Material test for extended time tests of aircraft

IABG Industrieanlagen-Betriebsgesellschaft mbH

HANCHEN®

1 | Airplane set up in a hall for material load tests.
2 | The test stand: Top view of wings.

Airbus under continuous stress

HYDRAULIC CYLINDER SERIES 300

- dimension
  piston -Ø 50–320 mm
  rod -Ø 36–225 mm
  stroke 50–6000 mm
- type of effect: doubble rod and synchronous
- sealing system:
  Servocop® und Servofloat®

Test bench with Hänchen cylinders pushes the boundaries of what is possible.

Turbulence can cause the wing tips of the A 340-600 to move over four metres. Anyone observing the constant up-and-down movement of the wings spanning several metres in trial conditions gets a glimpse of the material stress to which commercial aeroplanes are subject. This Airbus will complete at least 35,000 flights - and won't even leave the hangar directly adjacent to Dresden Airport to do so. The aeroplane is moved by 94 Hänchen hydraulic cylinders which form the core mechanical components of a time accelerator test, which simulates over a period of 18 months the sequences of movements of the entire life-span of an aeroplane lasting 25 - 30 years.

30 types of aeroplane in 40 years

The aeroplanes which have been tested since the 60's with Münchner IABG acting as main contractor range from the Tornado to the Airbus - including the Airbus numbers 300, 310, 320, 330 and 340. The aim of this extended time test is to provide experimental evidence that the airframe has sufficient serviceable life and to eliminate any possible weak points still in evidence. Clients requiring these tests include all the major European aircraft manufacturers. The current test is carried out by the IABG in conjunction with Dresdener IMA Materialforschung und Anwendungstechnik GmbH. It only took less than two years to design and construct the test. The static tests were started in April 2001 and shortly before the first flight in September, the endurance tests were started with a new control technique developed by the IABG to realize the tests in a extremely short timeframe.

3 | The test stand: Top view of wings

Test with Haenchen cylinders

Since 1974 Hänchen hydraulic cylinders have been used for the majority of these dynamic tests for aircraft. The cylinders are supplied with a throughput of 4,400 litres of compressed oil per minute over many kilometres of pipelines with diameters of up to 20 cm on the main pipes. Process computers co-ordinate the sequences of movements in such a way that the loads correspond to the day-to-day flight realities of the Airbus A 340-600. In order to make these movements as realistic as possible, the hydraulic cylinders are driven by proportional valves. This process mainly uses testing machine cylinders with floating annular gap sealing, patented by Hänchen. For special tasks, however, cylinders with hydrostatically mounted piston rod guides are also used.

Simulation not only on the computer

"Discovering damage in this kind of test is part of everyday life", is how Klaus Woithe, graduate engineer and IABG branch manager in charge of the project sums up the experience gained over 40 years. "Even modern computer models with FEM, the finite elements method, still cannot replace the dynamic endurance tests", he maintains. Indeed, computer analysis cannot, as a general rule, reproduce certain effects occurring in reality with the required precision. Since aeroplanes are usually designed nowadays to resist a certain amount of damage, cracks several centimetres long can occur in the fuselage skin without compromising the safety of the aircraft. The demonstration trials in Dresden are carried out on the wing structure with approx. 60 metres wing span and a 33 metre long fuselage segment. Undercarriage and engine pylon dummies serve to introduce the loads coming from these components.

Hydraulics as a core technology

"Hydraulics is the core technology for load simulation in the dynamic test for material fatigue on aircraft. This is because control, measuring and fluid technology work hand in hand here", says Woithe. "The computers have to make stipulations in real time which are then activated in the set-actual comparison with the help of PLCs via control circuits with load cells. Apart from control they also serve to prevent overload. High-quality testing cylinders are a basic prerequisite for guaranteeing that this test is realistic. In this respect we have, over 27 years together with Hänchen, pushed the boundaries of what is possible time and time again, yet we have nevertheless achieved a good cost-performance ratio while remaining highly committed to running on schedule. The testing cylinders from Ostfildern were successful on account of their strengths, especially their low friction, optimum tightness, excellent response, low abrasion,

4 | Hydraulic cylinders are also used for systematic application of stress to the hull

extreme piston speed, low initial break-out torque, fatigue strength and long serviceable life.

Two and a half lives in 18 month

For safety reasons experimental evidence is taken over more than two and a half times the expected life of an aircraft. In order to test the material fatigue, all the stages of flight are simulated. This includes take-off and landing as well as all stages of flight in which the Airbus is subject to load alternations, namely vertical and horizontal gusts and flight manoeuvres. In this way even a long-haul transatlantic flight in good weather conditions can be condensed into a simulation program of quarter of an hour or half an hour. In the categories of short, medium and long-haul flights a series of typical flights in each case were defined from the standard flight right through to the difficult flight in extreme conditions. They consist of load data for the airframe mapped on a gradient diagram. This is because the cabin is set at an increased internal pressure by means of a compressor unit and two air chambers depending on the simulated altitude, in order to simulate the difference in pressure between the cabin and the surroundings depending on the altitude of each flight. A flight-by-flight program sequence encompassing more than 1,000 flights is generated from these types of flight. It is repeated as many times as necessary to reach the stipulated total number of flights. Constant monitoring by inspectors, comprehensive, day-long inspections of the entire test structure as well as regular measuring of 3,600 strain gauges and 80 displacement transducers guarantee that damage is detected as soon as it occurs. Since the aircraft is constructed in such a way as to resist a certain amount of damage, the development of cracks is observed from the point at which they arise until they reach a critical length. Then they are repaired or the part is replaced. A cleverly devised monitoring system ensures that the aircraft is not inadvertently exposed to unintentionally excessive loads in particular.

Floating annular gap sealing

Precision requirements dictate that disruptive forces such as stick-slip effects of the cylinders should be avoided. Very low restoring force occurs on the wingtips, for example, but they must be moved at the same time at up to 670 mm/s. In the process the wings are moved upwards up to 2.9 m from the zero position and downwards up to 1.2 m. Spurious oscillations of the flexible structures can easily occur, however, if the pistons and piston rods of the hydraulic cylinders are not as smooth running as possible. In this case tolerances of only 3 per cent of the nominal load of the cylinder are accepted; in practice they are under 2 per cent. Spurious oscillations would lead to unwanted load variations and would distort the test results. For this reason, the

5 | Application of stress to the hull using hydraulic cylinders.

cylinders with the floating annular gap sealing patented by Hänchen are particularly favoured for use in structure trials on aircraft, since they always have the same friction irrespective of the pressure. A steel bush inside them deforms through a choke gap and thus produces a non-contact packed sealing gap of a few 1/100 mm. The prerequisite for this technology is a production precision in the region of a few µm, since otherwise the leakage would lead to high hydraulic losses. This cylinder series (PZR) has a cost advantage of around 30 % when compared with cylinders with hydrostatically mounted piston rod guides (PLZ). This is because the PZR cylinders, on account of their very low friction, offer the possibility of very high positioning and repeat precision, are stick-slip free and admirably suited to both extremely slow and extremely fast movements alike. Another crucial factor determining the choice of the Hänchen cylinders, however, was their stability. After all, the trial runs for 24 hours seven days a week.

Jörg Beyer, mediaword

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