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Research Result

# Investigate The Effect of Ejector Throat Diameter on Ejector Performance

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## ABSTRACT

*There are not many experimental works available in the open literature dealing with variable geometry ejector cooling systems. In several works, the influence of the ejector geometry is evaluated by changing ejector parts (e.g., nozzle) between experiments. Most published works with actual variable geometry ejectors are numerically or experimentally approached that were carried out under well-controlled laboratory conditions. There is a very limited amount of data on actual solar-driven variable geometry ejector cooling units. Thus, this study is carried out for variable geometry ejector cooling systems at various working conditions. The objective of the present work is to "Find out the effect of throat diameter on the performance of ejector at different working pressure and temperature of the primary and secondary fluid.".*

## KEYWORDS

*Ejector, refrigeration system, mass flow rate, inlet pressure, inlet temperature, entrainment ratio*

## 1. INTRODUCTION

### Working Principle of Ejectors

Figure 1.1 depicts the basic design of an ejector. The pieces' shape and proportioning are just illustrative. The motive (or "primary") fluid is delivered through a nozzle that is usually designed like a converging/diverging duct to facilitate a supersonic exit flow. The entrained (or "secondary") fluid enters the annular region surrounding the primary nozzle and is supplied through it. As a result, the two streams collide at the nozzle outlet. Because their velocities are so dissimilar, a momentum transfer accelerates the secondary flow while decelerating the original flow. A central core of primary flow and a lateral shell of secondary flow may remain mostly unaffected, while mixing occurs in an intermediate zone structured like a cylindrical wedge, where turbulent shear stress generates a velocity distribution that grows rapidly toward the ejector axis. In fact, if the primary flow is supersonic, a series of oblique shocks will emerge along the mixing zone, each of which will be reflected several times.

The secondary flow in current applications typically accelerates to sonic speed, making the entire mixed stream supersonic. This mixed stream must be decelerated in order to convert its kinetic energy and eventually achieve the exit pressure, which is halfway between the motive fluid's high value at the intake and the entrained flow's low value ("suction pressure"). This occurs in a supersonic diffuser with a convergent-divergent or cylindrical-divergent form that follows the mixing zone.

It's worth noting that the ejector replaces the far more complex system illustrated in Fig. 1.2 from a functional standpoint. The ejector prevents mechanical work from being transferred from expansion to compression via the connected shaft. Flow energy is immediately transported between the two flows, bypassing revolving blades, bearings, lubrication, and other components.

Obviously, direct interaction between streams moving at various speeds results in some restrictions and losses. The transition between supersonic and subsonic flow, for example, should ideally occur at the diffuser throat, with the velocity decreasing continually. This ideal state only occurs for a specific set of inlet/exit conditions, making it practically impossible to achieve. In practice, a second shock train decelerates the supersonic flow to subsonic velocity.

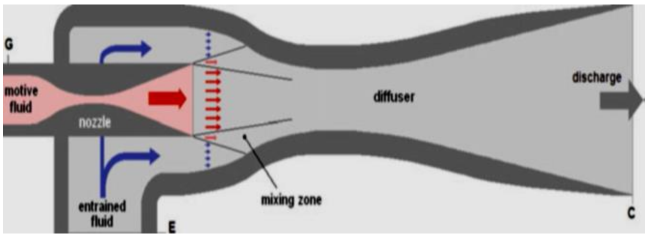


Fig 1.1 Schematic section of a supersonic ejector

A set of nondimensional parameters may be introduced:

- Entrainment ratio i.e., ratio between the secondary and the primary mass flow rates
- Compression ratio, i.e., ratio between the discharge (PC) and entrained fluid (PE) pressures
- Expansion ratio, i.e., ratio between the motive (PG) and entrained fluid (PE) pressures.

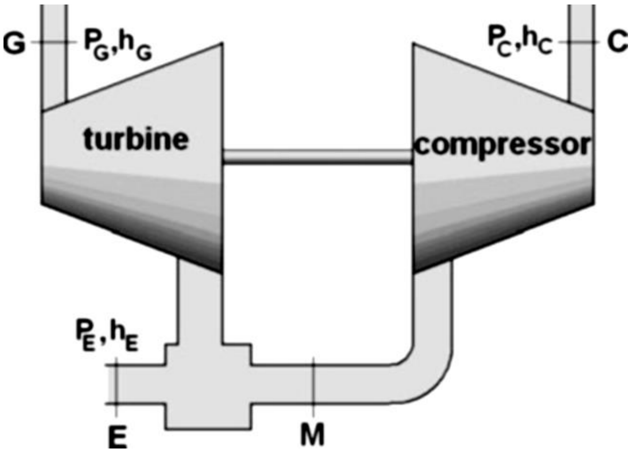


Fig. 1.2 Functionally equivalent assembly

## 2. LITERATURE REVIEW

Vu Van Nguyen et al., 2020, offer an experimental evaluation of the impact of a variable geometry ejector (VGE) design on the performance of a small-scale, 1.5 kW nominal capacity solar heat driven ejector air-conditioning system in real-world settings. Fixed geometry ejectors perform poorly under varied operating conditions (e.g. solar radiation, ambient temperature), hence the goal of this study was to demonstrate the benefits of the VGE approach. The area ratio can be modified via a movable spindle (SP) and the nozzle exit position (NXP) in the experimentally demonstrated VGE to respond to operational conditions. During the studies, the cooling cycle was shown to be extremely stable.

H. Akbari, M. Sorin; 2020 proposes a comprehensive strategy for the design and optimization of an ejector refrigeration system, which includes the selection of the best working fluid. The ejector refrigeration system is modelled as a hybrid of a power and vapour compression sub-cycles, with the ejector acting as an expander compressor device. In two steps, the equivalent temperature notion is applied. The first stage is to optimise the ejector refrigeration system at the system level, which is independent of the working fluid.

Ejectors have been used in general refrigeration and air conditioning systems in a growing number of research in recent years. However, studies using cryogenic refrigeration systems with ejectors are uncommon. The use of an ejector in a cryogenic refrigeration system was first proposed by Rietdijk.

Jisung Lee and colleagues (2018) examine the use of ejectors in cryogenic refrigeration systems. To improve the thermodynamic efficiency of the Joule-Thomson (JT) refrigeration system, a new refrigeration cycle based on ejector technology is proposed. The ejector, in conjunction with the JT refrigeration cycle, uses a mixed refrigerant of nitrogen and neon. The goal refrigeration temperature is set to be close to nitrogen's freezing point (63.15 K). The ejector entrainment ratio and the ejector exit pressure are used to create an ejector-JT cycle performance map.

Solar cooling methods have piqued interest in recent decades, particularly in Mediterranean areas where standard refrigeration systems consume the most electricity during the summer. In fact, refrigeration systems account for roughly 40%–45% of total energy consumption in residential and commercial buildings.

José Galindo et al., 2020, calculate the viability of a solar jet-ejector refrigeration system from an efficiency maximization standpoint using three low-emission refrigerants: R1234yf, R1234ze, and R600a. Internal jet-ejector geometry optimization is given special attention as a tool for improving overall cycle performance. The jet-ejector entrainment ratio is calculated using a validated Computational Fluid Dynamics (CFD) approach that includes real gas models of R1234yf, R1234ze, and R600a in various operating situations and geometric configurations. In terms of overall system efficiency, R1234yf was the most efficient, followed by R600a and R1234ze.

In order to reduce electricity usage, ejector refrigeration systems have been used to replace traditional compression refrigeration systems in air conditioning systems in recent decades, and many researchers have looked into it. However, the environmental degrading effects of certain refrigerants in such systems have prompted researchers to look for alternatives. By using water steam as a low-cost, non-toxic, and readily available refrigerant, these negative effects are reduced.

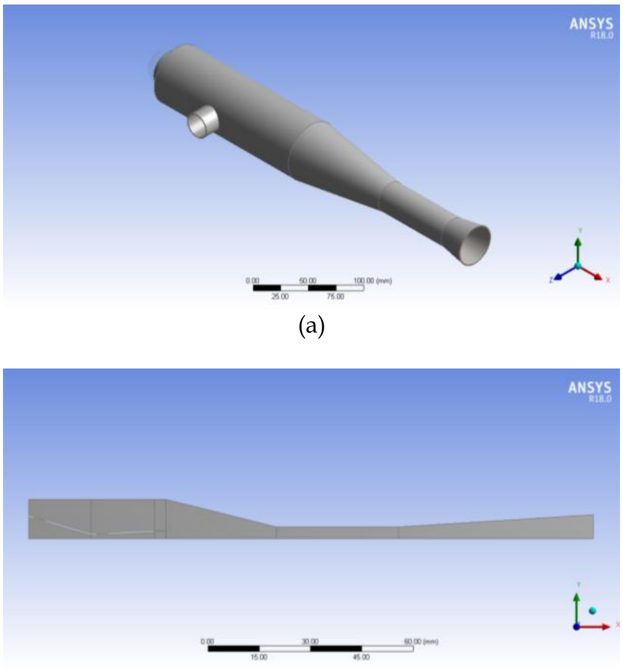
Farzaneh Foroozesh et al., 2019, investigated how changing the shape of an ejector might increase its performance as a critical part of an ejector refrigeration system. Water steam was chosen as a low-cost, non-toxic, and readily available refrigerant and the wet steam model was used for more precise numerical simulation and analysis. The effect of modifying geometric parameters in response to the presence of wetness in the flow field is examined.

## 3. RESEARCH METHODOLOGY

### CFD Modelling

### Geometry

The ejector geometry is modelled with design modeler of Ansys.



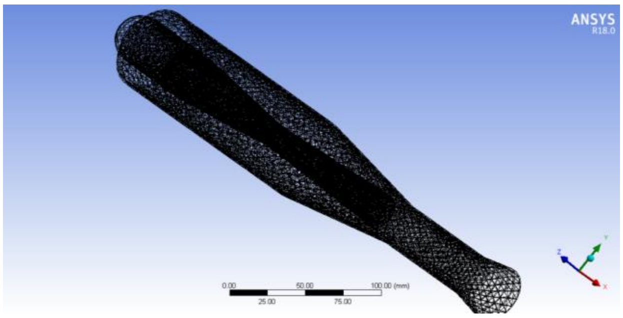
(a)

(b)

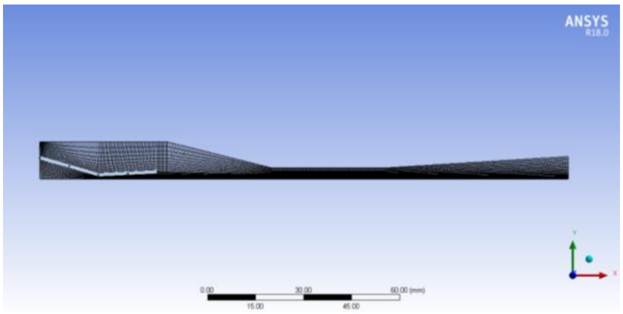
Fig. 3.1. (a) Ejector geometry imported in Ansys (b) 1/4th of ejector for analysis

- **Discretization (Meshing)**

The results reveal that the mesh density has a strong influence on convergence and stability. Mesh is refined from the primary nozzle lips along the shear layer and also in the vicinity of walls. 23945 nodes and 98080 elements were generated at basic geometry.



(a)



(b)

Fig. 3.2 (a) Ejector meshed model (b) Meshed model of 1/4th of ejector for analysis

## 4. RESULTS AND DISCUSSION

The following results have been obtained:

**Results considering 1.32 cm throat diameter**

- **Results considering 1.32 cm throat diameter at primary fluid pressure 2.5 bar**

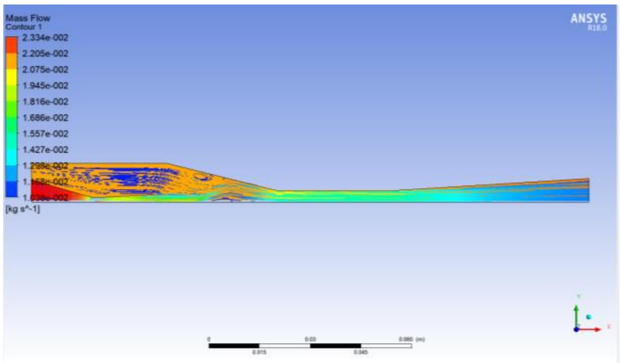


Figure 4.1 Secondary fluid mass flow rate for 1.32 cm throat diameter at fluid 2.5 bar pressure and 70°C temperature and secondary fluid at 0.35 bar pressure and 5°C

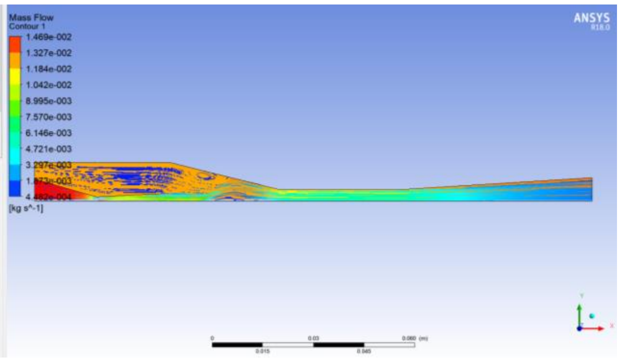


Figure 4.2 Primary fluid mass flow rate for 1.32 cm throat diameter at fluid 2.5 bar pressure and 70°C temperature and secondary fluid at 0.35 bar pressure and 5°C

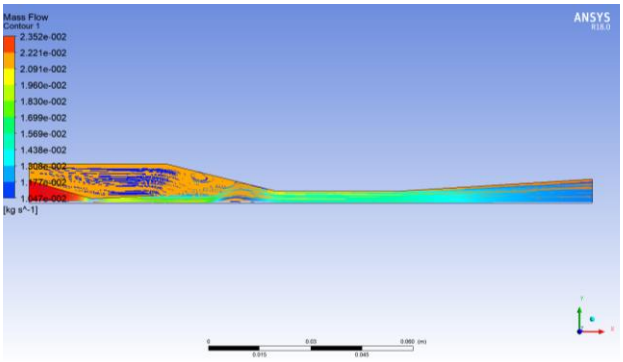


Figure 4.3 Secondary fluid mass flow rate for 1.32 cm throat diameter at fluid 2.5 bar pressure and 75°C temperature and secondary fluid at 0.35 bar pressure and 5°C

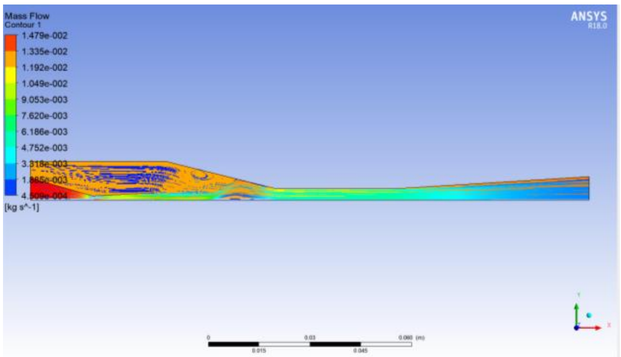


Figure 4.4 Primary fluid mass flow rate for 1.32 cm throat diameter at fluid 2.5 bar pressure and 75°C temperature and secondary fluid at 0.35 bar pressure and 5°C

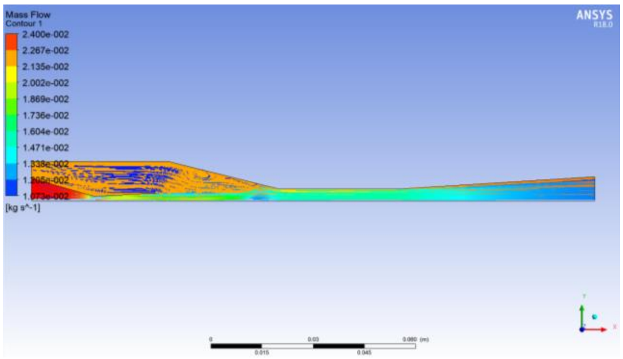


Figure 4.5 Secondary fluid mass flow rate for 1.32 cm throat diameter at fluid 2.5 bar pressure and 80°C temperature and secondary fluid at 0.35 bar pressure and 5°C

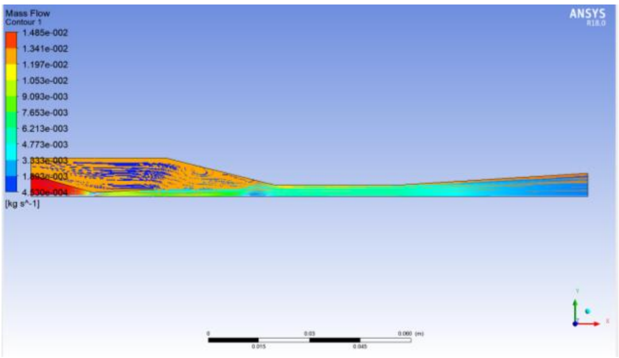


Figure 4.6 Primary fluid mass flow rate for 1.32 cm throat diameter at fluid 2.5 bar pressure and 80°C temperature and secondary fluid at 0.35 bar pressure and 5°C

Figure 4.7 shows the effects of primary fluid temperature on ejector's performance at different inlet pressure at 2.5 bar, 4 bar and 5.5 bar inlet pressure respectively. It is found that by increasing the primary fluid temperature, ER decreases due to the impact on the total exergy losses.

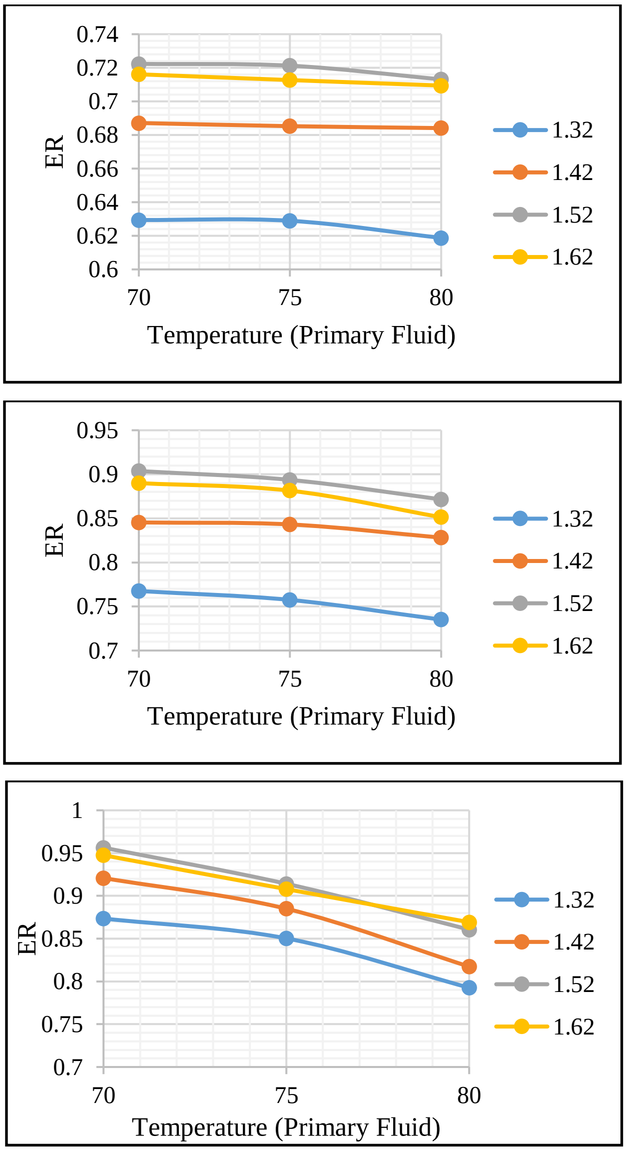


Figure 4.7 Entrainment Ratio at different throat diameter with varying primary fluid temperature and (a) 2.5 bar inlet pressure (b) 4 bar inlet pressure (c) 5.5 bar inlet pressure

## 5. CONCLUSION

A finite element analysis has been carried out for analyzing the effect of geometry, fluid flow temperature and pressure on the performance of ejector. The parameter considered are mas flow rate, inlet temperature, ER for the analysis.

Following conclusions can be made after study:

- By increasing the primary fluid temperature, ER decreases due to the impact on the total exergy losses.
- Increase in diameter of primary nozzle's throat results in increase in ER, but it is maximum for 1.52 cm and it again starts to decrease at 1.62cm considerably thus, applying an opposite change (decreasing in throat diameter after 1.52 cm of nozzle) can be desirable.

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