Performance and environmental targets drive the design of next generation aircraft architectures towards closer integration between the propulsion system and the airframe. These architectures are likely to feature concepts with ultra-high bypass ratios (UHBR) and larger fan diameters where a short
and slim intake design will be necessary to compensate for the drag and weight penalties of the increased diameter fan. Although such aircraft configurations may meet future targets, their short intakes can cause high levels of unsteady flow distortion especially under cross-wind operation during aircraft take-off. Such distortions can adversely affect the engine’s performance, operability and safety margin with potentially catastrophic consequences for the entire propulsion system. Today these problems are typically discovered late in development programmes and consequently have serious impacts on the aircraft development timescales, costs and certification.

Current practices for aero-engine testing and safety certification rely on the use of intrusive measurements of pressure upstream of the fan to quantify the flow distortion. The emerging need for development of advanced design metrics for distortion tolerant aero-engines is still hampered by the relatively low spatial and temporal resolution of the current methods. Additionally, the intrusive nature of these methods is detrimental in configurations where the fan and intake are tightly coupled.

Non-intrusive optical measurements techniques such as Particle Image Velocimetry (PIV) have proven their potential in wind tunnel testing over the past decades across many areas ranging from automotive to aeronautical applications. The application of PIV to measurements of flow distortion near fan face of a turbofan is highly challenging. Both optical access and surface reflections hamper the application of the technique. Furthermore, traditional PIV techniques involve complex setup and calibration requirements which can be tolerated in small and medium (often academic) laboratory wind tunnels but make them uneconomical solutions for large industrial scale test environments such as the DNW Large Low-Speed Facility (LLF).

Using internationally recognised expertise and recent technological progress, the partners within the NIFTI consortium have come together to define this project which has the following four measurable technical objectives:

Objective #1: Demonstrate a non-intrusive technique based on stereo PIV to measure the velocity field upstream of the fan of an UHBR aero-engine in a large industrial wind tunnel at representative engine operating conditions capturing the full inlet annulus.

Objective #2: Demonstrate a highly flexible multi-camera PIV implementation in a representative industrial test environment to cover a wide range of inlet incidence angles in a time efficient way.

Objective #3: Develop advanced data processing methods to generate dynamic distortion metrics that will aid the development of novel design rules for closely-integrated, stall tolerant propulsion systems.

Objective #4: Develop advanced numerical methods to enable the aerodynamic and aero mechanical characterisation of the fan across the operating range when coupled with a short intake

Conventional stereo PIV has been selected as the baseline solution within NIFTI for flow field measurements within the UHBR inlet. After initial exploration and de-risking, a multi-camera approach was designed with full automated control of the camera focus, and Scheimpflug angle and axis direction to allow productive measurements within a range of model attitudes. Furthermore, the approaches for light sheet delivery and reflection mitigation were established. The newly developed
PIV system is operational and the system and design solutions will first be tested in a small-scale wind tunnel test before proceeding with final validation in the DNW-LLF. For the small-scale wind tunnel test a modern UHBR aspirated inlet model has been designed. Conventional pressure instrumentation at fan face will be installed to allow validation of numerical models and PIV methodologies for both high incidence and cross wind conditions. The post-processing techniques, including pressure reconstructions from PIV results and advanced distortion metrics derivation have been developed and a numerical model of the aspirated inlet model has been set up.

The final verification of the developed techniques will be performed on a fan powered inlet model in the DNW-LLF. This will demonstrate industrial efficient measurement capability close to a rotating fan assembly. To ensure the safety of the fan in the presence of severe inlet distortion a fan-coupled CFD model has been developed and validated. From these results, safe operating conditions have been selected for testing in the wind tunnel environment.

Progress beyond the state of the art and expected potential impact (including the socio-economic impact and the wider societal implications of the project so far)

NIFTI aims to develop non-intrusive measurement and numerical techniques as enabler of UHBR technology. As such NIFTI will contribute in the roadmap of maintaining the leadership of the European aeronautics industry and reducing CO2 emissions by increased propulsion efficiency. The NIFTI PIV innovations will open up new possibilities and measurements solutions. Measuring a richer dataset in less time will support the ACARE goals for more efficient, cost-effective testing and upgrading physical facilities to and beyond state-of-the-art. Apart from providing significant benefits to the aviation sector, exploitation of these NIFTI outcomes will also have synergies with other transport modes such as the European automotive industry. The development and validation of unsteady numerical modelling of unconventional propulsion systems are vital to support the backbone for any future aircraft and propulsion development as it delivers richer, more accurate aerodynamic characterization.

Within the first reporting period of the project activities, development of new PIV techniques has already taken a huge step. Both the camera adjustment solution and developed fibre optics laser sheet delivery are innovations that will lead to new products and applications within and well outside the scope of the project. The developed PIV innovations are currently laboratory validated, and a target of TRL5 is set at project end. The experimental datasets that will be acquired by the project will offer a unique opportunity to validate the numerical models currently developed within the project. This improved understanding will contribute to full maturity of simulation techniques for novel propulsion concept.

The excellent cooperation of major academic and industrial stakeholders within the project guarantees the future application of the experience gained in the project. The project partners are fully committed to ensure effective exploitation of the numerical and experimental toolsets developed within NIFTI. The current project scope and direction closely matches the needs of industry and reflect the ambitions to progress beyond state of the art.
Inlet distortion at cross wind conditions for a fan-coupled UHBR configuration

Last update: 10 May 2022

Permalink: https://cordis.europa.eu/project/id/864911/reporting

European Union, 2023