SUMMARY AND OVERALL OBJECTIVES OF HUC

The continued demand for improved gas turbine engine efficiency stimulates the constant development and application of higher performance materials. The higher the turbine inlet temperature, the higher the efficiency and lower emission of greenhouse effect gases. Hence, the gas turbine engines are affected by a demand to increase their operating temperatures, which is typically limited by the materials used. Ni-base superalloys are commonly used in aircraft engines due to their exceptional combination of high temperature strength, toughness, and great corrosion and oxidation resistance.

High γ' volume fraction is desirable for high temperature applications. Astroloy with high amount of Al and Ti, which are linked with formation of γ´, $Ni_3(Al,Ti)$, is very interesting materials for more efficient engines. However, the vast presence of γ' precipitates in this material make very difficult the manufacturing process by conventional cast and wrought route. Thus, new routes based on powder such as additive manufacturing (AM) or powder + hot isostatic pressing (HIP) processes are potential choices. Although AM technologies offer benefits from the manufacturing standpoint, the deposited material shows low ductility compromising the containment capacity of the casing. Instead, powder + HIP is more promising technique, in fact, HIP + forging route is the standard manufacturing route for high temperature discs with Ring Rolling as the naturally competitive choice. High temperature powder HIPped materials are less susceptible to being forged in the inherently non isothermal conditions under which Ring Rolling occurs. This together with the higher comparatively raw material costs (powder vs billet) would further challenge the competitiveness of any powder HIP + Forging based solution.

Consequently, Powder HIP without subsequent Forging is a competitive solution for high temperature casing manufacturing route although this technique presents several challenges.

HUC project belongs to the Clean Sky 2 programme and the main objective of HUC has been to develop and validate a powder HIP manufacturing route for Astroloy that has improved the buy to fly ratio through Near Net Shape HIP (NNSHIP). The material developed is suitable to fabricate IPT casings for the very high bypass ratio (VHBR) Ultrafan® engine under development by Rolls Royce, being the IPT casings able to withstand engine relevant conditions guaranteeing its ability to contain. Project had 8 technological objectives:

1: Development and Optimisation of a powder HIP processing route for a high temperature material.

2: Characterisation of mechanical properties to generate a database which supports the component design.

3: Development of experiments and numerical simulations to assess the material´s behaviour under dynamic and ballistic conditions.

4: Characterisation and understanding of mechanical properties with long exposure at high temperatures.

5: Development of low cost tooling for HIPping high temperature superalloy casings.

6: Development and validation of process modelling capabilities.

7: Manufacturing of canning to guarantee the compliance of the finish product with the requirements.

8: Manufacturing of 2 low cost demos and 3 full size IPT casings: 2 for real engine tests and 1 for NDTs.

Once these objectives are reached, HUC will contribute to one of the key societal challenge: smart, green and integrated transport. Moreover, HUC will also contribute to the strengthening of the competitiveness of the European Aircraft and Airlines industry and related SME's through the development of state-of-the-art technologies.

PERFORMED WORK AND MAIN ACHIEVEMENTS

HUC project has been successful and 100 % of activity scheduled has been completed.

Optimization and validation of the HIP route by means of depth microstructural characterisation and basic mechanical tests. Powder+HIP+Heat Treatment have been defined.

Mechanical tests to obtain material design data. All the material without and with exposure was manufactured and sent to a Nadcap approved laboratory. Mechanical results were analysed discussed as a function of the microstructures and processing route including powders characteristics and recorded for material design.

A material containment capacity model was developed and validated with experimental data (ballistic test and impact toughness tests), Figure 1.

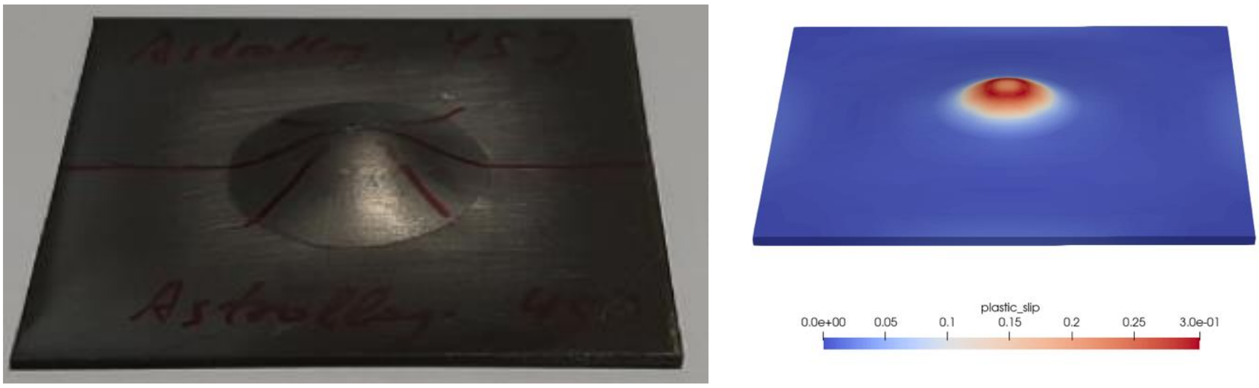

Figure 1. Experimental vs simulated results of post-mortem specimens after drop-weight impact tests.

A new HIP model has been developed incorporating viscoplastic mechanism and modifications of the shape of the pores during HIPping. A filling model have also been developed which incorporates the role of the powder particle characteristics and a phase diagram of vibrated powders.

Low-cost tooling manufacturing technique was chosen and 2 demonstrators were successfully manufactured, Figure 2. One of them is a full scale casing.

Figure 2. Inner and outer manufactured by low-cost techniques.

Three canning have been manufactured, HIPped and machined for full scale demonstrators. Figure 3.

Figure 3. Three full scaled demonstrators manufactured by Near Net Shape in HUC project.

NDT inspections and dimensional measurements for the different engine and demonstrator casings have been defined and performed. In addition, acceptable criteria for powder HIP parts including acceptable defects base on the results of the trials manufactured during the project have been defined.

WP8: within the project management process, different press realises and conference and journal papers have been published.

PROGRESS BEYONG THE STATE OF THE ART AND EXPECTED IMPACT

Progress beyond the state of the art: HUC has gone a step further from the state of the art for powder-HIP process by using high quality tailored powders thanks to having a powder manufacturing company as a partner. In addition, a full process optimising has been carried out related to HIP parameters outgassing procedure and heat treatments.

In terms of HIP modelling, in HUC project both the DEM and the new CFD with powder apparent viscosity physical modelling have been applied and validated through experimental measurements, to develop a dedicated solution for reliable and robust simulation of real “big” industrial shapes capsule filling.

HUC has contributed to create a database with mechanical property values onto Astroloy materials without and with exposure treatments.

A novel damage model based in combination of Johnson- Cook and Zerilli-Armstrong and including material thermal exposure effect has been developed to measure containment capacity for Astroloy.

The computational tools in HUC, to forecast distortions associated with HIP, has been a clear improvement on the status quo as they address the problem in an integral manner including capsule filling modelling, HIP process modelling and an algorithm for optimizing canister design.

HUC has proposed a low cost process for canning manufacturing, that will significantly reduce the cost of NSHIPping.

Potential impacts:

An efficient raw material usage: more than 70 % against less than 15 % of the traditional fabrication route; An efficient energy consumption: 80 % of energy savings by using NNSHIP instead of the traditional fabrication route; and 80 % reduction of equivalent CO_2 emission: due to the more efficient energy consumption the use of NNSHIP instead of traditional manufacturing route.

ITP Aero has delivered the first IPT for the new Rolls-Royce UltraFan® engine, with a casing developed in HUC.

Address (URL) of the project's public website

http://huc-cs2.eu/

https://zenodo.org/deposit?page=1&size=20