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Due to see its maiden flight next year, the A400M's wing assemblies have benefited from UK-developed machining technology

Automating aerospace

Automation of repetitive tasks, like drilling holes in wings, plus the automated, right first time laying up of composite parts are areas of activity for AMTRI*, as the organisation's Bob Lloyd explains

Next year is crucial for the Airbus A400M military transport aircraft: it is due to make its first flight. At the company's wing manufacturing plant in Filton, Bristol, a new way was required to automate and accelerate the production of leading and trailing edge assemblies for the wings. With the highest possible accuracy and consistent quality, drilling, countersinking and fettling operations had to be performed on a combination of titanium, aluminium and carbon fibre reinforced parts.

Each material required different cutting speeds and feeds. Working closely with jig designers from a partner company, AMTRI* designed, developed, and manufactured a sophisticated special-purpose machine for Airbus UK. This automatically performs a number of repetitive operations on the assemblies, a workpiece over 30 m long. Technology to support this milestone achievement was, in fact, derived from ideas previously proven on related projects.

Now commissioned and in full-scale operation at the Airbus wing manufacturing plant, the machine was supplied as part of a comprehensive turnkey contract through Hyde Group, an AMTRI partner. The 5+2-axis CNC machine employs a number of design innovations to minimise set-up times, and high precision machine features.

Of particular note is a unique beam arrangement which allows two-sided operation of the machine, posting out to the left or right as required. The whole machine is mounted on a bogie that travels along a 60 m rail track, enabling an entire wing-set of spar assemblies to be machined in a single set-up, saving much cost and time. In each and every working zone, special transformation algorithms devised by the machine designers are used to reference automatically the co-ordinate frame of the machine to that of the components. This feature combined with the implementation of comprehensive error compensation ensures high precision is maintained over the full working volume of the machine and jig.

For Airbus UK, the resource represents a critical production system for the A400M wing assembly. The machine is performing well in production in all of the varied and demanding conditions, and the hole quality is very good. In addition, the automated adaptive fettling process is also performing to the required specification.

GENESIS OF TECHNOLOGY

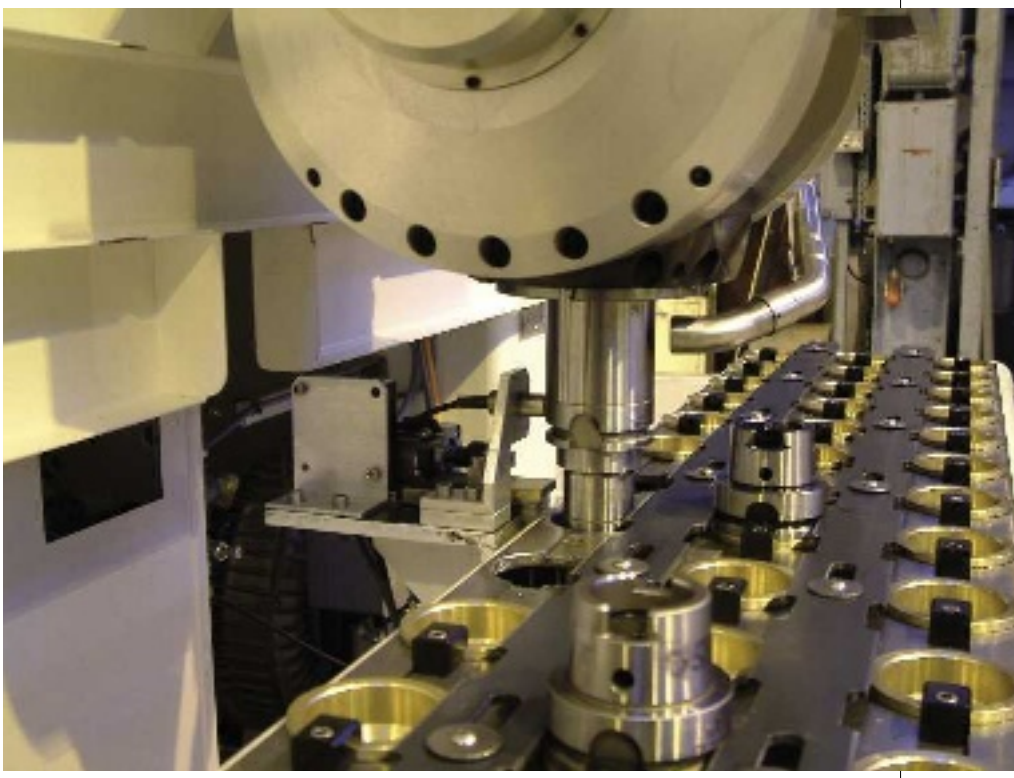
Many of the machine's features came from technologies developed in two previous research projects, where AMTRI was a key participant. DARWIN (Drilling Automation Research for Wing manufacture) was a £1 million collaborative initiative to design a new generation of automated wing assembly

systems for Airbus UK. Led by AMTRI, it was part-sponsored by the DTI and also involved Hyde Group. The project's goal was two-fold: first, to investigate and develop the use of orbital drilling for the production of high quality holes in advanced materials; second, to demonstrate the use of vision systems and lasers to generate adaptive, electronic versions of the traditional hard-drilling templates – so called 'virtual templating'.

ORBITAL DRILLING

The DARWIN machine installed at Airbus's Filton plant features one of a new generation of orbital drilling units from Novator. Orbital drilling tests were carried out on advanced materials such as aluminium, carbon fibre reinforced parts (CFRP) and combinations of these materials. AMTRI's role in the project was largely concerned with the control, software and algorithms required for the management of what was essentially an 8-axis machine carrying out 5-axis milling and drilling, but the company also assisted with the mechanical design. Feature-based navigation converted the task of positioning and orienting the cutter into one of local, rather than global, accuracy. Frame manipulation allowed the system to accommodate build and part-orientation variations that inevitably occur when constructing large semi-flexible structures such as aircraft wing components.

AWBA (Automatic Wing Box Assembly) was another key and relevant project where the company played a major role in the research to conceive, design and implement a demonstrator for a new generation of automated wing box assembly systems for Airbus UK. Other development partners were AEA Technology, Sowerby Research Centre, Tecnomatix, Leica, and UK Robotics. Until the advent of AWBA, wing box assembly had been carried out manually in large dedicated jigs. The project focused on redesigning the process for automation in order to dramatically reduce lead time, and make possible assembly of parts too large for conventional manual assembly.



Feature-based navigation converted the task of positioning and orienting the cutter into one of local, rather than global, accuracy. Just one of the novel developments in the AMTRI machine

A demonstration system was built and installed at Airbus UK's Broughton facility.

Thus the technology for the Airbus A400M machine was based on well-proven precedents. Key features of the new machine include five CNC axes: three linear and two rotary. A special spindle is capable of low speed titanium drilling and high speed aluminium and composite machining, with a speed range of 100 to 10,000 rpm. An automatic tool changer incorporates a tool run-out measurement station and tool storage.

In effect two machines in one, the unique post-out beam feature enables two-sided operation to maximise productivity and minimise machine idle-time. Trailing-edge spars may be loaded and unloaded from one set of jigs while machining operations are performed on leading-edge spars on another set. A complete aircraft wing-set of spar assemblies can be machined in a single set-up; mounting the entire machine on a 60 m-long rail system allows rapid re-deployment to the next working zone. On arrival at each new zone, the wheels are raised and the bogie is hydraulically clamped in position.

CO-ORDINATE TRANSFER

High precision is maintained throughout the whole working volume of the machine, achieved by probing known reference points on the jigs on arrival at each new zone, enabling machine co-ordinates to be transformed to those of the local workpiece co-ordinates. This feature reduces the problem of maintaining 'global' accuracy to one of 'local' repeatability and avoids the need to maintain high accuracy over the machine's full length of travel.

Another area of automation being developed by AMTRI is poised to enter the aerospace and automotive sectors later this year, but will be applicable to a

An A400M wing, pictured here at Filton in Februay this year. The first 'flying' set, as opposed to test set, has now been delivered to the aicraft assembly plant in Seville, Spain

range of industries. The development is a joint project called PhysVis featuring technology transferred from the serious computer games industry. The aim is to develop a low-cost, commercially available, high performance physics-based software product for the visualisation and simulation of complex manufacturing systems. Led by AMTRI, other partners are Advanced Composites Group, a British world leading maker of high performance composite materials for many industries, including the aerospace sector, and Banbury-based Innoval Technology, a materials and process technology consultancy.

PhysVis will offer at far lower cost higher levels of performance and capability than currently available in the application modules of far more expensive CAD suites from major vendors. Integration of real physics simulation capability with kinematic and discrete event simulation is what makes the project so exciting. The 19-month project, started in October 2006, is part-funded by a Technology Programme grant from the Department of Trade and Industry (DTI is now DBERR) and contributions from the partners, making a total investment of £400,000.

British manufacturing industry, particularly SME manufacturers, will benefit from this new and valuable resource. The high performance and low cost of PhysVis are designed to offer a range of specialist companies in fast-growing high technology sectors a major opportunity to exploit carbon fibre-based composite components. The system will enable more innovation and new business to be achieved in areas that would otherwise be too risky, technically and financially, for SMEs to consider. It will allow them to compete more effectively in a global market.

SIMULATED INTERACTION

Today, complex parts are invariably laid-up by hand and are subject to significant variation. Soon, PhysVis will open up the opportunity to simulate the interaction of the composite and the mould as the manufacturing robot's trajectory and speed are varied, allowing these specialist suppliers to design 'right first time' production systems and processes. This cannot be done now, even with the resources available to larger companies.

The product features advanced software and hardware solutions based on proven technology identified by AMTRI. Much of this was developed originally for computer games platforms by US company AGEIA. A pioneer of hardware-accelerated physics for PC games, it launched the world's first dedicated physics processor. The company's PhysX Accelerator powers massive and pervasive real time interactive scenarios that for the first time obey the laws of physics. It allows challenges posed by the handling and visualisation of large data sets associated with complex systems to be addressed. The rest of the system being developed by AMTRI is based on a low cost but advanced PC-based digital factory simulation system from Finnish company, Visual Components.

Innoval's role in the project is to categorise the material (carbon fibre) using the consultancy's unique fabric modelling approach. The simulations start with an individual fibre and models the fabric weave in all its detail to create an accurate mechanical representation of the woven carbon fibre material. The output of the simulations is a constitutive model that represents a 'unit patch' of the material. AMTRI is currently mapping these patches to AGEIA's PhysX Accelerator and simulating both the material and the robotic manufacturing system to achieve accurate process and product interactions. This technique will enable the best manufacturing process to be determined by the user of PhysVis. Advanced Composites Group will play an important role as the first customer for the new system and provide the application domain, that of aerospace composite manufacture.

AMTRI is also mapping into the system characteristics of spraying resin and coatings to show that the same PhysX-based technology can be used to visualise different complex manufacturing processes. To date there is no commercial system that can do this in a way that faithfully follows the laws of physics.□

** Based in Macclesfield, Cheshire, AMTRI supplies technical consultancy services. Its aim is to help clients improve productivity and efficiency, saving time and reducing costs by providing technical solutions to production problems across all sectors, but mostly in aerospace, automotive, metals and food processing industries.*

Most of AMTRI's work comprises conceiving, planning, designing, developing, building, commissioning and installing cost-effective, and often innovative, bespoke, special-purpose machinery and automation systems.

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