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Light metals shape the future of flight

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Deep within the labyrinth of Monash University's Clayton campus in Melbourne is a metallurgy laboratory so significant in what it is doing that it has attracted some of the biggest companies in the global aerospace industry from the other side of the world.

They are keeping close to the technology that could make this laboratory the genesis of the next generation of aerospace manufacturing. They are also keeping close to a scientist in whose hands their futures may well sit.

When Professor Xinhua Wu, recognised internationally as a leader in advanced light metals research, agreed to head the Australian Research Council's (ARC) Centre of Excellence for Design in Light Metals, her research moved with her from the UK to Melbourne. Such is the importance placed on her work that the giants of European aerospace – Bombardier, Airbus, European Space Agency and SAFRAN-Microturbo – followed.

At stake for these European aircraft manufacturers is finding the technological means to ward off increasingly aggressive competition from new manufacturers in Brazil, Canada, China, India and Russia, while concurrently meeting stringent greenhouse reduction targets imposed by the European Union.

Manufacturers are looking for new materials that are lighter yet stronger, cheaper to manufacture, reliably safe and which will also help them halve aviation's overall carbon emissions by 2050.

For Professor Wu and her centre it means changing the very nature of metals such as titanium, aluminium and magnesium, modifying their fine-scale structures to give them new and improved characteristics. It requires advanced industrial research underpinned by fundamental science that is exploring new paradigms in metals and their properties.

A spokesperson for SAFRAN-Microturbo said the company followed Professor Wu to Australia because of her focus on the industrial applicability of fundamental research. This is a critical industry–academia link and for the European Union companies, an essential relationship through which to keep ahead of rivals.

One of the centre's projects is a new aluminium alloy that will make an aircraft 30 to 40 per cent lighter, twice as fuel-efficient and still structurally as strong.

It is already known this can be achieved by adding a tiny amount of a rare element such as scandium to the aluminium when it is alloyed. Just a fraction of a per cent of scandium or other rare earth element is enough to make aluminium stronger, less prone to corrosion and easier to weld. Russia used such an aluminium-scandium alloy for its MiG fighter planes during the Cold War era. But from a commercial perspective, the alloy is prohibitively expensive.

The scientific challenge that Professor Wu's centre has taken on is to determine how scandium works when added to aluminium alloys, and to then find a cheaper substitute.

"We are working at the atomic level. In metallurgy, just a few atoms in a million added to an alloy can influence engineering at the macro-scale; how we control the homogeneity of metal sheeting when it is rolled, or the integrity of the metal when it is fabricated into a component."

However, Professor Wu says the key factor with such industrial research is achieving this economically. "From just a materials research perspective, without worrying about costs, we can make the most wonderful metal and alloy materials. But the goal is not just to develop stronger, lighter, more durable and more stable metals. They must also be produced through more efficient and cheaper manufacturing with lower energy consumption, both during construction and during the aircraft's operational life over 25 or more years. We have to create new materials that not only have the best performance but are also the cheapest.

"This is what makes industrial science exciting. Yes, the fundamental science must be good, but it is the industrial science that has to deliver this material, functionally and cost-effectively, to industry. And it doesn't stop with developing the material; new manufacturing processes have to be designed for each new material developed."

Professor Wu's approach to science has been strongly influenced by the 20 years she worked with the Rolls-Royce aerospace division – "a technology-driven company and world leader in materials technology and manufacturing".

It has imbued her with a robust 'can-do' attitude, which is why other major European companies have set up collaborations with her and her centre. "It is because we deliver on the promise," Professor Wu says.

Her own special field of interest is titanium metallurgy. Aside from the offer by Monash to replicate her research facilities in Melbourne, the other attraction of moving from the UK was that Australia has 51 per cent of the world's known titanium ore deposits. She was keen to apply her metals science closer to its raw materials.

Professor Wu has been involved extensively in developing titanium and titanium aluminide (TiAl) alloys, and in advanced powder processing for titanium and nickel alloy powders.

Her most recent research has been into the development of innovative manufacturing technologies such as 'laser additive' manufacturing and net-shape hot isostatic pressing (HIPping), which are able to produce complex 3-D components from computer designs in a single step. It is anticipated that this alone will reduce material wastage by 90 per cent, cut overall manufacturing costs by 30 to 50 per cent, and reduce the lead time from 24 to three months for titanium, nickel, aluminium and steel components.

This is the advanced technology that Professor Wu has brought to the ARC Centre of Excellence for Design in Light Metals, which is a collaboration of six universities and more than 100 researchers. Professor Wu wants to build an Australian aerospace industry from this core research. "It is a global industry. It doesn't matter where you are," she says. "Industry will follow the delivery of innovation and science."

Already her team has developed several new engine components for one of the European aerospace companies, and these are undergoing early evaluation trials. "If they pass – if they are lighter, equally durable and cheaper to manufacture – this company is prepared to offer an exclusive six-year manufacturing deal for an Australian company to manufacture these components. This demonstrates the incentives on offer to encourage Australian manufacturers to take up the challenge, noting the preference for new technology manufacturing to be close to the innovation and science.

"We are delivering on the science and innovation, but so far haven't found a manufacturing partner. We realise there are no existing companies with the expertise, but that is what we are providing … in abundance. We need a far-sighted company willing to invest in this."

It is an interesting challenge, coming at a time when the traditional manufacturing sectors in many of the world's so-called rich countries are suffering a crisis of confidence. Professor Wu is trying to overcome this by articulating her belief in the 'third industrial revolution': the discovery of new materials and engineering these materials at the molecular or 'nano-structural' level. Coupled with this is the emergence of laser additive manufacturing and net-shape HIPping technologies, which she says set free the production of complex 3-D components from the shackles of dated manufacturing practice and can bring manufacturing from low-cost economies to the innovative, high-technology ones.

In her own work Professor Wu believes she has a two-year edge on rival researchers elsewhere. "If in this time we cannot establish manufacturing capability in Australia, the science will move on … and with it the industry that Australia could have had."

This is an industry, she points out, that globally generates US$539 billion of GDP per year and desperately needs revitalising. It was estimated by the industry's umbrella body, the Air Transport Action Group, that to reach the target of improving average fleet fuel efficiency by 1.5 per cent per annum from 2010 to 2020, the world's airlines would have to buy 12,000 new-generation aircraft at a cost of US$1.3 trillion.

Further, it would take an investment of ˇ100 billion to deliver the technology required to meet the 2050 Advisory Council for Aeronautics Research in Europe target to cut carbon dioxide emissions by 75 per cent and nitrous oxide emissions by 90 per cent.

"These are the stark realities that these companies are facing," Professor Wu says. "And from these realities are the massive opportunities being presented to us."

Provided by Monash University

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