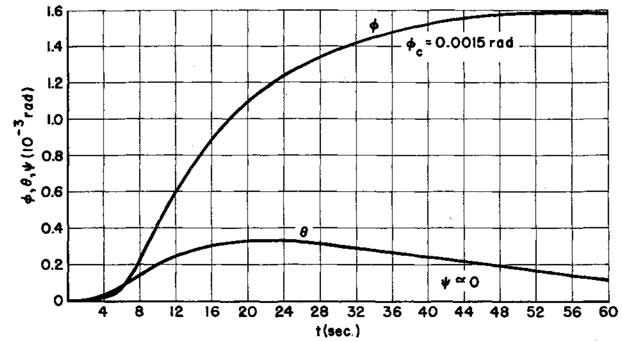

Fig. 12 Attitude control system response; control equations A

axes. Then, as the vehicle assumes the correct attitude, the vehicle rate must be reduced to zero. The gimbal orientation, of course, must be consistent at all times with the initial angular momentum of the system. For small vehicle reorientation angles this results in a final orientation of the gimbals which is essentially the same as that at the beginning of the maneuver.

If $\alpha(0) = 0$ and $\beta_1(0) = \beta_2(0) = \pi/2$ as before, a change in roll attitude ϕ requires that the outer gimbal precess through approximately $\pi/2$ rad and then back to nearly zero. In Fig. 12 the system response is shown for the forementioned initial conditions, control equations A, and $\phi_c = 0.0015$ rad. The values of K_1, K_2, K_3 seem to be critical for this case. As they are increased above about 0.5, the overshoot in attitude becomes appreciable. For the system gains chosen, control equations B give a response almost identical to that shown in Fig. 12. Further study is required to determine the relative merits of the two sets.

Conclusions

A gyro momentum exchange device has been described which, for general application, probably contains the minimum number of wheels and gimbals. The cross-coupling between vehicle axes is somewhat greater than that with three separate single-axis controllers, but in most cases it should be tolerable. The gyro controller has been shown to be a very efficient device from an energy point of view. In addition, the motor size required for a given response time is greatly in favor of the gyro system over the flywheel system.

Control system synthesis is hindered by the fact that gimbal motion is not associated with a particular vehicle axis, thus requiring closely coupled control equations. In addition, the equations describing the motion of the gimbals are nonlinear. The possibility that more efficient control equations exist should be investigated, and methods of mechanizing the equations should be considered. The gyro controller possibly could operate as efficiently with different definitions of system error. For example, it may be possible to eliminate the vehicle angular rate measuring equipment. In any case, careful analysis will be required to uncover any possible system limit cycles that occur as the result of discontinuities or nonlinearities in the control equations.

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