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Framework for Evaluation and Improvement of Workover Rigs in Oilfields

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ABSTRACT : The aim of the work is to develop a framework evaluation for operational performance of the workover rigs in oilfields. This framework is used as a basis to analyse and enhance the performance of the workover rig including the improvement in rig efficiencies and reduction in operational costs. The framework is built on the collection and analysis of the overall equipment efficiency (OEE) established from the data gathered by the workover and production engineers on the workover rig. It can be usefully adopted in certain circumstances to calculate the efficiency of workover rigs. The results of measure OEE are effective when used to improve the workover rig and ESP efficiencies. To illustrate some of our work we present and discuss results from one of many case studies, which demonstrate the value of maintenance strategies such as framework. The framework and OEE measure are shown to be effective when used to improve rig efficiency and reduce downtime cost. Finally, the work suggests a way that can help both workover rigs and ESP users to cooperate with an aim to help oil wells to produce more with efficient equipment at any oilfield.

I.   INTRODUCTION

The oil and gas industry spends millions of dollars each year collecting vast amounts of drilling data, yet has not made effective use of this data to improve drilling performance. With rig costs estimated to consume 37% or USD 92.5 billion of that spending, every effort to reduce drilling time has a direct impact on our bottom line. Estimates of non-productive time (NPT) ran from 15–40% or USD 14–37 billion, depending on well type, maintenance and operator [1].

Workover supports oilfields to return oil wells to production by delivering operating equipment reliability and operating equipment risk reduction. The oil wells are dependent of maintenance services such as cleaning, reinstatement and stimulation. These services can be performed by a limited number of workover rigs. Usually, wells need maintenance services and a preparation of the workover rigs must be defined. This preparation must consider some factors such as the well production, the type of service to be performed and time windows for the well maintenance [2].

There is a production loss associated to wells waiting for maintenance services, so it is important to attend them as soon as possible. Thus, the workover rig scheduling problem consists of finding the best schedule for the limited number of workover rigs, minimising the production loss associated with the wells waiting for maintenance service [3].

The workover rigs must service oil wells requesting maintenance as soon as possible. When a well requires maintenance, its production is reduced or stopped for safety reasons and some workover rig must service it within a given deadline. It is therefore important to service the wells in a timely fashion in order to minimise the production loss. The total cost includes the rig expenses (transport, assembly and operation), which are functions of time and distances, plus the losses of revenue in the wells waiting for the rig, which are dependent on time [4].

The purpose of the study is to investigate the current problems and practice in the workover activities in the Oilfield. This study evaluates the steps needed to implement Total Productive Maintenance (TPM), based on how it is defined by Nakajima (1988) and H. Mansour & M. Munir (2013) [3].

In this work the Practical Framework is mainly built on a quantitative measure of performance based on data collection and subsequent analysis of overall equipment effectiveness (OEE) originally introduced by Nakajima (1988). The Framework method, when implemented in the company, resulted in the operators recognising the benefits that OEE carries in tracking and reducing hidden losses to improve their workover rig's efficiency. In addition, in this research, we show how a simplified version of this OEE measure can be usefully adopted in certain circumstances to calculate the efficiency of workover rigs. Both Framework and the OEE measure are shown to be effective when used to improve equipment efficiency [6].

1.1 Workover Processes

Workover program is an orderly step-by-step procedure to be followed in conducting the workover operation. This procedure of the workover include the main stage of workover processes, the first step in the process is to move the rig to the location of the oil well where many procedures must be followed in order to return the oil well to normal production see fig 1. The procedures such as the rig up (R/U), rig down (R/D) and ESP installation, Run in Hole (RIH) and pull out of hole (POH) of the equipment such as ESP. The program must provide operating personnel with all information necessary to achieve the required objectives safely at the minimum cost and with the minimum expenditure of resources [7 and 8].

Oil well inspection and workover consists of measuring actual processes from start to finish the workover job. To keep oil wells ruing, they require maintenance and repair, from time to time, due to normal wear and tear, age and the effects of the environment to which the equipment is exposed. Workover operations include any number of activities performed on a well, after initial completion, including recompletion and remedial repair work to achieve the required objective safely, at the minimum cost, with minimum expenditure of resources [10].
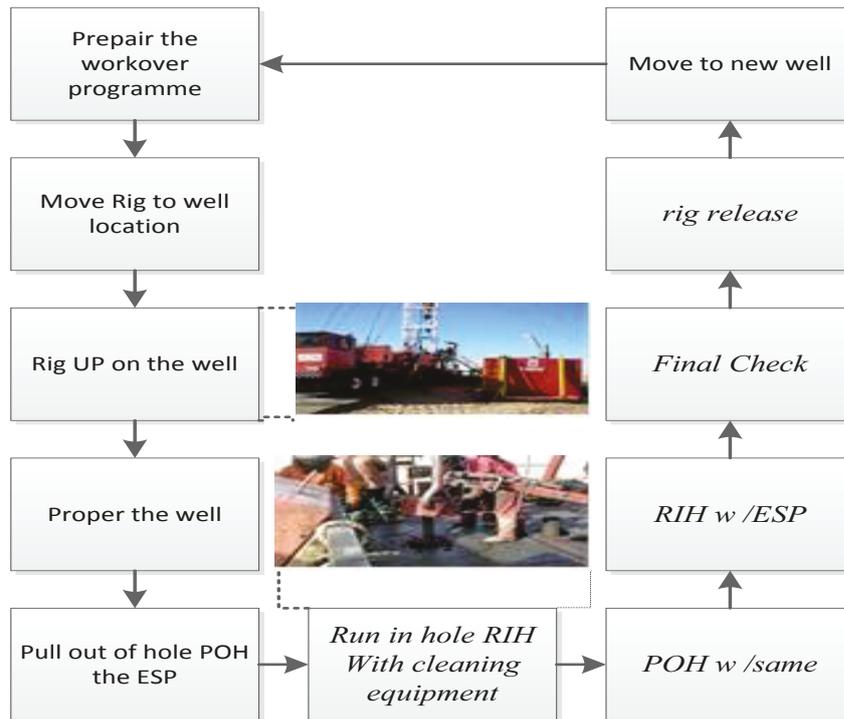
Figure 1: The Main Stage of Workover Processes (Mansour 2012)

II.　　　　1.3 PURPOSE OF OEE IN OIL INDUSTRY

In the oil industry, every well in the oilfield is a product line to produce the oil; it has many processes to keep the oil well in production [6]. The oil well is as a small manufacturing plant and each plant needs different equipment as the conditions for each plant are unique [1 and 7]. In the field of application of OEE in oil and gas industries, the researcher compares the overall equipment effectiveness in workover rigs with World Class Manufacturing [4 and 6].

2.1 Overall Equipment Effectiveness (OEE) For Workover

Equipment effectiveness includes equipment availability, performance efficiency and rate of quality of output. Operational performance data collection of the three OEE variables, availability, performance and quality [13 and 3]

$$OEE = \text{availability x performance x quality}$$

The first element of the OEE calculation is process availability: It is the ratio of the workover time to the planned workover time [3].

$$\textbf{Availability}\,\% = \frac{workover\ operating\ time}{\text{planned workover time}}$$

$$\text{Planned workover time} = \text{TWT} - \text{breaks}$$

$$\text{Workover operating time} = \text{planned workover time} - \text{downtime}$$

The second element is "performance rate". This element measures the ratio of the best time achieved to the actual time. That has been calculated in the method of evaluation of the workover [3].

$$\textbf{Performance } \% = \frac{\text{BTWT}}{\text{TWT}}$$

Where :

$\text{BTWT(hours)} = \text{total best (hostorical) timeachieved by workover rig} = \text{moving} + \text{Rig Up}$
$+ \text{pulling ESP} + \text{RIH with equipment} + \text{POH with equipment} + \text{RIH with ESP} + \text{Final check} + \text{Rig release}$

$\text{TWT(hours)} = \text{total workover time(actual time)} = \text{moving} + \text{Rig Up} + \text{pulling ESP} + \text{RIH with equipment}$
$+ \text{POH with equipment} + \text{RIH with ESP} + \text{Final check} + \text{Rig release}$

The third element of the OEE calculation is the "quality rate", and is used to indicate the proportion of defective time for good workover to the total workover time [3].

$$\textbf{Quality } \% = \frac{\text{time for good workover}}{\text{time for total workover}}$$

III.   RIG EFFICIENCIES

The rig efficiencies of four rigs in different oilfields in Libya (Sarir, Nafoora and Messla oilfields) have evaluated to identify the gap for improvements. The below table 1 shows many examples of results obtained with evaluation method of the workover rig efficiency. It shows the average efficiency of the rigs and also the efficiency of the rigs.

Table 1: workover rig efficiencies

Rig No.	Oilfield name	Average rig efficiency %	Highest efficiency achieved by rig %	lowest efficiency achieved by rig %	Gap identified for improvement %
Rig 10	**Sarir**	70	93	48	45
Rig 23	**Sarir**	68	83	52	31
Rig 32	**Nafoora**	67	84	51	33
Rig 21	**Messla**	66	85	54	31

The variation in efficiencies identifies the potential for improvement. For example, the highest efficiency is 93% for rig number 10 in Sarir oilfield, and the lowest efficiency is 48% for rig 10 at the same oilfield. Therefor it is possible that in practice all the rigs could perform at 93% efficiency given the right

procedures adopted with very little variation. Therefore, a workover rig in this case study should be most efficient if it is running at the highest efficiency achieved.

Each year, non-productive time during drilling operations costs the oil and gas industry billions of dollars; this equates to a loss of approximately one-third of oil and Gas Company's average annual drilling budget. The downtime Cost can give a good display to see the impact of the rig efficiency [14]. It can be seen in the figure 6 the improvement in each rig can be performed and the improvement of the efficiency of the rigs can be maintained. Each rig has target obtained hours in each steps of the workover operation.

The improvement in workover procedures greatly could reduce the downtime caused by incorrect operating procedures while a good workover program reduces downtime caused by worse workover procedures could be achieved [9].

Table 2: Summary statistics for Rigs downtime (DT).

	Rig10	Rig23	Rig32	Rig21
Av. Rig Efficiency %	70%	68%	67%	66%
Av. TWT	70.9	70.8	69.4	70.7
Av. DT hrs	13.1	22.8	14.54	20.5
Av DT cost £	19,926	33,816	20,863	33,514
DT cost %	20%	34%	20%	30%

The variation in downtime (DT) and its impact on different workover rigs (table 2) reflects the condition of the rig equipment, the quality of the rig equipment, the quality of workover programme and the company's operating policies, the location of the well, and the nature of the work.

The utilisation of the resources is the main factor that affects both the performance and profit of a company, this means decreasing the downtime hours and keeping operation running without any failures. The facility in this research will be workover Rig in the Libya area focusing on the performance improvement.

Is it possible for workover to implement TPM in the way it has been mentioned. In order to address this question the solution could lie in a simple and practical maintenance framework for these companies to follow, and allow them to improve their situations, taking into consideration their time, abilities and resources. The framework could be presented as a solution for workover rigs efficiency problem.

IV.   PROPOSED FRAMEWORK

The framework's steps as shown in table 3 are strongly based on the twelve steps of Nakajima's development program with different degree of sophistication [13 and 6]. Framework, as a method concentrates on the elements that are practical and suitable for maintenance development program, which are training, autonomous maintenance, and periodic maintenance [6].

In this work, the framework can be defined as a procedure that provides a practical workover maintenance system for workover rig and production engineers in the oilfield. This procedure involves operators, Electrical Submersible Pump (ESP) technicians in the workover jobs acting as a team to monitor the workover procedures including ESP processes (installation and uninstallation) and reduce the production losses in the oil wells by return the oil well to production at right time. In the first section, framework is defined and its linkage to Nakajima's twelve steps of TPM illustrated. Then each framework step is defined in detail and the way it could be used and implemented.

Table 3: Brief description of framework steps.

Framework Steps	Description
One	Determine the gap between target and actual OEE in the workover activities.
Two	Introduction of framework to staff by the management
Three	Improve relationship between operators and maintenance people
Four	Launch education and training to improve worker's skills
Five	Monitor process performance, set/raise target level
Six	Implement autonomous maintenance
Seven	Implement periodic maintenance

The oil production company's workforce can implement framework steps without the need for external advisers. These steps, as shown in table 3 above are flexible and can be tailored by engineers and the management to the individual oil company's capabilities, where each company could develop its plans differently because of different needs and challenges they are faced with, depending on the different artificial methods applied in the oilfield, production equipment conditions, and type of rigs.
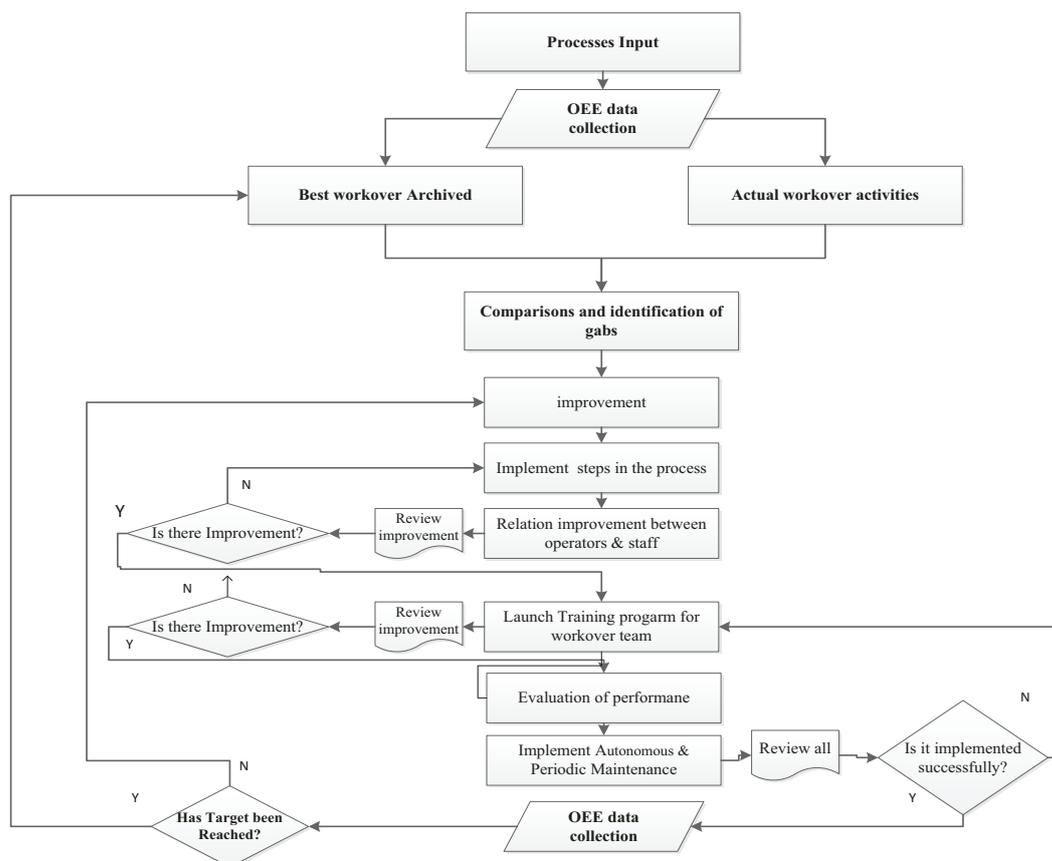

Figure 2: Framework for Evaluation and Improvement of Workover Rigs in Oilfields [6].

The fundamental measure of the method is the overall equipment effectiveness (OEE) value, which as described by Nakajima (1989), should be the driving force and provides direction for improvement-based activities within manufacturing organizations.

The framework proposed in Fig. 2 supports workover rigs and production engineering department in oil companies in four ways; first, the framework is simple and easy to follow as it only has three stages and seven steps. Second, framework does not require a significant financial commitment; steps could be implemented by the production engineers at oilfields (there is no need for a consultant to explain and help implement the method) and training is carried out by the crow (operators) and workover engineers at the rig and this reduces the additional financial pressure. The maintenance technicians will train the workover operators on autonomous maintenance and will be responsible for planning their own periodic maintenance program. This is because maintenance technicians are the best people that have the maintenance skills to train workover operators, and also have the knowledge and experience to plan their periodic maintenance program [6]. Third, improvements could be achieved shortly after implementation. Fourth, the framework does not involve specialist TPM teams and committees; instead there is only a single team to which everyone in the company will be attached. The benefit that companies will gain by applying framework is through the reduction of lost time, wasted effort and incurred cost. [6]

V.　　CASE STUDY - WORKOVER RIG NUMBER (10)

In this case study a workover rig number 10 in Sarir oilfield has been chosen to implementing the framework, the introduction and preparation stages took seven working days, and the research was agreed to be applied on only two workover rigs. The ideal cycle time is a standard known value for the machine. The workover manager and the maintenance and ESP technicians were responsible for investigating any problems on the workover rig that caused the decline in OEE.

The implementation of framework on one workover rig took only a short time to be accomplished in this case study. The total time of the introduction and preparation stages was only seven working days. Each oil well has taken an average of 6 to 8 days from start to return the well to production. On the other hand, the implementation of AM helped in reducing breakdowns on the rig by controlling and eliminating contamination on the rig machines and in the surrounding area.

The purpose of this case study was to show that the Production Engineering Department (PED) management at oilfields can improve the workover rig's efficiency and quality which allows engineers to return the oil well to production in the correct time to minimise costs and maximise production.

Table 4: OEE for Rig data

Rig No	Well No.	DT	BTWT In work (hrs)	Total operating Hours	Availability	Performance	Quality	OEE	Average OEE
Rig 10	well 1	13.2		75.5	88%	59%	53%	28%	
	well 2	22.8	44.5	85	87%	52%	46%	21%	27%
	well 3	14.4		70	79%	64%	53%	27%	
	well 4	22.5		54	65%	82%	62%	33%	

The practical method for evaluating the operational performance of workover activities in Sarir oilfield is varies greatly. The rig 10 efficiencies remain relatively constant when they are operated in the different locations. The table 4 shows the combined effect of rig efficiency and the efficiency to perform all other workover operations as the effective daily workover cost, which is a practical measure of the overall workover performance. Each rig has target obtained hours in each steps of the workover operation. The table 4 below shows many examples of results of current OEE obtained.

The data obtained from the workover rig in Table 4 above showed that Average OEE was only 27%. After OEE was analysed we were able to show the PED the causes of loss on the equipment.

When the causes were located and identified, it was explained to the PED management how the workover crew and ESP technicians could eliminate the causes of these problems with the help of framework. We explained to the PED management that when AM is implemented on the rig equipment it could help reduce and eliminate the causes of ESP failure.

4.1 Framework Application

The steps, as shown in table 3 in previous section (IV) are flexible and can be tailored by PED engineers and the PED management to the individual oilfield's capabilities, where each oilfield could develop its plans differently because of different needs and challenges they are faced with, depending on the different artificial methods applied in the oilfield, production equipment conditions, and type of rigs. The fundamental measure of the method is the OEE value, which as described by H. Mansour and M. Munir (2013), should be the driving force and provides direction for improvement-based activities within workover rig activities [3].
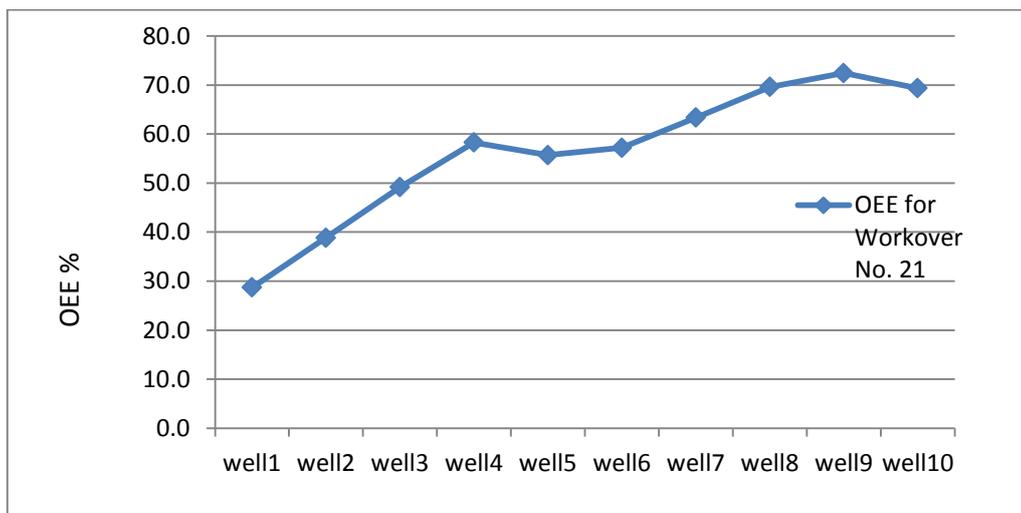

Figure 3: OEE for Rig 21

We explained to the PED that periodic maintenance would help reduce major and minor breakdowns on the machine thereby improving the condition of the machine. In addition, we explained how OEE could help the PED to track any causes of reduction in the workover rig's efficiency.

The results of OEE has been improved, the OEE for the first rig selected has increased from approximately 29 % to 72 %. This is the result of improvement in: availability, performance efficiency and rate of quality as in Fig 3.

The framework introduced in this research contributes mainly in terms of the following features. First, the framework identifies factors that cause downtime. Second, the framework emphasizes the importance of

focusing on crew-level factors. Third, the framework shows how the ramifications of downtime can occur by generating a feedback structure through managerial action and decisions. Finally, the framework provides a framework for tracing the causes of downtime and its impact on project performance.

Table 4 summarises overall evaluation results the DT cost impacts on the workover in each workover job from well number 1 up to well number 10 against the OEE results during the study period. The framework presented in this paper could assist managers in minimising the impact of downtime by providing insight into equipment management [6].

Table 4: Summarizes of overall evaluation results

Well No.	Previous OEE %	Current OEE %	Downtime/ hr	Downtime cost £
Well 1	28.7	28.7	20	33,514
Well 2	28.7	38.8	18	29,986
Well 3	38.8	49.2	14	23,215
Well 4	49.2	58.3	10	16,500
Well 5	58.3	55.7	8	13,405
Well 6	55.7	57.2	6	10,000
Well 7	57.2	63.4	5	8,400
Well 8	63.4	69.6	3	5,001
Well 9	69.6	72.4	3	5,024
Well 10	72.4	69.4	2	3,300

The implementation of framework on one workover rig took only a short time to be accomplished in this case study. The total time of the introduction and preparation stages was around 4 months. Each oil well has taken an average of 6 to 8 days from start to return the well to production. On the other hand, the implementation of AM helped in reducing breakdowns on the rig by controlling and eliminating contamination on the rig machines and in the surrounding area.

The workover process improvement opportunities continue to be identified based on OEE results and new variations of these measures can be implemented for other oilfields using the same artificial lift method [2 and 4]. Workover supports oilfields to return oil wells to production by delivering operating equipment reliability and operating equipment risk reduction. Good and bad workover procedures affect both the cost and time of operations [2 and 4].

VI.   CONCLUSION AND FUTURE WORK

The result of the study was impressive, in that framework helped improve the overall equipment effectiveness of a chosen machine in the workover rigs, from 29% to approximately 72%. This was the result of a cooperative effort of the operator and the maintenance staff. The period of improvement was short, being only eight months. Due to this success, the management decided to commit to further implementation of framework on other workover rigs.

The results of the example show that the proposed method of OEE is very effective for doing improvements to increase the effectiveness of the workover procedures within specific time period by identifying the problem exactly. However, the importance of practical workover performance measure which can aid in rig procedures negotiation and rig selection. Improvements tools such as TPM can be applied to enhance the performance of workover activities. Further, the metric OEE for workover activities can be used as a benchmark at various levels to achieve world-class standard in other sectors such as manufacturing sector.

Extension to this work is to initiate further studies on the effectiveness of framework, based on the extension of cost analysis on different rig drilling and workover companies on both onshore & offshore operations with different cultural backgrounds. This would enable a comparison of the applicability of the method to different company's results with the research finding.

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