Lifespan Test Report of 25-120 High-Torque SWG

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1 Overview

1.1 Test Objective

The test report pertains to the lifespan testing of the eRob110H120I-BM-18ET module (hereinafter referred to as eRob110 in this report). The objective is to confirm the rigidity, backlash variation, and condition of the gear surface after failure of the 25-120 high torque Strain Wave Gear (SWG) following prolonged operation under a load torque of 154.4 N.m (the SWG's rated maximum average load torque is 140 N.m) and a speed of 144,432 counts per second (motor end 2000 revolutions per minute). This evaluation will assess the service life of the 25-120 high torque SWG.

1.2 Test Scope

The primary focus of this test is the lifespan evaluation of the 25-120 high torque SWG.

1.3 Test Module Information

Table 1-1 Test Module Information

Product Name	Product Number
Model	eRob110H120I-BM-18ET
Version Number	MC1C.7C.2B
Serial Number	LK-TG4-202111100018
SWG Brand	Han's Motion
SWG Model	25-120
SWG S/N	B750602030

2 Test Tools and Environment

2.1 Test Tools

Table 2-1 Test Tools

Tool Name	Specification	Purpose
Customized Tool	—	Tool used to exert load on SWG
Dial Indicator	0-25.4mm, resolution 0.001mm	Measure the customize tool displacement
Tensiometer	200N	Cross Roller Rigidity Force Test
Microscope	CNC3020	Microscopic observation and photography
Weights	7KG, 825g	Exert load on SWG to measure rigidity and backlash

2.2 Test Condition

Table 2-2 SWG Parameters

Property	Value
Model	25
Gear Ratio	120
Rated Torque at 2000 RPM	87 N·m
Peak Torque during Start and Stop	217 N·m
Permissible Maximum Torque with Average Load	140 N·m
Permissible Maximum Momentaty Torque	395 N·m

Table 2-3 Loading Conditions for the Test

Property	Value
Loaded Wight	47.66 kg
Center of Mass	0.331 m
Moment of Inertia	0.7699 kg·m^2
Torque	154.4 N·m
Acceleration/Deceleration Time	1 sec

Table 2-4 Test Operating Conditions

Condition Name	Standard Measurement Unit Value	eTuner Setting
Speed	16.529 r/min	144432
Acceleration/Deceleration	1.86 rad/s^2	155660
Stop Time	1000 ms	1000
Operating Range	Back and forth between 0° and 180° horizontally	—
Operating Duration	More than 8000 hours	—

2.3 Installation Environment

The load installation method for the tested eRob110-120 under the aforementioned test load conditions is as shown in Figure 2-1.

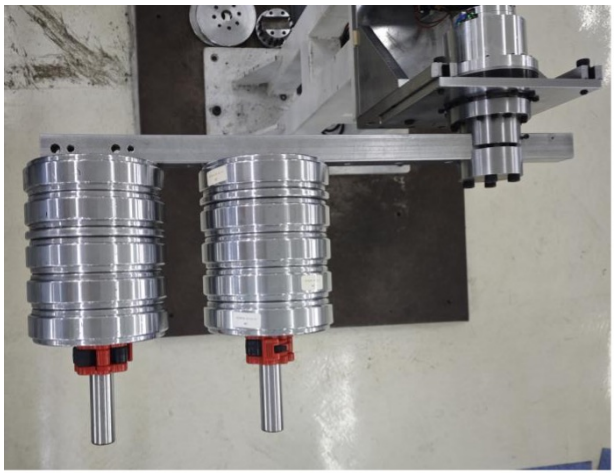

Figure 2-1 eRob110-120 Load Installation Diagram

2.4 Manpower Arrangement

Table 2-5 Testing Personnel

Role	Personnel	Responsibilities
Test Applicant	Xie Jihua	Submits the test requirement application form and coordinates the implementation of the test plan
Test Executor	Ning Miao	Executes the test plan as per the requirements and arrangements of the test

Table 2-6 Test Workload

Task	Start Time	End Time	Total (hours)
Planned	Jul 20, 2022, 15:20	Jun 24, 2023, 09:00	8000
Actual	Jul 20, 2022, 15:20	Sep 27, 2022, 08:00	4776

3 Testing Procedure

The eRob110 is tested under the aforementioned load and operating conditions, running continuously for over 8000 hours. During this period, the module's rigidity, backlash, and bearing rigidity are periodically recorded. After the test concludes, the SWG is disassembled, and samples of the flexspline, circular spline, and grease debris are collected. These samples are observed under a 2D measuring instrument to examine the grease and gear surface wear, and are photographed and archived. The method for recording the test data is detailed in Table 3-1.

Table 3-1 Test Data Records

Name	Unit	Recording Frequency	Recording Method
Module Rigidity	N·m/rad	Once every 7 days	Recorded in a table
Backlash	Arc Sec	Once every 7 days	Recorded in a table
Temperature	°C	Once every 12 hours	Recorded in a table
Grease Debris	—	Once at the end of the test	Photographed under a microscope
Flexspline Bearing Wear	—	Once at the end of the test	Photographed under a microscope
Gear Surface Wear	—	Once at the end of the test	Photographed under a microscope

4 Test Results and Analysis

4.1 Definition of Critical Values

(1) New Machine Qualification Critical Values
- SWG Rigidity: According to the SWG manufacturer's manual, the minimum qualified rigidity value for the 25-120 model SWG is 37200 N·m/rad.
- Backlash: According to the SWG manufacturer's manual, the maximum qualified backlash value for the 25-120 model SWG is 10 arc sec.

(2) Significant Wear Critical Values
- SWG Rigidity: At a distance of 1 meter from the module's rotational center, applying a force of 50 N, if the end displacement exceeds 5 mm, significant torsion is observed. This condition is defined as significant wear, with a rigidity value of 10000 N·m/rad being the significant wear critical value.
- Backlash: With the module placed horizontally, if a gentle shake at a distance of 1 meter from the module's rotational center results in an end displacement exceeding 0.3 mm, significant backlash is felt. This condition is defined as significant wear, with a backlash value of 50 arc sec being the significant wear critical value.

(3) Triple Significant Wear Critical Values
- SWG Rigidity: At a distance of 1 meter from the module's rotational center, applying a force of 50 N, if the end displacement exceeds 15 mm, the torsion angle is too large to meet general use requirements, indicating failure. The rigidity value at this point is 3333 N·m/rad, which is the three times significant wear critical value.
- Backlash: With the module placed horizontally, if a gentle shake at a distance of 1 meter from the module's rotational center results in an end displacement exceeding 0.9 mm, the backlash is too large to meet general use requirements, indicating failure. The backlash value at this point is 150 arc sec, which is the three times significant wear critical value.

Note: The eRob using a fully closed-loop control system, hense these test data represent only the SWG data and do not reflect the module's overall precision.

4.2 Test Data

(1) SWG Rigidity

- Test Load Weight: 7 kg
- Load Distance: 0.215 m
- Measurement Point Distance from Center: 0.2 m

The variation curve of the SWG rigidity test data is shown in Figure 4-1. The data in the figure represent the torsion angle under a load of 14 N·m.

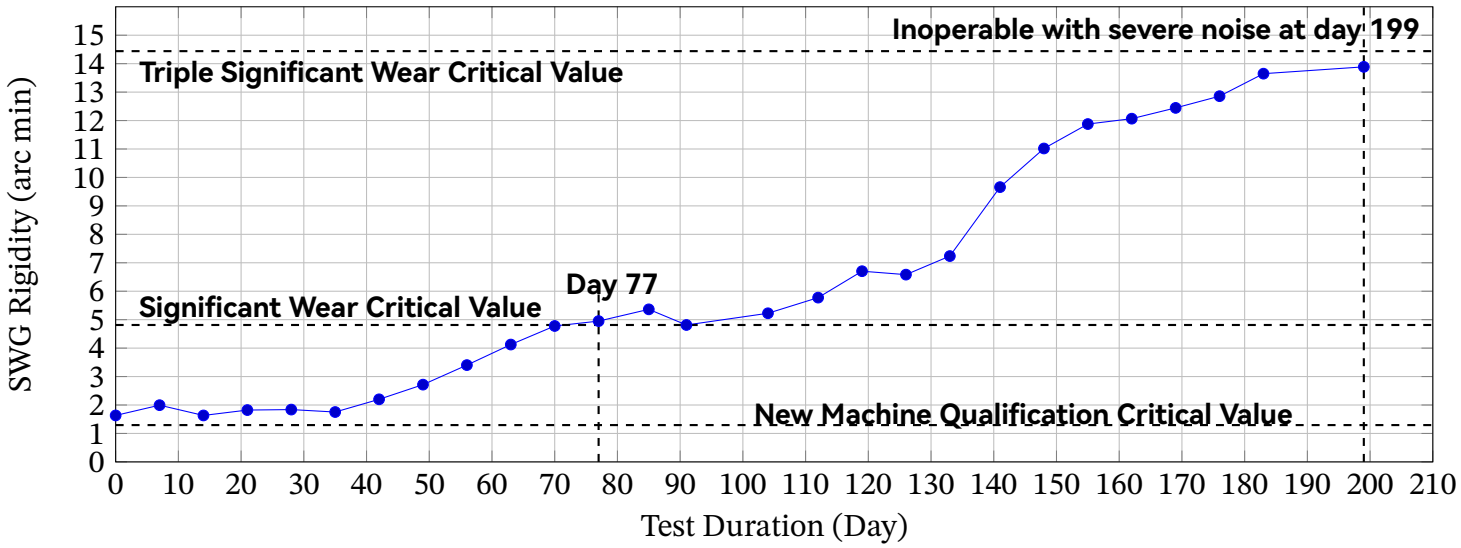

Figure 4-1 SWG Rigidity Lifespan Test Plot

(2) SWG Backlash

- Test Load Weight: 825 g
- Mounting Distance: 0.215 m
- Measurement Point Distance from Center: 0.2 m

The variation curve of the SWG backlash test data is shown in Figure 4-2.

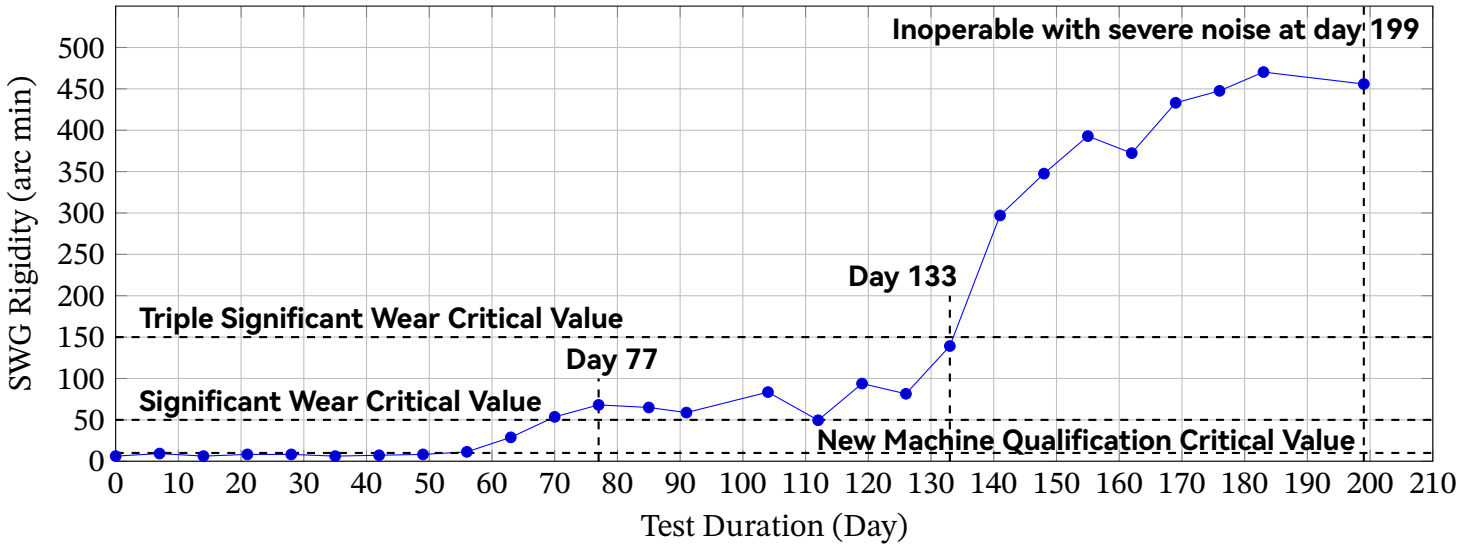

Figure 4-2 SWG Rigidity Lifespan Test Plot

(4) The variation curve of the ambient and eRob temperature data is shown in Figure 4-3.

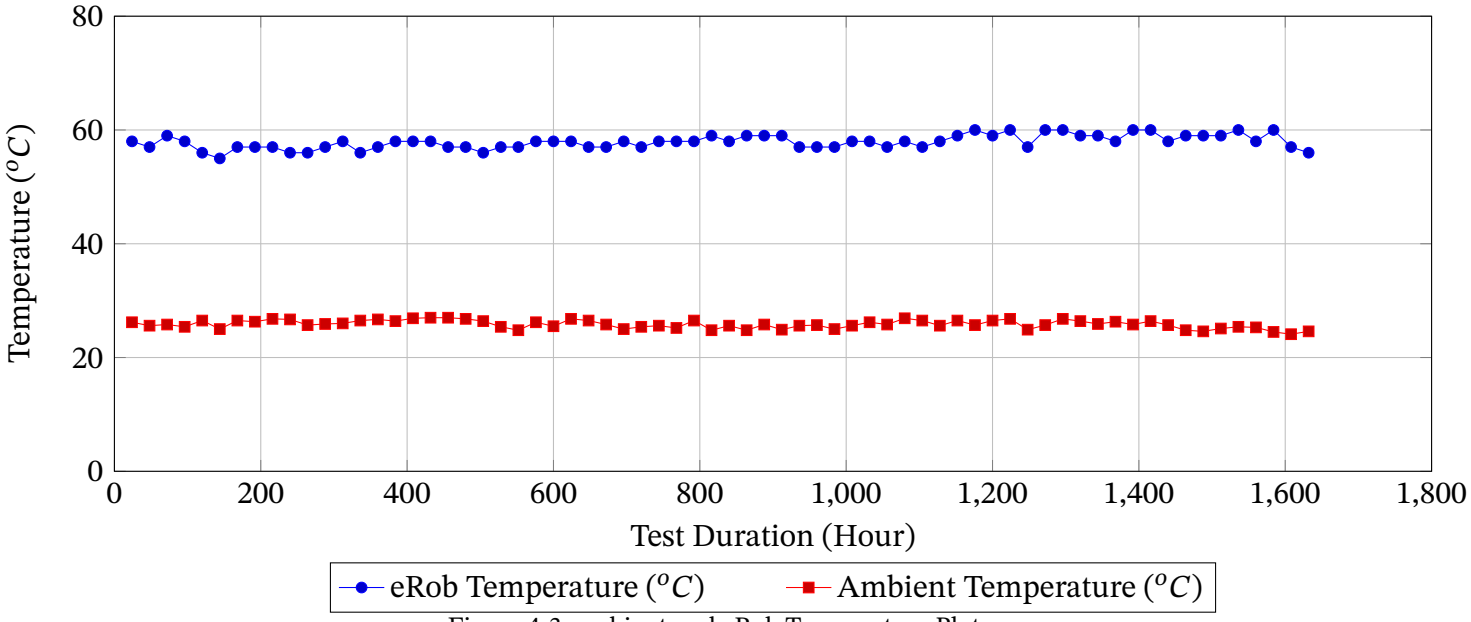

Figure 4-3 ambient and eRob Temperature Plot

(5) Photographs were taken during the disassembly of the sample eRob. After continuous operation for 4776 hours, the SWG exhibited severe abnormal noise and was unable to function normally. The disassembly images are shown in Figures 4-4.

Figure 4-4 Photographs of the disassembled eRob

(6) Microscopic photographs of the flexspline ball bearings were taken, images are shown in Figures 4-5.

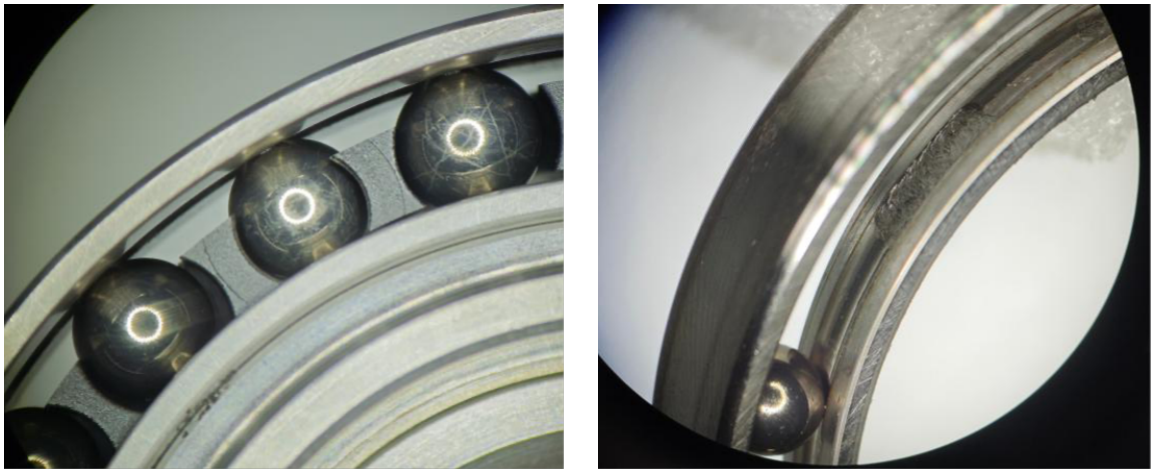

Figure 4-5 Photographs of the flexspline ball bearings

(7) Microscopic photographs of the SWG circular spline teeth were taken, images are shown in Figures 4-6.

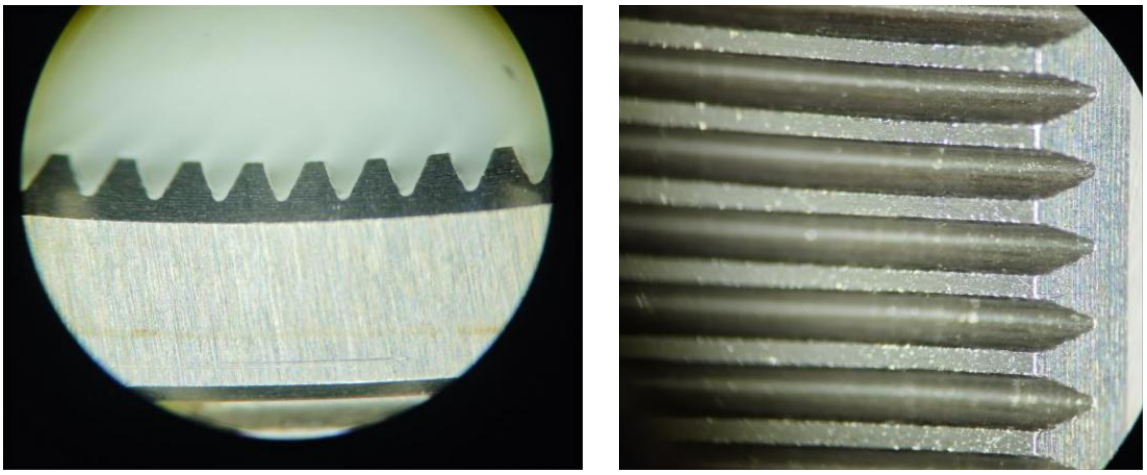

Figure 4-6 Photographs of the SWG circular spline teeth

(8) Microscopic photographs of the SWG flexspline teeth were taken, images are shown in Figures 4-7.

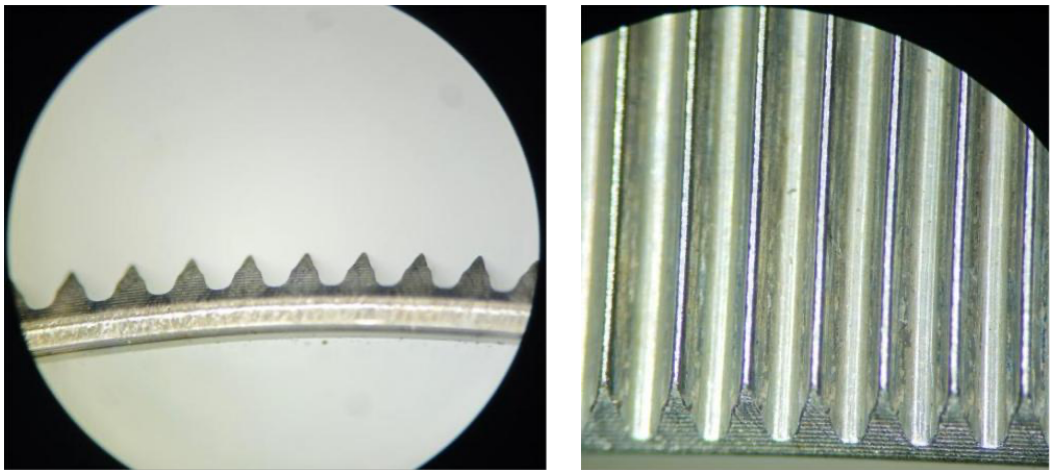

Figure 4-7 Photographs of the SWG flexspline teeth

4.3 Phenomenon Description

After continuous operation for 4776 hours under test conditions of an applied torque exceeding the rated load torque of 67.4 N·m (77.5%) and a rotational speed of 16.529 rpm, the following phenomena were observed for the Han's Motion 25-120 SWG based on the obtained photographs and data:

(1) Phenomenon 1: From the measured rigidity and backlash change curves of the eRob110 eRob (Figures 4-1 and 4-2), it can be seen that during the initial 70 days of the test, changes in rigidity and backlash were minimal and did not exceed the critical value for significant wear. However, the data deteriorated sharply in the later period, reaching triple critical value for significant wear backlash by day 133.

(2) Phenomenon 2: From the measured temperature change curve of the eRob110 eRob (Figure 4-3), it is evident that the eRob maintained a consistent temperature of around 58°C during long-term continuous operation, with no significant temperature fluctuations in the module.

(3) Phenomenon 3: Photographs taken during the disassembly (Figures 4-4) revealed that the gear grease and wave generator grease contained black gelatinous substances, and the grease appeared black-brown with black particles.

(4) Phenomenon 4: Magnified images of the flexspline ball bearing (Figure 4-5) showed noticeable scratches on the balls and significant damage to the raceways.

(5) Phenomenon 5: Enlarged microscopic photographs of the rigid gear teeth of the 25-120 high-torque speed SWG(Figure 4-6) indicated slight wear on the gear teeth surfaces, with no obvious changes in tooth profile.

(6) Phenomenon 6: Enlarged microscopic photographs of the flexspline gear teeth of the 25-120 high-torque speed SWG (Figure 4-7) demonstrated that the originally trapezoidal tooth profiles had worn into triangular shapes, indicating severe wear.

4.4 Results Analysis

Based on the aforementioned phenomena, the following analyses can be made:

(1) Analysis of Phenomenon 1: The module operated relatively smoothly during the initial period. However, after 70 days, wear intensified, leading to a decline in precision.

(2) Analysis of Phenomenon 2: The small variation in the module's temperature suggests minor fluctuations in current, indicating that the speed SWG operated relatively stably during the test period.

(3) Analysis of Phenomenon 3: Considering the materials of the SWG and the composition of the grease, the black gelatinous substance is attributed to severe wear of the SWG, with the grease mixing with iron particles, resulting in the observed color.

(4) Analysis of Phenomenon 4: The magnified images of the flexspline ball bearing reveal that damage to the raceway of the flexible bearing led to significant abnormal noise.

(5) Analysis of Phenomena 5 and 6: The projection images of the gear teeth surfaces indicate that the fine black iron particles observed in Phenomenon 3 originated from the wear of the circular spline and flexspline gear teeth.

5 Test Conclusion

Based on the above test data and phenomenon analysis, the following conclusions can be drawn regarding the 25-120 SWG tested under conditions of a torque exceeding the rated load torque of 67.4 N·m (77.5%) and a rotational speed of 16.529 rpm for continuous operation over 4776 hours:

(1) Initial Wear and Backlash: After continuous operation for 70 days, the backlash of the SWG exceeded the critical value for significant wear. Its significant wear life at this stage was 1680 hours. Using the Formula 1 shown below to convert this to normal life time, the service life under rated load and rated speed is calculated to be 9391 hours.

(2) Accelerated Wear: After continuous operation for 133 days, the backlash exceeded triple significant wear critical value. The triple significant wear life was 3192 hours. Using the Formula 1 shown below to convert this to normal life time, the service life under rated load and rated speed is calculated to be 17843 hours.

(3) Bearing Failure: After continuous operation for 4776 hours, the flexspline ball bearing was damaged, producing abnormal noise and rendering the SWG unable to function normally. The operational life was 4776 hours. Using the Formula 1 shown below to convert this to normal life time, the service life under rated load and rated speed is calculated to be 26696 hours.
Calculation formula for life (L_h) by actual operation condition

$$L_h = L_n \times (\frac{T_r}{T_{avg}})^3 \times (\frac{n_t}{n_{avg}}) \tag{1}$$

Symbol	Definition
L_h	Life measured in hours.
L_n	Life of L_{10} or L_{50}.
T_r	The Rated Torque Output by the eRob Module.
T_{avg}	Average Load Torque on the SWG Output Side.
n_t	Motor Rated Rotational Speed Used for Module Rated Torque Testing (2000RPM).
n_{avg}	Average SWG Input / Motor Output Rotational Speed.

6 Test Completion Confirmation Item

Table 6-1 Test Completion Confirmation Table

Confirmation Item	Confirmed By	Signature	Date
Test content has been completed	Test Executor		
Test requirements have been met	Test Requestee		
Test instruments have been returned to place	Test Executor		
Test samples have been processed	Test Executor		