



Impact of Fluid Properties on Electric Submersible Pumps (ESP) Performance and Run Life in a Well

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ABSTRACT: The primary goal of every operator is to optimally recover reserves at minimal operating costs. Unfortunately, due to inherent primary drive mechanisms that may not be strong enough and poorly designed completion jewelrys that increases the complexity of well configurations, most reservoir are not efficiently depleted. This study investigates the impact of fluid properties on electric submersible pumps (ESP) performance and run life in a well. It was observed that the pump speed increases with increase in API gravities and vice-versa. However, decrease in pump speed was observed with crudes having high API gravity from wells with high water-cut (HBSW). High water-cut increases the viscosity of the crude and thus decreases the pump speed. The pump speed also increased as the GOR increases, howbeit, decreased as the GOR exceeds a certain optimum value due to cavitation. The pump intake pressure and the production rate were also investigated. The higher the intake pressure, the higher the pump speed and thus, the higher the production. Well specific models for real-time ESP performance prediction were also developed for each property against the pump speed and they exhibited cubic relationships. It was also observed that the quality of the crude significantly affects the performance of ESP's and therefore, must be checked to prevent early failure and short run life.

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The use of artificial lift in reducing the residual oil saturation in oil fields production cannot be over emphasized. About 95% of global oil wells use artificial lift systems to boost production, of which 10% of these are Electrical Submersible Pumps (Schultz *et al.*, 2015). Electrical Submersible Pumps are efficient, reliable, and economical and the fastest growing pumping technology in terms of penetrating rates amongst the pumping methods (Breit and Ferrer, 2011). Although, sucker rod pumps remain the most widely used artificial lift method and accounts for about 85% of the artificial lift in the United States alone (Guo *et al.*, 2017), they are not efficient with deeper and highly deviated wells; hence not considered applicable for offshore installations (Breit and Ferrer, 2011). ESP is the second most used pump method (Zhu and Zhang, 2017), due to its suitability under harsh environmental conditions, particularly for wells with high H₂S (Hein, 2012). Over 100,000 wells use it globally, with Russia and United States of America amongst the top users due to its better performance in terms of high discharge head and convenient management (Zhu and Zhang, 2018). Despite their established performance histories in many fields across the globe, many companies do not consider using ESP until all other possibilities are exhausted mainly due to the fear of unknown factors and failure rates (Baillie, 2002). In the Niger Delta

region, gas lift is mostly the preferred choice over ESP's due to the availability of injection gas. Although, in terms of gross profit, ESP is a better choice compared with gas lift. A lot of modifications have been done to the design of ESPs to overcome its failure limitations, but gas lift is still preferred in most cases compared to ESP due to its high failure rate, maintenance and workover costs, higher risk, complexity of equipment and limited life span (Ezekiel *et al.*, 2015). Failures comes mainly from the mechanical (i.e. pump, seal or protector section) and electrical (cable or motor) sections of the ESP. Most failures of ESPs are electrical in nature since it is the lifeline that provides energy to the motor and pump and often the weakest link of the system (Baillie, 2002). However, it has been discovered that failure in ESP systems cannot be attributed to only mechanical and electrical operational components alone but can result from a combination of several factors such as data integrity for the design of ESP, reservoir inflow plugging, fluid properties and pump intake pressure (Baillie, 2002, Vandevier, 2010, Brown, 1980, Ofuchi *et.al*, 2017, Amaral *et al*, 2009). Data obtained from a field operated with ESP in Niger Delta shows that outside the mechanical and electrical component failures that account for about 79% of the failures of ESP's, 21% of these failures are attributed to unknown factors collectively categorized as others as shown in

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Figure 1. Thus, the fluid composition and properties could be the major constituents of these unknown factors classified as others and thus, the reason for this investigation. Although, many failures have been recorded in the application of ESP's, it is worthy to mention that in some fields across the globe and even in Niger Delta, some ESP's had not just done exceedingly well but have also recorded a considerable long lifespan. ESP failure rates have mystified many companies, hence the delay in their deployment in most cases. This study investigates the impact of fluid properties on electric submersible pumps (ESP) performance and run life in a well.

MATERIALS AND METHODS

To investigate the impact of fluid composition and properties on ESP run life, 33 data sets were obtained from three reservoirs in a field in Niger Delta, Nigeria for the analysis. All the wells in the field are produced through Electrical Submersible Pumps. The range of API gravities of the crudes from this field is between 21.7-29 degrees. Moreover, the gas-oil ratio (GOR) values range between of 140-331scf/STB; thus, the crudes can be said to be somewhat between heavy and light crudes. Since the pump speed is a measure of the performance and working capacity of the pump, this work explores to establish relationships between the pump speed and some fluid properties such as the API gravity, gas-oil ratio, water cut, and production rate and pump intake pressure for wells in the same cluster. These variables were critically investigated to show how each parameter affects the performance of ESP run life. For purpose of data confidentiality, cluster of wells draining the same reservoir are classified as Reservoirs A, B and C, respectively. The data consists of pump speed, water-cut, API gravity, and pump intake pressure, GOR and production rate.

RESULTS AND DISCUSSIONS

Figure 1 shows data obtained from a field operated with ESP in Niger Delta; showing the contributions from different parameters that directly influence ESP run life. As can be seen in Figure 1, the electrical components constitute 32%, the pump 22%, the motor, 25% and 21% is attributed to unknown factors where the contributions of fluid properties could be eminent. Figure 2 is a plot of pump speed against API gravity. The family of wells in these three pseudo reservoirs exhibits a cubic relationship with high values of coefficient of correlation between the pump speed and API gravity. API gravity against wells in Reservoirs B and C which has lower pump speed but higher API gravities. The API gravity is a measure of lightness or heaviness of a crude.

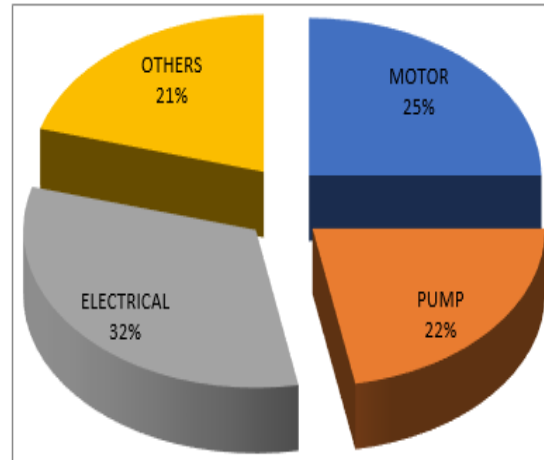


Fig 1: Factors affecting ESP performance and run-life

Wells in Reservoir A have higher pump speed but low Heavy crudes are viscous which leads to decreased head, decreased efficiency and increased power requirement for pumps (Olivia *et al.*, 2017). Hence, it is expected that higher API gravity crudes should exhibit a proportionate pump speed against those with low API gravities. Although, this lightness is mostly attributed to the percentage of lighter hydrocarbons in the oil, high water-cut can also influence the viscosity of the crude (De Oliveira, 2018). Hence, pumps with higher API gravity that experience lower pump speed may be associated with high water-cut problems as shown in Figure 3. Figure 4 shows the relationship between production rate and the pump speed. From Figure 4, as the pump speed increases, the production rate also increases. This is expected, however, for wells in reservoirs A and C, production pump speed peaked at 2700 and 3200b/d before a decline as against wells in reservoir B which was seen to be on continuous increase. The reason for the decline, although not specified, could be attributed to possible mechanical or electrical failures. The pump intake pressure is another factor that plays a major role that could strongly influence the performance of an ESP as shown in Figure 5. The pump intake pressure determines the amount of free gas that may cause the least performance degradation (Lea *et al* 1986, Dunbar 1989, and Olivia *et al.*, 2017). Low intake pressure would generally affect the output from the pump. Although, this can be attributed more too electrical or mechanical defects, it could also result from fluid properties such as density that would inhibit efficient intake pressure to guarantee a high pump speed for production. This was observed in Figure 5 where increase in intake pressure leads to increase in pump speed across all the reservoirs. Another parameter that was investigated was the gas-oil ratio (GOR) of the crude as shown in Figure 6.

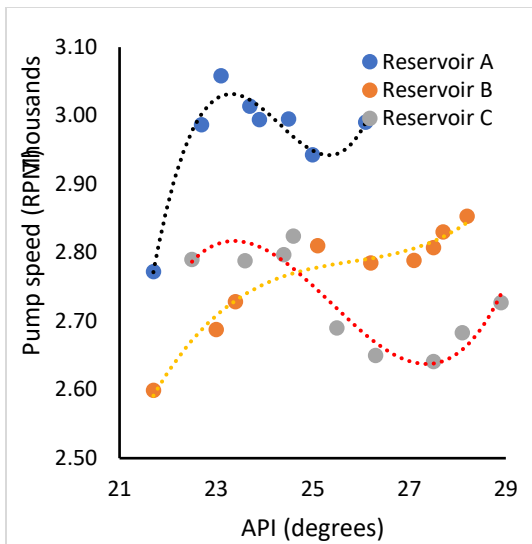


Fig 2: Showing relationship between pump speed and API gravity from the three reservoirs, exhibiting a cubic relationship

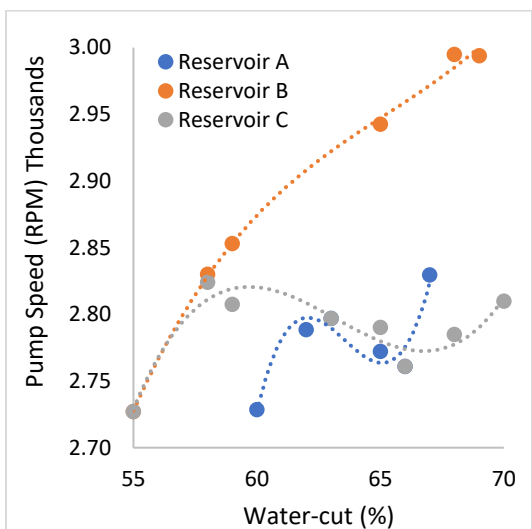


Fig 3: Plots of water-cut against pump speed for different reservoirs. A cubic relationship was also established between the pump speed and the water-cut

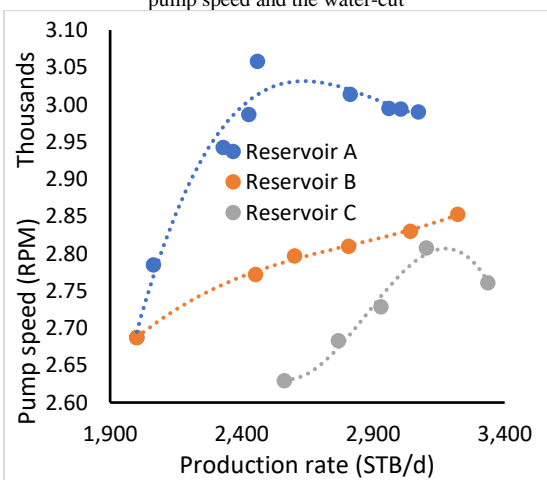


Fig 4: A plot of Production rate against pump speed.

The GOR is critical as it indicates how heavy or light a crude would be based on the amount of dissolved gas in it. Generally, there is gas in every oil reservoir, existing as dissolved gas or dissolved and free gas in combination. At higher pressures, most gases will be dissolved in the oil and liberated when there is production resulting from decline in pressure. When this happens, the liberated gas leaves a denser and more viscous crude that may be difficult to produce. Unfortunately, this effect becomes more and more pronounced as the well ages following substantial reduction in pressure and liberation of dissolved gases; drastically affecting the performance of the ESP as shown in Figure 6. From Figure 6, initially, the pump speed increases as the GOR increases. However, at some GOR across the reservoirs, the pump speed drops as the GOR exceeds a certain optimum value. This decrease in the pump speed may be attributed to cavitation which results to decreased performance of the ESP (Klimes, 2017).

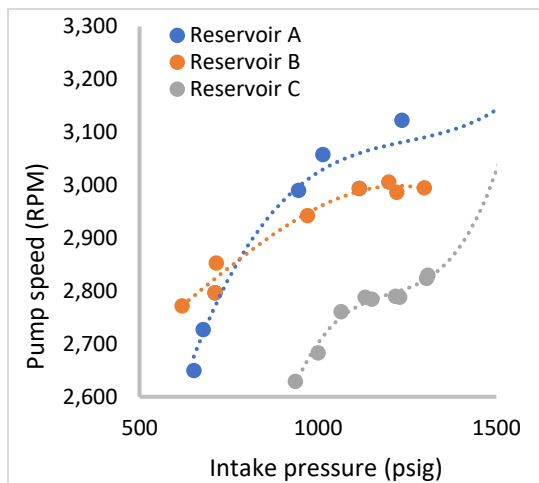


Fig 5: Plot of pump intake pressure against pump speed

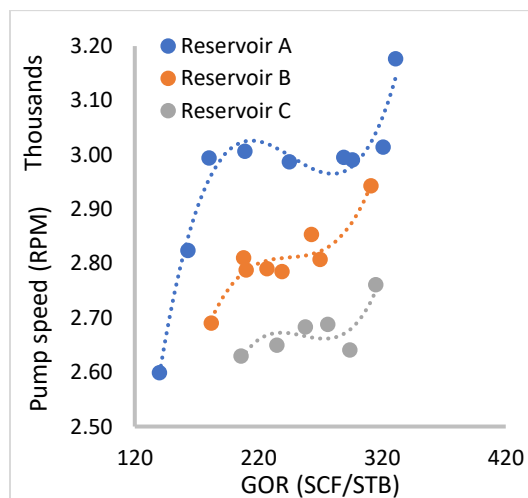


Fig 6: Relationship between pump speed and GOR of fluid

An increase in the GOR and a reduction in the intake pressure directly influence the amount of free gas at the suction end which could further deteriorate the head and the performance of the pump since increase GOR and decrease intake pressure substantially reduces the amount of dissolved gas in the liquid (Olivia *et al.*, 2017). The models that best describes the relationship between API gravity, water-cut, production rate, pump intake pressure and GOR against pump speed are presented in Table 1. It was observed as shown in Table 1, that all the parameters investigated exhibits a cubic relationship with the pump speed in the three reservoirs. Solving these

models show that, of the three roots from these cubic models, there is only one real root, and which represents a value of the any of the parameters (API, water-cut, production rate, GOR, pump intake pressure), that can be used to predict the pump speed and thus, well specific performances of pumps. One major advantage of this procedure is that once a model of this kind is developed, the expected values of the pump speed can be determined in real-time as flow conditions deteriorates over time in the well and reservoir.

Table 1: Relationship between pump speed and various fluid properties that impacts on ESP run life

Parameter	Reservoir	Model relationship between pump speed and parameters	R ² value
API Gravity	A	$y = 21.561x^3 - 1573.3x^2 + 38202x - 305668$	0.9613
	B	$y = 2.1811x^3 - 168.82x^2 + 4366.5x - 34956$	0.9604
	C	$y = 5.702x^3 - 433.94x^2 + 10940x - 88638$	0.8699
Water-Cut	A	$y = 2.5126x^3 - 479.16x^2 + 30442x - 641550$	0.9241
	B	$y = 0.0943x^3 - 18.436x^2 + 1213.9x - 23949$	0.9972
	C	$y = 0.2729x^3 - 51.762x^2 + 3262x - 65510$	0.9037
Production Rate	A	$y = 6E-07x^3 - 0.0049x^2 + 14.129x - 10502$	0.9707
	B	$y = 1E-07x^3 - 0.0009x^2 + 2.4858x + 315.73$	0.9977
	C	$y = -2E-06x^3 + 0.014x^2 - 39.808x + 40032$	0.9816
Pump Intake Pressure	A	$y = 2E-06x^3 - 0.0057x^2 + 7.2067x - 38.727$	0.9673
	B	$y = -6E-07x^3 + 0.0011x^2 - 0.1415x + 2580.7$	0.9735
	C	$y = 6E-06x^3 - 0.0229x^2 + 27.706x - 8456.5$	0.9956
Gas-Oil Ratio	A	$y = 0.0004x^3 - 0.3326x^2 + 80.747x - 3420.9$	0.9612
	B	$y = 0.0004x^3 - 0.302x^2 + 74.115x - 3267.2$	0.9115
	C	$y = 0.0005x^3 - 0.4156x^2 + 105.87x - 6282.5$	0.7368

Conclusions: ESP remains one of the most viable artificial lift methods for enhancing production and reducing the residual oil saturation in reservoirs. Unfortunately, despite their known and well-established efficacy in production operations, ESP's are susceptible to high failure rate when deployed. The high failure rate of ESP's had been attributed to mainly mechanical and electrical in nature, but data obtained has shown that whereas the mechanical and electrical components are the most significant and constitutes about 79% of failures, other factors collectively called unknown factors also play major roles in inhibiting the efficient application of ESPs. This study considers fluid properties as the likely unknown factors that could inhibit the efficiency of ESPs. Hence, fluid properties like API gravity, water cut, GOR etc. were investigated to unravel how they influence the performance of ESPs. Well specific cubic models were developed that depicts relationships between the pump speed and the fluid properties considered, and

thus the performance of ESPs. With these models, the variations of each fluid property can be determined and monitored, and its impact on the overall performance of ESPs predicted as flow conditions changes.

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