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MANIPAL INSTITUTE OF TECHNOLOGY
Manipal University

SECOND SEMESTER M.Tech. (ASE) DEGREE END SEMESTER EXAMINATION
May/June 2016
SUBJECT: RENDEZVOUS AND DOCKING [ICE 586]

TIME: 3 HOURS **MAX. MARKS: 50**

Instructions to candidates

- Answer **ANY FIVE** full questions.
- Missing data may be suitably assumed.

1A. List the main phases of an RVD/B mission. What are the objectives and end conditions to be achieved for each phase?

1B. What are the various complexities and constraints involved in rendezvous approach and mating process?

1C. Write any four applications of Rendezvous and Docking/Berthing mission?

(5+3+2)

2A. For the trajectory shown in Figure Q.2A, obtain the equation of motion governing the trajectory and calculate the total ΔV expenditure.

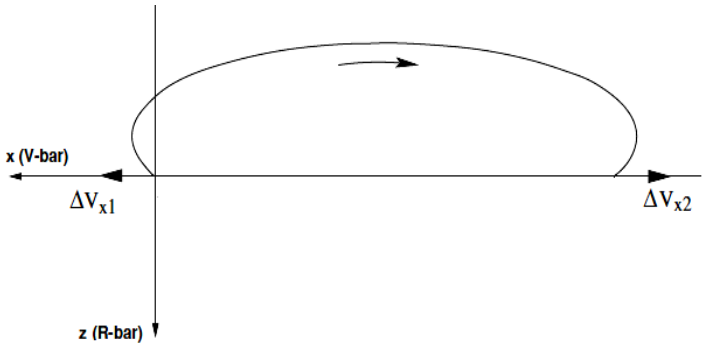

Figure Q.2A

CW equation without input forces are as follows:

$$x(t) = \left(\frac{4\dot{x}_0}{\omega} - 6z_0\right)\sin(\omega\tau) - \frac{2\dot{z}_0}{\omega}cos(\omega\tau) + (6\omega z_0 - 3\dot{x}_0)\tau + (x_0 + \frac{2\dot{z}_0}{\omega})$$

$$y(t) = y_0\cos(\omega\tau) + \frac{\dot{y}_0}{\omega}\sin(\omega\tau)$$

$$z(t) = \left(\frac{2\dot{x}_0}{\omega} - 3z_0\right)\cos(\omega\tau) + \frac{\dot{z}_0}{\omega}sin(\omega\tau) + \left(4z_0 - \frac{2\dot{x}_0}{\omega}\right)$$

2B. The absolute position, velocity and acceleration of spacecraft A is given by:

$$\boldsymbol{r_A} = -266.71\,\hat{I} + 3865.8\,\hat{J} + 5426.2\,\hat{K} \text{ (km)}$$

$$\boldsymbol{v_A} = -6.4836\,\hat{I} - 3.6198\,\hat{J} + 2.4156\,\hat{K} \text{ (km/sec)}$$

$$\boldsymbol{a_A} = 0.00035870\,\hat{I} - 0.0051980\,\hat{J} - 0.0072962\,\hat{K} \text{ (km/sec}^2\text{)}$$

Also, absolute position, velocity and acceleration of spacecraft B is given by:

$$r_B = -5890.7\,\hat{I} - 2979.8\,\hat{J} + 1792.2\,\hat{K} \text{ (km)}$$
$$v_B = 0.93583\hat{I} - 5.2403\,\hat{J} + 5.5009\,\hat{K} \text{ (km/sec)}$$
$$a_B = 0.0073359\hat{I} + 0.0037108\,\hat{J} - 0.0022319\,\hat{K} \text{ (km/sec}^2\text{)}$$

The unit vectors of moving frame:

$$\hat{\imath} = -0.040009\hat{I} + 0.57977\hat{J} + 0.81380\hat{K}$$
$$\hat{\jmath} = -0.82977\hat{I} - 0.47302\hat{J} + 0.29620\hat{K}$$
$$\hat{k} = 0.55667\hat{I} - 0.66341\hat{J} - 0.5000\hat{K}$$

The angular velocity and angular acceleration of the moving frame are:

$$\Omega = 0.00065183\,\hat{I} - 0.00077682\hat{J} + 0.00058547\hat{K}(rad/sec)$$
$$\dot{\Omega} = -2.47533(10^{-8})\hat{I} + 2.9500(10^{-8})\hat{J} - 2.2233(10^{-8})\hat{K}(rad/sec^2)$$

Calculate the position $r_{rel)x}$, velocity $v_{rel)x}$ of spacecraft B relative to spacecraft A, measured along *xyz* axes of the co-moving coordinate system of spacecraft A.

(5+5)

3A. Explain active trajectory protection and passive trajectory protection

3B. Write a short note on collision avoidance maneuver (CAM) on R-bar. Sketch the trajectories.

3C. What are the different causes of deviations of actual trajectory from planned trajectory.

(5+3+2)

4A. With neat diagram, explain navigation filter for rendezvous and docking mission.

4B. How does the operational ranges and measurement accuracies of rendezvous sensors act as a driver for approach strategy during docking.

4C. Briefly explain the process of manual state update for the automatic GNC system.

(5+3+2)

5A. Describe various steps in the berthing process for a manned RVD mission.

5B. Consider two spacecrafts which are docking with following impact conditions:

Mass of chaser, $m_c = 5*10^3$ kg; Mass of target, $m_t = 100*10^3$kg;
Inertia of target, $I = 10*10^6$ kgm^2; Velocity of chaser, $Va_0 = 0.1$m/sec;
Assume, Velocity of target before capture, $V_{b0} = 0$ and angular velocity before capture, $\omega_{b0}=0$.

A. Find the joint velocity after capture if the location of impact is located on line joining COM of two vehicle.
B. Find the angular velocity induced in target spacecraft if the impact line has a distance of 20m to the COM.

5C. With a neat sketch brief about the sizing feautures for pressurized mating system

(5+3+2)

6A. List and explain the major tasks of chaser control center and target control center during the rendezvous mission?

6B. Describe verification stages in the development life – cycle of a space project.

(5+5)