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Artificial-Lift Method Screening for One of the Southwestern Iranian Oil Field Based on Fuzzy Logic Approach

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Summary

The choice of an artificial lift method in fields that have been faced with declining production has always been a challenge. Therefore, in this paper, by designing a two-stage screening process and using fuzzy logic approach, it is attempted to select the most accurate method for one of the southwest Iran squares. Fuzzy logic will make the ranking system more accurate and more sensitive to the operating conditions of artificial lift methods. By the method ranking with this screening procedure, Electrical Submersible Pump (ESP) and Sucker Rod Pump (SRP) are selected as the priorities.

Introduction

Hydrocarbon reservoirs reach a stage during their lifetime that the reservoir pressure is not sufficient to generate the expected production value of fluids. Artificial lift is one of the standard methods to compensate for this problem and increase production. Artificial lift is a method of increasing the longevity of the oil well Lifting as one of the IOR methods reduces the minimum pressure at the bottom of the well to produce and thereby increasing the volume of the production fluid from the reservoir. The proper selection of artificial lift method for the long-term profitability of productive wells is essential. In fact, poor selection can reduce production and increase operation of artificial lift costs. The choice of a suitable artificial lift method is dependent on the effective parameters in reservoir production, well constraints, fluid properties and operational conditions. (Hullio et al., 2018)

In general, the force that drives oil from underground reservoirs to the surface is funded by expansion of gas and water pressure that is usually accompanied by oil in the reservoir. But as time has passed, reservoir energy is gradually depleted by the production process. Typically, natural production mechanisms cannot recover the bulk of remained hydrocarbons in the reservoir. Over the last few years, the need to use methods to improve production - often in the mature or/and depleted reservoirs - has been dramatically increased. Artificial lift methods are used for wells which naturally lack the energy necessary to deliver fluid to the well, or this energy is not sufficient to produce economical from the reservoir. Artificial lift systems are divided into two main categories: Pump system and gas injection systems. Also pump systems are grouped as follows: 1. Sucker Rod Pumps (SRP) 2. Electric Submersible Pumps (ESP) 3. Progressive Capacity Pump (PCP) 4. Plunger Pumps 5. Hydraulic pumps Table 1 shows the most widely used artificial lift methods with their practical operation domain. As shown in the table, the maximum capacity of the production fluid volume belongs to electric submersible pumps and gas lift. Beside, sucker Rod pumps are the most common method among other artificial lift methods. The production capacity of each artificial lift system depends on the following factors: 1. Depth of the well (reservoir) 2. Well geometry 3. Productivity of reservoir (fluid transfer from the tank to the well). (Kefford & Gaurav, 2016)

Artificial Lift Method	Maximum TVD (ft)	Production Capability (bbl/d)	Temperature (F)	Gravity (API)	Efficiency (%)
Sucker Rod Pumps	16,000	5,000	100 to 550	> 8	45 to 60
Progressive Capacity Pump	6,000	4,500	75 to 250	< 35	40 to 70
Gas Lift	15,000	30,000	100 to 400	>15	10 to 30
Plunger Lift	19,000	5	120 to 500	-	-
Hydraulic Piston	17,000	4000	100 to 500	>8	45 to 55
Hydraulic Jet	15,000	15,000	100 to 500	>8	10 to 30
Electric Submersible Pumps	15,000	30,000	100 to 400	>10	35 to 60

***Table 1** Artificial lift operation domain for each method. (* Lea & Nickens, 1999)

To design an efficient and cost-effective artificial lift system, engineers should consider a set of reservoir and well parameters. These parameters are: 1. Physical and chemical properties of reservoir rock (formation type, temperature, pressure, depth, etc.) 2. Nature and characteristics of reservoir fluids (viscosity, density, etc.) 3. Reservoir production parameters 4. Well geometry and its equipment (depth of the well, type of completion, casing and tubing condition, etc.) 5. Surface facilities and equipment. 6. The financial and temporal terms and requirements of the project. The collection and analysis of the mentioned parameters guide engineers to design and employ the best method in each case. For example, lifting systems with gas (gas lift) and electric submersible pumps (ESP) are more used to increase production in massive offshore reservoirs because they are capable for transferring large amounts of fluid and to occupy less surface space (Valbuena et al., 2016). On the other hand, although sucker rod pumps require and occupy a lot space on ground, but they are low-cost and reliable. These types of systems are mostly used for onshore reservoirs. This article discusses how to select and screen the best and most suitable method of artificial lift and to test this method on one of the south-western Iranian oil fields (Worth et al., 2019).

Method and/or Theory

Figure 1 shows a practical procedure for artificial lift development in a real field. This protocol consists of six main steps. 1. Data gathering: for a comprehensive study, a full set of data from the reservoir and well are required. 2. Data evaluation: After collecting the data and being aware of the actual field conditions, the overall compatibility of the requirements of each method with the current field conditions is discussed. Mainly due to the specific environmental, economic and operating conditions that make an artificial refining method not suitable for field such as: sand production (sucker rod and electrical submersible pumps limitation), high-costly gas supplement and compressor (gas lift limitation), high buildup in well direction (hydraulic pump limitation), etc. 3. Method limitation evaluation: It leads to eliminate impractical methods from the evaluation process. 4. Benchmarking nominated methods: By comparing the well and reservoir data with the operating range of each method, fuzzy logic is used to calculate the points of each method. Fuzzy logic is a kind of computer science approach that operates based on accuracy (numeric between zero and one) rather than zero and one. That is, in classical systems and machine language, an array is either true or false, or is 1 or zero, but in fuzzy systems an array can, for example, be almost right or nearly false. But in fuzzy systems probability, that value is defined as being zero or one, or a number between zero and one. By defining each parameter as a membership function as trapmf, it has point 1 if the well data is within the 60 percent middle range of operational domain. Also, if the well data is in the upper and lower range of 20 percentage, it has a constant slope point of one to zero. The total under investigated well point is resulted by multiplying each evaluated parameters (Equations 1 to 5)

$$If\ T_{re} > T_{max}\ or\ T_{re} > T_{min} \rightarrow P_T = 0 \quad (1)$$

$$If\ T_{min} + \frac{(T_{max} - T_{min})}{5} < T_{re} < T_{max} - \frac{(T_{max} - T_{min})}{5} \rightarrow P_T = 1 \quad (2)$$

$$If\ T_{min} < T_{re} < T_{min} + \frac{(T_{max} - T_{min})}{5} \rightarrow P_T = \frac{5T_{re}}{(T_{max} - T_{min})} \quad (3)$$

$$If\ T_{max} - \frac{(T_{max} - T_{min})}{5} < T_{re} < T_{max} \rightarrow P_T = \frac{-5T_{re}}{(T_{max} - T_{min})} \quad (4)$$

$$\boldsymbol{P_t = P_{API} \times P_T \times P_d \times P_{eff} \times P_q} \quad (5)$$

Where T_{re} is reservoir temperature and P_T, P_{API}, P_d, P_{eff} and P_q are points of temperature, gravity, depth, efficiency and flowrate condition. After that 5. Selection and design of the best method will be started by using engineering software tools and results will be ready for 6. Operation and installation. Real data monitoring could help in process optimization. Next, this procedure is employed for one of AL screening and decision making in one of the south western Iranian oil field.

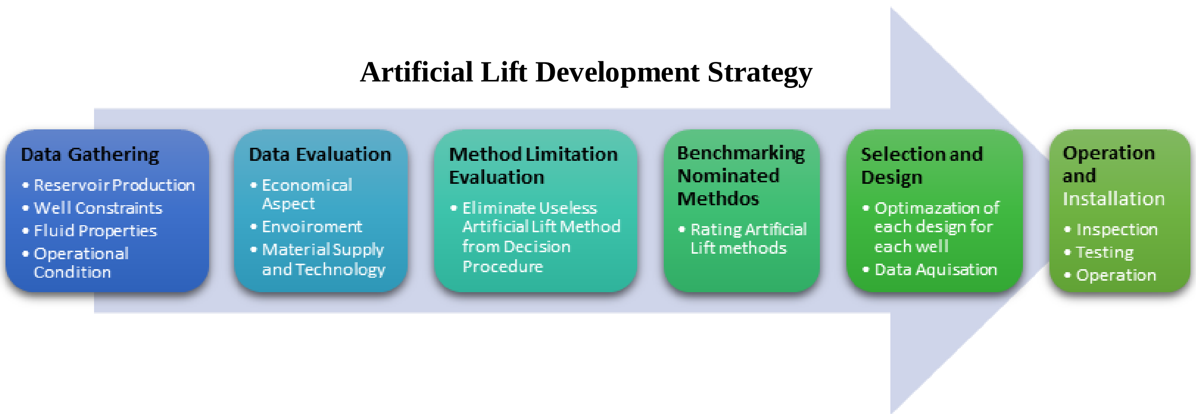

Figure 1 *Artificial Lift Development Strategy.*

Example

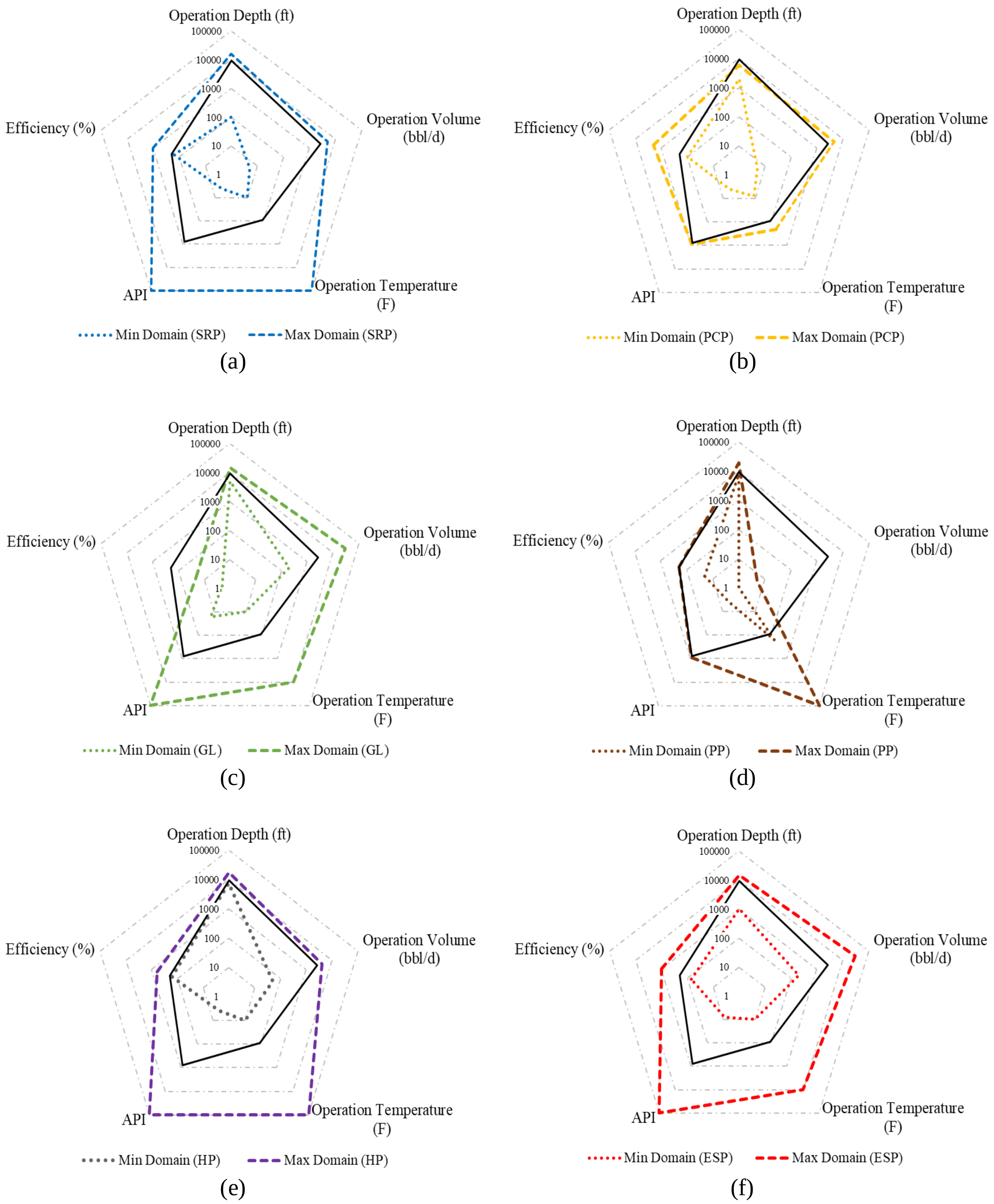

Figure 2 *Comparison operating domain of artificial lift methods with well and reservoir conditions. A)Sucker Rod Pump, B)Progressive Capacity Pump, C)Gas Lift, D)Plunger Lift, E)Hydraulic Piston and F)Electrical Submersible Pump.*

Well A is a deviated well placed in one of the south western Iranian oil field with following properties. Depth of 9200 ft and expected to produce fluid with rate of 2700 bbl/d with 32^{o} API gravity from an oil-rich sandstone formation. The pressure and temperature of reservoir are 3900 psi and 191 F. Initial evaluation of the data indicates that hydraulic pumps are not suitable for use in this case due to high deviation of well path and also sandy being of the production layer increases the probability of sand production in near future which can be problematic for electrical submersible and sucker rod pumps. On the other hand, because of high cost and lack of appropriate technology to supply hydraulic jet pumps, this option has been eliminated from decision procedure. Afterward, the operating domain of other methods have been compared with well and reservoir conditions and the results of this comparison are shown in radar diagrams of figure 2.

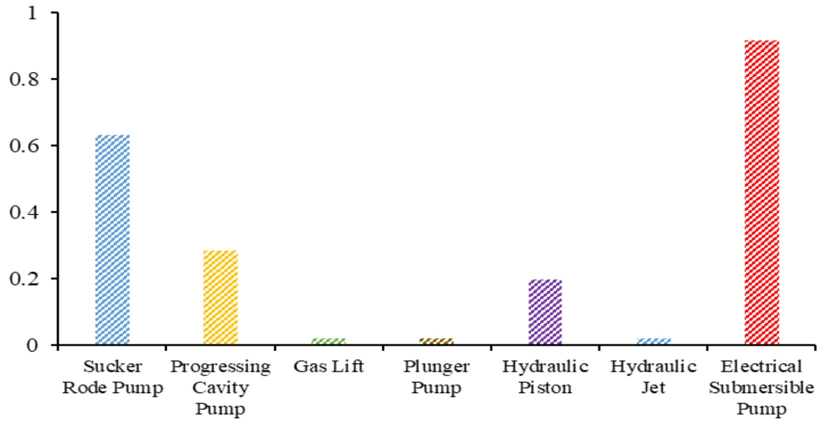

Figure 3 *Artificial lift methods ranking for understudy resevoir.*

Specifically, when the pentagonal of well and reservoir conditions cross the minimum and maximum ranges of each method, that method is not appropriate for this case. How this has not happened, only four methods, Sucker Rod Pump, Progressive Capacity Pump, hydraulic piston and electrical submersible pump have entered the rating phase. The four mentioned methods mean Sucker Rod Pump (SRP), Progressive Capacity Pump (PCP), Hydraulic Piston (HP) and Electrical Submersible Pump (ESP) have earned points of 0.633, 0.286, 0.198 and 0.915 in this ranking respectively. These results are shown in figure 3. Therefore, Electrical Submersible Pump (ESP) method is recommended for artificial lift development in this reservoir. As it was discussed, probability of sand production is a hazardous risk for further operation ad that must be considered.

Conclusions

The choosing of an artificial lift method is an essential step in the development of a field. A proper and principled selection and screening procedure can save costs and get the most production from well and reservoir. In this research, after introducing successive steps for developing an artificial lift method in a field, in phase of method evaluation and ranking, fuzzy logic was employed to make a screening and rating approach. Fuzzy logic is a kind of computer science approach that operates ased on accuracy (numeric between zero and one) rather than zero and one. After an initial review and considering the critical limitations of each method, the methods which are opposed to well and reservoir conditions, are removed from the screening and rating phase. Then, after point calculation for each method for a well in one of west southern Iranian oil field according this approach, Electrical Submersible Pump (ESP) and then Sucker Rod Pump (SRP) gained the highest point in rating respectively and are recommended for that condition.

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