Welcome to the 3rd edition of the AIM² newsletter providing you an update on the activities within the EC funded project AIM² - Advanced Inflight Measurement Techniques 2. The 10 partner organisations Airbus (F), Avia Propellers (CZ), Cranfield University (UK), DLR (D), Evektor (CZ), MPEI (RUS), NLR (NL), ONERA (F), Piaggio Aero Industries (I) and Rzeszów University (PL) are shortly before completing the 48 months collaborative project dealing with the application of modern optical measurement techniques to flight testing. Within the last year several challenging flight tests have been performed, e.g. the wing deformation measurements on the Fairchild Metro II and the Evektor VUT 100 Cobra by means of IPCT (Image Pattern Correlation Technique), the in-flight application of Particle Image Velocimetry (PIV) for flow field measurements around a Dornier Do-228 and the successful performance of IPCT propeller deformation measurements with a newly developed rotating camera.

On the following pages further information about these activities is given. Furthermore a dedicated Advanced Flight Testing Workshop was performed at Rzeszów (PL) to present the AIM² measurement techniques to the flight testing community. With the help of lectures and exercises, the participants of the workshop learned how IPCT, PIV, BOS (Background Oriented Schlieren Method), IRT (Infrared Thermography), FBG (Fiber Bragg Gratings) and LIDAR (Light detection and ranging) function and how they might apply those methods to their own testing activities. An article in this newsletter will give you an impression of the workshop.

Flight tests with the LIDAR technique for air data calibration were performed on a Piaggio P.180 during the time of completion of this newsletter.

Within the next six months of the AIM² project several other impressive flight testing activities are planned. An instrumented PW-6 glider will be flown to apply IRT to flow transition measurements on the wing and later to apply IPCT for wing deformation measurements for comparison with FEM. FBG will be applied on a Scottish Aviation Bulldog airplane for pressure and deformation measurements. Last but not least, the landing gear movement of the Piaggio P.180 will be measured with a stereoscopic camera system.

As a major outcome of the AIM² project, the further developed advanced in-flight measurement techniques and several useful accompanying tools will now be more and more applicable for further flight, ground and large scale testing activities. Maybe they will also interest you in the near future?


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Compilation of contributions and editing: Christina Politz (E-mail: christina.politz@dlr.de, Phone: +49 551 709-2462).
Published by the coordinating partner DLR ViSta/Protokoll - responsible: Fritz Boden (German Aerospace Center, Bunsenstr. 10, D-37073 Göttingen, Germany, Phone: +49 551 709-2299, Telefax: +49 551 709-2830).
Flight test to evaluate IPCT for wing, flap and aileron deflections

On 17 April 2013 a successful AIM² flight test was performed with the NLR Fairchild Metro II. Aim for the test flight was to generate images of the speckled wing, flap and aileron under different loads and dynamics to test IPCT (Image Pattern Correlation Technique). IPCT has been further developed for measuring deformations of dynamically moving surfaces and of the rotating flap and aileron surfaces.

In a three hour flight all manoeuvres described in the Flight Test Plan were executed. Wing loads were changed during turns and parabolic flight segments, turbulence was sought and found, touch-and-go’s were flown on an airport and flaps and ailerons were deflected. Dynamical manoeuvres were included. A wealth of measurement data was gathered with the two high-speed, high resolution AOS S-EM cameras viewing the speckled pattern on the right wing, the flap and the aileron. Dynamical measurements were possible by the use of high-speed cameras. For the determination of the rotation and deformation of the flap and aileron additional functionality of the processing algorithm was developed. Reference data was recorded from the Inertial Reference System (IRS), a synchro measuring the aileron position and a potentiometer that measured the flap position. The two pictures show the measurement setup on the wing and in the cabin.

The IPCT technology for determining the aileron and flap rotations and the wing, aileron and flap deformations is implemented in an Optical Wing Deflection Modelling (OWDM) tool. The OWDM software tool is under development to enable the processing of images with IPCT easily, quickly and with a user friendly Graphical User Interface. First measurement results and first versions of the OWDM software tool have been generated and subsequently presented at the AIM² flight testing workshop in 2013. Work is in progress to check and improve the capabilities of the processing.

Kunovice (CZ): After the successful tests on the NLR Fairchild Metro II and the proper evaluation of DLR wing vibration measurements on an Airbus aircraft, an application of the IPCT under industrial boundary conditions was performed at EVEKTOR in Kunovice (CZ) in late Summer 2013. One wing of an EVEKTOR VUT-100 Cobra was equipped with an IPCT pattern and recorded by a similar camera installation as for the Fairchild measurements. First data evaluation showed good results and detailed image processing is on-going. FB.
It works :-)  

Rotating Camera successfully flight-tested

Beginning of January the rotating camera for measuring the deformation of a propeller blade flew for the first time. The flight tests were performed by Evektor, Avia Propeller and DLR at the EVEKTOR plant in Kunovice (CZ).

The camera, especially designed for IPCT propeller deformation measurements, was mounted on the propeller hub of an Evektor VUT-100 Cobra experimental airplane. One propeller-blade is observed for the complete revolution. For the application of IPCT, a special dot pattern was sprayed on the blade surface. For that purpose a painting mask was created and affixed to the blade.

After painting, the whole system (Propeller with painted blade and mounted rotating camera) was balanced and transported to EVEKTOR. There it was fitted to the Evektor VUT-100 COBRA experimental airplane.

During four flights in total the newly developed rotating camera recorded one propeller-blade phase-locked and also with a moving phase-shift to measure the complete revolution.

In total around 200GB of image data was recorded including several on-ground and in-flight propeller loadings. First data evaluation shows that the recordings can be processed by IPCT to get information about the in-flight shape and behaviour of the propeller-blade. An evaluation example is shown to the right – the solid surface is an example 3D surface of the propeller blade in flight, the dotted surface shows the reference surface of the propeller blade if the propeller does not rotate.

Within the next months of the AIM² project all data will be analysed in order to check the applicability of IPCT for deformation measurements in a rotating frame.

Thanks to the teams of EVEKTOR, AVIA-Propeller and DLR, as well as the polish company HARDsoft, the flight test of the rotating camera was a great success.
Fly with Light:

In-flight PIV Campaign 2013

Finally, on June 7, 2013, the D-CODE of the DLR flight operation center in Braunschweig took off to carry out the first flight test with the largely extended PIV measurement system. A series of 4 more flights followed up in October the same year with the very same setup. This campaign was an essential milestone of the PIV activities within the 5th workpackage of the AIM² project. The main objective of these experiments was the assessment of the accuracy and performance of Particle Image Velocimetry under flight test conditions.

The PIV system was arranged inside Dornier Do 228-101 D-CODE to determine the boundary layer flow close to the fuselage surface. In addition, a traversable rake with two differential pressure probes was installed close to the field of view of the two stereoscopic PIV cameras to provide velocity data with the help of a conventional and tried measurement method.

The seeding source for PIV was naturally occurring hydrometeors such as cloud droplets, haze or precipitation. The behaviour of these tracer particles with varying diameters inside the examined boundary layer is to a certain extent unknown. Hence, a particle sizing system based on the Interferometric Laser Imaging for Droplet Sizing (ILIDS) technique (for further information refer to AIM² Newsletter No. 1) was also introduced, designed, tested (in cooperation with the Cranfield University) and certified to help determine the particle behaviour during the PIV measurements.

The cabin of the aircraft was extensively modified for the experimental installations of this flight test campaign. A pressure probe traverse as well as a camera stand with two stereoscopic PIV cameras and an ILIDS camera were placed in front of the penultimate window on the right hand side of the fuselage. In order to improve the optical access for the cameras the standard cabin window was replaced by a rigid aluminium frame housing a high quality optical glass pane and a cut-out for the pressure probe stem. The stem of the traversing probe supported two pitot probes with differential pressure sensors and was able to move 100 mm out- and inwards. Thereby the velocity profile of the boundary layer thickness of 140 mm could be captured by means of the traversing probe. The traverse as well as the new window were designed and certified by the company Leichtwerk AG.

The field of view of the PIV camera covered an area of 65 x 95 mm². The observation distance between the laser light sheet and the cameras was around 95 mm. For the last flight test the laser light sheet was moved 30 mm closer to the aircraft fuselage surface to obtain additional PIV data from a different position inside the boundary layer.

All flights were conducted at night to avoid the negative influence of sunlight on the PIV and ILIDS images. During every flight at least 6 different conditions were flown with mainly changing velocity and flap settings. The recording strategy of each measuring point was based on a simultaneous run of the PIV and ILIDS systems as well as the pressure probes positioned at the light sheet height inside the boundary layer.

The most challenging issue to resolve during each and every flight was the detection of suitable clouds as seeding sources. This parameter strongly depended on the meteorological conditions during the flight test. Hence, either only small cloud layers or clouds...
featuring a strong convective nature including precipitation dominated the available atmospheric seeding. This circumstance did not only affect the hardware (moisture inside the probes) but also the amount of analysable PIV data with sufficient image density.

Nevertheless, a first glance at the results indicates agreement between the PIV and pressure probe data. Within the next months this comprehensive set of flight test data will be further evaluated and summarised within several AIM² reports and publications.

LIDAR for airdata calibration

ONERA Lidar flight tests conducted during AIM² project took place from 17th to 26th of February on the Piaggio site in Genova (I). The aim of these flight tests is to demonstrate that the measurement of the static error, the angle of sideslip as well as the angle of attack with LIDAR can increase the quality of flight test data and simplify aircraft certification procedures.

The figure below shows the ONERA Lidar implementation on board the P.180 experimental aircraft. The system includes the driving unit which is composed of four single components (laser, optical/electrical detector, power supply and PC), all compliant with aeronautical constraints, located in one rack provided by Piaggio.

The Sensor head which is precisely positioned with respect to the aircraft reference frame is integrated in another rack. The four lidar beams are sent through an optical grade glass window to probe the atmosphere and measure the true air speed (see figure in the upper left corner).

Three flights of about one hour were performed during the test campaign. The diagrammes below illustrate the acquired raw data and preliminary processing for a pull-up manoeuvre.

The left hand side diagram shows the raw spectra of the four lidar axes, and on the right are the three components of the aircraft true air speed after processing of the Doppler frequencies extracted from the spectra. Beyond the steady flight sequence (corresponding to samples 0 to 150), the pilot pulled the stick up to a load factor of 2g (samples 150 to 220). We can see the speed component Vx along the path decreases and vertical speed component Vz increases.
Gather Around:

The AIM² Workshop in Rzeszów

The AIM² Advanced Flight Testing Workshop took place in Rzeszów, POLAND, from 9th to 14th of September 2013 and was attended by 25 participants from aircraft industries, research institutes and Technical Universities all over Europe.

The workshop was organised in the frame of TASK 6.4 of the AIM² Project. The aim of the workshop was to present the state-of-the-art knowledge on the application of modern optical measurement techniques to measure the thermal and flow parameters in-flight. Furthermore, advanced optical methods to measure the deformation of the surface of the wings and rotor blades of aircraft were presented. The venue of the workshop was the Aviation Training Centre of Rzeszów University of Technology, Jasionka 13, POLAND, where its resources were reorganized and adapted for the workshop. Exercises and practices were performed both inside and outside of the ATC hangar. The main part of the meeting was split into six sessions which corresponded to advanced optical methods: Background Oriented Schlieren Method (BOS), Fiber Bragg Grating Method (FBG), Image Pattern Correlation Technique (IPCT), Infrared Thermography (IRT), Light Detection and Ranging (LIDAR) as well as Particle Image Velocimetry (PIV).

For each topic, experts from AIM² personnel delivered lectures and conducted exercises and demonstrations. In order to look into the workability of the selected methods in more detail, four working groups were created. It allowed the participants to have a better opportunity to join several exercises on real aircraft with advanced FTI and to discuss with the specialists of each measurement technique. The glider PW-6 was used to demonstrate IRT and IPCT methods, the PZL-Okecie 110 Koliber to demonstrate Background Oriented Schlieren Method. Given a range of applications, the participants gained knowledge on how a suitable measurement technique can be chosen. More details (and photos) can be found at the web-page: www.workshop.prz.edu.pl.

Since May 2013, all lecturers have developed and prepared multimedia presentations and supporting material for workshop participants on the topics of their lectures. A folder with the printed presentations was handed out to the participants.

Moreover, all lecturers have prepared chapters devoted to the presented methods/tools and results obtained during the project, which have been collected in the book: Handbook of Advanced In-Flight Measurement Techniques, ed. Fritz Boden, BoD, Norderstedt, 2013, ISBN 978-3-7322-3740-1. The book was handed out to the workshop participants. All participants received a Diploma of Workshop Attendance and have had opportunities to visit Łańcut, Rzeszów and Bezmięchowa in organised tours.