Numerical investigation of an air-air ejector behavior in the transient operating conditions of Ultra High Bypass Ratio (UHBR) engine bleed systems

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ABSTRACT

Compared to typical bleed systems used in aircraft engines, a passive device, such as an air ejector, significantly improves the system's overall efficiency by reducing fuel consumption leading to environmental and economic benefits. Within the CleanSky2 EJEMOD project, steady-state and transient behavior of air ejector characteristics are generated by performing a numerical analysis of the entire operational map of ejectors used in an Ultra High Bypass Ratio (UHBR) engine bleed system.

A typical supersonic ejector usually operates either in on-design (double-choked) or in off-design (single-choked) conditions representing a general performance curve in normal conditions. However, the ejector does not necessarily work in normal conditions for the UHBR application, justifying an in-depth analysis through the entire possible range of operation, including abnormal conditions. The current numerical study provides knowledge of these unconventional operating conditions and its time-dependent transition between any operating points. These operating conditions include the flow regimes such as closed primary, secondary, or outlet ports, reverse flows, and start and unstart conditions of the ejector.

The present investigation utilizes steady-state RANS simulations to analyze normal and abnormal modes of operations individually and unsteady simulations (URANS) to explore the transition between two operating points, such as the transition between normal and abnormal operating conditions or between normal operating conditions. When the timescale used for the closing/opening of the valves of the bleed system is large compared to the ejector timescale, the ejector flowfield is expected to behave as quasi-steady during these transitions. Thus, the present work investigated different time-dependent profiles (rate of change) of the parameters at the ejector boundaries. The computed transient results are compared with steady-state solver results to quantify the required magnitude of time scales for the ejector's flowfield to be quasi-steady.

KEY WORDS: Ejector, operating map, abnormal modes, transient operations, reversed flows.