# Rotor Structure Design and Optimization of MW-class Brushless Doubly Fed Generator for Offshore Wind Turbine

*Hao Wang, Fengge Zhang, Siyang Yu, Shi Jin, Guangwei Liu*

Shenyang University of Technology, Shenyang, China

**Shenyang University of Technology**

## Abstract

In this paper, based on a 10MW brushless doubly fed generator (BDFG) used for offshore wind turbine, three rotor structure with different spiders are designed. The three rotors under idle state and rated operation condition are simulated by FEA respectively. According to compare the simulation results, the rotor which spider has four webs is selected. Finally, the selected rotor under super-synchronous and sub-synchronous operation condition is also simulated. The simulation results verify the reliability of the designed rotor further.

## Introduction

BDFG is novel wind power generator with many advantages, such as high reliability, brushless, low cost, and smaller capacity of the required converter and so on, therefore, it has a broad application prospect in variable speed constant frequency (VSCF) offshore wind power generation system. In recent years, MW-class generators for offshore wind turbine has becoming the research hot-pot. Due to the large volume and weight of MW-class generators, if the common-used solid rotor is selected, there will be some difficulties in the process of transportation and installation, and the cost of production and installation is higher. In order to reduce the weight and cost of the generator, it is significant to research the rotor structure of MW-class generator.

## 1. Electromagnetic Design

A 10MW BDFG is designed, the specific parameters are obtained, and shown in Tab. 1.

TABLE I. Specific Parameters of 10MW BDFG

| Parameter, Symbol(Units) | value |
|---|---|
| rated power, $P_N$(MW) | 10 |
| stator voltages,$[V]_{p,c}$ (KV) | [6, 1.2] |
| rated speed, $N_{RPM}$(RPM) | 200 |
| frequency of stator $[f]_{p,c}$(Hz) | [50, 10] |
| pole pair, $[p]_{p,c}$ | [10, 8] |
| The frequency range of control winding | [-30,30] |
| Stator inner diameter $D_{i1}$(m) | 3.912 |
| Stator outer diameter $D_1$(m) | 4.400 |
| Core length $l_{ef}$ (m) | 1.830 |
| Number of stator slot $Z$ | 240 |
| Air gap width $\delta$(mm) | 2 |
| Pitch $t_1$(mm) | 51.84 |
| Slot height $h$(mm) | 95 |
| Slot width $b_2$(mm) | 20 |

## 2. Design of Rotor Structure

The designed rotor consists of three parts, i.e., magnetic barrier rotor, insulation layer, and rotor spider. The 3-D structure diagram of rotor is shown in Fig. 1. the used material of three part is alloy steel, aluminum, and Silicon sheet from inside to outside, the specific are shown in Tab. 2.

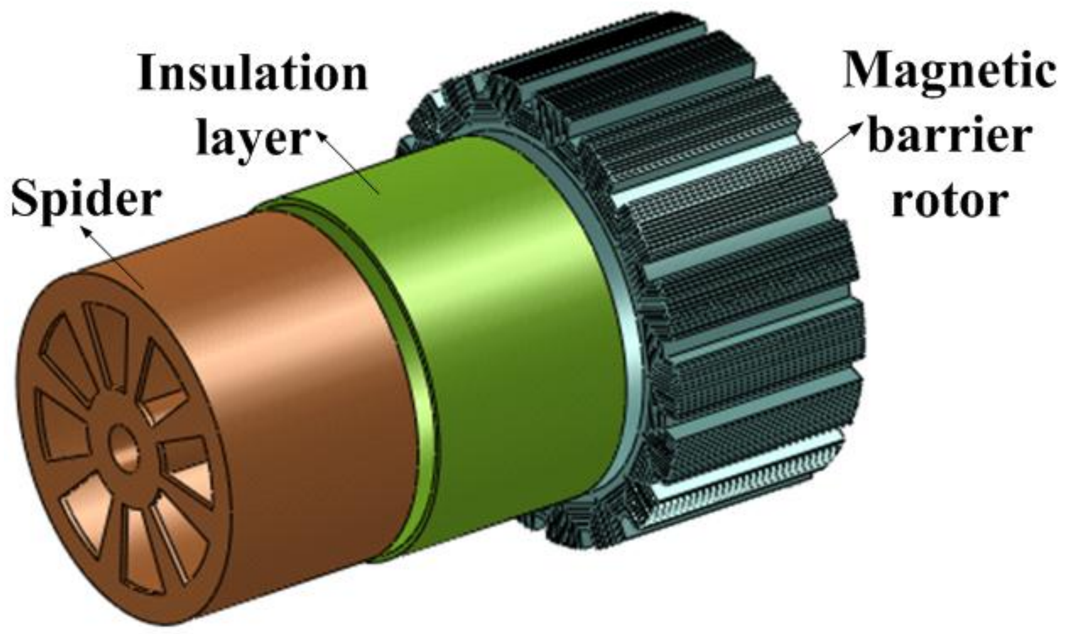



Fig.1 3-D structure diagram of rotor

Three rotor is designed, the difference of the three rotor is that the web number of the three rotor spiders is 3,4, and 5 respectively, and as shown in Fig. 2.

TABLE II Material Properties

| Properties | Alloy steel | Al | Silicon sheet |
|---|---|---|---|
| Density（g/cm³） | 7.85 | 2.7 | 7.7 |
| Thermal Expansion Factor（μm/m/℃） | 12.0 | 23.6 | 13.0 |
| Modulus（MPa） | 2.0E+5 | 7.2E+4 | 1.92E+5 |
| Poisson Ratio | 0.3 | 0.25 | 0.32 |

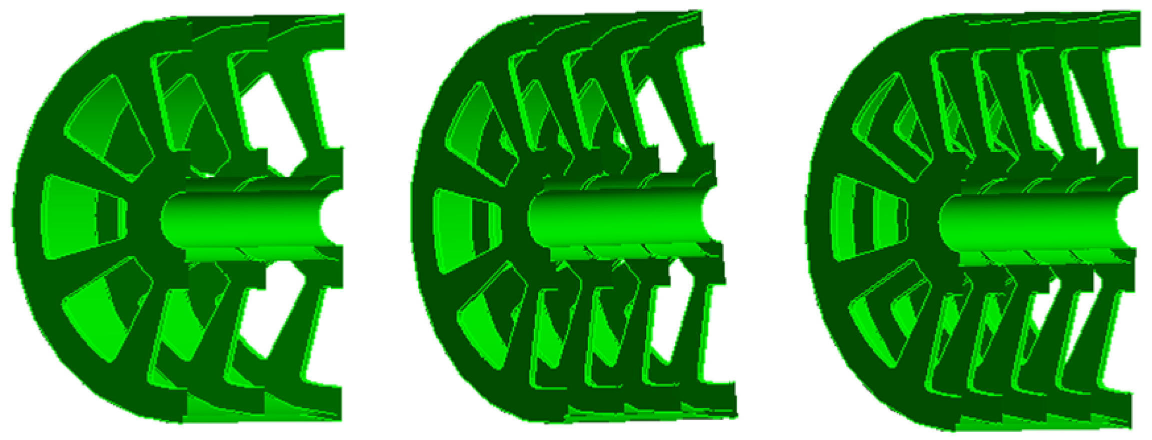



Fig.2. Section view of rotor spider

## 3. Rotor Structure Analysis

Firstly, three designed rotors are simulated under idle state, the load is only gravity, the stress and deformation distribution are obtained, and the value of maximum stress and deformation is very small, and meet the design requirement. Secondly, the designed rotors are simulated under rated operation condition, the load is more complex than that of idle state, and consists of gravity, rotation speed, and torque. The load of rated operation condition is shown in Fig. 3. The stress and deformation distribution can also be obtained, and shown in Fig. 4and 5.

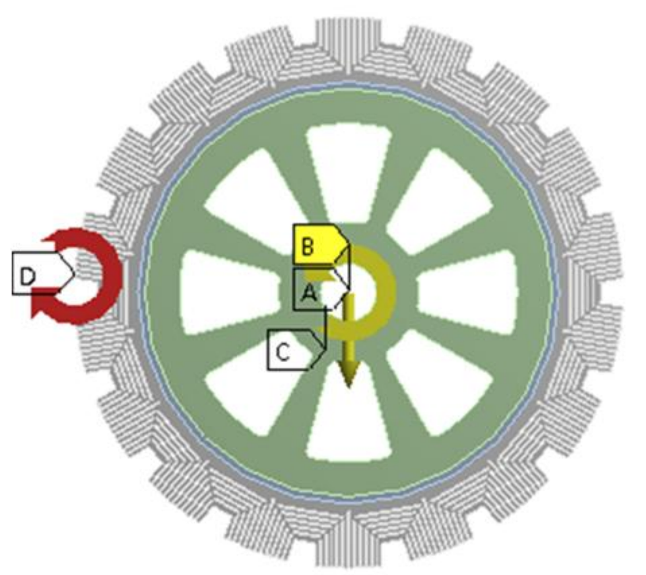



Fig. 3Load of rated operation condition

Where:

A: Standard Earth Gravity:9806.06m/s²

B: Rotational velocity:20.93rad/s

C: Displacement

D: Moment:4.77e+008N ·mm

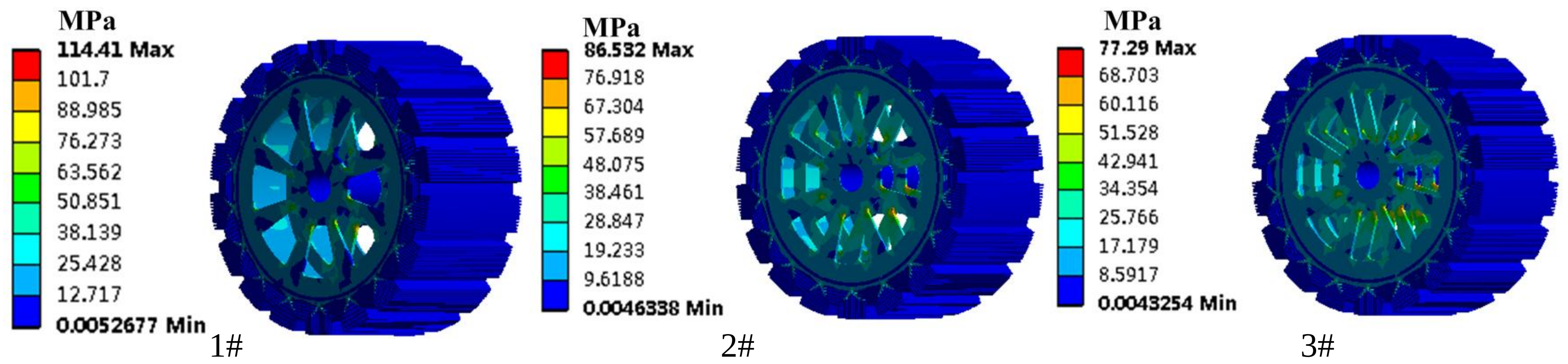



Fig.4. Stress distribution under rated operation condition

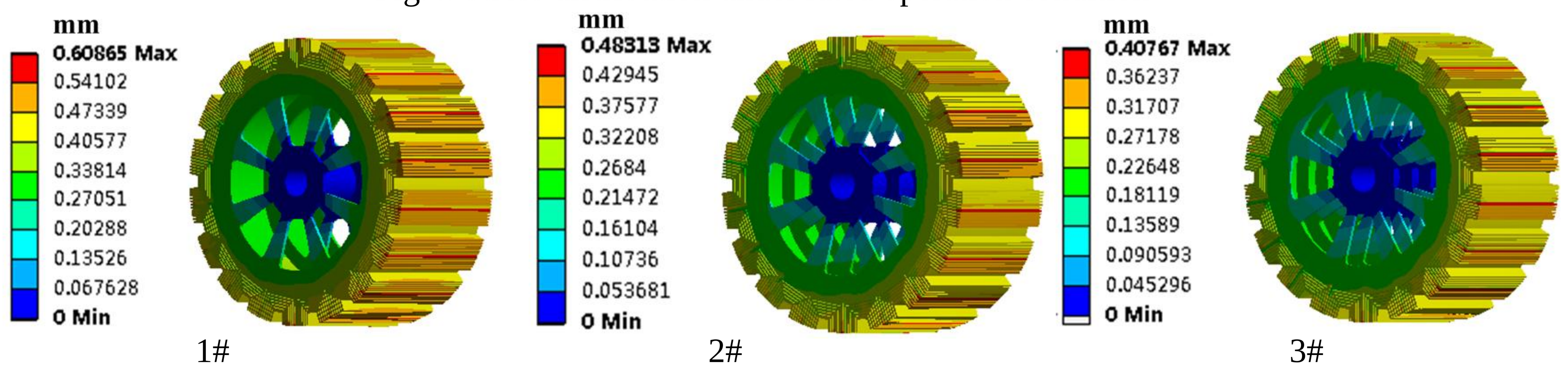
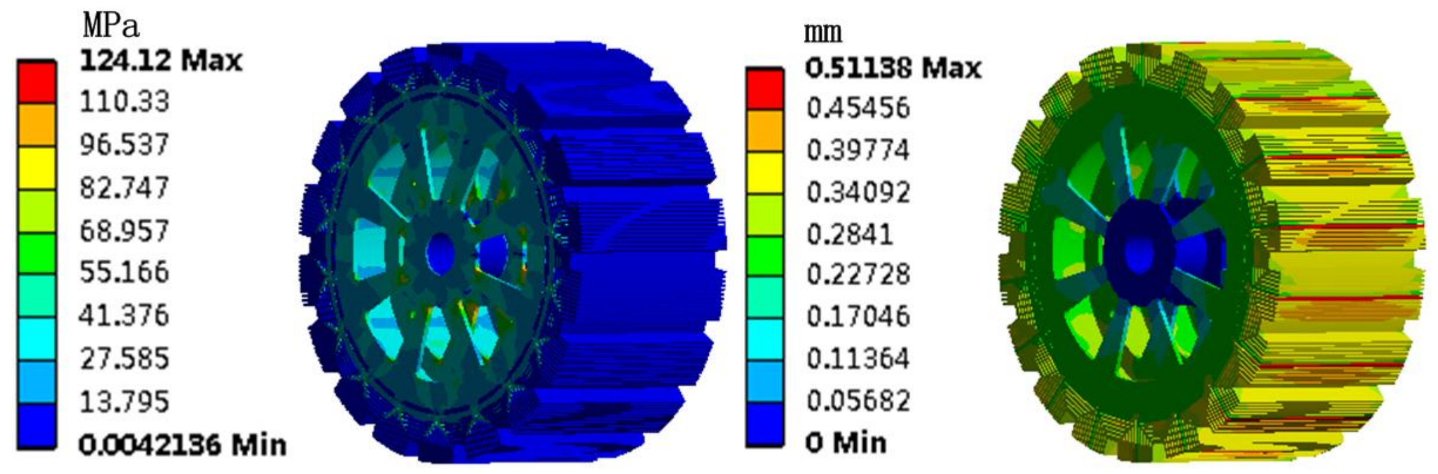



Fig.5. Deformation distribution under rated operation condition

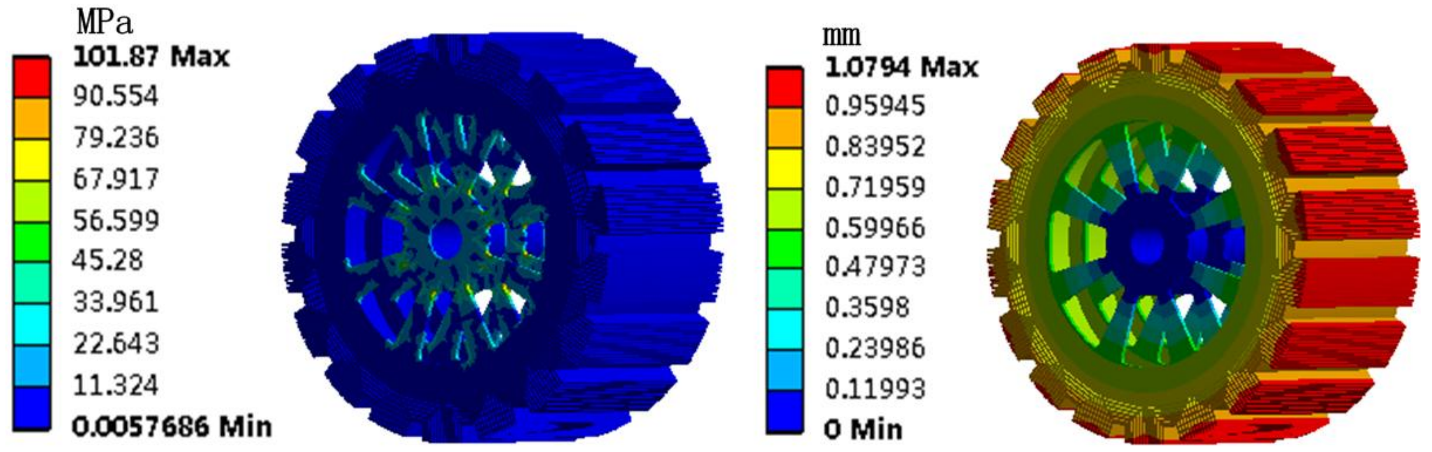
According to Fig. 3 and 4, it can be known that the maximum stress of three designed rotor is 114.41, 86.522, and 77.29Mpa, and the value is much smaller than the allowable stress value of material. Through comparing the maximum deformation, it can be seen that the maximum deformation of 2# rotor is 20.62% lower than that of 1# rotor, and the maximum deformation of 3# rotor is 15.62% lower than that of 2# rotor. After comprehensive consideration, the 2# rotor is selected.

## 4. Verification of designed structure




(a) Stress (b) Deformation

Fig.6 Stress and deformation under super-synchronous operation condition




(a) Stress (b) Deformation

Fig.7 Stress and deformation under sub-synchronous operation condition

In order to verify the reliability of the selected rotor further, the limit state of the selected rotor under super-synchronous and sub-synchronous operation condition is simulated respectively. The simulation results are shown in Fig. 5 and 6. From the simulation results, it can be known that the selected rotor can meet the operation requirement, the reliability of the designed rotor is verified further.

## 5.Conclusion

In this paper, the electromagnetic design of 10MW BDFG was researched, and the specific parameters were obtained. In order to avoid the disadvantages of the solid rotor, three rotor structures are designed, and the idle state and rated operation condition are simulated based on FEA. According to compare the simulation results, 2# rotor is selected. Finally, the super-synchronous and sub-synchronous operation condition of the selected rotor is also simulated, the simulation results verity the reliability of the designed rotor further.

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