

MSE 440 Towards sustainable composites?

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The last presentation is called towards sustainable composites. It's saying that, yeah, we're not there yet and we have further to go. And I've only included some aspects and you may always say, hey, I know about something else that should be here. Well, if you do come and tell me. Okay. Put it in for next year.

We're going to look at these different things. Policy, materials, applications, some manufacturing, three printing, and some challenges.

First thing I want to talk about is policy. When you leave here, there are some policies that you need to know about. One is the Green Deal. Anyone heard of the Green Deal in the EU? Keep people nodding. The European Commission a set and proposals to try and reduce greenhouse gas emissions. And set these targets. Some relates to renewable energy and some relate to transportation. These targets are things that industry needs to work on to meet these green deal objectives. In the European Union, they can't sell these disposable stirrers for coffee anymore, okay? Things are changing and it affects companies and what they're working on.

To prepare this lecture, I spoke to five polymer companies. Interviewed them.

One thing that you need to know about is reach, which is the registration, evaluation, authorization, and restriction of chemicals. This is European legislation. So some composite ingredients that we used to use are now bands under reach because the chemicals were hazardous. Okay, so it's a legal framework and you need to know about this thing or reach that affects substances that are often used in composite processing. Just store that word in your head, you haven't got time to go in depth into it. You get people in companies who spend their entire career looking at reach compliance of the company's products. Okay.

Another one is the End of Life Vehicle Directive in the European Union, which basically is basically says, we need to reuse and recycle 85% of the car. There is legislation at a European level that affects the end of life vehicle that we have to meet.

Okay, we're going to look at, first of all, materials from an end of life and recycling perspective. And then we'll look at biobased materials from End of Life and Recycling.

This is an upside-down pyramid where we want to try and prevent reuse, repurpose, recycle, recover. Okay, so we want to keep parts for longer. Design for dismantling, that's the design part of the process. We want to reuse components that can be maintenance and repair. We want to repurpose to keep parts going often in a different application.

Then you come to recycling, which is where most people think about composites in terms of lifecycle analysis and the different approaches. Chemical, mechanical, you can do a range of processes here to recover materials, but the desirability is highest at the top. Not just recycling but preventing.

The automotive recycling approach today is you take your old car and you take out the fuel and you drain your oil from the shockers absorbers. You remove the catalytic converter, you dismantle some nice to have parts like bumpers, big plastic components. And then you take it to the shredder and you crush it. And you turn it into small particles of material that gets rid of about 80% of the vehicle. Unless you've dismantled your composite part, it's going to end up like this. In the future, we need to dismantle more components from the vehicle. What you get is called automotive shredder residue. And there's a lot of this, we haven't got time to go into this slide in lots of detail. And there's two fractions, what they call shredder fluff, which is all this bulky plastic stuff, seating, but it's also contaminated with hard to recycle materials and then there's a heavier fraction. Car Companies often make statements that this will be future treated using new technologies to a greater extent, but they haven't yet got it figured out. Be aware of this and be critical ways to recycle plastic from the end of light vehicle. Well, you can landfill. You can burn it to recover energy. You can use it to fire a cement kiln. You can use the feedstock and the blast furnace approaches. There are some better ones. These are the dominant polymers that are in this residue. But often it can be quite expensive to recover the materials. Landfill is becoming illegal in European Union that's going out. Only three, 4% of plastics in cars are currently really recycled.

In aerospace, there is no equivalent legislation to the end of life vehicle. Currently, you've got 2000 aircraft parked in the desert in the US or other places and a lot more military aircraft. Over the next 20 years, there'll be about 5,000 airliners to be brought from service. Airbus had a project called Pamela, looking at recycling, but the only commercialized method from this research for composites is to grind them up for use as filler materials, in rods or in sheet molding compound. You take your old Airbus, it's got a carbon fiber tail today, that's what happens to it and it's not good enough. We need to go further than that. With recovering materials are very valuable. It's one company in the Netherlands where they buy old aircrafts, they take them to pieces. And there's actually a database online where you can rebuy parts of the aircraft, service your Airbus. They're starting to go that way, but there's no legislation for aerospace, end of life, I was very surprised.

Glass fiber composite. If you look at wind energy, E.g. what they do is they take the wind turbine, they chop it up into big chunks using mobile source logging machinery, I suppose. Then they get this regrind. What they like to use it for is to replace hydrated or carbonated materials in portland cement. And that's a fuel for the cement furnace. And they say that that can deliver 15% of the CO₂ emissions needed, depending on how much of it you put in, in the cement industry to power the furnace and to help become part of the cement itself. But again, that's not really going far enough. You're losing so much value.

We can also try and recycle by solvolysis, physical chemical separation. So you put your piece of composite with solvent pressure and heat and you get fibers back. That is a way of recycling thermoset composites using solvolysis. That's interesting and there's a company here called Carbon. They were recently purchased and they are here in terms of technology readiness level TRL eight and very attractive. They now take old bicycle frames and bits of carbon mats and they put it on the conveyor belts and it goes into an oven without oxygen and they can get the carbon fiber back, but it's all manual, you see in the video. And people cutting out these things with scissors and Pals and putting it on a conveyor belt so it's not as automated as those other factories that you saw at Airbus or BMW. So you run the risk actually, that it costs more than the Virgin material. But nevertheless, this company has converted waste into a variety of material feed stocks, either random fiber or chopped. They can't make a line fiber, you can't get back from woven product to UD material. Very difficult. But they've made a whole range. Well, their customers have made a whole range of products from recovered carbon fiber. That is possible. Okay.

That is commercial chemical recovery of epoxy resins. There are two methods coming out. First is using disassociative chemistry, where we convert the resin into a thermoplastic epoxy resin. Have a system.

Now that's commercially available, they actually break the cross links. The second is associative chemistry. This is a really trick material because below the TG is a thermoset and above the Tgs a thermoplastic, it's a vitrimer resin. You can do wacky things. You can heat it up above the TG and stamp form it, and then you can stick this and dissolve the resin. Proxy resins are really changing, People are reinventing them. Okay, I've found that really quite fascinating.

Recycling similar plastics is also possible using solvolysis or gasification, and this is like molecular recycling, as one of my industrial colleagues like to call it. Rather than chemical recycling, you basically break down the polymer into the building block it and new polymer, you're recreating the defeat stock.

An example for polyamide is you take your waste, carpets, your automotive parts, and you use an ammonia reaction with the phosphate catalyst and you get back to your dipentaerythritol, which is the building block of hexamethylenediamine, which is what you make polyamide. You're not mechanically recycling. You're actually breaking it down into the molecular building block needed to remake a polymer.

When I spoke to the Responsible for Sustainability at Dow, he was saying this is the way to go. He was saying bio-based plastics, they don't like to talk about because of the conflict with water and agriculture and food. But here there's a lot of waste plastic around that can be recovered and broken back down with really quite high yields if you run the chemical plant with renewable energy. The lifecycle analysis is interesting.

Something else which I just put in at the last minute that you'll hear about is block chain technology. It's basically a way to put a marker in the plastic material so that you can know what it is all the way through the value chain. When it comes to re using or end of life you can know what kind of plastic it is. Which company polymerized it many times. It's being recycled, it can pass through the recycling step. It's a way of using secure cloud data to be able to track your polymer through the stages of its life to help recycling. Dow and Solvay are both using this experimentally.

Now to look at bio-based materials, start with carbon fiber. You can use different level precursors and different carbonization approaches to reduce costs and improve your CO2 positioning. This is a lifecycle study of carbon fiber production using a conventional precursor and conventional carbonization. Here someone has taken a bio-based precursor and they've used renewable energy for efficient plants and it completely changes the lifecycle picture. An example from SGL carbon. They're trying to use what they are using experimentally Algae biomass. They ferment to make algae oil. This is converted by hydrolysis into glycerine, which is then made to make the PAN, which is the carbon fiber precursor. And then they convert the precursor into carbon fiber using plasma and microwave techniques, powered by hydropower or renewable energy, wind energy, to make greener carbon fiber.

That's really interesting to me because you could imagine that being scaled, it's not really competing with food. The problem is we need that in place. So if you want to make hydrogen storage tanks, again, you need to have enough kiloton capacity in the supply base to make your tank. And this is like 20 years behind where we need it in society. But nevertheless, that's the kind of thing that's going on. People are looking at biobased plastics is an example from Evonik, where they're using the castor bean, where you can use that to polymerize nylons. A whole range of long chain polyamides, P610 1010 1012 To give very equivalent properties to their conventional petro chemical based polymers. They can now polymerize this from biobased material. Trouble is I spoke to someone from Invista which is a Milon producer and they say it's bio renewable and it's great. But that land could be used to grow food. The water could be used to grow food. It's very controversial. Technically, it's possible, but it has questions.

Bio-based does not mean biodegradable. Just to be clear, and biopolymers are not recycled polymers, they are polymerized from plants.

Also bio-based epoxies are available from Solvay a company we can know quite well, it has produced a bio-based epichlorohydrin base for epoxy that's now from vegetable glycol derived from biodiesel which comes from plant oil. These resins are now becoming commercially available.

Natural fibers, also very interesting, this is an EPFL spin off bacomp. They use European flax that they can weave and then they can impregnate with plastics. So you can see their value proposition. It's very good in safety. They have some very interesting projects here.

Another one you may have heard of is self healing composites. Another EPFL spin off and this reduces, that's the hammer part reference composite. And this is the healing composites where applying heat, they can actually heal fractures in the matrix. Not damaged fibers but fractures in the matrix. 12 years research in Veronique's lab led to the start-up and it reduces maintenance costs and extends the lifetime that composites a very circular approach.

I'm going fast because we're running out of time applications. Electric vehicles a huge investment. This is investments in battery factories, in giga factories. And we need to make sure that we have answered questions about the environmental impacts and the recycling of these rare earth metals and lithium.

Because you're all material scientists ask about these things. I'm going to have to go quick. Composites have a role to play in battery housings for vehicles because you need to make these battery housings lightweight. And that's a key to their range and their increased adoption. Lots of people are looking at the battery case for electric vehicles. You can read about it here. Wind energy needs to become more circular. It's growing, like we said.

And there's a company, Siemens, that's now using a new resin, which is recyclable via solvolysis. You can chop up your wind turbine blade rather than grinding it and putting it in the road. You can use solvolysis, separate the resin from the fiber and the glass, plastics and wood. You can really get back in the materials with a higher value, just grinding up the waste. It's got almost no value here you've retained value. This is a circular approach.

Another important application is the hydrogen economy. And the idea there is that we can use hydrogen as a fuel source. It's got a high energy per mass, but low energy per volume. Hydrogen does give a very high energy density and it is a key to hydrogen economy towards moving this curve down, especially when you're not using dirty fuel to create the hydrogen, but you're starting to use renewable power. Hydrogen economy needs tanks to store the hydrogen in. You can look at vehicles, you can look at refueling stations, boats, aircraft trains, longer range vehicles. Not for in town, but for driving long distances. And they all need composite tanks to store the hydrogen in. How can we make composite tanks circular in their design philosophy? Those of you who are doing the project will be aware of this. There are different classes of composite tank and they use carbon overlap in compressed gas and cy, compressed tanks. We're going to need a lot of carbon fiber to help support the hydrogen economy. It's going to be a huge market area and a lot of work on pressure vessels. Airbus also their zero E concepts. They want to have a zero emission commercial aircraft by 2035. So they're going to fly aircraft around with giant hydrogen tanks rather than burning conventional fuel. Here you can see here a concept already for a 400 mile range.

Okay, manufacturing, we talked about this diagram previously and additive manufacturing is part of this. I'm going to give you a super high speed tour until the next lecturer comes in around additive manufacturing. The idea is that you can manufacture your product in different locations. Rather than

having one massive factory. You're going to have dispersed factories. It reduces shipping. It's flexible and highly customizable, with lots of design freedom and the investment in a machine is much lower. Composite materials have been following additive concepts for a long time.

There are four companies doing this, where you take a tape and you heat and I press. And now we start to see more and more of this going on. This is all an additive manufacturing approach of thermoplastic composites. This is just chopped carbon fiber, but there are now large printers available that can print huge components. Really large boat holes can even be three printed from different combinations of chopped carbon and thermoplastics.

When we go on to look at continuous carbon fiber 3D printing, there are machines available which go from desktop systems all the way up to advanced robotic systems. And I'm just going to quickly through these as a quick tour company called Aervo that can place bicycle frame type components by heating up tape and applying pressure with a consolidation roller. And it's basically advanced fiber placement, but rename this 3D printing.

9tllabs, a Swiss company, place strands of carbon fiber using a 3D printer. And then they put that into a second module and they heat it up and press it so you can make a really complex component by printing the fibers first and then heating it up.

The Mark forge process, we have that one at EPFL and here are some parts where this has continuous carbon fiber inside printed on a printer. Another process, desktop metal. They can take a tape like this carbon tape and they can print that apply pressure with a micro Afp head, like the big process.

Looking at some properties, some normal weight specific yield strength. We can get some amazing properties with these three D printing materials because they're highly directional. You can put the fibers really where you need them. That's the interesting part. I'm going to play this video because it's cool. This shows the combination of tool less 3D printing where they print the mandrel and then they print UD tape onto the mandrel.

You can start to see here people are overprinting onto a laminates. And they're combining filament winding with printing their own mandrel system and the attachment points to go inside the tube. It's starting to revolutionize composite manufacturing. That's what I would like to say. People are starting to mix metals and composites. They're starting to embed conductive fibers inside the composites. You're looking at multi material systems, stiff and flexible damping. Conductive design freedom is going up and up and up. You can start to put conductors in your composite as it's printed.

What are the unmet challenges? This is from a company, consulting company relating to the widespread production of circularity in composites. There are technical challenges relating to the limitations of materials. Trying to sort out different materials. Sorting is complicated. Block chain can help market looks at the value chain and we need to make sure that the secondary materials are cost effective compared to diverging product prices. Then the policy in Europe is not really in place yet to enable composite circularity. But that's something that will come.

one last Slido. How interesting or relevant do you think is incorporating sustainability themes into lectures?