

# Study on vibration characteristics of drill pipe drilling mining seam for gas drainage

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**Abstract**—In the process of coal seam gas drainage drilling, under the pressure of the drilling machine, any position of the drill pipe will have the possibility of transverse vibration, then made the phenomenon of contact and collision between drill pipe and hole wall. Through the analysis of the transverse vibration, axial vibration and torsional vibration of drill pipe, reveals the changes of drill pipe diameter, drilling depth and other factors on lateral vibration, axial vibration, torsional vibration and natural frequency of the drill pipe, found that the transverse vibration of drill pipe is the root cause of drill pipe fatigue fracture, at the same time, it is also an important reason for the phenomenon of coal seam hole wall collapse, plugging hole and stuck drilling.

**Keywords**—Soft coal seam, drilling tool, vibration characteristics, drilling depth

## I. INTRODUCTION

In coal seam gas drainage drilling operation, because of the complicated geological conditions, the failure of drill pipe is more prominent, the harm is also very big. Drill pipe failure is often because the drill pipe cracks on lateral, axial and ring, and the drill pipe and hole wall frictional contact makes the pipe wall thinning. cracks at the end of the end of the thread and so on, these are parts of the failure of the drill pipe. How to effectively reduce the failure of drill pipe is a very critical issue in the drilling engineering of gas drainage. Rotary drilling rod mainly bear pressure, centrifugal force, bending force, torsion, etc. The drill rod is also subjected to alternating stress loads. Due to the axial vibration of the drill pipe produces bending stress, torsional vibration caused by the

shear stress, is an important factor to cause fatigue failure and fracture failure of drill pipe[1-4].

Due to the influence of the vibration of drill pipe, the drilling pressure can not be effectively uniformly applied to the drill bit, because of the severe vibration of the drill pipe, the drill bit is circulated through the bottom of the coal, and the phenomenon of "jumping drill" appears, the drill bit impact load caused by uneven stress premature failure, greatly reducing the drilling progress and drilling speed; the severe vibration of drill pipe makes the drill pipe on the weak parts of the screw thread and drill pipe prone to fatigue fracture. in the process of construction operation, serious vibration and fatigue failure of drill pipe is always a difficult problem to research and resolve the industry experts[5-6].

## II. ANALYSIS OF AXIAL VIBRATION OF DRILL PIPE

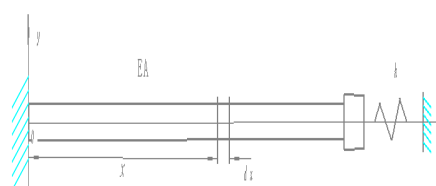


Fig. 1: The simulation model of drill pipe axial vibration

### 2.1 Force equation of axial vibration of drill pipe

In the process of coal seam gas drainage, the drill pipe is connected by several dozens or hundreds of drill rods through threads. Therefore, according to the connection characteristics of the drill pipe and the working condition of drilling, the transverse vibration of drill pipe stress analysis does not consider the drill pipe, torsion vibration

and other factors, only the axial vibration[7-9].The simplified model of axial vibration simulation is shown in figure 1.

The pipe port is composed of a power wheel is fixed while the output torque drilling pressure and drilling speed, the bottom end of the bit by the drill pipe in contact with the coal wall.In the axial vibration of drill pipe, the cross-section always maintain line with the drill rod axis in the same horizontal plane, without taking into account the drill rod transverse force and deformation effects.namely on the same cross section only produces Z to the same displacement, to  $u(Z, t)$  that section at the moment of t displacement.

**2.2 The influence of drilling depth on the axial vibration of drill pipe**

With the diameter of 73mm drill pipe as an example, analyze the influence of drill pipe length to drill axial vibration inherent frequency. Through the simulation of drill pipe finite element axial vibration analysis, extract of different length of drill pipe natural frequency results, as shown in Table 1.

**Table 1.each order natural frequency of axial vibration of drill pipe**

drill pipe length h(m)	natural frequency of drill pipe (HZ)									
	1	2	3	4	5	6	7	8	9	10
100	12.93	38.79	64.66	90.55	116.4	142.4	168.3	194.4	220.4	246.5
200	6.456	19.39	32.32	45.26	58.19	71.14	84.08	97.03	109.9	122.9
300	4.310	12.93	21.55	30.17	38.79	47.41	56.04	64.66	73.29	81.92
400	3.232	9.697	16.16	22.62	29.09	35.56	42.02	48.49	54.96	61.43

From the data analysis results of the table 1 can be seen as the rod length increased its natural frequency decreased significantly,and the frequency band gap between the natural frequency of the axial vibration of the drill pipe is also reduced.To more significantly more intuitive depicts this variation, according to table 1 that the data, rendering [www.ijaers.com](http://www.ijaers.com)

the drill pipe in different drilling length natural frequency curve diagram as shown in Figure 2.

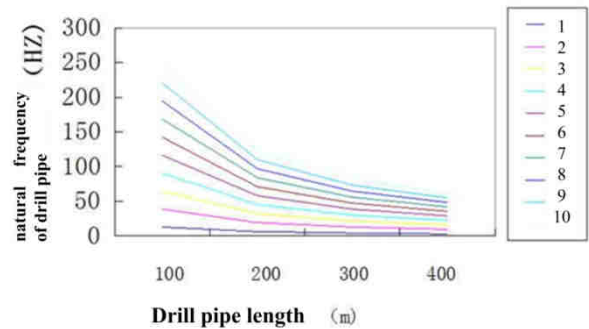


Fig. 2:The change curve of axial vibration of drill pipe

As can be seen from the figure when the drill pipe drilling is not very deep the axial vibration frequency is relatively high, with the continuous growth of the length of drill rod, the natural frequency will be significantly reduced.And the hole depth more shallow, the frequency interval of the natural frequency in each order for the drill pipe is also greater, so in the shallow hole drilling, the drilling parameters can be modified, to reduce the occurrence of the drill pipe resonance phenomenon.

The above analysis shows that the drill pipe length is one of the main reasons that affect the axial vibration of drill pipe. The longer the drill rod, the smaller the frequency, more easy to produce resonance; the shallower the borehole, the higher the drill pipe frequency, that is, the resonance situation is much smaller than in the deep hole drilling. In the actual work process, we can reduce the vibration frequency and install BHA or shock absorber on where the drill pipe axial displacement occurs bigger or the frequent occurrence of axial vibration, so the drilling efficiency can be improved, and the accident rate of drill pipe wear and drill stem fatigue fracture can be reduced ,at the same time, it can also play a very good stability for the hole wall stability, and reduce the gas pressure, situ stress on the jet hole, collapse hole, hole collapse and the formation of drill holes.

**III. TRANSVERSE VIBRATION OF DRILL PIPE**

In the vibration form of drill pipe, the action mechanism

of the transverse vibration is the most complicated. Because of the drill pipe under the drilling pressure and drilling speed will be due to the lateral vibration and bending deformation.

**3.1 force equation of the drill pipe transverse vibration**

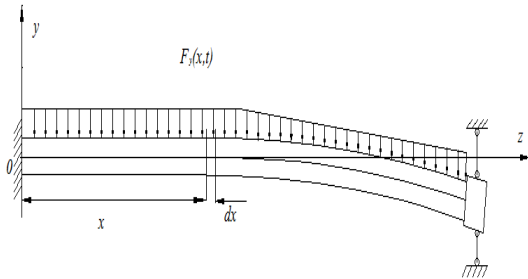


Fig.3: The simulation model of drill pipe transverse vibration

In boreholes, with rig drilling, length of drill pipe is increasing, drill pipe under the action of gravity will gradually deviate from the drill pipe horizontal center line downward breaking coal drilling. According to the characteristics of the structure of the drill pipe and the working conditions of the drilling, analysis of the influence of transverse vibration, the simplified model of the lateral vibration force is shown in Figure 3, known: drill pipe density  $p$ , flexural rigidity  $EI$ , Cross sectional area  $A$ , deflection of section  $y(x,t)$  forward direction is upward, intercept infinitesimal section from the  $X$  section of the drill pipe, the loading force in the direction of the cross section of the drill pipe is  $F_y(x,t)$ , without taking into account the effect of viscous damping, the  $C_s$  is the strain internal damping coefficient.

**3.2 Effect of drill pipe length on the lateral vibration of drill stem**

With the diameter of 73mm drill pipe as an example, with the analysis of drill pipe length change of the transverse vibration frequency, as shown in Table 2.

Table 2 Each order natural frequency of Transverse Vibration of drill pipe

drill pipe length	natural frequency of drill pipe (HZ)									
	一	二	三	四	五	六	七	八	九	十

(m)	1	2	3	4	5	6	7	8	9	10
100	1.04	0.40	0.31	0.23	0.17	0.13	0.10	0.08	0.06	0.05
200	0.52	0.20	0.15	0.11	0.08	0.06	0.04	0.03	0.02	0.02
300	0.34	0.14	0.10	0.07	0.05	0.04	0.03	0.02	0.01	0.01
400	0.26	0.10	0.07	0.05	0.04	0.03	0.02	0.01	0.01	0.01

From the results in Table 2, we can see that the longer each order natural frequency of drill pipe is smaller, and the gap between the frequencies is also accompanied by increase drilling depth decreases, and compared with the drill pipe axial vibration that the lateral vibration frequency changes very little, and the amplitude of vibration no transverse vibration of large amplitude, so lateral vibration mode shape changes obviously. In order to more visible depict the drill pipe of each order vibration frequency change with the length of drill pipe, according to table 2 data to draw the graph as shown in Figure 4.

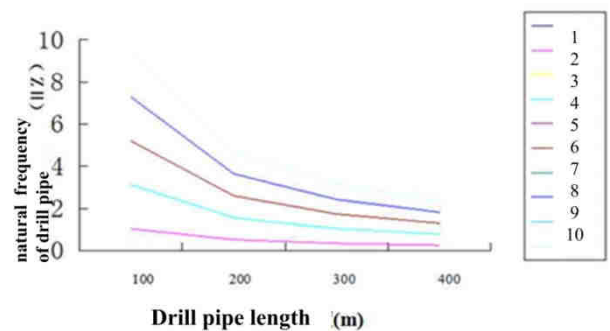


Fig.4: The changing curve of Transverse Vibration of drill pipe

From the graph, we can see that the transverse vibration of drill pipe is related to the depth of drill hole, the longer the drill pipe is, the lower the frequency of the transverse vibration is. It can be seen from the model of the drill pipe that the amplitude of the transverse vibration is much higher than that of the axial vibration, so we see that the mode of motion is similar to the sine curve. The transverse vibration of drill pipe is one of the most complex of axial vibration, lateral vibration and torsional vibration.

**IV. TORSIONAL VIBRATION ANALYSIS OF DRILL PIPE**

Rig in the process of downhole operation, Breaking coal body to realize drilling, the resistance of the bit in drilling is changed periodically, that is the phenomenon of "sticking",with repeated drill rod of rotary drilling , exacerbated by the torsional vibration .Torsional vibration of the drill pipe produce alternating shear stress, severe cases will be caused by drill pipe failure and threaded connections fatigue fracture, which occurred in the broken drill accident.

**4.1 Mechanical equation of torsional vibration of drill pipe**

According to the drill pipe structural characteristics and drilling work, ignoring the role of other forces influence in drill string ,only analysis torsional vibration of drill rod, the simplified model of torsional vibration is shown in Figure 5.During drilling, the drill rod rotates around its own axis.The pole moment of the drill pipe is  $I_p$ , the shear modulus is  $G$ , the cutting resistance moment is  $T$ .

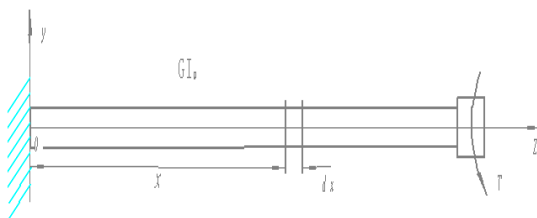


Fig.5:The simulation model of drill pipe torsional vibration

**4.2 Effect of drill pipe length on torsional vibration of drill rod**

Drill pipe drilling in the coal seam, due to intermittent cutting coal wall so that the drill pipe reverse around its axis as a center torsion, drill pipe reverse energy production continue to accumulate and continue to release, the drill pipe "sticky - release" phenomenon occurred, the drill pipe under the impact has been rapid wear. Using the diameter of 73mm drill pipe as an example to analyze the effects of drill pipe length on its natural frequency.

Through the analysis and calculation of the drill pipe by the ANSYS software, the natural frequency values of each step of the drill stem are shown in Table 3<sup>[10-12]</sup>.

Table 3 Each order natural frequency of Torsional Vibration of drill pipe

drill pipe length (m)	natural frequency of drill pipe (HZ)									
	一	二	三	四	五	六	七	八	九	十
100	8.01	24.0	40.1	56.1	72.2	88.3	104.	120.	136.	152.
92	6	06	62	32	2	43	57	73	93	
200	4.00	12.0	20.0	28.0	36.0	44.1	52.1	60.1	68.2	76.2
96	29	49	71	94	19	47	78	13	53	
300	2.67	8.01	13.3	18.7	24.0	29.4	34.7	40.1	45.4	50.8
31	92	66	12	6	08	56	06	57	09	
400	2.00	6.01	10.0	14.0	18.0	22.0	26.0	30.0	34.0	38.1
48	44	24	34	44	54	65	76	88		

From table calculation results show that, with the drill pipe length increases the natural frequency decreases, and along with the length of drill pipe drill growth low order frequency value decreased gradually, at the same time high order frequency value also decreased. The natural frequency of the drill pipe with different length curve as shown in Figure 6.

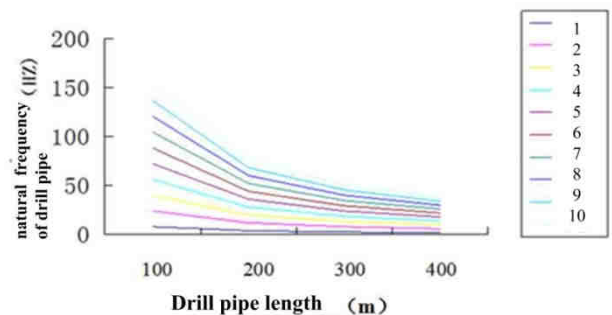


Fig.6: The changing curve of Torsional Vibration of drill pipe

From the curve shown in figure can be seen when drill pipe drilling is not deep in the torsional vibration frequency is very high, with increasing the drilling depth, natural frequency will significantly reduces.And the drilling depth is shallow, the frequency band of the frequency band of the drill stem is larger.The analysis of the above results with increasing frequency of drill pipe, drill pipe length (decrease) the natural frequency will be

smaller (increase).The analyses provide the basis for solve the problems, such as wear bit, resonance destruction, fatigue failure of drill pipe joint thread and strength.

## V. CONCLUSION

Through analysis of drill pipe in the axial vibration, the transverse vibration and torsional vibration, respectively, to calculate three vibration modes for each order inherent frequency and vibration type of drill pipe. Through the comparative analysis of the calculation results, under the same drill pipe diameter and hole depth, The transverse vibration frequency of drill pipe is the minimum of the axial vibration frequency, transverse vibration frequency and torsional vibration frequency. The analysis results also show that in the actual rotary drilling process, the drill pipe has the transverse vibration of the probability is the largest, followed by torsional vibration, the last is the axial vibration. Transverse vibration will cause vibration of drill stem amplitude is relatively high, and high drilling speed will cause the emergence of the centrifugal force, and so that the drill pipe drilling center axis deviation, drill pipe and the coal hole wall contact friction phenomenon, caused by drill rod fatigue fracture and coal seam gas drainage hole wall of hole collapse, plugging holes and sticking etc. Phenomenon.

## ACKNOWLEDGEMENTS

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