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PARAMETRIC STUDY OF AIR CURTAINS FOR AIRFRAME NOISE REDUCTION

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Abstract. The advancement of European society is dependent on safe, efficient, and environmentally-friendly technologies. It is an on-going challenge for European industry to meet customer and legislative requirements, satisfy societal demands and sustain competitiveness in the global arena. Development of novel aircraft concepts requires a complex compromise between contradictory requirements in safety, exhaust emissions, noise, performance and price. Landing gear noise is an example of airframe noise caused by turbulent airflow around aircraft components. Landing gear are very complex and as a result many components such as hydraulic cables, electrical wiring, torque links, front and rear braces etc. are exposed to the airflow. The contribution to the overall level of the generated noise from the various components depends on the specifics of the actual design of the landing gear. Air curtains are a novel concept, currently at a low TRL, which apply an upstream air jet to deflect the flow around a landing gear component, thus reducing the local flow speeds and therefore the aerodynamically generated noise. Small-scale proof-of-concept tests were successfully performed in NLR's Small Anechoic Wind Tunnel using an air curtain to shield a bluff body [1]. Broadband noise reductions of 3–5 dB were obtained using an air curtain with vertical blowing. The noise reductions could be increased by oblique blowing and by applying a small flow deflector directly behind the blowing slot. However, the research found that there is an optimal air curtain flow velocity beyond which the beneficial effects can be lost. This is primarily due to the noise generated by the air curtain itself.

In this work several air curtain nozzles designs were tested with the objective of developing an effective air curtain whose operational range could be extended through the use of low noise nozzle designs. The nozzle designs consisted of single, dual and triple stream air curtains. For each of these nozzles the flow field was investigated by a combination of flow visualisation and PIV measurements. Acoustic measurements of the source strength were made with a 25 microphone beam forming array. In these experiments the landing gear component was represented by two rods in tandem. These two rods in cross flow create a narrowband tone that can be very easy detected by the beam-forming array.

The design of the air curtains was based on the works of Oerlemans et al. [1] and Ramaprian and Haniu [2] who developed an equation for a single stream planar jet in cross flow to predict the centre line and air curtain width. This equation can be used to predict the effective shielding area of the air curtain. The use of dual and triple stream air curtains is novel and as such no equivalent equations exist to predict the behaviour of the flow. The dual and triple stream air curtains were investigated with a combination of flow visualisation, Figure 1–2, and hotwire anemometry in order to achieve the same effective shielding area as the equivalent single stream nozzles. The resulting nozzle configurations are given in Table 1.

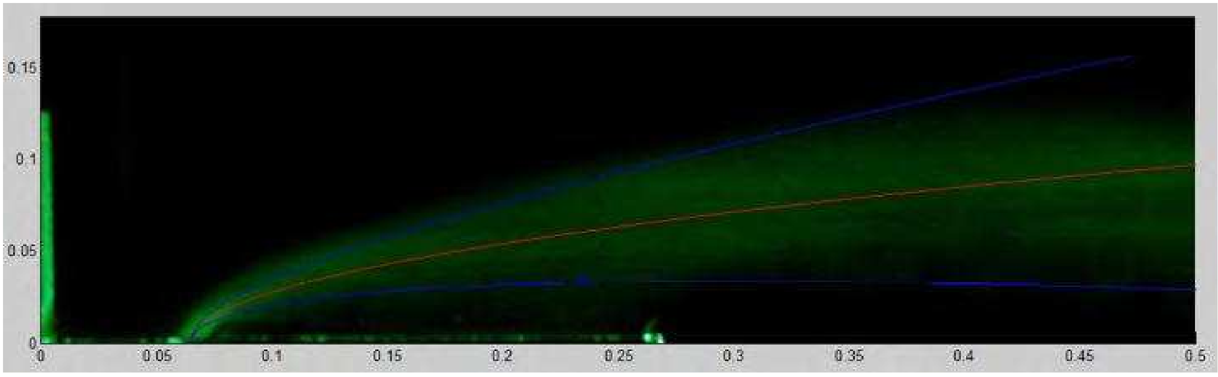

Fig. 1. Flow visualisation of single stream 14mm AC with centre line (red) and width (blue) predicted from equations

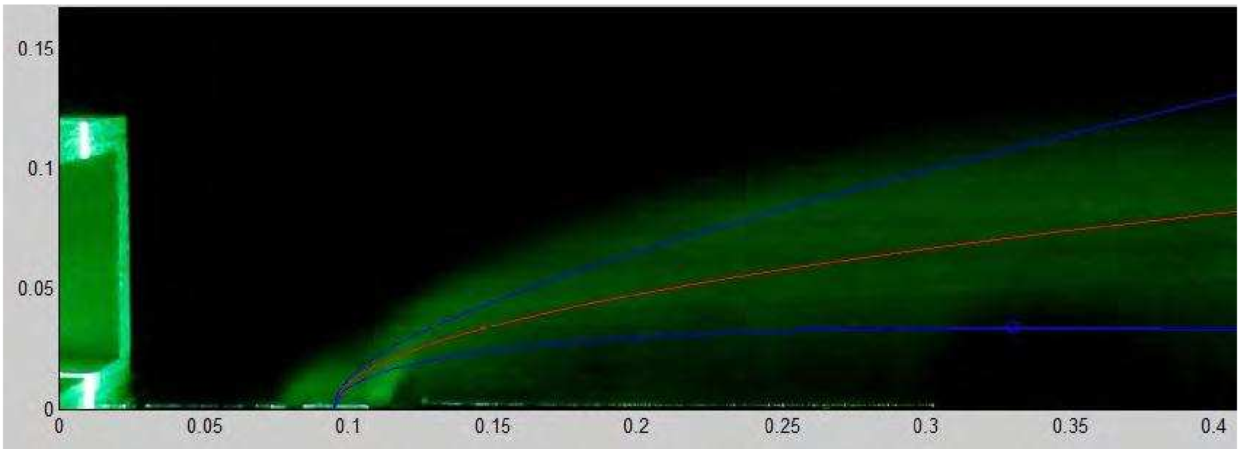

Fig. 2. Flow visualisation of dual stream 8mm and 10mm AC with center line (red) and width (blue) predicted from equations for equivalent single stream curtain

Table 1. Air curtain nozzle configurations

Air Curtain	*Width*	*Velocity*	*Mass Flow*
Single Stream AC1	8 mm	64.44 m/s	0.061 kg/s
Single Stream AC2	10 mm	60.94 m/s	0.072 kg/s
Single Stream AC3	14 mm	50.04 m/s	0.059 kg/s
Dual Stream AC4	8 mm 10 mm	38.00 m/s 60.29 m/s	0.036 kg/s 0.057 kg/s **0.093 kg/s (Total)**
Triple Stream AC5	8 mm 10 mm 8 mm	19.13 m/s 21.41 m/s 18.40 m/s	0.018 kg/s 0.025 kg/s 0.017 kg/s **0.060 kg/s (Total)**
Triple Stream AC6	8 mm 14 mm 8 mm	17.35 m/s 19.22 m/s 17.33 m/s	0.016 kg/s 0.032 kg/s 0.016 kg/s **0.065 kg/s (Total)**

The effectiveness of these air curtain designs in shielding the two rods in tandem, and hence the noise source, was investigated through the use of a microphone beam-forming array. The microphones used in the array were 25 KE4 Sensheiser Electret microphones with integrated amplifiers. The peak noise level from the beam-forming map as well as the OASPL averaged on the microphone array were used to assess the performance of the air curtains, as reported in Table 2. The largest noise reduction was obtained with the triple air curtain (AC6) implying that the use of triple stream coplanar nozzles has a strong potential to extend the operational range and performance of air curtains. Since the effective shielding area was used to compare the air curtains there is a difference in mass flow for the various nozzle designs. The cost of implementing an air curtain can be reduced if the required mass flow can be reduced. In this regard the triple configuration also performs well as the single stream air curtains have comparable or higher mass flows with lower levels of noise reduction achieved.

Table 2. Air curtain performance

Air Curtain	*Peak Noise*	*OASLP*	*Mass Flow*
Main Flow + Rods	87.27 dB	95.03 dB	NA
Single Stream AC1	85.61 dB	93.16 dB	0.061 kg/s
Single Stream AC2	85.13 dB	92.46 dB	0.072 kg/s
Single Stream AC3	85.24 dB	92.32 dB	0.059 kg/s
Dual Stream AC4	84.96 dB	92.63 dB	0.093 kg/s (Total)
Triple Stream AC5	84.81 dB	92.06 dB	0.060 kg/s (Total)
Triple Stream AC6	83.89 dB	92.63 dB	0.065 kg/s (Total)

In conclusion the application of dual and triple stream nozzles has improved the performance of air curtains applied as a noise reduction technology. The application of air curtains to more realistic designs or to more localised components could be investigated with multi-stream nozzles to help meet the constraints placed on mass flow and air curtain generated noise.

Keywords: air curtains, multi-stream coplanar nozzles, noise reduction technology.

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