Modal analysis and research of the BTA drill pipe based on ANSYS software

Zhen Dong

North university of china,Taiyuan,Shanxi,030051, China

zhen1137@126.com

Keywords: BTA drill; modal analysis;ANSYS software

Abstract. Made the modal analysis of BTA drill pipe by ANSYS software,analysis the modal of the BTA drill pipe when encountered the excitation frequency in the actual processing.Determine the appropriate drill pipe vibrations at different excitation force, to further optimize the design of the drill, provide the basis to avoid the resonance frequency.

1 Introduction

In the process of deep hole machining, when the frequency of the external excitation is equal with or close to BTA drill pipe , the natural frequency of BTA drill string resonance occur, and each frequency excitation corresponds to a fixed mode.[1]Therefore, in the modal analysis, what should be analyzed is BTA drill pipe vibration mode which the excitation frequency can meet in the practical machining.In the structural design, we should make the natural frequency of the drill pipe avoid the frequency of the external excitation, so it can avoid resonance.[2][3]Through calculating the inherent vibration mode of the structure, we can determine the action of the corresponding vibration under the different exciting force, and then control the excitation frequency to avoid the resonance vibration mode.So it can improve the machining precision of the deep hole processing.

2 ANSYS modal analysis extraction method

The basic equation of modal analysis is：

$$[K]\{\phi_i\} = \omega_i^2 [M]\{\phi_i\}$$

In the formula：

$[K]$is the stiffness matrix；

$[M]$is the mass matrix。

$\{\phi_i\}$is the first modal vibration mode vector；

ω_i is the first-order natural frequency of mode；

In the ANSYS software,we can extract the structure modal by seven methods.They are the block lanczos method,reduction method,subspace method,asymmetric,Power Dynamics method,damping method and QR damping method.The previous five methods of the seven methods are the modal extraction for undamped free vibration system.the two behind are the modal extraction for the modal damping of the structure.[4]

Block lanczos method and subspace technique has higher accuracy and efficiency and little user intervention.The Power Dynamics is a approach which suits unit model included only.In this article,it need modal analysis on the structure under the static load,that is analysis from the initial vector.[5][6]So we choose the first method: block lanczos method.

3 Modal Analysis

(1) establish a model

Modal analysis is an analysis of the linear structure.If it contains some nonlinear factors in the process of modeling, ANSYS will solve these nonlinear factors into linear factors when calculating.The elastic modulus and density of the model must be given while building the model.[7]

In the process of deep hole processing with a diameter of 38.3mm,The drill sizes used were:the outer diameter $\phi 35mm$, the inner diameter $\phi 20mm$, the length 40000mm,the materials 40Cr, modulation processing.

(2) Loading and Solution

Loading and solving steps

①To start the solver

②Select analysis types and options

③Master degrees of freedom

⑤Specify load step options

⑥To solve and calculate

⑦Exit SOLUTION

(3) extended modal

Last step is to load the structure and calculate, and this step is to expand mode to the whole structure,which is used for testing results or other analysis.They have the modal expansion and stored in a structural analysis results file after the structure was calculated to solve in the ANSYS software.This part of the result data include the structure of the stress and strain, the structure of the natural frequency and natural frequency of the vibration mode.[8]

(4)Observation

This step is a visualization result of modal analysis and calculation and the analysis of the results.In general postprocessor,we can observe the modal analysis results.

4 The modal calculation results and analysis

Modal analysis of drill pipe is the calculation of its natural frequency and vibration mode in the condition of drill pipe structure undamped free vibration.In this paper, it make the modal analysis for it using finite element method in ANSYS software.The main excitation is drill mode shapes which frequencies is within 2-70Hz .

We can get low frequency band frequencies and corresponding vibration mode of the drill pipe system by the modal analysis.In the actual processing, we found that ttorsion and bending of the drill pipe is the main mode of the structure.It can be divided into horizontal bending, vertical bending, twisting in the horizontal plane and the vertical plane twisting and other types.[9]

Table 1 Drill pipe first ten order vibration frequency

Order	Frequency（Hz）
1	2.3515
2	2.3545
3	9.0923
4	9.0936
5	14.716
6	14.739
7	28.532
8	28.546
9	68.361
10	68.423

Figure 1 - Figure 10 is a vibration frequency of the drill first ten modes corresponding to FIG.

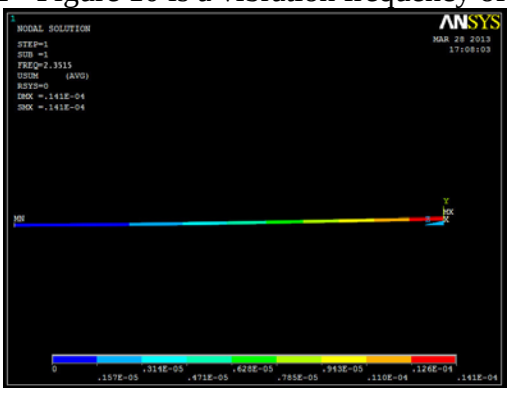

Figure 1. Figure drill first mode

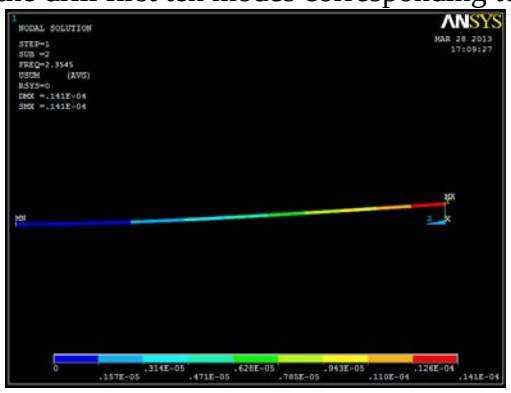

Figure 2. Figure drill Second mode

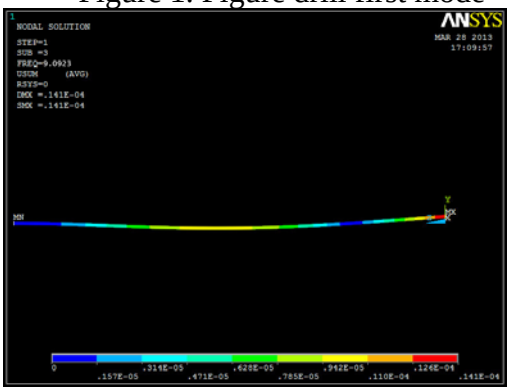

Figure 3. Figure drill Third mode

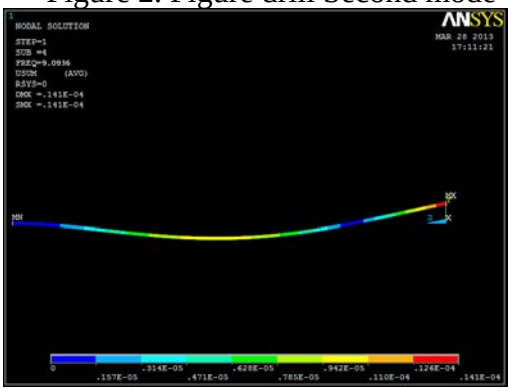

Figure 4. Figure drill Fourth mode

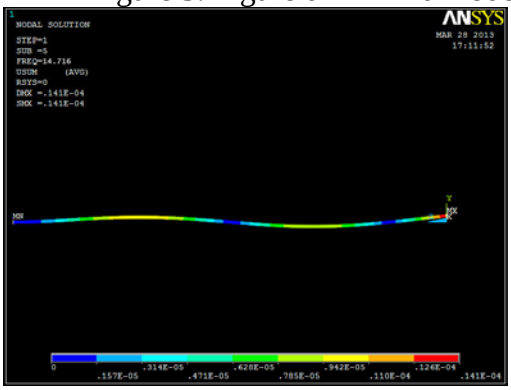

Figure 5. Figure drill Fifth mode

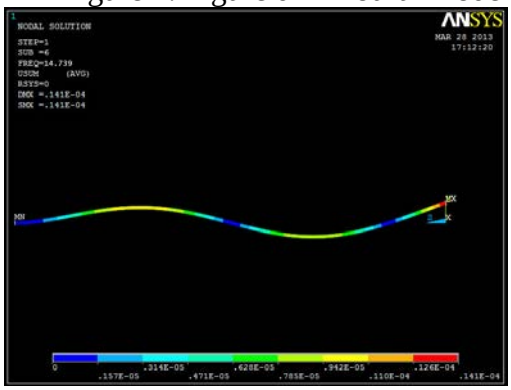

Figure 6. Figure drill Sixth mode

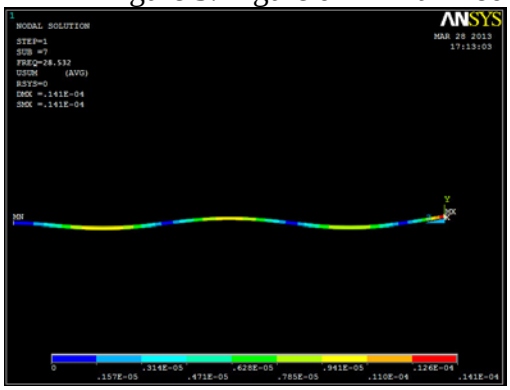

Figure 7. Figure drill Seventh mode

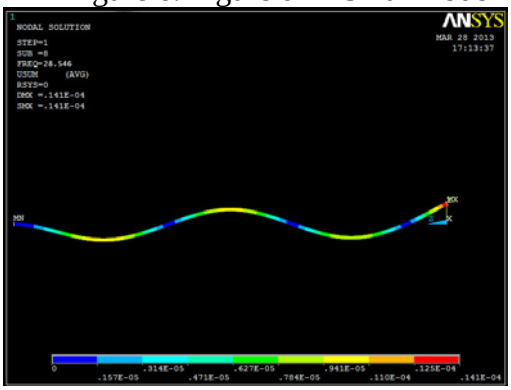

Figure 8. Figure drill Eighth mode

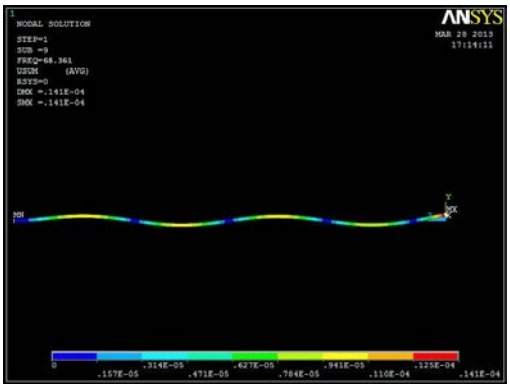

Figure 9. Figure drill Ninth mode

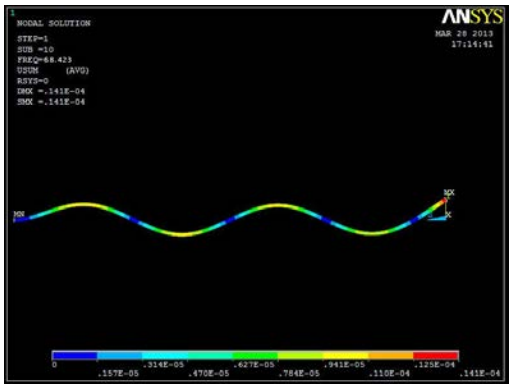

Figure 10. Figure drill Tenth mode

The analysis of modal results:

(1)Table 1 shows the drill pipe first ten order vibration frequency.The drill pipe vibration mode under the stimulus of the frequency is shown in the above.We can find it produce the large amplitude when the external excitation frequency close to the table value, which affects the processing quality.[10][11]In order to reduce the influence of vibration on the processing quality and improve the processing quality, we should control the corresponding excitation frequency to avoid the resonance vibration mode;or change the drill pipe vibration frequency range by the optimization design of drill pipe to reduce the vibration amplitude.

(2) Analysis of the drill mode shapes: The first order and second order bending deformation occurred,bit part stress is concentrated,and the second order deformation is greater than the first order.The third order and fourth order torsional deformation occurred,drill part stress concentration[12],drill pipe arched in the middle,and the deformation is greater than the third and fourth order order.The fifth order and sixth order torsional deformation occurred,the 1/3, 2/3 of drill and drill part concentrated stress,the middle and end of drill's stress is less,the deformation of fifth order is greater than sixth order.The seventh order and eighth order torsional deformation occurred,the drill pipe, 3/7, 5/7 and 1/7 bit part stress is the largest,the deformation of seventh order is greater than sixth order.The ninth order and tenth order torsional deformation occurred,drill pipe in 1/9, 3/9, 5/9, 5/9 and bit five stress concentration.

(3) In the process vibration,vibration energy mainly concentrated in the first ten order according to the knowledge of vibration theory.According to the analysis of the modal analysis results above, the torsion and bending pipe is the main vibration mode.

Acknowledgements

This work was financially supported by the National Natural Science Foundation of China(51175482)and International S&T Cooperation Program of China(2013DFA70770).

References

[1] RD Han and JL Guo:'Turning slender rod system dynamics modeling' Mechanical Research and Application, china，2004,17 (3) :16-17

[2] J H Chin,R J Jiang.Dynamic modeling and simulation of hydraulic-driven fight simufator under different controllers.Proceedings of the JASTED I nternational Conference on Modeling,simulation and Optimization,2008:52-56

[3] K. Weinert，O. Webber，M. Husken. Time Series Analysis of BTA Deep Hole Drilling COST P4，Nonlinear Dynamics in Mechanical Processing[J]. EU-Frame Work COSTActionP4，University of Dortmund，Dortmund，Germany，2009：245-258.

[4] N Raabe.dynamic Disturbances in BTA Deep-Hole Drilling：Modelling Chatter and Spiralling as Regenertive of the Effects[J].Intelligence，Studies in the Classification，Data Analysis，and Knowledge Organization，2010：82-91.

[5] H Zhao:‘deep processing of special boring bar Dynamic Characteristics and applications’. Master's thesis. Shanghai Jiao Tong University. China .2005

[6] I.Ciupitu，N.Dumitru，St.Gheorghe et al.Static analysis of the guiding bearing drill contact by finite element method[J].Journal of Materials Processing Technology，2003，143-144：270-276.

[7] STONE J,MURALIKRISHNAN B.Geometric effects when measuring small holes with micro contact probes[J].Journal of Research of the National Institute of Standards and Technology,2011,116(2):573-587.

[8] B Qin:‘Deep processing power damping dynamics simulation and parametric analysis of the boring bar’.Master's thesis.Harbin: Harbin Power Engineering, Electrical and Mechanical University,China.2006

[9] LF Kong:‘Drill deep hole machining study nonlinear dynamic behavior.’PhD thesis. Xi'an University of Technology,China.2010

[10] RIBY A B,PRASHANT S,SONAKAR M,et al.Identificantion of defect on highly reflective ring components and analysis using machine vision[J].International Journal of Advanced Manufacturing Technology,2011,52(1/2/3/4):217-233

[11] U.weker.On the influence ofdrilling depth dependent modal damping on chatter vibration inBTA deep hole drilling. CIRP Ann Manuf Technol,2004,54:363-366

[12] MURANAKA Y,INABA M,ASANO T,et al.Parasitic rotation in parallel spring movements[J].Int Jpn Soc Pre Eng,1991,25(3):208-213