Inlet shape design for BLI engines

Control of inhomogeneous inlet flows

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In Short

- Boundary Layer Ingestion
- Passive and active flow control
- Sustainable aviation

The increasing demand for sustainability in every major aspect of our lives rises the need for a more efficient and cleaner aviation. While there exist multiple options to achieve this goal, one known possibility is the ingestion of boundary layer. Today's aircraft typically have pylon mounted underwing engines. While this concept has proven to be reliable, efficiency could only be improved by reducing the overall drag of the airframe or the fuel consumption of the engines themselves. The latter is typically achieved by increasing the bypass ratio. However, these concepts alone have their technical limitations. Therefore, new approaches have to be chosen to further boost efficiency in the future. One of which is the ingestion of boundary layer into the engines. This potentially yields efficiency gains through two main aspects. First, it accelerates the slowed surface flow, reducing mixing losses downstream, and second, it allows for a reduced jet velocity, resulting in the same benefit of less mixing losses. These concepts are shown in 1 from 1. An additional benefit can be seen due to the integration of the engines into the fuselage itself. This is needed in order to properly capture the boundary flow, but at the same time it decreases the wetted surface area and enables an aerodynamically optimized design approach for the combination of engine and fuselage, in contrast to the pylon-mounted, airframe-separated engines. 1,2,3

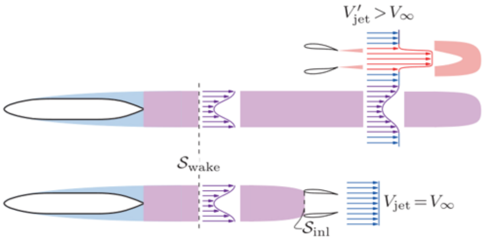

***Figure 1:** "Simplified body–propulsor configurations without boundary layer or wake ingestion (top) and with ideal wake ingestion (bottom). Propulsors are far enough downstream that pressure field interactions can be ignored." 1*

The basic idea of boundary layer ingestion (BLI) is known for some time, but harvesting its benefits proves difficult. One of the occurring problems is flow separation due to the angled inlet area needed for integrated engines as depicted in figure 2. Another difficulty is that due to the boundary flow, the engine will intake fluid with strongly varying speeds. This distortion reduces the overall performance of the fan and therefore contradicts the benefit of the BLI effect. Different studies addressing these problems have been carried out before, for example by 4.

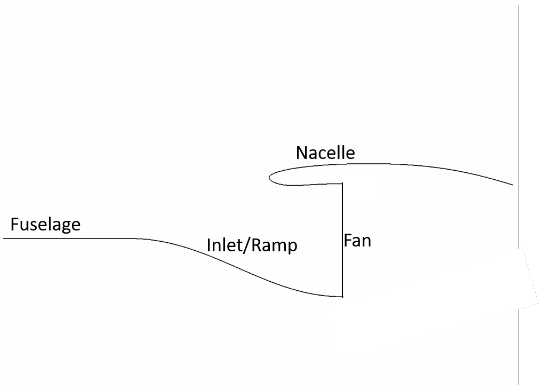

***Figure 2:** Sketch of the inlet area*

This project focuses on the design of the inlet area as highlighted in figure 3 for integrated engines to tackle these aspects in detail. The engines have been placed at the rear end of the fuselage, as the boundary layer first needs to develop and the fluid stream leaving the engines shouldn't be slowed down again before mixing with the free stream. This is simply due to the effect BLI wants to provide. As mentioned before, the basic concept is to accelerate slowed down fluid to decrease mixing losses in the wake. If the engines would be placed further upstream, the boundary layer wouldn't be as thick and after leaving the engines, the fluid would again get in contact with the airframe, starting to slow down again. This would contradict the benefits gained by BLI. Starting with an extensive study and optimiza-

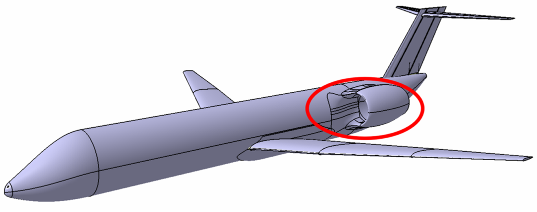

***Figure 3:** Inlet area in context of the whole aircraft*

tion of the passive design, using RANS simulations, the main focus is to obtain a geometry, that is aerodynamically suitable for BLI, increasing the overall efficiency compared to pylon mounted engines. This includes the prevention of any major flow separation in this region, as well as keeping the distortion level at the fan below a specific level. The first aspect is generally important as flow separation is hard to simulate correctly using RANS, and more importantly it increases the drag, leads to unpredictable flow phenomena and generally decreases the efficiency drastically. Additionally, it also increases the distortion at the fan, which in return reduces the performance again. Besides the full scale simulations, a geometry suitable for wind tunnel conditions will be derived as well. This will be used as a starting point for experiments, conducted by one of the project partners within the major project "SynTrac". Due to the much lower Reynolds number within the wind tunnel, the design has to be adapted for these conditions. This will lead to a less steep inlet to prevent flow separation.

Prior to the optimization process, initial geometries have to be obtained and evaluated. Therefore, the inlet area has been highly parameterized. Including lengths and widths at multiple sections and the whole outer nacelle. A small selection can be seen in figure 4. This allows to quickly adapt the inlet shape, researching a broad variety as well as adapting it in accordance to new findings. Having a selection of viable geometries, an optimization will be conducted, using an adjoint method. This allows to fine tune and further improve the designs in accordance to efficiency benefits of the whole aircraft. Conducting simulations on a multitude of different shapes and optimizing the most promising ones, will yield beneficial insight into the occurring flow phenomena of integrated engines. In return, this allows to better understand how to implement BLI and harvest its benefits as much as possible.

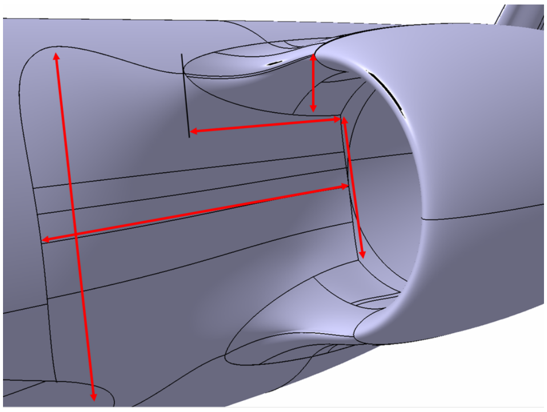

Figure 4: *Selection of inlet parameters*

In a later stage of the project, active flow control (AFC) will be introduced into the inlet geometry. This can further increase the efficiency and/or allow the passive design to be solely optimized for cruise conditions by improving the conditions at off-design points. Proper integration and evaluation of AFC benefits require an already optimized passive design. Otherwise, a clear distinction of the impact of AFC cannot be made, due to the losses occurring simply due to the design itself.

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`https://www.tu-braunschweig.de/ism`

More Information

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[2] A. P. Plas, et al. *Performance of a Boundary Layer Ingesting (BLI) Propulsion System* ,AIAA 2007-450

[3] P. Laskaridis, et al. *Opportunities and challenges for distributed propulsion and boundary layer ingestion* doi:10.1108/AEAT-05-2014-0067

[4] A. Vinz, A. Raichle *INVESTIGATION OF THE EFFECTS OF BLI ENGINE INTEGRATION ON AIRCRAFT THRUST REQUIREMENT* ,DLR, 2022

Project Partners

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DFG Subject Area

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