

Model Change of Gas Engine Alternator

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Abstract

In the large market of medium-speed engine generating systems, there is a constant and stable demand for gas engines. While we are diligently working to increase our market presence in this field, we recently conducted a model change on a gas engine alternator in order to meet the various demands of our customers.

Compared with our conventional models, we aimed to improve alternator efficiencies and a light-weight design. By applying various analysis technologies, we conducted an optimal design, a study on strength, and a review on performance. In addition, we made a 10MVA class prototype and conducted verification tests, compared the analytical results, and conducted conventional tests such as temperature rise test, measurement of losses, insulation test, as well as other various tests. We verified the design analysis and product performance. As a result, we realized more than 10% light-weight design than 0.2% efficiency gain (under 100% load at the rated power factor) by comparing the conventional model and the prototype.

1 Preface

In the field of medium-speed engine generating systems, gas engine generating systems maintain a stable demand as it offers high combustion efficiencies and low CO₂ emission. We have manufactured and supplied a variety of engine alternators. We recently made a model change of an engine alternator in order to increase sales in overseas markets.

In order to realize an improvement of performance (efficiency) and a light-weight design compared with the conventional model, we took research on an optimal design, thermos-fluid analysis, and mechanical strength analysis in order to reflect the measured results into a design for new model change. This paper introduces our approach using various analytical technologies and the results of design comparison verification using a prototype.

2 Details of Improvements

2.1 Attaining Higher Efficiency

To realize a higher efficiency, we made improvements primarily focusing on the reduction of copper

and mechanical losses because they make up a large part of the total losses.

As a measure to reduce copper losses, we reviewed the method of forming the armature winding. The number of coils is decreased and the cross-sectional area is increased. As such, we created a design to reduce copper losses in armature coils. As a measure to reduce mechanical loss, it is important to reduce cooling air volume. This measure is disadvantageous, however, for cooling efficiency. As such, we created a new design using thermos-fluid analysis and conducted an optimal wind-volume design in consideration of the temperature rise in windings. In this way, we studied the minimal windage loss possibility by reducing the size of the cooling fan blades.

2.2 Light-Weight Design

The reduction of the alternator weight effects the quantity of all materials used. This results in the reduction of environmental loads and the enhancement of the competitiveness of product sales. For alternator characteristics, the total quantity of winding wires and core used is dependent on the performance specified for the alternator. As such, we

evaluated the structure of the rotor and stator as key units of the entire alternator, down to individual components.

In this assessment, we adopted a Value Engineering (VE) approach so that existing components can be examined from various angles and found points for improvement while satisfying the required functions. The reviewed results were reflected in the latest alternator design. In so doing, we streamlined the number of required components, simplified the structure design, and realized a light-weight design.

3 Examination of the Design through Analysis

3.1 Fluid Analysis and Thermal Analysis

Most mechanical loss is in the alternator windage loss. In order to reduce windage loss, it is most effective to decrease the volume of cooling air. We analyzed in order to reduce the wind volume, while considering winding temperatures. The result of this analysis was reflected in the design of the cooling fan blades.

For analytical software, we used the ANSYS. With this software, air flows and temperature distribution before and after the model change were visualized. In so doing, we found design issues and studied possible measures to correct. As a result, we realized the reduction of the total mechanical loss by 40% by lowering the wind volume while satisfying the required conditions for satisfying winding temperatures. Fig. 1 shows the result of fluid analysis and Fig. 2 shows that of thermal analysis.

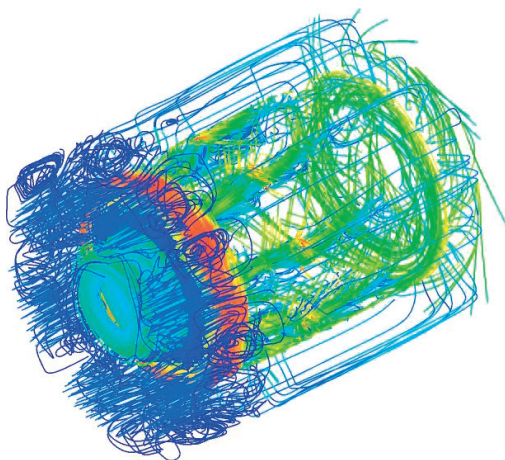


Fig. 1 Result of Fluid Analysis

The result of fluid analysis into the generator interior is shown. The rotating state of the rotor is visualized in order to make the flows visible in the armature.

3.2 Mechanical Strength Analysis and Eigenvalue Analysis

When the plate thickness and materials to be used are reviewed and the design policy is greatly modified, it is necessary to carefully confirm resultant reliability. For this purpose, we used analytical software for evaluation.

The rotor was confirmed to have sufficient strength, even under the condition of over-speed at which the revolving speed is greater than the rated level. The operating condition for the generator was based on the Daily Start and Stop (DSS) system. A cyclic load was continuously exerted on the rotor. The analysis and evaluation were, therefore, carried out in regard to strength against fatigue. It became clear that there is no problem in this subject. Fig. 3 shows

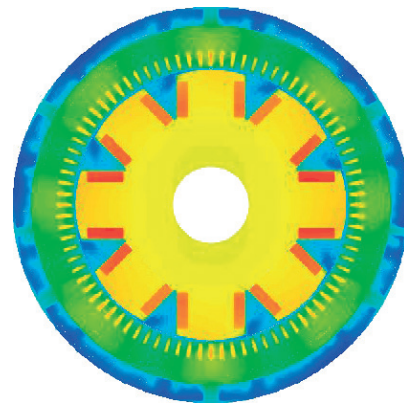


Fig. 2 Result of Thermal Analysis

The distribution of temperature rises inside the alternator is shown. The temperature rises in windings were analyzed so that the obtained data can be reflected in the design for the cooling fan blades.

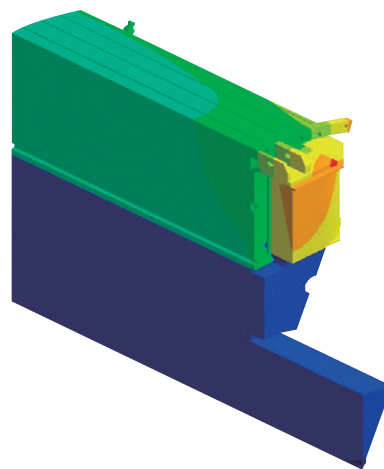


Fig. 3 Result of Rotor Pole Strength Analysis

The analytical result of the rotor magnetic pole is shown in regard to the 1/16 analytical model. Based on the obtained result, we confirmed that there is no problem in strength against over-speed.

the result of rotor pole strength analysis and Fig. 4 shows that of cooling fan blade strength analysis.

In general, the stator gives rise to a resonance phenomenon when the natural frequency of the component parts coincides with the vibrational frequency of the engine being a prime mover and the alternator itself. Such a phenomenon leads to the occurrence of abnormal vibration or alternator damage. For this reason, we analyzed and evaluated in order to check that the natural frequency is far different from the vibrational frequency. We confirmed there is no problem. Fig. 5 shows the result of eigenvalue analysis for brackets and Fig. 6 shows that of eigenvalue analysis for the stator as a whole. Based on these analytical results, we reduced the total generator weight by more than 10% compared

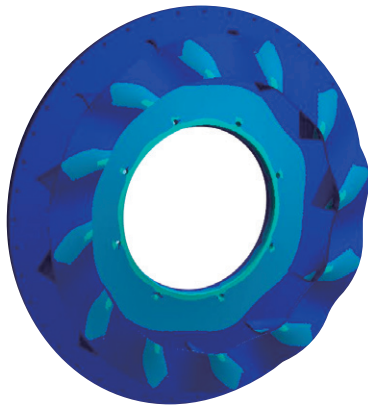


Fig. 4 Result of Cooling Fan Blade Strength Analysis

The analytical result of cooling fan blade strength is shown. We confirmed that there is no problem in strength against over-speed.

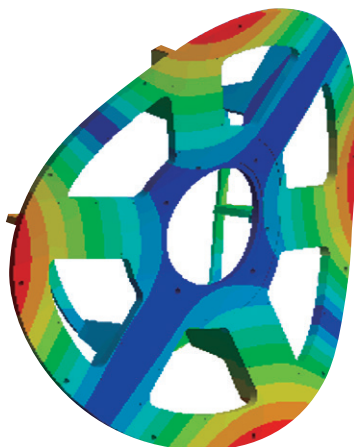


Fig. 5 Result of Eigenvalue Analysis for the Brackets

The result of eigenvalue analysis for the bracket unit is shown. The natural frequency is sufficiently different from the vibrational frequency and this suggests freedom from any problem.

with conventional model of a similar size, without sacrificing quality.

4 Verification by a Prototype

We made a 10MVA class prototype to perform a verification test and a performance test in order to verify the matters checked by the analysis results.

In examining winding temperatures, we performed a temperature rise test. We confirmed that temperature rises in both stator and rotor windings at the estimated full load conditions will be below the temperature rise limit specified by a relevant standard.

We also confirmed an efficiency gain by more than a design target value of 0.2%. Fig. 7 shows a comparison of losses with a conventional model.

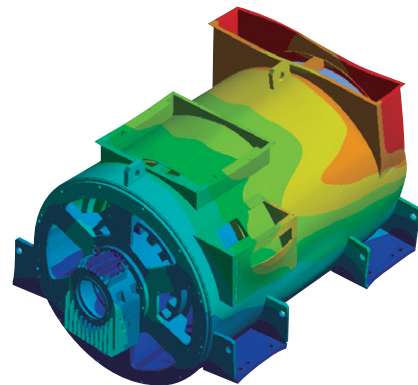


Fig. 6 Result of Eigenvalue Analysis for the Stator as a Whole

The result of eigenvalue analysis on the entire alternator stator is shown. The natural frequency value was sufficiently different from that of the vibrational frequency. As such, we confirmed that there is no frequency problem.

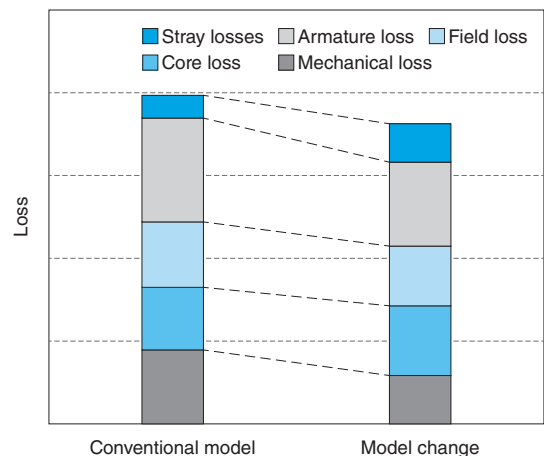


Fig. 7 Comparison of Losses

The comparison of losses with conventional versions is shown. Compared with conventional model, we achieved over a 0.2% efficiency gain.

View : 3D View (Complex)
BLK : Result 01
Freq : 12.5Hz

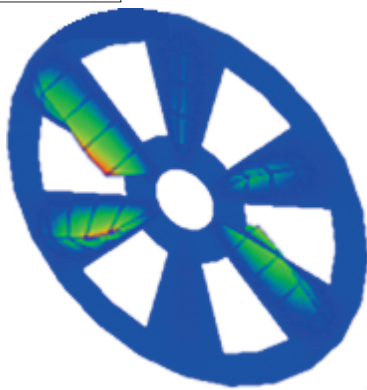


Fig. 8 Result of Measurement in Vibration Mode by Hammering Test

The result of measurement in vibration mode by bracket hammering test is shown.

For the verification of natural frequency, we measured actual frequency by performing a hammering test. Comparing the actually measured values with the result of analysis, we confirmed that there is no problem in analytical accuracy. **Fig. 8** shows the result of measurement in vibration mode and **Fig. 9** shows the result of natural frequency measurement by hammering test.

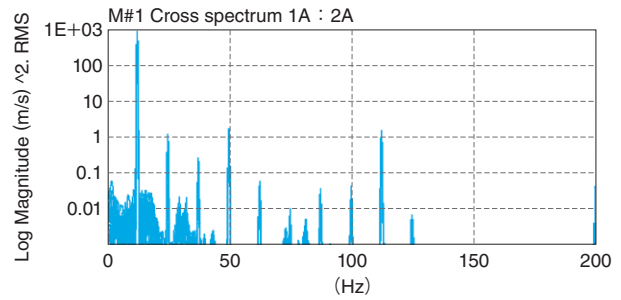


Fig. 9 Result of Natural Frequency Measurement by Hammering Test

The result of natural frequency measurement by bracket hammering test is shown. Comparing with the result of analysis, we confirmed that there is no problem in analytical accuracy.

5 Postscript

After performing various analysis and verification tests by a prototype, we realized a model change for higher efficiency and a light-weight design. Going forward, we will continue to make efforts to introduce advanced technologies and the latest analytical technologies so that we can supply high-performance and highly reliable products to our customers.

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