Contribution from Materials to the Stable Operation of Bearings in Wind Turbine Gearboxes

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Sanyo special steel promote development of eco products that contribute to CO_2 emission reduction in the parts manufacturing stage at users and during usage as end products. Our developed steel, which contributes to longer life of bearings for wind turbine gearboxes, is an eco-product. This report describes the results of our evaluation of the CO_2 emission reduction contribution by the application of the developed steel grade as an eco-product.

Keywords: *CO_2 emission reduction, eco product, contribution by material, wind power, bearing steel for gearbox, development steel, special heat treatment, longer service life,*

1. Introduction

With the rise in efforts for environment conservation, there is a global demand for the realization of a carbon neutral (CN) society in recent years and several countries have announced specific goals to that effect.

Sanyo Special Steel aims to achieve CN by FY2050 and to reduce 50% (at least 420,000 t) CO_2 emissions compared to FY2013 values by FY2030. To achieve this goal, we are promoting "Eco Process" that increase energy efficiency in our in-house manufacturing processes and "green energy utilization" such as carbon-free electricity. Additionally, we plan to develop and supply "Eco Product", which include products that contribute to CO_2 emission reduction during their entire life cycle and also contribute to create an eco-friendly lifestyle for the consumers.

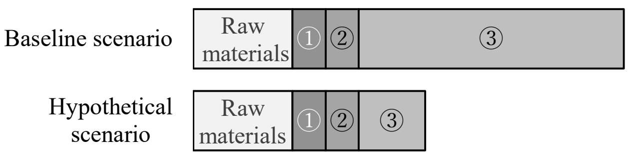
Moving towards the realization of a CN society, there is an increasing need of products and technologies that reduce environmental impacts, including the expansion of renewable energy like wind power, the miniaturization and weight reduction of automobile parts, and promotion of BEV (Battery Electric Vehicle) development. Therefore, our company is engaged in the development of steel materials that have reduced failure rates and maintenance efforts owing to the extension of the bearing steel life used in wind turbines. Furthermore, it can help with the miniaturization and weight reduction of automobile parts and improving their durability. As eco-friendly products, these steel materials can help in CO_2 emission reduction.

In this study, we present the quantitative results of the evaluation of CO_2 emission reduction by the use of eco product bearing steel developed using special heat treatment for wind turbine gearboxes.

2. Evaluation settings by scenario creation

Our company defines Eco Product as "items that contribute to CO_2 emission reduction at the stage of parts processing and final usage". We evaluated the contributions to CO_2 emission reduction according to the "Evaluation of Emission Reduction Amount during the High-Functionality Steel Material Usage Stage" by The Japan Iron and Steel Federation[1)]. An overview of this evaluation is presented here. In our evaluation, the process where conventional steel was used is considered as the baseline scenario and the process with an Eco Product (high-functionality material) as a substitute was considered as the hypothetical scenario. We quantitatively evaluated the difference between these scenarios in terms of CO_2 emissions. Additionally, to present the contributions that are convincing to the society, we used numbers based on "publicly known data", such as the literature, and "our company's factual data" for the calculations.

When considering the life cycle of the product, the comparisons of the processes where the amount of CO_2 emissions changed were as follows. The processes are ① Material Manufacturing, ② Parts Processing, and ③ Product Usage. The material manufacturing process includes CO_2 emissions that occur at the material manufacturing stage in our company (Fig. 1). The parts processing process includes the CO_2 emissions that occur at the parts processing stage with our customers. The product usage process refers to the CO_2 emissions that occur at the product usage stage by the user. In this study, we quantitatively evaluated the CO_2 emissions reduction effect at the third, that is, product usage stage.



process	Increase Factors CO_2 Emission	Decrease Factors CO_2 Emission
① Material Manufacturing	Heating temperature Additional heat treatment process	Steel manufacturing chances due to longer service life
② Parts Processing	Decrease in workability	Reduced process/ Cold-forging
① Product Usage	-	Longer life of bearings

Fig. 1 Image Figure of Scenario Overview

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3. Calculation examples

3.1 Evaluation object and method

The evaluation object in this study is the bearing steel for gearboxes in domestic wind turbines at their usage stage. Wind turbine gearboxes are devices that increase the rotational speed of a rotor section that rotates with the blades to a speed range that enables optimal power generation efficiency. It is expected that applying the developed high-functionality steel to these gearboxes can extend the life of bearings due to their higher performance. This is expected to affect CO_2 emissions in the aforementioned process during the product usage stage. In this study, we evaluated the amount of CO_2 emission reduction achieved using the high-functionality steel in this process.

An extended life of the gearbox bearing is expected as a result of using the developed steel in the ③Product Usage stage. We also expect that the downtime of equipment (wind turbine generators) due to failures caused by the gearbox bearings can be reduced. When conventional steel is used, the alternative power generation, such as thermal power generation required during the downtime period, results in increased CO_2 emissions. An extended life of the bearing steel can help control CO_2 emissions during periods of failure. Consequently, the contributions to CO_2 emissions due to the developed steel is equivalent to the amount of CO_2 emissions during failure periods seen with conventional steel.

The difference in CO_2 emissions between wind power generation and alternative methods such as thermal power generation is calculated by the CO_2 emission factor, which indicates the CO_2 emissions per kWh of power supply[2),3)]. A higher CO_2 emission factor indicates higher CO_2 emissions during power supply. The CO_2 emission factor for wind power generation is lower than that for alternative power generation calculated using the energy mix (a power generation method in Japan that combines various power generation methods). Therefore, it is believed that reducing the need for alternative power generation use will lead to reduced CO_2 emissions.

3.2 Calculation equation and components

The functional unit considered during the product usage stage is the amount of steel used per wind turbine. The amount of contribution to CO_2 emission reduction due to the functioning of the developed steel was calculated using the following equation.

Amount of contribution to CO_2 emission reduction
[t-CO_2/yr]
= (A) Steel sales volume [t/yr]
÷ (B) Steel usage volume [t/unit]
× (C) Average power generation capacity [kW/unit]
× (D) Capacity factor [%]
× (E) Downtime [h]
× (F) Gearbox failure rate suppressed by usage of developed steel [%]
× (G) CO_2 emission factor of energy mix (E.M.) excluding wind power generation ([t-CO_2/kWh]

(A) Steel sales volume [t/yr]
(based on our company's factual data)

It is the amount of developed steel sold by our company in FY2021.

(B) Steel usage volume [t/unit]
(approximate value obtained from the customers)

It is the amount of bearing steel used in gearbox of one wind power turbine.

(C) Average power generation capacity [kW/unit]
(public data)

It is the power generation capacity per wind power turbine[4)].

(D) Capacity factor [%][5)] (public data)

It is percentage of actually generated power relative to the amount of power generated when wind turbine was continuously operated at its rated output.

(E) Downtime [h] (public data)

It is the average number of days of downtime of wind turbine due to gearbox-related failure[6)].

(F) Gearbox failure rate suppressed by usage of bearings that used developed steel [%]

It is calculated by using the gearbox failure rate6) and the lifespan characteristics of the conventional and developed steel.

As shown in Fig. 2, the developed steel achieves a lifespan that is four times higher than conventional steel (SUJ2) as a result of the optimization of alloy composition and the customer's special heat treatment (Super-TF*)[7)]. The extended life of the bearing steel reduces the bearing-induced wind turbine downtime hours. The rated life is 20 years. It is assumed that the failure rate from 5–20 years tends to zero, and a failure rate where such failure was suppressed was calculated.

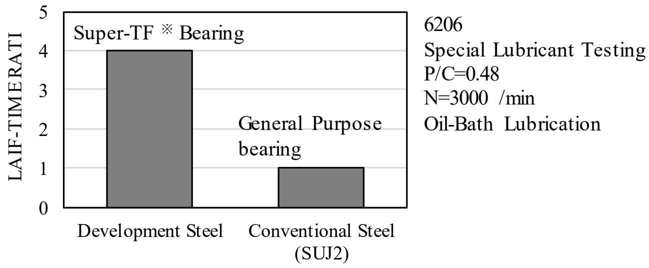

Fig. 2 Comparison figure of life time ratio[7)]

※ "Super-TF" is a heat treatment technique that extends the lifespan of bearings in special environments, and it is a registered trademark of NSK Ltd.

(G) CO_2 emission factor [t-CO_2/kWh]

The CO_2 emission factor of the alternate power generation was calculated using the E.M., which is a power generation method in Japan that combines various power generation methods including thermal power generation. This value was calculated using the domestic power source composition ratio[2)] and the amount of CO_2 emissions per kWh of power supply for each power source[3)]. Considering life cycle analysis (LCA), the amount of CO_2 emissions for each power source included the emissions during fuel combustion for power generation and those during the installation and

operation of equipment.
CO_2 emission factor of E.M.
= Σ (composition ratio of each power source × Amount of CO_2 emissions according to LCA for each power source)

The amount of CO_2 emissions reductions by applying the developed steel that was calculated using the above method was estimated as 15,000 t-CO_2/yr approximately.

4. Conclusion

We calculated the contributions to CO_2 emission reduction in the gearboxes of wind power turbines by using steel developed with special heat treatment. We believe that the extended life of the bearings owing to the use of the developed steel reduced the gearbox bearing-induced downtime of the turbine. We calculated the estimated amount of emission reduction owing to the improved functionality of the developed steel. Results showed that it can lead to approximately 15,000 t-CO_2/yr reduction in CO_2 emissions.

Our company is aiming to further extend the lifespan of bearing steel and promote new research and development. Furthermore, we are promoting the development of eco-friendly products other than bearing steel and working towards the realization of a CN society.

5. Reference

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