CASE STUDY OF THE CHALLENGING INSTALLATION OF A TURBOPROP FLOW EVACUATION SYSTEM

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Summary:

The integration of the airframe and a turboprop propulsion system entails several challenges. One of them is the installation of the exhaust. On the one hand the nacelle cowlings have to be protected from the effects of hot gases expelled from the engine. This is a challenge especially in case that no metallic cowls are used for weight reduction reasons. On the other hand, if the exhaust is part of the nacelle ventilation system acting as an eductor, the equipments housed inside the engine ventilation bay have to be also protected from the effects of the exhaust hot gases.

This paper is an account of how exhaust installation problems were faced in the A400M. The engineering process from the problem diagnostics to the final solution is described. CFD codes were extensively used for the problem identification and the solution searching. Ground and Flight test campaigns showed that proposed solutions, nowadays implemented in the A400M production A/C, were efficient at mitigating those problems.

Aerothermal problems and initial mitigations:

Figure 1 shows the contribution of an eductor system in the ventilation of the engine bay. Ventilation flow is energized as it is mixed with the engine flow.

Flight and ground tests conducted on A400M prototypes showed that for some conditions, particularly at low power setting, two events occurred (fig 2):

1. Overheating of nacelle equipments and structural components (>200ºC).
2. Impact of the engine exhaust plume on the rear cowls.

Initially, conventional mitigation means were analyzed and implemented to go ahead with A/C testing:

- Nacelle ejectors to prevent reingestion of engine exhaust gases into the nacelle ventilation bay.
- Replace cowling by heavier metallic cowls able to withstand high temperatures. (fig. 3)
- Curved exhaust. Deflect engine plume downwards, away from exhaust cowling. Affects engine and ventilation performances (fig. 4).

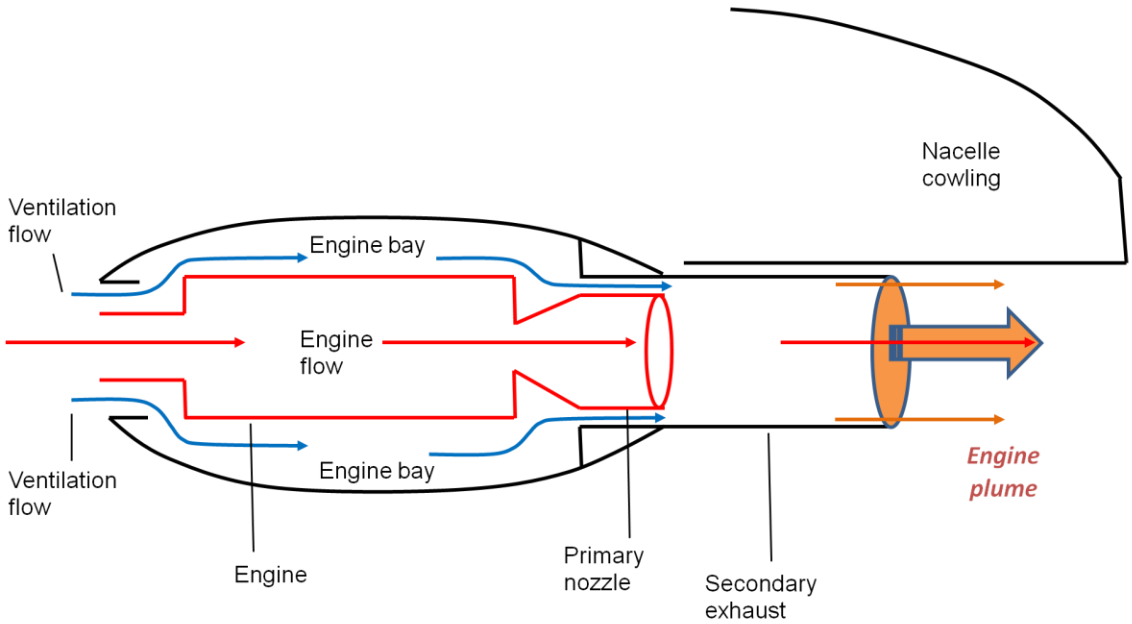

Fig 1. Eductor system operation

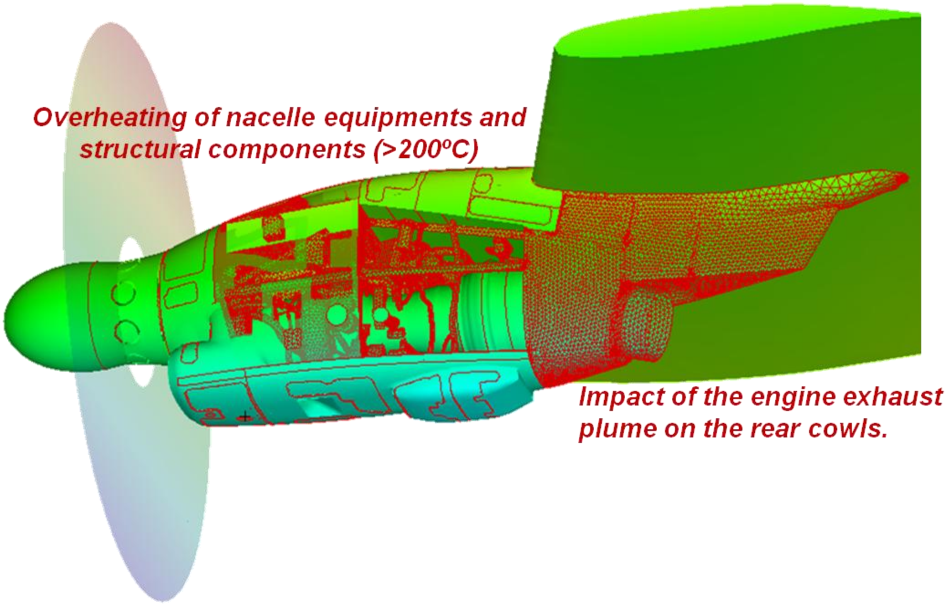

Fig 2. A400M Nacelle faulty events (early flights)

Fig 3. A400M metallic exhaust cowl (early prototypes)

Fig 4. A400M curved exhaust (early prototypes)

These solutions entailed some penalties.

Investigation and Solutions

Flight and ground measurements revealed that the source of the problem was the highly swirling gases of the engine at the primary nozzle at low power settings.

CFD analyses were conducted to assess the effect of the engine swirl on the eductor operation (figs 4 and 5). These analyses confirmed that the unstructured flow derived from the engine swirl caused the failure of the eductor operation.

A set of simple devices were investigated in the exhaust region. Several promising solutions were identified: chevrons, modification of local flow passages, and ***local flow conditioners*** (LFC-fig 6). All these devices were characterized by means of CFD models.

Finally, LCF devices proved to be the most effective solution to the mentioned problems at minimum cost.
The effects of the installation of LFC on the engine nozzle will be shown, and the great benefits for the engine ventilation presented.

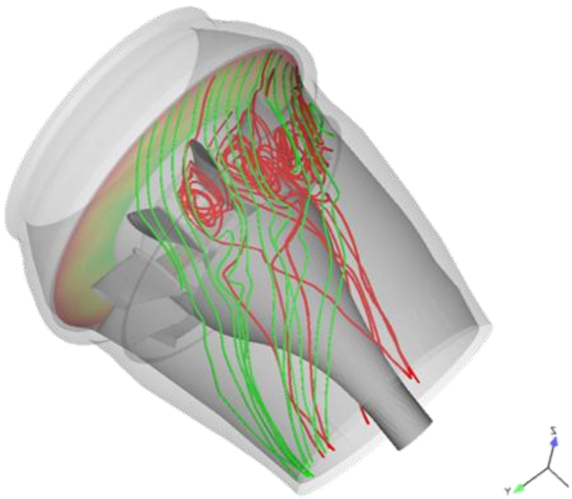

Fig 4. CFD Streamlines (engine nozzle).

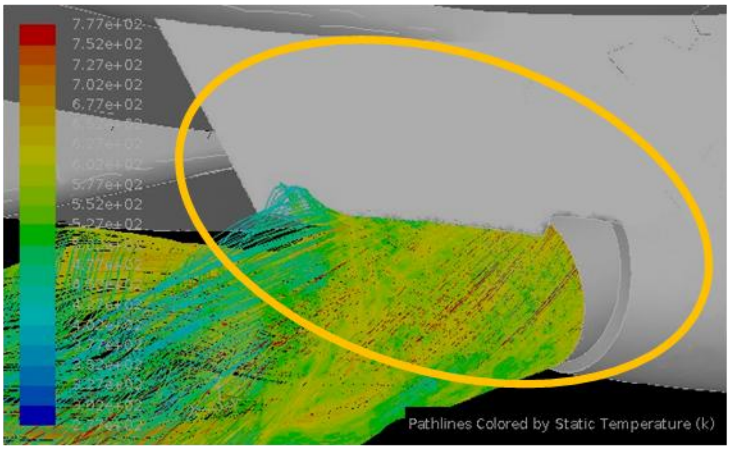

Fig 5. CFD Streamlines (impact on exhaust cowling).

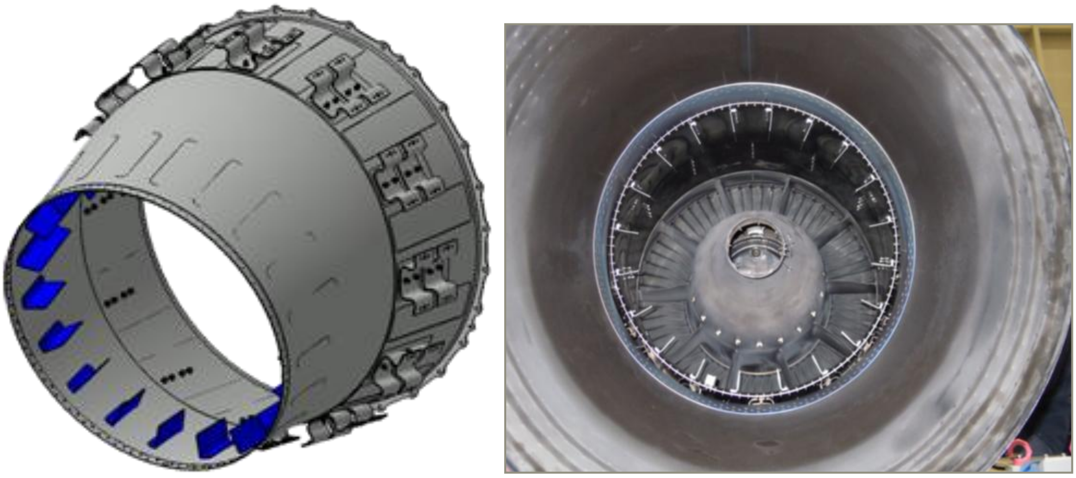

Fig 6. Local Flow Conditioners on the engine nozzle.