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The reliability Analysis of Microresistivity Scanning Tool Is Based on System Structure

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Abstract: By controlling the position of the logging tool, the system can ensure that it can accurately descend or rise along the hole, and then measure the required formation properties to obtain higher quality formation data. In order to study the structural reliability of microresistivity scanning logging tool, the statics analysis of the microresistivity scanning logging system is carried out first. It is concluded that the maximum total deformation of the microresistivity scanning logging system is 0.04851m and the maximum equivalent stress is 9.387MPa. Secondly, the load and material parameters of each component of the push-pull system are taken as input variables, and the maximum equivalent stress and maximum total deformation are taken as output variables. Through ANSYS Workbench software, the structural strength and stiffness reliability of the push-pull system are analyzed based on Six Sigma theory. Finally, according to the probability distribution table and probability distribution histogram of the input parameters to the output parameters, when the maximum allowable deformation is 0.048519m, the stiffness reliability of the push-rely system structure is 0.98793, and when the maximum allowable stress is 9.387MPa, the structural strength reliability of the push-rely system is 0.96747.

Keywords: Push-on system, Statics analysis, Six Sigma theory, Structural reliability.

1. Foreword

By controlling the position of the tool, the push system ensures that it can accurately descend or rise along the hole to measure the desired formation properties, while monitoring obstacles and minimizing the tool being blocked or damaged, and it ensures that the tool is operating properly in complex subsurface environments to obtain higher quality formation data to support oil exploration and production activities. The push-pull system is the key to the failure of the microresistivity sweep logging tool, and its failure mode is usually due to the insufficient strength and stiffness of the push-pull system.

At present, there are few literatures about the structural reliability analysis of the push by system at home and abroad, but some scholars have carried out structural reliability analysis of other institutions based on the Six Sigma theory on the existing basis. The finite element model of the frame structure of the dual well pumping unit is established by using the APDL module of the finite element software ANSYS. The Monte Carlo method and response surface method provided by the finite element software are used to analyze the overall reliability of the frame structure of the dual well pumping unit. The results show that the frame structure is reasonable and reliable. [1]According to the static characteristics of the robot arm, Liu Zhihai used the research method of SolidWorks and ANSYS Workbench to obtain the change law of stress and deformation on each part of the robot, analyzed and found the dangerous position and weak point in the actual work process, which has certain reference value for the design and optimization of the robot structure. [2]Yang Peng takes a four-degree-of-freedom loading and unloading robot used in the loading and unloading process of stamping machine parts as the research object, and establishes the three-dimensional model of the robot through SolidWork software. ANSYS software is used to carry out static analysis of the robot arm under the maximum force and the first 10 modal analysis of the three typical postures in the horizontal posture, vertical posture and folded state. The simulation results show that it is necessary to avoid the low order frequency or stiffen the whole structure of the robot in the work. [3]Chen Huililiang used the Latin Hypercube sample Monte Carlo method, the central composite design sample response surface method and the Box-Behnken matrix sample response surface method in ANSYS to analyze and calculate the structural reliability. The comparative analysis results show that the response surface analysis results approximate the Monte Carlo results only in the mean, maximum and minimum values of the output parameters for structural reliability analysis of static problems. [4]In order to reasonably design the coordination gap between the rotors of the screw expander, Zhou Tao took the yin-yang rotor as the research object, modeled the yin-yang rotor through SolidWork, and introduced ANSYS Workbench to carry out static analysis on it, and obtained the distribution law of the stress and strain of the rotor under high-speed rotation. It provides a reference for the design of coordination gap between rotors of screw type machinery.[5]

To sum up, there are few researches on the structural reliability analysis of logging tool pulling system at present, and most of the researches only carry out static analysis on the research object, and do not give the structural reliability analysis and reliability. In this paper, the structural reliability of the microresistivity scanning logging tool push system is studied. Firstly, the statics analysis is carried out to obtain the maximum total deformation and the maximum equivalent stress of the push system in the measurement process. Secondly, the load and material parameters of each component of the push-pull system are taken as input variables, and the maximum equivalent stress and maximum total deformation are taken as output variables. Through ANSYS Workbench software, the structural strength and stiffness reliability of the push-pull system are analyzed based on Six Sigma theory. Finally, the response surface diagram of the input parameters to the output parameters and the probability distribution table and the probability distribution histogram of the output parameters are obtained, and then the influence of the input parameters on the output parameters and the reliability of the structure are analyzed.

2. The Microresistivity Scanning Logging Instrument Is Built by System Model

2.1. Establish the 3D model of the push-pull system

Use SolidWorks to 3D model the main parts of the push-pull system, build its outline structure, simplify the motor, pump and hydraulic cylinder, and carry out assembly and interference inspection after the model is established. As shown in Figure 1, microresistivity scanning logging tool push-pull system Push-pull system mainly includes: support arm, pump, hydraulic cylinder, main rod, motor, ejector rod, main push rod, auxiliary rod, piston, regulating rod and plate.

Figure 1. 3D model of microresistivity scanning logging tool push and pull system

After the 3D model is constructed, save the 3D model established in SolidWorks and open it in the Space Claim module of ANSYS Workbench. Drag the size of the model that needs to be parameterized in the 3D model and click it to generate a group. The number of groups is the sum of the number that needs to be parameterized.

2.2. Define the structural materials

The 3D model of the push-back system established in SolidWorks was imported into ANSYS Workbench, and "45 steel" in the material library was selected. The specific material parameters were shown in Table 1.

Table 1. Mechanical properties of materials in the push-pull system

Density /(kg/m)	Young's modulus /GPa	Poisson's ratio	Tensile yield strength /MPa	Compressive yield strength /MPa	Tensile strength /MPa
7850	200	0.3	250	250	460

2.3. Grid Division

Considering the accuracy of the finite element mesh division of the pin slots, cams, pin holes and other special structures contained in the push system, and improving the accuracy and efficiency of the calculation results, the tetrahedral element mesh division method is adopted in this paper. After grid division, the push-pull system is divided into 255,871 units and 363,951 nodes, and the average mesh mass after division is 0.85796, which proves that the mesh quality is good. The grid division of the push-pull system is shown in Figure 2.

Figure 2. Push-pull system meshing

3. Simulation Analysis of System Statics

3.1. Constraint and load application

According to the actual situation, add boundary conditions to the measurement process of the push system.

Constraint boundary: the main push rod is fixed constraint, that is, the full degree of freedom constraint; The horizontal sliding constraint between the top rod and the ground is single degree of freedom, and the top rod is subject to the force in the horizontal direction and only moves in the X direction. The support arm, the main rod and the auxiliary rod are connected with the ground hinge in the position of the shaft, while the main rod and the top rod, the support arm and the main push rod through the groove between the collinear coordination, the plate and the main rod and the auxiliary rod hinge coordination, the main rod and the top rod between the line constraint, play the role of a CAM.

Load boundary: add X positive load at the left end of the top rod, and the load value is 300N; Add the Z-forward load on the plate, and the load value is 2600N. After the push system imposes constraints and loads, it is shown in Figure 3.

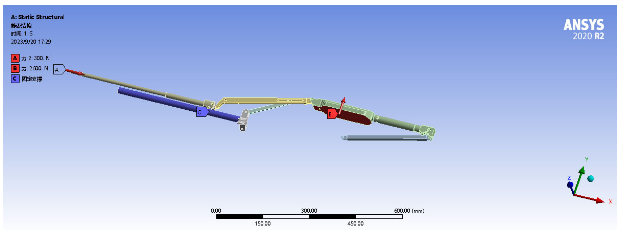


Figure 3. Pushing system constraints and load boundary application

3.2. Solution calculation

After applying the load and constraints, under the action of the load, the maximum total deformation diagram and maximum equal effect diagram of the push system are obtained, as shown in FIG. 4 and FIG. 5 respectively.

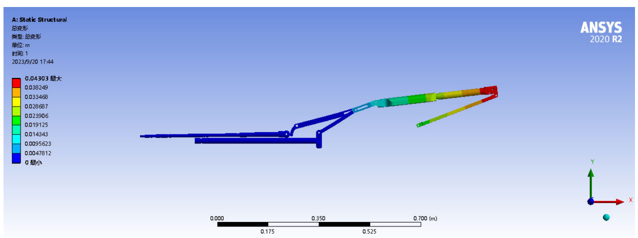


Figure 4. Maximum total deformation of the pusher system

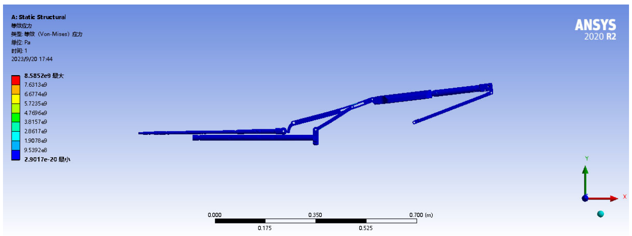


Figure 5. Maximum equivalent stress of push-pull system

3.3. Analysis of Results

(1) As can be seen from Figure 4, the maximum total deformation of the system is 0.04851m, and the deformation amount is small. The deformation of the ejector rod, the main push rod, the main rod and the support arm is the smallest, and the deformation of the plate and the auxiliary rod begins to increase, and the maximum deformation appears at the joint of the plate and the auxiliary rod. On the one hand, the plate and the auxiliary rod are close to the well wall during the measurement process, resulting in a larger deformation than other positions, which is in line with the actual situation. On the other hand, the stiffness of the joint of the plate and the auxiliary rod is insufficient, which leads to the occurrence of deformation, which may cause certain safety hazards in the actual measurement process, so improving the stiffness of the joint of the plate and the auxiliary rod or optimizing the structure of the joint of the plate and the auxiliary rod is the main solution.

(2) As can be seen from FIG. 5, the maximum equivalent stress borne by the pusher system is 9.387MPa, which is far less than the maximum yield limit of the pusher system material, and no danger will occur.

4. Reliability Analysis of The Push-pull System Structure

The existence of multiple input parameters will make the simulation results vary in a certain range, so the reliability analysis of the extrapolated system structure is an uncertain analysis[6]First, set the input parameters and output parameters of the analysis, as well as the corresponding distribution of the input parameters and output parameters data. Secondly, determine the sampling method, based on the parameter distribution characteristics of sampling combination, multiple simulation[7]. Finally, according to the multiple simulation results, output variable distribution characteristics, reliability is obtained according to the strength reliability calculation formula and reliability analysis.

4.1. Determination of input parameters and output parameters

Through the static simulation analysis of the push-pull system, it is found that the stress concentration occurs in the local position during the operation of the push-pull system, which will cause serious damage to the position after a long time operation, and then affect its reliability[8]Select the constraints and loads in Chapter 2 as input parameters, set the material properties and carrying load as normal distribution, and make fluctuations within 1% above and below the mean value. In order to analyze the influence of the changes of input parameters on the performance and reliability of the push-pull system, the maximum total deformation and maximum equivalent stress of the push-pull system are taken as output parameters to conduct reliability analysis of the push-pull system. The distribution characteristics of the input parameters are shown in Table 2.

Table 2. Random distribution characteristics of input parameters

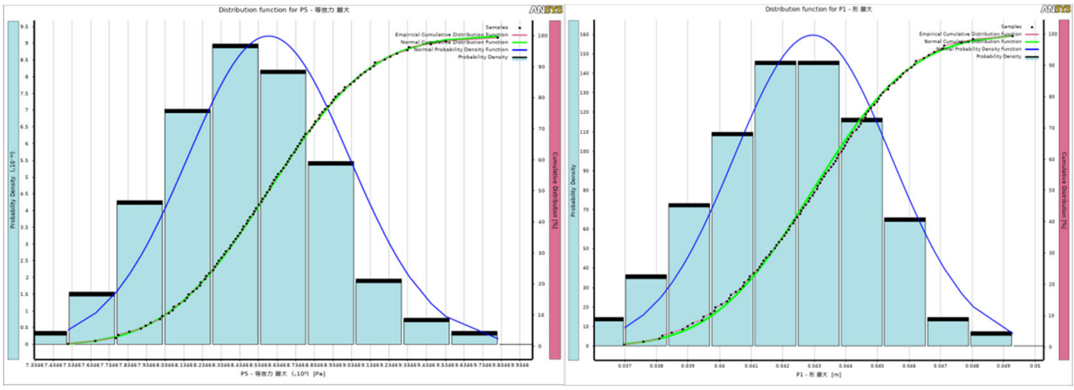
Parameter name	Mean	Distribution characteristics	Standard deviation
Density (kg/m)	7850	Normal distribution	423
Young's modulus (MPa)	200000	Normal distribution	10350
Poisson's ratio	0.3	Normal distribution	0.015
Top rod X-force (N)	300	Normal distribution	13.7
Plate Z-force (N)	2600	Normal distribution	68.9

4.2. Generation of random samples

The most commonly used sampling methods are Monte Carlo method and Latin Hypercube sampling (LHS) method. Compared with Monte Carlo method, LHS method can not only greatly reduce the sampling quantity, but also ensure that the sampled samples are distributed in the whole distribution range as much as possible. The LHS method first stratifies the sampling space so that the probability density function of each layer is equal. In the parameter space, the layers of each parameter intersect to form a hypercube. Then, each hypercube is screened so that the coordinates of each hypercube are independent of each other. Then through sampling fitting, the distribution form and distribution characteristics[1]For Six Sigma analysis, LHS method is used for sampling analysis, and the obtained data has a better balance and avoids the occurrence of repeated sampling. Therefore, LHS sampling method is used for sampling analysis in this paper.

4.3. Reliability Analysis

Based on the Six Sigma module in ANSYS Workbench, the probability distribution table and the probability distribution histogram of the output parameters are obtained through multiple simulations. Through the cumulative distribution function in the probability distribution histogram, the probability corresponding to any sampling point can be obtained. In this paper, sampling method will be adopted to analyze 10,000 sample points generated by LHS sampling method to obtain the maximum equivalent stress probability distribution histogram and maximum total deformation probability distribution histogram of the extruding system, as shown in FIG. 6.



(a) Histogram of maximum equivalent stress probability distribution
(b) histogram of maximum total deformation probability distribution
Figure 6. Probability distribution histogram

Based on the reliability analysis of the maximum equivalent stress and maximum total deformation of the push-pull system, the probability that the maximum stress of the push-pull system in actual work is less than the allowable stress of the materials used is obtained through the Six Sigma module, and the probability distribution table is obtained, as shown in Figure 7.

表格 Outline A9: Statistics for P1 - 总变形 最大

	A	B	C
1	P1 - 总变形 最大 (m)	Probability	Sigma Level
2	0.049288	0.99309	2.462
3	0.048519	0.98793	2.255
4	0.04775	0.97565	1.9712
5	0.046981	0.94995	1.6444
6	0.046212	0.9111	1.3476
7	0.045444	0.83818	0.98701
8	0.044675	0.74797	0.66812
9	0.043906	0.63077	0.3339
10	0.043137	0.51815	0.045513
11	0.042368	0.40275	-0.24623
12	0.041599	0.2985	-0.52872
13	0.04083	0.20914	-0.80941
14	0.040061	0.13589	-1.099
15	0.039292	0.081249	-1.3967
16	0.038523	0.04731	-1.6715
17	0.037754	0.01954	-2.0634
18	0.036985	0.0069075	-2.462
*			

表格 Outline A10: Statistics for P5 - 等效应力 最大

	A	B	C
1	P5 - 等效应力 最大 (Pa)	Probability	Sigma Level
2	9.8193E+09	0.99309	2.462
3	9.6752E+09	0.98899	2.29
4	9.5311E+09	0.98252	2.1089
5	9.387E+09	0.96747	1.8448
6	9.243E+09	0.93366	1.5036
7	9.0989E+09	0.87993	1.1746
8	8.9548E+09	0.80798	0.87046
9	8.8107E+09	0.69499	0.51005
10	8.6666E+09	0.57255	0.18287
11	8.5225E+09	0.44364	-0.14175
12	8.3784E+09	0.31394	-0.48472
13	8.2343E+09	0.20932	-0.8088
14	8.0903E+09	0.12891	-1.1315
15	7.9462E+09	0.071207	-1.4669
16	7.8021E+09	0.039163	-1.7605
17	7.658E+09	0.016284	-2.1374
18	7.5139E+09	0.0069075	-2.462
*			

(a) Probability distribution table of maximum total deformation
(b) probability distribution table of maximum equivalent stress
Figure 7. Probability distribution table

4.4. Analysis of Results

(1) It can be seen from the analysis of FIG. 6 that the maximum equivalent stress and maximum total deformation of the system also have the characteristics of random distribution under the action of various random input parameters, and the distribution histogram of the output parameters does not have large intervals and jumps, and the histogram is evenly distributed, and the results are good.

(2) The black lines in the figure represent the cumulative distribution function curve of the output parameters. After 10,000 times of sampling, the cumulative distribution function curve is relatively smooth without abnormal fluctuations and fluctuations, indicating that the number of simulations meets the requirements.

(3) As can be seen from the analysis of FIG. 7 (a), the probability that the total deformation of the system is less than 0.049288m has reached 99.309%; It can be seen from the analysis of FIG. 7 (b) that the probability of the maximum stress being less than 9.819MPa has reached 99.309%.

(4) According to the analysis in FIG. 7, when the maximum allowable deformation is 0.048519m entered into the probability distribution table, the stiffness reliability of the deduced system structure is 0.98793. When the maximum allowable stress is 9.387MPa, the structural strength reliability of the push-pull system is 0.96747. Therefore, when the allowable value has been set, it is more accurate to measure the reliability of the push-pull system through the input of the allowable value set in the probability distribution table, and it is more authoritative to evaluate the structural reliability of the push-pull system based on the stiffness.

5. Conclusions

(1) After applying the load and constraint, the statics analysis of the push-pull system shows that the maximum total deformation of the push-pull system in the measurement process is 0.04851m, and the maximum equivalent stress is

9.387MPa.

(2) The reliability analysis of the push-pull system was carried out through the Six Sigma module of ANSYS Workbench, and the probability distribution histogram and probability distribution table of the output parameters were obtained. The results show that the probability that the total deformation of the push-pull system is less than 0.049288m has reached 99.309%, and the probability that the maximum stress is less than 9.819MPa has reached 99.309%.

(3) According to the probability distribution table, when the maximum allowable deformation is 0.048519m, the stiffness reliability of the push-pull system structure is 0.98793. When the input maximum allowable stress is 9.387MPa, the structural strength reliability of the push-pull system is 0.96747.

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