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Liquid Jet Ejector Efficiency Improvement

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Abstract

The issues of application of an agitator, a diffuser, and a vertical pipe in a liquid jet ejector are considered. Possible versions of an agitator as a rotating nozzle with blades are recommended. A physical and mathematical model based on fundamental equations, which reflect the operating process of the device, is developed. The estimated dependencies and restrictive conditions of operation of the electrically driven rotating nozzle and blades ejector are provided. The increase in the efficiency of application of the agitator, diffusor, and vertical pipe is numerically quantified by means of extreme characteristics. Thus, a maximum efficiency gain of 37% after agitator is installed; 13% when diffuser is installed; 5% when vertical pipe is installed can be reached. The characteristics that reflect the relationship of maximum attainable operating parameters and the corresponding values of optimum relative nozzle area are obtained. The constancy of the optimum relative nozzle area in a wide range of operating parameters, while using the agitator alongside the diffuser and the vertical pipe, is revealed. Hence, if the agitator is applied, the optimum relative nozzle area is 0.29 ... 0.30, if the diffusor and vertical pipe are added, then – 0.40 ... 0.41. The recommendations on the implementation of the obtained results are made.

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Keywords: ejector; active liquid jet; passive gas medium; agitator; diffuser; vertical pipe; efficiency.

1. Introduction

The ejector is a device that is widely used as a pump, compressor, mixer, heater or transport device in many industries [1-3]. The research, focused on improvement of the ejector operating process, is continuous and held throughout the world. Literature review has shown that the efficiency of the liquid jet ejector can be improved via additional effect on the active jet stream [4-7] and / or on the passive gas medium, entrained by liquid jet [8-10]. Additional effect on the active and passive mediums can be geometrical one due to profiling of intake devices, also it

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can be hydrodynamic one – due to application of agitator units (AU). AU installation presupposes transfer of additional energy to passive flow which is necessary for the mixing process of active and passive mediums in the mixing chamber with minimal energy losses. This article refers to agitator application in a liquid jet ejector.

Nomenclature

m_l, m_g, m_{mix}	mass flow rates of liquid, gas and gas-liquid mixture
T_l, T_g	absolute temperatures of liquid and gas
p_i	absolute static pressure of medium in the *i*-th section
p_{sv}	pressure of the saturated liquid vapor
ρ_{gi}, $\rho_{\text{mix}i}$	densities of gas and mixture in the *i*-th section
R_g	gas constant
Q_{vgi}, Q_l, Q_{gi}	volume flow rates of saturated gas-vapor mixture, liquid and gas in the *i*-th section
$\overline{p_i}$	absolute total pressure in the *i*-th section
U_{li}, $U_{\text{mix}i}$, U_{gi}	velocities of liquid, mixture and gas in the *i*-th section
d_{i}	diameter of the *i*-th section
ζ_{10}, ζ_{34}, ζ_{dif}, ζ_{56}	resistance coefficients of the nozzle channel, the mixing chamber, the diffuser and the vertical pipe
φ	nozzle velocity ratio
τ_{34}	averaged (per length) wall-adjacent shear stress
λ_{34}	coefficient of hydraulic friction in the mixing chamber
A_{34}	surface area of the mixing chamber
L_{34}, L_{56}	length of the mixing chamber and the vertical pipe
k_{vi}	correction factor for pressure of saturated liquid vapor in *i*-th section
α_{g2}	volumetric coefficient of gas ejection in the suction chamber
ψ	factor of phase slipping
N_{sup}	supplied power
η_{nb}	efficiency of the electric driver and the nozzle device
ε_{42}	ratio of backpressure of the mixing chamber and suction pressure
$\varepsilon_{52}^{\text{max}}$	maximum attainable ratio of gas compression
ε_{12}	degree of pressure reduction in the nozzle device
k_t	correction factor for temperature difference between liquid and gas
n_{sup}	specific power for acceleration of passive gas flow
Γ	jet dynamic parameter

2. Possible versions of an agitator unit

Liquid-gas ejector (LGE) can include a gas accelerator or a rotating nozzle with blades used as an agitator.

Fig. 1 shows a schematic diagram of LGE with rotating nozzle and blades (NB). Unlike the conventional ejector design, there is a rotating nozzle with blades 1 in the suction chamber 3. It should be noted that the nozzle and blades are of rigid construction. The blades have a shape similar to the shape of the axial fan blades [11]. A straightener 2 is installed just after the blades.

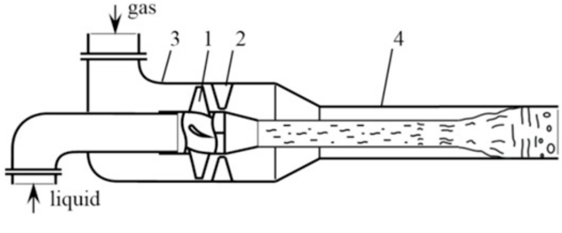

Fig. 1. Schematic diagram of LGE with rotating nozzle and blades driven by fluid energy: 1 – rotating nozzle with blades; 2 – straightener; 3 – suction chamber; 4 – mixing chamber.