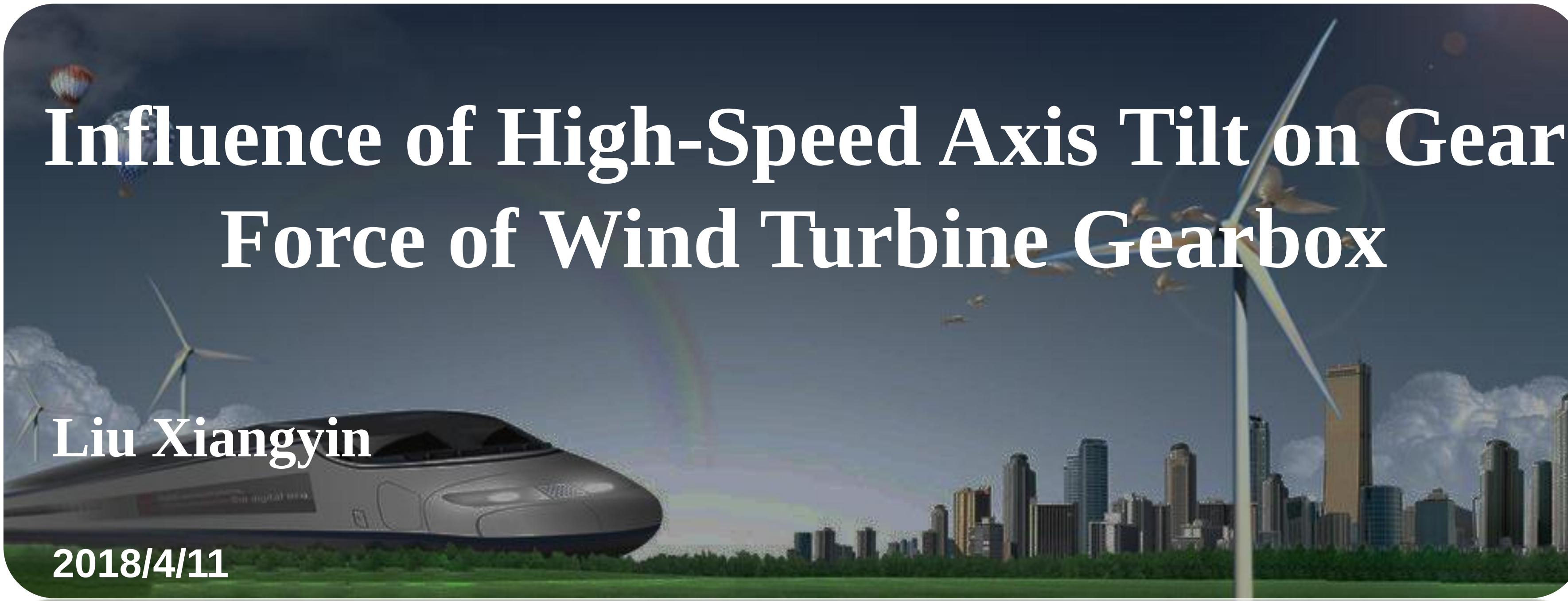
中国中车
CRRC



Influence of High-Speed Axis Tilt on Gear Force of Wind Turbine Gearbox

Liu Xiangyin

2018/4/11

CRRC Wind Power (Shan Dong) CO., LTD.

www.crrcgc.cc

Abstract

Based on the multi-body dynamics software SIMPACK, a rigid-flexible coupling gearbox dynamics model was established to simulate the high-speed shaft fault of the gearbox. The axial and radial force of the high-speed shaft gear were simulated and calculated under different tilting angles and input torques, also the variation rules of root mean square of the gear axial force and radial force and dynamic load coefficient were studied. The results show that the gear axial force is mainly related to the input torque, while the radial force is mainly related to the input torque when the tilt angle is less than 0.3°, and mainly related to the tilt angle when the tilt angle is greater than 0.3°. The rules of variation for dynamic load coefficient in the radial and radial directions were basically the same when the tilt angle is between 0° and 0.3°, and when the tilt angle goes to 0.4°~0.5°, the two parameters will have different change rules.

中国中车股份有限公司 版权所有 2015
CRRC

Table of Contents

中国中车股份有限公司 版权所有 2015

CRRC

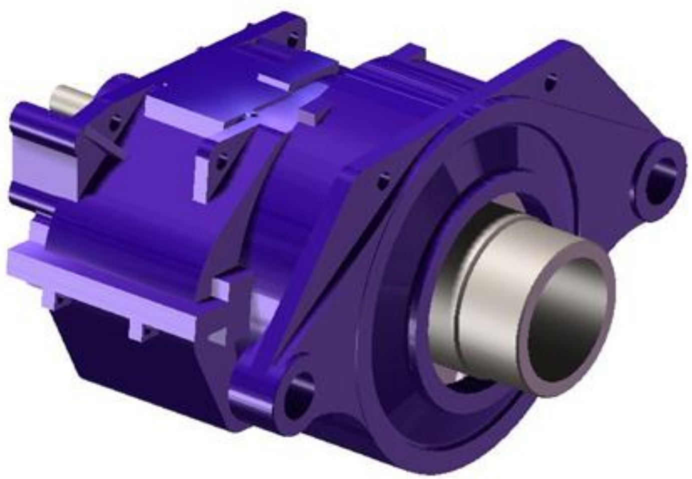
1、 Introduction

Wind turbines often suffer from all kinds of failures due to their bad working environment and wind loads under variable load. Relevant data show that [1-5], in the mechanical failure of wind turbines, the gearbox has the highest failure rate, and the high-speed shafting fault of the gearbox occupies a large proportion. If the high-speed shaft of the gear box is tilted due to a fault, it will cause misalignment of the gear pair, affecting its normal meshing transmission, causing a change in the load, and causing damage to the gear and the bearing. As one of the core components of a wind turbine, its failure not only affects the safe operation of wind turbines, but also affects the economic benefits of wind farms.

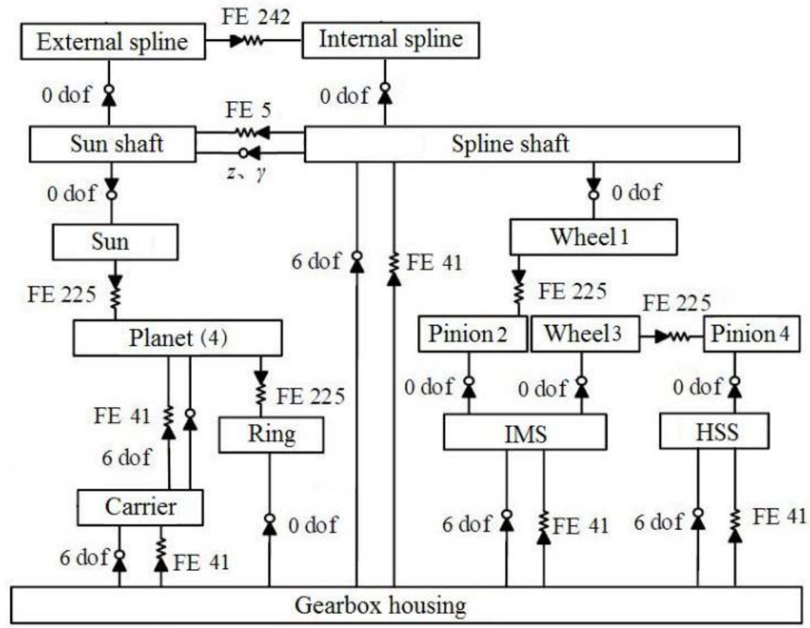
Multi-body dynamics software Simpack has a powerful wind turbine dynamic modeling and simulation analysis capabilities, and has been recognized by the certification society German Lloyd's Register (GL), widely used in the wind power industry. In this paper, a multi body dynamic model of a rigid and flexible coupling wind turbine gear box is built on the platform of Simpack, [7-9], which is used to study the variation of the root mean square of the gear axial force and radial force and dynamic load coefficient of the gear box high speed shaft at different angle of tilt and different input torque. This research can provide reference for gear box design.

中国中车股份有限公司 版权所有 2015

2、Gearbox dynamic model



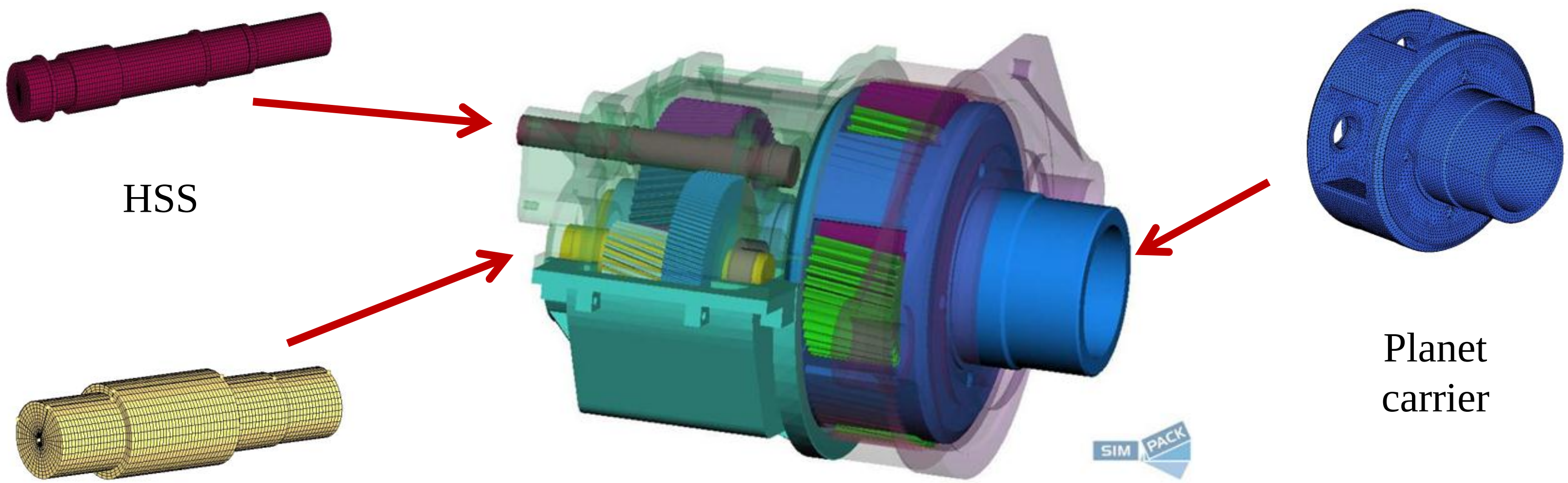
A first-order planetary gear +
two-stage parallel shaft gear



Topological diagram of the gearbox

中国中车股份有限公司 版权所有 2015
CRRC

2、 Gearbox dynamic model



HSS

IMS

Gearbox

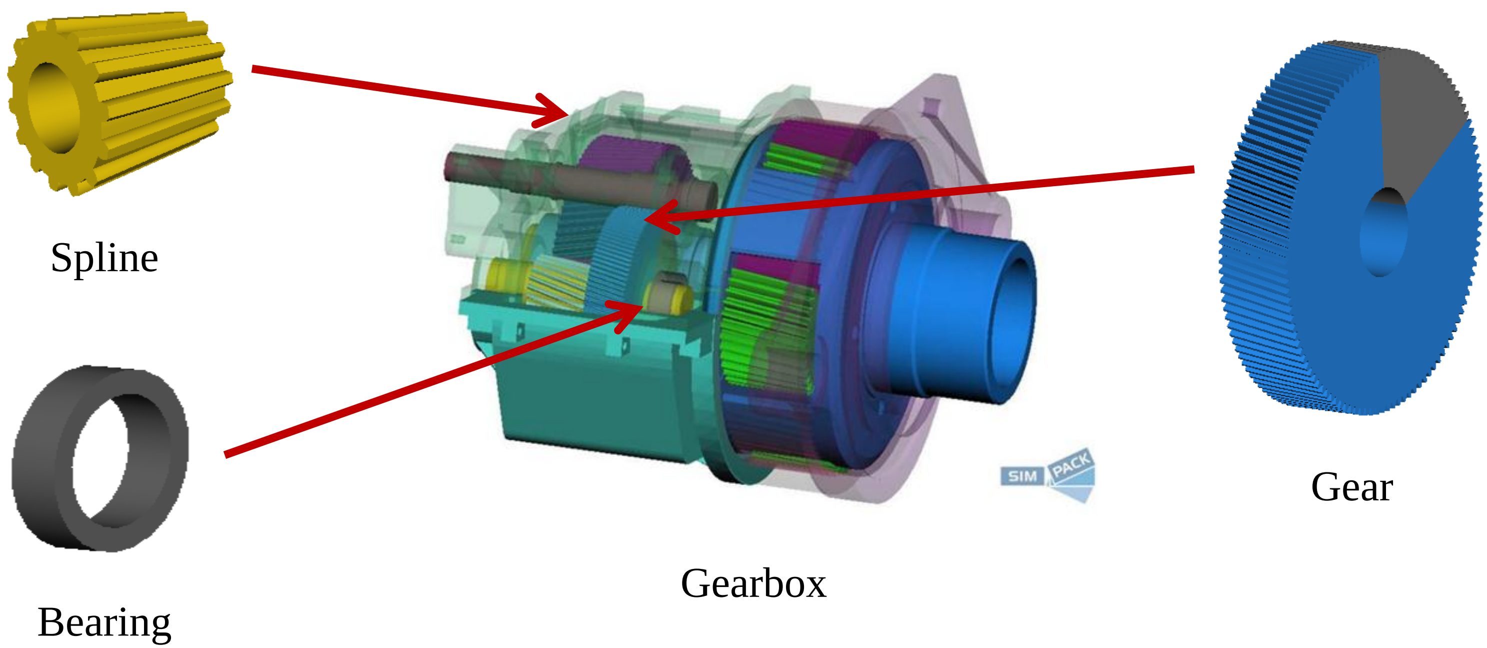
Planet carrier

ANSYS was used to establish the finite element analysis model of each gear shaft and planet carrier, and the finite element model was reduced through modal synthesis method.

The flexible models of gear shaft and planet carrier were established through the interface of the finite element software in Simpack .

中国中车股份有限公司 版权所有 2015

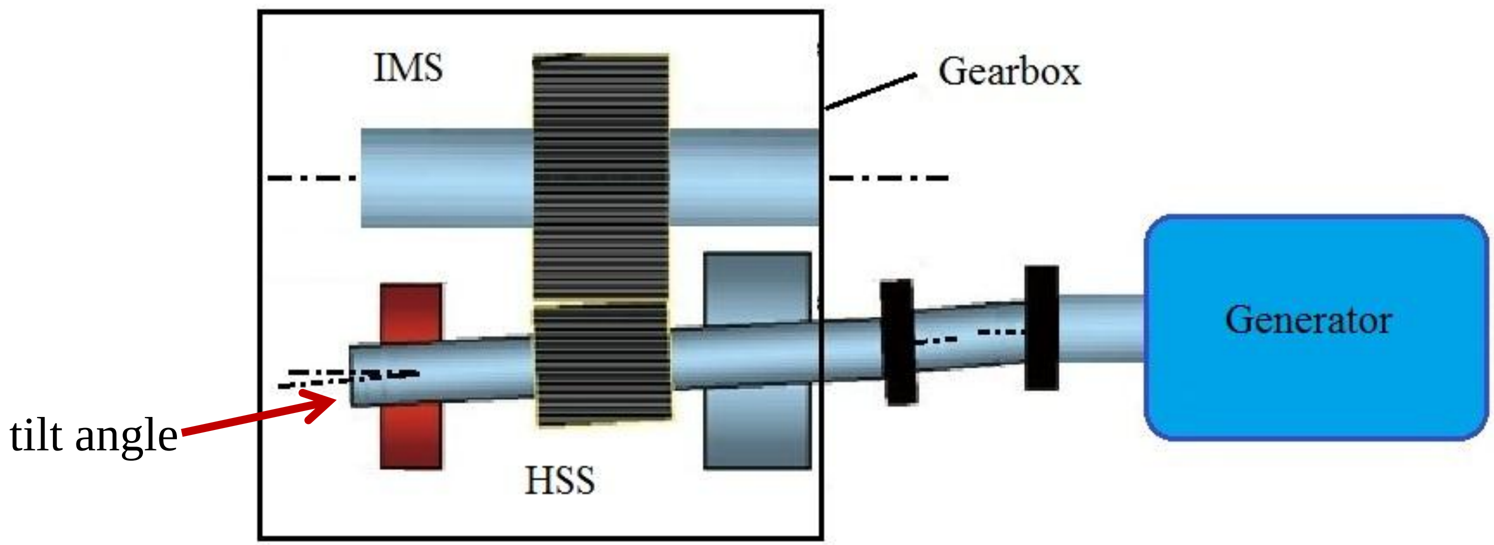
2、 Gearbox dynamic model



The gears are modeled using Primitive Element 25 gear wheel as rigid body, and the meshing force between the gears is simulated by Force Element 225 gear pair. The spline connection is simulated by Force Element 242 spline coupling, and bearings adopt Force Element 41 spring-damper matrix cmp.

中国中车股份有限公司 版权所有 2015

3、 Simulation and analysis



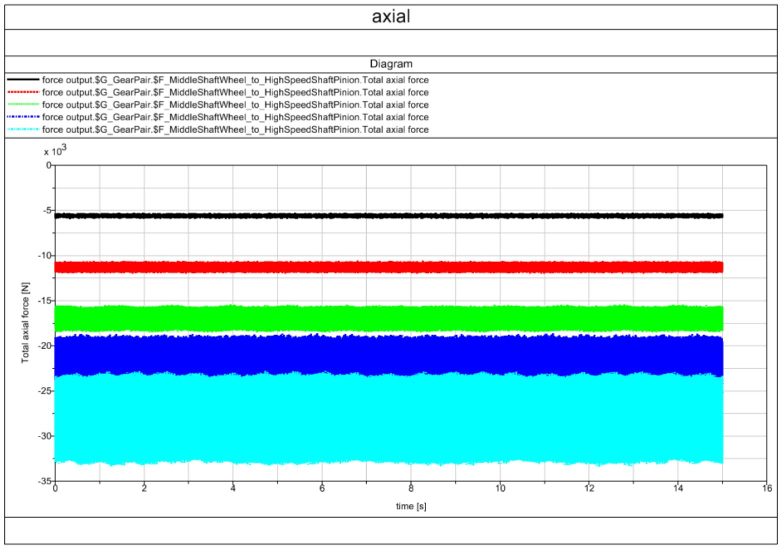
Tilt fault diagram

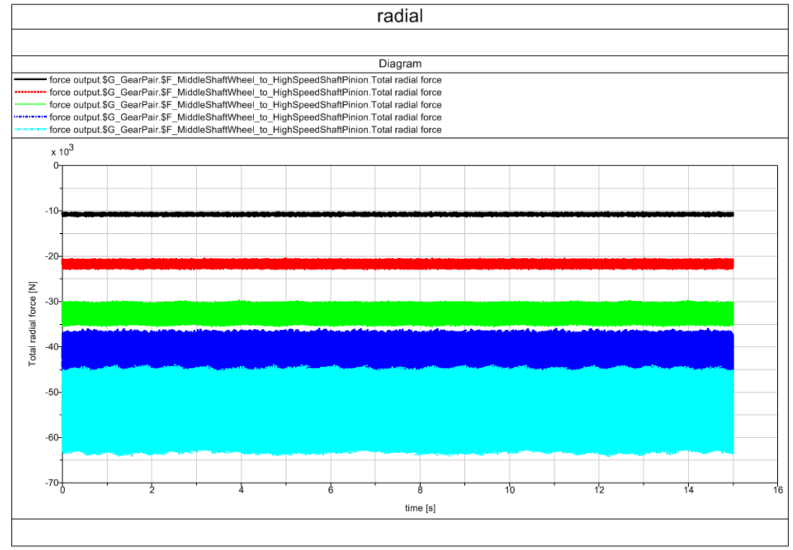
As the wind turbine is at rated speed, calculate the axial and radial force of the high speed shaft gear separately , when the input torque of the gear box is 0.2M, 0.4M, 0.6M, 0.8M and 1M (rated torque), and the tilt angles of the high-speed shaft is 0°, 0.1°, 0.2°, 0.3°, 0.4°, and 0.5°.

中国中车股份有限公司 版权所有 2015

3、 Simulation and analysis

3.1 The gear force



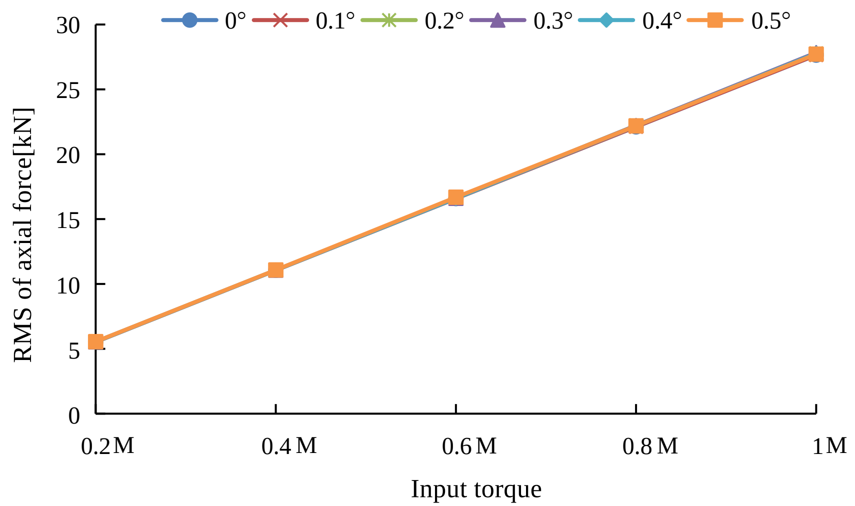


Figures respectively give the curves of the axial and the radial force of the gear at different input torques when the tilt angle is 0.2°. It can be seen that the gear radial force is greater than the axial force, but the degree of fluctuation of the change curve increases as the input torque increases.

中国中车股份有限公司 版权所有 2015
CRRC

3、 Simulation and analysis

3.2 RMS of the gear axial force

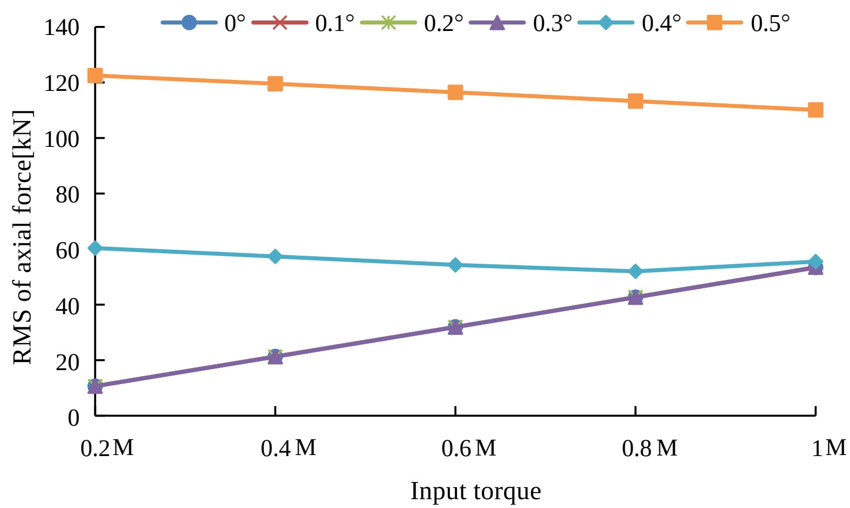


The RMS value of the axial force increases with the increase of the input torque and shows a linear relationship. The RMS values of the axial forces at different tilt angles are not significantly different, which means when the tilt angle is 0°~0.5°, the RMS of the axial force of the gear is mainly related to the input torque and is basically not affected by the tilt angle.

中国中车股份有限公司 版权所有 2015

3、 Simulation and analysis

3.3 RMS of the gear radial force

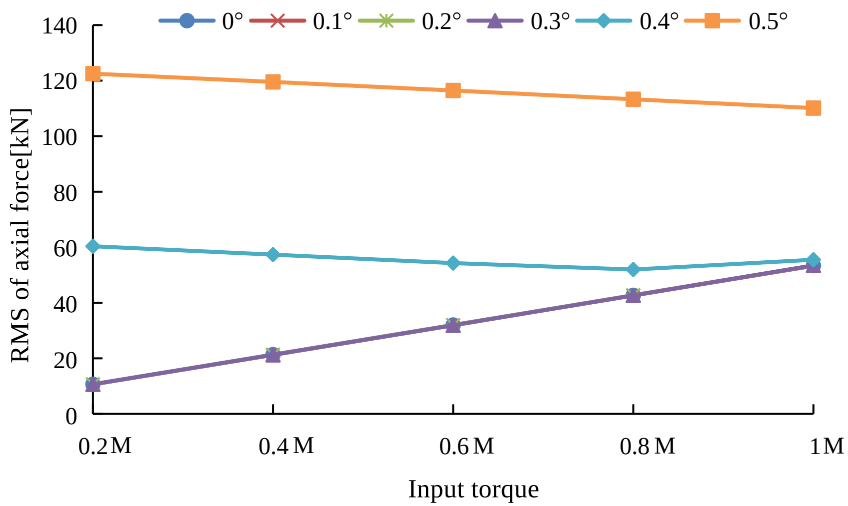


(1) When the tilt angle is 0°~0.3°, the change trend of the RMS value of the gear radial force and the RMS value of the gear axial force are basically the same, but the value is larger. But when the tilt angle is 0.4 ° and 0.5 °, the radial force RMS value and the change law all change, not only decreases with the increase of the input torque, but also increases with the increase of the tilt angle.

中国中车股份有限公司 版权所有 2015

3、 Simulation and analysis

3.3 RMS of the gear radial force



(2) When the tilt angle is 0.4 °and 0.5 °, the RMS value of radial force and the change law all change, not only decreases with the increase of the input torque, but also increases with the increase of the tilt angle, the RMS of radial force is greater than the RMS of the radial force when the tilt angle is 0° ~0.3 °

(3) The RMS value of radial force with the tilt angle of 0.5° is approximately 2 times the RMS value of the radial force with the tilt angle of 0.4 °, indicating that the RMS value of radial force is mainly related to the tilt angle, when the tilt angle is greater than 4 °.

中国中车股份有限公司 版权所有 2015

3、Simulation and analysis

A dynamic load coefficient D is defined to analyze the change of the gear force, defined by the following formula:

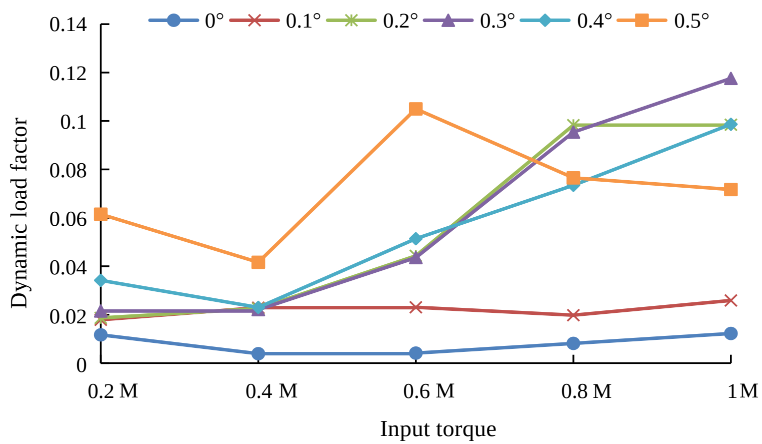
$$D = \frac{\sigma_F}{\overline{F}}$$

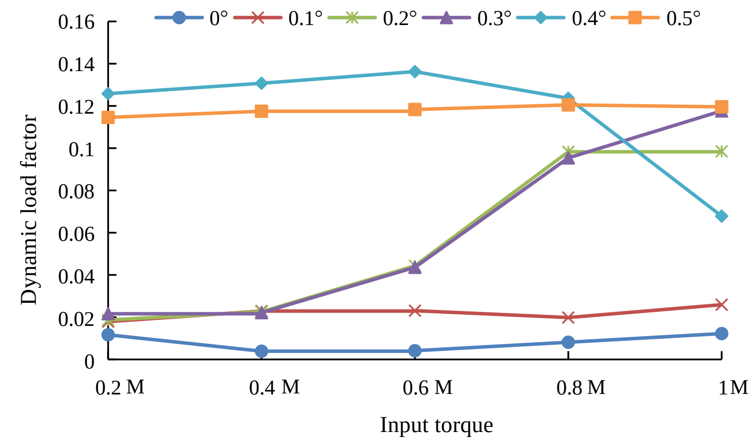
Where: σ_F is the standard deviation of the gear force; $\bar{F}$ is the average value of the gear force.

中国中车股份有限公司 版权所有 2015

3、 Simulation and analysis

3.4 dynamic load coefficient





(1) when the tilt angle is 0°~0.3°, the dynamic load coefficient of the axial force and the radial force of the gears is basically the same in magnitude and variation.

1) When the tilt angle is 0°, the dynamic load coefficient first decreases and then increases with the increase of input torque.

2) When the tilt angle is 0.1°, the dynamic load coefficient does not change much.

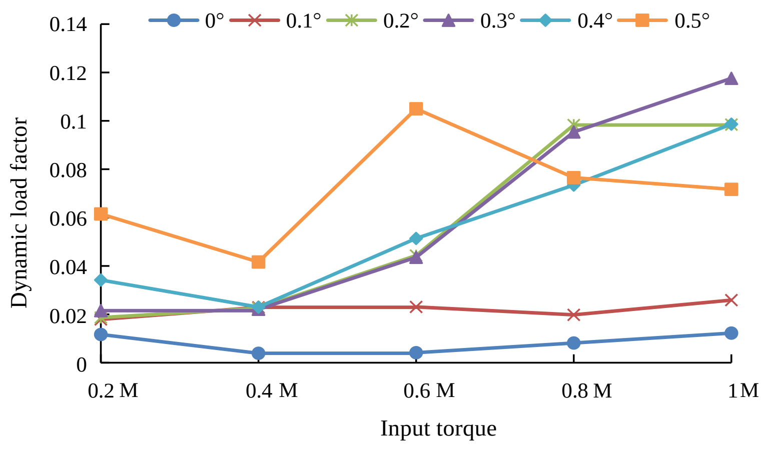
3) When the tilt angle is 0.2° and 0.3°, the dynamic load coefficient increases with input torque.

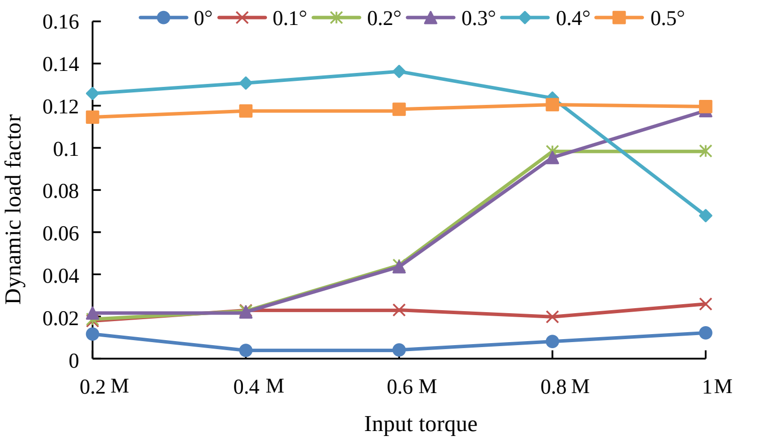
4) When input torque is greater than 0.4M, the dynamic load coefficient increases significantly, and when input torque is 0.2M~0.8M, the dynamic load coefficient is not much different;

中国中车股份有限公司 版权所有 2015

3、Simulation and analysis

3.4 dynamic load coefficient





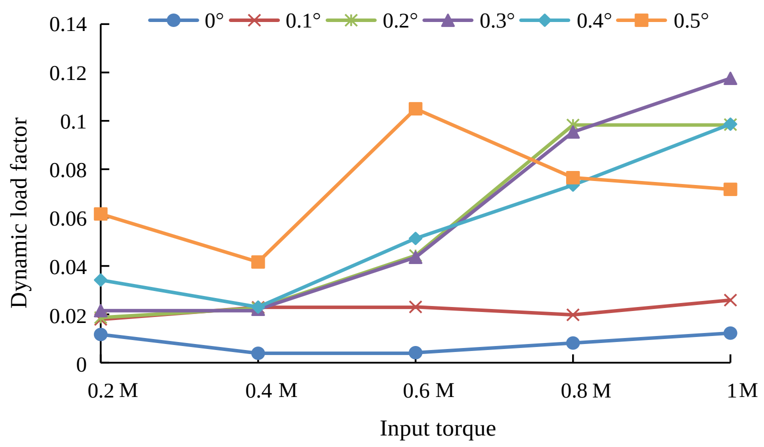
(2) When the tilt angles are 0.4° and 0.5°, the dynamic load coefficient and the variation law of the axial force and the radial force of the gear are different.

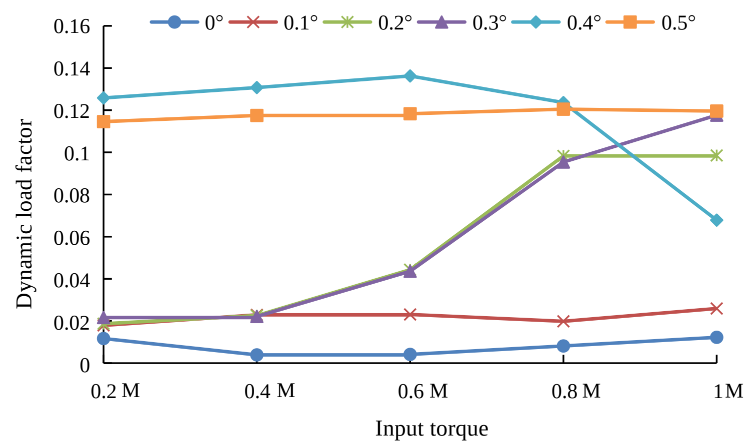
1) In terms of axial force, when the tilt angle is 0.4°, the dynamic load coefficient decreases first and then increases as the input torque increases. The dynamic load coefficient when the input torque is 0.2M~0.8M, when the tilt angle is 0.4°, it is smaller than when the tilt angle is 0.5°. When the tilt angle is 0.5°, the dynamic load coefficient changes greatly with the input torque.

中国中车股份有限公司 版权所有 2015
CRRC

3、Simulation and analysis

3.4 dynamic load coefficient



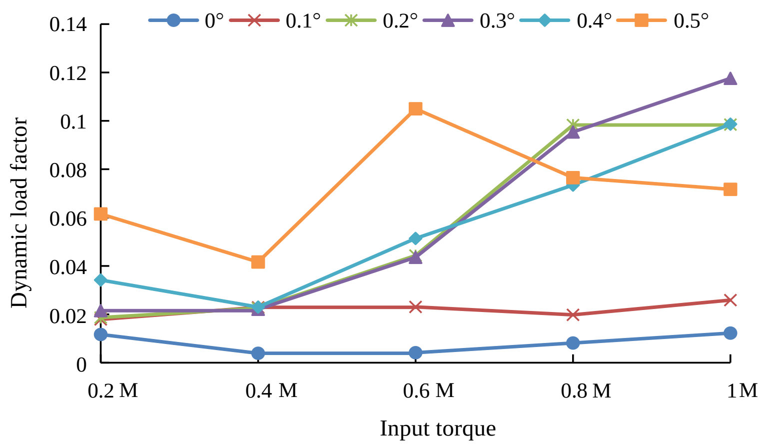


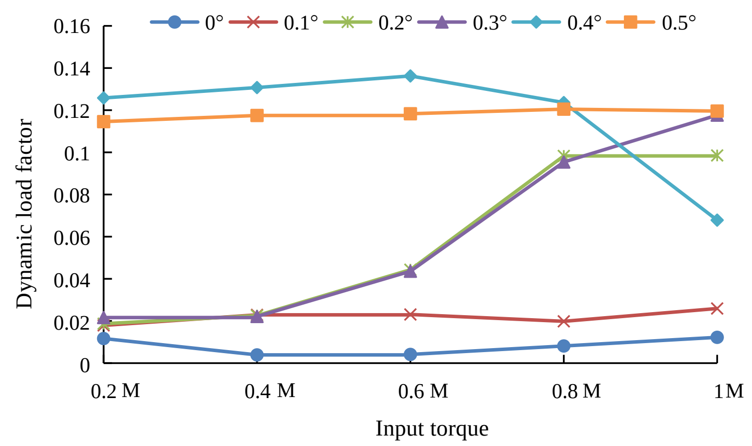
2) For the radial force, when the tilt angle is 0.4°, the dynamic load coefficient first increases and then decreases with the increase of the input torque. When the tilt angle is 0.5 °, the dynamic load coefficient increases with the increase of input torque, but the difference is not significant. The dynamic load coefficient when the input torque is 0.2M~0.8M, when the tilt angle is 0.4° it is greater than when the tilt angle is 0.5°. The dynamic load coefficient when the input torque is less than 0.6M, when the tilt angle is 0.4° and 0.5° is much larger than when the tilt angle is 0° to 0.3°.

中国中车股份有限公司 版权所有 2015

3、Simulation and analysis

3.4 dynamic load coefficient





(3) The tilt angle is 0°, regardless of the input torque, the dynamic load factor of the gear is always the minimum; when the tilt angle is 0.3° and the input torque is 1M, the axial dynamic load factor is the largest; when the tilt angle is 0.5° and the input torque is 1M, the radial dynamic load factor is the largest.

中国中车股份有限公司 版权所有 2015

4、Conclusion

(1) Using Simpack software, a multi-body dynamic model of a rigid-flexible coupled wind turbine gearbox was built, and the axial and radial forces of the high speed shaft gear were simulated and calculated with different tilt angles and different input torques.

(2) The RMS value of gear axial force increases with the increase of input torque, and the RMS value of the axial force of gears with different tilt angles is not much different. It is indicated that the RMS of the axial force of the gear is mainly related to the input torque when the tilt angle is 0° ~0.5° . When the tilt angle is 0° ~0.3° , the RMS value of gear radial force is basically the same as RMS value of gear axial force. When the tilt angle is 0.4° and 0.5° , the RMS value of gear radial force decreases with the increase of input torque, and increases with the increase of tilt angle, this shows that the RMS value of radial force is mainly related to the tilt angle.

中国中车股份有限公司 版权所有 2015

4、Conclusion

(3) When the tilt angle is 0°~0.3°, the dynamic load coefficient and the variation law of the axial force and radial force are basically the same. When the tilt angle is 0.4°~0.5°, the dynamic load coefficient and the variation rule of the axial force and radial force are different. When the tilt angle is 0°, No matter the input torque is large, the dynamic load coefficient of gear is always the smallest. When the tilt angle is 0.3 °, and the input torque is 1M, the axial dynamic load coefficient is the largest. The tilt angle is 0.5 °, when the input torque is 1M, the radial force load coefficient is the largest.

中国中车股份有限公司 版权所有 2015
CRRC

5、references

[1] Han Tian，Shi Lin，Zhao Aiguo．Gear fault analysis on wind turbine generator based on Adams[J]．Computer Aided Engineering，2013，22(S1):256-260．

[2] Cao Jufeng．Dynamics Research of 1.5 MW Wind Turbine Gearbox[D]．Inner Mongolia University Of Science and Technology, 2015．

[3]Li Helin，Zeng Chengzhi．Early warning of faults in high speed shaft parts of wind turbine gearbox and analysis of its mechanism [C]// China Agricultural Machinery Industry Association Wind Energy Equipment Branch Wind Energy Industry．2013．

[4] Ding Zeyu．Simulation and Characteristics Analysis of Misalignment Fault of Double fed Wind Turbine Transmission System [D]．Beijing Jiaotong University，2016.

[5] Zhou Xiang．Experimental Research on The Misalignment Fault of MW Wind Turbine Gearbox Shaft[D]．Dalian University of Technology，2016.

[6] Liao Mingfu，Liang Yuanyuan, Wang Siji, etc. Misalignment in Drive Train of Wind Turbines[J]. Mechanical Science and Technology for Aerospace Engineering, 2011, 30(2):173-180．

[7] Hou Haibo. Analysis and Research on the Dynamic Performance of MW Grade Wind Turbine's Simulation[D]．Chongqing University，2012.

[8] Du Jing, Qin Yue, Li Chengwu, etc. Full Flexible Multibody Dynamics Modeling and Simulation Analysis of Gearbox of Large Scale Wind Turbine [J]．Acta Energiae Solaris Sinica，2015，36(6):1435-1441．

[9] Qin Yue．Analysis and Research On the Wind Turbine Drive Train's Dynamic Modeling and Simulation [D]．Chongqing University，2014．

中国中车股份有限公司 版权所有 2015

CRRC


Thanks for watching