SEPTA41 EV – A FULLY INTEGRATED SOLAR ARRAY DRIVE MECHANISM

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ABSTRACT

The SEPTA41 Ev is used to drive the Solar Array and to transmit power and signals to and from the satellite. It is the smallest Solar Array Drive Assembly (SADA) of the mechanisms family manufactured by Oerlikon Space AG (OSZ). It is composed of:

- a Solar Array Drive Electronics (SADE) which commands the rotation of the SEPTA41
- a Solar Array Drive Mechanism (SADM) which supports the Solar Array and allows it to rotate at command

Because of its highly compact design, it is well-suited for micro-satellites (i.e. in the 100kg class range), and there are already SEPTA41 flight models currently being used on micro-SAT platforms developed by CNES, such as DEMETER and PARASOL.

A new enhanced version of the first models, called SEPTA41 Evolution, is currently under qualification and will be used for CNES PICARD Satellite, as well as by THALES ALENIA SPACE France's.

This qualification is performed by Oerlikon Space AG and is the final step concluding the transfer initiated in 2006 after CDR of all SEPTA41 activities originally performed by SNECMA and now performed by OSZ.

This paper presents mechanism performances with a specific focus on the torque margin, the lesson learned and the design changes of the second version of this particular SADA labelled SEPTA 41 Evolution.

1. INTRODUCTION

The SEPTA 41 Ev mechanism includes highly integrated control electronic design with commercial on the shelf parts (COTS). This approach allows having a mechanism that is successfully qualified for space application with an important cost reduction. This advantage, combined with the miniaturisation effort and an optimisation process that will be finalised within the "Evolution" activity allows Oerlikon Space AG to provide an attractive compact and efficient SADA suitable for a large variety of micro satellites.

The challenging approach of the 1.5 kg SADA was related to compact design. Mass and volume reductions were achieved by selecting a direct drive concept.

Therefore, torque margin becomes a challenging issue which was carefully analysed. Friction characterisation of all sub-system was achieved and in particular the aspect related to thermal gradient was studied. Analyses showed that the SEPTA41 design offers sufficient torque margins under the operational conditions, including specific thermal environment under which sufficient torque is achieved by activating a boost mode if needed. This boost mode was implemented in order to power both the main and redundant wiring of the stepper motor and thus double the available torque, with the SEPTA41 overall design unchanged. The analyses of the tests results foreseen during the qualification for SEPTA41 Evolution will complete and confirm the torque margin investigation.

Figure 1. SEPTA 41 Evolution qualification model

2. DEVELOPMENT LOGIC

- The SEPTA®41-E index 001 has been developed for the Microsat / Myriade platform family.
- The SEPTA®41-E index 001 has been fully qualified under the Demeter and Parasol development programme.
- The proposed SADA for Picard & Spirale is an evolution of the SEPTA®41-E index 001 that takes into account previous flight model experience (Demeter, Parasol).

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- The only following modifications to the SEPTA®41-E index 001 are included:
  - Change of electronics board
  - Tolerance improvement on the SRA
  - Improved lubrication in bearing
- Qualification to validate above changes performed on a QM Model
- First flight unit with modification (SEPTA®41-E index 002) is for PICARD

3. MECHANISM DESIGN

3.1. Overall Design of SADM

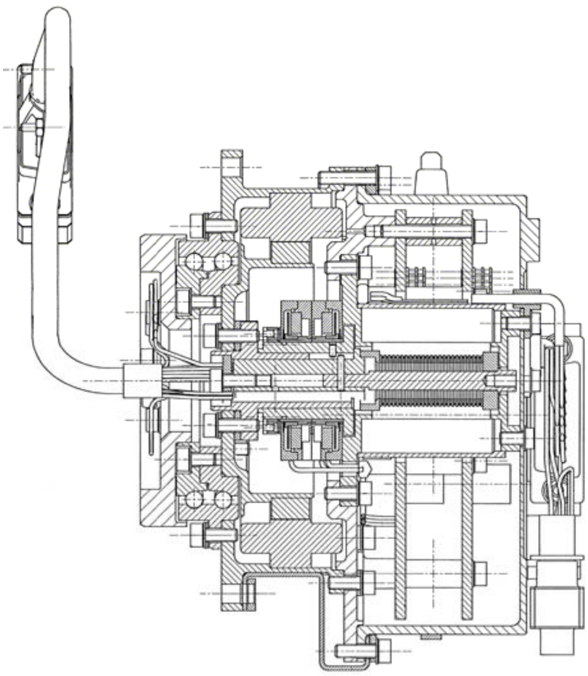

Figure 4. SEPTA41 Ev cut view

The SEPTA® 41 mechanism comprises:

One stepper motor with 360 steps for one revolution. This motor is manufactured with main and redundant coils which have a high impedance of 285 Ω. Under 28 Volts and room temperature this motor can provide a torque of 0.29 Nm. Main and redundant coils can be powered in the same time (depending on the SADA thermal conditions) in the so called "boost mode".
This motor is the same as the SEPTA® 31 one and is qualified through the SEPTA® 31 qualification campaign. This motor has been selected for PROTEUS program.

One pair of hard-preloaded bearing lubricated by Fomblin Z25 and preloaded in a "O" configuration.

Two potentiometers (main and redundant) with the same technology than the SARA® 21 Actuator (plastic film). The accuracy of this potentiometer is ± 0.5° when the position is calculated by comparison of the output voltage to the input voltage. The impedance of this potentiometer is 10 kΩ. The position measurement is given on a 357° angular range minimum and remains undetermined on a 3° range (i.e. dead zone).

A slip ring assembly mounted on the motor shaft. The slip ring allows power and signal transfers lines with a maximum of 825W (max. 1.5A per lines at 50 V).

Two electronic cards (main and redundant) can be interfaced to the on board computer via a RS-422 line and provide positioning control and monitoring of the mechanism. The synchronous motor command is achieved with 64 microsteps per degree that allow smooth motion and fine relative positioning.

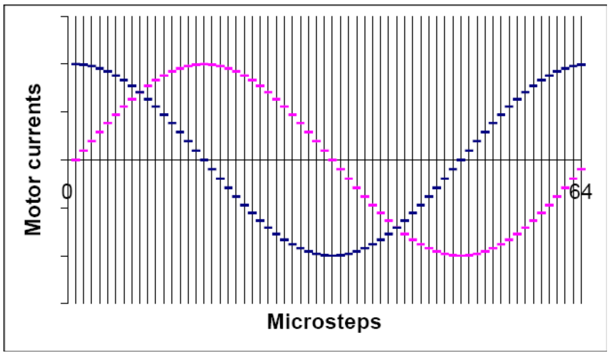

Figure 3. generation of motor current in synchronous mode

Additional capability like a 2/3 current mode were implemented in order to optimise the power consumption under nominal condition.

3.2. Design and Integration of the Electronic

The integrated electronic comprises two PCBs on which are placed a main and a redundant circuit (one for each PCB). These two PCBs are integrated at the rear end of the mechanism.

Each circuit comprises:
- A power supply circuit connected on the primary power bus through an EMC filter.
- A microcontroller which controls all the functions of the SADE
- A dedicated circuit driven by the microcontroller in order to command the motor which switches the motor coils current (taking into account rotation sense speed and mode telecommands).
- A RS 422 interface circuit between the On Board Computer (OBC) and the SADE. This circuit

insures a galvanic insulation with the platform. This interface allows the transmission of motor command orders from the platform to the SADE and the transmission of position serial telemetry from the SADE to the platform, through a serial asynchronous and full duplex link.
- A digitized position telemetry circuit which converts the analogue position measurement signal provided by the potentiometer to a serial digital word telemetry.
- Specific protection circuits (latch up protections, watchdog inside microcontroller).

All the electronic components are compatible with a cumulated dose of more than 15 K rads.

One of the main challenges due to the compactness of the design is to integrate and connect the electronic card to the main components.

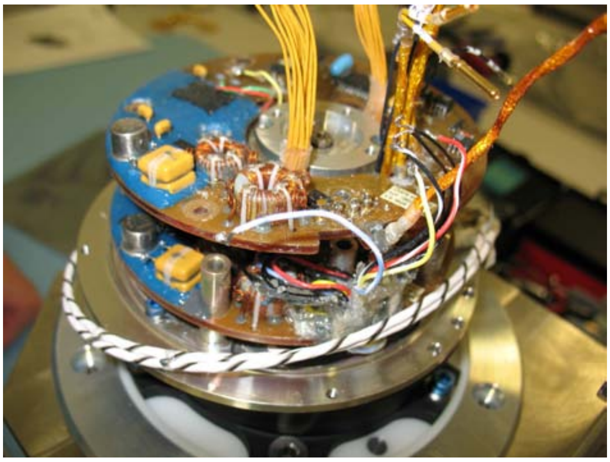

Figure 3. Integration of the Electronic cards

The thermal aspect is one of the most important issues that need to be carefully assessed because of the utilisation of commercial components and because it defines in effect the mechanism output torque. Based on the thermal analysis, thermal drains (see Figure 1) were added in order to optimise the thermal dissipation and reduce the thermal gradient within the mechanism.

4. PERFORMANCES CHARACTERISTICS

4.1. Test Bench

A clean room class 100’000 with thermal vacuum chamber are dedicated to SEPTA assembly and testing. It is original Oerlikon Space equipment combined with SNECMA acquisition / piloting equipment (hardware and software). The complete SEPTA 41 Ev test bench has been validated prior to qualification campaign.

4.2. Performances

The qualification test campaign is still on going so that only the results available at the time of writing this paper are presented and mainly focus on the motorisation margin that is the most important characteristic for this direct drive SEPTA.

The motorisation margin is estimated based on the minimal current necessary to perform a full revolution without losing steps. Then a comparison with the nominal current is achieved that defined the motorisation margin.

Based on previous SEPTA41 definition tests, such as PFM and FM models tested at SNECMA, the expected value was around 24 mA, approximately one third of the maximum current. The measured start-up current values for SEPTA41 Ev QM was consistent with this expectation and in line with the measurement performed at component level. Therefore, without a thermal gradient within the ball bearing, the motorisation margin is acceptable for all mission phases. No modification of this margin was detected after vibration, shock and combined load tests.

The second point is a direct measurement of the motorisation torque capability that was performed with the nominal current. The mean value is 0.20 Nm and the resistive torque was measured to be 0.05 Nm that is coherent with the motor torque capability before integration.

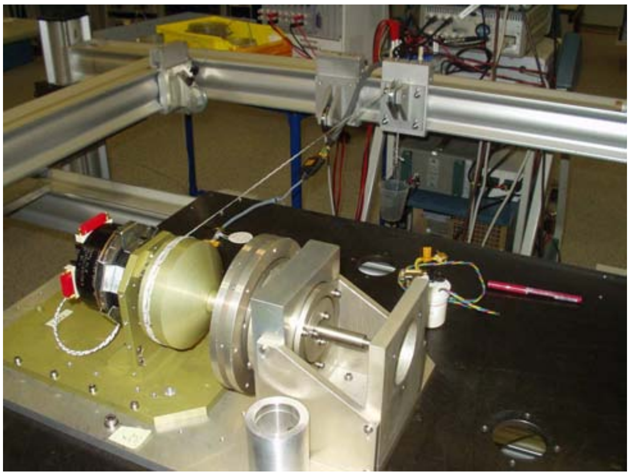

Figure 3. Test bench for motorisation torque measurement

5. LESSON LEARNED

Using the approach of COTS electronic components was successfully demonstrated during the previous evolution of the SEPTA41. However, the procurements and the acceptance of such components are not trivial and were achieved with an active support of the CNES.

The engineering and expertise effort necessary to handle commercial components have a cost that makes questionable the real gain when using such items. Only once qualified, this strategy is advantageous for reducing the recurring cost of the Flight Models.

The miniaturisation of the SEPTA41 does not allow integrating a reduction stage between the motor and the output. This direct drive mode calls for a careful selection of all subsystems having an influence on the motion resistance. Such strategy required a more detailed tribological and thermal analysis as normally required. Specific tests at component level must also be envisaged.

The study performed for the use of a “boost mode” demonstrates that such mode may be relevant under cold conditions, and if used under hot thermal conditions, it can be used only within certain boundary conditions.

6. CONCLUSION

The SEPTA41 Ev is the smallest Solar Array Drive Assembly (SADA) of the mechanisms family manufactured by Oerlikon Space AG (OSZ). Electronic card design and the overall miniaturization efforts make this compact mechanism attractive for small satellite platforms.

The previous version qualified and delivery by SNECMA is flying on Demeter, Parasol. Using this flight heritage, improvement were implemented and a new qualification and acceptance campaign is undergoing at Oerlikon Space in order to deliver the first new flight model for Myriade configuration.