Timoshenko acceptance speech, Norman A Fleck, November 2025

Introduction

Thank you Narayana for your warm introduction, thank you AMD awards committee, and congratulations to the other awardees. It is a real pleasure to get together in-person with many old and new friends. Fortunately, the dark days of on-line meetings during the covid years have passed and we can interact again in 3D, and enjoy the enriching human social experience of eating and drinking together, and enjoying each other’s company.

Being awarded the Timoshenko medal is a big event in my professional career. It is humbling and touching to be first nominated and then awarded this medal by ones colleagues and, hopefully, this means that some of my papers have been read, or at least are referred to. I want to thank Vikram Deshpande, John Willis, Bob McMeeking and John Hutchinson in particular for their support over the years. Sadly, I do not have the time to mention everyone by name.

The list of previous Timoshenko awardees contains many of my heroes. And, from their continued productivity, I can only assume that the Timoshenko medal is not a lifetime achievement award in the sense of saying to me ‘enough is enough, time to stop’. Rather, it is an encouragement to stay active until I come to the point where I am asked only to give nostalgic after-dinner speeches such as this one.

My old mentor and professor, Ken Johnson, who was the 2006 Timoshenko medallist and affectionately known as KLJ once told me, with a twinkle in his eye, the story of an elderly retired professor being visited by his grandchild. The grandchild saw 3 medals in a bottom drawer and, pointing at one, asked ‘why did you get that medal, Grandad?’

The grandfather replied ‘Well, I got that medal, because I previously got that medal’, pointing to a second medal.

‘But why did you get that second medal?’

‘Well, I got that one because of this third medal. But that third one was a mistake.’

Ken remained humble and down to earth all his life, and I have noted a similar trait in many other Timoshenko medallists. Thus, I am delighted to join the distinguished list, particularly as the first Irishman to do so. Of course, there were many Irishmen who predated the Timoshenko medal and were eminently qualified to receive it, for example Sir William Hamilton from Dublin who came up with Hamilton’s Principle and was the first foreign member of the American National Academy of Sciences, and William Thomson from Belfast who later became Lord Kelvin.

The Timoshenko lineage

My links to Stephen Timonshenko are tenuous. I am not Ukrainian and I did not go to Stanford. But, as I shall explain, my career has been interwoven with joint projects between friends and collaborators in the US and UK. A slim thread of connection with Timoshenko does however exist. Norman Goodier came from Lancashire, England and went to the University of Michigan to be a student of Stephen Timoshenko. Goodier not only co-authored major text books with Timoshenko but married his daughter Marina. After this, Goodier had a sabbatical in Cambridge and was kind and generous in his time in teaching and mentoring Ken Johnson, who in turn was my early mentor. Such generosity of spirit and attention to technical detail permeates the personality of many leaders in mechanics. It is a fine characteristic to be passed down from one generation to the next.

As Vice President of IUTAM, I asked myself, surely Timoshenko was involved in ICTAM or IUTAM? So I asked AI. The reply was ‘No, Stephen Timoshenko did not attend the International Congress of Theoretical and Applied Mechanics (ICTAM). The first International Congress of Theoretical and Applied Mechanics (ICTAM) was held in 1924, by which time Timoshenko was already in his mid-40s and had already established a significant professional reputation.’

Although IUTAM claims to be the global voice of mechanics, it is clear that in the early 1920s Timoshenko already was a global voice of mechanics, and so he had no need of IUTAM. von Karmann and G I Taylor were also global voices in mechanics at that time, and in contrast both of them were heavily involved in IUTAM and its international congress ICTAM.

So, if I did not know Stephen Timoshenko, what then are the stepping stones in my career in the field of mechanics?

Early Life

I had a fortunate childhood growing up in a rural part of Northern Ireland. I was raised in a family with a strong interest in education and was not afraid of hard work, whether physical or mental. My father was an academic Physicist who never had the opportunity to pursue research, and my mother was a school teacher. I think my early interest in mechanics came from my father. As a young kid (maybe 8 years old), I rediscovered SHM, simple harmonic motion. I still recall the thrill of standing on the dining room table, and fabricating a mass spring system: a knotted array of rubber bands and a silver tea pot. I discovered 3 phenomena:

(i) the period of up and down oscillation is independent of amplitude unless the amplitude gets large and the rubber bands get very stiff.

(ii) Silver is a soft metal that deforms plastically when struck against a hard surface such as the floor, and

(iii) There is competition between fatigue failure and ductile fracture. But I never got to find out the answer to this conundrum as my mother halted my insightful experiments by stopping me damaging the teapot. Had I continued, I expect that I would have discovered damage mechanics at the very least.

This link between theory and experiment, between fundamentals and applications continues to delight me.

Soon after, I was asked to write a school essay on career aspirations. I thought that the age of 8 was a bit young to be asked for such information, but nonetheless I stated that I wanted to be either an engineering professor or the managing director of an engineering company. Looking back, I made the right choice: for me, the financial rewards are less, but the intellectual rewards are greater.

Student days at Cambridge, and post-doc at Harvard

I enjoyed the breadth of the Cambridge undergraduate course, and the challenges of an experimental PhD on fatigue crack growth and the phenomenon of fatigue crack closure. At that time, it was possible to read almost the whole literature on fatigue crack growth, and to learn how to do research, but I lacked the theoretical tools. *Practical* skills always seemed common sense to me. I refer you to Allan Bower's excellent textbook on Applied Mechanics to explain how *theoretical* mechanics is acquired by Cambridge graduate students: it is acquired simply by breathing the same air that Isaac Newton breathed. I continue to lament the lack of challenging graduate courses in the UK. It resembles trying to climb El Capitan in Yosemite for the first time, without ropes and without training. Innate ability can only take you so far.

Despite this lack of knowledge of modern mechanics, I spent a successful post-doctoral year at Cambridge working on a new theory for cold rolling of thin foil, under the guidance of KLJ (K L Johnson). At the time (1983) it was recognized that existing theories erroneously predicted the existence of a limiting thickness of metallic foil, below which it is impossible to roll the foil. A large number of papers were written on the topic (including one by Rodney Hill), and several textbooks were produced, all explaining the existence of a so-called 'minimum gauge'. But they got the physics wrong: they all assumed that full slip occurs between the foil and rolls. The new insight was the fact that slip occurs over only a small portion of the contact region. This new theory (and the associated new conceptual framework) was quickly adopted by the industry via a control algorithm used to control the rolling mills.

Whilst I was adept at sketching slip-line fields, which was a local art form under the tutelage of Bill Johnson and in the home town of Rodney Hill, I realised that the only sure-fire way to become educated in solid mechanics was to take tough graduate courses, ideally under the tutorship of world leaders. And so I packed my bags and went off to Harvard to learn about plasticity, fracture mechanics and applied maths from John Hutchinson, Bernie Budiansky and George Carrier, all Timoshenko medallists. Jim Rice had also moved from Brown to Harvard by that time, but sadly I did not take any courses from Jim as he was on sabbatical leave at that time. It is ironic that much of the Hutchinson course on plasticity theory comprised a lucid exposition of the rather concentrated pioneering papers by Rodney Hill: Hill's papers were too dense for my inexperienced taste. So, I acquired a theoretical tool-kit at

Harvard that was augmented in later life through collaborations with my good friend, Timoshenko medallist John Willis.

Over the years I have had the good fortune of maintaining close links with my Harvard seniors and teachers. In the case of John Hutchinson, it was boosted by the fact that his father grew up in Ireland in the neighbouring farm to that of my own father. The Hutchinsons and Flecks dominated the village classroom and remained good friends.

Stepping stones in research journey

I would now like to mention a few of the topics in my research journey that highlighted to me the importance of critical experiments to identify new physics. I will state the obvious: experiments reveal the Achilles heel of a material that calculations can miss. Also, new phenomena may require the identification of new physics, new theoretical approaches, and new computations. The theory provides a conceptual framework but it is the experiments that reveal reality.

Compressive failure of Composites

When I began my lecturing career in Cambridge in 1985, I was ambitious to kick-start some new research projects. The Royal Aircraft Establishment (RAE) Farnborough approached me to work on the compressive failure of composites. The composites community was well versed in laminate plate theory but not in plastic buckling theory. It was commonly assumed that the compressive failure of long-fibre composites is dictated by the shear modulus on the basis of a very nice 1965 paper on elastic shear buckling by Rosen. The Rosen analysis predicted that the elastic buckling response is imperfection *insensitive*. However, the observed compressive strengths are imperfection sensitive and about ¼ of the shear modulus. Why? Ali Argon and then Bernie Budiansky correctly identified that compressive failure of long fibre unidirectional composites is by *imperfection-sensitive plastic buckling*. I performed a number of experiments to support this, and collaborated closely with Bernie to develop the theory further for multi-directional laminates under multi-directional loading. We deduced that a fibre misalignment of a few degrees was sufficient to knock-down the compressive strength to the observed values. In turn, this led to a collaboration with a local company Hexcel in the development of highly aligned fibre composites, and to collaborations with Tony Evans at UCSB and Brian Cox at Rockwell International: both were interested in metal-matrix and ceramic-matrix composites, particularly at elevated temperatures.

For me at that time, the golden age had dawned, whereby some of the stellar PhDs from Harvard would cross the pond to finishing school at the other Cambridge. At the very least, they learnt how to hold a knife and fork at College feasts. And, I think they enjoyed the change of scene, before returning to the US. Although the main elements of the mechanics of fibre composites was largely understood by the late 1980s, publications continued in the field and continued experiments supported the new theory. More recently, the so-called wonder-material of multi-layer graphene has appeared on the scene, and it was rewarding to show that its very low compressive strength is again due to plastic microbuckling. New materials are not always fit-for-purpose, regardless of the hype, and regardless of the large sums of research funds that are thrown at them.

The interface between Materials Science and Solid Mechanics

Advances are frequently made at interfaces. Not just interfacial fracture, thin films, and other physical interfaces. But also the interface between fields. Take strain gradient plasticity as an example. The Materials community (Cottrell, Nye, Ashby) all realised that geometrically necessary dislocations arise from strain gradients, and a wide range of size effects exists in the metallurgical literature. But there was no satisfactory macroscopic theory. Thus, it was necessary to extend plasticity theory to the world of plastic strains and plastic strain gradients. I have fond memories of learning some of the mysteries of single dislocations and dislocation arrays from Mike Ashby, and then rephrasing it at the continuum level with John Hutchinson. Experiments followed, such as the torsion of thin copper wires, and micro-indentation. It was non-trivial to ensure that the observed size effects were real and not experimental artifacts. But the field is now established, not least by the emergence of a wide range of small-scale experiments by the community.

Recently, Li ion batteries have emerged as a ubiquitous storage device for energy. They are full of electro-chemical interfaces and fail by a wide range of mechanical mechanisms. The research activity into Li ion batteries sits at the interface between Chemistry and Mechanics, and in order for advances to be made the two communities need to realise that they need each other. Many of the observed failure mechanisms are generic and are not eliminated by tweaking the chemistry alone. However, it remains a challenge to identify the operative mechanisms of degradation and failure, and thereby generate quantitative models that are useful to industrial partners.

The UK team and MURIs

My subsequent career has been dominated by a succession of successful Multi-University-Research-Initiative (MURI) projects under the leadership of the late Tony Evans. This was the era of UK meets MURI. There was Tony Evans (the commander in chief, from Wales and UCSB), Bob McMeeking (Scotland and UCSB), Mike Ashby (England and Cambridge), Haydn Wadley (Border country between England and Wales, and UVA), John Hutchinson (honorary Irish and Harvard), Lorna Gibson (Canada and MIT) and myself (Ireland and Cambridge). There was a steady flow of challenging projects that involved design, manufacture, test and application of first metallic foams, then lattice materials and finally the dynamic response of sandwich structures. Each project was successful in terms of new science and new applications. Advances were made by discovery of new physics through critical experiment and supported by predictive theory. Industrial impact was more challenging as it required close links with industrial partners, and mechanisms for technology transfer such as material subroutines in finite element code. Tony Evans was particularly adept at being the glue between the two communities. Much of this research was grounded in the pioneering textbook by Gibson and Ashby on cellular materials, and I strongly recommend that anyone working in micro-architected materials, including additive manufacture, should read this monograph before publishing their own papers, as there is no point in re-inventing the wheel. Indeed, this was a major life-lesson that I learnt from my colleagues: when a problem in mechanics is solved, it is solved, and it is best to move on to a new problem.

Advice

What then is my advice to the next generation? Stay young by being intellectually active and physically active. Take up new problems. GI Taylor jumped from mountaintop to mountaintop in his research due to his creativity, extensive toolkit and internal motivation to work on new problems. In contrast, an old Cambridge colleague once said ‘You cannot teach an old dog new tricks’. At the time, I realised he was really saying, ‘I have lost my passion for research’. My advice: do not lose your passion for solving challenging research problems. And if you do, then do not worry but move on to something else, and make way for the young. By working with young people, you yourself stay young, and remain humble.

I close with some words of latin that I had to recite recently in the chapel of Pembroke College to my university colleagues at the time of admitting a the new Head of College. This exhortation is several hundred years old but remains relevant today:

Pos**trē**mō, **om**nēs **hu**jus Socie**tā**tis **So**ciōs

hor**tā**mur ut **op**timīs **stu**diīs sē **tō**tōs **cōn**secrent,

Sta**tū**ta **nos**tra dīli**gen**ter et fi**dē**liter ob**ser**vent,

nūllam **cal**lidam aut si**nis**tram

interpretāti**ō**nem **con**trā ip**sō**rum **sēn**sum ad**hi**beant.

And in English: *Finally, we exhort all Fellows of this Society to consecrate themselves to good learning, to observe our statutes diligently and faithfully, and attach to them no crafty or underhand interpretation contrary to their intention, but hold them firm and fixed.*

Or, rephreased, beware of hallucinations in AI! Be honest and true to our field equations, and constitutive laws, and be honest in our publications.

Finally, we do not need to fear that we will run out of problems, as technology continues to advance. There are challenges and opportunities as never before. For example, how do we embrace AI without losing our physical insight and individual creativity? Thanks for listening and many thanks again for awarding me the 2025 Timoshenko medal.