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Optimization of drilling parameters by analysis of formation strength properties with using mechanical specific energy

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By increasing the daily needs of human energy, human manipulation of natural energy sources are expanded and encouraged the human society to developing science, knowledge and technology. Mechanical specific energy is required energy for drilling the unit of formation volume of oil wells. This parameter can be used for functional analysis of drilling, drilling bit optimization and investigating of instability has been made during drilling operations. This parameter can be used for decreasing of drilling costs of oil wells by increasing drilling speed, optimized the useful life of the drilling bit and determine the right time to replace the drilling bit, and in some cases reduced to a minimum amount. In South Pars field in Iran many wells have been drilled, however detailed statistics processes hadn't done for optimizing drilling parameters and their impact on mechanical specific energy. By results of this study we can use to analyze performance and drilling parameters such as weight on drilling bit, rotational speed, penetration rate, etc. In most cases, mechanical specific energy at the end of each drilled wells, because of reducing movement speed has been increased. Although by investigating middle formations in section of 12.25 inch, all existing wells on a platform in one of the phases of Iran's South Pars field are being studied, which contains formations such as Hith, Surmeh, Neyriz, Dashtak and Kangan.

Studies was done in two parts. In the first part, the range of optimized drilling parameters that is increasing drilling speed and reducing the required amount of energy for drilling formation. This process by investigating mechanical specific energy and its relationship with uniaxial compressive strength in five studied formation have been presented. In the second part, correlations to predict the mechanical specific energy in this area by statistical methods by SPSS software, presented and reviewed. Then, by the most appropriate relationship, the most influential drilling parameters on mechanical specific energy have been set.

However, for drilling the next wells in this area drilling parameters with the most priority influences on mechanical specific energy, proposed in the optimum range, will be recommended.

Keywords: mechanical specific energy, drilling bit penetration rate, compressive strength, statistical methods, oil wells.

INTRODUCTION

Special mechanical energy, is the required amount of energy for drilling the formation. This parameter is a function of drilling parameters such as weight on bit, rotational speed, torque, drilling penetration rate in the formation and the well diameter. Although if you used mud pumps, this parameter depended to proportion of speed to flow rate, the maximum rate of torque and maximum rate of pressure difference.

Mechanical specific energy for both relational concept and correlational was introduced in 1964 by Tail. Since this parameter used in the diagnosis of instability during drilling operations was valuable. Drilling engineers are always by applying different weights on bit, speed of rotation and mud flow rate within the range of normal operation. They try to minimize the amount of mechanical specific energy and maximize the penetration rate of bit on the formation. Drilling engineers always try to approach mechanical specific energy within current formation compressive strength. Unexpected changes in mechanical specific energy may indicate changes in the rock properties or drilling instabilities or both of them. In an ideal process, there is a relationship between input energy and an accurate compressive strength of a formation. However, this one by one relationship to compare with uniaxial compressive strength due to the effect of hydrostatic pressure of mud column on the depth, does not remain.

By optimizing of mechanical specific energy, we can reduce unappreciable non-beneficial times and also drilling costs by using drilling optimization parameters for increasing beneficial life of bit, increasing penetration rate to maximum limit(without types of bit) and obtain optimum time for changing bit(when the performance of bit is lower than optimum limit).

By accurate using of mechanical specific energy within analysis of this parameter, it can be diagnosed for slowing bit speed or damaged bits, choosing efficient bit for current formation,

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efficient rotation per minute and inhabitation of poor mud circulation.

In Iran, despite drilling many wells in South Pars field, statistical research to optimize independent drilling parameters such as weight on bit, bit rotational speed, drilling speed and also its impact on each of the relevant parameters (mechanical specific energy) has not been done. Also due to high costs of hiring drilling rigs and limit use of some tools such as bit and borehole assembly that we have in Iran, this research is done for optimizing drilling parameters due to formation strength parameters by using mechanical specific energy.by investigating mechanical specific energy and its relationship with uniaxial compressive strength with increasing drilling speed, lengthen beneficial life of bit and borehole assembly, we can optimize costs that it is the main concern of petroleum companies.

WORKING PROCEDURE

The principal of this research can be divided into two parts.

In the first part, the data are collected in the study area. Then which points that have higher drilling speed and also have lower mechanical specific energy and the ratio of mechanical specific energy to uniaxial compressive strength, in each well and formation to formation are separately recognized. Drilling parameters are collected at these point and with summarizing all of these data in all wells, for formations such as Hith, Surmeh, Neyriz, Dashtak and Kangan, range of optimum drilling parameters and so the amount of increasing penetration rate and decreasing mechanical specific energy will be determined.

In the second part, firstly descriptive statistics, including the number of samples, the highest and lowest dispersion and its causes will examine. Then, in inferential statistics, there are some correlations for estimating mechanical specific energy by SPSS software in the studied area and their accuracy are investigated and optimum linear and non-linear correlation are determined. Then with the most appropriate correlation the most influential independent parameters on mechanical specific energy will be obtained.

A total of first and second stages, for appropriate optimization of mechanical specific energy during drilling, efficient drilling parameters on mechanical specific energy(obtained in the second stage),in the optimal range, increasing drilling speed and reduce mechanical specific energy, for drilling other wells in this area (South Pars field in Iran) is recommended. More detailed statistical and inferential methods are further summarized.

CASE STUDY

1. Data collection

To collect and summarize all information related to wells 1 to 10, in Table 1-1 range of each independent parameters such as weight on bit , pressure difference, rotation per minute and flow rate, dependent drilling parameters, including penetration rate mechanical specific energy for section with 12.25 inch diameter that Total investigated wells are examined for each formation. In studied area range of independent drilling parameters including the rotational velocity in the range of 0 to 120 (RPM), weight on bit from 0 to 223 (kIbs), mud flow rate from 200 to 9000 (psi), the pressure difference of 10 to 1270 (psi) and of torque from 0 to 29 (kFT-Ib) is. This has led to a range of dependent drilling parameters include penetration rate of between 0.96 to 107.69 (ft / hr) and particularly mechanical specific energy between the 0 to 34292.5 (MPa).

2- Identify the optimum points in each of the formations

In the following tables, the areas with the highest drilling velocity, the lowest mechanical specific energy and the ratio of the lowest amount of mechanical specific energy to uniaxial compressive strength are the optimum points.by determining these points independent drilling parameters appropriate with those data that prepared these optimum points. This information is then presented in Tables 1-1 to 1-5.

Table 1-1: Optimization of drilling in the formation Hith

Formation	well	Original Points	From	To	Drilled	ROP	rpm	min WOB	max WOB	Flow	ΔP	min TQ	max TQ	MES	MES/UCS
Hith	1	MSE(min)	1853.2	1882.1	28.9	12.8444	40	15	20	843	340	10	13	69.551	0.46
		rop(max)	1930	1939	9	18	70	20	22	845	290	8	14	70.8595	0.469
		MSE/UCS(min)	1853.2	1882.1	28.9	12.8444	40	15	20	843	340	10	13	69.551	0.46
	4	MSE(min)	1840	1854	14.4	13.7	40	15	22	855	180	9	14	37.867	0.25
		rop(max)	1911	1939	28.3	24.8	120	19	24	855	300	5	13	81.858	0.542
		MSE/UCS(min)	1840	1854.4	14.4	13.7143	40	15	22	855	180	9	14	37.867	0.25
	5	MSE(min)	1980	1986	6	3.52941	90	12	15	795	280	0	0	0.00012	6.62E+07
		rop(max)	2020	2030.9	10.9	16.0294	90	13	16	795	310	13	17	191.981	1.271
		MSE/UCS(min)	1980	1986	6	3.52941	90	12	15	795	280	0	0	0.00012	6.62E+07
	6	MSE(min)	1877	1892	15	18.9873	40	18	24	900	300	7	11	33.0802	0.219
		rop(max)	1877	1892	15	18.9873	40	18	24	900	300	7	11	33.0802	0.219
		MSE/UCS(min)	1877	1892	15	18.9873	40	18	24	900	300	7	11	33.0802	0.219
	7	MSE(min)	1908	1911	3	9.09091	30	3	12	820	120	10	15	40.5985	0.268
		rop(max)	1990.5	2019	28.5	21.1111	100	18	20	800	240	10	18	130.537	0.864
		MSE/UCS(min)	1908	1911	3	9.09091	30	3	12	820	120	10	15	40.5985	0.268
	9	MSE(min)	1766.5	1767.5	1	10	90	4	25	822	110	6	11	86.8285	0.575
		rop(max)	1835	1845	10	19.2308	105	19	21	835	250	5	13	126.76	0.839
		MSE/UCS(min)	1766.5	1767.5	1	10	90	4	25	822	110	6	11	86.8285	0.575
	10	MSE(min)	1752	1772	20	41.6667	50	15	18	797	220	10	12	25.8027	0.17
		rop(max)	1752	1772	20	41.6667	50	15	18	797	220	10	12	25.8027	0.17
		MSE/UCS(min)	1752	1772	20	41.6667	50	15	18	797	220	10	12	25.8027	0.17
	12	MSE(min)	1795	1809.8	14.8	13.2143	60	15	20	800	300	8	15	112.6	0.745
		rop(max)	1868	1895	27	26.7327	110	23	25	910	310	10	15	114.613	0.759
		MSE/UCS(min)	1795	1809.8	14.8	13.2143	60	15	20	800	300	8	15	112.6	0.745
	14	MSE(min)	1781.4	1799	17.6	9.16667	70	18	24	900	205	8	13	166.912	1.105
		rop(max)	1838.5	1867	28.5	11.5385	100	18	25	900	240	8	17	290.013	1.92

		MSE/UCS(min)	1781.4	1799	17.6	9.16667	70	18	24	900	205	8	13	166.912	1.105

Table 1-2: Optimization of drilling in the formation Surmeh

Formation	well	Original Points	From	To	Drilled	ROP	rpm	min WOB	max WOB	Flow	ΔP	min TQ	max TQ	MES	MES/UCS
Surmeh	1	MSE(min)	2566	2567	1	5.26	0	30	35	875	90	0	0	0.00028	2.82E-06
		rop(max)	2069	2081.4	12.4	56.3636	115	18	24	875	440	7	13	51.2784	0.339592
		MSE/UCS(min)	2566	2567	1	5.26	0	30	35	875	90	0	0	0.00028	2.82E-06
	4	MSE(min)	2397	2411	14	7.25389	0	1	10	800	100	0	0	4.67E-05	5.1E-06
		rop(max)	2194.5	2207	12.5	69.4444	120	20	25	900	300	7	17	45.2235	0.32
		MSE/UCS(min)	21638	2174.6	6.6	5.40698	0	5	8	900	180	0	0	5.52E-05	5.1E-06
	5	MSE(min)	2300	2304	4	9.09091	0	3	5	840	50	0	0	3.40E-05	3.06E-07
		rop(max)	2590	2600	10	43.4783	120	6	15	843	350	15	25	118.843	1.7
		MSE/UCS(min)	2094	2099.5	5.5	5.28846	0	4	5	795	50	0	0	3.82E-05	3.06E-07
	6	MSE(min)	1908	1914	6	5.40541		10	20	900	140	0	0	0.00013	6.62E-07
		rop(max)	2092	2092	12	70.5882	100	20	28	900	180	8	14	42.0923	0.298
		MSE/UCS(min)	1908	1914	6	5.40541		10	20	900	140	0	0	0.00013	6.62E-07
	7	MSE(min)	2981	2992.5	11.5	7.41936		10	20	850	160	0	0	0.00013	1.02E-05
		rop(max)	3005	3008	3	50	120	10	12	850	270	11	22	114.001	1.163
		MSE/UCS(min)	2822	2825.6	3.6	3.39623	0	5	25	800	150	0	0	0.00013	1.02E-05
	9	MSE(min)	2162.5	2165	2.55	3.89438	0	2	5	833	70	5	13	2.97E-05	2.11E-07
		rop(max)	2469	2475	6	35.2941	105	1	10	900	280	6	13	66.6123	0.662
		MSE/UCS(min)	2162.5	2165	2.55	3.89438	0	2	5	833	70	5	13	3E-05	2.11E-07
	10	MSE(min)	2326	2330.4	4.4	3.89381	0	1	5	800	40	0	0	2.55E-05	3.06E-07
		rop(max)	2204.8	2233.5	28.7	37.2727	70	10	20	800	220	10	17	45.7477	0.56
		MSE/UCS(min)	1954.5	1969.3	14.8	5.32374	0	0	5	800	100	0	0	2.6E-05	1.99E-07
	11	MSE(min)	2618.3	2621	2.7	10.3846		5	10	950	100	14	22	6.37E-05	5.56E-07
		rop(max)	3050	3050.8	0.8	40		80	80	898	70	0	0	0.00068	6.93E-05
		MSE/UCS(min)	3050.8	2621	-430	10.3846		5	10	950	100	14	22	6.4E-05	5.56E-07
	12	MSE(min)	1981	2000.1	14.8	39.7917	110	19	23	905	350	11	17	97.3658	0.644

		rop(max)	2009.6	2038.5	27	46.6129	110	20	25	905	445	10	18	105.678	0.699
		MSE/UCS(min)	1981	2000.1	14.8	39.7917	110	19	23	905	350	11	17	97.3658	0.644
	14	MSE(min)	1979	1982	17.6	42.8571	105	10	18	850	200	5	16	64.3015	0.425
		rop(max)	2066.5	2073	28.5	43.3333	105	12	20	850	375	6	19	145.324	1.03
		MSE/UCS(min)	1979	1982	17.6	42.8571	105	10	18	850	200	7	16	64.3015	0.425

Table 1-3: Optimization of drilling in the formation Neyriz

Formation	well	Original Points	From	To	Drilled	ROP	rpm	min WOB	max WOB	Flow	ΔP	min TQ	max TQ	MES	MES/UCS
NEYRIZ	1	MSE(min)	2990	2998.7	8.7	28.0645	120	7	9	845	160	8	18	55.09	5.60E-01
		rop(max)	2998.7	3004	5.3	31.1747	120	4	6	845	330	8	16	196.9897	0.927
		MSE/UCS(min)	2990	2998.7	8.7	28.0645	120	7	9	845	160	8	18	55.09	0.56
	4	MSE(min)	2927	2955.5	28.5	22.8	120	8	21	850	260	8	18	2.19E+02	2.356
		rop(max)	2927	2955.5	28.5	22.8	120	8	21	850	260	8	18	2.19E+02	2.356
		MSE/UCS(min)	2927	2955.5	28.5	22.8	120	8	21	850	260	8	18	2.19E+02	2.356
	5	MSE(min)	3289.8	3295.3	5.8	14.5	120	8	11	922	130	15	22	1.53E+02	1.56E+00
		rop(max)	3295.3	3306.5	11.2	15.5556	120	6	10	922	200	17	22	231.89	2.366
		MSE/UCS(min)	3289.8	3295.3	5.8	14.5	120	8	11	922	130	15	22	1.53E+02	1.56E+00
	6	MSE(min)	2789.8	2818	28.2	17.7359	120	15	18	900	325	8	19	96.71303	4.58E+00
		rop(max)	2789.8	2818	28.2	17.7359	120	15	18	900	325	8	19	96.71303	4.577
		MSE/UCS(min)	2789.8	2818	28.2	17.7359	120	15	18	900	325	8	19	96.71303	4.577
	7	MSE(min)	3033.6	3061.3	27.7	15.0544	120	15	25	750	300	10	21	395.203	2.224
		rop(max)	3033.6	3061.3	27.7	15.0544	120	15	25	750	300	10	21	395.203	2.224
		MSE/UCS(min)	3033.6	3061.3	27.7	15.0544	120	15	25	750	300	10	21	395.203	2.224
	9	MSE(min)	2773	2788	15	20.548	120	10	20	895	350	6	13	1.77E+02	1.63E+00
		rop(max)	2773	2788	15	20.548	120	10	20	895	350	6	13	177.4622	1.625
		MSE/UCS(min)	2773	2788	15	20.548	120	10	20	895	350	6	13	177.4622	1.625
	10	MSE(min)	2689.9	2718.7	28.8	28.2353	60	9	22	800	330	5	17	6.33E+01	9.35E-01
		rop(max)	2689.9	2718.7	28.8	28.2353	60	9	22	800	330	5	17	63.26608	0.935
		MSE/UCS(min)	2689.9	2718.7	28.8	28.2353	60	9	22	800	330	5	17	63.26608	9.35E-01

	11	MSE(min)	3430.4	3459	28.6	16.7252	100	5	10	950	160	14	26	3.82E+02	2.66E+00
		rop(max)	3430.4	3459	28.6	16.7252	100	5	10	950	160	14	26	382.498	2.657
		MSE/UCS(min)	3430.4	3459	28.6	16.7252	100	5	10	950	160	14	26	382.498	2.657
	12	MSE(min)	3072.7	3101	28.3	13.4123	120	15	23	905	220	10	20	429.2771	2.536
		rop(max)	3072.7	3101	28.3	13.4123	120	15	23	905	220	10	20	429.7771	2.536
		MSE/UCS(min)	3072.7	3101	28.3	13.4123	120	15	23	905	220	10	20	429.2771	2.536
	14	MSE(min)	2785.3	2814	28.7	18.9934	120	10	15	880	170	9	16	143.1483	1.409
		rop(max)	2785.3	2814	28.7	18.9934	120	10	15	880	170	9	16	143.1483	1.409
		MSE/UCS(min)	2785.3	2814	28.7	18.9934	120	10	15	880	170	9	16	143.1483	1.409

Table 1-4: Optimization of drilling in the formation Dashtak

Formation	well	Original Points	From	To	Drilled	ROP	rpm	min WOB	max WOB	Flow	ΔP	min TQ	max TQ	MES	MES/UCS
Dashtak	1	MSE(min)	3314.5	3315.5	1	3.44828	115	20	30	857	10	11	13	10.91976	7.50E-01
		rop(max)	3004	3007.9	3.9	27.8571	120	1	2	845	260	8	16	45.1.3396	0.818
		MSE/UCS(min)	3314.5	3315.5	1	3.44828	115	20	30	857	10	11	13	10.91976	0.75
	4	MSE(min)	2997	3003.7	6.7	3.52632	0	10	22	850	160	0	0	1.36E-04	1.02E-06
		rop(max)	2958	2960	2	25	120	10	18	850	150	8	18	1.03E+02	1.0911
		MSE/UCS(min)	2997	3003.7	6.7	3.52632	0	10	22	850	160	0	0	1.36E-04	1.02E-06
	5	MSE(min)	3323.4	3334	10.6	14.3243	120	10	15	922	180	15	24	2.67E+02	1.77E+00
		rop(max)	3493.4	3514	20.2	19.2381	120	20	25	920	240	21	24	259.6177	1.643
		MSE/UCS(min)	3514	3522.1	8.1	16.5306	120	18	23	920	195	20	24	2.40E+02	1.52E+00
	6	MSE(min)	2826	2827	1	6.66667	100	2	6	900	60	9	12	94.46068	7.37E-01
		rop(max)	2827	2830	3	13.6364	100	9	12	900	240	9	26	307.8718	2.405
		MSE/UCS(min)	2826	2827	1	6.66667	100	2	6	900	60	9	12	94.46068	0.737
	7	MSE(min)	3443	3444	1	8.33333	80	5	8	620	85	13	19	160.62	1.46
		rop(max)	3374	3388	14	21.2121	120	10	15	800	340	12	26	2982.986	2.838
		MSE/UCS(min)	3443	3444	1	8.33333	80	5	8	620	85	13	19	160.62	1.46
	9	MSE(min)	3164	3165	1	12.5	80	15	20	835	240	6	12	1.34E+02	1.41E+00
		rop(max)	2801	2807.5	6.5	17.5676	105	14	16	900	370	7	11	163.24	1.275

		MSE/UCS(min)	2994	2995	1	3.7037	80	1	5	800	100	7	14	137.397	0.869
	10	MSE(min)	2747	2775.7	28.7	19.7931	60	18	22	800	320	7	12	7.86E+01	6.14E-01
		rop(max)	2718.7	2747	28.3	21.4394	60	15	22	800	320	8	16	91.66605	0.935
		MSE/UCS(min)	2747	2775.7	28.7	19.7931	60	18	22	800	320	7	12	78.60491	6.14E-01
	11	MSE(min)	3587.5	3587.7	0.2	6.66667	10	1	1	200	10	20	20	3.20E+00	2.40E-02
		rop(max)	3459	3482.4	23.4	15.1948	100	10	25	950	222	14	26	311.5558	4.058
		MSE/UCS(min)	3587.9	3587.7	0.2	6.66667	10	1	1	200	10	20	20	3.198676	0.024
	12	MSE(min)	3427	3427.5	0.5	3.57143	50	10	10	905	30	17	17	83.04912	0.525
		rop(max)	3441.1	3469.5	28.4	16.7929	100	20	25	905	260	17	20	333.1624	2.289
		MSE/UCS(min)	3427	3427.5	0.5	3.57143	50	10	10	905	30	17	17	83.04912	0.525
	14	MSE(min)	3199	3213	14	107.692	100	20	25	880	150	10	15	23.20481	0.174
		rop(max)	3199	3213	14	107.692	100	20	25	880	150	10	15	23.20481	0.174
		MSE/UCS(min)	3199	3213	14	107.692	100	20	25	880	150	10	15	23.20481	0.174

Table 1-5: Optimization of drilling in the formation Kangan

Formation	well	Original Points	From	To	Drilled	ROP	rpm	min WOB	max WOB	Flow	ΔP	min TQ	max TQ	MES	MES/UCS
Kangan	1	MSE (min)	3750	3758	8	10.3896	115	25	28	846	290	13	15	429.0907	3.90E+00
		Rop (max)	3758	3766	8	10.8108	115	25	28	846	335	13	15	476.3617	2.977
		MSE/UCS (min)	3766	3768	2	10	105	25	28	846	190	13	15	470.2043	2.938
	5	MSE (min)	4121.6	4127	5.4	5	120	18	21	800	150	20	25	1.44E+03	9.00E+00
		Rop (max)	4121.6	4127	5.4	5	120	18	21	800	150	20	25	1439.4	8.996
		MSE/UCS (min)	4121.6	4127	5.4	5	120	18	21	800	150	20	25	1439.4	9.00E+00
	6	MSE (min)	3441	3442	1	1.96078	110	30	33	900	80	9	11	717.7812	6.53E+00
		Rop (max)	3460	3462.5	2.5	2.23214	110	30	33	900	120	9	14	1673.307	10.458
		MSE/UCS (min)	3441	3442	1	1.96078	110	30	33	900	80	9	11	717.7812	6.525
	11	MSE (min)	4253.8	4261	7.2	2.75862	110	20	30	850	110	25	29	2.53E+03	2.30E+01
		Rop (max)	4253.8	4261	7.2	2.75862	110	20	30	850	110	25	29	2525.428	22.958
		MSE/UCS (min)	4253.8	4261	7.2	2.75862	110	20	30	850	110	25	29	2525.428	22.958
	14	MSE (min)	3526	3550	24	6.4	120	24	28	875	160	11	16	809.6629	7.36
		Rop (max)	3526	3550	24	6.4	120	24	28	875	160	11	16	809.6629	7.36
		MSE/UCS (min)	3526	3550	24	6.4	120	24	28	875	160	11	16	809.6629	7.36

Table 1-6: optimum range of independent drilling parameters in total investigated wells

Formation	N(RPM)			WOB(kIbs)			Flow(gal/min)			ΔP(psi)			TQ(KFT-Ib)		
	min	max	Average (Around)	min	max	Average (Around)	min	max	Average (Around)	min	max	Average (Around)	min	max	Average (Around)
Hith	30	120	66.85	3	25	17.55	795	910	840.77	110	340	243.33	0	18	10.22
Surmeh	0	120	77.5	0	80	35.75	795	950	864.4	40	445	195.33	0	25	7.43
Neyriz	60	120	111	4	25	33.65	750	950	869.7	130	350	248.5	5	26	14.15
Dashtak	0	120	81.5	1	30	33.63	200	950	808.36	10	370	163.9	0	26	13.61
Kangan	105	120	114.33	18	33	25.7	800	900	854.2	80	335	157	9	29	17.5

Table 1-7: optimum range of dependent drilling parameters in total investigated wells

Formation	ROP(ft/hr)			MSE(Mpa)			MSE/UCS		
	min	max	Average (Around)	min	max	Average (Around)	min	max	Average (Around)
Hith	3.53	41.66	17.13	0.000758423	1999.549	578.7459	4.57E-06	13.23793	3.73695845
Surmeh	3.4	70.59	25.16	1.75E-04	1001.946	243.1781	1.37E-06	11.72109	2.11669048
Neyriz	13.41	31.14	19.745	379.8321786	2959.712	1508.78	3.861064	31.5573	14.3410951
Dashtak	3.44	107.69	21.73	0.000930792	2297.071	816.0635	7.03E-06	27.97893	7.27396893
Kangan	1.96	10.81	5.32	2598.471401	17412.16	8645.06	20.2568	158.2898	69.4991534

STATISTICAL METHOD

1.Descriptive statistics

In this research to determine display characteristics of descriptive properties, a collection set data, the range of changes, minimum and maximum average, offset scale and gear ratio of changes are provided in the Table 1-8 that the purpose of this investigate to affect any of the existing parameters on mechanical specific energy. That's why parameters (TQ, ΔP, Q, WOB, N, ROP and drilled) become independent variables. Changes in these parameters will change in the MSE as a dependent parameter.

Table 1-8: Descriptive characteristics of data collection that are used

Parameter	Unit	Range of changes	Minimum	Maximum	average	Offset scale	Ratio of changes
riDlled	m	29.6	0	29.6	10.36	9.033	0.872
ROP	ft/hr	38.49	1.3	39.79	11.75	8.31	0.707
N	RPM	110	20	130	103.89	19.938	0.192
WOB	Klbs	32.5	1	33.5	18.96	7.381	0.389
Q	GPM	300	650	950	866.75	49.171	0.057
ΔP	psi	510	10	520	225.49	81.034	0.359
TQ	Kft.lbs	20	7	27	15.04	4.694	0.312
MSE	ksi	3366.97	19.62	3386.59	494.53	468.977	0.948

The number of collection samples are 1485 that show the importance of derived correlations from the investigated formations in different wells. The range of changes and the offset scale, is important indicators for measuring volume dispersion amount one variable a. Average is the most important and easiest central index data. Using the average it can be compared many number of variables together. Gear ratio of the changes obtained from divided offset scale of one variable on average, relative index for comparing different variables, whatever the gear ratio of the changes to be more, variable distribution will be more.

Mechanical Specific energy has the biggest range of changes, the offset scale and gear ratio of changes. High dispersion of this variable, due to the different resistor properties in different lithology. After mechanical specific energy, pressure difference has the highest scope of the changes and the offset scale, low pressure difference relevant to low special weight and high pressure difference represents high special weight of cuttings in that part. The least range of changes and the offset scale related to the torque and the lowest gear ratio of changes related to the mud flow rate that is revealed parameters were close and less distribution.

The histogram is a method to display the distribution of data in different quantity categories. The range of parameters related to this region in addition to the table descriptive characteristics specified in Fig1-1. Proposal relations related to this ranges and if we use this equations for outside parameters of the range it needs more careful nesses and more caution.

2, Inferential statistics

As we know, this statistical method can refer to regression method. In the inferential statistics, linear correlations and non-linear correlations are evaluated.

3. Wrap up

in this case firstly descriptive statistics that includes number of samples, the most and the least dispersion and their reasons are review. For the studied area, investigated descriptive characteristics shows the range of the changes, the offset scale and high gear ranges of mechanical specific energy, pressure differences and true vertical depth that shows more dispersion on this variables. Low amount of these parameters such as torque, rotational speed and mud flow rate, revealed low dispersion for this parameters.

Then, in inferential statistics there were correlations to predict mechanical specific energy in the studied area by using statistical methods with SPSS software was presented. The most appropriate Linear and non-linear correlations were investigated.by investigating suggested correlations in the studied field and compare their accuracy , the following results were obtained:
-In the proposed linear equations, linear correlation without intercept, with number of test 383/946 , correlation coefficients 0/904 and coefficients of determination 0/818 , is superior and more reliable than linear correlation with intercept , the statistic test 344/567 , correlation coefficients 0/788 and coefficient of determination is 0/62.

In comparison of non-linear correlation, proposed non-linear correlation with a coefficient of determination 0/775, the two proposed non-linear correlations to state that we didn't use the mud pump in the well coefficient of determination were 0/819 and 0/813. When we use the mud pump in the well coefficient of determination were 0/837 and 0/832 that compared to other non-linear correlations were higher. This represents a further connection between the parameters and higher accuracy, especially in mechanical specific energy correlation with other independent drilling parameters into two correlations.

RESULTS AND DISCUSSION

1. To use the results of this study, it should be considered that the range of parameters provided, in addition to the descriptive specification table, in normal curve and drilling histogram parameters are specified. As well as from a variety of statistical methods, SPSS software was used in this research. Several proposed correlations for mechanical specific energy was done by this software.

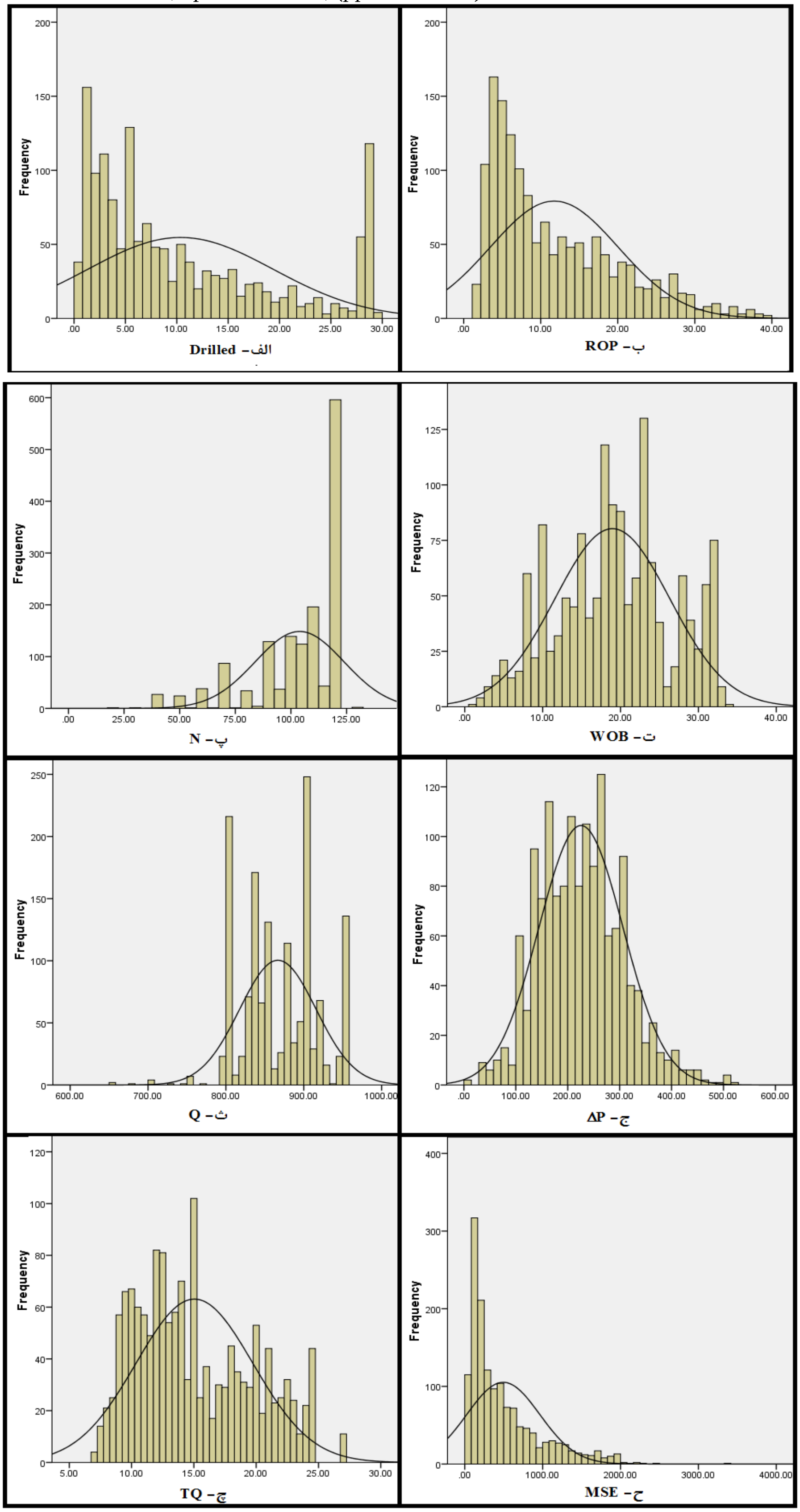

Fig 1-1: Normal curve and histogram of drilling parameters. a)Drilled; b) ROP.c) N, d) WOB, e) Q f)□□□**P** , g) TQ , h) MSE

2. It is recommended that the neural network application software must be designed to determine with serial changes in drilling parameters, the most appropriate model for achieving the optimal combination of mechanical specific energy.

3. As noted above, the mechanical specific energy can help for checking drilling performance (selecting and optimizing drilling parameters), checking the performance of bit (bit design with more efficiency) and the instability of drilling operations. Although appropriate statistical processed for optimizing drilling parameters and their effect on mechanical specific energy on the studied area hadn't been done and also mechanical specific energy have an important role in reducing costs. In this research by using mechanical specific energy we can analyze and optimized drilling parameters on the part of Iran's South Pars field. As a result of this research it recommended that by using mechanical specific energy to investigate drilling instabilities during operation (which can include bit plunging and BHA in the mud, vibrations, improper cleaning of wells, etc.) and checking the bit performance in the area. By selecting the appropriate type of bit (fixed cutter, PCD, etc.), appropriately designed of bit (number of blades, size and density of cutters, , number and size of nozzles) and taking cutting depth, adjacent pressure and etc., must be increased drilling speed and minimize the damages to the bit.

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