

Development of Backlash-Less Reduction Structure Capable of Suppressing Wiper Reversing Sound

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ABSTRACT

A wiper system is characterized by its continuous reversing movement. This means that a wiper motor is repeatedly subjected to forward and reverse loads under the influence of the variable load which a wiper blade receives when moving on the glass surface, and of the weight of a wiper arm and blade. Consequently, the system generates reversing sound inside the motor, i.e., collision sound between gears resulting from backlash. This is a challenge to be overcome.

In this study, the authors have established a new backlash-less and high-efficiency reduction gear structure by adopting pinion gears that can move in response to the load variations at reversing in the existing double worm gear reducer. With this structure, the growing needs for noise reduction, downsizing and weight saving of wiper motors can be met concurrently.

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INTRODUCTION

In recent years, the need for downsizing and weight saving of wiper motors has grown in the context of the efforts for reducing CO2 emission through the improvement of car design and fuel efficiency [1],[2],[3],[4]. We think it is best to reduce the size of the magnetic circuit components including armature and yoke because the weight saving effect is comparatively large. However, downsizing of armature is associated with torque reduction. So it is necessary to increase torque generation with a high reduction gear ratio. A double-reduction structure with a double worm shaft and two pinion gears (hereinafter referred to as "double worm gear reducer"), which enjoys high efficiency, is known to be effective for motor downsizing.

On the other hand, there is also the need for the reduction of vehicle interior noise, which has grown as electric and hybrid vehicles have become widely used [5]. To meet this need, wiper systems, like any other in-vehicle electric/electronic components, must have a structure to contribute to quieter vehicle interior. The double worm gear reducer mentioned above has a large number of backlash generating points, and thus generates large collision sound between gears, i.e. reversing sound inside a motor.

In order to meet both of the needs, it is necessary to develop a high-efficient reduction gear structure with less motor reversing sound.

In this study, we have established a new backlash-less and high-efficiency reduction gear structure by incorporating pinion gears with gradually-changing tooth thickness that can move in response to the load variations at reversing into the existing double worm gear reducer. With this structure, the needs for noise reduction, downsizing and weight saving can be met concurrently.

DOWNSIZING OF MOTORS WITH A REDUCTION GEAR

Downsizing of Motors with a Reduction Gear

A motor with a reduction gear including a wiper motor is composed mainly of an armature, a stator, a power feeding part, a gear case and gears. Among them, the downsizing of the armature and the stator, which consist mainly of metallic parts, will generate high weight-saving effect. However, the downsizing of these components leads to torque reduction. So it is necessary to increase torque generation with a high reduction gear ratio.

A high reduction gear ratio can be achieved by increasing the number of gear teeth. However, it leads to the increase of the gear diameter and accordingly the size of the reduction part. Of course, if gear module is reduced, the number of teeth can be increased without increasing the gear diameter.



But it is also impractical since the gear strength would be reduced.

The double worm gear reducer we used in this study has successfully solved the disadvantages above, and allows downsizing of a reduction part without reduction in gear module.

Double Worm Gear Reducer

The following is the explanation of the existing double worm gear reducer. As shown in Fig.1, it consists of an armature shaft with two oppositely-directed worms, two pinion gears, a spur gear and a gear case that receives the rotating gears. By arranging the pinion gears on the sides opposite to each other with reference to the armature shaft so as to allow them to mesh with the double worm and the spur gear in each position, the size of the reduction part can be reduced in terms of the projection area while a high reduction gear ratio is ensured.

Besides, in this reducer, the thrust and radial loads onto the armature shaft are almost eliminated, in other words the losses in the thrust and the radial bearings are reduced to almost zero, because the pinion gears can counterbalance the load applied via the motor output shaft (the spur gear). This provides a high mechanical efficiency.

The motor output shaft torque is obtained by the [equation \(1\)](#) below. In general, the armature shaft torque (τ) must be set in consideration of the reduction gear ratio (G) as well as the mechanical efficiency. Since the reducer enjoys high reduction efficiency (η) as mentioned above, the armature shaft torque (τ) can be lowered without reducing the resulting motor output shaft torque (T), allowing downsizing of the armature and the yoke.

$$T = G \cdot \tau \cdot \eta \quad (1)$$

Where,

T : Motor output shaft torque

G : Reduction gear ratio

τ : Armature shaft torque

η : Reduction efficiency

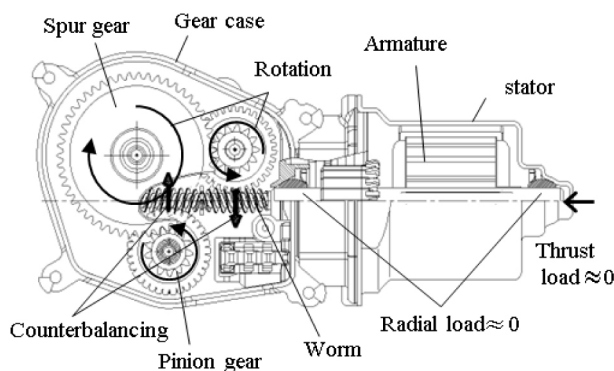


Fig. 1. Structure of double worm gear reducer and loads on it

Negative Aspects of Double Worm Gear Reducer in Terms of Noise Reduction

In a motor with reduction gear, it is desirable to reduce magnetic sound, mechanical sound due to sliding shafts and meshing gears and, especially for a wiper motor, reversing sound inside the motor [6].

The wiper operation is summarized as shown in Fig. 2 (a) below. The load applied to the motor varies depending on the factors such as glass surface condition, weight of a wiper arm, inertia force and reversing movement. Specifically, the motor receives the “forward load” and “reverse load”, which are generated when the motor rotates by itself and by external forces, respectively. Figs. 2 (b) and (c) are the enlarged views of the inside of the reducer. As shown in Fig. 2 (c), if there is a backlash between the gears, collision sound occurs at the switching of the loads. This is the main cause of the reversing sound inside the motor.

In this paper, we focused on the reduction of this reversing sound inside the motor.

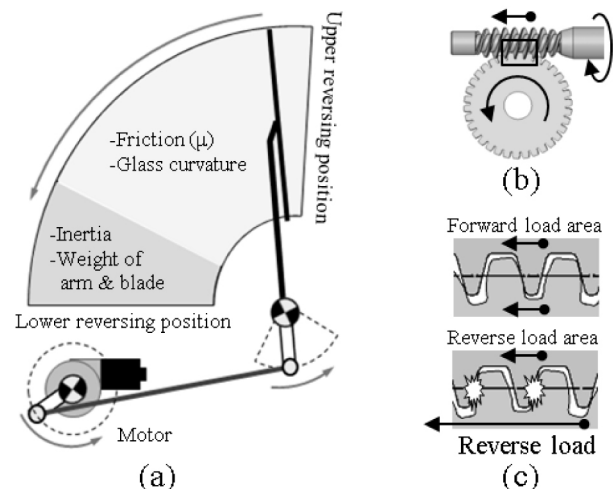


Fig. 2. Mechanism of reversing sound occurrence

Gears and Backlash

In general, in order to ensure smooth meshing of gears, it is necessary to set a proper backlash amount in consideration of the increase in tooth thickness due to thermal expansion, the dimensional variation of single gear and the positional error during installation as shown in Fig. 3 [7]. So, there is a limit to the backlash reduction. Table 1 shows an example of backlash setting.

Compared to the typical single worm gear reducer, the double worm gear reducer we used for this study, which is in the category of double reduction gear, has a larger number of meshing points, i.e. a larger number of backlash generating points. Thus, the resulting reversing sound inside the motor is relatively large, and this is a challenge to be overcome.