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Case Study

PERFORMANCE OPTIMISATION OF JET PUMP WITH MINIMAL CAVITATION PROBLEM & FEASIBLE GAS OIL RATIO : (A CASE STUDY)

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ABSTRACT

Many oilfields production capacities decrease due to the steady decline in pressure of the reservoir. To enhance the production different enhancement remedies implementation become necessary in order to improve total oil recovery and sustain production from a developed oil field.By using artificial lift such as pumps or gas lift these production enhancement remedies can be supported. Although jet pumps are the efficient artificial lift method tools , yet their performance is negatively affected by the cavitation problem and poor nozzle/throat combination. In this study, the feasible nozzle and throat combination has been investigated by using wellflo software to achieve optimum flow rate with least cavitation problem. Firstly water as power is used and suitable nozzle/throat combination is selected, secondly oil as power fluidisused and suitable nozzle/nozzle throat combination is selected then afterwards comparison of both the nozzle/throat combinations is done most suitable is recommended after comparing different parameters. Influence of gas oil ratio on operating pressure and operating rate is also analyzed to achieve suitable oil rate. It was observed that increasing gas oil ratio decreases operating rate but increases operating pressure.

Keywords: Jet Pump, Cavitation, Wellflo, GOR.

INTRODUCTION

To lift the reservoir fluid artificially to the surface from bottom of the well artificial lift system can be used. The pressure at the bottom is enough in a self flowing well, to naturally lift up the fluid to the surface. But the pressure at bottom of the wellbore drops makes it inadequate to come to the surface of its own once the crude is produced. One more cause due to which the wells do not flow naturally is high viscosity (Takacs 2005). No form of Artificial lift is necessary if the reservoir has enough energy to flow naturally to the surface and delivers desired quantities. The energy shortfall of the natural lift will have to be supplied if the well do not flow or do not deliver the desired rates, by using some form of artificial lift. Artificial lift systems which are commonly used are Hydraulic lift, Gas lift, Reciprocating rod lift, Electrical submersible pump, Plunger lift and Progressive cavity pump. Hydraulic pumping has numerous advantages as compared to electrical submersible pump, sucker rod or gas lift system. Hydraulic pump can operate over wide range of conditions of well such as setting depth of over 20,000ft and production rates of 35,000bpd, it is one major advantage of the pump. (Brown, 1977). Jet pumps some other advantages include, such as no mechanical part or moving parts that wear. High fluid volume can be produced by jet pumps. As a “free style” they could be run and retrieved via slickline or by circulation. Jet pump can quickly and easily retrieved and replaced when maintenance is required they are of low maintenance (Kalwar *et al.,* 2016). Hydraulic lift system contains down hole jet pump, power unit and vessel cleaning unit. Nozzle, throat and diffuser are the main components of down hole jet pump. In the hydraulic lift system operation, the power fluid (Crude oil or water) is fed into multiplex pumptaken from horizontal vessel. From surface power fluid is pumped at a given rate (Q_N) where it reaches a nozzle of the down hole jet pump with pressure (P_N) as shown in Fig.1, it changes into the high velocity at the exit of nozzle, static pressure flow from low velocity, high static pressure flow. High velocity fluid, low static pressure allows well fluids to enter in to the well bore pushed by reservoir at the desired rate. Reservoir fluid then travel up from the wellbore and enters to the annular area of the nozzle and throat with pressure (P_s) and rate (Q_s) as shown in Fig.1Then power fluid and the reservoir fluid enter into the throat, inside the throat momentum transfer from power fluid to produced fluid takes place and mixing action occur. Through a diffuser section flow exits from the pump, which converts it to a low velocity state, high pressure. The discharge pressure should be high enough that it can lift (P_d the combined flow rate (Q_t) to surface (T. Pugh 2009).

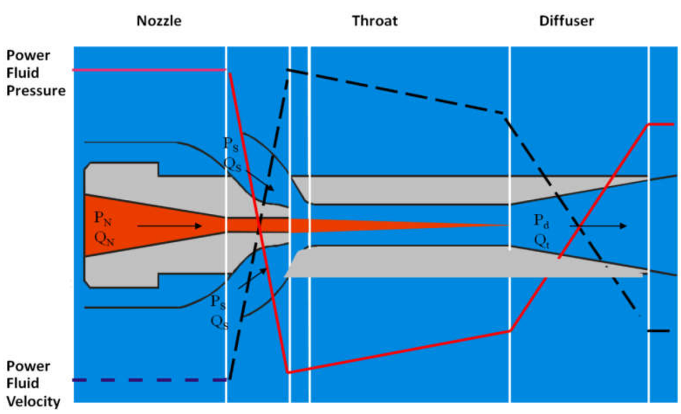

Figure.1 working principle of down hole jet pump (Haris Shakeel *et al.,* 2020)

RESEARCH METHODOLOGY

The software wellflo is used to create this model. The particular procedure is used to design the nozzle/throat combination of the jet pump and to analyse the effect of GOR on operating rate and

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pressure using wellflo software. Wellflo is a Nodal Analysis tool that analyses how hydrocarbon fluids behave in wells, as a function of flow rate and fluid parameters. Initially, data is collected then a model is created on the wellflo software, model includes the nature of the well, completion type, fluid type, reservoir and fluid properties, IPR data, deviation and downhole data. After putting the data performance of well is analysed either it need artificial lift system or not. Afterwards, the first step is the to achieve optimum flow rate by selecting feasible nozzle/throat sizes. The jet pump will be modelled for the well at various sensitivities to get optimum production. Various nozzle/throat combinations will be analysed to check which combination would work well on the basis of power fluid gravity, engine horse power, cavitation rate, injection rate and injection pressure. After analysing the results optimum parameters will be selected. The second step to analyse the impact of varying GOR values on the operating rate and pressure, how it can affect the production in future.

Tbale.1 Reservoir Data

Parameter	Values	Unit
Pressure	1560	Psi
Temperature	222	F
Mid Perforation Depth	7165	Ft
Water Cut	0.299	Fraction
GOR	134	Scf/stb
IPR	Vogel	-

Table.2 Well & Flow Type

Parameter	Options	Values
Artificial Lift Method	None/ESP/JP/GS/PCP	Jet Pump
Well Type	Producer/Injection/Pipeline	Producer
Flow Type	Standard/Reverse	Standard
Fluid type	Heavy/Black/Volatile/Condensate oil	Black oil
Analysis	Nodal/Completion Network	Nodal Analysis
Well Orientation	Vertical/Horizontal/Multi Frac	Vertical

Table.3 Down hole and Jet Pump Data

Parameter	Values	Units
Measured Depth	7306	Ft
Tubing Length	7099	Ft
Tubing ID & OD	2.362 & 2.875	Inches
Casing Length	7306	Ft
Casing ID & OD	6.276 & 7.00	Inch
Jet Pump Depth	7037	Ft
Minimum Injection Pressure	2000	Psi
Maximum Injection Pressure	4000	Psi

RESULTS AND DISCUSSION

By using wellflo software jet pump is designed by checking different nozzle/throat combinations and eventually power requirement of each nozzle/throat combination is calculated by considering the cavitation rate, power fluid injection pressure and injection rate. A X well of Y field in Pakistan stopped producing oil, firstly it was producing on natural pressure. Reservoir pressure is still have potential to produce the oil on the basis of natural flow but this time bottomhole flowing pressure is needed to be reduced to increase drawdown and improve the production. Artificial lift method installation is necessary to reduce bottom hole pressure. Table 4 shows various nozzle/throat combinations available for the well, out of which the most suitable are optimised considering the cavitation rate should be greater. After optimising the different nozzle/throat ratios further they are selected by observing the other parameters such as horse power, power fluid injection pressure and power fluid injection rate. The target is to select the nozzle/throat combination with least power requirement and power fluid injection pressure and rate.Table.4.7 shows different nozzle/throat sizes available when the power fluid is oil. For optimum selection we look for less horse power requirement with high production rate and high cavitation rate. Therefore jet pump is needed to optimise at optimum parameter with operating point outside the region of cavitation zone

Table.4 Available N/T sizes power fluid water

Suitable Pumps

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Serial #	Pump Manufacturer	Pump Type/ Nozzle Number	Nozzle Size/ Throat Number	Minimum Flow Rate (STB/d)	Maximum Flow Rate (STB/d)	Cavitation Rate (STB/d)	Target Production Rate(STB/d)	Power Fluid Injection Pressure (psia)	Power Fluid Injection Rate (STB/d)	Horse Power (hp)
1	KOBE	A-	7	231.72	382.1	316.42				
2	KOBE	A-	8	277.99	413.15	357.17				
3	KOBE	A-	17	0	397.91	0				
4	KOBE	A	5	142.75	340.37	309.43	298.57	3300	616.67	41.15
5	KOBE	A	6	168.93	377.71	351				
6	KOBE	A	7	195.72	407.43	387.17				
7	KOBE	A	8	221.93	428.11	417.42				
8	KOBE	A	9	244.92	444.38	438.62	301.41	2200	1530.62	68.02
9	KOBE	A	10	260.23	459.2	456.58				
10	KOBE	A	16	0	415.81	0				
11	KOBE	B	4	39.27	300.73	332.66	299.43	3950	505.19	40.35
12	KOBE	B	5	42.97	339.45	371.9	302.03	3550	631.12	45.3
13	KOBE	B	6	45.1	371.24	405.01	300.81	3250	792.99	52.11
14	KOBE	B	7	45.9	396.34	429.48	297.17	3050	1003.99	61.91
15	KOBE	B	8	45.93	417.63	448.88	301.96	2950	1283.52	76.55
16	KOBE	B	9	41.74	430.71	0				
17	KOBE	B	10	32.64	441.42	0				
18	KOBE	B	11	0	449.01	0				
19	KOBE	B	12	0	452.8	0				
20	KOBE	B	13	0	446.8	0				
21	KOBE	B	14	0	424.41	0				
22	KOBE	B	15	0	346.01	0				
23	KOBE	C	7	0	303.97	455.38				
24	KOBE	C	8	0	314.99	0				
25	KOBE	C	9	0	323.63	0				
26	KOBE	C	10	0	325.28	0				
27	KOBE	C	11	0	312.89	0				

Table.5 Available N/T sizes power fluid oil

Suitable Pumps

Suitable Pumps

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Serial #	Pump Manufacturer	Pump Type/ Nozzle Number	Nozzle Size/ Throat Number	Minimum Flow Rate (STB/d)	Maximum Flow Rate (STB/d)	Cavitation Rate (STB/d)	Target Production Rate(STB/d)	Power Fluid Injection Pressure (psia)	Power Fluid Injection Rate (STB/d)	Horse Power (hp)
1	KOBE	A-	7	251.85	420.52	321.52				
2	KOBE	A-	17	46.36	444.02	0				
3	KOBE	A	5	171.07	374.96	313.8				
4	KOBE	A	6	204.35	417.01	364.91				
5	KOBE	A	7	239.89	437.92	403.29				
6	KOBE	A	8	275.79	453.39	428.53				
7	KOBE	A	16	68.28	460.93	0				
8	KOBE	A	17	0	328.31	0				
9	KOBE	B	4	106.75	324.77	341.77	300.74	3750	544.3	38.42
10	KOBE	B	5	124.24	379.12	386.26	301.35	3300	673.04	41.78
11	KOBE	B	6	141.91	414.57	419.15	297.31	2950	836.34	46.39
12	KOBE	B	7	159.46	433.65	439.09	301.26	2750	1056.43	54.61
13	KOBE	B	8	174.74	448.71	455.88	302.51	2600	1339.25	65.43
14	KOBE	B	9	185.91	459.85	0				
15	KOBE	B	15	31.2	437.49	0				
16	KOBE	B	16	0	326.95	0				
17	KOBE	C	5	41.9	317.76	427.06	298.5	3850	708.72	51.36
18	KOBE	C	6	45.38	353.45	445.79	299.62	3625	896.26	61.14
19	KOBE	C	7	48.22	383.14	0				
20	KOBE	C	8	49.18	402.41	0				
21	KOBE	C	9	49.29	416.68	0				
22	KOBE	C	10	44.67	422.37	0				
23	KOBE	C	11	36.06	423.71	0				
24	KOBE	C	12	0	417.66	0				
25	KOBE	C	13	0	394.83	0				
26	KOBE	C	14	0	344.53	0				

Figure.2 shows maximum flow rate and cavitation rate of each different nozzle/throat sizes when the power fluid water is used, here we can see that maximum flow rate is of 9A N/T combination and maximum cavitation rate is also of 9A N/T combination.

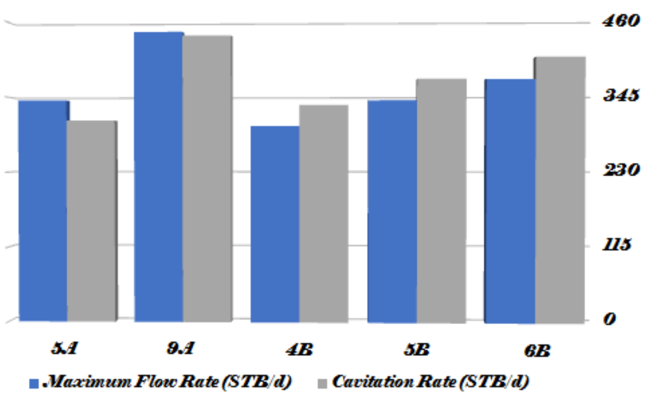

Fig.2 Maximum flow rates and Cavitation rates power fluid water

Table.6 Maximum flow rates and Cavitation rates power fluid water

N/T Combination	Maximal Flow Rate (STB/d)	Cavitation Rate (STB/d)
5A	340	309
9A	444	439
4B	300	333
5B	339	372
6B	371	405

Figure.3 shows maximum flow rate and cavitation rate of each different nozzle/throat sizes when the power fluid oil is used, here we can see that maximum flow rate is of 8B N/T combination and maximum cavitation is also of 8B N/T combination.

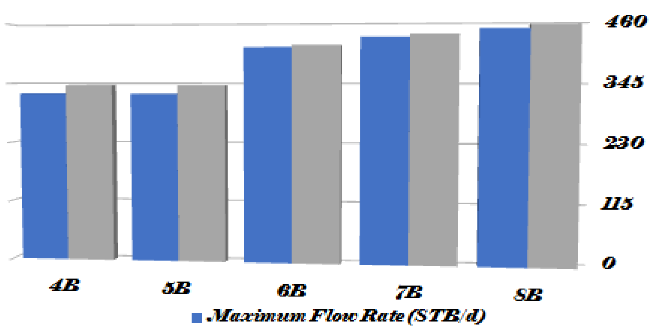

Fig.3 Nozzle Throat Combinations Power Fluid Oil

Table.7 maximum flow rates and cavitation rates power fluid oil

N/T Combination	Maximal Flow Rate (STB/d)	Cavitation Rate (STB/d)
4B	325	342
5B	325	342
6B	415	419
7B	434	439
8B	449	456

From table 8 it can be easily observe that water as a power fluid will be much better option after comparing all the parameters also economically and practically for this particular well with a slight greater requirement in horse power (5.5 hp) and power fluid injection pressure (300 asia).

Table.8 Selection of power fluid between water and oil

Parameters	Water	Oil
Pump manufacturer	Kobe	Kobe
Pump type nozzle/throat no	6B	5B
Minimum flow rate (STB/d)	45.1	124.24
Maximum flow rate (STB/d)	371.24	379.12
Cavitation rate (STB/d)	405.01	386.26
Target production rate (STB/d)	300.81	297.31
Power fluid injection pressure (psia)	3250	2950
Power injection fluid rate (STB/d)	792.99	836.34
Horse power requirement (hp)	52.11	46.61

Effect of Gas Oil Ratio on operating rate and operating pressure was analysed, in this case we can see that various increasing GOR values were modelled to check influence on the operating rate and operating pressure as shown in fig.4 and table.9.Increasing GOR will reduce the operating rate and increase the operating pressure. Increasing of operating pressure will require higher horsepower it can affect economically, and presemce of gas also create cavities therefore it reduces the efficiency of the pump.

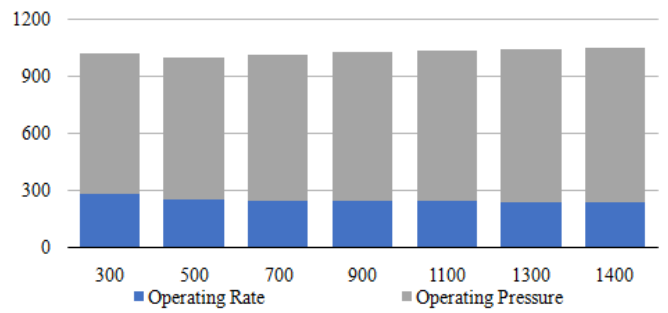

Fig.4 Effect of GOR on Operating rate and Operating pressure

Table.9 Effect of GOR on Operating pressure and Operating rate

GOR	Operating Pressure (psi)	Operating Rate (STB/d)	Oil Rate (STB/d)
300	748.34	274.7	192.5647
500	745.18	249.5	174.8995
700	767.12	244.8	171.6048
900	780.12	242	169.642
1100	793.31	239	167.539
1300	805.3	236.3	165.6463
1400	809.78	235.3	164.9453

CONCLUSION

The jet pump was designed and optimised by wellflo software. Different nozzle/throat size combinations with different power fluids were tried for the well which was not able to produce. Kobe 6B provided satisfactory results with power fluid water and was found better option economically and practically. Influence of GOR on the operation rate and pressure was analysed the results show that increasing GOR will cause a decrease in operating rates and increase in operating pressure. Considering the absolute open flow target rate should be selected because well cannot flow above AOF.

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