DLR tests solar aircraft for round-the-world trip

17 April 2014

To fly once around the world, across continents and oceans – powered by the Sun; this is the unprecedented goal of the SolarImpulse project. The flying venture is expected to take place in 2015, using an extremely lightweight aircraft covered with solar cells and powered by four electrically driven propellers. The German Aerospace Center (Deutsches Zentrum für Luft- und Raumfahrt; DLR) has been investigating the structural behaviour of the unique lightweight aircraft in a stationary vibration test that ran for around two weeks up to the beginning of April. The test provided the solar flight pioneers from Switzerland with valuable information regarding the behaviour of their prototype during flight – an important step in the journey around the world.

"Solar Impulse is a fascinating aeronautical pioneer project," says Rolf Henke, the DLR Executive Board Member responsible for aeronautics research. "Brave pilots and bold designers have come together to find new ways of flying – just as in the early days of flight. With a tradition in aviation research stretching back to 1907, DLR is supporting Solar Impulse in this ground-breaking project by offering its expertise and measurement technology."

Several years ago, Solar Impulse built a solar-powered aircraft prototype with which flight during both day and night was achieved for the first time. Now a second, even larger solar plane is standing in its home hangar in the Swiss town of Payerne. With a wingspan of 72 metres, the new, larger solar aircraft that will fly once around the world almost completely fills the hangar. But despite its size, the lightweight aircraft, with the identification HB-SIB, weighs only about 2.5 tons. Almost half of the weight is accounted for by the cockpit and the four engine nacelles, which have integrated batteries to provide the aircraft with power at night. "What we have here is an extremely lightweight structure – a minimal frame made of carbon-fibre reinforced polymer elements with a high-tech film just 0.2 millimetres thick stretched over it," says Yves Govers from the DLR Institute of Aeroelasticity in Göttingen. "Such an aircraft exhibits very unusual vibration behaviour when it encounters gusts of wind or performs control manoeuvres, and we have been investigating these in stationary vibration tests using special measurement technology."

Yves Govers was responsible for the extensive tests conducted on the new Solar Impulse aircraft. Stationary vibration tests are an important part of the test programme for aircraft prototypes. Resistance to flutter must be demonstrated for every new aircraft design. Flutter is a dangerous vibration state that should never occur in flight. If it does, the vibrations in the aircraft are exaggerated as energy is absorbed from the airflow over the wings. The DLR Institute of Aeroelasticity is in charge of the stationary vibration test site, having already taken measurements of vibration behaviour for prototypes of larger aircraft such as the Airbus A380 and A350. "But the stationary vibration tests with the Solar Impulse prototype were not carried out with the primary purpose of investigating flutter," explains Govers. "The extremely light solar aircraft travels at just around 70 kilometres per hour to be especially energy-efficient during flight. At such low speeds, flutter is a somewhat low-priority problem." The results of the stationary vibration tests are of primary importance for verifying the predictions made by computer models of this special aircraft and thus to reliably predict its structural behaviour in flight.

The extremely lightweight structure combined with its 72-metre-wingspan was a particular challenge for the DLR researchers: "The wings of the solar-powered glider are comparable in size with those of a modern airliner; but they vibrate much more slowly due to their extreme lightness," says Govers. "We were dealing with vibration periods of up to three seconds. In this range we are at the very limits of measurability." The DLR researchers made the Solar Impulse prototype vibrate in various places using electrodynamic exciters known as shakers; these

generate vibrations via a coil in a magnetic field, as with loudspeakers. Here, however, the magnetic force is not used to move a loudspeaker cone; instead, it is used to vibrate the aircraft structure directly.

When conducting stationary vibration tests on larger vehicles, the undercarriage is placed on a soft support so that it floats as if in flight. "Because of the extremely low weight, we had to place the Solar Impulse prototype on a gimbal," says Govers. "The gimbal only prevents vertical movement of the aircraft; all other movement is unrestricted. Additional bracing with elastic cords was needed to stabilise this unstable mounting."

DLR already supported the construction of the first Solar Impulse prototype, HB-SIA, in 2008 and 2010 during its development stage, performing component tests and a stationary vibration test. If everything goes according to plan, the second prototype will make its solar-powered world trip in 2015. And the measurement technology from DLR in Göttingen will have played a part in this revolutionary aeronautical adventure.

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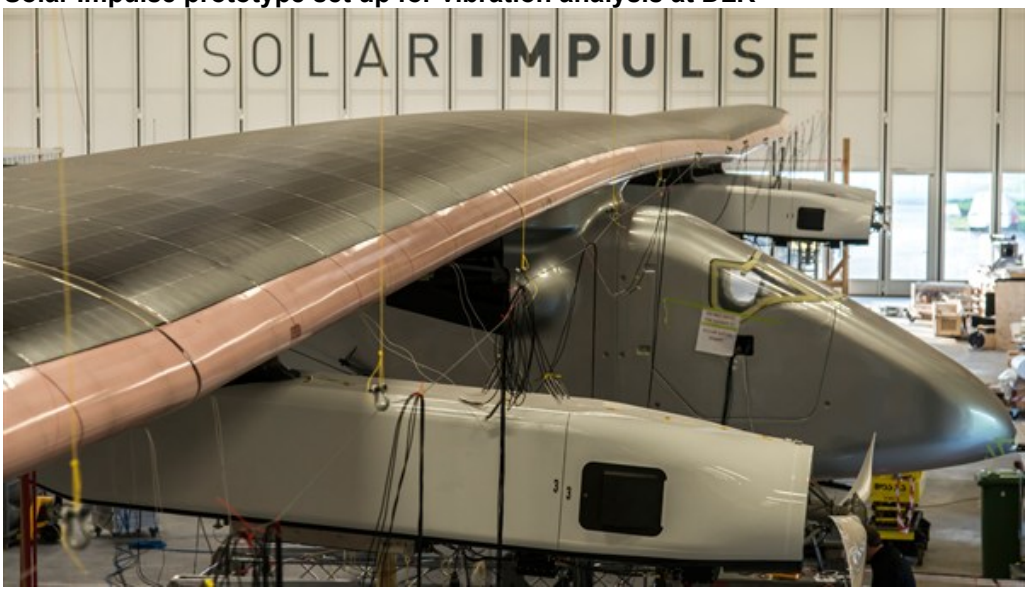
First Solar Impulse prototype HB-SIA over San Francisco

DLR already supported the construction of the first Solar Impulse prototype, HB-SIA, in 2008 and 2010 during its development stage, performing component tests and a stationary vibration test. In 2010, the Solar Impulse solar aeroplane succeeded in, for the first time ever, flying non-stop for one whole day and night. In 2013, the first Solar Impulse prototype flew across the United States of America. Here, a view of the solar-powered aircraft as it flies over San Francisco.

Credit: SolarImpulse/Revillard/rezo.ch.

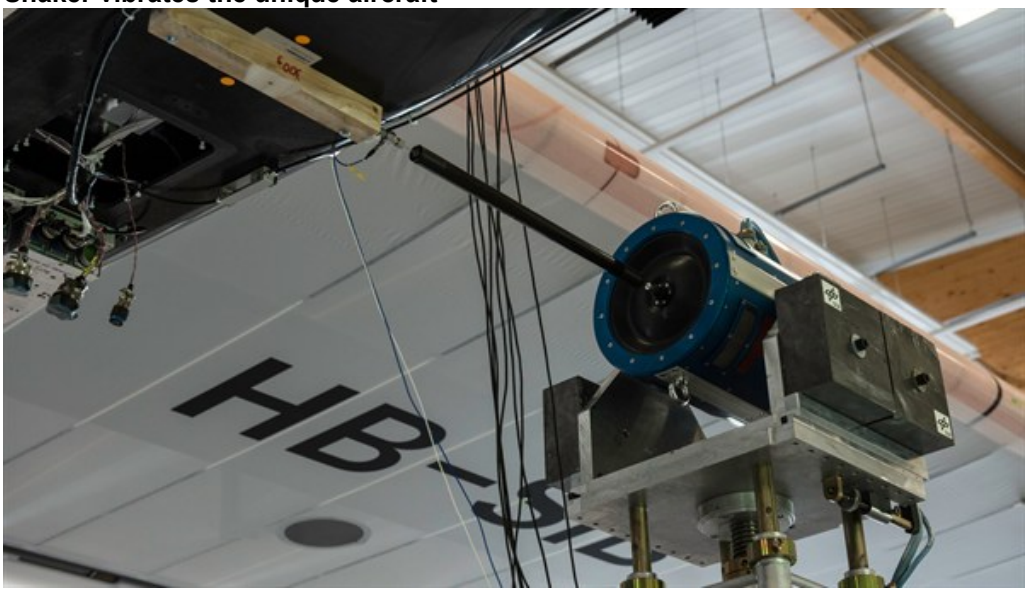
Solar Impulse prototype set up for vibration analysis at DLR



The extremely lightweight structure of the solar-powered aeroplane, combined with its 72-metre wingspan was a particular challenge for the DLR researchers – the wings are comparable in size with those of a modern airliner, but they vibrate much more slowly.

Credit: SolarImpulse/Anna Pizzolante/rezo.ch.

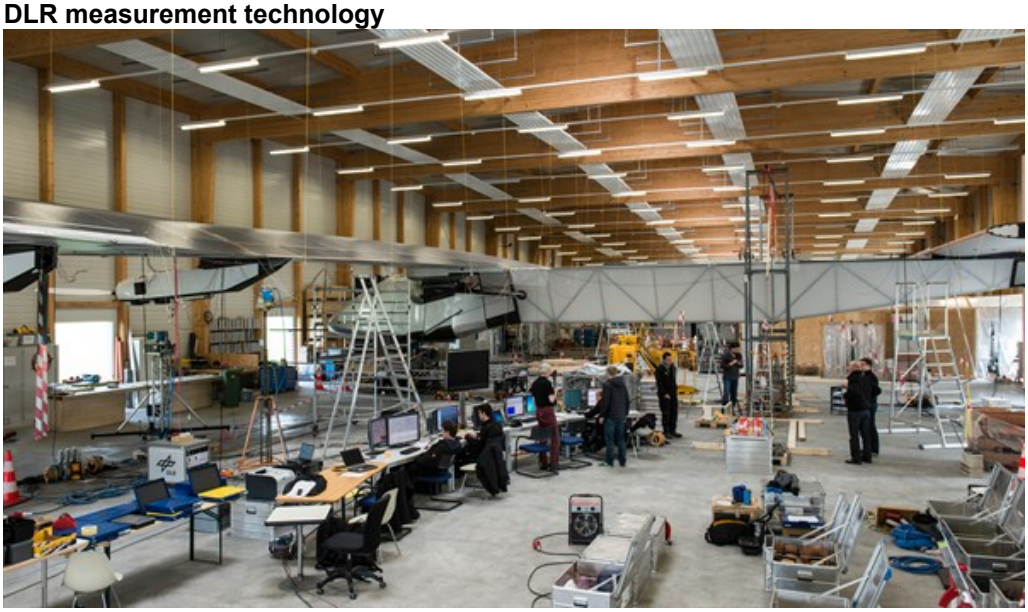
Shaker vibrates the unique aircraft



The DLR researchers made the Solar Impulse prototype vibrate in various places using electrodynamic exciters known as shakers; these generate vibrations via a coil in a magnetic field, as with loudspeakers. Here, however, the magnetic force is not used to move a loudspeaker cone; instead, it is used to vibrate the aircraft structure directly.

Credit: DLR (CC-BY 3.0).

DLR measurement technology



All the cables connected to the vibration sensors are suspended above the Solar Impulse prototype. The weight of the cables must not affect the sensitive vibration measurements.

Credit: SolarImpulse/François Wavre/rezo.ch.

Yves Govers at work

Numerous measurement cables carry the signals from vibration sensors that are distributed over the fuselage, wings and tail of the Solar Impulse prototype. Here, researcher Yves Govers checks a connector at an interface where the measuring cables converge.

Credit: SolarImpulse/François Wavre/rezo.ch.

Solar Impulse aircraft with lightweight propellers

Despite its wingspan of 72 metres, the lightweight aircraft, with the identification HB-SIB, weighs only about 2.5 tons. Almost half of the weight is accounted for by the cockpit and the four engine nacelles, which have integrated batteries to provide the aircraft with power at night.

Credit: SolarImpulse/Anna Pizzolante/rezo.ch.

The measurement team at the DLR Institute for Aerolasticity

The DLR Institute of Aeroelasticity is a leader in the field of stationary vibration testing, having already performed measurements on the vibration behaviour of prototypes of large airliners such as the Airbus A380 and A350.

Credit: SolarImpulse/François Wavre/rezo.ch.

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