Indian National Society for Aerospace and Related Mechanisms
Bangalore Chapter

E Newsletter

Vol 6, No. 1 Feb-May 2014

From the Editor

Dear Member,

It gives me great pleasure to present you with this edition of our E-newsletter. The first half of this year was very significant for the members of Spacecraft Mechanisms Group (SMG) at ISAC. The SMG team witnessed on-orbit deployment of solar array and reflectors onboard GSAT 14 spacecraft and solar panel deployment of IRNSS-1B spacecraft, summing up to six on-orbit deployments during the first half of the year 2014. All these mechanisms developed by SMG have worked flawlessly in orbit. The editorial committee congratulates the past and present members of Spacecraft Mechanisms Group, ISAC for this excellent achievement.

The article titled "Motor selection for Spacecraft Mechanisms" presents a systematic approach towards selection of motors for the spacecraft mechanisms. It highlights the comparison of parameters amongst the three prominently used motors in space industry for deployment and steering of payloads.

E news letter is putting best possible efforts to showcase the talents and achievements of INSARM members. In this regard I am happy to inform that the paper titled *"Mobility Performance Analysis of a Six Wheeled Rover using SMART"* written by our INSARM members Sri. Gaurav Sharma, Sri. Abhishek Kumar, H.N. Suresha kumar, Sri N. Viswanatha, Smt. G. Srividhya and Sri. G. Nagesh was selected and presented during Satellite Technology Day-2014 held at ISRO Satellite Centre on 13th May 2014. The editorial committee congratulates for their achievement.

I am happy to inform that INSARM Bangalore Chapter had initiated an award in this year to encourage the young talents interest in science. This edition presents the details of the award winning student.

This news letter is intended to be a platform for the exchange of information regarding the current developments, new ideas and novel concepts in the area of mechanisms and related field through active participation of members. I request all INSARM members to actively contribute technical articles related to mechanisms to enhance the technical value of the e-new letter.

With best regards,

Dr. B.P. Nagaraj

Chief Editor

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Quote:

"Innovation comes only from readily and seamlessly sharing information rather than hoarding it."

By Tom Peters

FROM INSARM BANGALORE CHAPTER

MOTOR SELECTION FOR SPACECRAFT MECHANISMS

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1.0 Introduction

Motors are generally electromechanical devices which use electro-magnetic forces to provide torque/force and generate rotation/linear motion. This technology has been in existence ever since the early 1880s where motors used copper brushes of various configurations riding on copper commutator [1]. The winding of copper wires and making use of brushes led to the invention of the first type of brush machines. The early machines were not actually motors, they were rather generators. Very soon the technology was adopted for obtaining rotary motion using electric power and this was called as the motor.

Motors have found their place in spacecraft mechanisms from the very beginning. All the mechanisms which require continuous rotation or intermittent rotations or to and fro motion invariably require motors. However, the need for the use of motors for deployment mechanism has to be understood based on several factors. The requirement of a particular type of motor for the mechanisms is very specific to the particular project and should be dealt case by case rather than generalizing. An approach can be adopted for the choice of motor but strict adherence of the same might not be possible in many cases. Motor selection in many cases is dictated based on the heritage. In such cases even though a particular motor may result in slight over-designing of the system, still the reliability factor associated due to the heritage of usage acts as the governing factor.

2.0 Motorised actuator Vs Spring based Actuator for deployment mechanisms

The deployment mechanisms can be designed using spring based actuators as well as motor based actuators. Thus, the requirement of the type of actuator has to be understood considering all the advantages and disadvantages. Table 1 shows comparison between the springs based actuator and motor based actuators.

Sl No.	Description	Spring Based Actuator	Motorized Actuator
1.	Usage	Can be used for one time deployment only	Can be used for repeated movement and deployment of the mechanism
2.	Latch-up shock	Produces significant latch up shock at the end of deployment	Negligible latch up shock is produced at the end of deployment
3.	Power usage	It's a standalone type of actuator which does not require any electric power.	Electric power is essentially required for the operation.
4.	Thermal	Use of suitable material avoids the use of active temperature control devices	Active temperature control system is essentially required.
5.	Torque margin	Only limited torque margin can be provided to limit the latchup load.	High torque / variable margin can be provided.

Table 1: Comparison between spring based actuator and motorized actuator

3.0 Standard types of motors available

There are mainly three types of motors which are primarily used for spacecraft applications which are Brush DC motors, Brushless DC motors and Stepper motors. These motors are further sub categorized as shown below

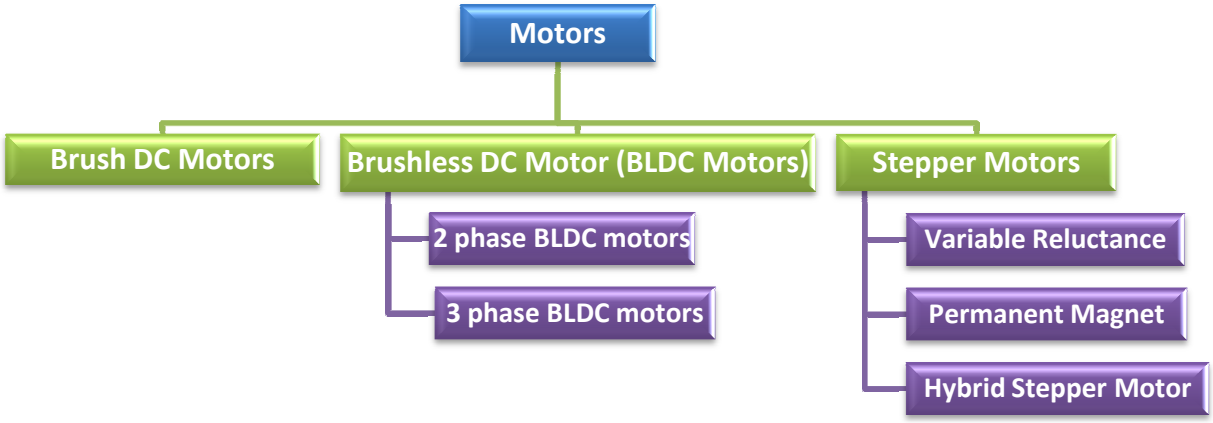

Chart 1: Various types of motors used in Spacecraft Mechanisms

Each type of motor has its own pros and cons which will be discussed and highlighted in further sections.

4.0 Motor selection based on application.

The following factors are considered which may lead to a judicial decision for the type of motor.

4.1. One time operation

There are several mechanisms which have to be operated only once. The general requirement of such types of mechanisms is the minimum latchup shock inducing deployment where a large drive torque is required. Since this is a onetime deployment mechanism thus use of Brush DC motor can be considered. However, several ground tests of the mechanism should not be left un-accounted. Brushes are also susceptible to arching and brush wear which becomes dominant in space due to the absence of atmospheric lubrication. Table 2 summarizes the advantages and disadvantages of three major types of motors

Sl No.	Description	Advantages	Disadvantages
1.	Brush DC Motor	• Simplest electronics • No feedback device required	• Susceptible to arching and dependant on brush reliability • Poor thermal coupling
2.	BLDC motors	• Contact-less commutation ensuring better efficiency.	• Complicated electronics but use of 3 phase motor will reduce the complexity
3.	Stepper motors	• Simple electronics compared to BLDC motors. • High Holding torque	• Operating speed should be low

Table 2: Advantages and disadvantages for one time operation of three major types of Motors

It can thus be seen that for highly reliable one time operations with slightly complicated electronics stepper motors turn out to be the suitable choice.

4.2. Repeated operation or continuous operation

Such type of mechanisms requires careful understanding of the mode of operation for proper selection of the motors. Brush motors are generally not considered keeping in mind the wearing of the brushes. However, for interplanetary activities where traces of atmosphere are present, in such places brush motors can still be used. Still brush motors are kept as the last choice for repeated and continuous motions. If accurate positioning is not of prime concern to be derived from the motor directly then the following points can be considered for selection between BLDC and Stepper motor. Table 3 presents the merits and demerits of different types of motors.

Sl No.	Description	Advantages	Disadvantages
1.	Brush DC Motor	• Simple motors at low cost	• Short motor life • Low efficiency & limited speed • Large Mechanical noise • Poor thermal characteristics in vacuum • DC motors have low detent torque
2.	BLDC motors	• Preferred for drives requiring frequent change in speed/torque • In the event of motor stalling, the feedback device can be used to know the condition. • Can be used for high torque at high speeds.	• Works in a closed loop mode thereby essentially requiring a position sensor. • DC motors have low detent torque.
3.	Stepper motors	• Preferred for drives requiring constant torque/speed applications. • Works on open loop principle, number of steps can be used to determine the motor shaft position. • No accumulative position errors	• In the event of motor stalling and additional feedback device is required. • Requires low speed operation • Steppers motors have higher detent torque. • Step motion may induce disturbance on spacecraft.

Table 3: Advantages and disadvantages for repeated or continuous operation of three major types of Motors [2]

Thus, it can be seen that there is no clear solution which indicates which type of motor to be used for continuous motion drives. However, the first point itself specifies the type of operations required. BLDC motors are preferred when torque and speed conditions are variable and BLDC motors are generally used for high speed applications. Stepper motors have to be carefully chosen based on the type of torque disturbance on spacecraft and operations required and these are helpful if torque and speed conditions are known.

5.0 Design parameters of the motor

Keeping application of the mechanism in mind there are several design parameters which have to be considered for proper motor selection. These are presented in Table 4

Motor design parameters	
1. Operating speed	2. Operational torque
3. No load speed	4. Stall torque
5. Power requirement	6. Heat dissipation
7. Environment of application	8. Number of rotations
9. Weight	10. Volume
11. Torque ripple	12. Controllability

Table 4: Motor design parameters in the order of priority for Spacecraft mechanism applications

The continuous torque rating of the motor should be higher than the operating torque with a margin of 1 to 3. Parameters like torque constants (mNm/A), speed constants (rpm/V), resistance (Ω), inductance (mH), motor constant (Nm/$\sqrt{\omega}$), rotor inertia (gm-cm^2) are very important to describe the motor behaviour over its extreme working range. Mechanical design of the motor becomes very important in view of vacuum and extreme temperature conditions of space and vibration conditions during launch. Bearings, lubrications and mounting interfaces should be carefully seen before selecting a motor for aerospace application. Most often, motors are used with a gear drive to enhance torque as only motor cannot impart the required torque. Making use of direct drive through a motor without using a gear head will make the motor bulky which is an unwanted consequence.

6.0 Type of motors used for already flown Spacecraft Mechanisms in India

Spacecraft Mechanisms Group in ISAC developed the first motorized drive for Sail boom mechanism in the year 1992. Since then there have been several advances in the technologies and several mechanisms have used motors till date as the prime mover which has been illustrated in Table 5. Space grade motors were procured from external agencies and were subsequently qualified for space applications.

Sl No.	Mechanism	Satellite	Motors	Motor Torque
1.	Sail-boom	INSAT 2 series & MTSat-2	Brush DC Motor	0.28Nm
2.	OCM Tilt	IRS P4 & OCENASAT 2	Stepper Motor (VSSC)	0.25Nm
3.	Antenna Pointing Mechanism	GSAT 1	Stepper Motor	0.4Nm
4.	SOXS Sun Tracking Mechanism	GSAT 2	Stepper Motor	0.4Nm

Sl No.	Mechanism	Satellite	Motors	Motor Torque
5.	DGA	CARTOSAT 2 Series & Chandrayaan 1	Brushless DC Motor	0.63Nm
6.	UHF Antenna Deployment	GSAT 7	Stepper Motor	0.077Nm
7.	Solar Panel Drive	Mars Orbiter Mission	Stepper Motor	0.4Nm

Table 5: Consolidated details of Mechanisms and related Motors flown

Amongst the above mentioned mechanisms, Sail Boom and UHF Antenna Mechanism required motor for one time deployment whereas in all the other mechanisms repeated operation has been done.

7.0 Conclusion

This article highlights the various parameters which justify the need of motorised drives and enables the mechanism designer to make a conscious decision for the use of the same. Based on the technologies three types of motors are used in spacecraft mechanisms which are Brush DC motors, Brushless DC motors and Stepper motors. The sub categories of these motors have also been depicted in the article. Each type of motor has a set of advantages and disadvantages and thereby the choice of a particular type of motor has to be dealt case by case, but this choice of motor can also be governed by heritage of usage. The design parameters mentioned in the article have been arranged in the order of priority based on which the appropriate choice of motor can be made. Motors in spacecraft mechanisms have been used for one time operation as well as for repeated operations.

References

1. Edited by peter L Conley " Space Vehicle Mechanisms: Elements of Successful Design", John Wiley & Sons, Inc. 1998
2. NASA preferred reliability practices, Practice No. PD-ED-1229, "Selection of Electric Motors for aerospace applications"

INSARM AWARD FOR BEST SCIENTIFIC TEMPER

INSARM Bangalore Chapter has conferred an award for the "*Best Scientific temper*" at the National Science Day Celebrations 2014 in ISAC, Bangalore on 28th February 2014. Cash Prize of Rs 1500/- was awarded to the student named *Miss Jasmine Jerry*, 9th Standard from Kendriya Vidyalaya, DRDO, C.V.Ramaannagar, Bangalore, who had secured highest marks in the quiz named "Test of Scientific Temper"

FORTH COMING SEMINARS

1. 3rd International Conference on Mechanical Engineering and Mechatronics (ICMEM '14)
   August: 14 -15 2014, Prague, Czech Republic
2. ASME 2014, International Mechanical Engineering Congress & Exposition
   November 14 – 20 2014, Montreal Canada
   Webpage: www.asmeconferences.org/congress2014/
   Paper Submission date: July 28, 2014
3. 2015 IEEE Aerospace Conference,
   March 7-14, 2015, Bigsky, Montana, USA

INVITATION FOR ACTIVE PARTICIPATION

We invite you to send technology news, technical articles, members' news and ;suggestions/comments on e-newsletter and the web contents to Chief Editor to improve the newsletter. The technical articles may be limited to 400 words only in MS Word format with two photographs. The direct extracts from references may be avoided. Kindly provide your e-mail & mail address to enable us to contact you.

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