International R&D

Lightweight Components for Large Jets

Metal Additive Manufacturing at Embraer

In the aerospace industry, additive manufacturing of metal parts shows huge potential yet also poses a major challenge. A relatively low level of technological readiness for critical applications, fragmented technology approaches and lack of full standardization are all factors that restrict the extensive use of metal additive manufacturing in the aerospace industry. Against this backdrop, Fraunhofer IPK and Embraer, the world's third largest jet manufacturer, have set out to acquire significant knowledge to understand and clarify key-points regarding selective laser melting (SLM), an additive manufacturing method specially developed for 3D printing of metal alloys. The partners aim to assess the SLM process status specifically for titanium-based alloys, including post-processing characteristics, mechanical tests and properties, design for additive manufacturing, manufacturing decision-making, and certification.

Embraer 190-2 belongs to the manufacturer's under 150 seat aircraft fleet. (© Embraer)

The history of aviation has been marked by an enduring discussion about who invented the first powered airplane. Much controversy has surrounded this question. It is widely held today that the Wright brothers in 1903 were the first to fly successfully. However, the plane of the Wright brothers only managed to fly with the aid of a ramp and a catapult. On October 23, 1906, in Paris, the Brazilian Santos Dumont, an experienced airship builder, took off on board his 14-Bis airplane, built of wood, covered in tissue paper and powered by a 50 hp engine without resorting to any system of catapult. For the first time a plane went airborne gaining speed in its takeoff run. Dumont flew almost 70 meters at a speed of 30 km/h up to two meters off the ground. Brazil regards Santos Dumont as the first successful aviator because the Wright brothers' flyer took off from a rail and used a catapult.

This is certainly a tendentious discussion. The only certainty is that since the time of Santos Dumont Brazil has become a nation with a great tradition in the construction of airplanes. The Brazilian General Command for Aerospace Technology (CTA) and its Aeronautics Institute of Technology (ITA) have been setting milestones that extend this Brazilian tradition. ITA is an institution of higher education and advanced research maintained by the Brazilian Federal Government with a focus on aerospace science and technology. On a strategic initiative of the Brazilian government, the Empresa Brasileira de Aeronáutica S.A. (Embraer) was founded in 1969 at São José dos Campos, within the premises of ITA. ITA engineers made a critical contribution to the development of its first Embraer aircraft called Bandeirante. Nowadays, Embraer is a holding company responsible for manufacturing military, commercial, executive and agricultural aircraft. It was listed as the world's third largest jet manufacturer. This year Boeing and Embraer announced a joint venture for Embraer's airliners.

► Additive manufacturing of titanium alloy for aircraft components

Embraer forecasts a need for more than 5,000 new jets in the 30- to 120-seat capacity segment over the next 15 years, with an estimated total market value of up to US$ 200 billion. In addition, the aviation programs ACARE 2020 (Advisory Council for Aviation Research and Innovation in the EU) and Flightpath 2050 both call for a reduction of aircraft fuel consumption together with CO_2 and NOx emissions over the course of the coming years.

Such framework conditions represent a challenge for the producers of structural parts and engines for aircrafts. To meet current and future requirements, the aircraft industry will have to undergo considerable technological development in terms of innovative materials and design techniques as well as new fabrication processes. To satisfy upcoming requirements for the aerospace industry, innovative material and manufacturing technologies are urgently needed.

SLM-structural prototypes for airplanes produced at Fraunhofer IPK for Embraer

Generated test specimens for mechanical characterization of titanium alloy parts produced by SLM

Additive Manufacturing opens new opportunities for engineers to design lightweight and topological optimized parts for aircrafts. One interesting additive manufacturing technology for the fabrication of components with innovative designs but also topologically optimized geometries is selective laser melting (SLM). SLM enables layer-by-layer production of complex components directly out of metal powder, based on CAD data. One outstanding advantage of SLM is the possibility it offers to manufacture complex lightweight structures that cannot be produced using conventional processes. Lightweight structures can contribute to the increase of efficiency and to the reduction of fuel consumption and emission levels of pollutant gases by aircrafts. However, more knowledge regarding the SLM process and the resultant material properties of the produced parts is essential. Over the past five years, Embraer has been working in cooperation with Fraunhofer IPK to investigate the process characteristics and mechanical properties of titanium parts produced by selective laser melting for a structural aerospace application.

► From process design to finished prototypes

Several projects involving the development of a complete manufacturing chain for the fabrication of components via SLM in a holistic way have been carried out both in Berlin and São José dos Campos. The first projects between Embraer and Fraunhofer IPK developed material qualifications for SLM and post-processing technologies. To analyze the potential of SLM additive manufacturing technology for the production of structural parts for airplanes, a wide range of tests were carried out in these projects. Characterization of raw titanium powder, development of SLM process parameters, and application of different surface finishing and heat treatment processes formed a key plank of the research approach. It was demonstrated that titanium alloy specimens and workpieces produced by an optimized SLM process can present mechanical properties similar to those of parts manufactured using conventional processes. Design for manufacturing and SLM part orientation trials provided the know-how needed for the optimization of support structures and reduction of manufacturing time and warping mitigation. Furthermore, economic aspects related to the SLM manufacturing process costs were analyzed and compared with costs associated with conventional manufacturing technologies.

With SLM technology, a new era of innovative component design has been launched. Application of this technology now opens the way to the fabrication of aeronautic parts with optimized geometry and topology that seeks a reduction in weight while retaining good mechanical properties. The qualification of the materials used by Embraer in concert with AM topological optimization, has enabled the production of real prototypes for the aeronautical industry. Certainly, the way ahead is still long before SLM structural parts will be flying in commercial aircrafts in conformity with all the necessary safety standards of the aerospace industry. However, the technologies of additive manufacturing have developed rapidly over the last years and expectations are high for the application of this technology in new products. ■

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