

State of the art – Background

Geared configuration for engine represents one of the most promising architectural innovations in the aeronautical market, considerably increasing the opportunity to improve engine performances.

The concept on which the geared engine architecture is based involves the mechanical uncoupling of the turbine from the fan section, by introducing a PGB – Power GearBox. By adding a further degree of freedom to the system, this solution allows the optimization of either power turbine or the fan performances in terms of rotational speed, with an overall enhancement of the whole engine efficiency.

Objectives

In the frame of SAGE4 activities, the GeT FuTuRe Project aims at performing a demonstration on a purposely developed full scale power test rig of the technologies matured by Avio Aero (IDS – Integral Drive System).

The IDS architecture has to envisage sophisticated and distinctive interfaces (mechanical, fluidic, functional) with the engine, therefore the experimental evaluation of its performance has to be carried out in a complex test environment that is able to:

- reproduce the distinctive interface conditions typical of the real installation environment of the test article;
- reproduce the complex and interdependent time history of the test parameters (e.g. speed, load, lubricant flow-rate and temperature);
- ensure proper behaviour of the IDS during the test, for instance avoiding unwanted dynamic coupling or instabilities.

The research theme proposed met the scientific interests and the strategic aims of Consortium Partners:

- University of Pisa – Department of Civil and Industrial Engineering (DICI), a centre of excellence, with high level multidisciplinary scientific competences in the field of advanced mechanical power transmissions;
- AM Testing srl (AMT), founded in 2008 as a spin-off of University of Pisa. The core business is the design of high performance test rig including support systems and the execution of relevant

comprehensive test campaigns on components/systems;

- Catarsi Ing. Piero & c. srl (CAT), leader Company in the field of manufacturing of precision mechanic devices. CAT business has grown over the last 40 years and now the Company can provide the most innovative production systems and control/measuring machines.

The proposed approach is innovative since it opens the collaboration with external partners on the experimental validation phase, which is generally retained by the system design responsible being strongly close to the design.

Description of work

The work plan is structured into 7 technical work packages, a Management work package and a Dissemination work package

- WP1 - Preliminary Rig Design
- WP2 - Detailed Rig Design
- WP3 - Rig Procurement
- WP4 - Test Facility Adaptation
- WP5 - Rig Integration & Commissioning
- WP6 - IDS Test
- WP7 - IDS Post Test
- WP8 - Management
- WP9 – Dissemination

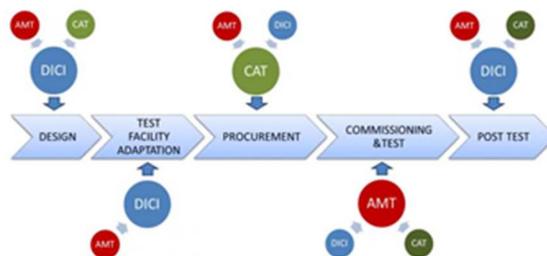


Figure 1: Partners responsibility and their involvement in the project.

Results

a) Timeline & main milestones



Figure 2: Project timeline.

The back to back power rig has been designed together with all required test bed equipment systems (WP1, 2).

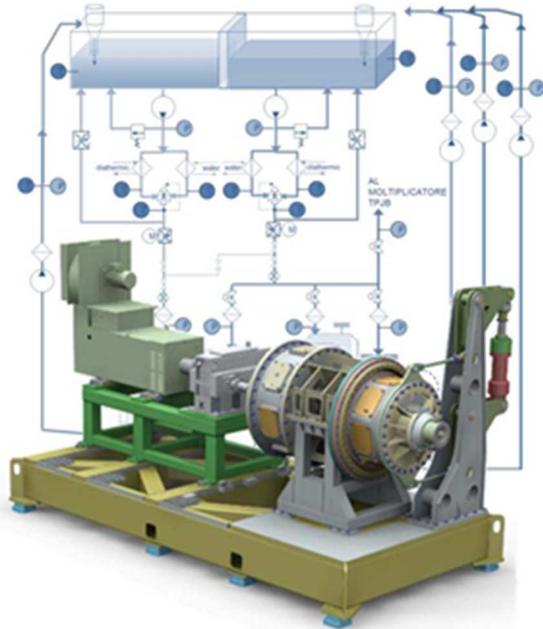


Figure 3: Test system design: test rig and auxiliary systems.

The test rig has been completely procured and delivered (WP3).

Two power gearboxes, provided by Avio Aero, have been installed in the test rig (D3.2 – Test Article and Slave gearboxes procurement, Topic Manager). One of these, the Test Article gearbox, has a dedicated instrumentation.

In parallel to the rig development, a new Test Facility has been built and made available by the University of Pisa for rig installation. The Test Facility is the result of a different research project, co-funded by Tuscany Region and sponsored by other important international Companies. Dedicated adaptation activities (WP4) have been performed in order to allow the installation and the operation of the test rig.



Figure 4: The new Test Facility

After the test rig installation in the test facility, the main commissioning activities (WP5) have been:

- verification that the required performances are reached;
- test rig characterization and identification of optimal testing regimes.



Figure 5: Test Rig under commissioning at the test facility

In WP6, several detailed test procedures for the execution of the functional tests in agreement with the test plan were defined.

The planned tests were carried out and the experimental data were validated.

The tests conducted in steady state regime were mainly aimed to reach the following objectives:

- to validate the experimental apparatus;
- to evaluate the IDS performances in terms of efficiency;
- to evaluate the LSF (Load Sharing Factor);
- to evaluate the performances of the IDS oil system.

Tests carried out in transient regime (load and speed ramp) were dedicated to the experimental investigation of the operating envelope and to the complete characterization of the system dynamic response.

In WP7, the main carried out activities have been:

- the preparation of a validated database of experimental data;
- the analysis of the experimental data;
- the final reporting and the means of evidence about the carried out experimental activities.

b) Environmental benefits

Get Future project contributes to reach ACARE and Horizon 2020 environmental goals by enabling, through the maturation of the IDS module, the development of next generation engine architectures.

In addition, testing on power rig can contribute to enhancement of general purpose technologies, like the selection of next generation materials, which can be applied to other gearboxes or other transmission systems with the aim at improving the overall product performances.

c) Maturity of works performed

A complex testing system was developed and commissioned. The carried out experimental activity enabled the Topic Manager to the validation of the SAGE4 architecture. The system is suitable and ready for the execution of further experimental activities.

d) Dissemination / exploitation of results

- M. Barsanti, M. Beghini, E. Ciulli, B.D. Monelli, S. Manconi, R. Catarsi, A. Demenego, Progetto e realizzazione di un banco prova per trasmissioni di potenza in ambito aeronautico, Atti del 45° Convegno Nazionale AIAS, Trieste 7-10 settembre 2016.
- M. Barsanti, M. Beghini, E. Ciulli, B.D. Monelli, D. Filippi, Effetti sulla ripartizione dei carichi dovuti alla configurazione dei satelliti in rotismi planetari, Atti del 44° Convegno Nazionale AIAS, Messina 2-5 settembre 2015.
- Monelli, B.D., Barsanti, M., Beghini, M., Ciulli, E., Filippi, D. (2015, 5-7 August). Analysis of the mechanical behavior of planetary gears for power transmissions. Paper presented at ACM 2015

International Conference on Advances in Applied and Computational Mechanics, Izmir, Turkey.

- Filippi, D., Barsanti, M., Beghini, M., Ciulli, E., Monelli, B.D. (2015, 5-7 August). Development of a lumped-parameter model for the study of the mechanical behavior of planetary gearings. Paper presented at ACM 2015 International Conference on Advances in Applied and Computational Mechanics, Izmir, Turkey.
- Barsanti, M., Beghini, M., Ciulli, E., Monelli, B.D., Filippi, D. (2015, 2-5 September). Planets configuration effects on the load sharing (in Italian). Paper presented at 44° AIAS Conference, Messina, Italy.
- Artoni, A., Barsanti, M., Beghini, Monelli, B.D., Demenego, A., Perona, E. (2014, 9-12 September). Analytical and numerical models for the dynamic analysis of GTFTR test rig (in Italian). Paper presented at the 43rd AIAS Conference, Bologna, Italy.
- Barsanti, M., Beghini, M., Monelli, B.D. (2014, 9-12 September). Development of a lumped-parameter model for the analysis of the load sharing in planetary transmissions (in Italian). Paper presented at the 43rd AIAS Conference, Bologna, Italy.
- Le Bone, L. (2014). Dynamic analysis of the GTFTR test rig (in Italian). Master's thesis, University of Pisa, Pisa, Italy.
- Filippi, D. (2014) A model of planetary gear transmissions in the presence of clearances (in Italian), Master's thesis, University of Pisa, Pisa, Italy
- Longobardi, G. (2014), Preliminary design of the GTFTR test rig (in Italian). Master's thesis, University of Pisa, Pisa, Italy.
- Raffaele, E. (2015) Rotor-dynamics of shafts with misalignments (in Italian). Master's thesis, University of Pisa, Pisa, Italy

e) Dissemination / exploitation of results

Events:

- Pisa, October 2013 – Kick off meeting of the project with the representatives of JU and local institutions
- Pisa, February 2015 – Critical Design Review with JU representatives
- Turin, June 2015 – Presentation of the project development to JU representatives and SAGE4 Members.
- Bruxelles, April 2016 – Clean Sky General Forum (Best projects from Partners' Awards)
- Pisa, June 2016 – Open day with the Clean Sky participation

Project Summary

Acronym: GTFTR

Name of proposal: Geared Turbofan Test Rig

Technical domain:

Involved ITD: Sustainable And Green Engine ITD

Grant Agreement: 620152

Instrument: Clean Sky JU

Total Cost: 3,142,568.00

Clean Sky contribution: 2,154,936.00

Call: SP1-JTI-CS-2013-01

Starting date: 01/10/2013

Ending date: 30/09/2016

Duration: 36 months

Coordinator contact details: Immacolata Viva
Largo Lucio Lazzarino 2, 56126 PISA
+39 0502217833 i.viva@ing.unipi.it
Marco Beghini
Largo Lucio Lazzarino 2, 56126 PISA
+39 0502218016 m.beghini@ing.unipi.it

Project Officer: Jean François BROUCKAERT (CSJU)
Jean-Francois.Brouckaert@cleansky.eu

Participating members: UNIVERSITÀ DI PISA
AM TESTING SRL
CATARSI ING. PIERO & C.