DIGNOSTIC AND PERFORMANCE ANALYSIS OF DRILLSTRING VIBRATIONS IN ZUBAIR FIELD

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ABSTRACT

In order to improve the drilling performance and prevent the drillstring damage, it is required to reduce the drilling vibrations of wells. Consequently, the main aim of paper is to diagnose and analyze the drilling vibrations for Zubair field wells. Types of the vibration modes are identified, their relative causes, and mitigated actions are then recommended. Further, these vibration are degreed and classified in order to determine the severity degree of each run in drilled wells. Drilling parameters are also plotted and their trend-lines are constructed so as to predict the best ones in future activities. It was found that most of wells' runs were subjected to a severe stick-slip due to highly torsional vibrations and they were required an intermediate reduction of these vibration by reducing the surface WOB and increasing RPM. Additionally, ZB-311 Run 400 and ZB-349 Run 600 were subjected to highly stick-slip and BHA whirl, and BHA whirl respectively. Finally, drilling parameters' plots showed non-uniformity and irregularity fitting between themselves.

Keywords: Drillstring vibrations, stick-slip, diagnostic study, mitigations, and drilling parameters

INTRODUCTION

Drillstring vibrations are tremendously complex owing to the random nature of several factors such as bit/formation contact, drillstring/borehole contact, and hydraulics. They include numerous phenomena that make the analysis relatively challenging. There are three major modes of vibration occurred while drilling: axial, torsional, and lateral. Associated to these modes are phenomena including bit bounce, stick/slip, and whirling, respectively.

Drillstring vibrations may be induced by external excitations like bit/formation contact [1]. In these situations, the modification of the excitation source to a natural frequency of the drillstring assembly or its components may produce damaging motions. Further, self-excited vibrations are existed downhole [2]. Vibrations may also be happened due to the flow in the drillstring annulus [3]. Transient (unsteady state) or steady state (static) are the dynamic behaviour of the drillstring.

Drilstring vibrations influence the drilling performance directly for the reason that the different assembly components may yield premature wear and damage [4-6], and the rate of penetration (ROP) declines as part of the drilling energy required to remove the rock cuttings is lost in vibrations [7-9]. Moreover, vibrations can produce obstacle with measurement while drilling (MWD) tools [10]. Lastly, vibrations often make wellbore instability that deteriorate the conditions of the well and decrease the steering control and the complete quality of the borehole [1].

Drillcollars (DCs) and adjacent drillpipes (DPs) have been known for long time that their components are exposed to the most destructive vibrations. Consequently, the bottomhole assembly (BHA) not only effects the whole the assembly dynamic response, but it also represents the place of most failures [11-12]. Therefore, vibration mitigation needs understanding the dynamic behavior of the BHA mechanics and performance [13]. However, downhole vibrations provide a good source of information that gives insight into formation properties, bit wear, and drillstring/borehole interactions. These information can be utilized as a valuable seismic source [14-15]. Additionally, the drillstring vibrations have been considered as a way of improving the drilling effectiveness by adding the available power at the bit [16]. Sources of drillstring excitation are showing that they frequently induce instantaneously several vibration modes as appeared through the summary of major drilling vibration modes shown in Tables 1 and 2. Managing these types is required the assistant of the BHA and recorded vibration log in order to select the best action of mitigating the arisen vibration (Figure 1).

Based on the above literature review, a good understanding of its scientific basis, theories, and practices is a key element in order to identify, diagnose, and analyze the produced drilling vibration. Mitigations are therefore determined with selecting the best drilling practices that prevent these kinds of vibration modes. Consequently, in this paper, the recorded drilling vibrations are diagnosed and analyzed for Zubair field wells. Types of the vibration modes are determined and their mitigated actions are hence suggested. Further, these vibration are ranked and classified in order to determine the severity degree of each run in drilled wells. Drilling parameters are also plotted and their trend-lines are constructed so as to show if there is a good relation for a certain run that may be useful in the future wells to predict the best ones.

Table 1 Major drilling vibration modes [17]

Vibration Mode/ Item	**Axial**	**Torsional**	**Lateral**
Alternative Name	Longitudinal	Rotational	Bending, Flexural, Transverse
Related Phenomena	Bit Bounce	Stick/Slip, Torque Reversals	Whirling
Coupling Mechanisms	Bit Boundary Condition	Bent Drillstring Components	-

Table 2 Drillstring-excitation vibration sources with their modes [17]

Source	Primary Motion	Secondary Motion
Mass Imbalance or Bent Pipe	Lateral	Axial/Torsional/ Lateral
Misalignment	Lateral	Axial
Tricone Bit	Axial	Torsional/ Lateral
Loose Drillstring	Axial/Torsional/ Lateral	-
Rotational Walk	Lateral	Torsional/ Lateral
Asynchronous Walk or Whirl	Lateral	Torsional/ Lateral
Drillstring Whip	Lateral	Torsional/ Lateral

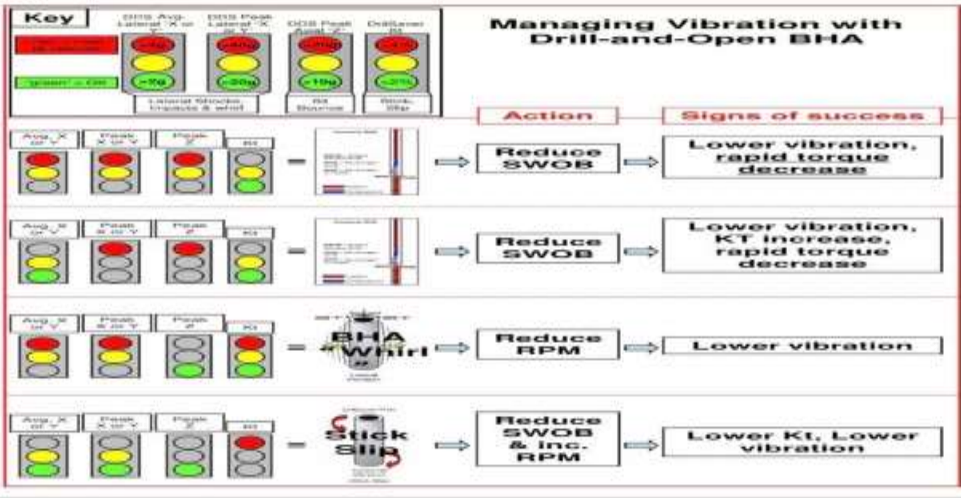

Figure 1 Drillstring vibrations management [18]

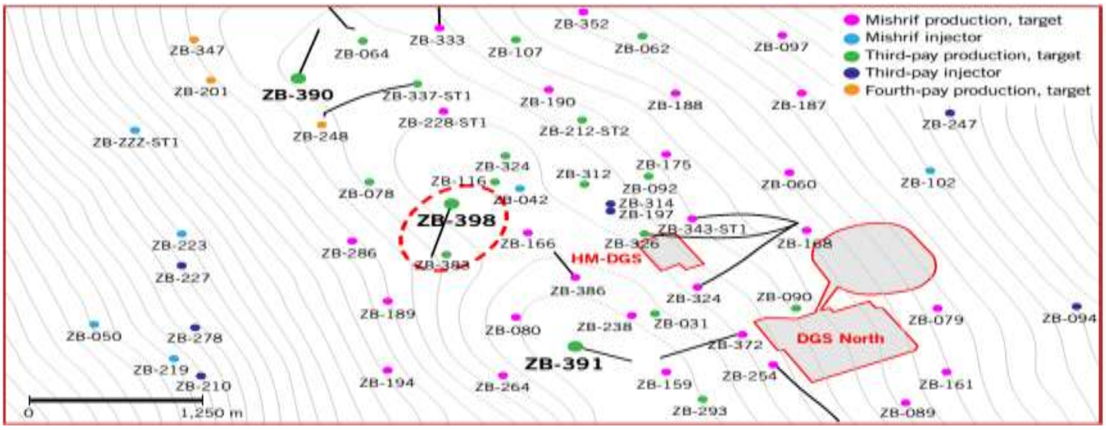

Figure 2 Structural map for reservoir pay zones and reference wells location [18]

Table 3 Vibration modes and their severity degrees

Mode/ Degree	DDS Avg , lateral (x or y)	DDS Peak , lateral (x or y)	DDS Peak Axial (z)
Red =must be reduce	>4g	>40g	>20g
Medium			
Green = ok	>2g	>20g	>10g
	Lateral Impacts	Shocks & whirl	Bit bounce

ZUBAIR FIELD DESCRIPTION

Zubair field is one of the onshore oil reservoir fields located in southern Iraq. Reservoir domes map and the structure contour map showing the producing zones: the 3rd and 4th pay zones and their drilled wells, are appeared in Figure 2. In the 3rd pay zone reservoir, the reference wells for production expectation for well ZB-398 Dir (planned) are ZB-283, ZB-325, ZB-078, ZB-116 as oil producers and injectors ZB-278 and ZB-210 as water injectors. However, in the 4th pay zone reservoir, the reference well for production expectation for ZB-385 Dir (new) is ZB-200. The future plans of the company are of increasing the production and exploring new fields. However, the present plans is a development strategy. In order to increase the oil production from the 3rd pay zone of Zubair field reservoir, three development wells are, therefore, planned to be drilled. There are 14 wells producing from the 3rd pay zone. The three wells, which would be drilled, are called ZB-390, ZB-391, and ZB-398. The drilling operations shall be carried out through different sections, where each one shall be drilled as described in the following steps:

- Rig Move – R/U & test equipment
- 23" Hole Section – Run & Set 18 ⅝" Casing @ specified TVD/MD
- 17 ½" Hole Section – Run & Set 13 ⅜" Casing@ specified TVD/MD
- 12 ¼" Hole Section – Run & Set 9 ⅝" Casing @ specified TVD/MD
- 8 ½" Hole Section – Run & Set 7" Liner @ specified TVD/MD

Time-based vibration data are recorded and the vibration logs are available for 6 wells: ZB-288, ZB-290, ZB-295, ZB-311, ZB-349, and ZB-367. Vibration logs are recored for three runs for each well as follows:

- Well ZB 288 RUNS: 500, 600, 700
- Well ZB 290 RUNS: 500, 600,700
- Well ZB 295 RUNS: 400, 500, 600
- Well ZB 311 RUNS: 400, 500, 600
- Well ZB 349 RUNS: 500, 600,700
- Well ZB 367 RUNS: 300, 400, 500

Depth interval of each run for each well is shown in Table 4. Vibration logs shown in Figures 3 through 5 contain recored data of combined gamma ray, total flow, ROP, Surface pressure, surface rotary speed, average WOB, average torque, lateral vibrations (Avg X and Avg Y), axial vibrations, DDSr RPM Variation, and Stick-Slip Severity versus depth. More descriptions and details of this field has been provided [19].

ANALYSIS AND DISCUSSION OF VIBRATION LOGS OF ZUBAIR WELLS

It clear that the drilling vibrations with their various modes have a great impact on drilling performance and increase the non-productive time. The non-productive cost hence will directly be increased. Here, there are six drilled wells of Zubair fields (Figure 1) with the recorded vibration logs (Figures 3 through 5). These wells are ZB-288, ZB-290, ZB-295, ZB-311, ZB-349, and ZB-367. A diagnostic-analysis study is done in order to identify the types of vibrations happened in each well and each run, their causes, severity, and selecting the mitigation methods for each well. From the first look to the six wells and their runs shown in Figure 3 through 5, it was found that all wells were exposing to high vibrations except some runs in wells ZB-288, ZB-290, and ZB-367. However, a deep look to the same data, after performing the diagnostic-analysis study (Tables 4 and 5) and making a classification table based on the literature review, showed that most of wells' runs were subjected to a severe stick-slip due to highly torsional vibrations and they were required an intermediate reduction of these vibration by reducing the surface WOB and increasing RPM. Although most of runs were subjected to higher vibrations, there were 4 runs in ZB-288, ZB-290, Z295, and ZB-367 which were exposed to low or normal vibrations (Table 4). These runs hence require nothing to do with these vibration. In order to reach low vibration and safe operations; lateral, torsional and axial vibrations are diagnosed, analyzed, and then degreed (Table 5). It also was found that Zubair wells were subjected to the stick-slip due to torsional vibrations and they were need to reduce the surface WOB and increase RPM. However, ZB-311 Run 400 and ZB-349 Run 600 were subjected to highly stick-slip and BHA whirl, and BHA whirl respectively (Table 5). Both are required a quick response to prevent drillstring damage. Finally, the drilling parameters are plotted together especially those affect directly on the degree and the mode of vibrations such as WOB, ROP, and RPM in order to generate new correlation or relation helps to recommend the best values for future activities. Most of constructed plots (figure 6 and figure 7) show non-uniformity and irregularity fitting between these parameters.

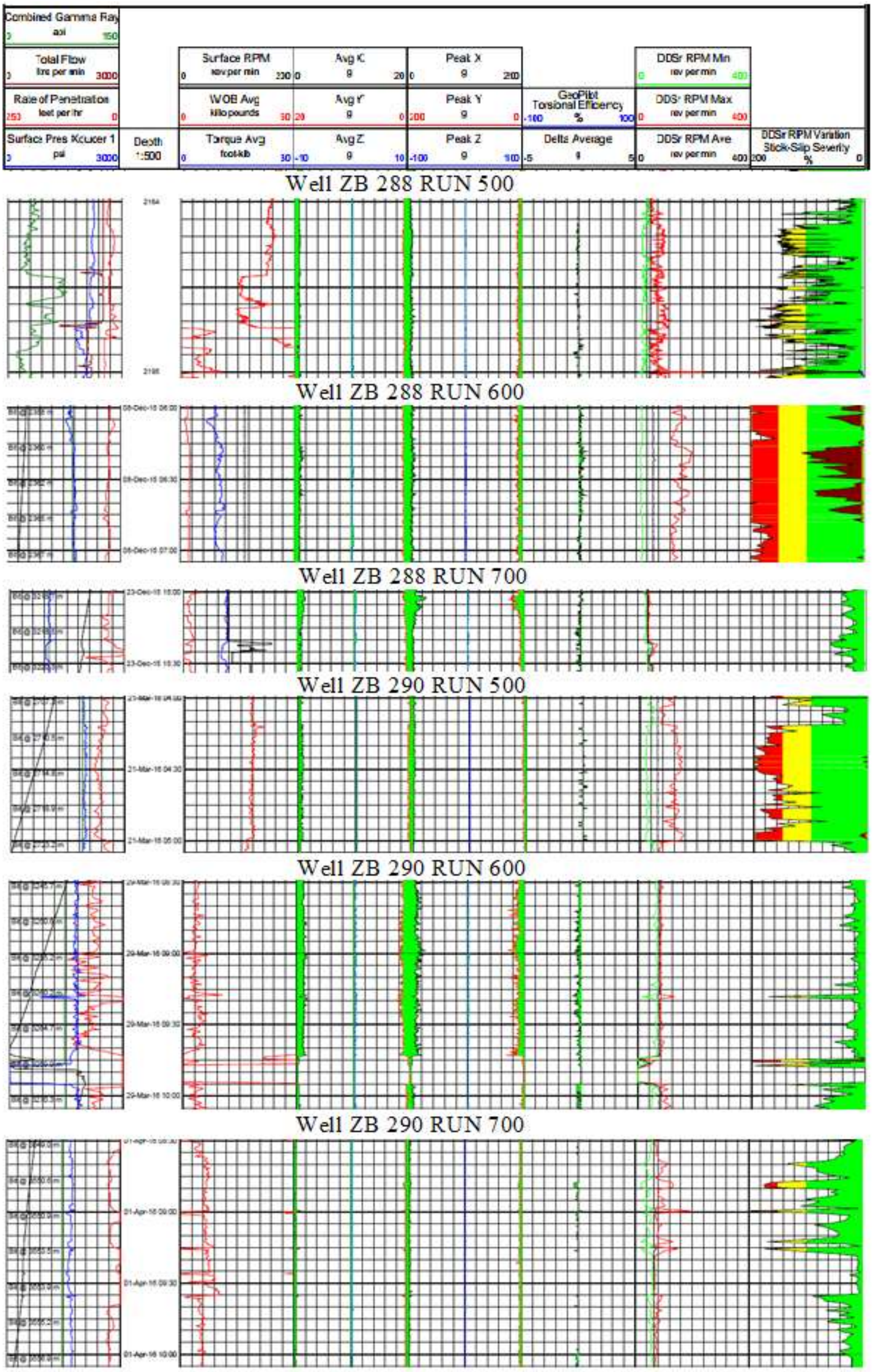

Figure 3 Recorded runs of vibration logs for wells ZB 288, and ZB 290.

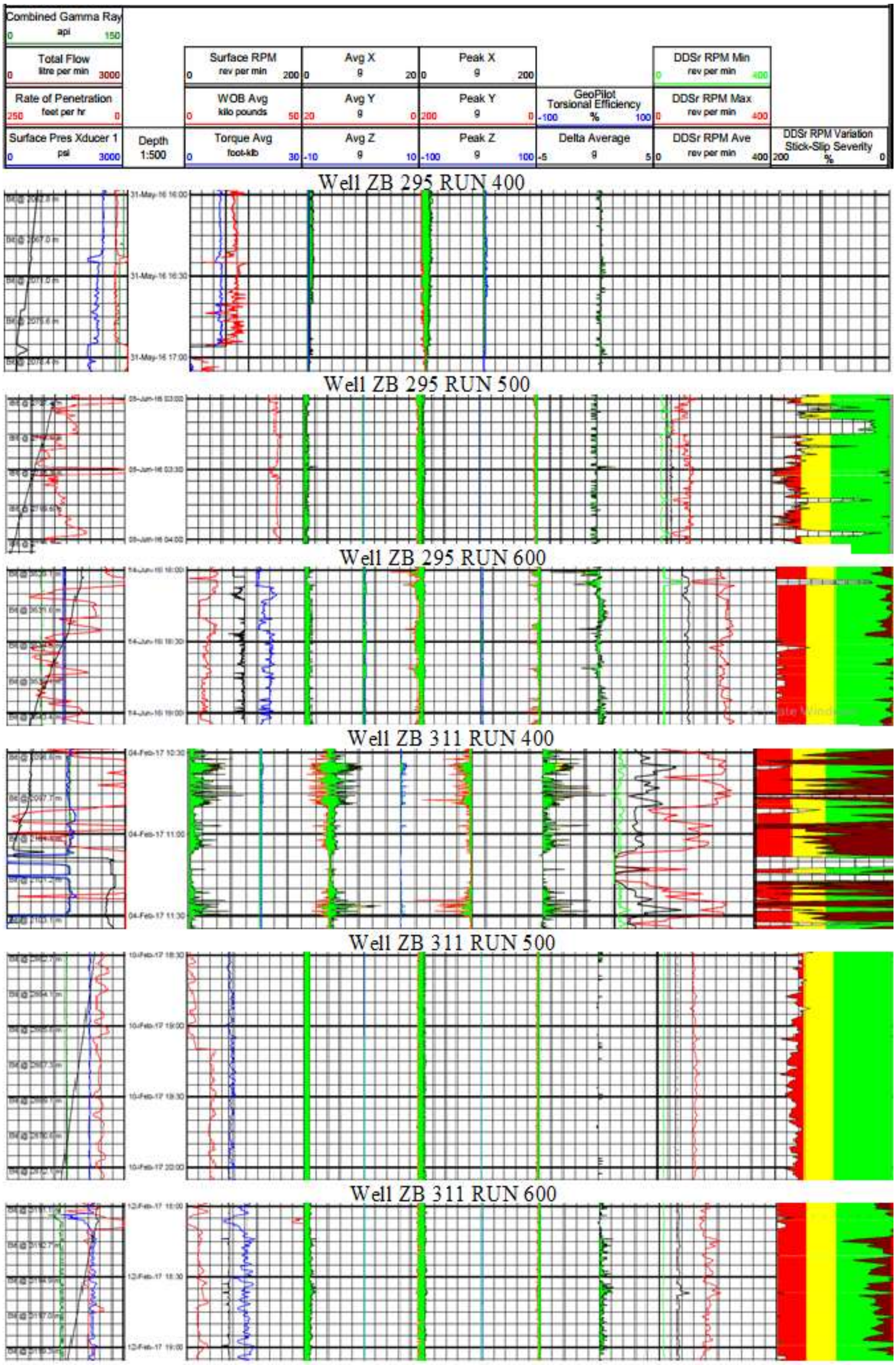

Figure 4 Recorded runs of vibration logs for wells ZB 295, and ZB 311.

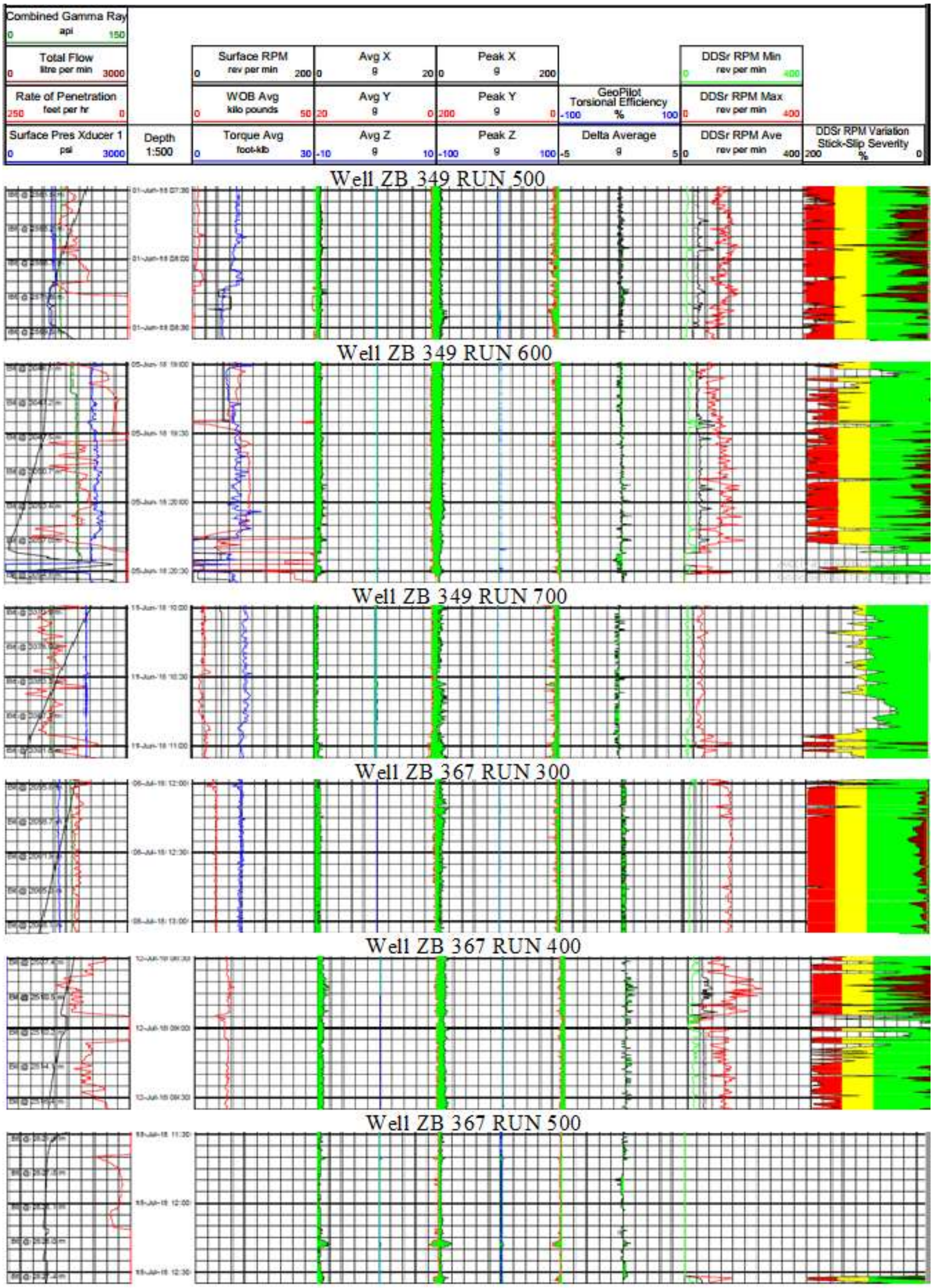

Figure 5 Recorded runs of vibration logs for wells ZB 349, and ZB 367.

Table 4 Diagnostic and vibrations analysis of data recorded in 6 Zubair wells

Well No.	VALUE (RPM) %	STICK-SLIP (RPM)% (RUN)	LEVEL	STATE	DEPTH (m)	LIMIT TIME
	140-160	>100 (500)	Severe	Stick-slip	2164-2195	Immediately reduce vibration
ZB 288	180-200	>100 (600)	Severe	Stick-slip	2358-2367	Immediately reduce vibration
	37-60	40~60 (700)	Medium	Torsional vibration	3215-3220	NO
	160-200	>100 (500)	Severe	Stick-slip	2707-2723	Immediately reduce vibration
ZB 290	20-40	0~40 (600)	Low	-	3245- 3270	NO
	80-120	80~100(700)	High	Stick-slip	3549-3556	Must reduce vibration 30 minutes
	0-10	0~40 (400)	Low	-	2062-2078	NO
ZB 295	180-200	>100 (500)	Severe	Stick-slip	2707-2723	Immediately reduce vibration
	200	>100(600)	Severe	Stick-slip	3529-3543	Immediately reduce vibration
	200	>100(400)	Severe	Stick-slip	2096-2103	Immediately reduce vibration
ZB 311	180-200	>100(500)	Severe	Stick-slip	2865-2872	Immediately reduce vibration
	200	>100(600)	Severe	Stick-slip	3111-3119	Immediately reduce vibration
	200	>100(500)	Severe	Stick-slip	2561-2569.5	Immediately reduce vibration
ZB 349	200	>100(600)	Severe	Stick-slip	3046-3054	Immediately reduce vibration
	80-100	80~100(700)	High	Stick-slip	3373-3391	Must reduce vibration 30 minutes
	180-200	>100(300)	Severe	Stick-slip	2055-2068	Immediately reduce vibration
ZB 367	180	>100(400)	Severe	Stick-slip	2507-2516	Immediately reduce vibration
	0-20	0~40 (500)	Low	-	2821-2827	NO

Table 5 Identifing the drilling vibration modes and their mitigation ways for Zubair wells

Well / Run	Value	Avg X(g)	Avg Y(g)	Avg Z(g)	Peak X(g)	Peak Y(g)	Peak Z(g)	Formal & Types	Action	Signs of success
288	RANG	0-20	0-20	0-(10/-10)	0-200	0-200	0-(100/-100)	Stick	Reduce	Lower
Run	MIN	0.8	0.92	0	4	5.36	0	Slip	SWOB	vibration
500	MAX	1.2	1.18	0.15	11.56	12.08	1.36	(torsional	& increase	
		>2	>2		>20	>20	>10	Vibration)	RPM	
288	RANG	0-20	0-20	0-(10/-10)	0-200	0-200	0-(100/-100)	Stick	Reduce	Lower
Run	MIN	0.53	0.58	0	4.05	2.76	0	Slip	SWOB	vibration
600	MAX	4	1.97	0	24.3	34.75	2.7	(torsional	& increase	
		>4	>2		>20	>20	>10	Vibration)	RPM	
288	RANG	0-20	0-20	0-(10/-10)	0-200	0-200	0-(100/-100)	Stick	Reduce	Lower
Run	MIN	0.34	0.387	0	1.72	4.18	0	Slip	SWOB	vibration
700	MAX	0.93	0.88	0.422	11.45	9.43	0.83	(torsional	& increase	
		>2	>2		>20	>20	>10	Vibration)	RPM	
290	RANG	0-20	0-20	0-(10/-10)	0-200	0-200	0-(100/-100)	Stick	Reduce	Lower
Run	MIN	0.13	0.40	0	2.7	1.36	0	Slip	SWOB	vibration
500	MAX	0.939	1.07	0	12.16	9.52	0	(torsional	& increase	
		>2	>2		>20	>20	>10	vibration)	RPM	
290	RANG	0-20	0-20	0-(10/-10)	0-200	0-200	0-(100/-100)	Stick	Reduce	Lower
Run	MIN	0.54	0.54	0	1.34	6.71	0	Slip	SWOB	vibration
600	MAX	1.21	1.21	0.273	12	12.08	2.73	(torsional	& increase	
		>2	>2		>20	>20	>10	vibration)	RPM	
290	RANG	0-20	0-20	0-(10/-10)	0-200	0-200	0-(100/-100)	Stick	Reduce	Lower
Run	MIN	0.54	0.54	0	1.34	6.71	0	Slip	SWOB	vibration
600	MAX	1.21	1.21	0.273	12	12.08	2.73	(torsional	& increase	
		>2	>2		>20	>20	>10	vibration)	RPM	

Table 5 Identifing the drilling vibration modes and their mitigation ways for Zubair wells (continued)

Well / Run	Value	Avg X(g)	Avg Y(g)	Avg Z(g)	Peak X(g)	Peak Y(g)	Peak Z(g)	Formal & Types	Action	Signs of success
290	RANG	0-20	0-20	0-(10/-10)	0-200	0-200	0-(100/-100)	Stick	Reduce	Lower
Run	MIN	0.13	0.45	0	2.48	1.83	0	Slip	SWOB	vibration
700	MAX	1.2	1.10	0.5	10.58	8.19	2.71	(torsional	& increase	
		>2	>2		>20	>20	>10	vibration)	RPM	
295	RANG	0-20	0-20	0-(20/-20)	0-200	0-200	0-(40/-40)	Stick	Reduce	Lower
Run	MIN	0.2	0.308	0	3.988	0	1.08	Slip	SWOB	vibration
400	MAX	3.77	0.83	0	11.74	0	3.25	(torsional	& increase	
		>2	>2		>20	>20	>10	vibration)	RPM	
295	RANG	0-20	0-20	0-(10/-10)	0-200	0-200	0-(100/-100)	Stick	Reduce	Lower
Run	MIN	0.405	0.4	0.27	2.70	4.08	1.36	Slip	SWOB	vibration
500	MAX	0.945	1.466	0.4	9.45	9.52	4.109	(torsional	& increase	
		>2	>2		>20	>20	>10	vibration)	RPM	
295	RANG	0-20	0-20	0-(10/-10)	0-200	0-200	0-(100/-100)	Stick	Reduce	Lower
Run	MIN	0.42	0.51	0.26	1.37	1.92	2.76	Slip	SWOB	vibration
600	MAX	1.429	1.892	0.742	5.38	9.83	5.17	(torsional	& increase	
		>2	>2		>20	>20	>10		RPM	
311	RANG	0-20	0-20	0-(10/-10)	0-200	0-200	0-(100/-100)	Stick Slip	Reduce	Lower
Run	MIN	0.344	0.28	0.40	3.25	1.97	0	BHA Whirl	SWOB	vibration
400	MAX	4.533	2.27	0.62	18	15.1	3.15	(torsional &	& increase	
		>4	>2		>20	>20	>10	lateral	RPM	
								Vibration)		
311	RANG	0-20	0-20	0-(10/-10)	0-200	0-200	0-(100/-100)	Stick	Reduce	Lower
Run	MIN	0.31	0.5	0	1.7	3.78	0	Slip	SWOB	vibration
500	MAX	2.28	1.38	0	13	11.12	0	(torsional	& increase	
		>2	>2		>20	>20	>10	vibration)	RPM	

Table 5 Identifing the drilling vibration modes and their mitigation ways for Zubair wells (continued)

Well / Run	**Value**	**Avg X(g)**	**Avg Y(g)**	**Avg Z(g)**	**Peak X(g)**	**Peak Y(g)**	**Peak Z(g)**	**Formal & Types**	**Action**	**Signs of success**
311	RANG	0-20	0-20	0-(10/-10)	0-200	0-200	0-(100/-100)	Stick	Reduce	Lower
Run	MIN	0.53	0.93	0	1.35	2.72	0	Slip	SWOB	vibration
600	MAX	2.93	1.46	0	8.1	6.8	0	(torsional	& increase	
		>2	>2		>20	>20	>10	vibration)	RPM	
349	RANG	0-20	0-20	0-(10/-10)	0-200	0-200	0-(100/-100)	Stick	Reduce	Lower
Run	MIN	0.24	0.44	0	1.4	1.53	0	Slip	SWOB	vibration
500	MAX	1.09	1.18	0	7.98	7.21	0	(torsional	& increase	
		>2	>2		>20	>20	>10	vibration)	RPM	
349	RANG	0-20	0-20	0-(10/-10)	0-200	0-200	0-(100/-100)	BHA	Reduce	Lower
Run	MIN	0.67	0.94	0.27	4.026	5.29	1.33	Whirl	RPM	vibration
600	MAX	4.18	2.7	0.54	28.18	23.84	5.33			
		>4	>2		>20	>20	>10			
349	RANG	0-20	0-20	0-(10/-10)	0-200	0-200	0-(100/-100)	Stick	Reduce	Lower
Run	MIN	0.64	0.36	0	4.18	1.14	0	Slip	SWOB	vibration,
700	MAX	1.51	1.35	0.67	19.9	17.32	22.87	(torsional	& increase	Rapid torque
		>2	>2		>20	>20	>20	vibration)	RPM	decreases
367	RANG	0-20	0-20	0-(10/-10)	0-200	0-200	0-(100/-100)	Stick	Reduce	Lower
Run	MIN	2.68	0.13	0	1.36	2.7	0	Slip	SWOB	vibration
300	MAX	0.93	0.94	0	6.8	10.81	0	(torsional	& increase	
		>2	>2		>20	>20	>10	vibration)	RPM	
367	RANG	0-20	0-20	0-(10/-10)	0-200	0-200	0-(100/-100)	Stick	Reduce	Lower
Run	MIN	0.667	0.53	0	2.72	1.34	1.35	Slip	SWOB	vibration
400	MAX	1.33	1.33	0	21.76	16.10	5.4	(torsional	& increase	
		>2	>2		>20	>20	>10	vibration)	RPM	
367	RANG	0-20	0-20	0-(10/-10)	0-200	0-200	0-(100/-100)	Stick	Reduce	Lower
Run	MIN	0.53	0.4	0	1.35	2.66	1.31	Slip	SWOB	vibration
500	MAX	3.46	1.48	0	14.86	18.67	6.57	(torsional	& increase	
		>2	>2		>20	>20	>10	vibration)	RPM	

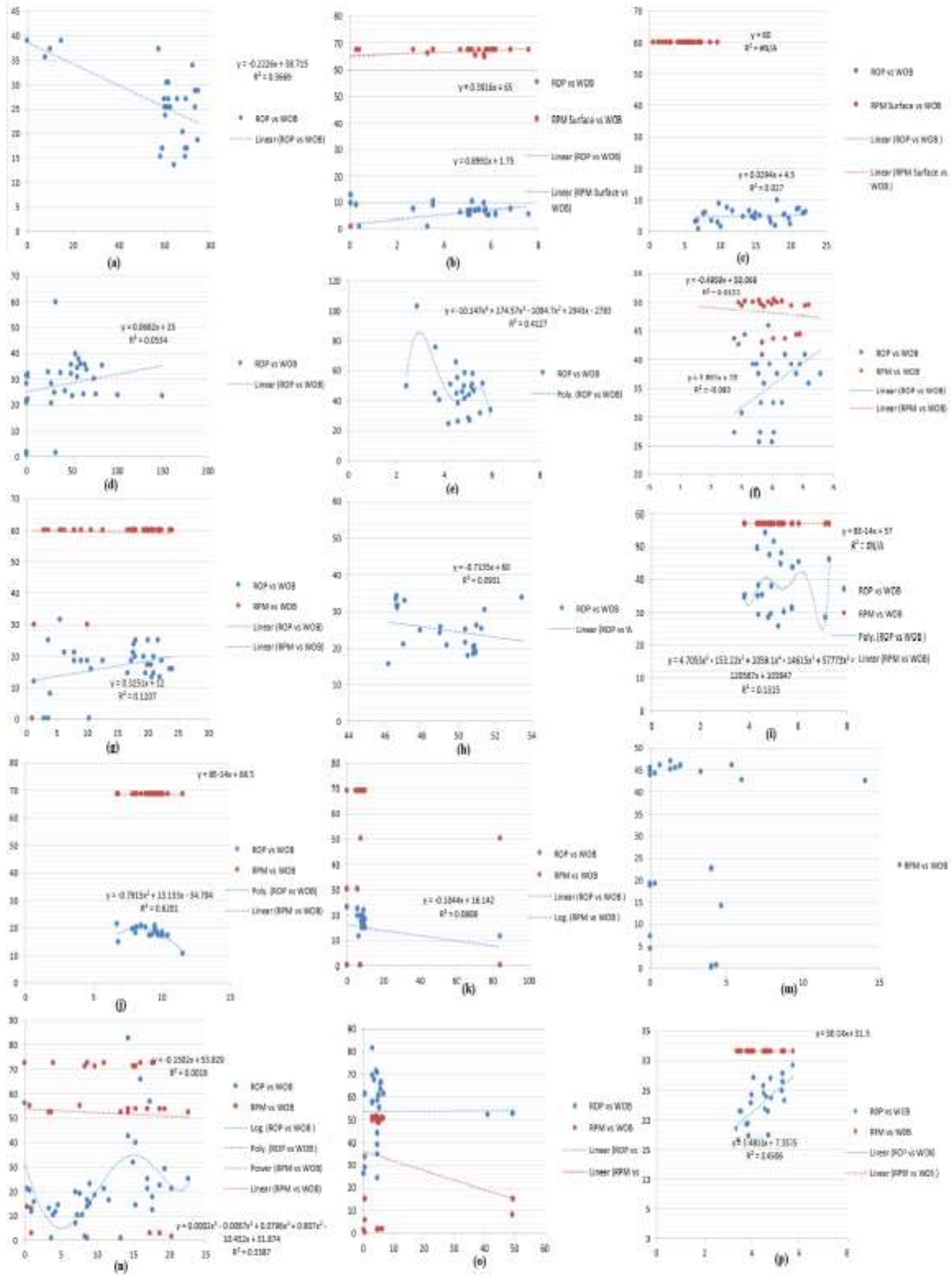

Figure 6 Plotted drilling parameters (WOB, ROP, and RPM) for Zubair wells: (a,b,c) for runs 500, 600, and 700 of ZB 288; (d,e,f) for runs 500, 600, and 700 of ZB 290; (g,h,i) for runs 400, 500, and 600 of ZB 295; (j,k) for runs 500, and 600 of ZB 311; (m,n,o) for runs 500, 600,and 700 of ZB 349; and (P) for run 300 of ZB 367.

CONCLUSIONS

Based on the results and analysis, the following conclusions and recommendations are extracted:

1. The diagnostic-analysis study is very useful for identifying the various vibration modes and their root causes
2. Reducing the surface WOB and increasing RPM are key-elements for mitigating drillstring vibrations
3. Vibration ranking is recommended for determining the acceptable range of drillstring vibration
4. Although plotting drilling parameter may not produce a good correlation or relation, they give an approximate value around the optimum ones.

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