil fields provide a stream of problematic wells with dynamic problems. Automating production enhancement systems is the most effective way to face these challenges in order to not only face existing problems, but also allow engineers the time to look for future problems and developments.

Acknowledgment

The authors would like to acknowledge all the invaluable support acquired by the Tatweer Executive Management, Production Engineering, Facilities Engineering, and Information Technology departments in terms of data and support.

Authors

Rami Esbai is a Production Engineer working at Tatweer Petroleum – Kingdom of Bahrain. He obtained his B.Eng. degree in Chemical Engineering from the University of Leeds in 2012 and MBA from DePaul University in 2016.

Mohamed Khalifa is an Automation Engineer working at Tatweer Petroleum – Kingdom of Bahrain. He is a graduate of Imperial College London with an MSc in Computing in 2008.

References

[1] Soffian, R. M., & Niven, T. L. (1993, January 1). Emulsion Treatment Program. Society of Petroleum Engineers. doi:10.2118/25346-MS

[2] McCoy, A. W., Shidel, H. R., & Trager, E. A. (1921, December 1). Investigations Concerning Oil-water Emulsion. Society of Petroleum Engineers. doi:10.2118/921430-G

[3] Jahanshahi, Esmaeil & Salahshoor, K & Kharrat, Riya. (2009). Modified distributed delay model for void wave dynamics in gas-lifted wells. Journal of Petroleum Science and Engineering. 69. 203-213. 10.1016/j.petrol.2009.08.015.

[4] Denney, D. (2000, March 1). Quantification of Factors Affecting Emulsion Stability. Society of Petroleum Engineers. doi:10.2118/0300-0041-JPT