AE5545 – DYNAMICS AND CONTROL OF SPACECRAFT

Assignment No. 3 (100 points)

(Attitude Rigid Body Dynamics & Passive Stabilizations)

Due: 13 October 2017

03 October 2017

1. A rigid spacecraft at an orientation of ψ=5 deg, θ=10 deg and φ=-3 deg has a total mass M= 100 kg and an Inertia Matrix **I** = Kg. . The COM of the spacecraft is moving with 5 and the (3-2-1) Euler angle yaw, pitch and roll rates are , and . Find the total Kinetic energy of this rigid body. What is its Principal Moments of Inertia (through eigenvalue, eigenvectors and the transformation using MATLAB)? (Shaub and Junkins)
2. A spacecraft is comprised of 3 rigid bodies: a cylinder, a rod and a solar panel as shown in the figure given below(CD Hall):



The body frame shown is coinciding with the COM of the cylindrical body. is parallel to the symmetric axis of the spacecraft and is parallel to the rod. The cylinder has a diameter of 1m, height of 2 m and a mass density of 100 Kg/. The rod has a length of 2 m and a mass of 1 Kg. The panel has a length of 2m, width 0.5 m and the mass of 4 kg. The panel is rotated about axis by 87 deg at the instant of showing. Then

1. Find the mass centre of the system in as
2. Find the Moment of Inertia of the system about the mass centre of the composite spacecraft.
3. A spacecraft is launched into a low earth orbit whose moment of inertias are , , and . For stability the spacecraft was launched into with the Major axis with angular rate equal to 0.5 rad/s. Because no deployment could be perfect, there were some residual angular velocities about other transverse axes 0.1 rad/sec and 0.02 rad/s. Making appropriate assumptions (a) describe the resulting spacecraft attitude motion assuming no other external disturbance torques. (b) Numerically compute and plot the nutation angle and (c) determine the precession rate. (d) Write a MATLAB code to integrate the dynamical equations and verify what you descriped (e) Suppose the spacecraft is spun about minor moment of inertia axis and if there is a perturbing torque , integrate your equations by suitably changing the MATLAB code with 0.01 rad/sec and 0.02 rad/s. Show that the flat-spin motion of the spacecraft occurs.
4. Consider a spacecraft shown below.



The spacecraft hub is a solid cubic block of mass 100 kg and side 1 m. To provide the gravity gradient stability, the spacecraft inertia is augmented by addition of 4 lumped masses of mass ‘m’ located from the spacecraft centre of mass by massless rods of length ‘l’.

(a) Determine the moments of inertia matrix of the spacecraft in terms of ‘m’ and ‘l’

(b) Is the spacecraft gravity-gradient stabilized?

(c) In addition to the gravity gradient torque, the spacecraft is acted upon by a constant solar radiation torque about pitch axis with magnitude = Nm. Assuming the spacecraft is in circular orbit and initial pitch angle and pitch rate θ(0) = 0, = 0, find the solution of the pitch angle θ(t) in terms of ‘m’, ‘l’ and orbital rate .

(d) Now assume that the spacecraft is in a circular orbit with period 6 hrs. Determine the length of the massless rods to limit the pitch angle θ(t) excursions within 5 deg. Assume m= 2 kg.

1. Suppose an astronaut tries to “capture” a tumbling space-station module by grabbing hold of a part connecting to another module, climbing onboard and firing the EMU (Extravehicular Maneuvering Unit). What is the possibility of his success in stopping the tumbling motion if

(a) MI of module about the initial axis of motion is 50000 kg-m2;

(b) the module’s mass is 3000 kg;

(c ) the module’s initial rotation rate is 4 rpm;

(d) the astronaut’s mass is 80 kg;

(e) the point he grabs is 5 m from the module’s COM

(g) the maximum thrust the EMU can provide is 150 N and

(h) the astronaut has 30 s of propellant at full thrust.

Support your answer with appropriate analysis.

Thrust

5m

Side

View

Top

View

% Matlab code for studying dynamics of gravity gradient satellites

function gravitygradient

%program for torque-free rotational dynamics and Euler 3-2-1 kinematics

%of rigid spacecraft with linearized equations

%x(1)=omega\_x, x(2)=omega\_y, x(3)=omega\_z (angular velocity in rad/s)

%x(4)=psi, x(5)=theta, x(6)=phi (rad)

%(c) 2017 R. Pandiyan

pi = 3.14159265;

xin(1) = 0.0;

xin(2) = 0.0;

xin(3) = 5.0\*pi/180.0;

xin(4) = 0.0;

xin(5) = 0.0;

xin(6) = 0.0;

[t,x]=ode45(@f,[0 20000],[0.0,0.0,0.0\*pi/180.0,0.0,0.0,0.0]');

subplot(311), plot(t,x(:,1)\*180/pi), hold all, ...

title('phi');

xlabel('time in secs');

ylabel('phi in degrees');

subplot(312), plot(t,x(:,2)\*180/pi), hold all, ...

title('theta');

xlabel('time in secs');

ylabel('theta in degrees');

subplot(313), plot(t,x(:,3)\*180/pi), hold all, ...

title('psi');

xlabel('time in secs');

ylabel('psi in degrees');

function xdot=f(t,x)

%x(1)=omega\_x, x(2)=omega\_y, x(3)=omega\_z (angular velocity in rad/s)

%x(4)=psi, x(5)=theta, x(6)=phi (rad)

%w0=orbital velocity in rad/s

J1=80; J2=82; J3=4; %principal moments of inertia (kg.m^2) before boom deployment

f1=(J2-J3)/J1;

f2=(J1+J3-J2)/J1;

f3=(J1-J3)/J2;

f4=(J2-J1)/J3;

f5=(J3+J1-J2)/J3;

w0=0.00104; % Orbital rate of the spacecraft motion

w02=w0\*w0;

xdot(1,1)=x(4);

xdot(2,1)=x(5);

xdot(3,1)=x(6);

xdot(4,1)=-4\*w02\*f1\*x(1)+w0\*f2\*x(6)+1.0e-5/J1; % with disturbance torque

xdot(5,1)=-3\*w02\*f3\*x(2)+0.0e-5/J2;

xdot(6,1)=-w02\*f4\*x(3)-w0\*f5\*x(4);