Laser-beam welding makes aircraft lighter

A new laser-beam welding plant for joining large 3D parts in the aerospace industry was inaugurated on June 25, 2004.
© Airbus

Giant passenger airliners of the XXL generation raise huge challenges for aircraft manufacturers, as the production and operating costs for the high-flyers must be kept within reasonable limits. High-precision joining technologies for fuselage sections, saving up to 15 percent of the aircraft's weight, are being developed at an innovative 3D laser welding plant.

The demand for air travel continues unabated. Experts predict that the number of passengers will double over the next 15 years. But many airports have already reached the limits of their capacity. Aircraft manufacturers and airlines are therefore investing their hopes in the XXL generation. 550 passengers can travel comfortably for 14,800 kilometers nonstop on the twin decks of a huge airliner like the Airbus A380. But the giants will do more than just reduce the amount of air traffic in future. They also set new standards for environmental protection and fuel consumption. The A380 is considerably quieter than today's aircraft, and it consumes 20 percent less kerosene. This also benefits the environment, as fewer pollutants are released into the atmosphere. The aircraft's operating costs are about one fifth lower than those of its rival, the Boeing 747. It takes a tremendous effort on the part of the design engineers to build a giant passenger aircraft like the A380. They are hoping that new aluminum composites and production methods will help to save weight and costs. Since the end of June, the Fraunhofer Institute for Material and Beam Technology IWS in Dresden has possessed the technical facilities for joining large spherical fuselage sections and stiffening stringers in a single step. The gigantic laser welding plant for joining 3D parts is 16 meters long, seven meters wide and five meters high. A joint venture between Fraunhofer IWS, Airbus Deutschland GmbH, Schuler Held Lasertechnik GmbH Dietzenbach and ibs Automation GmbH Chemnitz, the project is being funded by the Saxon Ministry of Science and the Fine Arts (SMWK) and by the European Fund for Regional Development (EFRE).

Riveting lacks potential for further development

"At the present time, aircraft fuselages all over the world are joined together from thousands of separate parts, some of which are highly complex, using something like a million rivets," says Professor Berndt Brenner, who heads the laser-beam welding project for aircraft fuselage parts, describing the routine work in the aircraft manufacturers' assembly shops. "Riveting is an advanced automated technology, but it has reached the limit of its development potential and cannot be expected to yield notable increases in productivity or significant weight savings any more." For a good ten years now, aircraft manufacturers like Airbus and Boeing have been exploring new technologies that could replace riveting. It quickly became evident that laser-beam welding is the only option for joining large metal fuselage parts with stringers, like those in the Airbus A380.

"When you compare the speed of riveting – 200 to 400 millimeters per minute – with the speed of laser welding, which is six meters per minute, you can clearly see the advantages of the new technology. It still pays off even though it requires a greater amount of inspection," Brenner continues. "Another advantage of our method is that the wide rivet straps in the aircraft skin and at the butt ends of the stringer are no longer required. It also eliminates the need for a filler metal between the riveted parts. This reduces the structure's weight by five percent. Even better, the welded joint displays greater compressive and shear strength despite its lighter weight. Not only is the cost of production lower, but the structure is less susceptible to corrosion." Experts expect further material and welding technology enhancements to yield an overall weight reduction of up to 15 percent.

Aircraft manufacturers know that even one kilogram of weight is worth saving. Project manager Hartmut Brenneis of Airbus Deutschland GmbH, which initiated the venture, gives an example to illustrate. "The snowball effect – that is, a lighter aircraft needs less powerful engines, smaller wings, etc. – means that for every 1,000 kilograms of weight that we save, we achieve a 1.45% reduction in fuel costs compared to an Airbus A 340-300. That would be 750 kilograms less kerosene on a transatlantic flight. Spread over the calculated service life of the aircraft (25 years), that corresponds to a saving of about nine million euros!"

The new welding plant at IWS is the first plant ever to permit the welding of stiffening elements such as stringers, clips or frames to the fuselage skin using the same plant. A unique feature of the XXL plant is its double gantry structure, with two separately driven y-axis bridges and a hybrid system for moving the parts. The x-axis stage can move in the same direction or in the opposite direction from the y-bridges. In this way, the scientists have been able to expand the machine's dynamic properties while reducing its actual size. Guided by a sensor in the gantry machine, 3D components measuring 10.5 x 3 x 1.5 meters can be welded to the stiffening stringers on both sides at the same time. In the first step, the scientists scan the CAD data of the components that are to be joined together. They then create a CNC program to control the action of the 21 axes of movement. After this, the skin section is tautened by vacuum clamping and the seam-tracking sensors are calibrated. When the two laser beam foci have been directed at the welding point, the stiffening stringer is inserted into the stringer clamping and guiding unit. The CNC program is started, and the welding process begins.

XXL laser-beam welding plant with welding shell.
© Fraunhofer IWS

Double-gantry structure has clear advantages

A hitherto unique construction principle sets new standards: "At this plant we have two independent, 3D movable laser welding heads and a 3D movable clamping and guiding unit. For technical reasons, the laser beam foci with a diameter of 160 µm have to be created by using focusing mirrors with a focal length of 150 to 250 millimeters. This means that the focusing mirrors, the welding wires and the gas supply have to be controlled very accurately. Our unique guidance method facilitates coordinated high-speed dynamic movement of both the laser beam foci and the attached clamping unit anywhere within their range, with an accuracy of plus or minus 0.05 millimeters," says Brenner, explaining a special feature of the plant. The CO_2 lasers can optionally be replaced by Nd:YAG lasers. The latter are of particular interest for future applications. "There are many new developments in solid-state lasers at the present time, including disk or fiber lasers, and some of these could later be incorporated in the plant with no difficulty," the expert comments.

The IWS researchers have been working alongside Airbus engineers since 1999 to improve the welding methods used in aircraft construction and develop new strategies for fuselage design. In an initial project, various test sections such as cylindrical fuselage shells were laser-beam welded to the stringers of the lower fuselage area at a test plant. The process is not only suitable for cylindrical fuselage sections, though. It also enables airbrakes, spherical fuselage shells, wheel wells or wing cowling to be joined to stiffening elements such as stringers, clips or ribs. Brenner is confident that the IWS plant will be of interest to many other sectors as well. Not only aircraft manufacturers but also makers of road vehicles, construction cranes, engineered steel structures and semi-finished products could all benefit from the new technology.
Isolde Rötzer