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SPACE VEHICLE STABILIZATION USING ANGULAR VELOCITY SENSORS SIGN AND GAS JETS ACTUATORS

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Abstract. *This paper presents the control system and its sub-systems of a Sub-Orbital Platform (PSO), which apply a new procedure to perform the spin reduction of the platform. The PSO control system is based on a hardware architecture composed of a gyrometric block, an on board computer and an hydrazine gas jet system. Four thrusters strategically placed across the vehicle longitudinal axis, which is not coincident with the mass centre, are used as actuators. The software implemented instead of working with the Platform angular velocities values, it has an algorithm that uses only the sign of the angular velocity. That strategy is applied because the gyros only measure rotation below 3,4rpm, and considering that in the beginning the rotation of the PSO is approximately 300rpm, that values therefore, is out of scale not being possible to be sensed by the gyros. The computer simulations showing the efficiency and the good performance of the control system proposed. are presented. Besides, the PSO control system hardware and software are discussed.*

1 INTRODUCTION

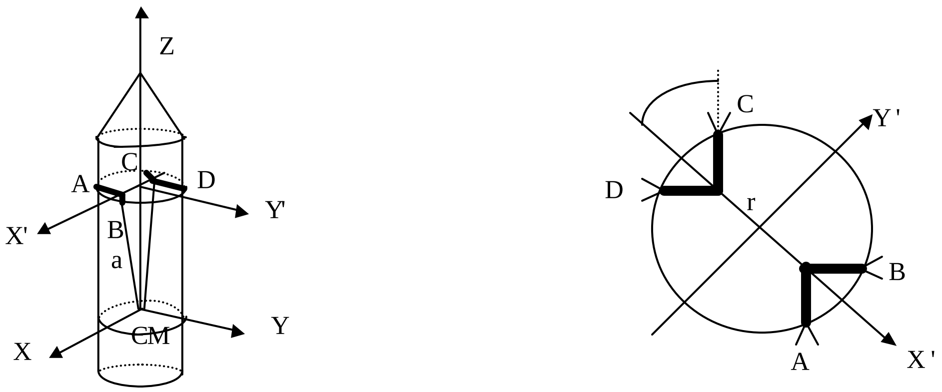
The Space Mechanics & Control Division (DMC) of the National Institute for Space Research (INPE) of Brazil has been involved in different space programs. The construction of Data Collection Satellites (SCD) was the first program. The SCD-1 stayed in orbit for four years, being replaced by the SCD-2 which still operational nowadays. The co-operation between Brazil and China has resulted in the construction and launch of the first China-Brazil Earth Resource Satellite (CBERS-1), the CBERS-2 is in the integration phase and it will be launched in a near future. A French-Brazilian micro satellite is the result of the co-operation between Brazil and France[1] . Brazil is also taking part in the construction of the International Space Station (ISS). A project called ROKVISS (Robotic Components Verification at The ISS) is an agreement of technical scientific co-operation between INPE and DLR and it has result in research in many different area such as dynamics and control of flexible space structure[2,3] ; and parameters identification and sensor failure detection applied to Space Robotic Joint[4] .

A more recent space mission of INPE/DMC is to build a Sub-Orbital Platform[5] . The PSO objective mission is to test some hardware and software equipment developed by the National Institute for Space Research and some Brazilian Industries in order to provide conditions to perform micro-gravity experiments. The PSO has a cylinder shape with 2.7m long and a diameter of 0.3m. It will be put in a 300Km of altitude parabolic flight orbit by a SONDA III rocket launched from the Barreira do Inferno Launch Centre located in Natal city at North of Brazil.

This paper presents the control system and its sub-systems of a Sub-Orbital Platform (PSO), which apply a new procedure to perform the spin reduction of the platform. The PSO control system is based on a hardware architecture composed of a gyrometric block, an on board computer and a hydrazine gas jet system. The Platform design and control logic, which is based on four thrusters strategically placed across the vehicle longitudinal axis, which is not coincident with the mass centre and are used as actuators is presented in section 2. The gyroscope sub-system software implemented instead of working with the Platform angular velocities values, it has an algorithm that uses only the sign of the angular velocity is presented in section 3. That strategy is applied because the gyros only measure rotation below 3,4rpm, and considering that in the beginning the rotation of the PSO is approximately 300rpm, that values therefore, is out of scale not being possible to be sensed by the gyros. The computer simulations showing the efficiency and the good performance of the control system proposed and the conclusion where the PSO control system hardware and software are discussed are presented in section 4.

2 PLATFORM DESIGN AND CONTROL LOGIC

The inferior part of the PSO has a cylinder shape and the superior part has a cone shape. The angular velocity reduction is performed by four thrusters A, B, C, and D, which are assembled in a transversal section of the vehicle located in a distance a from the mass center (MC). The thrusters are inclined of a angle α with respect to the axes X´ and Y´ of the co-ordinate system XYZ, where r is the distance from the thrusters position to the longitudinal axis Z, see Figures 1 and 2.



Figures 1 and 2 – Thrusters location with respect to the MC and the transversal section.

The forces generated by the four thrusters at the beginning of the firing are nominally equal to 2 Newton. They vary slowly during the time due to the pressurization of the nitrogen fuel tank, which has the pressure of 22 atmospheres. Considering that the distance d and d´ have components d = ri + ak and d`= -ri+ak , respectively in the direction x and z, the components of the torques Tj = dxFj , where j=A,B,C and D, are given by Table 1.

Table 1 – Torques due to the thrusters A, B, C, and D.

Torques	X	Y	Z
T_A	$- F\ a\ s\alpha$	$- F\ a\ c\alpha$	$F\ r\ s\alpha$
T_B	$F\ a\ s\alpha$	$- F\ a\ c\alpha$	$- F\ r\ s\alpha$
T_C	$F\ a\ s\alpha$	$F\ a\ c\alpha$	$F\ r\ s\alpha$
T_D	$-F\ a\ s\alpha$	$F\ a\ c\alpha$	$- F\ r\ s\alpha$

Table 1 shows such that it is possible to generate torques about all the three axes simultaneous, even when only one thruster is switched on. The control strategy of switching on one or more thrusters is associated with the need to reduce the spin in short time or not. The control law implemented has the angular velocity as a feedback and the maximum torque is limited by the thruster force and by its location in the body of the vehicle. The control law is given by

$$U_n = -T_n \bullet \mathrm{sign}(W_n) \tag{1}$$

where n=x,y,z ; T is the torque due the thrusters combination (A,B,C,D) and the function sign gets just the signal of W.

The angular velocity used in the stabilization is read out by gyros, that signal is send to the onboard computer, following the control logic showed in the table 2. That logic must identify the thrusters to be turned on in order to generates torques to increase or decrease the angular velocity.

Table 2 – Control logic of thrusters' action

Angular Velocity	Torques	Thrusters
$w_x>0$	$-T_X$	A , D
$w_x<0$	$+T_X$	C , B
$w_y>0$	$-T_Y$	A , B
$w_y<0$	$+T_Y$	C , D
$w_z>0$	$-T_Z$	B , D
$w_z<0$	$+T_Z$	A , C

The control logic incorporates a dead band which magnitude is the limited by the thrusters' action. The dead band is function of two factors; the first one is due to the signal codification analog/digital used to discrete the gyro coming signal. The second one is associated with the smallest medium impulse provided by the thrusters. In the simulation performed the second case turn out to be more significant, as a result, it has established the dead band limit in the three axes.

3 GYROSCOPES SUB-SYSTEM

The angular velocity in the three axes are measured by a system composed by two gyroscopes forming a angle of 45º with Z axis of the platform (see Figure 3), where Wx1,Wy1 and Wx2, Wy2 are the measures of the components of the angular velocity in the gyroscopes reference system.

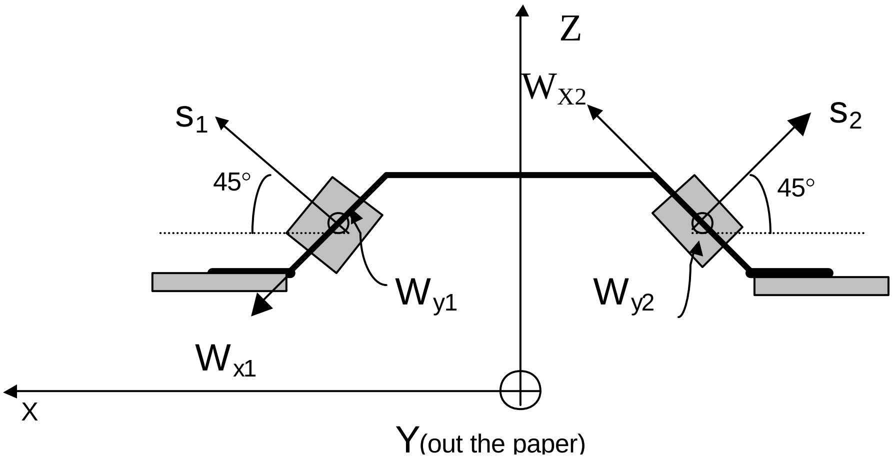


Figure 3- Gyroscope Sub-System Design

The transformation from the gyroscope system, presented in figure 3 to the platform system of figure 1 is done by the flowing set of equations

$$W_{XPSO} = (W_{X2} + W_{X1})\cos\beta\ /\sqrt{2}\ + (W_{Y1} + W_{Y2})\text{sen}\beta\ / 2$$

$$W_{YPSO} = -(W_{X2} + W_{X1})\text{sen}\beta\ /\sqrt{2}\ + (W_{Y1} + W_{Y2})\cos\beta\ / 2 \qquad (2)$$

$$W_{ZPSO}= (W_{X2} - W_{X1})\ /\sqrt{2}$$

where the angle β is due to the asembly of the gyroscope block inside of the platform.

4 SIMULATIONS RESULTS AND CONCLUSIONS

In order to verify the performance of the control system proposed, one simulates a worse case, trying to evaluate the robustness of the system and the viability of its application to the PSO. The data used are : WX = 18°/s, WY = 18°/s and WZ = 1440°/s with a dead zone of = 1°/s. The stabilisation time and the final residual accelerations obtained are, respectively, 300s and 10-5g. Two control strategies are simulated; in the first one, the angular velocity is reduced first in the axis Z, followed by the axes X and Y. In the second one, the reduction is performed in all three axes simultaneity. On the right hand side and left-hand side of Figures 4 to 9, the results of the first and second case are showed, respectively. The new logic for stabilisation of the PSO platform using only the three signs of the angular velocity has been tested and it works efficiently. The stabilisation time obtained is big because the initial rotation (WX and WY) used for the test were also big. However, for the real case where the initial rotation are about 0,2° /s the stabilisation time will be shorter.

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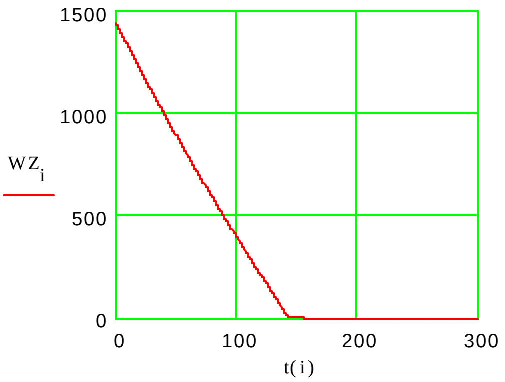

Fig.4 - WZ em graus/s

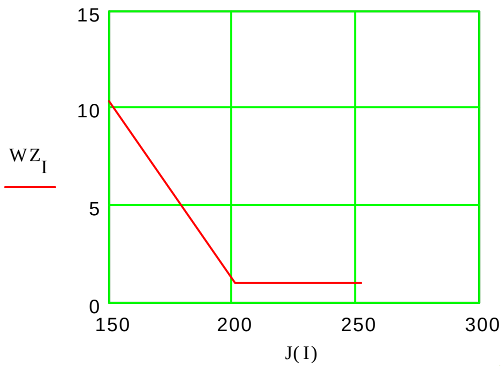

Fig.5 - WZ em graus/s

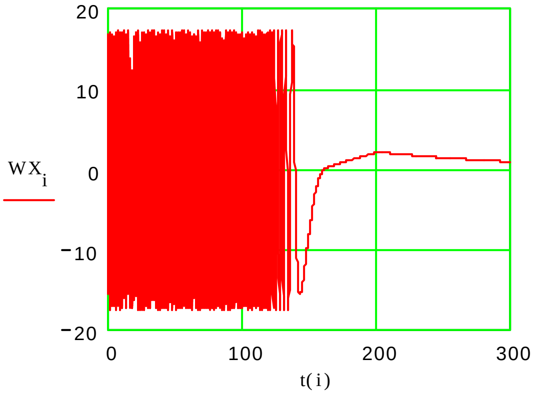

Fig.6- WX em graus/s

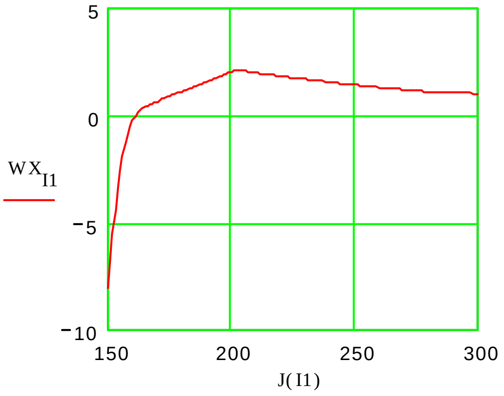

Fig.7- WX em graus/s

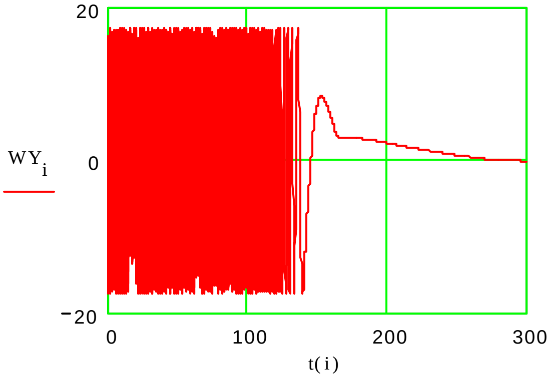

Fig.8 - WY em graus/s

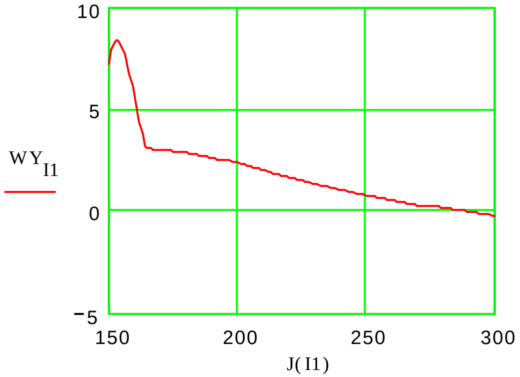

Fig.9- WY em graus/s