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Sucker Rod Pump Design using Petroleum Engineering Application– PEARL 4.0 as a Breakthrough Solution in Digitalization (Study Case PWP-13) at Limau Field, Pertamina Hulu Rokan, South Sumatra, Indonesia

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ABSTRACT

PT. Pertamina Limau Field in South Sumatra, producing 4,113 BOPD and 10.69 MMSCFD from 11 structures, have a significant low production issue with well PWP-13. Although the well produces 40 BOPD, frequent failures in the sucker rod pump (SRP) system cause excessive downtime and low production, reaching 4,505 barrels oil (BO) in 2023. This research aimed to optimize PWP-13 production by redesigning the SRP system, applying API RP 11 L standards to improve the pump's reliability. Build new calculation, The Petroleum Engineering Application (PEARL 4.0) integrated variables such as taper rod arrangement and sucker rod type. This PEARL 4.0 was then applied to well PWP-13 with Rig Service. Monitoring results indicated a production increase to 90 BOPD, with average incremental production reaching 60 BOPD, supported by extended operational lifetime. Financial analysis showed a high net present value (NPV) of 693 MUSD, internal rate of return (IRR) of 498%, and a payback period (POT) of 0.189 years, confirming a rapid return on investment (ROI) 8.6. The SRP redesign offers a sustainable solution for sucker rod failures, enhancing production efficiency and profitability for company.

Keywords: artificial lift, sucker rod pump design, petroleum engineering application

I. INTRODUCTION

Upstream oil and gas activities consist of exploration and production phases. During production, oil and natural gas are extracted from production wells, either through natural flow or with artificial lift methods, such as using a Sucker Rod Pump (SRP). The oil produced from these wells is then managed according to pre-set production targets, which serve as a reference to determine the daily oil production rate. Once extracted, the oil undergoes further processing at production facilities, either at a Gathering Station (GS) or at a Main Gathering Station (MGS).

To achieved production targets, it is essential that oil extraction is optimized. This requires careful monitoring of all parameters affecting optimal oil production, including reservoir conditions, well conditions, submergence, pump capacity, and production facility capabilities. These parameters influence the oil production rate and the pump's efficiency. If the pumping capacity significantly exceeds the well's optimal production rate, equipment may wear out more quickly. Conversely, if pumping capacity falls short, the optimal oil production rate will not be reached. Therefore, production evaluation and well monitoring, using tools like sonolog and dynagraph, are critical for assessing well performance and identifying issues. Additionally, optimizing production may involve adjusting parameters such as pump capacity, submergence, and pump depth to achieve optimal production rates and achieved targets.

The study area is located in PT Pertamina EP Limau Field, South Sumatra. PWP structure is situated within the South Sumatra Basin. It consists of 28 wells, of which 15 are currently active. PWP-13 is one of the highest-producing oil wells in the PWP structure. Due to low reservoir pressure resulting from the mature nature of the field and decreased production capacity of the formation this well operates using an artificial lift method, specifically a Pumping Unit (PU), as it can no longer flow fluids naturally to the surface.

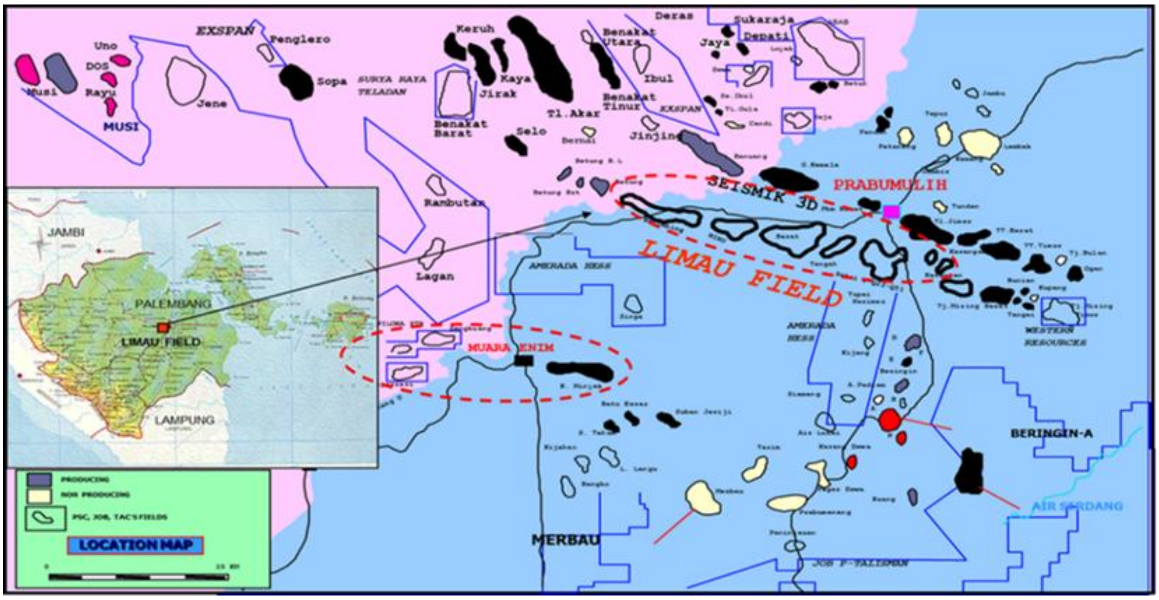

Figure 1. Overview of The Study Area

PWP-13 produces 40 BOPD; however, it also contributed 4,505 barrels of low and off production in 2023, primarily due to three main issues: an increased Gas Oil Ratio (GOR), rising water cut (WC), and artificial lift problems. Among these, artificial lift issues are the largest cause of production loss, accounting for 3,440 barrels and resulting in a financial loss of USD 302,583. Frequent downtime due to sucker rod failures shortens “PWP-13” operational lifetime to under three months. This is largely due to the inadequacy of the current Taper Rod, which cannot perform optimally. The sucker rod, essential for transmitting motion from the surface Pumping Unit to the downhole plunger pump, experiences repeated stress cycles. Over time, this continuous tension and compression induce micro-cracks, weakening the material and ultimately causing the rod parted. With suboptimal production from “PWP-13”, a redesign of the downhole pump, from both technical and economic perspectives, is necessary to achieve significant production improvements.

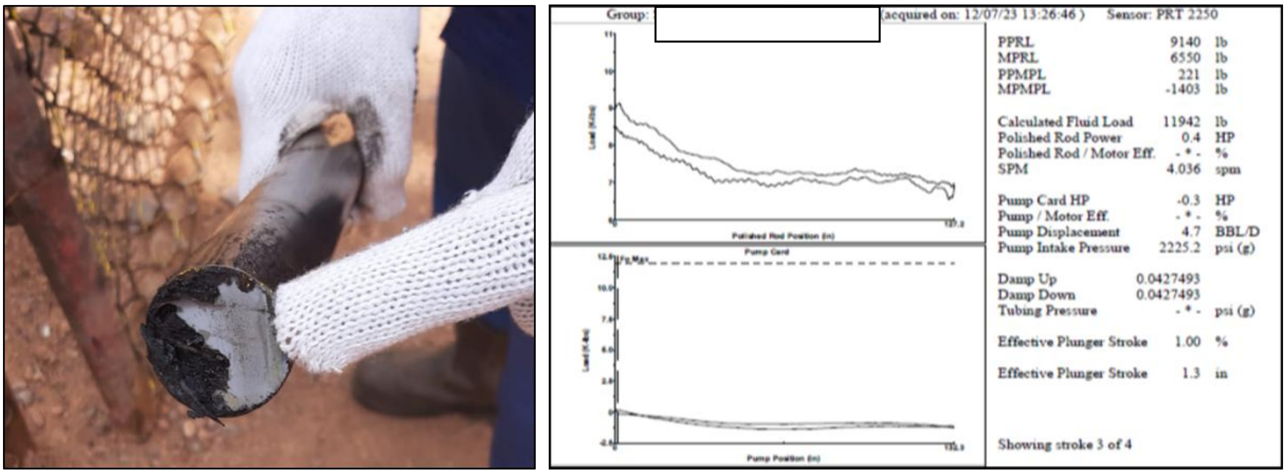

Figure 2. Sucker Rod Parted Well PWP-13

II. METHODS

The methodology applied in this research combines theory with field data to create a problem-solving approach. The data used includes both primary and secondary data. Preparations for the research involved gathering all necessary field data to support the writing’s objectives.

2.1 Reseach Process

The study process involving the redesign of the Sucker Rod Pump (SRP) to address the issue of Sucker Rod Parted. Below is the complete workflow:

1. **Data Collection**
   The first step is gathering comprehensive and accurate data to serve as the foundation for analysis and redesign. This includes:
   - Production Rate Data (BPD): This measures the daily production rate of the well in barrels per day (BPD). It helps assess the efficiency of the well and the extent of production loss caused by the Sucker Rod Parted issue.
   - Field Geology Data: Understanding the geological structure is critical to identifying how subsurface conditions might contribute to rod failure, such as stress on the equipment or operational challenges.
   - Fluid Properties Data: Parameters like fluid density, viscosity, and pressure are essential to determine the proper load capacity and operational conditions for the pumping system.
   - Well Profile Data: A detailed technical profile of the well, including depth, trajectory, and casing specifications, helps in designing a system tailored to the specific conditions of the well.
   - SRP & Pumping Unit Data: Details about the current Sucker Rod Pump, such as dimensions, materials, and operational settings, are used to analyze its limitations and plan improvements.

2. **Problem Analysis and Impact Assessment**
   In this stage, the focus shifts to identifying the root cause of the Sucker Rod Parted problem. This involves:
   - Root Cause Analysis (RCA): Determining if the failure is caused by mechanical fatigue, improper load distribution, suboptimal materials, or operational errors.
   - Impact Assessment: Quantifying the effects of the failure, such as production downtime, increased costs, and potential damage to other well components. This step helps prioritize solutions based on severity.

3. **Redesign Calculations for SRP**
   Based on the analyzed data, this step involves calculating the specifications for a redesigned Sucker Rod Pump. Key aspects include:
   - Load Optimization: Ensuring the pump can handle the load caused by fluid weight, tubing pressure, and other forces without exceeding its capacity.
   - Material Selection: Choosing materials with higher durability to reduce the likelihood of rod failure under stress.
   - Pump Dynamics: Adjusting the stroke length, pump speed, and rod dimensions to enhance performance and reliability.
   - These calculations aim to create a tailored SRP design that addresses the well's unique conditions.

4. **Implementation of SRP Redesign**
   Once the redesign is complete, the new SRP system is installed and tested in the production well. This stage involves:
   - Installation: Replacing the existing system with the redesigned components while ensuring proper alignment and calibration.
   - Initial Testing: Conducting short-term production tests to verify that the new design operates as intended under real conditions.

5. **Production Monitoring and Evaluation**
   - After implementation, continuous monitoring is crucial to determine the redesign's effectiveness:
   - Production Monitoring: Measuring production rates and observing any changes in operational stability.
   - Performance Metrics: Comparing pre- and post-redesign data to evaluate improvements in efficiency, reliability, and output.
   - Operational Feedback: Gathering input from field operators to identify any remaining issues or areas for further optimization.

6. **Evaluation of Success or Failure**

   Based on monitoring and evaluation, the effectiveness of the redesign is determined:

   - If Successful: The issue of Sucker Rod Parted is effectively resolved, leading to improved production rates, reduced downtime, and better overall efficiency.
   - If Unsuccessful: The reasons for failure are analyzed. This could involve identifying flaws in the redesign process, unexpected operational conditions, or limitations in data accuracy. A new redesign cycle is initiated if needed.

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7. **Key Outcomes:**
   - Resolution of Sucker Rod Parted: A successful redesign mitigates failures and ensures long-term reliability.
   - Operational Insights: The process generates valuable data and experience for optimizing future designs.
   - Cost Savings: Addressing rod failures reduces maintenance costs and minimizes production losses.

2.2 Redesign Calculations for SRP

The process of developing a Petroleum Engineering App aimed at supporting tasks related to the selection and analysis of Sucker Rod Pumps (SRP) requires structured and meticulous stages. The first stage involves a literature review of **API RP 11L**. The API RP 11L document contains standards governing the design, selection, and operation of pumping units in the oil and gas industry, particularly regarding beam pumps. Based on the findings of this review, a database is compiled containing technical information such as: Types of pumping units (PU) available in the market, Detailed specifications of taper rods, Non-dimensional sucker rod pump (SRP) tables.This data is essential to support subsequent calculation processes. Creating this database is a critical step as it serves as a reference for developing calculation algorithms within the application. Below are the well parameter data used as an example in the API RP 11L calculations.

Table 1. Well Parameter API RP 11L

Parameter	Simbol	Nominal	Satuan
Fluid Level	H	4500	ft
Metode	L	5000	ft
Pumping Speed	N	16	SPM
Length of Stroke	S	54	in
Plunger Diameter	D	1.5	in
Spec Grad of Fluid	G	0.9	-
Tubing Size		2	In
Anchored		No	
Sucker Rod	API 76	33.8 % x 7/8" + 66.2% x 3/4"	

To create an SRP design, 27 calculation steps and the plotting of Non-Dimensional graphs are required. These steps can be seen in the API RP 11L calculation form on Figure.3

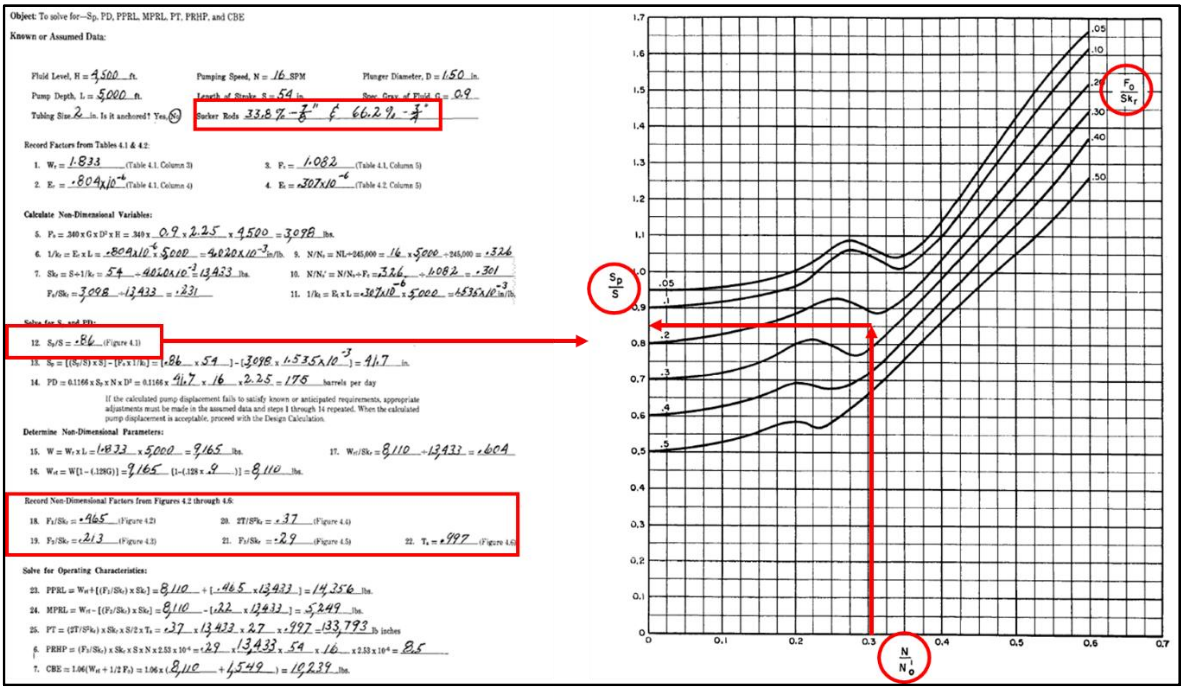

Figure 3. SRP Design Calculation (API RP 11L)

Tabel 2. Non Dimensional Graph Conversion Example

N/N_o'	S_p/S					
	0.05	0.1	0.2	0.3	0.4	0.5
0.0000	0.9500	0.9000	0.8000	0.7000	0.6000	0.5000
0.0010	0.9512	0.9014	0.8020	0.7000	0.6005	0.5010
0.0020	0.9524	0.9029	0.8039	0.7001	0.6010	0.5020
0.0030	0.9526	0.9031	0.8042	0.7001	0.6012	0.5022
0.0040	0.9526	0.9032	0.8044	0.7002	0.6014	0.5024
0.0050	0.9526	0.9033	0.8046	0.7003	0.6016	0.5026
0.0060	0.9527	0.9034	0.8047	0.7004	0.6017	0.5028
0.0070	0.9527	0.9034	0.8049	0.7005	0.6019	0.5029
0.0080	0.9527	0.9035	0.8051	0.7006	0.6021	0.5031
0.0090	0.9527	0.9036	0.8052	0.7007	0.6023	0.5033
0.0100	0.9527	0.9037	0.8054	0.7008	0.6024	0.5035
0.0110	0.9527	0.9038	0.8056	0.7009	0.6026	0.5036
0.0120	0.9528	0.9039	0.8057	0.7010	0.6028	0.5038
0.0130	0.9528	0.9039	0.8059	0.7011	0.6030	0.5040
0.0140	0.9528	0.9040	0.8061	0.7011	0.6031	0.5042
0.0150	0.9528	0.9041	0.8062	0.7012	0.6033	0.5043
0.0160	0.9528	0.9042	0.8064	0.7013	0.6035	0.5045
0.0170	0.9529	0.9043	0.8066	0.7014	0.6037	0.5047
0.0180	0.9529	0.9044	0.8067	0.7015	0.6038	0.5049
0.0190	0.9529	0.9044	0.8069	0.7016	0.6040	0.5051
0.0200	0.9529	0.9045	0.8071	0.7017	0.6042	0.5052
0.0210	0.9529	0.9046	0.8072	0.7018	0.6043	0.5054
0.0220	0.9529	0.9047	0.8074	0.7019	0.6045	0.5056
0.0230	0.9530	0.9048	0.8076	0.7020	0.6047	0.5058
0.0240	0.9530	0.9049	0.8077	0.7021	0.6049	0.5059
0.0250	0.9530	0.9049	0.8079	0.7022	0.6050	0.5061
0.0260	0.9530	0.9050	0.8081	0.7023	0.6052	0.5063
0.0270	0.9530	0.9051	0.8082	0.7024	0.6054	0.5065
0.0280	0.9531	0.9052	0.8084	0.7025	0.6056	0.5067
0.0290	0.9531	0.9053	0.8086	0.7026	0.6057	0.5068
0.0300	0.9531	0.9054	0.8087	0.7027	0.6059	0.5070
0.0310	0.9531	0.9055	0.8090	0.7028	0.6061	0.5072
0.0320	0.9531	0.9056	0.8094	0.7029	0.6063	0.5074
0.0330	0.9531	0.9057	0.8098	0.7030	0.6064	0.5075
0.0340	0.9531	0.9058	0.8101	0.7031	0.6066	0.5077
0.0350	0.9531	0.9060	0.8105	0.7032	0.6068	0.5079

Microsoft Excel was chosen as the tool to test and validate these formulas due to its capability to perform complex calculations quickly and easily. Testing was conducted manually using several data scenarios to ensure that the calculation results align with applicable theories and standards.

The calculation results using the latest Sucker Rod Pump design formulas offer distinct advantages over the API RP 11L standard because they are more flexible and adaptive to specific field conditions. In the Petroleum Engineering Application, these formulas allow rounding adjustments tailored to operational needs, making it easier for field users to obtain results that are more practical and relevant to the specific conditions of a given well.

Tabel 3. Petroleum Engineering App Vs API RP 11L Comparation

PARAMETER	Symbol	Unit	Petroleum Engineering Application	API RP 11 L	Accuracy (%)
Rod Specific Weight	Wr	lb/ft	1.833	1.833	100.00%
Rod Elastic Constant	Er	in/lb.ft	0.000000804	0.000000804	100.00%
Frequency Factor	Fc		1.082	1.082	100.00%
Tubing Elastic Constant	Et	in/lb.ft	0.000000307	0.000000307	100.00%
Differential Fluid Load	Fo	lbs	3098	3098	100.01%
Total Rods Elastic Constant	1/kr	in/lb	0.00402	0.00402	100.00%
Load to Stretch Total Rods String (Non Dimensional Variable)	Skr	lbs	13433	13433	100.00%
	Fo/Skr		0.231	0.231	100.00%
	N/No		0.327	0.327	100.00%
	N/No'		0.3018	0.302	100.00%
Unanchored Tubing Elastic Constant	1/kt	in/lb	0.001535	0.001535	100.00%
Pluber Stroke Factor	Sp/S		0.86	0.86	100.00%
Bottom Hole Pump Stroke	Sp	in	41.79	41.7	100.22%
Pump Displacement	PD	bbl/day	175.43	175	100.24%
Total Rods Weight in air	W	Lbs	9165	9165	100.00%
Total Rods Weight in fluid (Non Dimensional Parameters)	Wrf	Lbs	8109	8110	99.99%
	Wrf/Skr		0.604	0.604	99.95%
	F1/Skr		0.463	0.465	99.60%
	F2/Skr		0.214	0.213	100.43%
	2T/S2kr		0.368	0.370	99.58%
	F3/Skr		0.292	0.290	100.80%
Adjustment	Ta	lbs	0.989	0.997	99.22%
Peak Polished Rod Load	PPRL	lbs	14330	14356	99.82%
Minimum Polished Rod Load	MPRL	lb.in	5236	5249	99.75%
Peak Crank Torque	PT	hp	132194	133793	98.81%
Polished Rod Horsepower	PRHP	lbs	8.58	8.5	100.98%
Counterweight Required	CBE		10238	10239	99.99%

Additionally, the Petroleum Engineering Application input variations in parameters such as pumps, sucker rods, and fluid characteristics in greater detail, making it more dynamic and accurate for daily operational contexts. While API RP 11L provides uniform general standards, the calculation accuracy of the Petroleum Engineering Application compared to API RP 11L is 99.98%. This high accuracy is attributed to rounding differences found in the example calculations of API RP 11L.

2.3 Build Petroleum Engineering Application (PEARL 4.0) on Android Studio

The development of the Android application was carried out using Android Studio. In this stage, all calculation logic that had been tested and proven accurate in Microsoft Excel was converted into programming code using the Java programming language. The application development process included designing an intuitive user interface (UI) so that users could easily input essential data, such as the type of pumping unit, sucker rod length, and other parameters. Additionally, the application is capable of retrieving data from the previously created database and performing automatic calculations based on the inputs provided by the user. The calculation results are displayed in an easily understandable format, such as graphs or tables, to help users analyze the performance of the pumping units they manage more effectively.

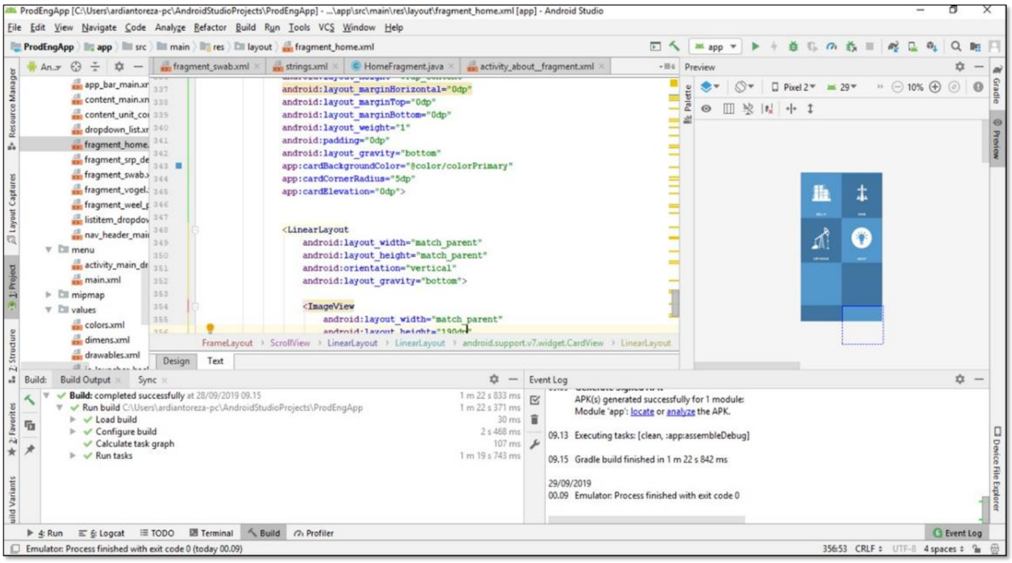

Figure 4. Development Coding on Android Studio

Figure 5. API RP 11L Calculation Example on PEARL 4.0

2.4 Calculate Inflow Performance Relationship PWP-13

The well's IPR (Inflow Performance Relationship) is determined by deriving the bottom-hole flowing pressure based on the target flow rate from the IPR graph. The bottom-hole flowing pressure associated with the target flow rate is then used as the basis for determining the Dynamic Fluid Level (DFL), which serves as the upper limit for pump depth planning.

$$\frac{Q}{Q\ max} = 1 - 0.\ 2\left(\frac{Pwf}{Pr}\right) - 0.8\ \left(\frac{Pwf}{Ps}\right)^2$$

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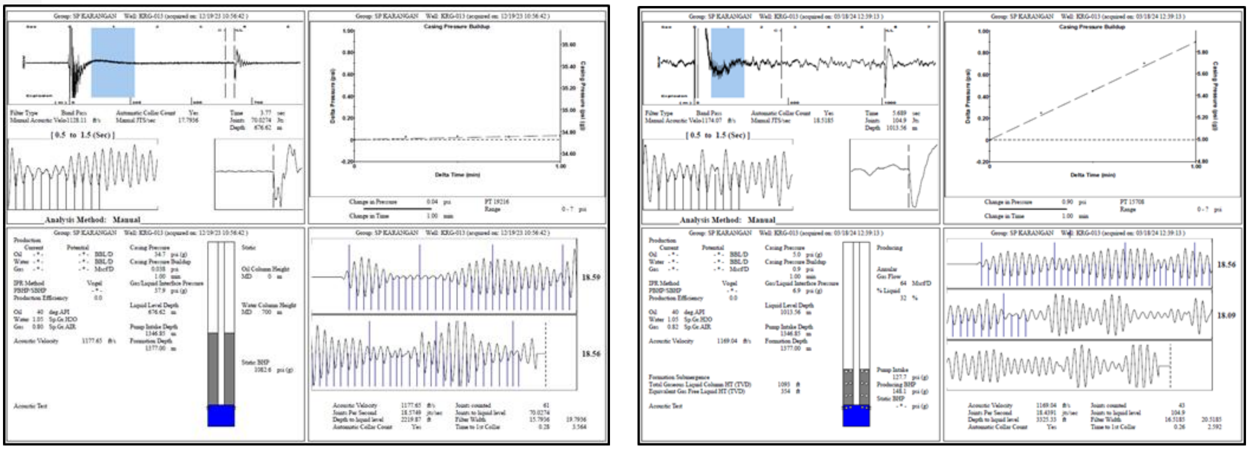

Figure 4. Static Fluid Level (SFL) and Dynamic Fluid Level (DFL) Well PWP-13

By understanding the production performance of a formation, as depicted by the IPR, a realistic production target can be established. In this study, for the calculation of the IPR for Well PWP-13, static pressure (Ps) and bottom-hole flowing pressure (PWF) are determined using data obtained from a Sonolog approach, specifically the Static Fluid Level (SFL) and Dynamic Fluid Level (DFL).

INPUT DATA			
Layer	:	"D1 dan D2"	
Mid Perforation	:	1377	m TVD
Rate	:	67	BFPD
Water Cut	:	30%	
SG Oil	:	0.85	
SG Water	:	1.00	
Static Fluid Level	:	677	m
Dynamic Fluid Level	:	855	m

OUTPUT DATA			
Fluid Gradient	:	0.388	psi/ft
Ps	:	890	Psi
Pwf	:	664	Psi
PI	:	0.3	B/D/Psi
Q. Max	:	165	BFPD

CALCULATION

Q str. line BFPD	Q vogel BFPD	Pwf Psi
0	0	890
26	28	801
53	54	712
79	77	623
105	98	534
132	116	445
158	131	356
184	143	267
211	153	178
237	160	89
263	165	0

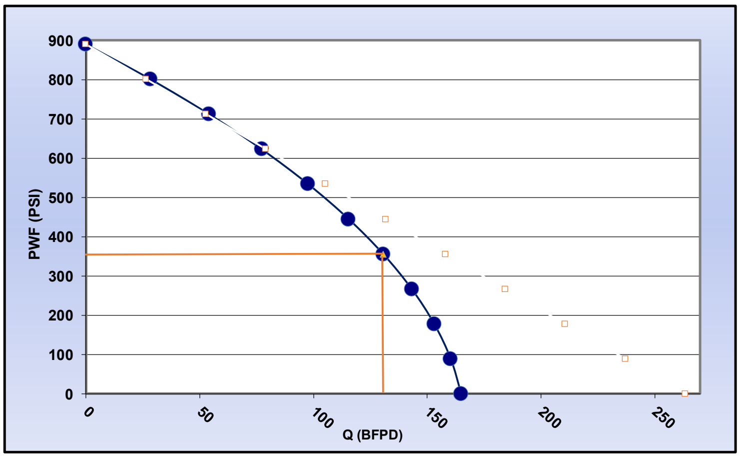

Figure 5. Inflow Performance Relationship (IPR) Vogel PWP-13

2.5 Implementation of SRP Redesign PWP-13

Based on the Qmax value obtained from the previous calculation, the production target is set at 80% of 165 BFPD, establishing a production target for Well PWP-13 of 132 BFPD, which corresponds to a bottom-hole flowing pressure of 356 psi. By converting the bottom-hole flowing pressure into the fluid column height, the minimum pump setting depth can be determined. For the target flow rate of 132 BFPD, the estimated minimum pump setting depth is 1350 m. Applying the rule of thumb, where the pump setting depth is placed 1 joint (9.3 m) above the pump, the installed pump

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can still effectively lift the well fluid according to the target without causing a pump-off condition. Therefore, the pump setting depth for optimizing Well PWP-13 is 1350 m.

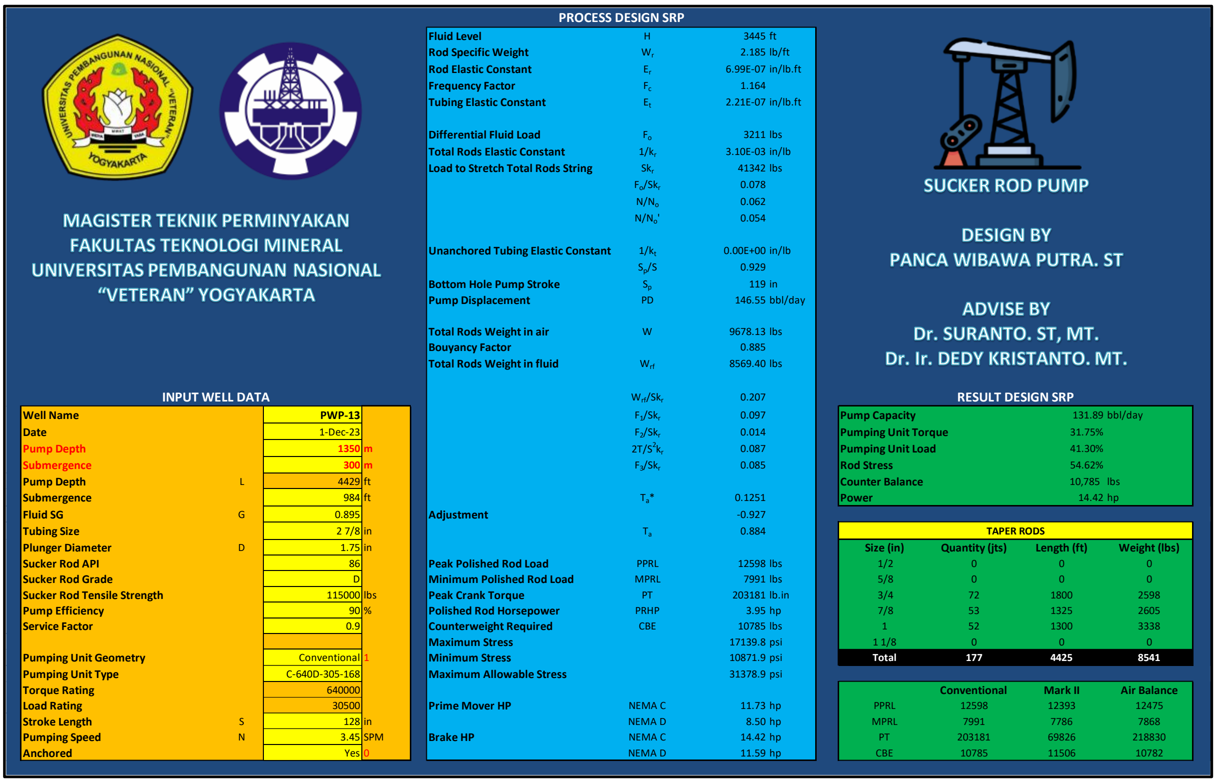

Figure 6. Re-Design SRP Well PWP-13 by Ms Excell

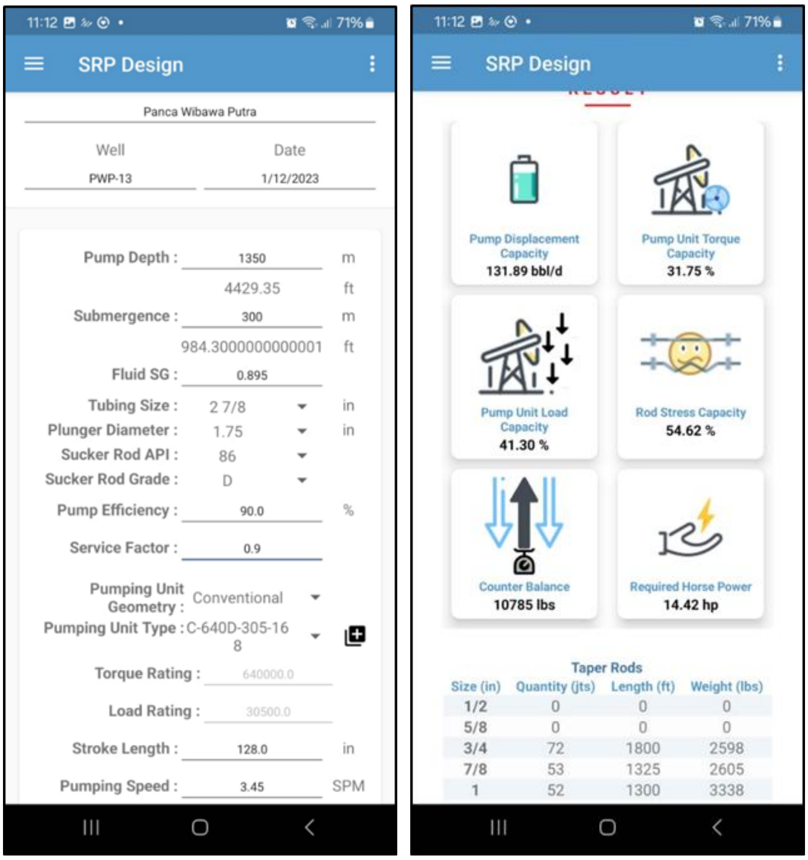

Figure 7. Re-Design SRP Well PWP-13 by PEARL 4.0

The replacement of the Pumping Unit (PU) from PU C-320D-256-144 to C-640D-305-168 was carried out to accommodate the tensile load on the sucker rod, ensuring it remains below 90% of the maximum allowable limit. This is critical to prevent sucker rod failure (sucker rod parted), which could disrupt well operations and reduce production. By using a larger and stronger PU, the sucker rod is expected to withstand the operational load without exceeding the specified stress limit, enabling safer and more efficient production operations.

Figure 8. Pumping Unit C-640D-305-168 Vs C-320D-256-144

III. RESULTS AND DISCUSSION

3.1 Production Monitoring and Evaluation

The success of the optimization was evaluated after implementing the SRP Re-design on well PWP-13. The evaluation method involved monitoring the production performance and reliability of well PWP-13 post-implementation. To assess the performance of the pump and sucker rod, periodic dynagraph and sonolog tests were conducted on the well.

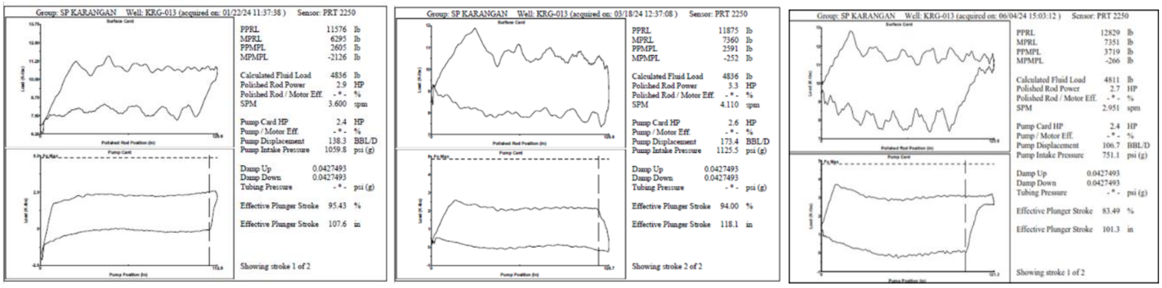

Figure 9. Monitoring Dynagraph Well PWP-13

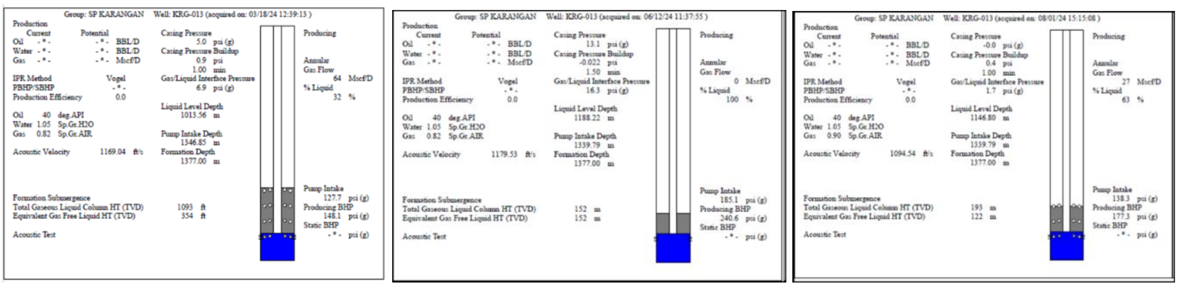

Figure 10. Monitoring Sonolog Well PWP-13

Monitoring during the period from December 13, 2023, to August 31, 2024, indicated a positive impact on the extended lifetime of well PWP-13, which continues to produce normally even now. The graph in Figure 11 illustrates the production monitoring for well PWP-13 during the monitoring period. This extension of well lifetime, exceeding nine months, provided additional benefits, such as reducing the frequency of well maintenance jobs. Previously, well

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maintenance with a rig service was required every three months. These improvements ultimately contribute to increased profit or revenue for the company.

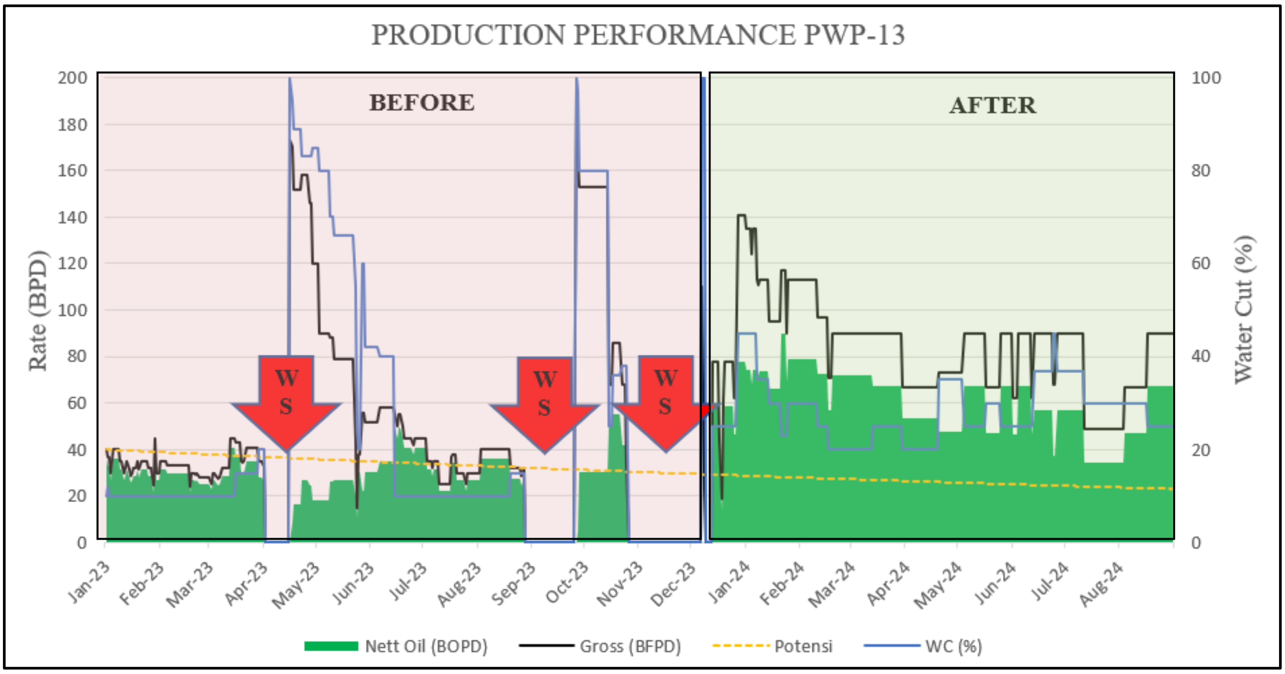

Figure 11. Production Performance Well PWP-13

The innovation provided by the Petroleum Engineering Application (PEARL 4.0) can be replicated and offers a quick solution for addressing issues in wells experiencing sucker rod failures. The production performance of well PWP-13 showed significant improvements. Gross production (BFPD) increased to over 100 BFPD, peaking at 141 BFPD in January 2024. Similarly, net oil production (BOPD) from 40 BOPD to 60 BOPD, with a peak of 90 BOPD.

3.2 Key Outcomes

The final step in the optimization planning of the Pumping Unit (PU) for well PWP-13 is conducting an economic analysis. This project demonstrates highly profitable results. The Net Present Value (NPV) reaches 693 MUSD, the Internal Rate of Return (IRR) is exceptionally high at 498%, the Payback Period (POT) is only 0.189 years, and the Profitability Index (P.I) is 8.6. This SRP design optimization clearly provides significant benefits to the company, with a remarkably fast and substantial return on investment.

INPUT DATA FOR SIMPLE CALCULATION
Re-Design SRP Sumur PWP-13

	Units	Value	Remark
Investasi	$(000)	91	
Capital	$(000)	56	SRP Assy
Non Capital	$(000)	35	Hoist 350 Hp
Opex			Anggaran Biaya Operasional
Oil	US$/bbl	28.00	
Gas	US$/mmbtu	0.66	
Asummsi			
Production forecast			
Qoi	Bopd	20	Gain Produksi
Qgi	mmscfd	-	
Decline	%/years	33%	
Prod. Life	Years	3	
Prices			
Oil Price	US $/bbl	84	
Gas Price	US $/mmbtu	6	

OUTPUT DATA FOR SIMPLE CALCULATION
Re-Design SRP Sumur PWP-13

	Total Gross Revenue	US $ (000)	3,756
1	Opex & Depresiasi	US $ (000)	1,343
2	Contractor Take	US $ (000)	965
3	Government Take	US $ (000)	1,448
	NPV (DF 12%)	US $ (000)	693
	IRR	%	498%
	POT	Years	0.189
	P.I	US $/US $	8.60

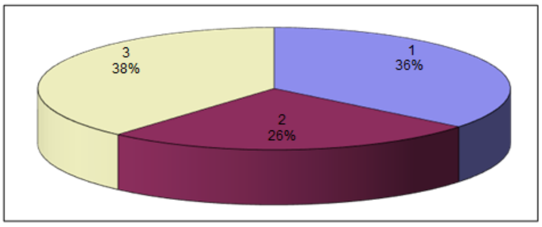

Figure 12. Economic Analysis SRP Design by PEARL 4.0

IV. CONCLUSION

Based on the research conducted, the following conclusions can be drawn:

1. The optimization of the Sucker Rod Pump (SRP) design is effective in preventing sucker rod failures and reducing operational costs. This process involves redesigning the system based on field data analysis and SRP calculations referencing API RP 11L, as well as developing a database that includes Pumping Unit, API Taper Rod, and Downhole Pump parameters in the SRP program using Microsoft Excel, complete with coding and design interfaces in the Petroleum Engineering application (PEARL 4.0).
2. Using the Vogel equation for Inflow Performance Relationship (IPR) analysis, the target flow rate for well PWP-13 was determined to be 132 BFPD (80% of the AOF of 165 BFPD). The implementation of the SRP redesign and the replacement of the Pumping Unit successfully reduced the risk of sucker rod failures.
3. After implementing the SRP redesign by PEARL 4.0 in December 2023, oil production increased from 40 BOPD to 90 BOPD, with an average increment of 20 BOPD. The well's production lifetime extended beyond nine months, compared to the previous three months.
4. The optimized SRP design provides significant economic benefits, achieving an NPV of 693 MUSD, an IRR of 498%, a payback period (POT) of only 0.189 years, and a profitability index (PI) of 8.6. It also reduces maintenance and operational costs, delivering a fast and high return on investment for the company.

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NOMENCLATURE

PI	Productivity index, bpd/psi
q	Measured liquid production rate, bpd
Pws	Static bottomhole pressure, psi
Pwf	Flowing bottomhole pressure, psi
qmax	Maximum production rate, bpd
Wr	Weight rod, lb/ft
Er	Elastic constant rod, inch/lb-ft
Fc	Frequency factor
Et	Elastic constant tubing, inch/lb-ft
Fo	Differential fluid load on full plunger, lbs
1/kr	Elastic constant total rod string, inch/lb
Skr	Pounds of load necessary to stretch total rod string an amount equal to polished rod stroke, lbs
N	Pumping speed, SPM
No	Natural frequency of straight rod string, SPM
No'	Natural frequency of tapered rod string, SPM
1/kt	Elastic constant pada unanchored portion of tubing string, inch/lb
S	Polished rod stroke length, inches
Sp/S	Plunger stroke factor
Sp	Bottom hole pump stroke, inches
PD	Pump displacement, bpd
W	Total weight of rods di udara, lbs
Wrf	Total weight of rods di dalam fluida, lbs
F1/Skr	Peak polished road load factor
F2/Skr	Minimum polished rod load factor
2T/S2kr	Peak torque factor
F3/Skr	Polished rod horse power factor
Ta	Torque adjusment constant
PPRL	Peak polished rod load, lbs
MPRL	Minimum polished rod load, lbs
PT	Peak cranck torque, lb inches
PRHP	Polished road horsepower, HP
CBE	Counterweight required, lbs
Wf	Weight fluid, lbs
W	Weight static rod, lbs
G	Specific gravity of fluid
Ap	Cross-section Area plunger, inch2
Ar	Cross-section Area rod, inch2

L	Lenght string, ft
ep	Elongation of rods due to acceleration, in
et	Elongation of unachored tubing due to fluid load, in
er	Elongation of rods due to gravity, in
Yr	Youngs modulus for rod material, psi
Yt	Youngs modulus for tubing material, psi
Ar	Cross-section area of rod, in2
At	Cross-section area of tubing wall, in2