SMART STRUCTURES IN EUROPE – SOME (PERSONAL) RECOLLECTIONS

Brian Culshaw

University of Strathclyde, Department of electronic and Electrical Engineering,
204 George Street, Glasgow G1 1XW, UK

ABSTRACT

Smart structures as an identified engineering concept emerged in Europe in the middle to late 1980's (though European structures were initially intelligent rather than simply smart ....). This talk will reflect on the early history of smart structures in Europe and speculate upon where the ideas have progressed.

1. INTRODUCTION

Smart structures has crept into Europe by infiltration and stealth. Indeed, whilst undoubtedly catching the technical imagination it has been less successful than the North American equivalent in achieving the quasi political recognition of dedicated programmes. There is a cultural issue here. The implications and meaning in the two words is understood but their utility as a descriptor is perhaps clouded by the more wide ranging interpretation of the word "smart" in the English language than its American progeny. People, and by inference, things can certainly be "too smart for their good" and iodine most certainly "smarts" when applied to an open wound. Couple that to twice the US population in 50 countries speaking more than 100 languages and the possibility for linguistic misunderstanding multiplies.

Perhaps this is part of the reason why the identifiable smart structures community in Europe is somewhat smaller than its US equivalent. However, I would argue that the research and development community within the generic area covered by smart structures is as large or larger but prefers to sit within its more traditional and inevitably more specialised descriptors of piezoceramic materials, control systems or data recognition. I would also argue that the management of activities which could be described as smart structures is as effective as anywhere else and that the products, processes, services (and papers) which emerge are globally competitive. The cultural diversity of Europe does, however, give colour, interest and often a hint of total confusion to technical progress. Project management and the use of terms and language and these cultural differences do (thankfully) inhibit the penetration of spurious jargon and – having written a book on smart structures and materials[1] – I think I can argue the case that the words can easily slip into spurious jargon.

But a lot has happened in Europe within the last 20 years in what can be termed the smart structures area. Advances in materials science, advances in computer techniques and technologies, greater demands on structural performance, the need to compete in global market places – all figure in the way in which manufacturing industries must evolve – and in the final reckoning, smart structures is about making things. However, thanks to the language and indeed the fact that there are untold numbers of languages in Europe, sometimes several per country, the jargon finds it much more difficult to permeate the community especially when our cultural values tell us that it is not necessarily always smart to be too smart.

What follows is a brief account of just some of the activities in Europe. It is written by someone with a sensor perspective and indeed the intention of the paper, despite its all embracing title, is to focus a little on the sensor domain: at least then the skeleton of the story can fit in a few pages. It is even more focused than that – we shall look at structural monitoring and use fibre optic systems as exemplars primarily because this has been the area to which I have had the most exposure. In doing so, of course, I have omitted at least 95% of the smart structures activity in Europe. I hope that this 95% of the community will forgive and understand the omission —my apologies and all those good people working in electronic noses or piezoceramic drives or polymer materials or biomemetics and will understand that without writing another book all I can do is acknowledge their presence and their immense contribution.

2. IN THE BEGINNING

The "new" materials which emerged in the post World War 2 epoch (lightweight alloys particularly those using titanium, glass and carbon composites in resin and metal matrices, ceramics .....) soon presented challenges to those whose tasks lay in the test and characterisation of these materials. They were new and therefore regarded with suspicion and consequently, especially for high performance applications, there was the inevitable long confidence building lead time.

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Most, if not all of these new materials are capable of operating under environmental and loading constraints which exceed those of most conventional measurement techniques. Further the materials community became aware that it would often be very nice to know what was happening inside, for example, during the curing process of resin matrix composites. However, this challenged sensing and measurement technology. The possibilities for fibre optic sensors first became apparent in the mid 1960's and the first serious work on interferometric sensors began to emerge about a decade later. In parallel the mechanical virtues of optical fibre became apparent and a number of early experiments on using fibres as strain gauges (figure 1) convincingly demonstrated the mechanical potential offered by the new strain sensing medium[2]. Of course, these structures only became "smart" later.

Probably the first European project to court the concept was OSTIC (1988)[3]. The European commission is fond of acronyms to the extent that they are a necessity. OSTIC stems from optical sensing techniques for intelligent composites. The more observant will note the language – this project resisted using the derisory word "smart" in favour of the more complementary and certainly less ambiguous "intelligent". But the idea was there and the thought was essentially to look at composites. In particular the concept was to see if we could find out how they were made and thereafter how they behaved mechanically. When the project was conceived (1987) the now ubiquitous fibre Bragg grating had yet to make its mark: that was to come later.

From OSTIC came lots of useful information – that optical fibres could indeed be embedded in composites without compromising the mechanical integrity thereof (figure 2), that methods probably did exist to observe what happened during the cure process (figure 3) but ours were not quite right: they simply indicated that something happened. Then once we had all these fibres in the composite material we could indeed see what was happening during loading cycles, though the sensors were a bit erratic, the exit and entry points for the optical fibres were vulnerable, temperature played an important part in any readings using fibre optics and so dynamic measurements were easier and we were unsure at that stage as to what to do with all the data (figure 4).

3. AND LATER ON

The European Commission in fine style encouraged the proliferation of acronyms. We had OSMOS, STABILOS, FORMS, MONITOR, SISCO, NISOST, ASSET, COSMOS, DAMASCOS, FOSMET, DEMOS ……. all associated with one form or another of structural monitoring[4]. The acronyms including an S might (but didn't) embrace the word "smart" and of course two S's are required for smart structures (only in ASSET!). The Bragg grating crept across the Atlantic and fibre sensors appeared in mines in aircraft panels, in the walls of nuclear reactors, in concrete structures. The appreciation that perhaps there really was a useful technology here was beginning to spread by the early 1990's. The stimulus that these projects provided began to target specific applications sectors. Now there are European luxury yachts floating the oceans with fibre Bragg gratings in their CRP masts[5]. There are bridges and dams incorporating fibre optic sensors[6] and – in the time honoured tradition of sensor technologies – the niches are beginning to be identified and the technology, initially greeted as the universal panacea is beginning to find its feet in the real world.

4. SPREADING THE WORD

Europeans like to talk and even like to communicate with each other through, I am relieved to say, the medium of the English language thereby encouraging our (i.e. UK) collective linguistic laziness. But talk they did and, by around 1990, the meetings had started to appear. The Smart Structures Research Institute at Strathclyde hosted its inauguration in La Defense, Paris back in 1991. The first European conference on Smart Structures and Materials was hosted in Glasgow in 1992 and has continued since[7]. More meetings followed, some in nicer places than others, from Loch Lomondside to London to Lyon. The IoP in England, launched a journal[8] (but it must be said with American editors …..) and a community began to emerge, though one which was never certain whether its structures were smart or, intelligent, or possibly discerning?

5. BIBLIOGRAPHY

1. Brian Culshaw, "Smart Structures and Materials" Artech House, Norwood and London 1996.

2. These tests were conducted by Westland Helicopters in 1982, in collaboration with Peter Gardiner. They are described extensively in Deepak Uttamchandani's PhD thesis (University of London , England, 1984)

3. B Culshaw, W C Michie "Fibre optic strain and temperature measurements in composite materials: a review of the OSTIC programme", Recent Advances in Adaptive and Sensory Materials and Applications, VPI, Blacksburg, VA, 1991 (Invited paper), published by Tech. Press.

4. Reports and summaries of these projects are available from the DGX11 offices of the European Commission in Brussels. Most are extensively reported in the open literature.

5. MAST Project, DTI, London UK. Information from Pendennis Shipyards, Falmouth, Cornwall.

6. Several reports by D Inaudi describe the work of Smartec SA, Switzerland in this area. The STABILOS project included evaluation in dams.

7. European Conference on Smart Structures and Materials, ECSSM1, Glasgow 1992 (SPIE Vol.2361), ECSSM2, Glasgow 1994 (SPIE Vol. 1777) ECSSM3/ICIM Lyon, 1996, (SPIE Vol.2779), ECSSM4, Harrogate, England, 1998 (IoPP, Bristol, England), ECSSM5, Glasgow 20000 (to be published by SPIE).

8. Journal of Smart Materials and Structures, Volume 1, 1992, IoPP, Bristol, England.

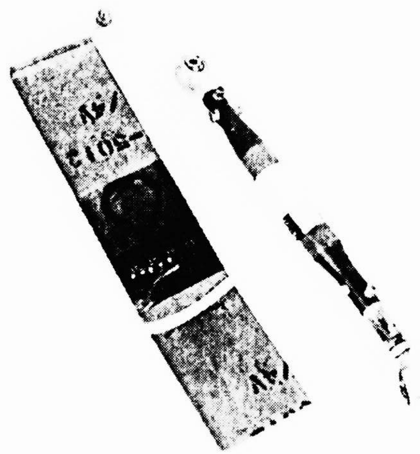

Figure 1: Fibre sensors survive strains!

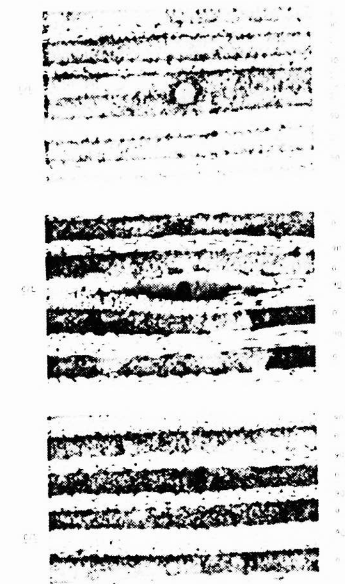

Figure 2: Optical fibres embedded into composite material

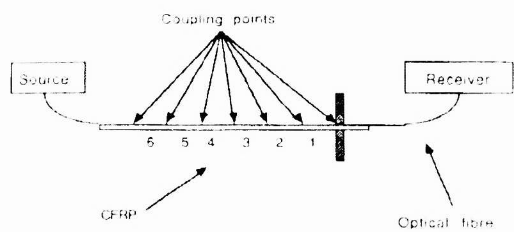

Figure 113

A view of the actual cantilever is given in figure 114, when views of the Michelson receiv
with its seven optical fibre outputs and the input in the processing unit are given in figure 115 a
116 respectively.

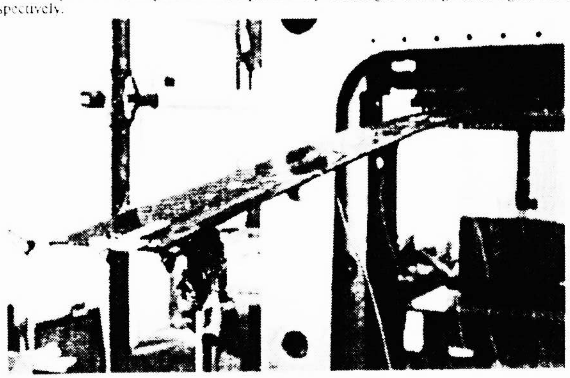

Figure 4: An early demonstration of multiplexed fibre optic sensing in composite beam

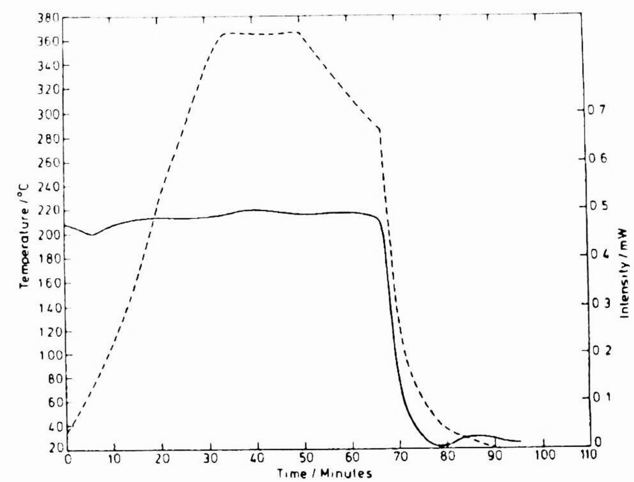

FIGURE 3.25 SIGNAL MODULATION THROUGH AN 80/93 μm POLYIMIDE COATED FIBRE EMBEDDED AT AN INTERFACE BETWEEN TWO ORTHOGONAL SURFACE PLIES IN A CROSS-PLY APC-2 $[(90/0)_3\ 90]_S$ LAMINATE

Figure 3: Monitoring epoxy cure using a simple multimode fibre attenuation measurement