Kanazawa Institute of Technology

Moulding the future of 21st-century materials

The open design of the new Innovative Composite Center at the Kanazawa Institute of Technology facilitates the collaborations needed to tackle the challenges of ageing infrastructure and sustainable material development.

The samurai of Japan's Edo period knew about the importance of materials — without the technology to forge and harden their razor-sharp *katana* swords, these warriors would have been powerless. Today, the city of Kanazawa, nestled between the Japanese Alps and the Sea of Japan, is home to one of the best-preserved samurai districts in the nation. Also considered a traditional home of Japanese scholarship, this vibrant location continues its long-standing association with materials science through the groundbreaking work being conducted at the Kanazawa Institute of Technology (KIT).

In 2013, the Japanese government selected KIT to host the country's largest centre dedicated to composite materials — products constructed from two or more substances with dissimilar properties, such as flexible polymers reinforced with tough carbon fibres. Completed in 2014 on a budget of over 2 billion yen (US$18.6 million), the new Innovative Composite Center (ICC) aims to expand the use of composite materials in a wide variety of fields through interdisciplinary, academia–industry collaborations in a facility designed to foster openness and transparency.

"Composite materials are light, strong and corrosion free. They're anticipated to be a key part of the next generation of land and marine infrastructure," says Kiyoshi Uzawa, director of ICC. "Instead of just basic research and development, ICC focuses on the technology needed to process composite materials and on specific projects that can really impact society, such as automobile parts and offshore windmills."

Fibre fundamentals

Carbon fibres are usually produced by heating spun polyacrylonitrile, a polymer similar to those used in acrylic clothing and carpets, into long strands thinner than human hair. Heat treatment expels nitrogen and hydrogen from the precursors, leaving an extended fibre composed of fused, graphite-like carbon rings. The fibres are

used to reinforce plastic resins, similar to how steel bars reinforce concrete.

The chemical structure of carbon fibres imparts the material with extraordinary strength — more than five times that of steel — while remaining lightweight. These desirable properties have led to it being widely used in the aerospace and automobile industries as well as in consumer goods such as sporting gear. But the complex machinery needed to spin, manipulate and heat process carbon fibres makes them significantly more expensive than metals. Because of this high cost, carbon fibres have found limited application, and hence their fabrication technology remains immature and their manufacturing cost high. "In the past, the high cost of carbon-fibre composites limited their applications," says Uzawa. "No one seriously thought they could be a substitute for iron or concrete in practical structures."

Putting vision into practice

Japan is a world leader in the carbon-fibre market, with its top three players accounting for two-thirds of global production. The ICC has a mission to open new markets for these unique materials and expand the use of composite materials in more fields by promoting the application technology development. To accomplish this, the institute was constructed to promote partnerships between universities and companies from the ground up.

The striking three-floor facility features an accessible work environment: doors and walls are minimized in large, integrated workspaces. Hallways are spacious and designed to promote communication between researchers. Plentiful windows bring in natural light and encourage passersby to look in on their colleagues' work.

The centrepiece of the ICC, however, is its massive, open prototyping area, which can be viewed from every floor of the facility. "One of the themes of ICC is to develop markets for composite materials in offshore structures and infrastructure fields," remarks Uzawa. "This requires large machines for moulding and testing. Luckily, in our layout, nothing blocks the view — the lab and analysis zones surrounding the prototyping area are transparent, making work visible and easier to share."

The right tools for the job

The ICC provides professional education encompassing a wide range of activities. Materials are engineered at the nanoscale to optimize their activity and then rigorously simulated for structural and process behaviour using high-level computational techniques. X-ray and atomic-resolution microscopy ensure the quality of experimental composites.

If a new material meets the researchers' standards, it passes from the design stage to processing. Here, pressing machines, custom moulds and high-temperature autoclaves test the possibilities of advanced composite applications.

Not cast from the same mould

ICC has three focuses. The first is the Center of Innovation (COI) project, which dedicates 800 million yen (US$7.5 million) per year to solving real-world infrastructure problems with composite materials. Carbon-fibre-based materials could allow infrastructure such as bridges, highways and high-rise buildings to endure for centuries with near-zero maintenance costs. In marine environments, efforts are underway to turn fibre-composite materials into lightweight, high-strength sails for ocean vessels and blades for offshore wind power.

Through the combined efforts of 10 research institutions and 16 companies, the COI project is striving to realize these applications using newly developed 'continuous' moulding technology. Conventional composite processing laminates a material into shaped moulds, cures at high pressure and temperature, and then has a waiting period as the part solidifies. Using a thermoplastic resin as the matrix enables continuous moulding in a short time, permitting extended structural elements used in infrastructure — for example, beams, pipes and boards — to be produced effectively and at lower cost than previously.

The Ishikawa Carbon Fiber Cluster, ICC's second project, is a collaboration between KIT and local companies in Ishikawa prefecture to make an impression on the world of thermoplastic composite manufacturing technology using 'stampable' sheets — intermediate materials of thermoplastic resin-impregnated carbon-fibre sheet that can be moulded under pressure. This time-saving process makes composites moulding significantly more economical.

Revving up for mass production

There is a vital need to establish mass-production systems for composite materials to make them competitive in the automobile industry, among others. Meeting this demand is the goal of ICC's third project. It seeks to advance 'high-cycle' moulding technology by the resin transfer moulding process. In this approach, thermoset and carbon-fibre composites can be fabricated extremely quickly — under a minute, in some cases — through using high-pressure injection and a special resin transfer mould that supports the formation of complex shapes. This project is also exploring alternative fibre treatments and textile technology to produce parts such as automobile exterior panels, door shells and even aircraft interior parts.

The benefits of going green

While the strength-imparting characteristics of carbon fibres attract much attention, the accompanying polymer resins are set to play an important role in expanding the possibilities of composite materials. But collaborations between resin researchers and industrial engineers to search for promising polymers are quite rare.

"ICC is the first domestic composite-materials research organization adopting a full-scale approach, which includes resin research," says Uzawa. "One area we focus on, in collaboration with Kanazawa University, is using biomaterials for composites."

Increasingly, researchers are examining renewable substances, such as wood-based biomass, as raw chemical sources instead of petroleum products. In conventional biorefining, tough molecules such as lignin and cellulose are broken down into smaller glucose rings, which can then be polymerized into resins. The ICC adopts a different strategy. "ICC is working on a production technology that skips glucose purification and produces resin directly from lignin and cellulose," Uzawa explains.

By promoting the products and manufacturing know-how of green, sustainable composite technology, the ICC hopes to spark a transformative effect on society in the next decade. "I see ICC as contributing to a spiral of positive expansion: turning practical examples into reality, will lead to the creation of new demands," says Uzawa. "It will be really exciting if these collaborations make ICC a major centre for composite-material research in Japan."