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Adaptive Structures

Engineering Applications

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Preface

This book is based around the concept of 'adaptive structures', by which we mean engineering structures which have the ability to adapt, evolve or change their properties or behaviour in response to the environment around them. In recent years this concept has developed into a richly diverse area of research which includes topics such as structures, materials, dynamics, control, design and biological systems. The interdisciplinary fusion of these individual topic areas creates the possibility for new and exciting technological developments. These developments have been taking place in a wide range of industrial applications, but are particularly advanced in the aerospace and space technology sector.

Each chapter in this book represents the current state of the art in a particular aspect of adaptive structures, written by leading experts in their respective fields. But what about future developments beyond the current state of the art? Well, many chapters include discussions on future developments. More than this, we believe that by bringing together so many interrelated and yet diverse topics in a single volume one can get a sense of the huge future potential of this rapidly developing field of research. We hope that by viewing these combined chapters as a whole, the reader can enjoy the same sense of excitement and inspiration we felt when compiling this volume.

WHAT ARE ADAPTIVE STRUCTURES?

Humans have long been fascinated by nature's ability to build structures which adapt to their environment. In contrast, our own structures often

appear inefficient, static and cumbersome. In engineering, the term 'adaptive structure' has come to mean any structure which can alter either its geometric form or material properties. These are processes which are currently much simpler than those which can be observed in nature. The terms 'smart', 'intelligent' and 'active' have all been applied to describe both materials and structures which exhibit some or all of these properties (see the selection of authored and edited texts referenced below). Increasingly, the ability to adapt to a performance demand or environmental conditions has become a key design criterion for a range of structural and mechanical systems in recent years. It is precisely this type of requirement which has become a key driver in the development of adaptive structure technology.

The adaptation process itself can be passive, active, based on material properties, control, mechanical actuation or some combination of these. As performance limits on structural systems are increasinlgly being pushed to more extreme levels, especially with respect to minimising weight, there is a strong requirement to find more efficient ways to apply adaption processes. This brings significant scientific challenges relating to structural stability, vibration, control/actuation, sensing and material behaviour.

There are many examples of adaptive structures from a broad range of engineering applications, but much of the driving force for development has come from the aerospace and space engineering sectors. The need for a high level of material performance in terms of strength, flexibility and minimal weight, coupled with the need for deployment and operation in extreme environments, has led to some of the most advanced adaptive structures currently in existence. There has also been considerable interest in new concepts such as 'morphing' wings for aircraft.

As these more advanced concepts of adaptive structures become realisable, the interaction and integration of material behaviour, control, sensing and actuation becomes ever more critical.

WHY ADAPTIVE STRUCTURES 2006?

This book forms a permanent record of the 2006 Colston Research Society Symposium on Adaptive Structures, held at the University of Bristol on 10–12 July 2006. The symposium formed part of of a wider celebration happening in Bristol during 2006 to mark the bicentenary of the birth of Isambard Kingdom Brunel (1806–1859), arguably the greatest engineer of all time. Brunel's influence on the science and application of engineering

led to some of the greatest engineering achievements in history. The historic city of Bristol has special links to Brunel, with structures such as the Clifton Suspension Bridge and the SS *Great Britain* forming a prominent part of the city's engineering heritage.

Bristol retains a strong link with modern engineering as a key centre for European aerospace manufacture. Representatives from local industry took part in the symposium and a public lecture by Gordon McConnell, Senior Vice President – Engineering at Airbus UK, was given on 'Continuing the Vision – Airbus A380 and Beyond'. The focus of this symposium was to consider the direction and key challenges associated with the rapidly developing field of adaptive structures.

WHAT DID WE LEARN?

The book chapters stand alone in giving detailed information in specific topic areas. However, there are some strong 'emergent' or common themes which relate the diverse array of subject areas – from precise theoretical mechanics and control in piezoelectric devices, through advanced polymer chemistry, to the innermost workings of a Venus Fly Trap.

Firstly, it is clear that advanced material properties lie at the very heart of adaptive structures. In this book, topics covered range from chemistry to theoretical mechanics – seemingly disparate areas but crucial to the understanding of many problems. In fact this example highlights one of the key concepts to emerge from this book – integrated thinking. What do we mean by this? Any material has a chemical make-up and at the same time a mechanical behaviour. Our traditional approach to scientific research means that these two things are treated as completely separate subjects, so much so that many practitioners from either field may not even be able to communicate with each other! What is clear for adaptive structures research is that integrated understanding of a material's behaviour can lead to novel ways of exploitation.

This becomes more specific when we think about 'material' and 'structural' properties. Again, although often separated, throughout this book we see examples of 'multifunctionality' which makes this traditional separation irrelevant. In essence we need to see a blurring of the distinction between 'structure' and 'material', because when we do this new possibilities emerge which can potentially be exploited. This is often possible across the length scales. Although the dominant motivations are for aerospace and space

applications (and a small amount of civil engineering) there are also many possibilities at the MEMS and nano scales.

Another common thread in this work is that of biological inspiration (or analogy/function). A clear message is that nature uses information and structure rather than energy to design its structures. Nature also makes significant use of hierarchy throughout its adaptive structures, leading quite naturally to multifunctional behaviour. It is also clear that with regard to obtaining information and acting upon it, our current sensing and control/actuation technology is some way behind that employed by nature. Again, we see that there is a strong driver towards integration of function – sensors which are also actuators, materials with integral sensors, etc. Structural health monitoring is relatively new in engineering, but an entirely natural (and essential) process for biological systems. Ways of efficiently closing the control loop to provide feedback continues to challenge our traditional engineering approach.

Imparting some degree of self-healing to an engineering structure/material is perhaps a prime example of how research is attempting to bridge the divide between the synthetic and organic. One can envisage such a functionality offering real benefit across a wide range of engineering applications; however, replicating the subtleties of the natural world continues to pose significant challenges.

Overall, there is a strong sense that we need to challenge existing ways of thinking: concepts, assumptions and design approaches. Throughout this book the reader will see examples of this type of new and questioning approach. But these thought processes are not just idle speculation – almost every one is backed up with high-quality experimental validation.

Arguably, had Brunel been alive today he would have been a champion of the thinking that is encapsulated within the work presented here. Never one to shy away from applying the latest technologies available, or indeed finding his own solutions to problems, Brunel would no doubt approve of the theme, topics and findings presented herein.

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