Journal of Education and Educational Research
ISSN: 2957-9465 | Vol. 6, No. 1, 2023

Analysis on Structural Reliability of Microsphere Focusing Logging Tool Pushing System

Zixuan Zhao, Wen Sun, Junyuan Zheng

School of Mechanical Engineering, Xi'an Shiyou University, Xi'an 710065, China

Abstract: The push system of the microsphere focusing logging tool is an important moving mechanism of this type of logging tool. The push system will periodically bear large loads under working conditions and is prone to stress concentration. Its structural strength and reliability are related to the logging accuracy. and even the success or failure of the logging mission. Based on ANSYS workbench software, this paper first conducts modeling and static simulation of the microsphere focusing logging tool push system under working conditions, and secondly conducts uncertainty analysis on the maximum equivalent stress of the push system based on the simulation results. , Finally, based on the analysis results, the six sigma module was used to conduct a reliability analysis of the pushing system, and the structural strength reliability of the microsphere focusing logging tool pushing system was given through the probability distribution table obtained from the analysis. The analysis results show that the maximum equivalent stress occurs on the link arm of the pushing system under working conditions. Under the current working condition, the link arm strength of the pushing system is highly reliable and can meet daily logging needs.

Keywords: Push System; Uncertainty Analysis; Six Sigma Module; Reliability Analysis.

1. Introduction

The microsphere focusing logging tool is a very important petroleum logging equipment in the field of petroleum logging. Its push system is installed on the microsphere focusing logging tool to assist the microsphere focusing logging tool in completing downhole logging tasks. The key system [1]. The push system will be subject to periodic loads during operation, and the load is relatively large, which is prone to stress concentration, leading to failure and damage.

At present, the research on the microsphere focusing logging tool push system is mostly focused on the design optimization of the push system, the wear resistance design of the push plate and the application of new materials. Dou Jinai is based on the current push pole of the microsphere focusing logging tool. In order to solve the problem of poor wear resistance of the plate, the material and manufacturing process of the original plate have been improved, so that the wear resistance and insulation of the plate are better than the conventional rubber plate [2]. Ren Tao aimed at minimizing the root mean square fluctuation of the transmission angle of the main transmission mechanism of the pushing system and the expected transmission angle, and optimized the transmission performance of the pushing system and the motion smoothness of the pushing system [3].

The microsphere focusing logging tool pushing system will be subject to large periodic loads during the working process, and it is easy to produce stress concentration, leading to system failure and damage. The failure mode is usually that the structural strength of the link arm is insufficient, so the microsphere focusing is required. The logging tool push system performs structural strength reliability analysis. At present, there are few studies on this type of analysis. Yang Baiqing discussed and analyzed the mechanical properties of the single-arm pusher. He analyzed the working conditions of the pusher and the action of each robotic arm to design high-quality the pusher has established a theoretical basis [4]. Zhang Guangzhou conducted a detailed study on the reliability design methods of logging instruments from multiple angles in view of the reliability of logging instruments in the petroleum development process, and proposed that attention should be paid to the instrument frame strength and impact resistance reliability in the design [5].

In this paper, through the static analysis of the microsphere focusing logging tool push system under working conditions, the position where the maximum equivalent stress occurs in the system is obtained, and the Six Sigma analysis module is used to conduct reliability analysis of the push system, and provide the basis for the push system. Provide reference for further optimization of the system.

2. Introduction to Microsphere Focusing Logging Tool Push System

The microsphere focusing logging tool push system mainly includes: motor, transmission system self- locking device, radial ball bearing group, push upper arm, push inner wall, push plate, link arm, push body, push system works the state structure diagram is shown in Figure 1.

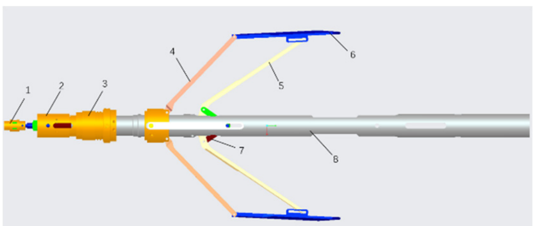


Fig 1. Structural diagram of the working state of the microsphere focusing logging tool pushing system

Note: 1. motor; 2. self-locking device of transmission system; 3. radial ball bearing group; 4. push against upper arm; 5. push against inner wall; 6. push against pole plate; 7. link arm; 8. push against main body.

When logging, the motor drives the thrust rod and thrust plate to move forward in a straight line through the screw, thereby compressing the spring and opening the push arm, thereby driving the push plate to move until the plate fits the well wall [6]. When the pole plate completely fits the well wall, the motor is powered off, and the spring provides the pushing force of the pole plate.

3. Static Analysis of Microsphere Focusing Logging Tool Pushing System

3.1. Model Import and Settings

Based on the actual working conditions, the microsphere focusing logging tool pushing system is modeled and assembled in CREO modeling software. To reduce the amount of calculation, this article only studies the single-sided pushing upper arm, pushing against the inner wall, pushing against the pole plate and the link arm is modeled, and the simulation model is imported into ANSYS workbench simulation software. The simulation model of the microsphere focusing logging tool pushing system is shown in Figure 2.

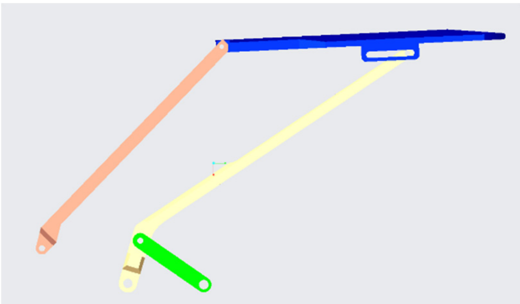


Fig 2. Microsphere focusing logging tool pushing system simulation model

3.2. Meshing

The tetrahedral method is used to divide the mesh of the pushing system, and the overall mesh size is set to 2mm. The entire model is refined through Body Sizing. The number of mesh units, the number of nodes, and the mesh quality of the model after processing are as follows: As shown in Table 1.

Table 1. Number of model mesh units, number of nodes and mesh quality

Name	Number of elements	Number of nodes	Mesh quality
push against upper arm	79128	122432	0.8341
push against inner arm	98426	147887	0.8391
push against plate	202911	295535	0.8474
link arm	7789	12756	0.8259

3.3. Add Contacts and Loads

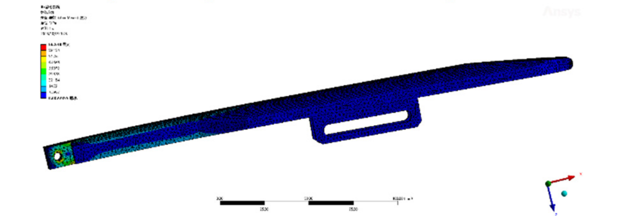
Table 2. Microsphere focusing logging tool push system motion pair connection information

Number	Kinematic pair type	Part 1	Part 2
1	Moving pair	Link arm	ground
2	Rotating pair	Link arm	Push against inner arm
3	Rotating pair	Push against inner arm	ground
4	Moving pair	Push against inner arm	Push against plate
5	Rotating pair	Push against plate	Push against upper arm
6	Rotating pair	Push against upper arm	ground

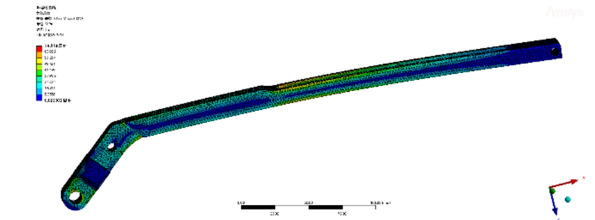
The connection methods of the kinematic pairs between the various parts of the pushing system are consistent with the actual connection methods, as shown in Table 2. Based on the actual working conditions and literature 7, the load added to the push system is as follows: the driving force on the pin hole at the lower part of the link arm is 225N, and the well wall pressure on the upper surface of the plate is 240N.

3.4. Analysis of Simulation Results

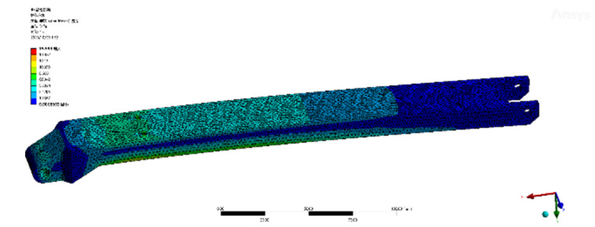
The maximum equivalent stress and deformation cloud diagrams of each part of the static simulation of the microsphere focusing logging tool pushing system under the load-bearing working state are shown in Figure 3 (a)-(d).



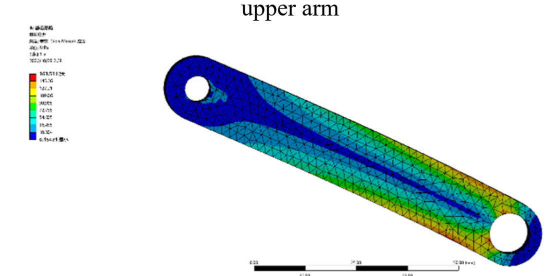
(a)Maximum equivalent stress cloud diagram of push against plate



(b) Maximum equivalent stress cloud diagram of push against Inner arm



(c) Maximum equivalent stress cloud diagram of push against upper arm



(d) Maximum equivalent stress cloud diagram of link arm

Fig 3. The maximum equivalent stress and deformation cloud map of each part

The simulation results of each component of the pushing system are shown in Table 3.

Table 3. Maximum equivalent stress of each component of the microsphere focused logging tool push-back system

Name	Maximum equivalent stress (MPa)
push against upper arm	66.548
push against inner arm	74.118
push against plate	15.593
link arm	163.51

It can be concluded from Table 3 that under working conditions, the equivalent stress on the link arm is the largest, which is 163.51MPa. The equivalent stress on other parts is much smaller than that on the link arm. Among them, the equivalent stress on the upper arm is the smallest, which is 15.593. MPa. Therefore, when designing the microsphere focusing logging tool push system, the strength of the link arm should be considered, and the strength reliability of the link arm should be analyzed.

4. Reliability Analysis of Link Arm Strength Considering Uncertainty

4.1. Link Arm Strength Reliability Analysis Process

The link arm strength reliability analysis steps are divided into the following two points:

1) Uncertainty analysis

In the strength reliability analysis, due to the existence of part processing errors, assembly errors, and the load under working conditions, there will be a certain deviation from the design value. Therefore, uncertainty analysis is performed on the basis of static simulation[8]. The input variables of the uncertainty analysis are set to (part rod length, pin hole diameter, load), and the output variables are set to the maximum equivalent stress on the link arm. Through analysis, it can be seen that each input variable obeys the normal distribution.

For the selection of random variables, this article uses the Latin hypercube sampling method. The Latin hypercube sampling method is a method of approximately random sampling from a multivariate parameter distribution. It is a stratified sampling technology and is often used in computer experiments or Monte Carlo integration[9]. Suppose there are k variables and N samples are taken from the specified interval. Then the cumulative distribution of each variable is divided into the same N small intervals. A value is randomly selected from each interval. The N values of each variable are summed. The values of other variables are randomly combined. Compared with the simple random sampling method and the stratified sampling method, the Latin hypercube sampling method does not have complex mathematical concepts, is easy to operate and use, can save a lot of computing resources, generates samples with higher spatial coverage, and the data obtained by sampling have high Good balance [10].

2) Reliability analysis

The calculation of strength reliability is usually based on the stress-strength interference model [11], and its schematic diagram is shown in Figure 4:

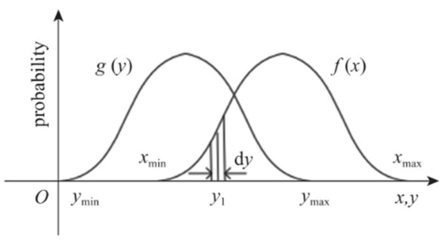


Fig 4. Principle diagram of interference model

Its functional functions are:

$$G(z) = f(x) - g(y) > 0 \quad (1)$$

Where f(x) is the strength of the part, and g(y) is the stress on the part. If f(x) and g(y) both follow a normal distribution, then:

$$R = \frac{1}{\sqrt{2\pi}\sigma_z} \exp\left[-\frac{1}{2}\left(\frac{z-\mu_z}{\sigma_z}\right)^2\right] \quad (2)$$

Then the reliability can be expressed as:

$$R = \int_0^\infty \frac{1}{\sqrt{2\pi}\sigma_z} \exp\left[-\frac{1}{2}\left(\frac{z-\mu_z}{\sigma_z}\right)^2\right] dz \quad (3)$$

If $\mu = (z - \mu_z)/\sigma_z$, then:

$$R = \int_0^\infty \frac{1}{\sqrt{2\pi}\sigma_z} \exp\left[-\frac{1}{2}u^2\right] du = \phi(\beta) \quad (4)$$

In formula:

$$\beta = \frac{\mu_z}{\sigma_z} = \frac{\mu_0 - \mu_u}{\sqrt{\sigma_0^2 - \sigma_u^2}} \quad (5)$$

In the formula, β is the strength reliability index, μ_u and σ_u are the mean and standard deviation of input variables, and μ_0 and σ_0 are the mean and standard deviation of output variables.

4.2. Uncertainty Analysis

The rod length, pin hole diameter and load of the link arm were selected as input variables, the distribution mode was set as normal distribution [12] and the coefficient of load variation was set as 0.02. The maximum equivalent stress of the link arm is taken as the output variable. The distribution characteristics of input variables for uncertainty analysis are shown in Table 4

Table 4. Characteristics of input variables for uncertainty analysis

Code name	variable name	mean	standard deviation
P1	Link arm length	84.4mm	0.1
P2	Link arm lower pin hole diameter	10mm	0.07
P3	Diameter of upper pin hole of link arm	6.4mm	0.06
P4	Lower pin hole X axial force	225N	4.5
P5	Lower pin hole Y axial force	420N	8.4

Latin hypercube sampling of input variables was carried out in the set distribution interval, and the number of samples was 10,000. After simulation, the average value of the maximum equivalent stress of the link arm was 166.44MPa and the coefficient of variation was 0.005, and the maximum equivalent stress distribution function of the link arm was obtained by fitting, as shown in Figure 5.

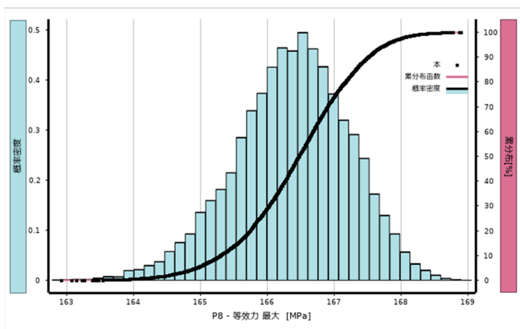


Fig 5. Maximum equivalent stress distribution function of the link arm

4.3. Reliability Analysis

In the Six Sigma module of ANSYS Workbench, the probability value corresponding to a certain fixed value can be intuitively obtained by analyzing the probability distribution table. The probability distribution table of the maximum equivalent stress of the link arm is shown in Figure 6.

	A	B	C
1	P8 - 等效应力 最大 (MPa)	概率	西格玛水平
2	177.83	0.99993	3.8106
3	176.85	0.9995	3.2889
4	175.88	0.99903	3.0991
5	175	0.9981	2.8948
6	173.94	0.99389	2.5055
7	172.97	0.9868	2.2203
8	171.99	0.97498	1.9597
9	171.02	0.9529	1.6736
10	170.05	0.91708	1.3857
11	169.08	0.86317	1.0947
12	168.11	0.7896	0.80503
13	167.13	0.69531	0.51097
14	166.16	0.58299	0.20956
15	165.19	0.4666	-0.083832
16	164.22	0.35688	-0.36681
17	163.25	0.25779	-0.65016
18	162.27	0.17484	-0.93522
19	161.3	0.11187	-1.2166
20	160.33	0.063551	-1.5256
21	159.36	0.035639	-1.8037
22	158.39	0.018257	-2.0912
23	157.42	0.0089689	-2.3669
24	156.44	0.0033283	-2.7135
25	155.47	0.0012886	-3.0141
26	154.5	0.00048142	-3.3012
27	153.53	0.00019027	-3.5532
28	152.56	6.9312E-05	-3.8106
*			

Fig 6. Table of maximum equivalent stress distribution of link arm

It can be seen from Figure 6 that the probability that the maximum equivalent stress of the link arm is less than 177.83MPa is 0.99993. According to the experience, the design maximum allowable stress of the link arm is 175MPa, and the strength reliability of the link arm is 0.9981. Take the variation coefficient of the maximum equivalent stress of the link arm as 0.02, and bring it into equation (4) and (5) to calculate $\beta=1.946$, $R=0.99813$, which is basically consistent with the corresponding probabilities in the probability sub-table, indicating that the simulation results are correct.

5. Closing Remarks

Aiming at the microsphere focused logging tool push-pull system, this paper conducts static analysis of the push-pull system under working conditions, and on this basis carries out uncertainty analysis. Based on the analysis results, reliability analysis is carried out and the maximum equivalent stress probability distribution table of the link arm of the push-pull system is obtained. The research shows that:

1. The maximum equivalent stress occurs in the link arm of the microsphere focused logging tool push-back system under working condition;
2. When the maximum allowable stress is 175MPa, the strength reliability of the link arm is 0.9981, indicating that the strength reliability of the link arm is high and can meet the current logging requirements.

References

[1] FENG Bin. Design and Research of Microsphere focused logging Instrument push-pull system [D]. Xi 'an Shiyou University,2021. DOI: 10.27400/d.cnki.gxasc.2019.000031.

[2] Dou Jinai, Liao Shengjun, Yan Yutao et al. Design and application of a new microsphere focusing measuring plate [J]. Petroleum Tubes and Instruments,2020,6(05):7-11.DOI:10. 19459/ j.cnki.61-1500/te.2020.05.002.

[3] Ren Tao, Feng Bin, Sun Wen, et al. Optimization Design of tool push-back system with Optimal Transmission Angle [J]. Machinery Design and Manufacture, 2021(01):54-58.DOI:10. 19356/j.cnki.1001-3997.2021.01.013.

[4] Yang Baiqing. Study on the mechanics of Single-arm Pusher [J]. Well logging technology, 1988(05):41-46+78.DOI: 10. 16489/j.issn.1004-1338.1988.05.008.

[5] ZHANG Guangzhou, Sun Yucai, Luo Xianyin. Research on Reliability design method of Petroleum logging Instrument [J]. Petrochemical Technology, 2019,26(07):314+201.

[6] WEI Wei, Li Fang, PEI Xiange et al. Performance analysis of self-locking mechanism of 3106XC microsphere focused logging instrument [J]. Petroleum instruments, 2003(05):32-33+61.

[7] Ren Tao, Feng Bin, Sun Wen, et al. Analysis and Study on Dynamic Characteristics of logging instrument push-pull System [J]. Journal of Southwest Petroleum University (Natural Science Edition), 2019,41(05):169-180.

[8] Jiang Lizhi, CAI Qi, Zhang Yongfa et al. Application and development of Latin Hypercube sampling in Reliability Analysis of Passive Systems [J]. Nuclear Science and Engineering, 2017,37(05):879-887.

[9] Xue Bing, Mi Jie, Gao Kaiye et al. Static Simulation and Reliability Analysis of Hook and Claw Assembly of Control Rod Drive Mechanism [J]. Quality and Reliability, 2021 (02): 26-30.

[10] Wang Han. Research on parametric uncertainty finite element model revision based on response surface [D]. Nanjing University of Aeronautics and Astronautics, 2023.DOI:10. 27239/ d.cnki.gnhhu.2021.001157.

[11] Qin Datong, Xie Liyang. Fatigue Strength and Reliability Design [M]. Beijing: Chemical Industry Press, 2013 : 139-142.

[12] WANG Ning. Reliability Analysis of Truck Crane Boom [D]. Chang 'an University, 2022.DOI: 10.26976/ d.cnki. gchau. 2021. 001857.