XVI – COLÓQUIO BRASILEIRO DINÂMICO ORBITAL

Spin-stabilized Satellite and Solar Radiation Torque: Spin Axis Angular Deviation and Solar Aspect Angle

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Jules Henri Poincaré
(1854 – 1912)

Abstract

The aim of this paper is to present an analytical solution for the rotational motion equation of the spin-stabilized satellite, considering the influence of *direct solar radiation pressure torque* (TPRS).

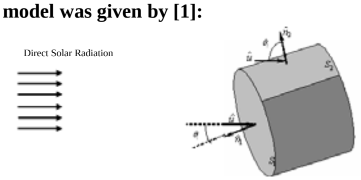
The theory uses a cylindrical satellite on a circular orbits model [1] and consider that the satellite is always illuminated. The average components of TPRS are determined in a orbital period. An analytical solution are gotten when these components are substituted in the rotational motion equations [3] and then the temporal behavior of the solar aspect angle and the spin axis angular deviation are determined.

These solutions are numerically implemented and compared with real data of the Brazilian Satellite Data Collection – SCD1 and SCD2.

The results show that the theory has consistency and it can be applied to preview the rotational motion of spin-stabilized artificial satellites.

Introdution

The TPRS model was given by [1]:



$$N_x = -\frac{\overline{K}}{R^4}(\beta_1\gamma_1 - \beta_2\gamma_2)\frac{h}{2}\pi\sigma^2 u_z^*\left(u_y^*\cos(\theta) + u_x^* sen(\theta)\right)$$

$$N_y = -\frac{\overline{K}}{R^4}(\beta_1\gamma_1 - \beta_2\gamma_2)\frac{h}{2}\pi\sigma^2 u_z^*\left(u_y^*\operatorname{sen}(\theta) - u_x^* cos(\theta)\right)$$

$$N_z = 0$$

The motion equations are given in terms of the spin velocity, right ascension and declination of the spin axis and were developed by [3]:

$$\frac{dW}{dt} = \frac{N_{zm}}{I_z} \qquad \frac{d\alpha}{dt} = \frac{N_{xm}}{I_z W\cos\delta} \qquad \frac{d\delta}{dt} = \frac{N_{ym}}{I_z W}$$

Development

The average components of TPRS are obtained by using:

$$\vec{N}_m = \frac{1}{T}\int_0^{2\pi} \vec{N}\ \frac{{r_c}^2}{h_t}\, d\varpi$$

with each component given by:

$$N_{xm} = B_c\left(GC_a + \frac{GC_b}{2}\right) \qquad N_{ym} = B_c\left(GC_c + \frac{GC_d}{2}\right)$$

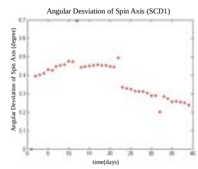
$$N_{zm} = 0$$

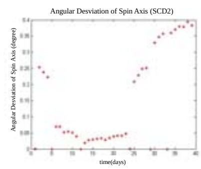
Using these components on the rotational motion equations and after the integration:

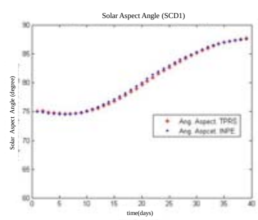
$$W = W_0 \qquad \delta = \frac{N_{ym}}{I_Z W_0} t + \delta_0$$

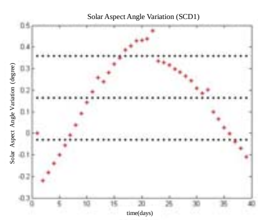
$$\alpha = \frac{N_{xm}}{N_{ym}}\ ln\left[\frac{sec\left(\frac{N_{ym}}{I_z W_0}t + \delta_0\right) + tan\left(\frac{N_{ym}}{I_z W_0}t + \delta_0\right)}{sec(\delta_0) + tan(\delta_0)}\right] + \alpha_0$$

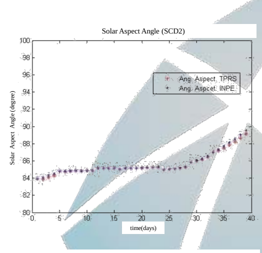
Results











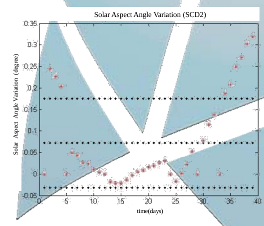


Table 1: Solar aspect angle variation between real data and calculated data($\Delta\chi$) and the spin axis angular deviation (η) of the SCD1 and SCD2.

	SCD1			SCD2	
	Δχ (°)	η (°)		Δχ (°)	η (°)
24/07/1993	0,000000	0,000000	**01/02/2002**	0,000000	0,000001
25/07/1993	-0,219121	0,396782	**02/02/2002**	0,244261	0,253318
26/07/1993	-0,182006	0,401403	**03/02/2002**	0,226381	0,238182
27/07/1993	-0,140433	0,409896	**04/02/2002**	0,203366	0,222357
28/07/1993	-0,100767	0,431807	**05/02/2002**	0,000000	0,000000
29/07/1993	-0,055499	0,426984	**06/02/2002**	0,049929	0,069401
30/07/1993	-0,008830	0,447622	**07/02/2002**	0,043944	0,069730
31/07/1993	0,037597	0,452605	**08/02/2002**	0,026305	0,052174
01/08/1993	0,092766	0,457268	**09/02/2002**	0,024166	0,054289
02/08/1993	0,142886	0,476206	**10/02/2002**	0,010747	0,050426
03/08/1993	0,193069	0,472875	**11/02/2002**	0,004796	0,038757
04/08/1993	0,258171	0,693971	**12/02/2002**	0,000000	0,000000
05/08/1993	0,239843	0,443828	**13/02/2002**	-0,017561	0,019553
06/08/1993	0,280709	0,446840	**14/02/2002**	-0,021891	0,027776
07/08/1993	0,321956	0,450361	**15/02/2002**	-0,021458	0,029886
08/08/1993	0,348531	0,454116	**16/02/2002**	-0,013259	0,031921
09/08/1993	0,387660	0,458011	**17/02/2002**	-0,003102	0,032764
10/08/1993	0,404214	0,454125	**18/02/2002**	0,005111	0,028291
11/08/1993	0,428726	0,453853	**19/02/2002**	0,009430	0,034869
12/08/1993	0,431185	0,448073	**20/02/2002**	0,015643	0,039305
13/08/1993	0,438593	0,444214	**21/02/2002**	0,019749	0,041773
14/08/1993	0,476325	0,495032	**22/02/2002**	0,026972	0,041278
15/08/1993	0,335323	0,335372	**23/02/2002**	0,031587	0,046940
16/08/1993	0,327017	0,329195	**24/02/2002**	0,000000	0,000001
17/08/1993	0,316243	0,324490	**25/02/2002**	-0,016776	0,208289
18/08/1993	0,296526	0,314175	**26/02/2002**	0,001880	0,229033
19/08/1993	0,284748	0,312725	**27/02/2002**	0,023062	0,247966
20/08/1993	0,265783	0,311427	**28/02/2002**	0,052705	0,250396
21/08/1993	0,243958	0,304947	**01/03/2002**	0,000000	0,000000
22/08/1993	0,209535	0,289846	**02/03/2002**	0,077917	0,329509
23/08/1993	0,185663	0,289468	**03/03/2002**	0,115437	0,346923
24/08/1993	0,201813	0,201814	**04/03/2002**	0,137942	0,356886
25/08/1993	0,099903	0,285354	**05/03/2002**	0,000000	0,000000
26/08/1993	0,065506	0,273284	**06/03/2002**	0,186505	0,360037
27/08/1993	0,025348	0,256206	**07/03/2002**	0,207715	0,369876
28/08/1993	-0,002772	0,258994	**08/03/2002**	0,248599	0,379175
29/08/1993	-0,038138	0,254935	**09/03/2002**	0,271615	0,378687
30/08/1993	-0,068734	0,250393	**10/03/2002**	0,302979	0,393056
31/08/1993	-0,108571	0,238139	**11/03/2002**	0,319340	0,383471
Média =	0,164480	0,370427		0,071642	0,145033
Desvio =	0,193859	0,116465		0,104017	0,146379

CONCLUSIONS

The simulations show a behavior on the SCD2 better than SCD1 because there is attitude control in SCD2 simulation period.

The theory can be applied to preview the spin motion of spin-stabilized artificial satellites using others significant torques.

The influence of TPRS is more important on bigger satellite with high altitude.

Acknowledgment: **This work had the support of CNPq.**

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