**00:00:10 Michael Cornish**

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

**00:00:16 Michael Cornish**

Today we are talking with Professor Maria Charalambides. Maria was the previous head of the Mechanics of Materials division in the Mechanical Engineering department here at Imperial.

**00:00:27 Michael Cornish**

And today, we're going to talk about the mechanics of materials division as well as how to make plastics more sustainable.

**00:00:34 Michael Cornish**

So what does the division of Mechanics of Materials do at Imperial College London?

**00:00:40 Maria Charalambides**

Thank you, Michael. There are three main areas of research in our division. These are: engineering for sustainability, manufacturing optimisation and fundamental mechanics research. The first one, engineering for sustainability includes topics which are key to delivering the worldwide goal to reduce global warming and pollution.

**00:00:59 Maria Charalambides**

For example, we look at how to develop methods for energy storage through a next generation of batteries and hydrogen fuel cells. We optimize materials for controlling nuclear fission and fusion energy generation. We study lightweighting which looks at reducing energy in vehicles, for example by having lighter components. Whether these are metallic.

**00:01:20 Maria Charalambides**

Or composite materials.

**00:01:22 Maria Charalambides**

We look at circular economy and how to minimize the use of valuable virgin material resources through novel methods of recycling of plastics, repair of plastic composites and the redesign of single use plastic packaging. Another example of our work in this area includes determining the optimum display and storage conditions of cultural heritage to achieve the goal of lowering

**00:01:45 Maria Charalambides**

Energy consumption associated with climate control in museums, whilst ensuring such works of art are preserved for future generations.

**00:01:53 Maria Charalambides**

The second theme, manufacturing optimisation and digitisation, looks at how to manufacture various materials more efficiently. For example, we develop novel metal forming technologies. This development is underpinned by models predicting material microstructure evolution during forming.

**00:02:12 Maria Charalambides**

We are creating the factories of the future by extending the state-of-the-art in additive manufacturing, harnessing its vast potential through digital transformation and smart instrumentation.

**00:02:23 Maria Charalambides**

Our work extends to manufacturing of a vast array of materials, including metals, ceramics, and foods.

**00:02:31 Maria Charalambides**

The latter, similar to the manufacturing of engineering materials such as metals, needs insight into the microstructure evolution during production.

**00:02:39 Maria Charalambides**

We're developing novel computational tools for designing products which will meet consumer demands and sensory perception, as well as meet our need to produce food structures with controlled digestive performance towards improving human health.

**00:02:54 Maria Charalambides**

The fundamental mechanics research team is the backbone of our research efforts, enabling the solutions summarised above in the landscape of sustainability and manufacturing.

**00:03:04 Maria Charalambides**

Our division is unique as it encompasses experience in understanding and predicting performance of a vast range of materials, metals and alloys, ceramics, polymers, composites, foods, coatings, foams,

**00:03:19 Maria Charalambides**

Gels and adhesives, we study their behavior and the impact fatigue creep loading under a range of conditions including temperature and humidity. We develop modeling and experimental techniques to enable us to build multiscale models linking the microstructural makeup to the macro scale mechanical response.

**00:03:38 Michael Cornish**

The transition to zero

**00:03:40 Michael Cornish**

pollution is a large theme inside Imperial College. How can engineers of materials help to achieve this goal?

**00:03:46 Maria Charalambides**

OK, so engineering is actually a fascinating field to be working in right now.

**00:03:51 Maria Charalambides**

It is obvious we can no longer continue on our current way of doing things. We urgently need to limit carbon emissions to fight global warming and its devastating effects on our planet. Engineers are probably the best equipped profession to help solve the climate change crisis with our unique analytical and problem solving skills by training.

**00:04:12 Maria Charalambides**

We’re best placed to develop new ways of energy production and storage, manufacture, sustainable materials and design recycling.

**00:04:18 Maria Charalambides**

Processes reduce waste manufacturing proposed high performance, but lightweight materials for transport limit carbon emissions from climate control in buildings, etc. These avenues I just mentioned are all currently research from our engineers within our mechanics and materials division. It is very exciting to be part of this mission, to change things for the better.

**00:04:39 Michael Cornish**

So next we'll jump into the topic of the circular economy for plastics.

**00:04:43 Michael Cornish**

So Maria, what is the problem with plastics? How do they affect the environment and what are their sustainability issues?

**00:04:49 Maria Charalambides**

Plastics are receiving a very bad publicity in recent years, for example by images of oceans littered with such materials after consumer use, we have all seen terrible images of empty drinks, bottles, plastic packaging, etcetera, swirling around in our seas and waterways, or washed out on coastlines and beaches. However, we need to remember that

**00:05:10 Maria Charalambides**

plastics are actually a fantastic material, offering several opportunities for new and optimized products.

**00:05:15 Maria Charalambides**

For example, they're used in food packaging in very clever multilayer designs and therefore reduce food waste, so they actually help solve environmental concern related to food waste.

**00:05:26 Maria Charalambides**

The concerns related to such food waste include the production of methane gas during food decomposition, the waste of valuable natural resources, carbon emissions during production of the food that will go to waste, and so on.

**00:05:38 Maria Charalambides**

Another example is that plastics are lighter than glass, so transporting plastic bottles as opposed to glass bottles leads to less energy spent during transport.

**00:05:47 Maria Charalambides**

So the advantages of plastics need to be kept in mind. Having said that, we need to come up with ways to use them more sustainably than what we are doing at present, limiting plastic pollution on our planet.

**00:05:58 Maria Charalambides**

Synthetic plastics are produced from fossil fuels, and as such we need to limit the production of single use plastic products from virgin.

**00:06:06 Maria Charalambides**

We need to develop a systems approach for circular economy where technological innovations and environmental policy can work synergistically to recycle and reuse plastics at much higher rates than at present. We need to upgrade the infrastructure in waste management companies to include more plastic types and mix plastic of smaller sizes.

**00:06:26 Maria Charalambides**

Finally, we need to rethink and redesign single use plastic products such as packaging with recyclability, strict design constraint.

**00:06:34 Michael Cornish**

What's the main goal of this research project? What would a sustainable future for plastics look like?

**00:06:40 Maria Charalambides**

OK. Within Mom with mechanics and materials Division, we're looking at various possible ways for how we can help. For example, we're focusing our efforts on multilayered plastic packaging widely used in packaging industries such as consumer goods, foods, pharmaceuticals. This packaging is essentially layers of different materials, laminated or extruded.

**00:07:01 Maria Charalambides**

Together, each layer having a specific purpose or function, mechanical support, barrier, protection against light, oxygen, and

**00:07:09 Maria Charalambides**

the trouble with such packaging is that because it is made out of different materials, it is very difficult to recycle and usually ends up being delegated to mixed plastic waste that then goes to either landfill or incineration, both of which are things we need to avoid if we are to move to more sustainable circular economy. So there are two contrasting

**00:07:30 Maria Charalambides**

solutions for this problem, either we do not try to separate the various material layers and try to blend them together to make a new composite material that can find used in new products, or we try to separate the layers such that they can each be mechanically recycled in their in their respective single plastic material streams.

**00:07:49 Maria Charalambides**

We're looking at both of these solutions.

**00:07:52 Maria Charalambides**

For the route towards blending a new composite from a mix of plastics, we're developing computational models that quantify how the strength of the interface between the various materials during blending of the multilayer plastic impacts on the mechanical properties of the new composite. This is relevant because there are various materials called compatibilisers on

**00:08:12 Maria Charalambides**

the market, whose role is to enhance the interface between the various polymers. So for the first time we have been able to show that we can't predict what the mechanical properties of the composite will be as a function of this very important interface behavior.

**00:08:27 Maria Charalambides**

For the second solution, we're looking at ways for how we can separate the various layers of the multilayer packaging to facilitate recycling in single waste streams.

**00:08:36 Maria Charalambides**

For example, we have designed laminates where adhesion is not uniformly applied between the base layers, but only in controlled areas or patterns leaving circular areas in the laminate where adhesion is weak. As a result of this during shredding, which is a common step in mechanical recycling processes, if we shred to areas

**00:08:56 Maria Charalambides**

smaller than the imposed adhesive pattern, we will release the non adhered.

**00:09:02 Maria Charalambides**

In addition, we have tested water soluble into lever adhesive, which can be easily removed during the washing stages of the recycling process. A more recent endeavour is to see if we can combine mechanical with biochemical recycling to unlock possible synergistic effects towards recycling of hard to recycle materials such as flexible packaging.

**00:09:22 Maria Charalambides**

So our work can lead to solving this specific problem related to the non recyclability of single use, multi layered packaging which make up the largest portion of non recyclable packaging.

**00:09:34 Michael Cornish**

What kind of alternatives or solutions can we develop for single use plastics from fossil fuels?

**00:09:40 Maria Charalambides**

Most of our plastic is made from fossil fuels, gas and oil.

**00:09:43 Maria Charalambides**

More recently, because of environmental concerns, the use of natural raw materials to make plastics has evolved. For example, using corn, sugar cane, straw, food waste, or potatoes, known as bioplastics. Having said that, there is an active debate going on whether bioplastics is a solution to end plastic waste.

**00:10:04 Maria Charalambides**

That is because not all bioplastics are biodegradable, or if they do degrade, they do not do so more readily than fossil fuel plastics. In addition, other problems are that even when these new bioplastics biodegrade,

**00:10:18 Maria Charalambides**

the question is, under what conditions do they do so? Do they need an industrial composting facility with high temperatures or can they biodegrade in the natural environment? What if they land on the bottom of the sea with no light and cold temperatures?

**00:10:32 Maria Charalambides**

There are also concerns that degradation into smaller particles can be a danger to marine ecosystems and water, like in the case of ordinary plastics, which degrade to smaller and smaller particles or microparticles.

**00:10:44 Maria Charalambides**

Another complicating matter is that consumers cannot separate biodegradable plastics from ordinary plastics. And if these two are mixed, it makes recycling even more difficult than it is now.

**00:10:55 Maria Charalambides**

My interest will also be on the mechanical properties of these bioplastics, as compared to the ordinary plastics. Can they be used for the same applications? For example, there are many questions that need to be answered here, so still a very active research field.

**00:11:09 Michael Cornish**

How can waste and plastic use be prevented and reduced?

**00:11:13 Maria Charalambides**

This needs large multidisciplinary teams from very diverse fields. You cannot solve such big societal problems with a team made from a single expertise. Technological advances related to better, more efficient recycling need policy interventions to ensure that such technologies are taken up.

**00:11:31 Maria Charalambides**

Often at the very early stages of a new technological advance, because of the small scale and limited initial uptake, such advances are often dearer. So incentivisation and policy become very important. At this stage, consumer behavior is also obviously a big part of the whole puzzle. But together, scientists, engineers in collaboration with governments and NGOs

**00:11:52 Maria Charalambides**

make the much needed difference that's needed to solve this huge problem.

**00:11:56 Michael Cornish**

How do Mechanical Engineers contribute to this work? Can you give a specific example?

**00:12:00 Maria Charalambides**

Yes, of course. Mechanical Engineers have the right skill set to contribute in this field. They can help with bringing up answers to various problems, such as how do we redesign the packaging such that it can be more easily recycled? What potential applications can recycled plastics be used for, and how can we improve their performance such that they do not get

**00:12:20 Maria Charalambides**

downgraded to a less valuable product.

**00:12:23 Maria Charalambides**

How can we improve mechanical recycling processes to increase the recycling rates which are only currently 15% in Europe? Is there a clever way we can solve the problem related to contamination in the high variety in plastic waste streams?

**00:12:37 Maria Charalambides**

Can we get smarter sensors for sorting if we are to reuse plastics for longer in certain applications? What materials will we need that will be more durable for longer product life? These are only some of the many questions that a mechanical engineer can get involved with.

**00:12:53 Michael Cornish**

So Maria, who's working on this project?

**00:12:54 Maria Charalambides**

At Imperial, we have a large team working on producing cleaner, greener plastics.

**00:13:01 Maria Charalambides**

We can therefore tackle this great societal problem using a systems approach rather than with isolated focus solutions that only tackle a small area of the issue. So here in Mechanical Engineering, we're working on easier to recycle multilayer packaging as we already discussed.

**00:13:16 Maria Charalambides**

In Chemical Engineering, they're developing novel methods to enable chemical recycling for difficult to recycle products such as multilayer packaging. The advantage of such processes is that the plastics can be turned back into their raw materials, that is, their individual monomers, such that new polymers can then be made.

**00:13:34 Maria Charalambides**

In Aeronautics they’re looking at making better use of post consumer mixed waste, using additives and reinforcing fibres.

**00:13:41 Maria Charalambides**

At our Design school, they're developing models for understanding user perception of sustainable consumer goods. They consider the entire life cycle of products and aim to produce closed loop material flows. In the Materials department, research is underway to understand possible

**00:13:56 Maria Charalambides**

toxicity on issues related to degraded plastics and the so-called microplastics, the small fragments produced when plastics degrade and find themselves in the human body, for example.

00:14:08 Maria Charalambides

And in our Centre of Environmental Policy, they investigate policy interventions that most effectively incentivise positive changes to reduce waste generation in the first place or improve recycling rates. There are many others within Imperial, which I'm not mentioning here, also outside Imperial, that are working on solving this immense research challenge.

**00:14:29 Maria Charalambides**

So there is a lot of hope that we will collectively make advancements that will manage to control and reduce plastic pollution.

**00:14:37 Michael Cornish**

And finally, where does the funding come from? Are there any industrial partners or other beneficiaries?

**00:14:43 Maria Charalambides**

Funding comes from the UK Research Councils, especially the Natural Environment Research Council. Also for ideas closer to commercialisation and application, Innovate UK. This is a hot topic at the moment on lots of agendas. Industrial supporters are big packaging industries, polymer processing manufacturers as well as industries that use the packaging

**00:15:03 Maria Charalambides**

Such as consumer goods and the food industry.

**00:15:06 Michael Cornish**

Thank you, Maria. We are very happy that you came to speak with us today and we're excited to see where your research goes into the future.