It’s about time: Human/robot collab zips up production rates

To enable European aeronautics to maintain its competitive advantage, lightweight composite technologies and systems are a prerequisite. However, to fully optimise their environmental benefit, the ways in which these new technologies are produced is vital too — manufacturing processes that are energy-efficient, time-saving, and minimise material wastage, in line with Clean Sky’s objectives and the European Commission’s Green Deal ambitions. One way to achieve this is to optimise collaboration between the human workforce and the use of robotic manufacturing techniques.

Within Clean Sky’s Airframe ITD Programme, part of the work is devoted to automated and human/robot collaborative systems for manufacturing, inspection and assembly processes for composites coordinated by Leonardo Aircraft Division, and supported by three complementary projects: SMART LAY-UP for semi-automated manufacturing; ACCURate for non-destructive inspection (NDI); and LABOR for fast assembly.

‘These projects will find direct application in achieving one of the major regional platform deliverables — the full-scale integrated composite fuselage ground demonstrators,’ explains Clean Sky Project Officer Elena Pedone. She says that ‘the primary impact will be improving the manufacturing lead time, which implies on one side a reduction in energy required for the final manufacturing phase and also a decrease in manufacturing waste. The reduced quantity of scrap material produced and lowered energy needs feed into Clean Sky’s sustainability goals. This project will also optimise the manufacturing process in terms of time and use of resources, therefore increasing competitiveness.’

Aircraft construction, especially for regional aircraft fuselage structure, relies heavily on the manufacture of composite panels which are typically constructed using thin and lightweight carbon fibre skins impregnated with resin (known as pre-preg) on the sides, with viscoelastic material embedded in the middle to attenuate the cabin noise. This production technique helps reduce weight, and therefore means less fuel-burn, in line with the Green Deal’s vision. But this process can also be slow and labour-intensive, posing a challenge when production rates need to be accelerated.

Clean Sky’s SMART LAY-UP project provided a cost-cutting approach to manufacturing fuselage panels within a shorter timeframe for Leonardo’s integrated cabin demonstrator for regional aircraft.

A rig with the capacity to lay down stiffened panels 4.5m long for a fuselage of up to 3.5m diameter was built. The centrepiece of the rig is an AFP machine for the pre-preg and viscoelastic material lay-up which reduces lay-up time and also produces panels with embedded acoustic insulation for suppressing cabin noise, in line with European noise reduction targets. The entire rig can be installed within a 10m x 5.5m footprint, making it convenient for multiple rigs to be set up in a manufacturing environment if needed, while also enabling Leonardo to validate the new
AFP process in a representative environment for production of the panels for its fuselage demonstrators. The system has been validated for assembly of fuselage sections for structural testing and also for cabin comfort studies.

‘Six fuselage skin-stringer panels for the structural demo were fabricated using the MTorres automated fibre placement machine installed at Leonardo Aircraft’s facilities in Pomigliano d’Arco,’ says work package leader Vittorio Ascione at Leonardo. ‘The biggest challenge in the SMART LAY-UP was to implement and get a reliable and affordable automated process for the manufacturing of the hybrid fuselage demonstrator in a limited time-frame.’

Another challenge in the project was the use of a new viscoelastic material, which Eurecat project manager Angel Lagrana describes as ‘the most “unknown” aspect of the project, which put the consortium’s experience of automated composite lay-up to the test.’

Lagrana says SMART LAY-UP is a key enabler for demonstrating hybrid manufacturing: ‘Without SMART LAY-UP it simply would not have been possible to make the panels within the specified conditions.’ What makes SMART LAY-UP particularly innovative is its versatility — it can be adapted to produce various types of panels using different tools and materials that can be tailored on a case-by-case basis, enabling modular ways to lay-up, laminate, shape and ultrasonically cut the materials.

According to Ascione, it’s the teamwork — not just between humans and robots but between the various project partners, that have brought the project to successful fruition: ‘Clean Sky is actually a unique opportunity to work in the aerospace research field with applicants of different European countries and diversified businesses, making it quite easy to collaborate with universities, research centres, high technology companies and small start-ups. In SMART LAY-UP, Leonardo has actively collaborated with MTorres and Eurecat, bringing the right mixture of heterogeneous knowledge together with a very cooperative approach. This has been the key for the project’s success.’

**Robotics and ultrasonic inspection for composites**

Composite materials (carbon fibre reinforced polymers) and laminates (hybrid polymer-metal multilayer sandwich structures) will provide effective pathways towards lighter, more fuel-efficient aircraft. The latest passenger airliners on the horizon will likely contain up to 80% of such materials in their primary structures. However, two prominent challenges are yet to be cracked: compared to conventional aluminium alloy structures, composites are expensive to produce, and it’s harder to detect internal defects or impact damage to these materials in service.

Complementing SMART LAY-UP, ACCURATe (Aerospace Composite Components - Ultrasonic Robot Assisted Testing) project developed an advanced prototype laser ultrasonic testing (LUT) system for optimising non-destructive inspection (NDI) techniques. These were used to inspect large hybrid and thick composite structures and structures containing acoustic damping materials (for cabin noise suppression), such as the stiffened panels of both REG IADP Fuselage Structural and Passenger Cabin Demonstrators.

**A demonstrator-oriented approach**

The project plan was to design, build, test and deploy a prototype cell (a type of rig) for validating component panels supplied by topic manager Leonardo, using hybrid materials technology. Validation took place at Leonardo’s site in Pomigliano d’Arco, using a combination of lasers.

The KUKA robotic system employed uses a 6 axis lightweight robot arm for deployment of the optical head, providing an unrivalled dexterity inspection solution compared to other LUT systems, since it has the ability to move on a rail track that runs the length of one side of the CFRP panel being inspected. The robot arm scan window is sufficient for the whole panel to be scanned at speeds of over 8m² per hour with just a single fixture rotation.

Leonardo’s Ascione says that the biggest challenge in ACCURATe was ‘the implementation of a fully automatic high-speed inspection process, based on contactless no-couplant laser ultrasound technology, able to assure defects detectability comparable with conventional ultrasound by a laser power optimisation — and to do this without causing damage to the part, and with no false signals.’

**Safety first**

Working with lasers requires heightened safety measures, says Kyriakos Mouzakitis, Senior Project Leader at TWI Technology Centre:

‘The ACCURATe inspection system is very complex. Achieving our targets whilst maintaining the highest standards of safety has been a very challenging process requiring intricate path planning of the robot, precise calculations for laser activation and deactivation, and designing the safety guards to ensure the wellbeing of personnel.’

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Currently the system is ready for installation at Leonardo’s Pomigliano d’Arco plant, where the Laser Enclosure is under construction. Looking ahead, the ACCURATe consortium has discussed the potential to form a separate venture for the commercialisation of its system, to be defined in the final year. The plan is that this separate entity (ACCURATe Ltd) will be led by KUKA systems, while other consortium partners also intend to exploit the IP developed in ACCURATe for other industries.

Putting it all together

To keep pace with demand as aviation recovers post-Covid, production and assembly rates have to play their part too. And that’s where Clean Sky’s LABOR (Lean robotised AssemBly and cOntrol of composite aeRostuctures) project comes in, bringing a lean, self-adaptive approach to using small/medium sized robots that can be adapted for different assembly operations.

LABOR developed a self-adaptive cell capable of automated drilling and fastener insertion based on robotised systems for composite structures.

‘The robotic cell, as an innovative automated system for manufacturing processes, developed in the Clean Sky’s LABOR project, supports the integration and assembly of both the full scale Regional IADP Fuselage Structural Demonstrator and the Passenger Cabin Demonstrator,’ explains project coordinator Dr. Cristina Cristalli, Research for Innovation Manager at Loccioni Group.

The system is capable of carrying out a range of automated functionalities, including referencing and high accuracy positioning, drilling, and countersinking of holes with several diameters of hybrid stack-ups via cooperative robots. The cell can also handle hole sealing and fastener insertion and can even inspect hole quality and fastener installation using real-time monitoring and robot speed modulation for safe human/robot coexistence.

One of the biggest ambitions of the project, according to Dr. Cristina Cristalli, has been the use of small/medium size robots for the assembly operations of big panels in co-presence with the operator. ‘The innovative approach proposed in the LABOR project relies on this aspect, together with the concept of distributed software modules that can be arranged to perform the desired cycle of work. The adaptability of the robots is also a new feature: through the 3D measure performed by a profilometer the robot’s path is adapted based on the real position of the components to be assembled.’

LABOR provides an instant exploitation path thanks to the fact that robots can be integrated with ease into pre-existing shop-floor environments. But getting here would not have been possible without Clean Sky’s philosophy of maturing research through the construction of demonstrators.

As the project currently undergoes final validation, results that can be potentially applied in industry beyond the LABOR work cell include smart tools for drilling, inspection, sealing and fastening in applications where similar assembly sub-operations are needed, along with applications requiring real-time workspace multimodal monitoring for human-robot collaborative work cells.