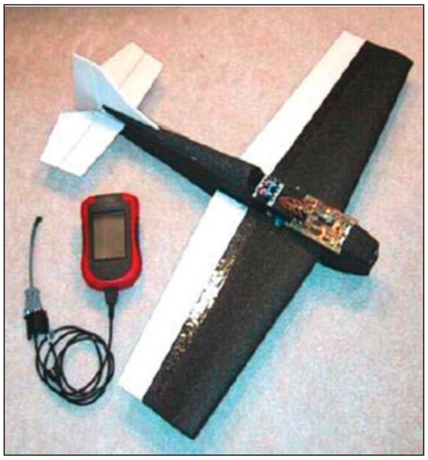
Mechanics/Machinery

Variable-Structure Control of a Model Glider Airplane

The conventional spin-recovery technique for fuselage-heavy aircraft is implemented by a modern control system.

Langley Research Center, Hampton, Virginia

A variable-structure control system designed to enable a fuselage-heavy airplane to recover from spin has been demonstrated in a hand-launched, instrumented model glider airplane (see figure). It has long been known that the most effective spin recovery technique for fuselage-heavy aircraft involves the use of ailerons to roll the airplane into the spin. This technique might be considered counter-intuitive because the pro-spin aileron deflection tends to initially increase the roll-rate component of the angular momentum of the airplane. However, it restores some controllability, enabling the pilot to perform subsequent maneuvers to pull out of the spin. The design of the present model-airplane control system was inspired in part by recognition that the aforementioned (and conventional) spin-recovery technique mimics a variable-structure control law.



This **Model Glider Airplane**, instrumented with sensors and control and data-acquisition systems, was used to demonstrate the use of variable-structure control for spin recovery.

Variable-structure control is a high-speed switching feedback control technique that has been developed for control of nonlinear dynamic systems. A variable-structure control law typically has two phases of operation, denoted the reaching-mode and sliding-mode phases. In the reaching-mode phase, a nonlinear relay control strategy is followed to drive the trajectory of the system to a pre-defined switching surface within the motion state space. The sliding-mode phase involves motion along the switching surface as the system moves toward an equilibrium or critical point.

A theoretical analysis has led to the conclusion that the conventional spin-recovery technique can be interpreted as a variable-structure control law with a switching surface defined at zero yaw rate. Application of Lyapunov stability methods in the theoretical analysis showed that deflecting the ailerons in the direction of the spin helps to insure that this switching surface is stable. It was shown that during the reaching-mode phase, a simple relay control law would drive the airplane to a critical point that would be characterized by almost pure rolling motion. The sliding-mode-phase control law would then eliminate the rolling motion, leading to a complete recovery.

For the demonstration of variable-structure control for spin recovery, the model airplane was equipped with attitude sensors and a microcontroller that drove servomechanisms for controlling the deflections of the ailerons, rudder, and elevator. A variable-structure control law incorporating a nonlinear model of the aerodynamic characteristics of the airplane was implemented in firmware. Flight tests have verified the stability of the reaching-mode phase.

This work was done by Martin R. Waszak of Langley Research Center and Mark R. Anderson of Paper Pilot Research, Inc. Further information is contained in a TSP (see page 1).

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Axial Halbach Magnetic Bearings

Complex active control systems are not needed.

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Axial Halbach magnetic bearings have been investigated as part of an effort to develop increasingly reliable noncontact bearings for future high-speed rotary machines that may be used in such applications as aircraft, industrial, and land-vehicle power systems and in some medical and scientific instrumentation systems. Axial Halbach magnetic bearings are passive in the sense that unlike most other magnetic bearings that have been developed in recent years, they effect stable magnetic levitation without need for complex active control.

In simplest terms, the basic principle of levitation in an axial Halbach magnetic bearing is that of the repulsive electromagnetic force between (1) a moving permanent magnet and (2) an electric current induced in a stationary electrical conductor by the motion of the magnetic field. An axial Halbach bearing includes multiple permanent magnets arranged in a Halbach array ("Halbach array" is defined below) in a rotor and multiple conductors in the form of wire coils in a stator, all arranged so the rotary motion produces an axial repulsion that is sufficient to levitate the rotor.