**00:00:06 Michael Cornish**

Hello and welcome to the Mechanics of Materials podcast from Imperial College London.

**00:00:12 Michael Cornish**

Today we are talking with Doctor Huizhi Wang. Dr Wang is part of the Electrochemical Science and Engineering group in the Department of Mechanical Engineering here at Imperial College London.

**00:00:23 Michael Cornish**

She is an electrochemical engineer with a particular focus on the thermal fluid aspects of electrochemical energy devices such as electrolysers, fuel cells and batteries. As we move towards further electrification of our world, we need a variety of energy storage solutions to meet our needs. One technology is the electrolyser.

**00:00:43 Michael Cornish**

So what are electrolysers and how do they fit into the energy storage landscape?

**00:00:48 Huizhi Wang**

So electrolysers are devices designed for facilitating the electrolysis processes with the basic principle of using electrical energy to drive a non-spontaneous chemical reaction. In simpler terms, it involves the use of electricity to bring about a chemical change. In the context of renewable energy storage,

**00:01:08 Huizhi Wang**

when you have excess electricity, for example, from the solar panels on a sunny day or wind turbines on a windy day, you can use that electricity to run an electrolyser.

**00:01:18 Huizhi Wang**

And if we take a water electrolyser, for example, then the electrolyser can use that electricity otherwise curtailed or wasted to turn water into hydrogen which can be stored and later used for power or heat generation or as a chemical feed stock for various industries.

**00:01:38 Huizhi Wang**

And in addition to the water electrolysers I just mentioned, there are also other types of electrolysers, for example carbon dioxide electrolysers and they use electricity to convert carbon dioxide into synthetic fuels and valuable chemicals that can be used in the existing infrastructure.

**00:01:58 Huizhi Wang**

They do not only provide a chemical storage solution for renewable electricity, but also help to reduce atmospheric CO2 by closing the carbon cycle. So these electrolysis technologies are collectively termed as power to X, meaning that to convert renewable electricity into more storable form, X.

**00:02:18 Huizhi Wang**

And they can complement other storage technologies such as battery storage, allowing for massive and longer duration storage in the form of chemicals balancing the seasonal mismatch of energy supply and demand.

**00:02:34 Michael Cornish**

Another aspect of your research are fuel cells. So what is a fuel cell and how are they used in conjunction with electrolysers?

**00:02:42 Huizhi Wang**

Fuel cells basically reverse the electrolysis process to turn fuels into electricity. Fuel cells somehow, like combustion engines or energy conversion devices, are used to convert the chemical energy stored in fuels into usable form. But they are different from combustion engines in that they use electrochemical reactions

**00:03:03 Huizhi Wang**

to directly convert fuel energy into electrical energy.

**00:03:07 Huizhi Wang**

Therefore, they are not subject to carnal efficiency limits and often operate at higher efficiencies compared to combustion engines. And if we compare fuel cells with batteries, fuel cells have a rapid refueling time and can generate electricity as long as fuel is supplied. Moreover, fuel cells can decouple

**00:03:28 Huizhi Wang**

the energy storage capacity, which relies on the size of the fuel tank and power which relies on the stack size, giving more flexibility in design and applications.

**00:03:39 Michael Cornish**

What are some current challenges with the electrolyser fuel cell system?

**00:03:42 Huizhi Wang**

The technologies are already there. I would say the most significant challenge hindering their widespread adoption is their costs. The costs can be reduced by multiple ways, for example by increasing the power density and durability.

**00:03:57 Huizhi Wang**

And we know higher power density usually means that the same amount of power can be achieved with a smaller stack or fewer materials.

**00:04:06 Huizhi Wang**

This can lead to cost savings in terms of materials, manufacturing and transportation and longer durability usually means less replacement or maintenance costs, and in the case of electrolysers, product selectivity also has a big impact on the cost of the process. High selectivity

**00:04:26 Huizhi Wang**

ensures the majority of the electrical energy is used for the intended products rather than being wasted on undesired byproduct or side reactions. High selectivity can also simplify the separation and purification procedures, leading to cost savings in connection with these steps.

**00:04:45 Michael Cornish**

You currently use the field of Thermofluid engineering to study these systems. What does it mean to study Thermofluid engineering and what problems are you attempting to tackle with this approach?

**00:04:56 Huizhi Wang**

As thermofluid engineers, we look into various transport processes involved in electrochemical energy devices and their interactions with electrochemical reactions. Thermofluid Engineering plays an important role in addressing all the challenges I just mentioned. Take the power density of a hydrogen fuel cell for example. A frequently cited power density targets for automotive fuel cells is 9 kilowatt per litre by 2040, as set by the new energy and industrial Technology Development Organization in Japan, the European Union fuel cells and hydrogen to joint undertaking said a similar goal of 9.3, but with an earlier deadline of 2024.

**00:05:41 Huizhi Wang**

In comparison, the current state-of-the-art taken from the second generation Toyota Mirai stands at 4.4 kilowatt per liter, achieving the set targets would require significant enhancements in reactant supply, heat removal, and electrical conduction

**00:06:02 Huizhi Wang**

in order to minimise the performance losses.

**00:06:05 Huizhi Wang**

And another key aspect relating to improved power density is water management. As we know, water is one of the byproducts of hydrogen fuel cells.

**00:06:15 Huizhi Wang**

If the fuel cell becomes too dry, it can lead to poor conductivity. On the other hand, if there is excessive water, it can flood the electrons,

**00:06:26 Huizhi Wang**

reducing the available surface area for electrochemical reactions and impeding the flow of reactants and products, resulting in a very fast voltage drop at high current densities. And water management is highly coupled with thermal management and we know the heat can affect the evaporation and condensation, freezing and melting

**00:06:49 Huizhi Wang**

of water within the fuel cell. So our job is to develop models and innovative engineering designs to engineer these transport processes with the goal to improve the performance of the electrochemical devices. If we take the power density, for example, again, and by using modeling approach, we have demonstrated by simply optimising the cell structure without shifting to new materials, we can achieve a 46% increase in power density.

**00:07:21 Michael Cornish**

The word Thermo in Thermofluids engineering is quite suggestive when it comes to thermal runaway. As a thermofluid engineer, how do you approach this problem of thermal runaway?

**00:07:31 Huizhi Wang**

Battery thermal runaway occurs when isothermic chemical reactions inside the battery are triggered due to the battery temperature rise. For example, the ACI decomposition or decomposition of battery materials.

**00:07:45 Huizhi Wang**

This can lead in a positive feedback loop to intensify the heat generation and further increase the battery temperature. We create models to describe the thermal runaway

**00:07:56 Huizhi Wang**

initiation and its propagation within a battery pack. By using these models we can perform virtual experiments enhancing our understanding of battery thermal safety and reducing the number of expensive safety experiments needed. Furthermore,

**00:08:12 Huizhi Wang**

our model enables the prediction of thermal runaway and its propagation,

**00:08:18 Huizhi Wang**

offering the potential to develop early warning technologies or other safety countermeasures.

**00:08:25 Michael Cornish**

Where does the funding for your work come from? Do you have any industrial partnerships?

**00:08:30 Huizhi Wang**

Our funding comes from EPSRC, Faraday Institution and Innovate UK and we collaborate with industrial partners spanning various sectors such as energy, automotive, aerospace and chemical manufacturing.

**00:08:44 Michael Cornish**

Well, Huizhi, thank you very much for talking with us today.