A Celebration of the Life of Professor Tony Kelly ScD FRS FREng PhD CBE DL

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Tony Kelly relaxing in his beloved Churchill College

The Materials Science community, in particular those who work in the area of composite materials, were saddened to learn of the death, peacefully in his sleep, of Professor Anthony Kelly. Known to friends and colleagues as Tony, Professor Tony Kelly was a founding Fellow of Churchill College, being elected to a Fellowship in October 1959 where he was College Director of Studies in Natural Sciences and lecturer in the Department of Metallurgy at Cambridge University until 1967. He subsequently worked for the government at the National Physical Laboratory, Teddington where he was deputy director until 1975. During his tenure at NPL, he spent a brief period at Imperial Chemical Industries before becoming

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Vice-Chancellor of Surrey University until 1994. In 2011, Tony Kelly was recipient of the President's Medal of the Royal Academy of Engineering through excellence in engineering. In his later years, he played a key role in assisting with establishing the Global Warming Policy Foundation and was a sharp critic of the application of climate science.

First and foremost, Tony Kelly was a materials scientist and an ardent campaigner for the application of discoveries of pure science in industrial enterprise, particularly in the field of composite materials. Indeed, he has been referred to as “the father of composite materials” as a result of his pioneering contributions to the understanding of the behaviour of fibre composites. However, during his early career at Cambridge, he worked with Robin Nicholson on the relation between the microscopic structure of metal alloys to their physical properties, studies of precipitation and dispersion hardened alloys using x-ray and electron microscopy methods to provide new insights that he successfully applied to composites.

He revealed the nature of metals to show polycrystalline ductility by glide and applied this to ceramic and other inorganic materials developed in the 1960's. He applied the same ideas to the climb of dislocations. This led to a fundamental understanding between brittle and ductile crystals and of the ideal strength of solids. This work underpinned the development of ceramic composites and laid foundations for understanding the strength of laminated composite structures.

It really all began in the “swinging sixties”, when a fashionable professor at Cambridge, Alan Cottrell, often gave invited lectures at The Royal Society. On such an occasion, it was usual of him to ask his young lecturer Tony Kelly, also in the Metallurgy Department, to consider the script before presenting it. In a discourse delivered to the Royal Society on 15th June 1960, Cottrell enunciated the principle of fibre reinforcement: “No, the practical approach is to admit the existence of cracks and notches and to try to render them innocuous. If there is a transverse notch cutting across a parallel array of fibres in a rod of some material like adhesive, the forces from the cut fibres can be transmitted to the intact fibres close to the notch tip only by passing as shearing forces through layers of the adhesive”. He continued: “If this adhesive has a fairly low resistance to shear ... it will then be incapable of focussing the transmitted forces sharply... There is a tremendous opportunity for developing this principle further using fibres of very strong atomic forces like oxides and carbides”.

This was “music” to Tony's ear. With his interest and knowledge of ceramics, he recognised immediately that the oxides and the carbides would make ideal reinforcements. Tony and his earliest research students were perfectly placed in that they were already elucidating the principles of the strengthening of metals and yet were lucky enough to spot the advantages of non-metallic solids as the major strengthening agent.

From this early work, Tony Kelly (with graduate student Bill Tyson) produced what could be called the colligative mechanical properties of an aligned fibre-reinforced system; the contribution each phase makes to overall strength; how it depended on volume fraction; and importantly upon the ratio of length to diameter of the fibre. Furthermore, they found a new means of dissipating energy...fibre pull-out.

But there was one more discovery still to make together with Tony's second research graduate, George Cooper, which was that a crack could not extend if faced with an interface which yielded easily in shear. However, it was not until both Tony and George went to the NPL did they discover the principle of multiple cracking by an insightful series of experiments. This involved incorporating silica fibres coated with carbon having a unique strain to failure of 4 % into a resin with a strain to failure of 6 % at room temperature and 1 % at 77 K. The contrast between the failure strains of fibre and matrix at the extremes of temperature was patently obvious. One of the components breaks in a series of parallel cracks while the other remains in tact and bears the load. Furthermore, the high elongation phase need not be continuous.

Here, indeed, was a very striking phenomenon; they had produced ductility in a non-ductile material system. To produce ductility with a metal matrix is common place, but to produce it in a totally brittle system, that is something special. Tony and George were the first to analyse such behaviour and to name it... multiple cracking.

Tony Kelly beginning with his first two research students had discovered totally separate new methods of dissipating energy in composites. Both were vital in understanding the materials science of composites, which is otherwise a very engineering discipline. Now, fragility of a material could be overcome by the incorporation of brittle fibres of oxides or carbides, for instance.

By these means are engineering ceramics toughened. The key that unlocked the secret of toughened ceramics (and other brittle materials) had been found, whether by laminating or by planar matting, or of oxide layers on metal surfaces, or of protective coatings and it is of the utmost importance. Controlling the phenomena of micro-cracking in composites determines whether or not glasses or ceramics are to be used in gas turbine engines.

By the turn of the new century, Tony had established the fundamental limits to the attainable packing density of assemblies of long straight fibres backed up with experimental evidence in order to determine the conditions for composite material elastic isotropy. Furthermore, he defined the conditions to control the thermal expansion coefficients of composite materials so as to obtain hitherto unattainable values combined with a desirable combination of other physical properties.

During Tony Kelly's time at NPL, he was seconded to Research & Development of Imperial Chemical Industries where he studied industrial management. Consequently, when he became Vice-Chancellor of the University of Surrey in 1975 his interest and contacts inclined him to foster strong links with industry. On arrival at the University of Surrey, some found Professor Kelly daunting. He commented: "the University did not feel itself as established as it should have been, nor as confident, despite the good work being done in many departments. On the whole the old Polytechnic culture of Battersea still prevailed, with many of the teaching staff not fully engaged in research".

Tony Kelly's leadership was to bring in an era of change by expanding research activities and so enhance the University's status and reputation, and with his background as a distinguished materials scientist he was elected a Fellow of the Royal Society at 44.

As Vice-Chancellor, Tony Kelly had an open-door ethos with all undergraduates, and continued his own research alongside his other responsibilities including making strong international ties, which he was well placed to do. These were difficult years for the new Vice-Chancellor in which to instigate ambitious plans for expansion, with high inflation and a squeeze on the economy. The University Grants Committee also had a stranglehold over university finances allowing, as Professor Kelly re-called: "little room for initiative... there was hardly any freedom to manoeuvre – you had to go to the UGC for everything you wanted to do. In fact, the UGC told you what to do, wrapping it up politely in the nice way the English have".

Margaret Thatcher once informed the Vice-Chancellor at a gathering of vice-chancellors at 10 Downing Street: "Professor Kelly, you cannot have funding for a new professorship at your University – you can, however, have additional funds for a Readership; take it or lump it!"

As Vice-Chancellor, Tony Kelly was closely involved with the founding and subsequent establishment of the Surrey Research Park in 1984, perhaps the most important achievement during his time at Guildford. The notion of a research park had first occupied his mind back in 1977, after he spent much of the summer vacation working in the research laboratories of Atlas Capo, a high-technology company whose labs stood in an attractive park. "There were researchers from all over the world, which brought a real international culture to the place. I

remember thinking, Guildford is an attractive place too... And we, the University, have land to spare. So why don't we build a university research park".

Tony would, have course, been very familiar with the success of the Cambridge Science Park. By '85/'86, the Vice-Chancellor was able to point out proudly that: "Surrey now receives a lower proportion of its recurrent income from exchequer grants (53.6 %) than any other UK university". Recognition for Tony Kelly's endeavours together now with optimistic support of the faculties won for the University the Queen's Award for Export Achievement in attracting students from overseas.

Tony Kelly returned to Churchill College in 1985 when he was elected to the College's prestigious Extraordinary Fellowship until his retirement in 1996. In his retirement he devoted much of his time to the College, including taking on the role of Editor of the Churchill *Review* for many years. He became Emeritus Professor and Distinguished Research Fellow at the University of Cambridge and joined the Department of Materials Science and Metallurgy, working in the Composites and Coatings Group.

The fact that Tony would reach 85 in 2013 had not escaped the notice of the "composites community", which inspired the occasion in the spring of 2013 at Queens' College Cambridge, of the Cambridge-Sheffield-Manchester Universities combined meetings on "Deformation and Fracture of Composites" and "Structural Integrity and Multi-scale Modelling of Engineering Composites".

The celebration took the form of a scientific meeting and college feast accompanied by the University of Surrey Swing Band. Papers were presented by distinguished scientists and engineers whose research over the years has been influenced in one way or another by the insightful work of Tony Kelly. Tony himself participated in most of the Meeting sessions, showing flair and imagination and capability for originality despite having suffered a stroke only a few weeks earlier on one of his lecture tours of Australia.

Tony continued to travel the world attending conferences and lecturing and most recently he supported a proposal to the Hooke Committee of The Royal Society for a Discussion Meeting on Composites, which proved successful. By chance, The Royal Society selected January 25th, 2016 for the Meeting, which happens to be the birthday of Tony Kelly.

He will be greatly missed.

Professor Anthony Kelly (25 January 1929—3 June 2014)

Emeritus Professor and Distinguished Research Fellow at Cambridge University; Extraordinary Fellow of Churchill College Cambridge; Vice-Chancellor, University of Surrey (retired); Fellow of the Royal Society; Fellow of the Royal Academy of Engineering; Foreign Associate of the US National Academy of Engineering; Fellow of the Institution of Materials, Minerals, and Mining (IOM³) (past President); Fellow of the Institute of Physics; Honorary Fellow of the Institute of Linguists; Chairman of the Committee on Structural Safety of the Institutions of Civil and of Structural Engineers.

Awards

William Hopkins Prize, Cambridge Philosophical Society

Beilby Medal, Royal Institution of Chemistry

A A Griffith Medal

First co-recipient of Medal of Excellence in Composite Materials, Delaware University

International Gold Medal of American Society of Materials

Platinum Medal of Institute of Materials

Acta Metallurgica Gold Medal

Alfred Ewing medal by Institution of Civil Engineers

President's medal of the Royal Academy of Engineering

Holliday (Leslie Holliday) Prize (IOM³) (2014)