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SUBJECT: Description of Accelerated Degredation Testing

Dear Mr. James:

Stress Engineering Services, Inc. (SES) appreciates the opportunity to assist you and Motus Labs with the review of your test program for the ML2000 series gear. SES has prepared this summary for the testing conducted at the Motus Labs facility. The contents of this document pertain to the testing to determine the runtime of the gears within the specifications.

SES anticipates that we will issue a revised/updated letter upon the completion of your test program.

Please contact me if you have any questions.

Regards,



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1. Background

Stress Engineering Services, Inc. (SES) was contacted by Motus Labs (Motus) to provide consulting services for the in-house testing conducted on the ML2000-86-60 model of the Orbital Flex™ enabled ML2000 gears. Throughout the testing program, SES has provided oversight and recommendations for the execution of the testing. SES has reviewed the testing methods and results, and the summary is provided herein.

2. Testing Description

The ML2000-86-60 gears tested by Motus were manufactured and assembled as production gears with no preferential treatment for the testing program. The objective of the testing conducted by Motus was to establish the number of hours that the gears could operate at the rated torque without exceeding the published specifications with a 90% reliability. To accomplish this objective, the gears were tested at torques exceeding the rated torque in order to reduce the required run times. The testing equipment built by Motus was designed to apply torque and motions that would simulate the loading profiles that would be expected during operation of the gears. A photograph of the testing apparatus (RAS) is shown in Figure 1.

The torque levels tested were the average torques calculated from the measured profiles during the movement program. Three average torque levels with three gears tested at each level were selected to provide a basis for validating a 10,000 hr run time before the gear no longer exhibited no backlash. Based on SES's previous experience, three samples were determined to be an adequate number of samples at each torque level for comparison to the design curve.

The gears were removed from the test bench periodically to measure the backlash. Once a gear exceeded 17 arcsec of backlash, testing ended for the gear and the accumulated run time was recorded. Due to testing restrictions, if the gears had not exceeded the backlash limit, the test was considered complete once the gear had reached a target run time.

The run times for each gear at each average torque level were used to create Weibull Plots and estimate the time with 90% reliability. These times were then compared to a design life curve required to achieve a 10,000 hr run time before exceeding zero backlash at an average applied torque of 45 Nm.

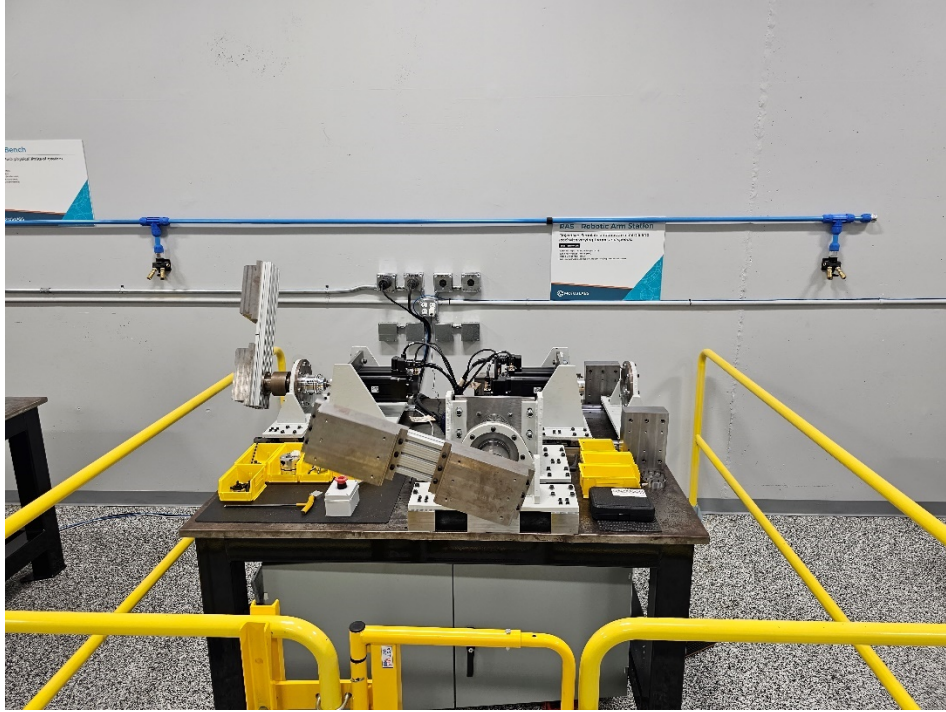


Figure 1: RAS Bench with Capability of Testing 3 Gears Independently.

3. Results

The run times for the gears tested are listed below in Table 1. With the exception of Gear S158, all gears were stopped prior to exceeding the backlash limit. The highlighted row represents a gear that is being tested at the time of this writing.

These times were used to estimate the 90% reliability times for the corresponding applied torque levels. These times were then compared to the curve shown in Figure 3. The design curve was generated using a k value of 5.4 and equates to a life of 10,000 hrs at the rated torque. As shown in the figure, the data from the testing program meet the required design curve.

Table 1: Run Times for Tested Gears.

Average Applied Torque (Nm)	Gear Serial Number	Time when Backlash Exceeded/Testing Stopped (hrs)
88	S148	1,117
	S145	1,075
	S149	795
100	S144	622
	S142	554
	S158	394
150	S164	100
	S152	70
	S150	70

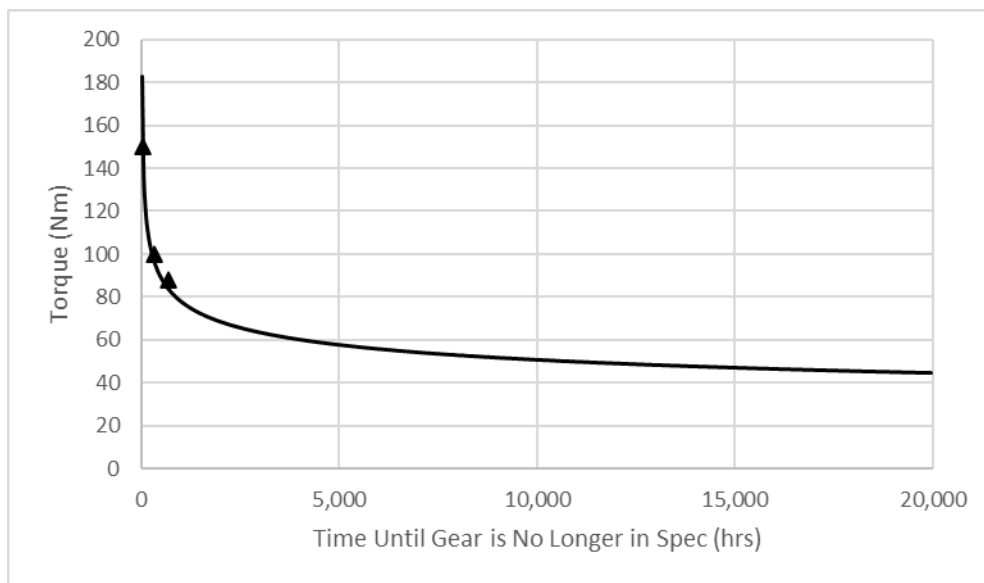


Figure 2: Plot of Average Applied Torque versus Time with 90% Reliability.

4. Conclusions

Based on the results collected to date, the ML2000-86-60 gears are expected to have zero backlash (<17 arcsec) performance at the rated torque for over 10,000 hrs. The focus of the current test program is to evaluate the backlash of the gears that is likely caused by wear of the gear teeth. Once this testing is completed, the testing of these gears will continue to establish the failure life.

5. Limitations of This Report

This report is prepared for the sole benefit of the Client, and the scope is limited to matters expressly covered within the text. In preparing this report, SES has relied on information provided by the Client and, if requested by the Client, third parties. SES may not have made an independent investigation as to the accuracy or completeness of such information unless specifically requested by the Client or otherwise required. Any inaccuracy, omission, or change in the information or circumstances on which this report is based may affect the recommendations, findings, and conclusions expressed in this report. SES has prepared this report in accordance with the standard of care appropriate for competent professionals in the relevant discipline and the generally applicable industry standards. However, SES is not able to direct or control operation or maintenance of the Client's equipment or processes.

6. Revision History

Document Control					
Rev	Date	Description	Originator	Checker	Reviewer
B	12-Oct-2023	For Client Review	Brent Vyvial	George Ross	George Ross
C	08-Feb-2024	For Client Review	Brent Vyvial	George Ross	George Ross
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