LOT – Live optimization tool for Sucker Rod Pumping System

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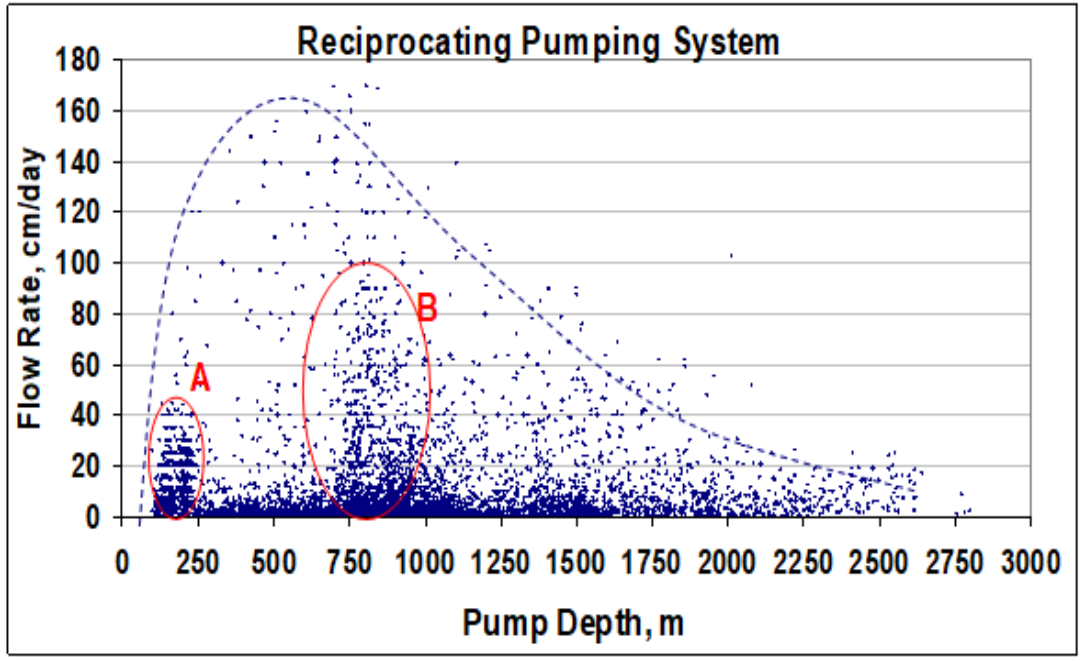
Why LOT for SRP?

- The number of total SRP active wells is about 3500

- The mature oil reservoirs of OMV Petrom represent a real challenge mainly because of the production specific conditions (large range of production, range of depth, from 200 m to more than 3000 m - see figure, more than 60% of SRP wells operate with higher than 70% water cut, main failure drivers such as paraffin, sand, gas, oil viscosity, well deviation etc.)

- The need to have during well by well review processes, an overview of the operational parameters of the wells in two scenarios: existing and optimum pumping mode

- To evaluate the wells performances from operating perspective at different production levels (reservoir, sector, assets)



The structure of application mainly consist of four modules of calculation:

- Database interrogation for SRP wells selection and data validation

- Produced fluids properties for standard and pump setting depth conditions

- Pump volumetric efficiency calculated for standard and pump conditions

- Checking of the sucker rod string design and propose the new design based on the same safety factor at the top of every sucker rod taper

- Evaluate the optimum pumping parameters (pumping speed, plunger size, pumping time) considering maximum pump volumetric efficiency criterion and minimum polished rod load

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How it works

Data base

Existing operational parameters

LOT

Tendency to failure of the equipment

Optimum operational parameters

Design equipment

Pump efficiency

Energy

Mathematical Model	
Operating Parameters	Calculation of the operational parameters: loads and stress at the top of the every taper (including polished rod), SR elongation, pump volumetric efficiency, downhole stroke length of the plunger.
Fluid Properties	-Oil density at P_n & T_n and at P & T (pump setting depth) -Density of mineralized/nonmineralized water at P and T -Gas density at P & T -Bubble Point Pressure -Solution Gas-Oil Ratio (GOR) -Volumetric Factor of saturated/non-saturated oil and biphasic components -Dynamic oil/emulsion Viscosity at T & P
Optimization Module	-Selection of the optimum pumping mode based on maximum pump volumetric efficiency and minimum polished rod load -Selection of the optimum correlation for the fluid properties calculation (e.g. for Bubble Point Pressure are analyzing 20 correlations and the proper one is selected based on an optimization algorithm) -Sucker Rod string design based on the equal safety factor at every top taper of sucker rod string

LOT – Live optimization tool (Design + pumping regime + energy calculations)

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Pump volumetric efficiency report

ASSET	Efficiency [P0; T0] Q/Qt	Efficiency [P; T] Q/Qt
Asset A	76.43%	76.59%
Asset B	72.43%	72.45%
Asset C	74.09%	75.33%
Asset D	68.90%	70.30%
Asset E	63.75%	64.48%

- Report execution time: 5 minutes
- Pump volumetric efficiency calculated at Petrom/ Asset/ Sector level
- Calculations are made for standard pressure/ temperature conditions (P0,T0) and at pump setting depth conditions (P and T)

	Efficiency [P0; T0]	Efficiency [P; T]
Asset A	76.43%	76.59%
Sector 1	76.43%	76.59%
Asset B	72.43%	72.45%
Sector 1	64.13%	64.15%
Sector 2	57.09%	57.12%
Sector 3	89.73%	89.70%
Sector 4	75.64%	75.66%
Sector 5	86.78%	86.80%
Asset C	74.09%	75.33%
Sector 1	73.08%	73.96%
Sector 2	79.86%	80.37%
Sector 3	63.13%	63.92%
Sector 4	62.71%	70.39%
Sector 5	89.59%	89.68%
Asset D	68.90%	70.30%
Sector 1	63.93%	64.85%
Sector 2	68.03%	70.13%
Sector 3	82.18%	82.64%
Sector 4	66.70%	68.49%
Sector 5	78.07%	79.18%
Sector 6	53.73%	54.63%
Asset E	63.75%	64.48%
Sector 1	68.76%	69.40%
Sector 2	57.16%	57.77%
Sector 3	52.77%	53.37%
Sector 4	67.37%	68.63%
Sector 5	68.66%	68.74%

Pump volumetric efficiency detailed report

Well	Pump setting depth [m]	Pump API description	Stroke length [m]	Uptime [h/ zi]	Pumping speed [strokes/ min]	Flow [m^3/ zi]	Theoretical flow at P0, T0 [m^3/zi]	Pump efficiency at P0 and T0 [%]	Theoretical flow at P, T [m^3/zi]	Pump efficiency at P and T [%]
Well 1	237	30-275 T H E M 15-3-2-0	2.5	24	6.2017	16	84.383444	18.851485	84.3874205	19.1700602
Well 2	310.5	30-275 T H E M 16-3-2-0	1.4	23.9219	5.8287	30	43.0765117	69.6254193	43.0796438	69.6597165
Well 3	221.86	25-225 T H E M 10-3-4-0	1.1	24	4.01	14	15.9830697	87.5245367	15.9835273	87.6440353
Well 4	831	25-175 R H B C 12-3-1-0	2	24	5.9	7	23.4721589	29.7865911	23.4867595	29.9788082
Well 5	822	25-225 T H B C 12-4-3-0	1.5	23.8761	5.1	8	21.8604888	36.547159	21.8907166	36.715332
Well 6	817	25-225 T H B C 12-3-3-0	1.5	21.6232	5.1	5	19.8009074	25.2056959	19.8289432	25.3470429
Well 7	858	25-225 T H B C 12-3-2-0	2	23.1948	7.8484	17	45.3427851	37.4556132	45.394576	37.5794584
Well 8	822	25-225 T H B C 12-3-3-0	1.5	23.969	5.4	6	23.0521639	25.993398	23.0851867	26.1117098
Well 9	900	25-175 T H B C 20-3-3-0	2	23.5123	5.9	17	22.3963706	75.8263229	22.4131844	75.9531143
Well 10	912	25-175 R H A C 12-3-0-0	2	24	6.5	16	25.2793023	63.247312	25.2973619	63.2862423
Well 11	910	30-275 T H B C 16-3-3-0	2.5	24	5.4387	36	60.4594973	59.5180078	60.5297384	59.5467681
Well 12	882	30-275 T H B C 16-3-3-0	2.5	24	8.8065	59	98.4857134	59.897282	98.5885403	59.8784518
Well 13	1308	20-175 T H B C 20-3-3-0	4	23.9768	5.9	32	45.6852542	70.0151895	45.7342632	70.0008304
Well 14	1355	25-175 R H B C 16-4-1-0	2.66	23.8916	6.1	12	28.1777181	42.5367603	28.2402487	42.6152474
Well 15	1339	25-175 R H B C 12-3-1-0	2	23.9845	5.8	8	18.536365	43.1166084	18.590309	43.0465045
Well 16	818	25-175 T H B C 12-4-3-2	1.2	22.8929	5.9	2	12.3978722	16.1016557	12.4107642	16.1752041
Well 17	808.5	25-225 T H B C 12-3-0-0	2	23.9923	5.3	6	32.7768679	18.2518898	32.8101267	18.4058932

- Report execution time: 9 minutes
- Operating parameters are calculated for every well
- The main Oil/ Water/ Gas properties at surface and pump setting depth are calculated based on mathematical correlations. The proper correlation is selected based on an optimization selection algorithm
- The viscosity, for e.g. of pumped fluid influences the pump volumetric efficiency, especially if the emulsion is present

Sucker rod pumping system optimization report

			Existing Pumping Mode						Optimum Pumping Mode					
Well	Pump setting depth [m]	Pump API description	Plunger diameter [in*100]	Uptime [h/ day]	Stroke length [m]	Pumping speed [strokes/ min]	Flow [m^3/ day]	Volumetric efficiency [%]	Plunger diameter [in]	Uptime [h/ day]	Stroke length [m]	Pumping speed [strokes/ min]	Volumetric efficiency [%]
Well 1	783	25-175 R H A C 16-3-0-0	175	23.2026	2.7	8.1645	32	71.0977	1.75	23.2026	2.7	8.1645	71.0977
Well 2	1038.2	25-225 T H - C 12-4-3-0	225	23.9845	2	6.571	23	63.4302	2.25	23.9845	2	6.571	63.4302
Well 3	1080.55	25-175 R H A C 12-4-1-0	175	24	2	5	18	96.0855	1.75	24	2	5	96.0855
Well 4	1082	20-125 R H A C 12-4-2-0	125	24	2	5.3	7	63.3183	1.25	24	2	5.3	63.3183
Well 5	971	25-175 R H A C 10-4-1-0	175	23.2239	1.4	4.9935	7	54.5255	1.5	23.2239	1.4	4.9935	70.7712
Well 6	702.34	25-175 R H A C 10-4-2-0	175	23.9226	1.5	6.2	16.0004	85.1569	1.75	23.9226	1.5	6.2	85.1569
Well 7	693	25-175 R H A C 16-4-2-0	175	24	3	5.6903	36	98.9073	1.75	24	3	5.6903	98.9073
Well 8	886.5	30-225 R H A C 16-4-1-1	225	23.8606	3.3	10.2	65	56.0176	2.25	23.8606	3.3	10.2	56.0176
Well 9	1730.6	25-125 R H B C 16-4-3-0	125	23.9923	2.6	5.5	5.06	35.4298	1.25	16.9923	2.6	5	55.241
Well 10	1725	25-125 R H B C 16-4-0-0	125	10.2194	2.4	4.3	3	69.2825	1.25	10.2194	2.4	4.3	69.2825
Well 11	793.5	30-225 R H A C 20-4-0-0	225	23.9923	4	6	79	93.5386	2.25	23.9923	4	6	93.5386
Well 12	943.56	25-175 R H A C 16-4-0-0	175	20.849	2.5	6.1	14	52.4806	1.75	20.849	2.5	5.6	57.2423
Well 13	952.62	25-175 R H A C 16-4-0-0	175	23.8219	2.5	5.6	22.1	78.5604	1.75	23.8219	2.5	5.6	78.5604
Well 14	975.89	25-175 R H A C 16-4-0-0	175	22.6232	3.3	5.6	12	33.5264	1.25	22.6232	3.3	4.6	76.6234
Well 15	1679.32	25-175 R H B C 16-4-0-0	175	7.6568	3.3	5.9968	3.204	26.9322	1.25	7.6568	3.3	4.9968	57.7909
Well 16	927	20-125 R H A C 10-4-2-0	125	21.4211	1.2	6.3923	6	84.7159	1.25	21.4211	1.2	6.3923	84.7159
Well 17	1564	25-175 R H A C 20-4-0-0	175	12.6026	3.3	5.4419	1.98	11.6501	1.25	5.1026	3.3	4.9419	55.2525
Well 18	1535	25-150 R H A C 12-4-0-0	150	11.1948	3.6	4.4	2.4997	22.8276	1.25	6.1948	3.6	4.4	57.3038
Well 19	1562.47	25-175 R H A C 16-4-0-0	175	12.4693	2	2.6756	0.999	24.2308	1.25	8.4693	2	2.6756	55.8605
Well 20	1541	25-150 R H A C 16-4-0-0	150	2.3084	3	3.9	1.0004	64.0238	1.5	2.3084	3	3.9	64.0238

- Report execution time: 2 minutes
- Optimum pumping mode is calculated for every well based on maximum pump volumetric efficiency
- The red color is used to indicate the wells with low pump volumetric efficiency value

Sucker rod string design report

			Existing design												Optimum design											
			Length of SR taper [m]				Safety factor				Asimmetry factor				Length of SR taper [m]				Safety factor				Asimmetry factor			
Well	Pump setting depth[m]	Number of tapers	5/8	3/4	7/8	1	5/8	3/4	7/8	1	5/8	3/4	7/8	1	5/8	3/4B	7/8	1	5/8	3/4	7/8	1	5/8	3/4	7/8	1
Well 1	237	1	0	0	237	0	0	0	9.79	0	0	0	0.35	0	0	0	237	0	0	0	10.20707	0	0	0	0.39529	0
Well 2	310.5	2	0	0	183	122	0	0	8.45	9.39	0	0	0.26	0.38	0	0	97.373	213.127	0	0	9.3982	9.3982	0	0	0.17087	0.41645
Well 3	305	1	0	0	300	0	0	0	7.6	0	0	0	0.35	0	0	0	305	0	0	0	7.89559	0	0	0	0.39777	0
Well 4	822	2	0	259	552	0	0	3.77	3.74	0	0	0.17	0.41	0	0	242.012	579.988	0	0	3.83592	3.83592	0	0	0.17377	0.44074	0
Well 5	900	2	0	586	303	0	0	4.32	4.71	0	0	0.38	0.48	0	0	459.298	440.702	0	0	4.77215	4.77215	0	0	0.35413	0.52056	0
Well 6	912	2	0	434	440	0	0	4.3	4.29	0	0	0.3	0.46	0	0	472.288	439.712	0	0	4.64003	4.64003	0	0	0.35207	0.51208	0
Well 7	910	2	0	0	420	467	0	0	2.84	3.01	0	0	0.2	0.36	0	0	296.34	613.66	0	0	3.09532	3.09532	0	0	0.16876	0.3999
Well 8	882	2	0	0	541	330	0	0	2.73	2.99	0	0	0.23	0.32	0	0	371.7	510.3	0	0	2.98031	2.98031	0	0	0.18977	0.3569
Well 9	1308	2	0	427	869	0	0	3.51	2.93	0	0	0.24	0.46	0	0	718.759	589.241	0	0	3.11145	3.11145	0	0	0.3513	0.48768	0
Well 10	1355	2	0	808	520	0	0	2.87	3.01	0	0	0.35	0.46	0	0	721.792	633.208	0	0	3.12232	3.12232	0	0	0.35897	0.50949	0
Well 11	1339	2	0	693	633	0	0	3.15	3.12	0	0	0.34	0.49	0	0	686.282	652.718	0	0	3.23382	3.23382	0	0	0.35835	0.52418	0
Well 12	818	2	0	404	409	0	0	5.24	5.17	0	0	0.34	0.5	0	0	402.491	415.509	0	0	5.37641	5.37641	0	0	0.35399	0.53507	0
Well 13	808.5	2	0	312	454	0	0	3.52	3.7	0	0	0.19	0.38	0	0	253.549	554.951	0	0	3.89659	3.89659	0	0	0.183	0.43756	0
Well 14	753	2	0	335	380	0	0	3.68	3.99	0	0	0.21	0.38	0	0	220.132	532.868	0	0	4.19029	4.19029	0	0	0.17288	0.44134	0
Well 15	755	2	0	411	329	0	0	5.49	5.63	0	0	0.35	0.49	0	0	375.044	379.956	0	0	5.76735	5.76735	0	0	0.35261	0.52946	0
Well 16	1139	2	0	655	474	0	0	3.23	3.2	0	0	0.3	0.4	0	0	666.786	472.214	0	0	3.26598	3.26598	0	0	0.33014	0.43761	0
Well 17	1258	2	0	556	655	0	0	3.23	3.14	0	0	0.29	0.47	0	0	653.226	604.774	0	0	3.39708	3.39708	0	0	0.35653	0.51665	0
Well 18	898	2	0	427	428	0	0	4.3	4.29	0	0	0.29	0.44	0	0	470.71	427.29	0	0	4.62583	4.62583	0	0	0.3479	0.50199	0
Well 19	814	2	0	0	533	276	0	0	3.98	4.28	0	0	0.32	0.41	0	0	422.17	391.83	0	0	4.33056	4.33056	0	0	0.29746	0.44582
Well 20	888	2	0	411	443	0	0	3.11	3.35	0	0	0.22	0.38	0	0	282.881	605.119	0	0	3.46378	3.46378	0	0	0.18	0.42634	0
Well 21	828	2	0	262	556	0	0	3.8	3.76	0	0	0.18	0.42	0	0	251.819	576.181	0	0	3.85743	3.85743	0	0	0.1814	0.445	0
Well 22	818	2	0	480	324	0	0	7.85	7.49	0	0	0.52	0.63	0	0	519.467	298.533	0	0	7.9354	7.9354	0	0	0.56677	0.67055	0
Well 23	804	2	0	442	355	0	0	4.91	4.9	0	0	0.33	0.45	0	0	436.408	367.592	0	0	5.03887	5.03887	0	0	0.34658	0.48663	0
Well 24	773	2	0	465	301	0	0	3.46	3.87	0	0	0.26	0.37	0	0	280.025	492.975	0	0	3.85886	3.85886	0	0	0.19238	0.40632	0
Well 25	785	2	0	236	538	0	0	6.13	5.25	0	0	0.25	0.51	0	0	394.525	390.475	0	0	5.58394	5.58394	0	0	0.3581	0.53178	0
Well 26	600	2	0	152	417	0	0	4.97	4.91	0	0	0.14	0.39	0	0	186.532	413.468	0	0	5.23668	5.23668	0	0	0.18109	0.43679	0
Well 27	776	2	0	365	399	0	0	3.73	3.94	0	0	0.23	0.39	0	0	262.952	513.048	0	0	3.97446	3.97446	0	0	0.19002	0.42447	0
Well 28	642	2	0	244	390	0	0	7.13	6.51	0	0	0.29	0.51	0	0	318.488	323.512	0	0	6.84642	6.84642	0	0	0.35585	0.53415	0
Well 29	792	3	0	290	463	30	0	3.76	3.83	4.87	0	0.19	0.38	0.39	0	-53.719	442.528	403.191	0	4.56492	4.56492	4.56492	0	0	-0.05207	0.30324
Well 30	751	2	0	404	342	0	0	3.96	4.34	0	0	0.27	0.42	0	0	230.986	520.014	0	0	4.37499	4.37499	0	0	0.18949	0.45701	0
Well 31	643	2	0	198	412	0	0	4.57	4.64	0	0	0.16	0.39	0	0	193.52	449.48	0	0	4.9107	4.9107	0	0	0.17732	0.44041	0
Well 32	535	2	0	0	335	196	0	0	6.4	6.86	0	0	0.33	0.44	0	0	257.705	277.295	0	0	6.97029	6.97029	0	0	0.30103	0.47794

- Report execution time: 3 minutes
- The report contains the actual status of SR string and proposals for new design of SR string

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Conclusions and way forward

- provides existing and optimum operational parameters
- the tool is very useful for well by well analysis actions
- a deeper analysis can be performed in order to increase the main KPIs (MTBF, MTBI, production) and to reduce the OPEX
- assesses safe operation envelope of SRP system

- for the next version of application, surface and subsurface dynamometer card will be available
- improve the optimization module by introducing a new criterion: the electric power consumption
- create the possibility to select every well and to see all operating parameters, dynamometer cards (surface and subsurface), fluid proprieties etc.
- interventions and failures history for every well will be added

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