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An Approach to the Characterization of Dynamic Seal for Torque Sensitive Application

Sangeetha Singhal[1], G Sreenivasa Reddy[2], P Vijaya Kumar[3], Pramod Kumar[4]

[1, 2]Scientist, Aeronautical Development Establishment, DRDO, New Tippasandra (PO), Bangalore-75, India
[3, 4]Technical Officer, Aeronautical Development Establishment, DRDO, New Tippasandra (PO), Bangalore-75, India

Abstract: ***Purging and sealing the stabilized electro-optic payload is required for satisfactory performance at low temperatures. The gimbal joints are to be sealed with dynamic seal whose performance shall restrict the sealability and drivability of these dynamic joints. A definite and concise approach shall help in characterizing these dynamic seal for optimizing their behavior to the system. A dynamic seal test set-up is configured and realized to test the dynamic joint variables. The variables are varied through the test cases and the most optimum joint variable is chosen which is tested at the operating temperature limits and found to deliver satisfactorily.***

Keywords: Dynamic seal, Characterization, Test-setup configuration

1. Introduction

The stabilized turret designed as a medium range electro-optic payload for Unmanned Aerial Vehicle (UAV) has an operating temperature requirement of -40^{o}C to +55^{o}C. The water vapor trapped in the turret shall condense at negative temperatures and shall result in performance deterioration of the payload assembly. This makes it inevitable to purge and seal the volume with pressurized with nitrogen.

The turret consists of 4 gimbals that are relatively rotating. The sealing at these joints are possible only with the use of dynamic seals. The unique characteristics of the systems which were critical in the selection of the dynamic seal are the low pressure (1.2 to 1.6 bar), the absence of stiction and low friction torque. These requirements were found to be appropriately met by spring-energized seals with PTFE jacket. The spring element responds with constant force, ensuring tight seal even at low pressures compensating for any influencing parameters that might alter the state. The open end of the seal oriented towards higher pressure allows increasing the contact pressure and thus eliminates potential leakage. The PTFE jacket around the spring with its chamfered/back beveled is found to concentrate the sealing force and hence yields the highest seal ability and lowest friction. The low-friction material formulation in the jacket helps reduce or eliminate stiction force and results in reduced jitter. The system demanded a face seal configuration at all the gimbal joints for defect free assemblies.

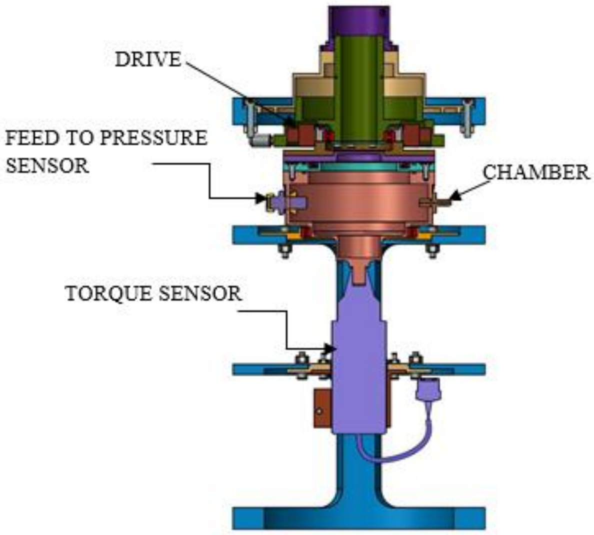
The dynamic seals contribute majorly to the friction torque and leakage of the turret assembly. The friction torque exerted shall eat away a major portion of the capacity of the drive. Hence it becomes imperative to characterize the dynamic seal before actually using on the turret assembly.

The objective of the characterization of the dynamic seal is to estimate the behavior with respect to Dynamic sealing efficiency V/S extrusion gap and Friction V/S extrusion gap.

The characterization can be done in a test set up with provision for creating a sealed volume whose leakage path is restricted to dynamic seal. The setup also should have features to enable variation and measurement of the critical parameters and drive to enable motion.

Configuration

The dynamic seal test set-up shall consist of a chamber sealed by dynamic seal, Filler valve for filling in nitrogen in the chamber, Pressure sensor for sensing the pressure, Motor for imparting motion to the dynamic plate, Torque sensor for measuring the friction torque and mechanism for adjusting the gap at the dynamic joint.



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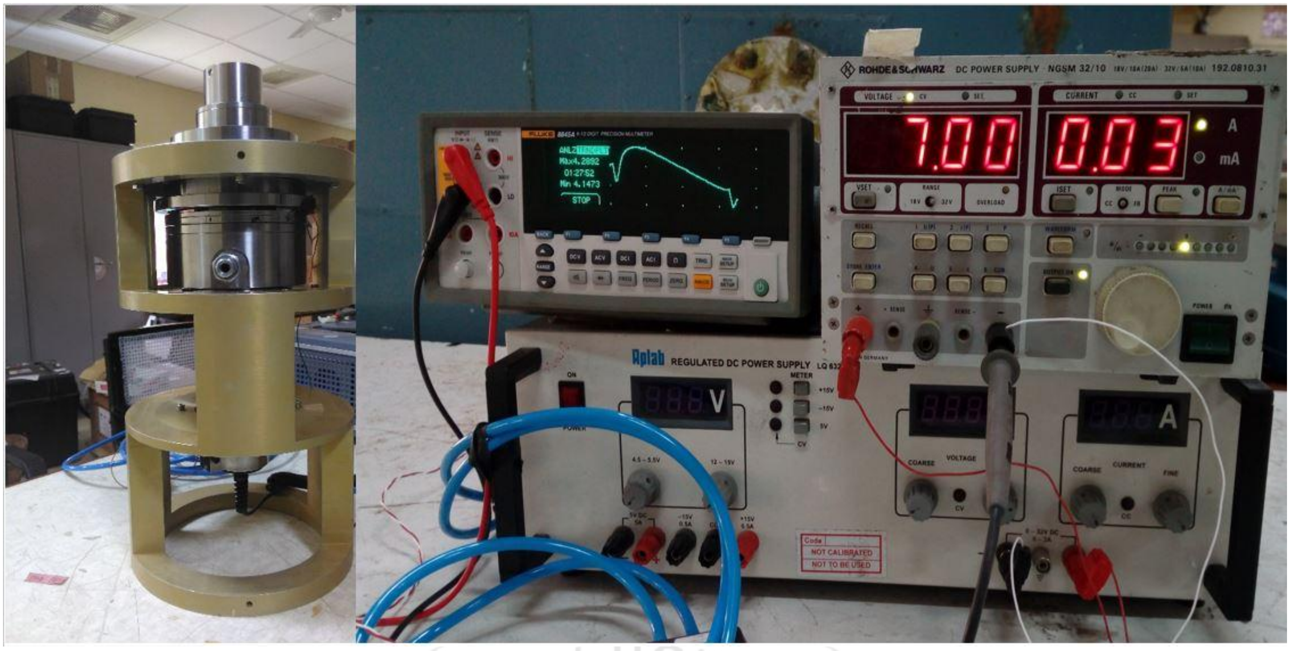

Figure 1: Configuration of dynamic seal test set-up

The configuration of the test set-up with respect to motor, sensors remains to be the same while the characteristic of the dynamic joint like the material, surface finish, hardness and conditions are varied and tested. The variables of the dynamic joints which were varied are:

1) Material: Stainless steel, Alumium alloy
2) Surface treatment: Passivation, hard chrome coating, hard anodization
3) Contact condition: Dry, Lubricated

Acceptance test

The leakage from chamber shall be restricted to the dynamic seal joint and hence the acceptance test is carried out to check that the static interfaces are leak proof. The test set-up shall be cleared for sealing before introducing dynamic seal at the chamber interface. During this test, the dynamic interface is also sealed using static seal. The dynamic plate can be brought down to compress the static seal and thus close the chamber. Nitrogen is filled at 4psi and the pressure drop is monitored for ensuring that the sealing is taken care at all joints

Characterization of dynamic seal:

During the characterization of the dynamic seal, the parameters that are being monitored are:

1) Voltage and current drawn by motor to drive the dynamic joint
2) Friction torque measured by torque sensor
3) Pressure in the chamber measured by pressure sensor
4) Gap between the dynamic and static plate measured using feeler gauge
5) Leakage rate measured by Helium spectrometer

The test procedure is as follows:

1) Place the dynamic seal inside the groove provided in the static plate with enough lubricant applied on the static and dynamic plate.
2) Adjust the dynamic plate such that the motion of the dynamic plate just couples to the static plate. (Ensure that the torque sensor is not attached to the static portion).
3) Measure the gap between static and dynamic surfaces. This gap corresponds to the zero compression gap and shall be considered datum for further compression.
4) The dynamic plate shall be advanced by 0.1mm to compress the seal by 0.1mm. The gap shall be measured and confirmed by the feeler gauge. The pressure is monitored in the pressure sensor.
5) The motor is powered ON to monitor the current and Voltage drawn by the motor. The friction torque can be monitored in the torque sensor. The pressure is monitored in the pressure sensor. The motor is rotated both in clockwise and anticlockwise direction for data capture.

2. Results

The tests are carried out with various combinations of material, surface treatment and contact condition. The test cases and the results are tabulated in Table 1.

Test cases	Properties of the Dynamic joint	Remarks
Test case1	Hard chrome plated dynamic interface (0.06microns to 0.65microns surface finish) with dry contact at the joint	The plot of the Seal Compression V/S Friction Torque is as shown in Figure 1. The chamber was filled with helium and the leakage was detected using spectrometer. There was continuous leakage and the pressure drop measured is 0.0003Psi/s
Test case2:	Hard chrome plated dynamic interface (0.06microns to 0.65microns surface finish) with greased contact at the joint.	The plot of the Seal Compression V/S Friction Torque is as shown in Figure 1. The chamber was filled with helium and the leakage was detected using spectrometer as 1.1x10-6 millibar. Ltr/s. The pressure drop measured is 0.0002Psi/s.

Test case3:	Hard chrome plated dynamic interface (0.06microns to 0.65microns surface finish) with oil lubricant contact at the joint.	The plot of the Seal Compression V/S Friction Torque is as shown in Figure 1. The chamber was filled with helium and the leakage was detected using spectrometer as 1.1x10-6 millibar. Ltr/s. The pressure drop measured is 0.0002Psi/s
Test case4:	Hard chrome plated & passivated stainless steel dynamic seal joint (0.06microns to 1.47microns surface finish) with oil lubricant contact at the joint	The plot of the Seal Compression V/S Friction Torque and the Seal Compression V/S pressure drop is as shown in Figure 2.
Test case5:	Hard chrome plated & passivated stainless steel dynamic seal joint (0.06microns to 1.47microns surface finish) with oil lubricant contact at the joint.	The plot of the Seal Compression V/S Friction Torque and the Seal Compression V/S pressure drop is as shown in Figure 3. The pressure drop measured is found to stabilize.
Test case6:	Hard anodized aluminium and passivated stainless steel dynamic seal joint (0.6microns to 1.47microns surface finish) with oil lubricant contact at the joint.	The plot of the Seal Compression V/S Friction Torque and the Seal Compression V/S pressure drop is as shown in Figure 4. The pressure drop measured is found to stabilize.
Test case7:	Hard anodized aluminium and passivated stainless steel dynamic seal joint (0.6microns to 1.47microns surface finish) with aerograde grease contact at the joint.	The plot of the Seal Compression V/S Friction Torque and the Seal Compression V/S pressure drop is as shown in Figure 5. The pressure drop is not measurable and is found to stabilize.

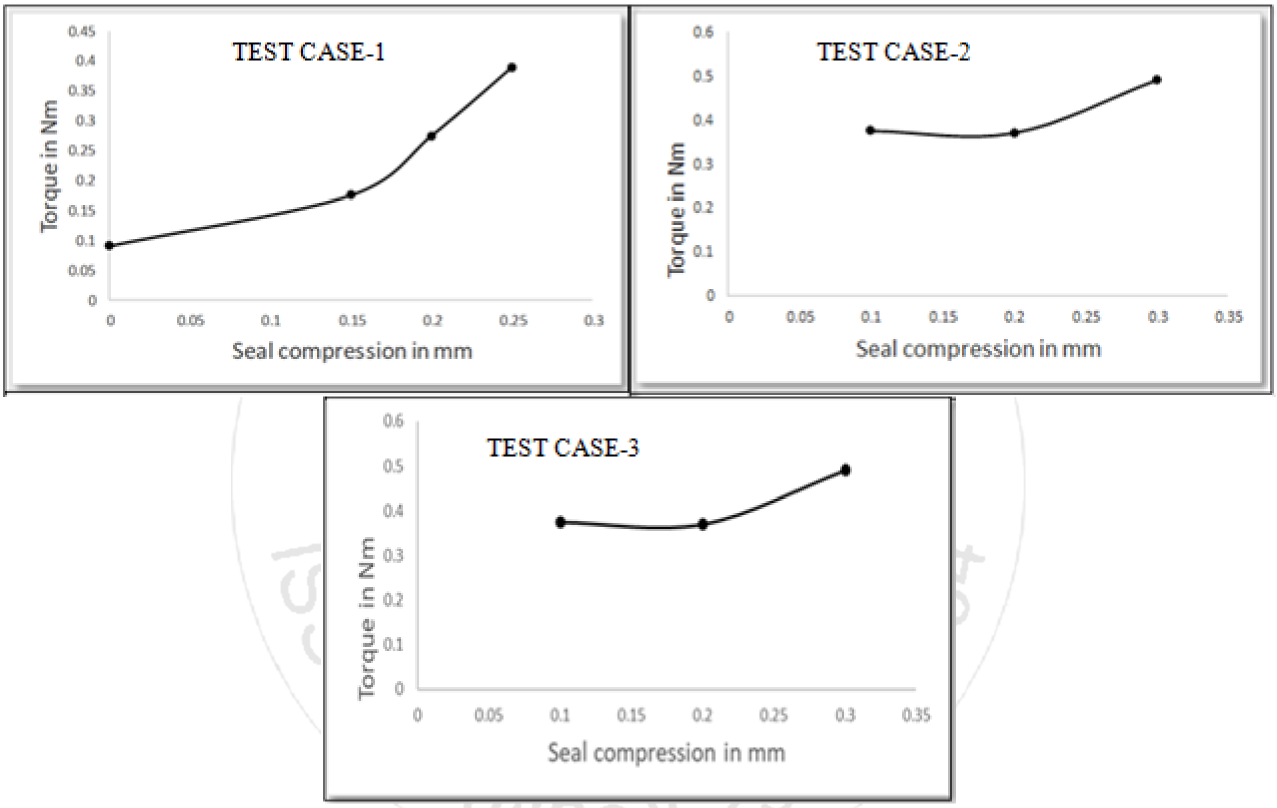

Figure 1: Seal compression V/S Friction Torque for Test case1, Test case 2 and Test case 3

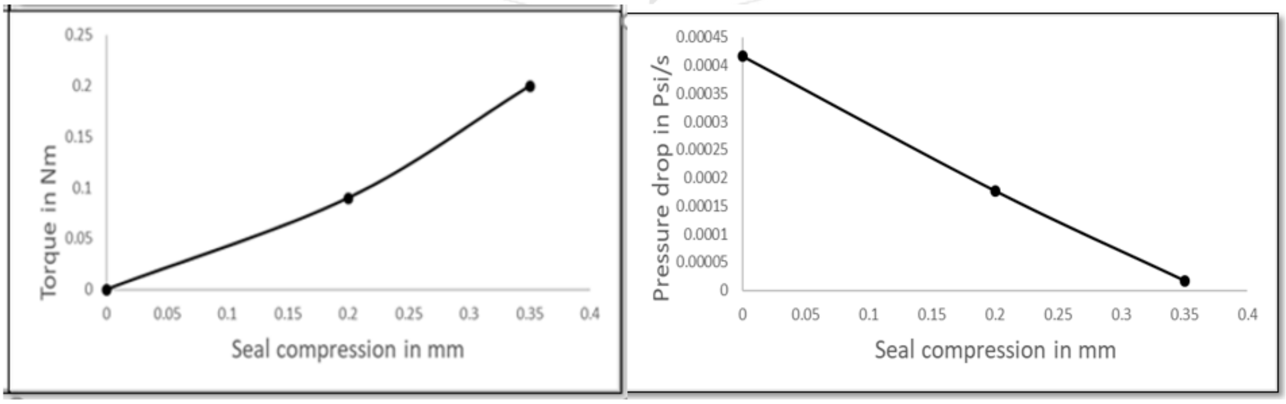

Figure 2: Seal compression V/S Friction Torque and Seal Compression V/S pressure drop for Test case4

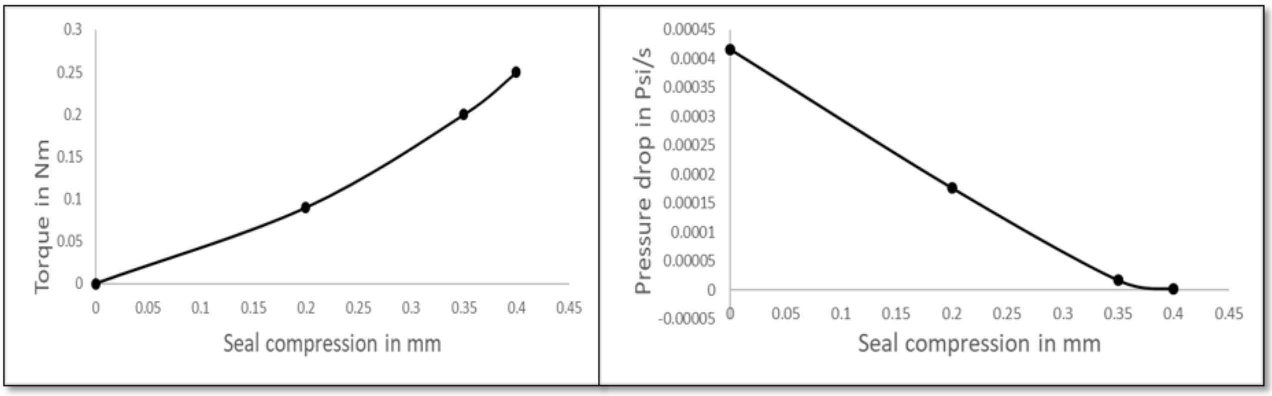

Figure 3: Seal compression V/S Friction Torque and Seal Compression V/S pressure drop for Test case5

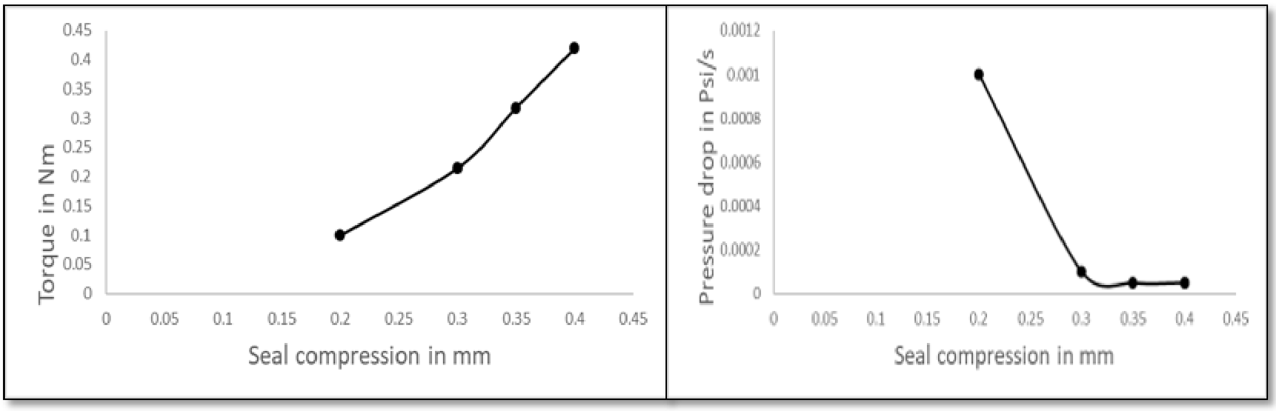

Figure 4: Seal compression V/S Friction Torque and Seal Compression V/S pressure drop for Test case6

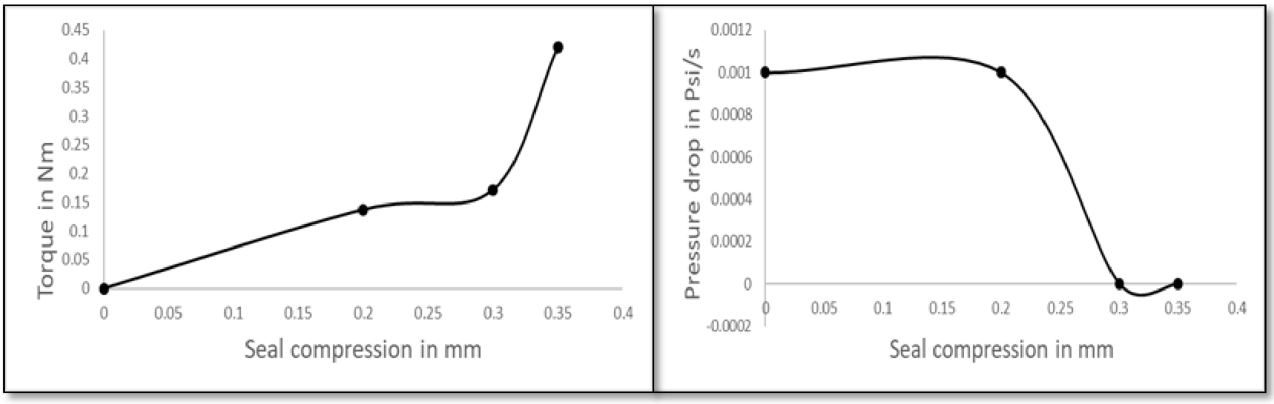

Figure 5: Seal compression V/S Friction Torque and Seal Compression V/S pressure drop for Test case7

The test case 7 gave very promising characteristic for the joint and this configuration was further tested at the operating temperature limits of -40°C and +55°C. The test outcomes are consolidated in table 1.

Table 1: Characteristic of the dynamic seal in the operating temperature range

Temp	Sense of rotation (CW/CCW)	Motor Voltage(V)	Motor current(A)	Friction Torque (Nm)	Pressure (Psi)	Measured pressure drop
Ambient	CCW	4.1	0.76	0.3Nm	4.2415	--
	CW	4	0.7	0.32Nm	3.3712	--
-40°C	CCW	5.7	2	0.9Nm	0.863	--
	CW	5.6	2	0.9Nm	0.863	--
55°C	CCW	5.6	0.7	0.3Nm	4.2415	--
	CW	5.6	0.6	0.27Nm	4.2415	--

3. Conclusions

The test set-up configuration proved to be a good approach to arrive at an optimum configuration of the dynamic joint. As the seal compression was increased, the friction torque also increased, but it was found that the leakage rate reduced and stabilized at a gap and further increase in seal compression is not required. The approach of identifying the characteristic effect of joint parameters helped in characterizing the system and identifying the best possible solution.