Passive input gearbox: innovation for robotic drilling

Engineers in the AMRC's new Design & Prototyping Group have developed a compact gearbox for an innovative robotic drilling system. Using the gearbox, the automated system can quickly adjust its parameters when drilling complex aerospace structures containing both metal and composite materials.

The latest aircraft use an increasing amount of carbon fibre and other composites. By using these lightweight materials instead of metals, aircraft can be made lighter and more fuel efficient. In some applications where extra structural strength is required, layers of composite are stacked with layers of titanium or aluminium alloy. Often, such a layered stack has to have holes drilled through it so that fasteners can be attached.

These composite and metallic materials have very different material properties, and would normally require different drilling parameters. For example, drilling a carbon fibre composite commonly requires high speed and low torque, while drilling titanium typically requires low speed and high torque. Drilling a hole through a stack of both materials demands a tool which can quickly and efficiently switch between these two modes.

Designing such a tool is made more complicated by the fact that they often have to be deployed in confined spaces, such as within wing boxes or engine intake ducts. Researchers at the AMRC with Boeing have previously developed flexible robots carrying lightweight tools to do essential tasks in such awkward spaces, including a confined space drill.

By definition, the confined space drill has to be small in size. The motor which can be fitted to it also has to be limited in size, and cannot necessarily cover the range of speeds and torques required for optimised stack drilling.

One solution to this problem would be to develop a compact, lightweight gearbox which could fit between the drill bit and the motor (a Maxon Powermax in the prototype system), and provide the required range of output torque and speed. The gearbox would need to provide two gear ratios to vary the speed and torque of the drill, without using electrical, hydraulic or pneumatic actuators and control systems which would increase the bulk and weight of the system.

The challenge fell to the AMRC's new Design & Prototyping Group as part of an internal generic project backed by Boeing. The project was led by senior design engineer Dr Garth Nicholson.

"Our solution was what we have called a passive input gearbox, which automatically changes gear ratios depending on the rotation direction of the drive motor, while always maintaining the same drill rotation direction," says Nicholson.

For detailed information about the development of the passive input gearbox,

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"Its design was particularly demanding because we had to fit it onto our existing confined space drill. It had to be as small and light as possible, while still covering a wide range of output speeds."

To create a first conceptual prototype, Nicholson turned to a well-proven technology: Meccano.

"We built a simple physical model out of Meccano, just to prove that the concept could work," Nicholson explains. "We investigated several basic designs, and settled on a multiple-stage spur gearbox as the most efficient and compact concept."

The final design featured a combined two-stage and seven-stage gear train, using a constant-mesh design to make the most efficient use of space. The two gear trains give a difference in output speeds of around 10:1 for the two equal but opposite input speeds. Each gear train includes a one-way 'sprag' clutch, so a change in input direction automatically causes a shift of drilling mode.

"It is a relatively simple matter to automate the reversing of the drive motor at the appropriate time," Nicholson notes. "We can either pre-program material thicknesses into the drill's feed motor controller, or use the current-sensing mode of the Maxon motor controller to detect the changes in power consumption as the drill tip reaches material interfaces."

Nicholson used a range of software tools to design a gearbox which would fit onto the confined space drill. The casing was then machined from aluminium in the AMRC's workshop, while the internal gears were produced by HPC Gears Ltd of Chesterfield to Nicholson's specifications.

The assembled gearbox is now being evaluated at the AMRC. Following successful tests with the drill motor, the gearbox is now being integrated into the confined space drill chassis. A full test program will trial the different options for material detection, and investigate the process capability of the whole system for stack drilling.

"Creating such a complex gearbox within very tight constraints was a challenging project, but shows the capabilities of our new Design & Prototyping Group," says Nicholson. "We are open for business, and would love to hear from anyone who needs help with any kind of design project".

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