TFAST project - Executive summary

The greening of air transport systems means a reduction of drag and losses, which can be obtained by keeping laminar boundary layers on external and internal airplane parts. Increased loads make supersonic flow velocities more prevalent and are inherently connected to the appearance of shock waves, which in turn may interact with a laminar boundary layer. Such an interaction can quickly cause flow separation, which is highly detrimental to aircraft performance, and poses a threat to safety.

In the case of an civil turbofan engine operating at particularly high altitudes the Reynolds number can drop by a factor of 4, when compared to the sea level values. The laminar boundary layer on the transonic compressor rotor blades interacts with shock waves and as a result a strong boundary layer separation is formed. This can seriously affect the aero-engine performance and operation. One way to avoid strong separation is to ensure that the boundary layer upstream of the shock wave is turbulent.

The main objective of the TFAST project is to study the effect of transition location on the structure of interaction. The main question is how close the induced transition may be to the shock wave while still maintaining a typical turbulent character of interaction.

In all of the investigated test cases there are two limiting conditions which provide a reference frame for the research. The first one concerns flows with natural transition. The location of transition relative to the shock wave is a key result. It is desirable to obtain a laminar boundary layer interacting with the shock wave in order to understand how transition occurs in such a case and how detrimental this can be. The second condition refers to fully turbulent flow which may be obtained using boundary layer tripping close to the leading edge. Of course, these two limiting cases cause large differences in the shock structure, in the pressure distribution, and in the history and state of the boundary layer.

The methods of transition induction are investigated as one of the main objectives of the TFAST project. For this purpose, various flow control techniques are applied: tripping strip, roughness patches, distributed roughness, Air Jet Vortex Generators (AJVG), Rod Vortex Generators and Cold Plasma Actuator. Until now, these devices were used only in turbulent boundary layers. TFAST objective is therefore to discover how these techniques work in a laminar environment and how they induce transition.

The main study cases - shock waves on wings/profiles, turbine and compressor blades and supersonic intake flows - help to answer open questions posed by the aeronautics industry and to tackle more complex applications. In addition to basic flow configurations, transition control methods are investigated for controlling transition location, interaction induced separation and inherent flow unsteadiness.

The objective of the TFAST is also to develop in Europe experimental and numerical expertise in basic laminar/transitional interactions for a better analysis of the transition effect on the structure of the interaction and to give access to researchers and industrial partners to efficient experimental and numerical procedures to study and to predict such flows. Experiments are designed by pro-active CFD work in order to link experiment and CFD as closely together as possible and to allow for cross-fertilisation, rather than on competition between them.

The ambitious goals defined by TFAST partners require basic knowledge regarding the laminar interaction as well as the turbulent interaction in chosen flow cases. Two shock wave types are taken into account. One is a normal shock which induces separation at Mach numbers = 1.2 to 1.3. The other is the case of oblique shock reflection in which incipient separation is obtained in the range of M = 1.45 to 1.7.