

The Dynamic Characteristic and Finite Element Analysis on Wheelset Driving System of Underfloor Wheelset Lathe

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Abstract. Wheelset driving system is a key function unit of CNC underfloor wheelset lathe, its properties and accuracy play a decisive role for working accuracy of the wheelset (trains, subways etc) tread. At first, it analyses the force of cutting point for wheelsets, and then, contact mechanics analysis and delivering power analysis are established based on friction wheels and wheelsets' actual contact mechanics equations on wheelset driving system in this paper. At last, in order to analyze wheelset driving system's rigidity and degree of deformation with loading condition, modeling analysis and static force analysis are set up in the finite element software after building wheelset driving system's three-dimensional model.

Introduction

Wheelset driving systems, which fulfill motion importantly by friction driving, is one of the main technical characteristics of CNC underfloor wheelset lathe. Furthermore, the improvement of CNC underfloor wheelset lathe is accomplished start from that point. At present, two friction wheels are fastened on each side of the friction wheel bearing frame separately by horizontal pressure floating support equipment to finish turing rather rapid and scientific. What's more, each of the friction wheel's parameters such as location of the rising, size of stress and speed of the floating up and down etc, are controlled and detected respectively by horizontal pressure floating support equipment, which will bring significant breakthrough on the overall performances of CNC underfloor wheelset lathe. Therefore, for the above-mentioned many advantages, CNC underfloor wheelset lathe is concerned by many specialists and scholars at home and abroad.

As regards driving systems, C.Segieth put forward its elastic suspension and isolability [1]. H.Hoedei and A. Haigermoser contrasted and evaluated the stability of the locomotive for driving systems in suspension way [2]. Josef Kolerus acquired the stable conditions to avoid stick-slip vibration for locomotive driving systems by simplifying linear model of locomotive driving systems [3]. Martin B. Sebald came up with boundary conditions to choose driving systems and based on driving system structure to make a comparison for driving performance and running properties [4]. Xiyong Zhao and Yongfang Wu provided a overall suspension pattern for driving system's suspension of high-speed locomotive bogie and made a great many of researches [5]. Dingchang Jin investigated driving system's suspension parameter's influence for the lateral dynamic performance of a locomotive [6]. Yongfang Wu established a locomotive dynamics model for motor frame hanging driving device and made an attempt on simulated calculation of pulley idling process [7]. Zan Luo and Dingchang Jin investigated the longitudinal and transverse stiffness of driving system's suspension condition for the influence of acceleration of vibration and locomotive stationary [8, 9].

In conclusion, although many scholars at home and aboard have studied modeling simulation, mechanical vibration and stability of machine tools and locomotive's driving systems, they seldom care about the study of driving system's dynamics of CNC underfloor wheelset lathe. This paper analyze the wheels under the action of cutting force and friction wheels and wheels contact mechanics, and then to calculate the stress on the friction wheels and driving wheel's force and moment. At last, in order to analyze wheelset driving system's rigidity and degree of deformation

with loading condition, modeling analysis and static force analysis are set up in the finite element software after building wheelset driving system's three-dimensional model. The model and analysis conclusion of this paper will contribute to improve overall performances and avoid driving system's lose efficacy.

Formulations

On the basis of transmission relationship of CNC underfloor wheelset lathe, the structure diagram is as shown in Fig.1.

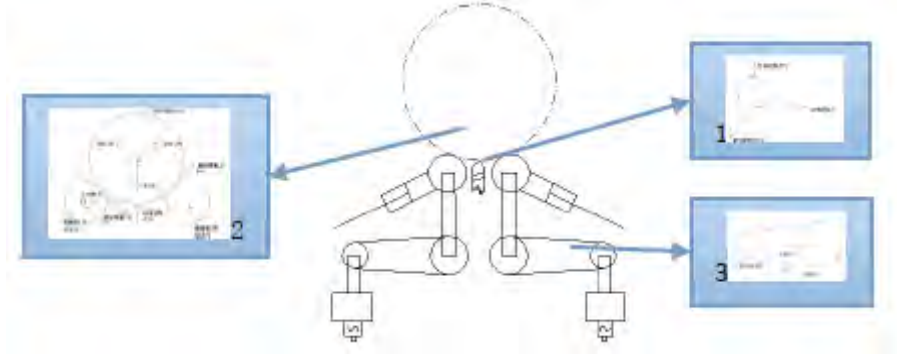


Fig. 1 Cutting Transmission Schematic Diagram

The Establishment of the Mechanical Model of Wheel Cutting Point

In the process of cutting, the cutting force of cutting point as shown in Fig.1 of 1.

On three directions equations under the cutting force is as follows:

$$\begin{cases} F_x = 9.81C_{px}t^{x_{px}}S^{y_{px}}V^nK_{px} \\ F_y = 9.81C_{py}t^{x_{py}}S^{y_{py}}V^nK_{py} \\ F_z = 9.81C_{pz}t^{x_{pz}}S^{y_{pz}}V^nK_{pz} \end{cases} \quad (1)$$

In the equation set: F_x —main cutting force, F_y —radial cutting force, F_z —axial cutting force.

C_{px}, C_{py}, C_{pz} —The workpiece material and cutting condition to the influence of cutting force coefficient.

x_{px}, x_{py}, x_{pz} —Back cutting depth to the influence of cutting force coefficient.

K_{px}, K_{py}, K_{pz} —Cutting condition to the influence of cutting force coefficient.

The Analysis of Contact Force for Friction Wheels and the Wheels

Based on the friction wheel driving principle can obtain mechanical analysis of wheels. Mechanics formulas can be establish in the light of the 2 in Fig.1:

$$\begin{cases} F_f = F_z / 2 = f \times N \\ T = F_f \times d / 2 \\ f = 0.15 \end{cases} \quad (2)$$

In the equation set: F_f —friction force, N —contact pressure, T —unilateral friction torque, f —coefficient of friction.

The Force Analysis of Belt Wheel

Assume that the torque of friction wheel shaft system's transmission is no loss.

$$\begin{cases} F_f' = T \div d_2 / 2 \\ \alpha = 180^\circ + \frac{d_2 - d_1}{a} \times 57.3^\circ \\ F_Q = K_Z \times F_f' \times \sin \frac{\alpha}{2} \\ K_Z = 1.581 \end{cases} \quad (3)$$

In the equation set: F_f' -friction force of the big belt wheel, α -angle of wrap of the big belt wheel, F_Q -the pressure of the shaft.

The Establishment of a 3D Model

The underfloor wheelset lathe has no chuck. The torque generated by the friction mode drives the workpiece (wheelset) rotation and cutting. Friction driving chain: main driving motor→retarder→pulley→driving shafts (two)→Friction rollers(two)→workpieces(wheel). Key components of an underfloor wheelset lathe - structure tree of wheelset driving system as shown in Fig. 2.

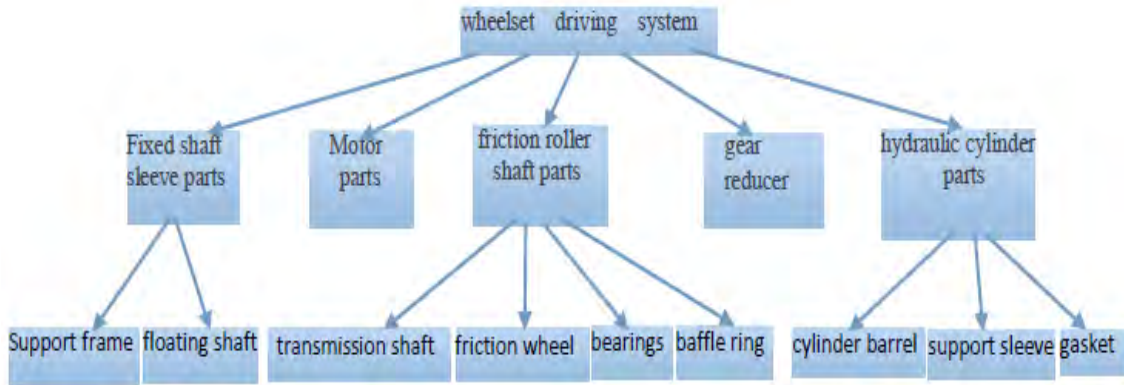


Fig. 3 the Structure Diagram of a Single Wheelset Driving System

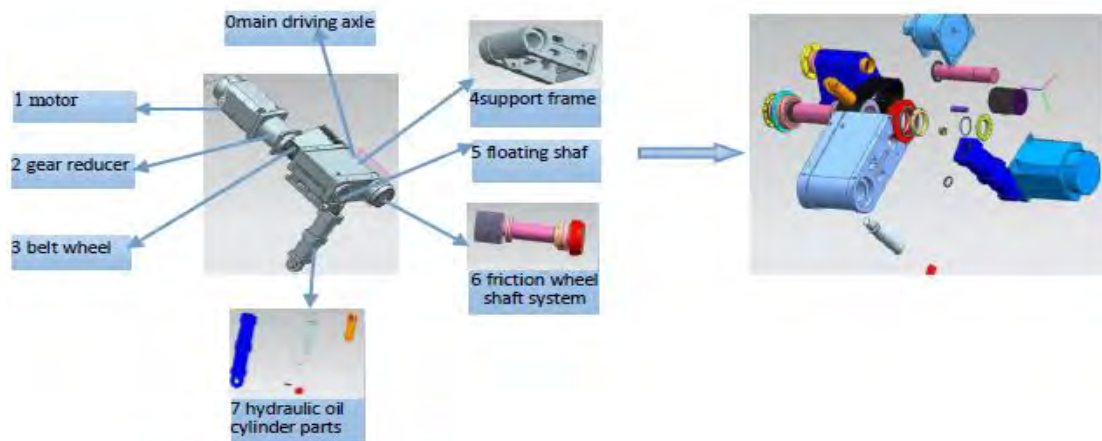


Fig. 4 the Exploding Diagram of Assembly

The entire model process is based on the two-dimensional machine tool drawing to converse and actual measurement. We can use the three-dimensional software UG6.0 to set up solid modeling. First, we should set up the parts and use the parts fitted into components, parts and components. Finally, the parts, components, parts are assembled into a piece. Then we make motion simulation and interference check.

Finite Element Analysis

The Static Analysis and Modal Analysis of Key Components

The simplification of Shafting model: 3d assembly shafting is very complicated. It contains a lot of screws and washers which influence model into finite element analysis software Ansys. The model is be simplified as shown in Fig.5. Then let the model import into Ansys to produce the definition of material property model of the parts according to the material of the density, elastic modulus, poisson's ratio parameters etc .

Tab. 1 Material Properties

part name	material	density(kg/cm ³)	modulus of elasticity	poisson's ratio
friction wheel	Cr12	7900	206	0.3
belt pulley	HT250	7250	121	0.25
transmission shaft	40CrMoA	7900	206	0.3
bearing	C45	7850	200	0.3

According to the actual situation, the ends of the shaft can be added the necessary constraints to limit axial freedom. As shown in Fig.6, Fixed constraint should be added on the bearing, and there is no friction between shafts and bearing. As shown in Fig.7. We can make whole grid division according to intelligent network. Then we can make mesh refinement to the main line .As shown in Fig.8.

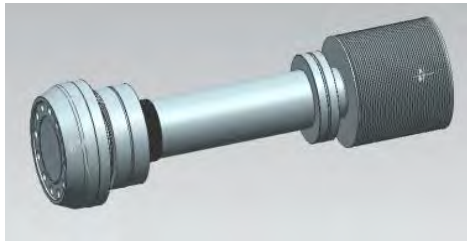


Fig. 5 Simplified Shafting System

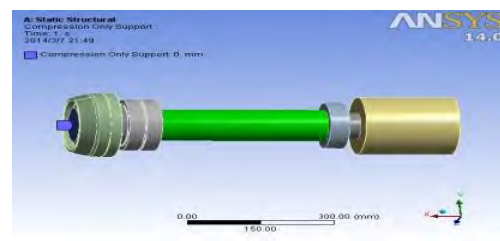


Fig. 6 Axial Constraint Graph

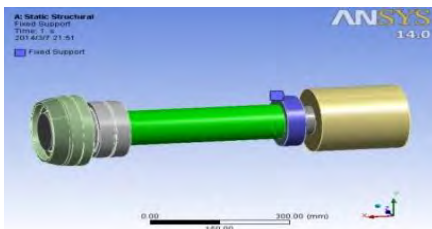


Fig. 7 Bearings Fixed Constraint and without Sliding Friction

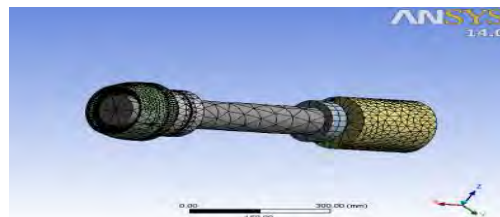


Fig. 8 Mapped Meshing

The Calculation of Boundary Conditions

In this paper, based on UGL30D CNC underfloor wheelset lathe parameters.

Tab. 2 Machining Parameters of CNC Underfloor Wheel Lathe

cutting speed (m/min)	turning (mm)	feed rate (mm/r)	motor's pulley diameter (mm)	the shaft pulley diameter (mm)	Belt wheel center distance (mm)	The motor power (KW)
80	6	2	140	200	265	15

According to wheel material and cutting conditions to select hard alloy cutter YT15.

By the look-up table:

$C_{pz} = 300$	$X_{pz} = 1$	$y_{pz} = 0.75$	$n = -0.15$	$k_{pz} = 1.012$
$C_{py} = 243$	$X_{py} = 0.9$	$y_{py} = 0.6$	$n = -0.3$	$k_{py} = 0.868$
$C_{px} = 339$	$X_{px} = 1$	$y_{px} = 0.5$	$n = -0.4$	$k_{px} = 1.582$

Put the table into (1):
$$\begin{cases} F_x = 7.736 \text{ KN} \\ F_y = 4.225 \text{ KN} \\ F_z = 15.575 \text{ KN} \end{cases}$$

Considering the influence of the improvement of tire tread mechanical strength in running condition. Take correction coefficient $K_{cpz} = 1.53$ (according to the correction coefficient peak selection).

Then $F'z = 1.53 \times 15.575 = 23.83 \text{ KN}$, by (2) $F_f = 11.915 \text{ KN}$; the friction wheel diameter: $d = 225 \text{ mm}$; $T = F_f \times d/2 = 1340.43 \text{ N} \cdot \text{m}$

Applying boundary conditions:

Toward a pulley 1.3404 e6 N.mm torques. Applied on the belt pulley's tensile force is converted pressure, the value is 0.17113 MPa . Applied on the friction wheel's torque when converted into pressure is 1150.6 MPa . Friction wheel contact force when converted into pressure is 1150.6 MPa . According to the previous import 3d model and applying boundary conditions can be static analysis and modal analysis.

Static Analysis and Modal Analysis

The static solution can be resolved by the previous modeling and the boundary conditions, the results shown in Fig.9.

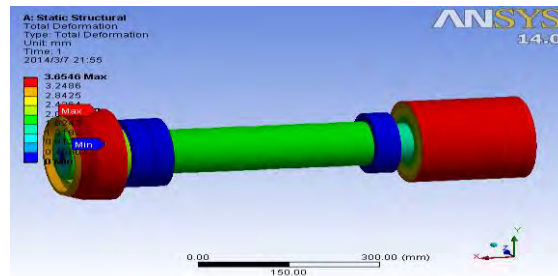


Fig. 9 Static Analysis

Modal Analysis of Shaft System

We can adopt the mesh generation and loading condition to solve the modal. the first six order modals is selected as follows:

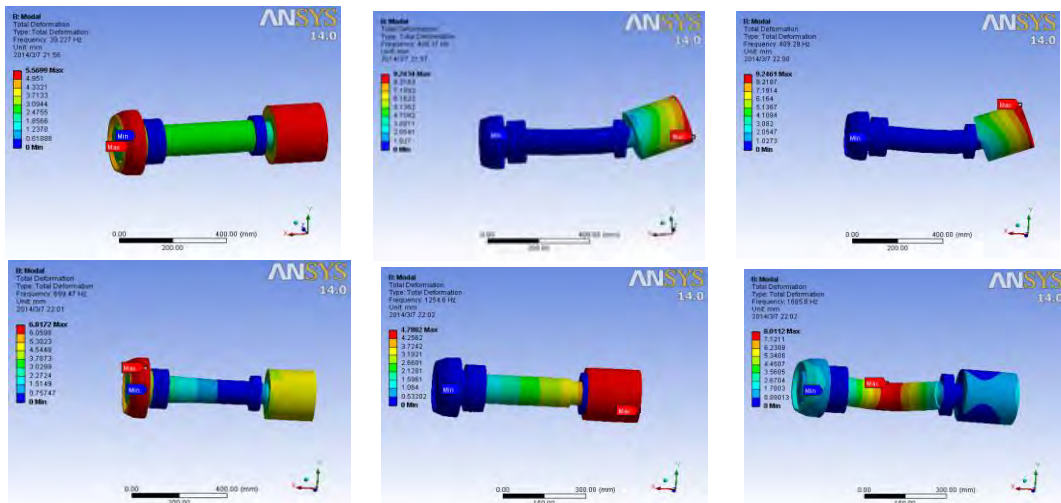


Fig. 10 Modal Analysis of Shaft System

Tab. 3 the First Six Order Modal Frequency

Modal order	The first modal	The second modal	The third modal	The forth modal	The fifth modal	The sixth modal
frequenc(Hz)	39.227	408.37	409.28	699.47	1254.6	1685.6

The Load Analysis of Lifting Body of Friction Wheel

The force on friction wheels is very big when 18t carriage body is supported by friction wheels .So it is necessary to analyze separately. We can use the same mean to import modal, define materials, constraint, loading, meshing to solve.

Tab. 4 the Performance Parameters of Friction Wheel

part name	material	density	modulus of elasticity (GPa)	poisson's ratio
friction wheel	Cr12	7900	206	0.3

The constraint: the friction wheel isn't revolving and fixed constraint in upraising condition.

Load: friction wheel can support 18t pressure of carriage body and convert 4.5t on the each wheel, the stress value is 6100MPa.

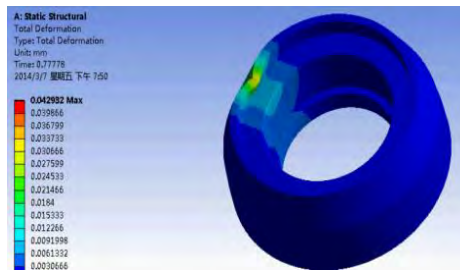


Fig. 11 Friction Wheel Static Analysis

It can be seen in the figure, the maximum deformation is 0.042932 mm in stress point. Static deformation is small when it is lifted, so it is safer.

The modal analysis results: As the first six order modal analysis

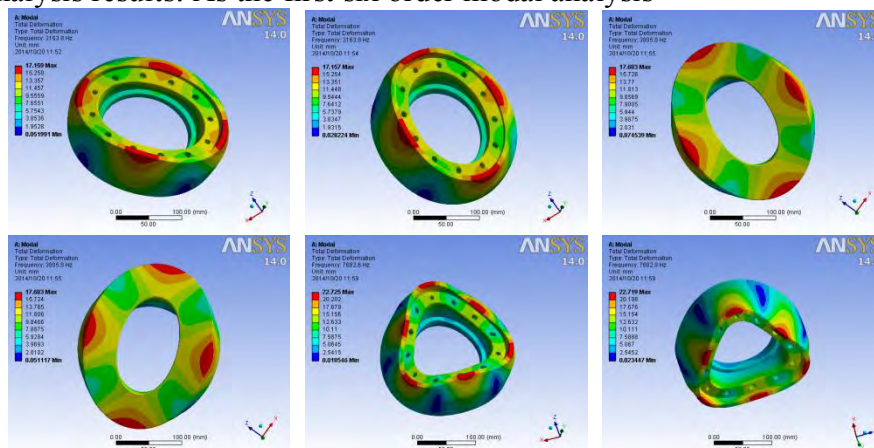


Fig. 12 Modal Analysis of Friction Wheel

It can be seen that when the first-order vibration frequency is 3163.8 Hz, friction wheel outside edge will produce lager deformation. So it should be strengthen treatment in the manufacturing, in order to reduce the deformation of movement.

Available in the following frequency as shown in table 5

Tab. 5 Friction Wheel Frequency Table

Modal order	The first modal	The second modal	The third modal	The forth modal	The fifth modal	The sixth modal
frequency (HZ)	3163.8	3163.8	3805.8	3805.8	7682.6	7682.8

It can be seen that the friction wheel's frequency is larger from the frequency table. They are equal in first-order and second-order, third-order and fourth-order, fifth - order and sixth-order .The minimum frequency of friction wheel is 3163.8 Hz, which is far away from the processing frequency of machine tool .So it won't produce resonance in the process and will be stable in the process of running.

Summary

(1)This paper simplifies the mechanical model of wheelset driving system from underfloor wheel lathe and does mechanical analysis. Friction wheels driving wheels' torque and friction torque are worked out and as the boundary conditions of finite element analysis.

(2)The conclusions of finite element analysis are as follows: as regards friction wheel shaft system, that the maximum deformation is a little larger is 3.6545mm in the contact surface of friction wheels and the wheels for static force analysis, and that modal analysis show the first vibration frequency is 39.227Hz; As regards friction wheels, the maximum deformation is 0.042932mm in static analysis and the deformation is small when static condition lift wheels. Modal analysis show the first vibration frequency is 3163.8Hz, but the outside edge deformation of friction wheel is larger.

Acknowledgment

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