33RD CONGRESS
OF THE INTERNATIONAL COUNCIL
OF THE AERONAUTICAL SCIENCES
STOCKHOLM, SWEDEN, 4-9 SEPTEMBER, 2022

ICAS 2022 SWEDEN

STATUS OF GKN AEROSPACE'S ENGINE MODULE DEMONSTRATORS IN THE CLEAN SKY-2 PROJECT

Robert Lundberg, Lars Ellbrant, Patrik Johansson, Ulf Johansson, Mattias Billson, Bernhard Gustafsson

GKN Aerospace Sweden AB

Abstract

This paper gives an overview of the status of the design, manufacturing and testing of GKN Aerospace's complex structures and modules for the engine demonstrators of the Clean Sky 2 project. GKN Aerospace is responsible for both turbine structures and compressor structures as well as more complex modules in the engine demonstrators led by MTU, Rolls-Royce and Safran. In some cases the validation test is already performed but in most cases engine testing is planned later in 2022 or in 2023.

Keywords: propulsion, turbine structure, compressor structure

1. Introduction

GKN Aerospace in Trollhättan, Sweden, is a Core Partner in the Engines ITD (Integrated Technology Demonstrator) in Clean Sky-2, with responsibility for design, development and manufacturing of a number of complex engine structures and modules. The Clean Sky-2 project started in 2014 and is closing in 2023. GKN is involved in the engine demonstrators led by MTU Aero Engines, Rolls-Royce and Safran Aircraft Engines.

2. GKN demonstrators

2.1 MTU led demonstrators

In the unique 2-spool compressor rig demonstrator led by MTU Aero Engines, GKN Aerospace is responsible for the low pressure compressor (LPC) and inter-compressor-duct (ICD). In this unique rig test the whole system of LPC, ICD and HPC will be optimized together. The specific design target for the ICD was a more aggressive design with a 25% shorter duct with acceptable pressure losses and no detrimental effect on the HPC. For the LPC design GKN could build on earlier experience of LPC design and validation [1][2]. In Clean Sky-2, aerodynamic tests of the inter-compressor-ducts have been performed both at GKN and at DLR, Germany [3]. The LPC parts for the 2-spool rig, such as bladed disks (blisks) and stators are now being manufactured for the final rig test at DLR.

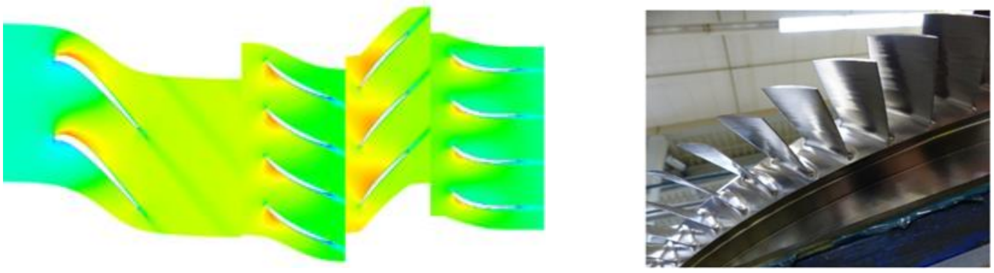

Figure 1. LPC and ICD aerodynamics (left). LPC blisk in manufacturing (right)

The design of the ICD included a study of how to separate water and particles, coming in to the engine through the air intake, from the core flow, before entering the high pressure compressor. The ICD rig at GKN was equipped with water injectors for injection of water droplets with a certain size in to the fair flow and a special feature for measuring water coming out through the bleed offtake.

A CFD method for tracking water droplets was developed and used for computations with the rig geometry and corresponding air and water flows. Water droplets distributions were modeled using Lagrangian particle tracking as well as Eulerian models.

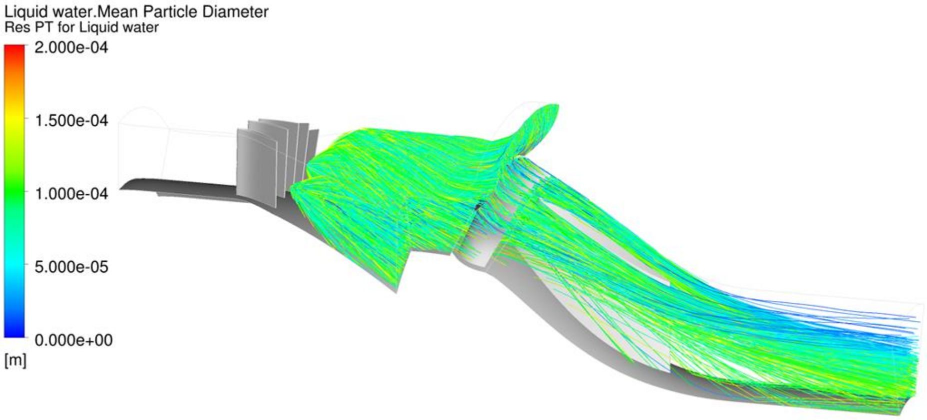

Figure 2. CFD simulation of the ICD rig. Water droplets are injected upstream of the bleed port and a Lagrangian particle tracking model was used.

GKN has also developed and delivered an exhaust module, including the rear turbine structure for a subscale engine test at MTU, Germany. This module includes a novel light weight rear turbine structure design with separated thermal and mechanical functionality which has been manufactured with extensive use of parts manufactured by additive manufacturing (AM), using selective laser melting (SLM). The turbine exit structure consists of an inner load-carrying structure and aerodynamically shaped vanes (or heat shielding fairings). The aerodynamic optimization of the turbine exit vanes has been performed in a national project in a unique turbine exhaust test facility at Chalmers University [4]. The design targets for GKNs module were a reduced weight by 20% and a +150°C higher temperature capability.

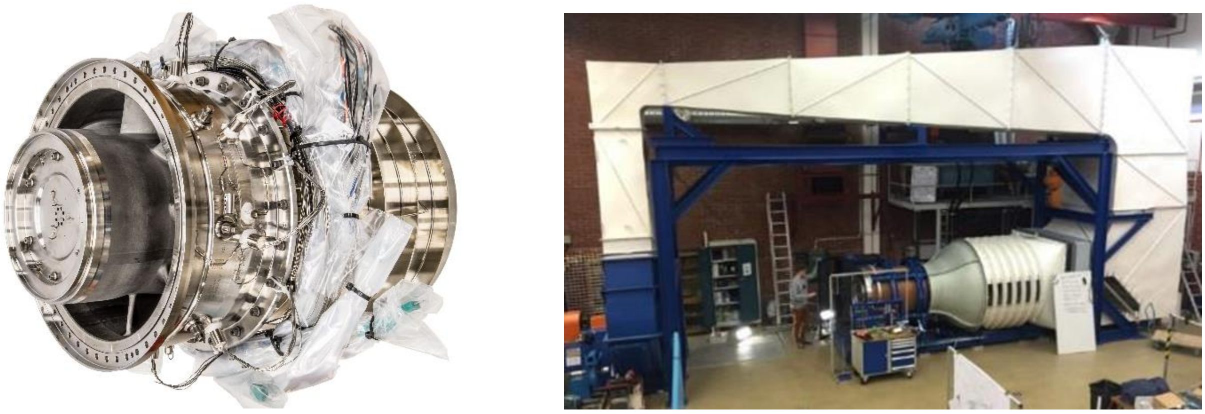

Figure 3. GKN’s exhaust module after assembly and instrumentation (left). Turbine exhaust test rig at Chalmers University (right)

2.2 Rolls-Royce led engine demonstrator

Rolls-Royce is leading the UltraFan® full scale engine demonstrator in Clean Sky 2. This novel engine targets 25% fuel savings compared with the first generation of Rolls-Royce Trent engines [5].

GKN is responsible for the Intermediate Compressor Structure (ICC), which is an electron-beam-welded assembly including smaller castings from a European supplier, as well as sub-elements manufactured by additive manufacturing using electron beam melting (EBM). The welding of these complex segments with varying thickness was only made possible with the help of extensive weld process modelling. Since the UltraFan® is a geared engine architecture this imposes new requirements for the ICC regarding for example stiffness and duct aerodynamic design. The compressor duct aerodynamics were studied in collaboration with Loughborough University and

Chalmers University in the Clean Sky 2 partner project IDA [6].

GKN also analysed the bleed system of the compressor structure with respect to acoustic resonance. The analysis identified that there was a risk of self-sustained acoustic resonance in the bleed system. The solution was to incorporate volume-restricting baffles in the bleed manifold which changed the acoustic response of the bleed system. The solution was found to sufficiently change the bleed system acoustic response to mitigate the risk of resonance.

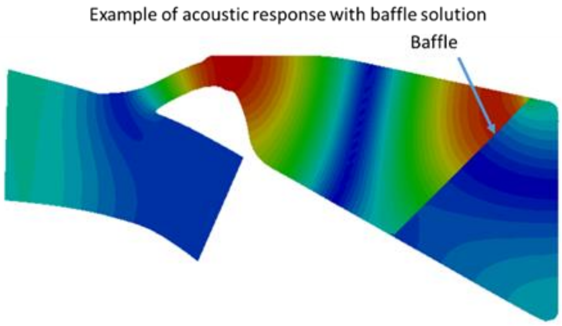

Figure 4. Example of acoustic response with baffle solution.

Along with meeting full compliance with the engineering requirements, the main focus of this compressor structure demonstrator for GKN is component cost reduction and enabling a fully European supply chain. Two sets of compressor structures have been delivered in 2021 to the engine assembly line at Rolls-Royce, Derby, UK [7] and engine testing is expected in 2022. Casting, weldability and additive manufacturing of alternative materials to the baseline titanium material, such as a novel aluminium alloy and alternative titanium alloys, have also been evaluated with promising results for future development and exploitation.

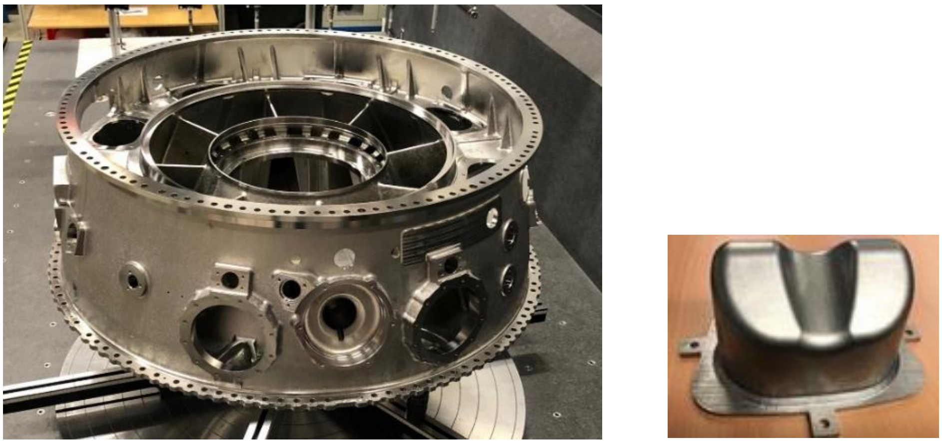

Figure 5. GKN’s intermediate compressor frame (left) and an attaching part made by EBM 3D printing (right).

2.3 Safran led engine demonstrator

In the demonstrator engine work package led by Safran Aircraft Engines, GKN is responsible for the intermediate compressor structure and the advanced rear turbine structure. The Safran led engine demonstrator is presented in more detail in another paper at this conference [8]. GKNs compressor structure is now in the design phase and will be validated in an engine test at Safran. GKNs turbine structure is an optimized welded lightweight structure. It is a laser welded assembly of sectors manufactured by different manufacturing technologies, such as precision casting and 3D printing, using selective laser melting (SLM). The material selected is a novel nickel base superalloy that is used for the first time in cast and printed form in a structural engine part. The demonstrator’s optimized balance between aerodynamic performance, weight and mechanical properties resulted in a shorter and 14% lighter part, contributing to lower carbon dioxide emissions of the engine. The multidisciplinary design optimization (MDO) of the turbine frame was made using a novel software tool enabling a rapid iteration of a large number of conceptual design alternatives [9]. The turbine structure demonstrator was tested in a full scale mechanical test at GKN in December 2021 [10]. Results from this test indicates good correlation with analyses.

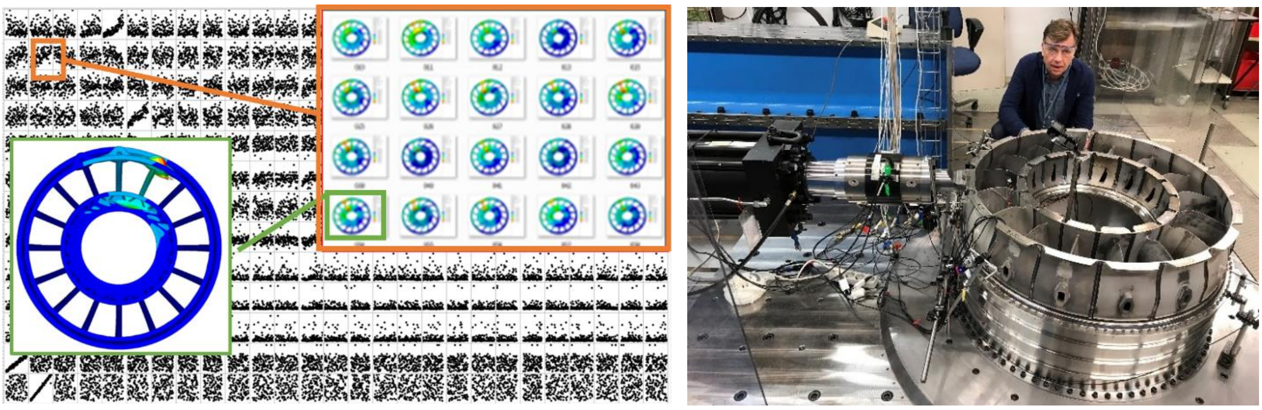

Fig. 6 MDO optimization example (left). The turbine structure in the mechanical test rig at GKN Aerospace, Trollhättan (right)

2.4 SME involvement

All demonstrator parts have been manufactured in cooperation with a number of Swedish small and medium size enterprizes (SMEs) engaged through the Vinnova funded SE national IntDemo Motor project (Brogren Industries, AIM Sweden, Bröderna Carlsson and TPC Components are some examples).

3. Clean Sky-2 overview and structure

Clean Sky-2 aims at developing cleaner air transport technologies for earliest possible implementation. This means integrating, demonstrating and validating technologies capable of reducing CO_2, NO_x and noise emissions by 20 to 30% compared to ‘state-of-the-art’ aircraft entering into service as from 2014. Besides improving the environmental impact of aeronautical technologies, the objective of Clean Sky 2 is also to develop a strong and globally competitive aeronautical industry and supply chain in Europe.

The Clean Sky-2 programme structure is composed of the three IADPs – Innovative Aircraft Demonstration Platforms – (Large Passenger Aircraft, Regional Aircraft and Fast Rotorcraft), three ITDs – Integrated Technology Demonstrators (Airframe, Engines and Systems) as well as three TAs – Transverse Activities (Small Air Transport, Eco-Design and Technology Evaluator). The three Transverse Activities have relevance to several ITDs and/or IADPs and require coordination or management across the ITDs and/or IADPs.

The work presented in this paper was performed in the Engines ITD, Work packages 2, 4, 5 and 6.

4. Acknowledgments

EU funding through the Clean Sky-2 Joint Technology Initiative as part of the Horizon 2020 programme is gratefully acknowledged, as well as national Vinnova funding for the project IntDemo Motor. Region Västra Götaland is thanked for funding Clean Sky synergy projects about advanced manufacturing technologies at the Innovatum Manufacturing Technology Centre in Trollhättan.

5. Contact Author Email Address

Robert Lundberg: Robert.Lundberg@gknaerospace.com

6. Copyright Statement

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