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# Configuration dependence and optimization of the entrainment performance for gas–gas and gas–liquid ejectors

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ABSTRACT

This paper describes a numerical study of entrainment behavior and its configuration dependence for gas–gas and gas–liquid ejectors. A computational fluid dynamics (CFD) model is developed and experimental validation is undertaken over a wide range of operation conditions for ejector with different configurations. The predicted values by CFD simulation prove to be in good agreement with the experimental data. The investigation results indicate that pseudo-shock length has a dominant effect on entrainment performance and geometry optimization. Significant difference is noted in pseudo-shock length for gas–gas and gas–liquid ejectors, and this is mainly because the viscosity similarity markedly differs within the range of 0.01–1.0, depending on the primary and secondary fluids of usage. Therefore the optimum mixing tube length to diameter ratio is about 1–2 for general gas–liquid ejectors while 5–7 for gas–gas ejectors. As an exception to the general gas–liquid ejectors, the optimum *L/D* ratio in He–$LH_2$ ejector is about 4, lying between that of the gas–gas ejector and gas–liquid ejector but still consistent with the pseudo-shock length. If the maximum allowable length of ejector mixing tube is less than the optimum value, placing the primary nozzle exit upstream of the mixing tube can greatly improve the entrainment performance.



## 1. Introduction

An ejector is a device in which a fluid at high pressure is accelerated by a primary nozzle and then the high speed primary jet entrains and compresses a secondary fluid at low pressure. The objectives for ejector design could be (a) To get large entrainment of the secondary fluid, (b) To produce intense mixing between the primary and secondary fluids, or (c) To pump fluids from a region of low pressure to a region of high pressure, depending on its area of application. Ejectors can be operated with compressible or incompressible fluids, and have found many applications in engineering, such as refrigeration, aerospace, chemical and biochemical process industries [1]. Their application in air-conditioning or refrigeration, either totally replace mechanical compressors or simply be used for cycle optimization (for example, the combined ejector-absorption refrigeration system), has a long-established history and as an environment-friendly technology, it has become a recent focus of research in response to the problem of global warming or ozone depletion [2–12]. In aerospace engineering, ejectors are used for thrust augmentation, exhaust noise suppression, altitude testing [13–15] or to mix exhaust gases with fresh air in order to reduce the thermal signature [16]. The incentive for their application in natural precooling system of cryogenic rocket engine is to intensify the precooling circulation and improve the cooling effect of rocket engine [17]. In chemical and biochemical process industries, ejectors are widely used for entraining and pumping corrosive fluids, slurries, fumes and dust laden gases, etc., which are otherwise difficult to handle [18], say, recovering natural gas from gas/oil mixture in oil storage tank. Ejectors may also be used for mass transfer, namely, liquid–liquid extraction, gas absorption, stripping, fermentation, hydrogenation, chlorination, etc [19]. One of the most promising applications is the biotechnological treatment of industrial gaseous wastes which concerns many industries: automobile industry, petrochemical, printing, fine and heavy chemicals industry, etc [20]. Advanced reactor systems utilizing steam-driven ejector as an emergency core cooling system have also been proposed [21]. When compared with others, an ejector system has the advantages of high reliability, low cost and at the same time, being easy to maintain and operate, therefore has attracted many research activities.

Theoretical study of ejector can be classified into two categories: constant-area mixing methods and constant-pressure mixing methods, both of which were first proposed by Keenan et al. [22,23]. The latter are believed to give superior performance and

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