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Flow behaviour of turbulent nozzle jets issuing from bevelled collars

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ABSTRACT

An experiment was conducted to investigate turbulent, low-speed air jets issuing from bevelled and non-bevelled circular collared-nozzle configurations. The collar-to-nozzle expansion ratio used was three and Reynolds number was approximately 20,000. Detailed mean flow velocity fields and velocity spectra of the resultant jet flows at different collar lengths and bevel angles were evaluated using hot-wire anemometry along both axial and radial directions of the jets. Centreline velocity decay was shown to be augmented when either collar length or bevel angle was increased, with the collar length playing a more dominant role. Results also showed that bevelled collared-jets vectored towards the longer collar-length region, the extent to which was enhanced when the collar length or bevel angle was increased. The study demonstrated that a bevelled collar exit could be used as an additional control device on top of the collar length to achieve finer jet flow control in terms of jet momentum vectoring and asymmetric jet spread.

1. Introduction

Nozzles with pipe-collars attached to their exits, or collared-jets, have been studied extensively in the past to understand the influence of the nozzle/collar geometries, collar-to-nozzle area ratios and nozzle/collar lengths on the resultant jet flow alterations. Depending on the exact configurations, collared-jets have been shown to be able to induce favourble flow behaviour through either acoustic or fluidic self-excitations. Acoustically self-excited collared jets are typically associated with smaller expansion ratios (collar to nozzle diameter ratios) [1–3], and sometimes known as whistler jets. These studies have shown significant reductions in jet potential core lengths in whistler collared-jets, rapid increases in the centreline turbulence intensity levels and jet spreads due to self-excitation behaviour. In particular, the increases in jet-spread and velocity decay rate were observed to be highly dependent upon the initial conditions, with self-excitations resembling artificially forced excitations.

New et al. [4] recently characterised the flow behaviour of acoustically self-excited collared-jets with different cross-sectional shapes and lengths of collars when a circular nozzle was used. The results showed that the circular collar requires the shortest optimal collar length to achieve the maximum centreline velocity decay, followed by square and triangular collars. A recent 3D numerical simulation [5] was performed to study the jet decay and jet-spread of a turbulent jet issuing from a pipe with a triangular collar measured by New et al. [4]. Different numerical models were adopted and the results showed that the standard RSM closure is able to produce reasonable data which agreed relatively well with the experimental data.

For fluidic self-excited collared-jets with a larger expansion ratio, low-frequency and large-scale fluidic self-excitation could lead to the creation of flapping, precessing and oscillating jets [6–8]. For example, Mi et al. [6] investigated the flow characteristics of a flapping jet issuing from a rectangular orifice into a square chamber of larger cross-sectional area with an expansion ratio of 6.4. The jet was found to induce a positive feedback process with an increase in jet spread and entrainment after entering the square chamber. Nathan et al. [7] also investigated the response of a circular collared jet with an expansion ratio of 6.4 in which both the nozzle and collar were identically shaped. The flow was observed to be dominated by an axial jet mode and a precessing jet mode which conferred additional jet control. Experiments on triangular and circular orifice-collar combinations with expansion-ratios between 2.1 and 3.5 were carried out by Lee et al. [8]. The flow issuing from the triangular orifice was first observed to reattach to the collar wall before being deflected by the collar lip, resulting in an oscillating jet stream with 'preferred' azimuthal directions corresponding to the vertices of the orifice.

While earlier studies have established firm relationships between these investigated parameters and the flow fields of the resulting jet flows, considerably less attention was paid towards other possible ways of varying the geometric configuration of collared-jets. In particular, the effects of modifying collared-jet geometries axially, rather than azimuthally, are not well-known and

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