При бурении алмазными коронками образуется шлам горной породы различной зернистости, в котором преобладают мелкие зерна фракции. При этом частицы шлама крупного размера, соизмеримого с высотой выступания алмазов, имеют высокую степень вероятности расклиниваться между забоем скважины и рабочим торцом коронки и активно деформировать мягкий материал матрицы. Снижение предела прочности на сжатие частиц шлама с увеличением их размера способствует дроблению образующихся при разрушении горной породы крупных частиц шлама при их расклинивании между рабочим торцом коронки и забоем скважины и снижению вероятности их дальнейшего активного участия в деформировании матрицы.

Определяющую роль в снижении абразивного воздействия частиц шлама играют прочностные параметры материала матрицы буровой коронки и высота выступания алмазов на ее рабочей поверхности.

Гидроабразивный износ поверхности матрицы коронки происходит в большей степени в результате пластического оттеснения (передеформирования) материала матрицы вследствие упруго-пластических деформаций. Это свидетельствует о том, что частицы шлама разрушатся раньше, чем будут достигнуты условия, необходимые для осуществления микрорезания ими материала матрицы.

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ANALYSIS OF DRILL PIPE TORSIONAL VIBRATION BASED ON SOFTWARE ANSYS

Буровая труба – важная часть в системе бурения скважин. Аналитическим методом трудно точно проанализировать вибрации буровой трубы в процессе бурения. Это можно осуществить с помощью программного обеспечения ANSYS. Посредством ANSYS было изучено крутильное колебание снаряда буровой трубы при условии, что глубина вертикальной скважины не превышает 2000 м. При этом не учитывалось влияние переходников и размеров коронок. В результате были получены законы влияния толщины стенки буровой трубы, длины удлинителя и буровой трубы на частоту трубы, а также модели первого-четвертого порядков для анализа крутильного колебания снаряда буровой трубы.

1. Introduction

Drill pipe is a very important part in drilling engineering. Drill pipe, is under complicated external force in complicated operation condition in the process of drilling, which come into being various intricate states such as distortion according to kinematics and dynamics [1;2]. Analytic method is difficult to analyze the drill pipe in a concrete and thorough way. The large-scale software ANSYS, which is made the finite elements to the level of simulation, provides an effective approach to the analysis and research of drill pipe, as well as simulation [3]. This paper writing, from the perspective of the torsional vibration, analyzes the all torsional vibration of the drill pipe in the vertical hole within 2000 meters depending on the software ANSYS, under the condition of ignoring of the influence of the tie-in and the geometric size of the aiguilles. As a result, we hope that there is a further analysis in a concrete and thorough way.

2. The analysis procedures for the drill pipe vibration depending on software ANSYS

The ANSYS is large-scale general finite elements analysis software, including the analysis from the perspective of structures, fluid flow, and heat flow, electromagnetic, acoustic and coupling. It developed by American ANSYS Corporation--one of the largest finite elements software company. Following are the steps of the analysis on drill torsional vibration depending on the software ANSYS:

(1) The preprocessing of establishing the finite elements model.

It includes defining the type of the element, and the attribute to both real constant and material, as well as establishing node and element and so on. The type of the appointed element is PIPE59. PIPE59 is a uniaxial three-dimensional flexibility straight-pipe element with tension-compression, torsion, and bending capabilities, and with member forces simulating ocean waves and current. The element has six degrees of freedom at each node. The element has stress stiffening and large deflection capabilities. PIPE59 is very suitable for stimulating the structure and realistic operation condition of the drillstring. Due to the distributed force per unit length quality by means of density method, instead of the general centralizing quality, the model is more realistic and concrete.

(2) Computation.

It includes the type of the mode shape analysis, setting up the analysis option, loading and computation etc.

ANSYS mode shape analysis provides 7 mode shape extraction methods such as sub-space method etc. Sub-spacing, a consistent improving method on the basis of Rayleigh-Ritz method, is effective to solve the large-scale general eigenvalue problem like drillstring having multiple degrees of freedom. It can work out the various ranks of the inherent frequency ratio and model of vibration by sub-spacing. There is little chance solving the problem of the model of the drillstring vibration beyond 10 ranks. As a result, this paper writing only figures out model of vibration at 10 ranks.

(3) Post-processing.

ANSYS provides strong post-processing function, such as looking over frequency ratio table, model of vibration, and cartoon.

3. Analysis of the inherent frequency of the drill pipe vorsional vibration.

(1) The influence of the wall thickness of drill pipe on the inherent frequency ratio.

As the data shown in Table 1, it prove that the thicker the wall thickness (the reduction of the inside diameter) of Ø 89 drill pipe, the higher the inherent frequency ratio for drillstring torsional vibration at the relative rank. But, to the extent, it is not obvious. This rule not only provides a valid reference to choosing the drill pipe, but also a new reference to optimizing the structure of the drill pipe in the future.

Table 1. **2000 meters drill string (1920 meters Ø 89 drill pipe＋80 meters Ø 121 drill collar) the inherent frequency ratio for torsional vibration at each rank**

Ø 89 drill pipe inside diameter (mm)	Inherent frequency ratio (Hz)									
	1 rank	2 rank	3 rank	4 rank	5 rank	6 rank	7 rank	8 rank	9 rank	10 rank
74.9	0.32989	1.0337	1.7985	2.5957	3.4080	4.2279	5.0521	5.8789	6.7073	7.5369
70.9	0.34130	1.0551	1.8180	2.6113	3.4203	4.2376	5.0597	5.8848	6.7118	7.5402
66.9	0.34887	1.0705	1.8331	2.6238	3.4303	4.2456	5.0661	5.8898	6.7156	7.5429

(2) The influence of the drill collar on the inherent frequency ratio.

Taking Ø 89 drill pipe with 74.9 mm inside diameter as an example, it research the influence of the drill collar on the inherent frequency ratio, and the result data is shown in Table 2.

Table 2. **The 2000 meters drillstring (Ø 89 drill pipe＋different length Ø 121 drill collar) inherent frequency ratio for the torsional vibration at each rank**

Ø121drill collar length (m)	Inherent frequency ratio (Hz)									
	1 rank	2 rank	3 rank	4 rank	5 rank	6 rank	7 rank	8 rank	9 rank	10 rank
80	0.32989	1.0337	1.7985	2.5957	3.4080	4.2279	5.0521	5.8789	6.7073	7.5369
128	0.30157	1.0018	1.7961	2.6230	3.4619	4.3062	5.1530	6.0012	6.8498	7.6979
176	0.28004	0.99163	1.8162	2.6700	3.5330	4.3993	5.2661	6.1310	6.9898	7.8303

Shown in Table 2, as the length of the drill collar increase, the inherent frequency ratio for the drillstring torsional vibration at low rank decrease, while the inherent frequency ratio at high rank increase quickly. This result, especially the change of inherent frequency ratio at low rank that avoids critical rotate speed through optimizing the mix of drilling, is quite constructive to avoid resonance.

(3) The influence of the drill pipe on the inherent frequency.

Taking Ø 89 drill pipe with 74.9 mm inside diameter, with 80 meters drill collar, it is to research the influence of the changing length (the depth of the hole) on inherent frequency ratio at each rank. The result is shown in Table 3.

Table 3. **The drill pipe (different length Ø 89 drillstring＋80 meters Ø 121 drill collar) inherent frequency ratio for torsional vibration at each rank**

The total length of the drillstring (m)	The inherent frequency ratio (Hz)									
	1 rank	2 rank	3 rank	4 rank	5 rank	6 rank	7 rank	8 rank	9 rank	10 rank
200	1.9236	13.051	20.124	27.183	38.603	42.619	54.068	62.194	69.077	81.822
404	1.1150	5.1755	9.9104	14.660	18.833	21.096	25.087	29.869	34.702	39.089
602	0.83512	3.3244	6.2454	9.2404	12.247	15.229	18.052	20.074	22.023	24.832
800	0.67786	2.4784	4.5772	6.7448	8.9329	11.127	13.319	15.493	17.603	19.422
1004	0.57148	1.9791	3.6012	5.2842	6.9879	8.7002	10.416	12.132	13.845	15.547
1202	0.49750	1.6638	2.9909	4.3720	5.7727	7.1821	8.5960	10.012	11.429	12.845
1400	0.44122	1.4401	2.5623	3.7321	4.9204	6.1173	7.3188	8.5228	9.7283	10.934

As the curve shown in the Fig. 1, which transform from the data in Table 3, the inherent frequency ratio for drillstring torsional vibration at each rank decreases obviously as the length of the drillstring increases. It prove that alternation of the inherent frequency ratio for drillstring torsional vibration at each rank is longer in the drilling of the fleet hole, so that the critical rotate speed at each rank is quite different, furthermore, the changing rotate speed, to some extent, will not easily result in resonance. In converse, alternation of the inherent frequency ratio for drillstring torsional vibration at each rank is short in the drilling of the deep hole, so that the critical rotate speed at each rank is similar, furthermore, the changing rotate speed, to some extent, will easily result in resonance. It is same to the phenomena that the changing rotate speed will result in resonance in realistic practice.

Fig. 1. The curve for the inherent frequency ratio for drillstring torsional vibration at each rank changing with the length of the drillstring.

There is multiple application value in the inherent frequency ratio eigenvalue of drill pipe torsional vibration at each rank, for example, it is capable of choosing the rank of the rotate speed in a rational way, which avoids the relative inherent frequency ratio for critical rotate speed.

4. Analysis of the inherent model of drill pipe torsional vibration

Taking 2000 meters drillstring (1920 meters Ø 89 drill pipe with 74.9 mm inside diameter + 80 meters Ø 121 drill collar) as example, it research the inherent model of drillstring torsional vibration. As limited, following only show the inherent models of drillstring torsional vibration at 1 to 4 ranks.

From left to right in the Fig. 2, it shows individually the angular displacement of inherent model of 2000 meters drillstring torsional vibration at 1 to 4 ranks. The radial size in the Fig. 2 magnifies 500 times. The unit of the maximal and minimal displacement, shown in the Fig. 2, is radian (rad). The plus sign indicate the direction, which is up to the right hand rule according to Z axis, and it is the same to circle the Z axis in the forward direction to the counterclockwise rotation. The minus sign is indicating circling the Z axis in the forward direction to the clockwise rotation

Shown in the Fig. 2, the maximal angel of rotation of inherent model of drillstring torsional vibration at 1 rank is 0.177124 radian, approximately for 10.15°, at the bottom of the drillstring. As the end of the drillstring is constrained, it doesn’t rotate. The maximal forward angel of rotation of inherent model of drillstring torsional vibration at 2 rank is 0.196438 radian, approximately for 11.25°. According to the data figured out by the software ANSYS, the maximal forward angular displacement is located at the place where the drillstring is 776 meters away from the drill hole, while the maximal negative angular displacement is 0.135101 radian, approximately for 7.74°, located at the bottom of the drillstring.

In order to research the angular displacement of inherent model of drillstring torsional vibration at 1 to 4 ranks changing with the distance between the drillstring and drill hole, there is a curve Fig. 3 by the data, which is from the result data of the model of vibration at each rank extracted from the software ANSYS. It directly show the distributing and maximal eigenvalue of the model of the vibration at 1 to 4 ranks along the drill hole axis towards the angular displacement. It is constructive to analyze the force, to learn the concrete vibration in the process of torsional vibration, and to choose a rational reduced vibration method and so on. Though, it is consistent between the inherent model of torsional vibration and the result of tortional vibration wave equation in Fig. 3, the former is convenient to gain than the latter.

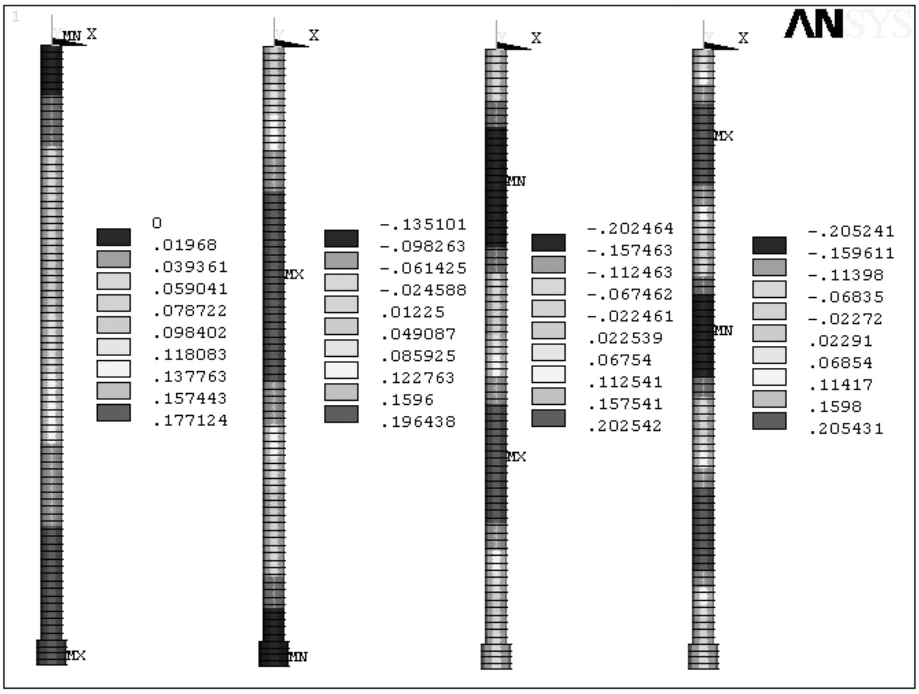

Fig. 2. The inherent model of 2000 meters drillstring torsional vibration at 1to 4 ranks (angular displacement)

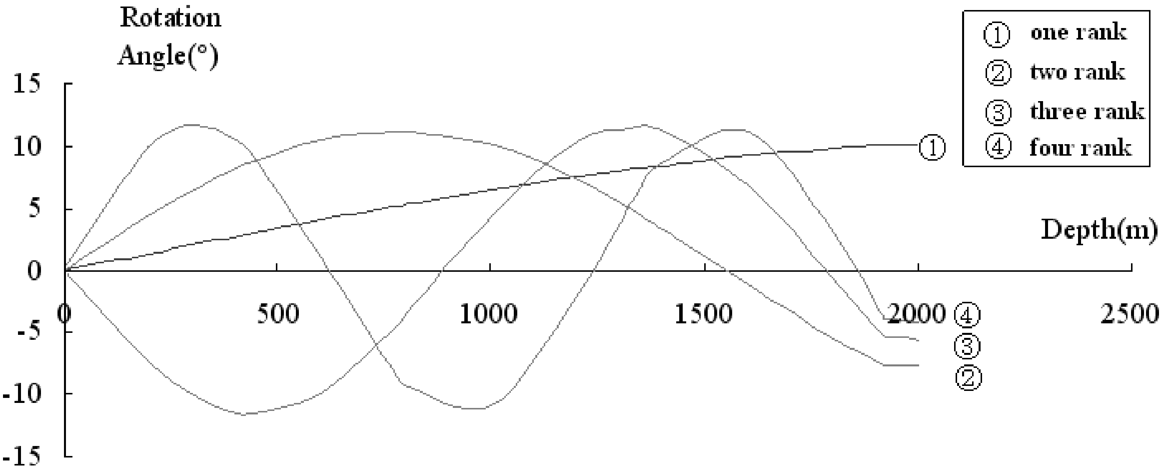

Fig. 3. The curve for the inherent model of the2000 meters drillstring torsional vibration at 1 to 4 ranks

5. Conclusion

1. The analysis result is precise and thorough by software ANSYS.

2. The thicker the wall thickness of the drill pipe, the higher the inherent frequency ratio for drill pipe torsional vibration, while the amplitude is not obvious.

3. As the length of the drill collar increases, the inherent frequency ratio for the drillstring torsional vibration at low rank decrease, while the ones at high rank increase quickly.

4. The longer the length of drillstring, the much lower the inherent frequency ratio for the drillstring torsional vibration.

5. The maximal angular displacement of the drillstring torsional vibration change with the rank of the main model of drillstring torsional vibration

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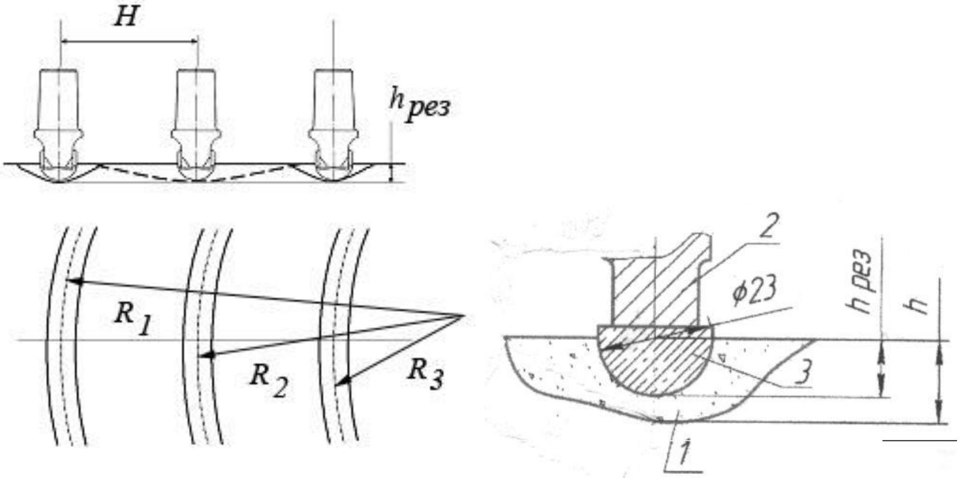
К ВОПРОСУ О ВЛИЯНИИ ВЗАИМОРАСПОЛОЖЕНИЯ РЕЗЦОВ НА ЭНЕРГОЕМКОСТЬ РАЗРУШЕНИЯ ГОРНОЙ ПОРОДЫ

Results of studies of dependence between arguments of interposition of chisels on a cutting head of a heading machine and specific energy of breaking down of rock of type of Terebovljansky sandstone are resulted. Optimum arguments of rock breaking proceeding from the minimum energy output are determined at the max output of its breaking down by chisels of type RP-221.

В настоящей работе описаны результаты анализа взаимосвязи удельной энергии разрушения горной породы и параметров, обусловленных топографией расположения резцов типа РП-221, в частности, расстоянием между резцами (шагом резания H) (рис. 1а) и глубиной резания $h_{рез}$, зависящей от типа резца и мощности привода многорезцового исполнительного органа, в данном случае горного комбайна. Шаг резания H выбирали так, чтобы его отношение к радиусу твердосплавной вставки 3 (рис.1 б) , запаянной в корпус резца 2 H/R изменялось от 1 до 5 (при R = 11,5 мм), а следовательно, взаимовлияние резцов по мере увеличения этого соотношения сводилось бы к нулю, т. е. напряженное состояние в окрестности резца, установленного на радиусе R_2 (рис. 1 а), формировалось бы вследствие влияния формы и глубины лунки, образованной в породе соседним резцом, установленном на радиусе R_1).



а б

Рис.1. Схемы расположения резцов на плоскости блока горной породы (а) (Н- шаг резания; R1, R2, R3 - радиусы окружностей, на которых устанавливаются твердосплавние резцы) и взаимодействия твердосплавного резца и массива горной породы (б) (1 - фрагмент шлама песчаника Теребовлянского месторождения; 2 - корпус резца; 3 - твердосплавная вставка; h- толщина фрагмента шлама ; hрез- глубина резания твердосплавным резцом