Unsteady 1D gas dynamics in ejectors: a pipeline analogy

Jan Van den Berghe[*†], Bruno R. B. Dias[†], Yann Bartosiewicz[‡] and Miguel A. Mendez[†]

[†] von Karman Institute for Fluid Dynamics (VKI)
Waterloosesteenweg 72, 1640 Sint-Genesius-Rode, Belgium
[*]e-mail: jan.vandenberghe@vki.ac.be

[‡] Institute of Mechanics, Materials, and Civil Engineering (iMMC)
Université catholique de Louvain (UCLouvain)
1348 Louvain-la-Neuve, Belgium

ABSTRACT

We present a 1D unsteady ejector model based on a pipeline analogy. It consists of gas dynamic equations in three 1D domains that are coupled through a junction model inspired by the model of Mindt and Lang [1]. The formulation admits travelling pressure waves across the junction, allowing to simulate unsteady operation and to establish the characteristic response time after a change in operating conditions.

The model was first calibrated and validated in steady state against experimental mass flow rates in on- and off-design operation on a sonic [2] and a supersonic ejector [3]. Next, the choking mechanism is shown to be compliant with the compound choking theory for ejectors [4]. Finally, the model was benchmarked against 2D URANS simulations in a sudden transient between operating conditions. The model correctly predicts the stream-wise evolution of integral quantities such as mass, momentum and energy flow rates and remains robust even in case of back flow.

We thus propose a low-cost alternative to CFD for unsteady ejector simulations, in conditions where pressure waves preclude a quasi-steady approach with more common 0D models.

REFERENCES

[1] P. Mindt, J. Lang, and P. Domschke. Entropy-preserving coupling of hierarchical gas models. *SIAM Journal on Mathematical Analysis* 51.6, pp. 4754-4775, 2019.

[2] G. Besagni, R. Mereu, P. Chiesa and F. Inzoli. An Integrated Lumped Parameter-CFD approach for off-design ejector performance evaluation. *Energy Conversion and Management*, 105, pp. 697-715, 2015. doi: 10.1016/j.enconman.2015.08.029

[3] F. Mazzelli, A. B. Little, S. Garimella and Y. Bartosiewicz. Computational and experimental analysis of supersonic air ejector: Turbulence modeling and assessment of 3D effects. *International Journal of Heat and Fluid Flow*, 56, pp. 305-316, 2015. doi: 10.1016/j.ijheatfluidflow.2015.08.003

[4] O. Lamberts, P. Chatelain, N. Bourgeois and Y. Bartosiewicz. The compound-choking theory as an explanation of the entrainment limitation in supersonic ejectors. *Energy*, 158, pp. 524-536, 2018. doi: 10.1016/j.energy.2018.06.036