Designing a Device for Physical Modeling of Sand Production

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ABSTRACT
When oil and gas are extracted from hydrocarbon reservoirs, sand production cost's too much every year in oil and gas industries the process of sand production causes erosion in pipes, faucets and valves, and every could stop the production. Separating the grains produced out of oil could be expensive itself. Cleaning the production line from the produced sand, needs hard work; there fore all these problems a kick are caused during sand production process have always made gas and oil producing companies find ways to handle the problems. In this study, using a device made to simulate the sand production process, the mechanism of the process of sand production was studied and in various conditions of fluid pressure and stress, the amount of sand produced was measured and studied. With this device, various rocks could be experimented with different types of fluids, under various stress conditions of modeling and prediction of sand production. In this study, sand with determined grain grading, and water were used to simulate sand production under various condition of pressure the Results showed that the fluid's higher pressure causes early damage in the pressure arc in rocks, and also in sand production consequently once the pressure are is damaged, the stress and the fluid's pressure dropped down immediately the experiments, also, revealed that the amount of sand produced increased just as the pressure are is damaged, and after that decrease. In this study, neural fuzzy network and multi-variable regression were used in order to study and analyze the experiment's results and to extract a proper pattern. The analyses show that there are a reasonable trend and an appropriate correlation among variables, and that the repeatability of the device is satisfactory, so it could be used to simulate sand production.

Keywords: Sand production; Physical modeling device; Oil well; neural fuzzy network

1. INTRODUCTION

When hydrocarbons are produced from a reservoir, solid particles sometimes follow the reservoir fluid into the well. This unintended byproduct of the hydrocarbon production is called solids production.

The amount of produced solid can vary from a few grams per cubic meter of reservoir fluid, which usually represent a minor problem, to a catastrophic amount which may lead to a complete filling of the borehole [1, 2]. Figure 1 shows the sand production process. In the first stage, around the borehole, some other small holes come to exist just because of the sand production. In the second stage, these holes will be extending and in the third stage extended holes reach each other and make a bigger hole which causes sudden entrance of sand into the well.

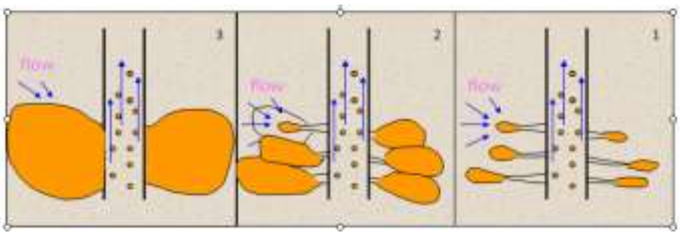

Fig. 1. Sand production process

When a hole in a porous layer (media), which is full of a high pressure fluid, comes to exist, then the fluid under pressure has a tendency to move toward the low pressure hole [1]. This movement is intensified near the hole and forces a power on porous layer grains which separates porous layer grain from primary matrix and leads them into the hole. About reservoir sandstone, while producing, there is a possibility of the above process [3-5]. In these reservoirs, there would be some holes in walls of the well to increase the amount of production. These holes are major oil producers and well stabilities depend on them. Sand production phenomenon which is noticed above will occur in these holes (Figure 2).

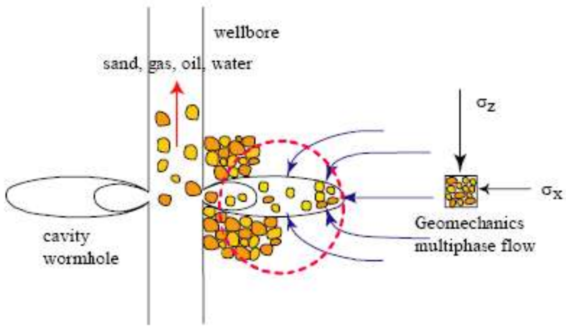

Fig. 2. Mechanism of sand production [6]

Major reasons of sand production are as follow:
Disturbed stress balance in layer
Established movement power by moving fluid
Reservoir pressure reduction
Toughness reduction of the structure
Fatigue of the rock
Production increase

Generally, concerning the amount of sand production in the well, sand production is divided into 3 states: unstable, stable and catastrophic [1].
Techniques to predict sand production are generally categorized as three groups of field observations (experimental), laboratory tests, and theoretical models. In experimental method [7, 9], a relation is established between the data achieved from sand production in wells and the parameters involved in this process. Since picking and monitoring such parameters in wells is not an easy job to do, we will face limitations in selecting the number of effective parameters in the sand production. Obviously, the lesser these parameters are, the simpler but less actual would be the estimations, and vice versa. In the laboratory methods [10-16] of sand production, this phenomenon is analyzed under controlled laboratory conditions where different mechanisms of sand production and the effect of various parameters on this phenomenon are realized. Analytical techniques are used in most methods of estimating [17-30] sand production to survey the stability of holes and cavities. In such cases, mathematical formulation is applied in respect to sand failure mechanism.

2. DESIGNING OF THE DEVICE

In order to predict the sand production in boreholes, this device can model rock or different particles of sand with different fluid flow under different stress. Of course, there is the possibility to change the number and size of perforations around the well. So, this device has the ability for physical modeling of sand production during different status. The device is shown in Figure 3.
The different parts of device are as below:
A steel cylinder with inner diameter of 35.8 cm, outer diameter of 40.6 cm, height of 20 cm.
A piston with diameter of 35.6 cm and thickness of 1.5 cm.
A pipe with inner diameter of 2.5 cm and outer diameter of 3.5
A circle steel sheet with diameter of 20 cm and thickness 1.5 cm
A jack with 600 bar capacity
Fluid pump with 4 bar capacity
A fluid tank with a volume of 40 liter
4 barometer
5 valve control

Fig. 3. Picture of the modeling device

3. PERFORMANCE MECHANISM OF THE DEVICE

At first the rock is placed inside the device cylinder. Then the piston is placed on its top surface. After that suitable of required stress will be applied to the rock by the jack. Afterwards fluid flow injects pressure and enters into the reservoir rock in order to saturate the rock and to flow the fluid out of the central pipe (well) of the device. As soon as the fluid comes out of the central pipe, the amount of fluid and sand are measured. It should be note that sand production can be measured with different grading of artificial or natural gravel. In this paper, water has been used as fluid and determined grained sand as reservoir rock. The experiments have been performed with Various fluid pressure from 0.2 to 2 bar and the pressure on the device from 0 to 200 bar with perforation diameter 1.5 and 3.3 cm which the amount of sand production in every level has been measured. Fluid flow direction in modeling device and schematic device has been shown in Figure 4. The physical characteristic of sand is shown in Table 1, the test results are shown in Table 2, and the provided image of lenses around the well perforation after doing the experiment is shown in Figure 5.

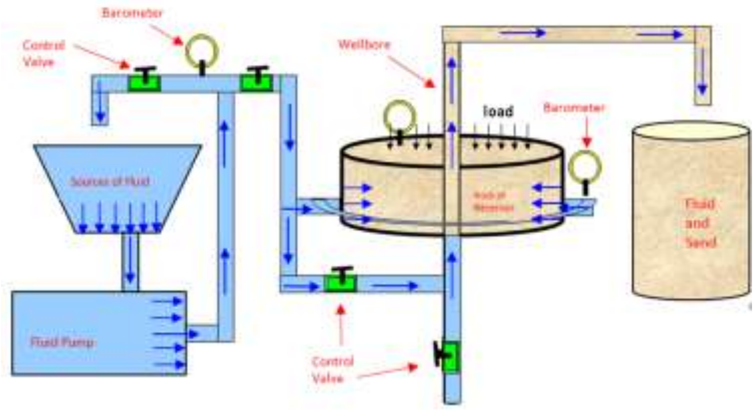

Fig. 4. Schematic of the sand production modeling device (not to scale)

Table 1. Physical properties of fine sand

Properties	Valve
Mineral	Quartz
Color	White
Grain	Rounded
Mohs hardness	7
Specific gravity	2,65
Minimum density	1.42 g/cm3
Maximum density	1.75 g/cm3

Table 2. Results of the tests

No	Time (s)	Over burden (bar)	Pressure of barometer(bar)	Perforation's diameter (mm)	Net weight of exit sand (gr)	Number of perforation (split) in well
1	97	200	1	3.3	8800	2
2	130	200	1	3.3	16960	2
3	90	300	0.5	3.3	7600	2
4	157	200	0.4	3.3	6200	2

5	37	0	0.8	3.3	5900	2
6	90	200	1	3.3	4500	2
7	115	200	2	3.3	5250	2
8	130	300	2	3.3	6100	2
9	100	100	1	3.3	9000	2
10	85	200	0.5	3.3	7400	2
11	70	200	1	3.3	4050	2
12	80	200	1	3.3	4100	2
13	90	100	1	3.3	8800	2
14	100	200	1	3.3	8900	2
15	35	0	0.5	1.5	7740	2
16	35	10	0.2	1.5	5800	2
17	40	100	1	1.5	3400	2
18	43	200	2	1.5	2950	2
19	40	200	2	1.5	2912	2
20	20	100	1	1.5	2202	2

Fig. 5. Lens around the well's perforation at the end of the test

Generally, the process of sand production and changes of fluid pressure as well as the pressure on the device is as Figure 6. This diagram shows that after turning on the device, fluid pressure increases from 0 point to 2 bar. The pressure remains stable until the sand production starts. When the device starts to work, the amount of pressure on the device is 200 bar which reduces gradually as the device starts to produce sand.

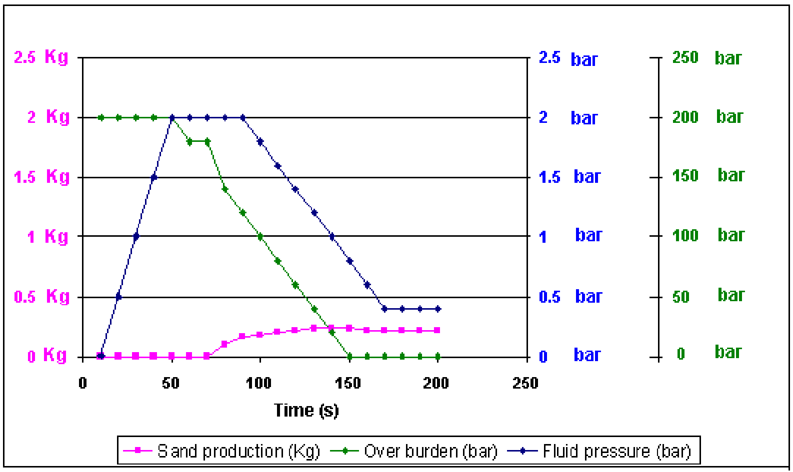

Fig. 6. Fluid pressure changes and device over burden and sand production

4. PREDICTION THE OUTCOME SAND WEIGHT WITH ANN, ANFIS AND MULTIPLE REGRESSION METHOD

Neural network has a remarkable ability to deduce result from complicated data. It can be useful in pattern deduction and recognition of different trends which are difficult for human and computers. In ANFIS (Adaptive Network Fuzzy Inference System), neural network and fuzzy system combine with each other in an organized structure. This model can be called a neural network with fuzzy parameters or a fuzzy system with distributed learning. In this analysis to model ANFIS, MATLAB software has been used. Before starting modeling, all parameters in [-1 1] range have been normalized in order to reduce the range of input parameters changes and their relation. With 15 groups of data, teaching fuzzy model has been completed. After that with 5 groups of data raw, functions of ANFIS models have been estimated. Evaluation criterion and built models comparison were RMSE (Root Mean Square Error) amount. By using trial and error method and with regard to RMSE amount, the best model is selected. This ANFIS has 2 Gaussian membership functions for every input, and optimal parameters are calculated by neural network and hybrid algorithm (a combination of BP and the least squares). The built system has 5 layers and 16 if-then (when) rules that are related by AND operator (Figure 7). Other parameters and properties of ANFIS are shown in Table 3.

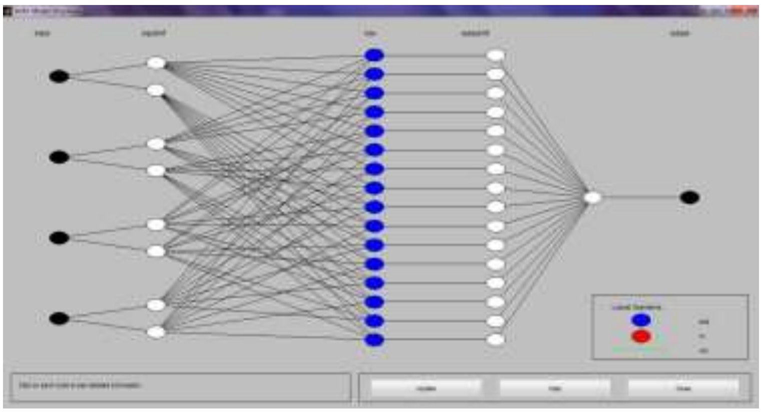

Fig. 7. Structure of ANFIS for sand production prediction

Table 3. Different parameter types and their used values for predicting of rest settlement ANFIS model

ANFIS Parameter Type	Grid Partitioning
Output MF	Linear
Optimize method	Hybrid
Epochs	40
Number of nodes	55
Number of linear parameters	80
Number of nonlinear parameters	32
Total Number of parameters	112
Number of fuzzy rules	16

Teaching algorithm, numbers of hidden layers, numbers of hidden layers neurons, activation functions, numbers of teaching repetition (IPAC) and teaching stop conditions, all have been reached based on trial and error manner. Figure 8 shows the characteristic and general structure of artificial made neural network.

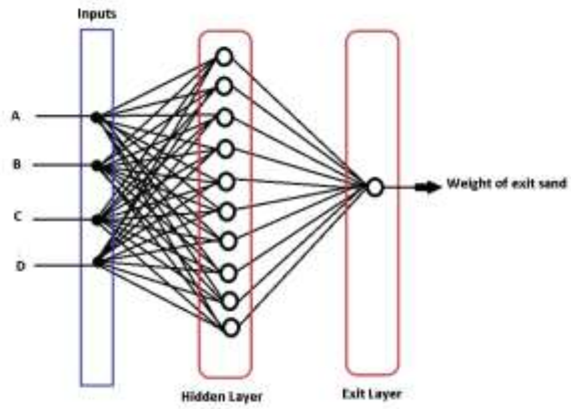

Fig. 8. Characteristic and general structure of made artificial neural network

Analysis shows, there is a reasonable process and suitable correlation between variables and the built device has suitable repeatability. The chart in Figure 9 shows the analysis results of ANN and ANFIS and it also shows that the outputs of ANFIS and ANN have suitable adaption to experimental data and they can be used for sand production prediction.

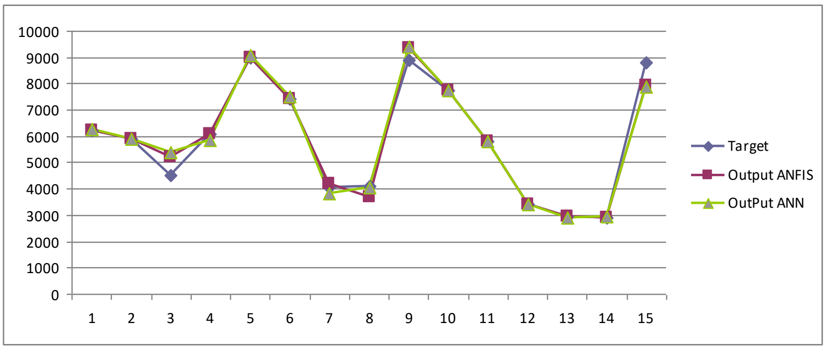

Fig. 9. Analysis results of ANN and ANFIS

Multiple regression results have function as follows:
Sand weight = 92.761 (time) – 13.435 (over burden) + 703.453 (barometer pressure)
R2= 0.841
Sig. for time = 0.000 this value very good and very important in equation.
Sig. for over burden = 0.267
Sig. for barometer pressure = 0.573 this value very bad and not important in equation.

5. CONCLUSION

Experiments results showed that higher pressure of fluid causes earlier destruction of the arc and after this destruction, the piston of the device moves downward and stress reduction on the rock is observed up to zero. Input fluid pressure is stable until the starting point of sand production and then it has a reduction process. In addition, experiments revealed that sand production, at the moment of deconstruction of sand arc, increases and afterward the rate of sand production decreases. Moreover, experiments results showed that there is a reasonable process and suitable correlation between variables, and also the device has a suitable repeatability, so the device can be used to predict and model sand production in oil wells.

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