Abstract

This dissertation is concerned with the development of analysis techniques which enable multistable structures to be designed with confidence that their performance will match predictions. The purpose of multistable structures is that they may be used as reconfigurable, adaptive structures which offer increased functionality over conventional structures.

An adaptive structure usually changes its configuration by means of incorporated actuators. If an adaptive structure is required to stay in a configuration for a long time, force must be maintained by the actuators. Multistable adaptive structures can remove this problem, as once the actuators have placed it in a desired stable configuration, it will remain there when the actuation is removed.

In a compliant structure, the functions of conventional mechanism components are replaced with elastic, flexing members. This can result in structures which have a substantially reduced number of parts, and which can operate in environments which are not suitable for conventional mechanisms. A disadvantage is that when the compliant components are flexed, restoring moments will be introduced. It is of interest to combine the concepts of multistable and compliant structures to retain the benefits provided by both. In this dissertation a number of design concepts for compliant bistable and multistable structures are presented.

The first concept is a multistable plate structure which is fabricated with a rapid-prototype technique. The polymer used exhibits nonlinear viscoelastic properties, which are characterised and implemented in a finite element analysis. It is demonstrated that it is vital to model viscoelastic material properties to have confidence in the multistable behaviour of a polymeric structure. Additionally, it is necessary to use alternative definitions of stability, as the standard definitions are only applicable to conservative systems.

Next, the design of a bistable switch is presented which integrates a polymer snap-through structure with dielectric-elastomer actuators. The importance of including viscoelastic material properties in the analysis is again demonstrated. Techniques for tailoring a bistable structure to a known actuator response are provided.

Structures are then presented which are asymmetrically-bistable, i.e. have a stable state which holds more strain energy than the other. This energy may be released to carry out mechanical work. First a jumping structure is designed which is based on a combination of tape springs and leaf springs. The structure is actuated with shape memory alloy springs. The available jumping energy is maximised, and a dynamic analysis is carried out to predict the jump height. A change in material from steel to CFRP results in a two-fold increase in jump height relative to characteristic dimension. Three-dimensional tetrahedral structures are then presented which exhibit strong imperfection sensitivity. In this case we are interested in maximising the change in geometry between stable states, and a final design is presented which increases its height by over 100% when actuated.

Finally, a technique is provided which enables bistable structures to be combined systematically using a nonlinear compatibility analysis. A multistable structure based around four asymmetrically-bistable tetrahedra is demonstrated.