The structural design of the wind-wave complementary device and the numerical simulation of aerodynamic characteristics of the blade

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Abstract. This paper designs a new type of wind-wave complementary device, and introduces the detailed design about a few key part of the device. The principle of the device adopts the wind-wave complementary system ,which collect the wave energy and wind energy respectively. Moreover, to increase the generating efficiency, an energy superposition equipment is used. Finally, based on the power generation device designed, a modal analysis for the blade of the device is made. This analysis provides the necessary basis for structure optimization design and dynamics.

Introduction

With the development of society and increasing population, environmental pollution and energy shortage has become the most severe crisis in the world, so that humans have devoted to the development and utilization of new energy. From 1990s, more and more researchers have paid much attention to the wind energy resources, which as a clean and pollution-free natural energy. This kind of new energy has been taken full advantage of at home and abroad, the achievement is remarkable as well. Wind technology has made great contribution to relieving energy crisis and created a new era of wind energy utilization.With the continuous researches, however, humans have found that there are various forms of natural energy resources in nature, especially wave, it contains plenty of power.Assumed that wind and wave can be combined together, the power generation efficiency will be increased greatly and the space utilization of all the power generation devices will be improved. And in fact, it is inevitable that the output of the dynamo is volatile, and it is also hard to get constant and stable output power, when the device is designed for merely using one kind of resources. Therefore ,the system based on wave energy and wind energy complementary power generation enable to deliver smooth and direct electricity ,in other means, power can be fed from wind and wave generators into the electricity grid system, and the system is of vital strategic importance to optimization of energy structure and promote the development of renewable energy. For reasons mentioned above, a new kind of wind-wave complementary device is designed. The article mainly introduces the structure of this new kind of device and analyzes the mechanical properties of the fan blade.

Mechanical structure

Fig.1 shows that the three-dimensional graphics of the wind-wave complementary device mainly

includes wind energy conversion device, wave energy conversion device, hydraumatic conversion device, energy superposition device and the body. Only each part work with coordination and cooperation can the corresponding energy transformation be done. Wave energy is converted into unstable mechanical energy by wave energy conversion device, and then throws the corresponding hydraumatic conversion device, the unstable mechanical energy becomes a much more stable one. At the same time, wind energy is accepted by wind energy conversion device and transformed into mechanical energy. Eventually, the two kind of different natural energy are stacked and output by energy superposition device. Thus, the transformation and superposition of energy have been realized.

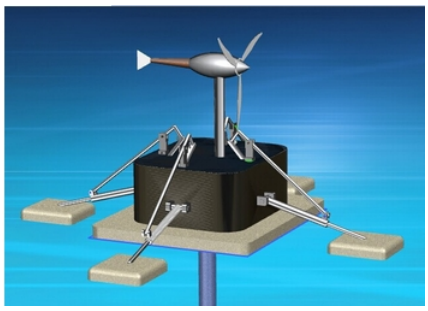


Fig.1, the three-dimensional graphics of the wind-wave complementary device

Wind Energy Conversion Device. The design of the wind energy conversion device sues that of Horizontal-axis wind turbine as a source of reference-rotational axis is perpendicular to the blade and parallel to the ground.Horizontal-axis wind turbine transmits the torsion to the output shaft connected with the energy superposition device by the gear box, and at the same time, the high-speed shaft is connected to the universal free shaft couplings. To avoid failing, it's essential to optimize the structure of the rudder and evaluate it's strength combined with the failure mode of wind power generator at present when designed.

Wave energy conversion device. Ocean wave energy is such unstable and powerful, so how to accept wave energy effectively is a key issue in the thesis. Multi-buoy wave attachment is adopted, and the working principle is that wave energy is absorbed by the rectangular floats arounding the generator, and then transformed to mechanical energy. The device mainly consists of floats, articulated mechanism, four-bar linkage, and fixed elements. Moreover, one end of the articulated mechanism is hinged on the side of the case, and another is hinged in a float. The middle of the articulated mechanism is coupled with four-bar linkage through rods. By combining these mechanism mentioned above, we realize the operation. When waves come, the floats will oscillate up and down with the cycle movement of waves, and transmit the power to the four-bar linkage by rods and articulated mechanism. Eventually, the power will be transmitted to the hydraumatic conversion device.

Hydraumatic conversion device. The function diagram of the Hydraumatic conversion device is shown in Fig.2. It's mainly used to accept the mechanical energy transmitted by the wave energy conversion device. After the piston rod of the Hydraulic cylinder accepts the mechanical energy delivered by the four-bar linkage. The hydraulic circuit will succeed to transmit the energy and make it much more stable through the hydraulic cylinder, solenoid directional valve, low-pressure tank, power accumulator and hydraulic motor at last.

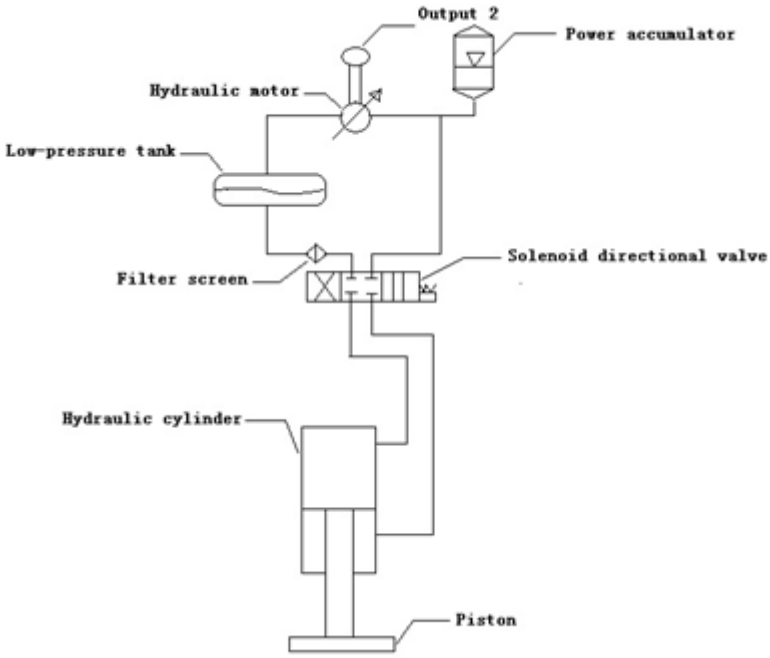


Fig.2, the hydraumatic conversion device

Energy superposition device. Fig.3 shows the three-dimensional graphics of the energy superposition device. The function of the device is absorbing energy from wind energy conversion device and wave energy conversion device, respectively. Then, superimposing the two kind of mechanical energy together and putting out finally.The core components of the structure are ratchet gear and epicyclic gear. The aim of the epicyclic gear is to ensure the consistency of axis in direction. The ratchet gear enable the mechanical energy (partly result from waves and another com from wind)to be added up,so that the efficiency of all the system can be improved.

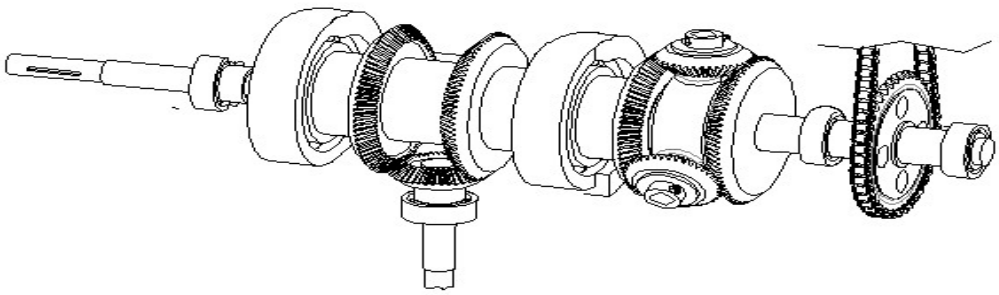


Fig.3, the three-dimensional graphics of the energy superposition device

The oscillation modal analysis of blade

In the process of designing the wind-wave complementary device, the two serious issues of the blade are the dynamical property and the strength. So it's essential to analyze the structure and review the pertinent date of the blade. After combining with the design of the wind-wave complementary device, the modal analysis of the strength and oscillation of blade was pushed further, in order to proof that whether the blade can satisfied the demand on structural strength when wind acts on it. All these provide the basis for subsequent optimization design and dynamic analysis.

Preprocessor of modal analysis

Modeling. Although there are three blades installed in the wind conversion device, merely one

blade is analyzed instead overall process of analysis. Because the oscillation frequencies are closed under the two kinds of situation. So the dynamic analysis to a single blade is of great significance as well. The 3D model is built in UG, and then imported into ANSYS WORKBENCH after the model is saved as IGES. It is shown as Fig.4.

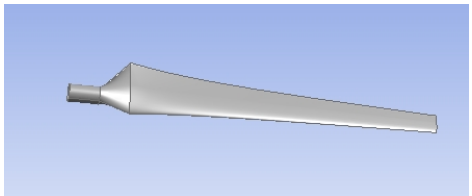


Fig.4, the 3D model of the blade

Mesh partition and impose restriction. Before mesh partition, the model must be defined firstly—material is aluminum alloy. The poisson's ratio is 0.24; The modulus elasticity is 75X103 MPa. Next, Automatic Mesh Division Method is adopted to complete the task. And the result of mesh partition is shown in Fig.5.

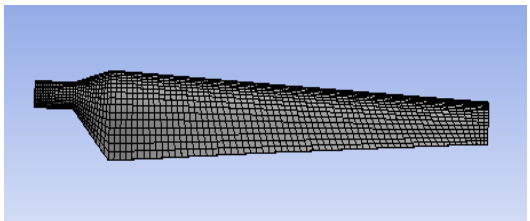
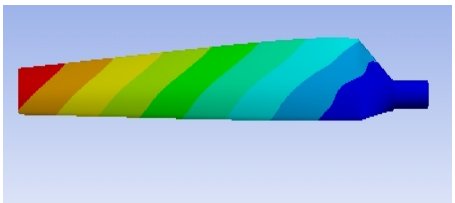
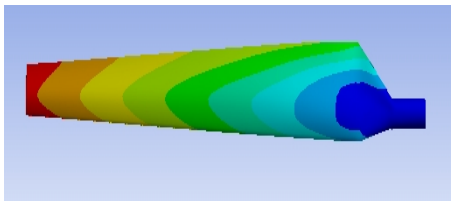


Fig.5, the result of mesh partition

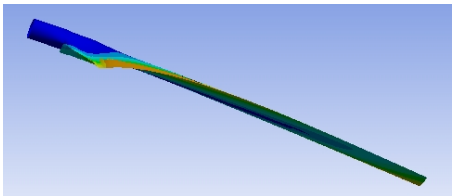
Solution of modal analysis. When the generation device works, the blades rotate constantly, which can cause a certain extend of vibration. After the preprcess of modal analysis, a static analysis of the structure is performed. Then complete corresponding modal analysis. Finally the result of four stages of modal analysis is illustrated in Fig.6.



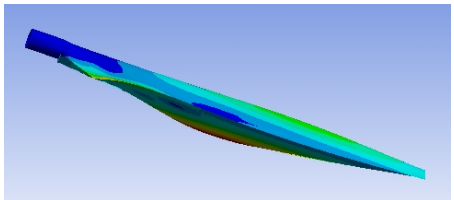
(a) The first order vibration pattern



(b) The second order vibration pattern



(c) The third order vibration pattern



(d) The fourth order vibration pattern

Fig.6, the modal analysis

As picture shown above, the blade do not become deformed greatly at former two phase, whereas the result is opposite at the third and the fourth phase. According to theory of vibration, energies are mainly concentrated on the former three phase, so what we need to do is just to alter the system rigidity to avoid reaching the level of thefrequency of the former three phase in the process of design and research.

	Mode	Frequency [Hz]
1	1.	16.325
2	2.	52.778
3	3.	104.11
4	4.	147.222

Fig.7, the results of modal analysis

As illustrated in Fig.7, the date of free frequency also can be observed, so modal analysis can work as a reference for optimization design and dynamic analysis.

Conclusion

The thesis presents the design of the new wind-wave complementary device. The sim of the device is to solve the problem that the output of the dynamo is volatile ,and it is also hard to get constant and stable output power,when the device is designed for merely using one kind of resources. The design uses two kind of different energy absorbing device—wind conversion device and wave conversion device to change the two natural energy resources into mechanical energy, and then to superimpose them with energy superposition device. Finally, the total mechanical energy is put out, thus, the wind and wave power complementary generating system is realized. Combining with the model designed, the modal analysis of single blade is discussed at last, which lay a foundation for latter optimization design and dynamic analysis.

References

[1]Zhang Xiliang. The Development and utilization Wind Energy[M]. Beijing: Chemical Industry Press,2005.

[2]Sathyajith Mathew, Wind Energy Fundamental Resource Analysis and Economics, Printed in Netherlands 2006.

[3]SHAN Guang-kun, WANG Xiao-dong, YAO Xingjia. Stability analysis on MW wind turbine [J] . Acta Energ iae Solaris Sinica, 2008, 29(7):209 -212.

[4]HAO Wen-hua. ANSYS 7.0 practicality example analysis and appliance[M]. Beijing: Tsinghua University Press, 2004.

[5]SHAN Guang-kun, LIU Ying-ming , YAO Xing-jia . Pitch-reg ulated mechanism analysis and experiment of big wind turbine [J]. Journal of Shenyang University of Technolog, 2007, 29(2):209 -212.)