

The Cottrell Legacy: the Metamorphosis of ICF into the World Academy of Structural Integrity 2011-2021

AI Carpinteri¹, D M R Taplin²

1. ICF-WASI President

2. ICF-WASI Chief Executive Officer

Abstract

This paper is designed to address aspects of the immense contribution and enduring legacy of Sir Alan Cottrell FRS FREng FICF (1919-2012) - especially in the context of the creation and development of ICF - at the "ICF13 Memorial International Cottrell Symposium". One theme of this paper builds on the ICFO paper of Cottrell in 1959, Cottrell's Opening Address at ICF2 in 1969 and Cottrell's ICF4 contribution "Fracture & Society" in 1977. A second theme of this paper is the BCS model of fracture and other models of fracture devised by Cottrell in the context of Cottrell's seminal 20thC contributions to the very creation of our disciplines of Structural Integrity and Materials Science: including archival research on the early work of Cottrell 1939-1941 on welding and cracking of low alloy steels at Birmingham. In particular, with the analytical BCS Model, Cottrell anticipated the numerical Cohesive Zone Models by at least two decades. This paper also addresses possible ways forward in this challenging 21stC for ICF-WASI following ICF13 in Beijing guided by the legacy of Cottrell's and Yokobori's ideas, inspiration & principles in establishing ICF during 1959-1969. At ICF13 the formal launch is arranged for the metamorphosis of ICF into "The World Academy of Structural Integrity". This is an ICF brand-development project explored at Sendai with Yokobori in 2010 and then initiated in 2011 at an ICF Interquadrennial Conference with ASTM in Anaheim, USA. This is much more than simply a name change but a comprehensive evolution in substance which like the original ten year creation process of ICF 1959-1969 is designed as a ten-year process 2011-2021. During the ICF13 Cottrell Forum in Beijing (as at the Sendai Interquadrennial in 2010) we seek full debate on the optimum ways forward for this metamorphosis.

1 Introduction

This paper is designed as an international tribute to Alan Cottrell at ICF13 and especially Cottrell's contribution to the creation of ICF. Following the "ICFO" MIT Swampscott Conference "Fracture" in 1959 (at which Cottrell was a principal speaker) work began on the creation of ICF. In 1961 at MIT the "Interim International Fracture Conference Committee" was established with Takeo Yokobori (Japan) as Chairman and as Committee Members, Alan Cottrell (UK), Ben Averbach (USA), Jacques Friedel (France), Max Williams (USA), Alan Head (Australia), Peter Haasen (Germany), Norman Petch (England), S N Zhurkov (Russia). Thereafter ICF1 was organised by the Japanese Society for Strength & Fracture of Materials at Tohoku University, Sendai, Japan in 1965 with over 300 delegates from 18 countries.

It is quite interesting to note that two of the key eleven references in the MSc thesis of Alan Howard Cottrell (Birmingham, October 1940 "The Arc Welding of High Tensile Alloy Steels") were Honda & Sekito 1928 and Honda & Nishiyama (1932) both from Tohoku Imperial University, Sendai, Japan. Indeed these were key references in Cottrell's PhD thesis as "Bowen Metallurgical Scholar" supervised by E C Rollason and D Hanson. So

that the fracture research at Sendai and Tohoku University was familiar to Cottrell from at least 1939.

This is all found in the "Cottrell Archive" in the Metallurgy & Materials Library at Cambridge which is also interesting in regard to a sheaf of letters to Cottrell in 1948-1949 when a Lecturer in Metallurgy at Birmingham University from Walter Boas (CSIRO

Australia and formerly Berlin, Germany), M B Bever (MIT, USA), Egon Orowan (MIT USA), W Hibbard (Yale, USA), R F Mehl (Carnegie, USA), Ulick Evans (Cambridge, England) indicating the strong thread of Cottrell's international connections still in his twenties as a young researcher, including with MIT.

ICF2 was held in 1969 in England with 480 delegates from 25 countries. A major driving force in this second conference at which ICF was founded was to be sure Alan Cottrell who presented the Opening Address with Roy Nichols as Quadrennial Conference Chairman. ICF3 was held in Germany in 1973 with some 500 delegates from 26 countries and ICF4 was held in Canada in 1977 with over 750 delegates from 38 countries.

An earlier paper (Taplin & Saxena) outlines the historical development of ICF and this paper along with the full ICF-WASI Archive is available on www.icf-wasi.org now formally launched. This includes the Proceedings from "ICF0", Swampscott 1959 through to ICF12, Ottawa 2009 and indeed ICF13, Beijing 2013 with plans forward regarding ICF14, Rhodes & ICF15, Vancouver, perhaps ICF15 Berlin 2025 we anticipate - plus various additional documents, papers and Interquadrennial Proceedings in a freely available internet library for the new "Academy".

This present paper builds on a Cottrell Forum paper at ICF4 "Fracture & Society" based on interviews with Cottrell in 1977 coupled to a series of interviews with current researchers who are legatees of Cottrell's enduring inspiration. A second part of the present paper focuses on the BCS model and related models devised by Cottrell. A third part of this paper addresses the future of ICF as a World Academy.

Metallurgy is arguably the oldest scientific and engineering profession perhaps seven thousand years old and the metallurgists who helped create the Parthenon attest to this with lead coated iron clamps for the epistyles. Some would argue that metallurgy was mainly a "black-art" until being transformed by such as Cottrell and others in the 1940's & 1950's to a modern science through for example Cottrell's books on Structural Metallurgy & Dislocations.

Cottrell himself was brought-up in Birmingham in the inter-war years of industrial expansion and was trained in the older black-art traditions based on optical metallography and one can discern this old (more art than science) tradition in Cottrell's MSc/PhD theses of over seventy years ago. In particular there are just two equations in Cottrell's PhD thesis on pages 38 and 83 which are simply stress calculation formulae. The thesis is based on simple tests and extensive optical metallography with an entirely qualitative approach consistent with the evolution of metallurgy as a discipline at that time.

Jim Charles was the first lecturer appointment Cottrell made at Cambridge as Goldsmiths' Professor in 1960 who one could deduce continued the black-art intuitive approach also researching archeo-metallurgy creating a wider perspective for the more modernistic new lecturers such as John Knott appointed by Cottrell at Cambridge. Knott worked with

Cottrell from 1959 on his PhD on fracture of steels and therefrom until 1990 the Cottrell-inspired Knott Group was extremely active in our discipline. Indeed Knott is arguably Cottrell's foremost research student and co-worker who has made massive contributions (including as ICF President) and after over twenty years at Cambridge from 1990-present transferred his group back to Cottrell's alma mater Birmingham very successfully.

Arguably the most lasting contribution of Cottrell was through his years at Cambridge especially as Goldsmiths' Professor. Indeed a new "Cottrell Chair" is planned to be established at Cambridge in 2014 via especially contributions from former students of Cottrell. Probably the most prominent successor to Cottrell as Goldsmiths' Professor is Colin Humphreys who held this prestigious Chair from 1991-2008. Evidence suggests that the most significant research accomplishment (2000-2013) of Humphreys in the Cottrell tradition is on crack prevention/stress management in the manufacture of GaN for LED applications. Humphreys has also been Director of the Rolls-Royce Technology Centre at Cambridge since 1994 focussing on nickel-base superalloys with many outstanding achievements of this Rolls-Royce Centre. This is linked also to his appointment in the early 1990's of Julia King to replace John Knott when he left Cambridge for Birmingham and to be Deputy Director of the Rolls-Royce Centre, later joining Rolls-Royce as Director of Materials in Derby. King was a key appointment of Humphreys as Goldsmiths' Professor just as Knott was a key appointment of Cottrell himself when Goldsmiths's Professor.

A key Cottrell Legacy is also the many world-class and very influential series of textbooks and programmes of Mike Ashby on Materials Design.

In addition to ICF and the new World Academy the chief guardians ongoing of the Cottrell Legacy are Knott, Humphreys and Ashby and in a further paper we shall explore these legacy aspects of Cottrell.

There is an extensive oral interview of Cottrell in the archives of the British Library which covers his whole career anecdotally and since Cottrell's death there have been very many tributes and obituaries published including an extensive review by John Knott which is available now on the www.ICFWASI.org website. Accordingly there is no need to here delve in to the very many books and works by Cottrell, his great fount of ideas that inspired generations of researchers and transformed various realms of science and engineering. Our task is to examine the international inspirations and legacy of Cottrell especially in the discipline of our newly burgeoning World Academy of Structural Integrity and the contribution to Society. Documents from Trevor Churchman, Harold Paxton, Jacques Friedel & others have come to light via ICF and Ron Armstrong is assembling a parallel paper to our own to thereby create a debate in a Cottrell Forum at ICF13. So that this paper is simply one short introduction to this Forum which is additionally designed to address the further metamorphosis in comprehensive substance of the new "Academy" through ICF14 in Rhodes in June 2017 and to ICF15 in Vancouver in July 2021 as a ten year project.

Already noted is the new Academy Internet Library launched in Turin, Italy in August 2012. The Gold Medal prestigious awards in the names of the three most significant creators of ICF based on a micro-macro vision, Takeo Yokobori, Alan Cottrell and George Irwin were established at ICF12 in Ottawa in July 2009. Building on the original ICF Interquadrennial in Beijing in November 1983 we now have a comprehensive programme of several Interquadrennial Conferences each year. As well we now have a global network of MoU agreements with various societies and institutions. There are plans at ICF13 to establish a programme of "ICF-WASI Regional Directors" – perhaps as

many as a dozen to create a proactive Academy programme regionally for the common good. Many other significant ideas have been mooted for the new Academy and all these should be explored for the beneficial development of our Academy here in Beijing.

May 3 2013