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An Examination on Improvement of Tracking Accuracy of Solar Tracking System

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Abstract

Background/Objectives: In order to improve the tracking accuracy of the solar tracking system, we try to check the angular resolution of the gearbox that were designed and manufactured.

Methods/Statistical analysis: In order to improve the accuracy of the solar tracking system, the drive unit was designed by applying a harmonic gear with less backlash. The angular resolution of the driving unit applying mock-up of the designed gearbox and the solar elevation data of Korea Astronomy and Space Science Institute were compared.

Findings: The angle was input in 0.1 degree steps to the drive control panel of the solar tracking system, and the angular resolution within 0.2 degree was checked by the rotation angle measurement of the drive unit. We checked the data deviation within 0.2 degree through comparison with the data of Korea Astronomy and Space Science Institute by the altitude and azimuth angle data of the sun according to time zone measured by the solar tracking system to which the mock-up drive unit was applied.

Improvements/Applications: The drive of the solar tracking system showed excellent angular resolution within 0.2 degrees.It can be applied to louver systems, natural light systems, photovoltaic power generation systems, etc. that can improve performance by tracking the altitude of the sun.

Keywords: *solar tracking, tracking accuracy, natural light, daylight, heliostat*

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I. Introduction

As the industry develops, buildings become more sophisticated and denser. As a result, high-rise building and underground spaces are increasing rapidly. With the rise of skyscraper and underground space, awareness of the violation of sunlight right due to mining inside the building and the shade of the building is increasing. Therefore, there is a high interest in

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natural light, which directly uses sunlight among the technologies for improving sunlight[1,2].Natural light directly condenses and reflects the sunlight to transmit light into the building and the underground space. The transmitted light plays a role of light energy saving of the daytime, plant growth, air purification, and sterilization. Therefore, we are making efforts to reduce energy consumption by using technology such as natural light to public buildings such as schools, public offices, and high efficiency buildings[3,4].In this study, the design and manufactured of the drive unit for improving the tracking accuracy of the solar tracking system was carried out, and comparative analysis was carried out to checked the angular resolution and solar tracking accuracy of the drive unit.

II. Materials and Methods

The solar tracking system for natural lighting continuously tracks altitude and azimuth of the Sun and delivers the sunlight to a certain target point through a light collector and a reflector[5-7]. For this, high endurance and accuracy against external force like wind are required. In general, this solar tracking system for natural lighting is exposed to the outside for a long time, it is very important to assure endurance against external factors[8,9]. Especially, the design of structure part to install light collector and reflector and the design of driving part to accurately run are critical. In conventional studies about sunlight tracking and reflection system, the system of either DC motor or linear motor to track altitudes and azimuths of the Sun took the most part[10]. These systems have been used in low-accuracy solar tracking photovoltaic power generation, and it is difficult to use them in a system requiring high accuracy like CPV or photovoltaic power generation tower. In general, there is a driving part at a center of light collector and a reflector for rotation, and this supports wide area of reflector, bringing a difficulty in rotation. Therefore, this study is to enhance accuracy of the solar tracking system for natural lighting through the design of driving part of accurate control combining a harmonic gear with low backlash and a servomotor. Moreover, to reinforce hardness of a driving part, a gear box has been directly manufactured, and for endurance against external force on large-area light collector and reflector, a square pipe has been welded on. With this, the system with high accuracy of angular resolution within 0.2degreesin a driving part and high accuracy of sun tracking within 0.2 degrees.

III. Results and Discussion

In this study, to improve driving accuracy and angular resolution of the solar tracking system for natural lighting and to simplify the rotational structure of light collector and reflector, azimuths and altitudes of the Sun have been divided. Furthermore, to minimize backlash of a driving part by external force, a harmonic gear and a servomotor have been combined to design a driving part. The system tracks altitudes and azimuths of the Sun, and to maintain accuracy, the upper driving part tracks altitudes, and the lower driving part tracks azimuths.

Figure 1 depicts the 3D modeling of the upper driving part. This part holds the large-area light collector and reflector and accurately tracks altitudes of the Sun.

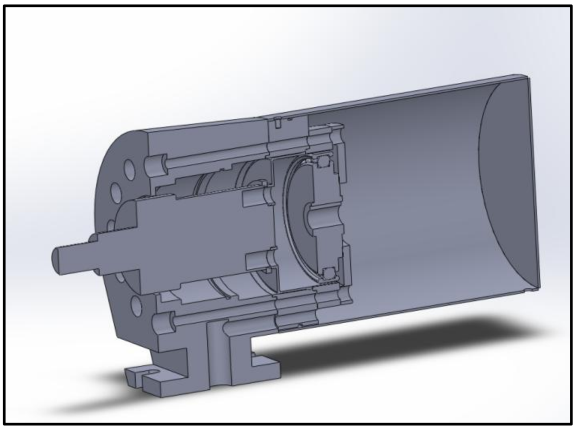

Figure 1. Elevation Driving Gearbox 3D Modeling

Figure 2 depicts the actual upper sub-driving part gear box mock-up, and for maintenance of hardness, it has been manufactured with casting.

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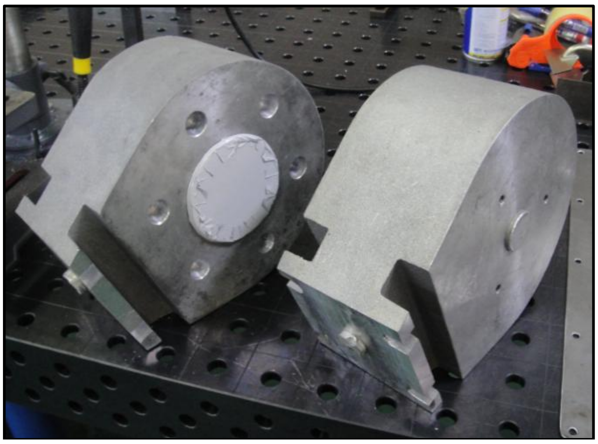

Figure 2. Elevation Driving Gearbox Mock-up

For light collector and reflector and accurate rotation, the spherical plain bearings have been applied at the upper driving part gear box.Figure 3 indicates the 3D modeling of the lower driving part, and it accurately tracks azimuths of the Sun.

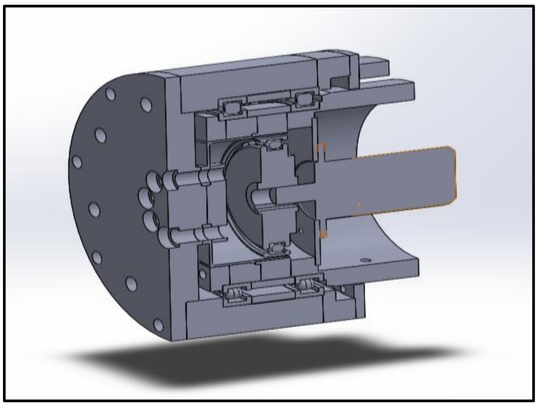

Figure 3. Azimuth Driving Gearbox 3D Modeling

Figure 4 is the mock-up of lower driving part gear box that has been actually designed. To endure external factors and loads of light collector and reflector, the multi-layer gear box housing has been designed.

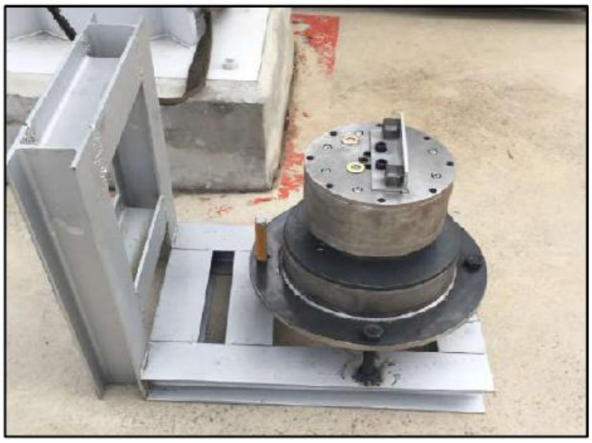

Figure 4. Azimuth Driving Gearbox Mock-up

The lower driving part gear box has been designed with direct processing for hardness, and the bearings for heavy load have been applied to hold external factors and self-load.Figure 5 shows the final solar tracking system for natural lighting with upper and lower driving parts developed, and a solar tracking system is generally called as a heliostat. In this study, the size of light collector of heliostat designed is 2,100[mm] × 2,100[mm] wide, 3,000[mm] high, and about 300[kg].

Figure 5. Solar Tracking System Mock-up

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In Figure 5 above, the control part of solar tracking system for natural lighting enters the information about installation location, and it enters GPS locational data, date, time, and others to calculate the orbit of the Sun and operates the upper and lower driving parts.To check the accuracy of calculated data by the control system, the data are compared and analyzed with the locational data of the Sun by the Korea Astronomy and Space Science Institute. The location of measurement by the solar tracking system is a general industrial complex in Geochang-gun, Gyeongsangnam-do, with longitude 27.9271 and latitude 35.539. Thereafter, to compare the system data with the locational data of the Sun by the Korea Astronomy and Space Science Institute, the unit conversion of longitude and latitude is required. The units are degree, minute, and second.The followings are values converted from GPS longitude and latitude.

Conversion of longitude degree, minute, and second: 127.9270 is:

Degree: 127 degrees,

Minute: 0.9270 × 60 = 55.62 = 55 minutes,

Second: 0.62 × 60 = 37.2 = 37 seconds.

Therefore, the converted longitude is 127 degrees 55 minutes 37 seconds.

Conversion of latitude degree, minute, and second: 35.6539 is:

Degree: 35 degrees,

Minute: 0.6539 ×60 = 39.234 = 39 minutes,

Second: 0.234 × 60 = 14.04 = 14 seconds.

Therefore, the converted latitude is 35 degrees 39 minutes 14 seconds

An azimuth is a value measured in clockwise direction from the north. The due south is marked as 0 degree, the eastern direction uses a negative (-) sign, and the western direction uses a positive (+) sign. Therefore, 180 degree should be added to the output value.An altitude is an angle between horizon and the Sun. If the light collector and the reflector of the sun tracking system for natural lighting are stood up vertically to be aligned with due south, it is 0degree, and the section below uses a negative sign (-) and the section above uses a positive sign (+) to indicate an angle.

The table below indicates the data of measured azimuth angles and altitude angles of the Sun in every hour from 10AM to 6PM on April 18th 2017. Table 1 indicates azimuths of the Sun, and Table 2 indicates altitudes of the Sun.

The data of Table 1 and Table 2 show that the driving part with harmonic gear and servomotor has an excellent angular resolution within 0.1 degree. The section with large deviation of data involves wind blowing, and as a load is put on the reflector, a reflector is shaken and brings deviation up to about 0.4 degree temporarily. It was confirmed that azimuths and altitudes on the solar tracking system were accurate within 1 degree. The section with great deviation of data has occurred from the difference in measuring time

Table 1. Solar Azimuth Variations by times (04.18.2017)

Hour	Azimuth by Korea Astronomy and Space Science Institute	Measured Azimuth (°)	Converted to DMS	DMS Deviation	Conversion Deviation of Degree
10	117 21 11.50	-62.61 (117.39)	117 23 24	00 02 13	0.3366
11	135 54 42.40	-43.58 (136.42)	136 25 12	00 07 70	0.2360
12	164 07 18.50	-15.87 (164.13)	164 07 48	00 00 30	0.0083
13	198 29 05.90	18.51 (198.51)	198 30 36	00 01 31	0.1746
14	225 54 37.70	45.92 (225.92)	225 55 12	00 00 75	0.0208
15	243 53 50.50	63.96 (243.96)	243 57 36	00 03 86	0.0738

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16	256 24 30.50	76.41 (256.41)	256 24 36	00 00 06	0.0017
17	266 16 06.60	86.26 (266.26)	266 15 36	00 00 70	0.0194
18	275 00 57.20	95.46 (275.46)	275 27 36	00 26 79	0.4552

Table 2. Solar Elevation Variations by times (04.18.2017)

Hour	Altitude by Korea Astronomy and Space Science Institute	Measured Altitude (°)	Converted to DMS	DMS Deviation	Conversion Deviation of Degree
10	48 22 44.6	48.41	48 24 39	00 01 95	0.0429
11	58 12 39.7	58.40	58 24 00	00 11 61	0.2002
12	64 24 58.1	64.42	64 25 12	00 00 54	0.0150
13	64 08 45.6	64.15	64 09 00	00 00 55	0.0153
14	57 33 57.8	57.57	57 34 12	00 00 55	0.0153
15	47 34 07.5	47.53	47 31 48	00 02 59	0.0497
16	36 06 45.7	36.12	36 07 12	00 00 67	0.0186
17	24 04 51.4	24.09	24 05 24	00 00 73	0.0202
18	11 54 45.1	11.27	11 16 12	00 38 33	0.6425

The table below indicates azimuths and altitudes on the solar tracking system and the angular resolution of driving part confirmed with the Korea Testing Laboratory from 10AM to 12AM on May 26th 2017.Table 3 shows the angular resolution of driving part, and the data of arbitrary angles from 0.1 degreeto 40 degreeon the control system have been entered to be compared with the measured angle.

Table 3. Gearbox Moving Accuracy

Angle in System Entry (°)	**Measured Angle (°)**	**Error (Entered-Measured)**
0.1°	0.1°	0°
0.3°	0.2°	0.1°
0.5°	0.5°	0°
1°	0.9°	0.1°
3°	2.9°	0.1°
5°	4.9°	0.1°
10°	9.9°	0.1°
20°	19.9°	0.1°
30°	30°	0°
40°	40°	0°

The data indicate that angles change by momentary wind, and deviation is within 0.1 degree, which is very highly accurate to be within 0.2 degree.Table 4 indicates azimuths and altitudes of the Sun, and the output values from the system have been compared with the orbital data of the Sun by the Korea Astronomy and Space Science Institute. Therefore, it is confirmed that the system has very high accuracy of solar tracking with deviation of at most 15 minutes.

Table 4. Solar Azimuth & Elevation Variations by times (05.26.2017)

Measured Time	**Solar Tracking System**		**Korea Astronomy and Space Science Institute**		**Deviation**	
	Azimuth (DMS)	**Altitude (DMS)**	**Azimuth (DMS)**	**Altitude (DMS)**	**Azimuth (DMS)**	**Altitude (DMS)**
10:24	110 33 36	059 49 12	110 33 12.50	059 48 25.9	000 00 23.50	000 00 86.10
10:31	112 36 00	061 12 36	112 29 35.30	061 07 49.3	000 06 64.70	000 04 86.70
10:38	114 37 48	062 28 12	114 34 11.50	062 26 04.0	000 03 36.50	000 02 08.00

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10:44	116 43 48	063 40 48	116 28 22.60	063 32 04.9	000 15 25.40	000 08 43.10
10:49	118 20 24	064 32 24	118 09 19.80	064 26 14.8	000 11 04.20	000 06 09.20
10:55	120 16 48	065 30 00	120 18 11.20	065 30 05.3	000 01 63.20	000 00 05.30
11:01	122 40 12	066 34 48	122 36 22.00	066 32 29.9	000 03 90.00	000 02 18.10

IV. Conclusion

This study is to improve the driving accuracy of the solar tracking system for natural lighting and the solar tracking accuracy. For precision driving and improvement on angular resolution of the driving part, a harmonic gear has been applied to minimize backlash. To check driving precision and precision on solar tracking, the azimuths and altitudes on the system have been compared with the data by the Korea Astronomy and Space Science Institute. It was confirmed that the angular resolution had deviation within 0.2 degreeto be regarded as highly accurate, and precision on solar tracking also had deviation within at most 15 minutes to show very high tracking precision. Therefore, this system is evaluated to be applied in various fields requiring solar tracking such as louver system, CPV, or photovoltaic power generation.

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