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Comparative CFD Investigation of Drag and Pressure Loss in Solid, Perforated and Modified V-Gutter Flameholders for Afterburner Applications

Gouri Dattatreya, Jainar Sahana, K S Dhyan Pemmaiah, Lakshmi B

Department of Aeronautical Engineering, MVJ College of Engineering

ABSTRACT

V-gutter flameholders are widely used in afterburner systems because the wake formed downstream of a bluff body provides a recirculation region that supports flame stabilization. However, the flameholder also obstructs the exhaust flow and introduces aerodynamic drag and pressure loss. This study compares three configurations—solid V-gutter, perforated V-gutter and modified V-gutter—using the computational fluid dynamics (CFD) results reported in the project study. The models were evaluated under the same stated numerical setup, with an inlet temperature of 300 K, inlet velocity of 17.3 m/s, an atmospheric pressure outlet, adiabatic no-slip walls and the SST k– ω turbulence model. The Chapter 6 result table reports drag forces of 16.162 N, 15.722 N and 13.042 N for the solid, perforated and modified configurations, respectively.

The corresponding reported pressure-loss values are 604.563, 569.295 and 442.069; the source does not clearly state the unit for these values. Relative to the solid V-gutter, the modified design reduces drag by approximately 19.31% and the reported pressure-loss value by approximately 26.88%. The perforated design gives smaller reductions of approximately 2.72% in drag and 5.83% in pressure loss. These results identify the modified V-gutter as the best-performing configuration for the two reported aerodynamic metrics within the investigated CFD setup. Since the study does not report combustion, flame stability or experimental validation results, the modified design should be treated as a promising aerodynamic candidate rather than a fully validated afterburner flameholder.

Keywords: Afterburner, V-gutter flameholder, bluff body, computational fluid dynamics, drag force, pressure loss, flame stabilization.

1. Introduction

An afterburner is fitted downstream of the turbine in some gas-turbine engines to increase thrust by adding and burning fuel in the exhaust stream. Because the exhaust flow has a high velocity, a flameholder is required to create a region in which the flame can remain anchored. A V-gutter is bluff-body flameholder: the flow separates around its edges and forms a wake with lower mean velocity and recirculating fluid. Hot products and recirculating gases can assist ignition and flame holding. Published measurements of V-gutter flows show that reacting and non-reacting conditions can produce different wake structures, demonstrating that flameholder aerodynamics and combustion are coupled [2].

The flameholder must therefore satisfy competing requirements. It should generate a sufficiently effective recirculation zone for flame stabilization while causing as little total-pressure loss and aerodynamic resistance as practical.

A conventional solid V-gutter is mechanically simple, but its blockage can create a substantial wake and pressure deficit. Perforations may permit part of the flow to pass through the body and modify the wake. Geometric modification, including rounding or reshaping an edge, may also alter separation andpressure distribution. Prior experimental work has shown that flameholder type and angle influence blow-off behaviour, combustion efficiency and emissions; perforated V-gutters were reported to improve blow-off performance in the tested configurations [3].

The present paper compares the solid, perforated and modified V-gutter configurations from the supplied project report. The focus is deliberately limited to the reported drag force and pressure-loss results. The purpose is to identify which geometry offers the most favourable aerodynamic performance under the stated numerical conditions and to discuss the limitations that must be addressed before selecting a design for a practical afterburner.

2. Related Work

Bush and Gutmark used particle-image velocimetry to study reacting and non-reacting flow around a confined V-gutter. They reported differences in wake vortex structures and reversed-flow regions between the two conditions, highlighting the importance of considering combustion effects when evaluating a flameholder [2]. Umyshev and co-workers experimentally investigated V-gutter flameholders and found that flameholder geometry and

angle affected blow-off limits, NOx emissions, combustion efficiency and exhaust temperature. Their results also indicated that perforated V-gutters could improve blow-off performance for the tested arrangements [3].

Numerical work on regular and wavy V-gutters has further shown that changes to edge geometry can influence recirculation length, vortex shedding and pressure drop. Mollaei and Ghassemi reported that a wavy configuration with a 90-degree phase difference produced a longer recirculation region and lower pressure drop in their investigated cases [4]. Srinivasan et al. examined drag reduction for an afterburner V-shaped gutter using tandem bluff bodies and CFD, demonstrating the relevance of flow-interference and wake control to reducing flameholder drag [5]. These studies support the general premise that flameholder geometry strongly affects the flow field. Their geometries and operating conditions differ from the present project, so their numerical values are not directly comparable.

3. Geometry and Numerical Methodology

3.1 Flameholder configurations

Three two-dimensional configurations were considered:

(i) a conventional solid V-gutter,

(ii) a perforated V-gutter containing openings in the V-shaped body, and

(iii) a modified V-gutter incorporating a rounded edge.

The project report specifies a V-angle of 60° and a thickness of 2 mm. For the perforated model, the reported hole diameter is 4 mm, the spacing is 8 mm and three holes are provided on each side. The modified geometry is reported to use a radius of 0.06 m at the rounded edge. The computational domain is reported as 0.882 m in length, 0.12 m in height and 0.08 m in depth [1].

3.2 Computational domain and boundary conditions

The project uses ANSYS-based CFD analysis. The stated inlet temperature is 300 K and the inlet velocity is 17.3 m/s. A pressure outlet at atmospheric pressure is applied downstream. The solid boundaries are treated as no-slip and adiabatic. Turbulence is modelled using the shear-stress-transport (SST) k– ω approach [1]. All three configurations are intended to be compared under the same boundary conditions so that differences in the reported outputs can be associated with the geometry within the numerical model.

The source report describes mesh refinement near the flameholder, where strong velocity and pressure gradients are expected. However, the available reported results do not provide a mesh-independence study, cell count, residual convergence history or quantified numerical uncertainty. These items should be included in a final journal submission if the underlying simulation data are available.

3.3 Governing relations and performance parameters

The flow solution is based on conservation of mass and momentum, together with the turbulence-model transport equations. The drag force is evaluated using the conventional aerodynamic relation:

$F_D = ½ \rho V^2 C_D A$

where F_D is drag force, ρ is fluid density, V is reference velocity, C_D is the drag coefficient and A is the reference area. The pressure loss across the flameholder is defined in the project as the difference between inlet and outlet pressure:

$\Delta p = p_{in} - p_{out}$

Lower drag and lower pressure loss are desirable from an aerodynamic viewpoint. They are not, by themselves, proof of improved afterburner performance: the flameholder must also maintain an adequate recirculation zone and stable combustion.

4. Results and Discussion

The comparative values below are transcribed from the Chapter 6 results table of the supplied project report [1]. The pressure-loss unit is not identified in that table and is therefore not assigned here.

Flameholder configuration	**Drag force (N)**	**Reported pressure-loss value**
Solid V-gutter	16.162	604.563
Perforated V-gutter	15.722	569.295
Modified V-gutter	13.042	442.069

4.1 Drag-force comparison

The solid V-gutter produces the highest reported drag force, 16.162 N. The perforated configuration reduces the force to 15.722 N, a reduction of approximately 2.72% relative to the solid model. The modified V-gutter produces the lowest value, 13.042 N, corresponding to a reduction of approximately 19.31% relative to the solid configuration. The modified geometry therefore provides the strongest drag reduction among the three configurations in the reported simulation. The perforated geometry provides only a modest improvement in drag under the same reported conditions.

4.2 Pressure-loss comparison

The Chapter 6 table reports pressure-loss values of 604.563 for the solid model, 569.295 for the perforated model and 442.069 for the modified model. Based on these values, the perforated configuration reduces the reported pressure-loss value by approximately 5.83%, while the modified configuration reduces it by approximately 26.88% relative to the solid model. Thus, the modified V-gutter gives the lowest reported pressure-loss value in this dataset.

4.3 Overall interpretation

Considering both metrics together, the modified V-gutter is the most favourable of the three designs in the Chapter 6 dataset. Its drag force and reported pressure-loss value are both lower than those of the solid and perforated designs. The perforated model performs better than the solid model for both tabulated parameters, but its improvements are comparatively small. These observations are consistent with the broader research finding that changes in bluff-body geometry can modify wake structure and pressure distribution [3], [4]. However, the present project does not provide quantitative recirculation-zone length, velocity contours, flame temperature, blow-off limits or combustion-efficiency data. It is therefore not possible to conclude from drag and pressure loss alone that the modified configuration provides superior flame stability.

5. Limitations and Data Consistency

An important inconsistency exists within the supplied project report. The Chapter 6 results table and its discussion state pressure-loss values of 604.563 (solid), 569.295 (perforated) and 442.069 (modified), which make the modified model the lowest-loss configuration. The report's conclusion section instead gives 564.563, 606.295 and 582.069, respectively, and states that the solid model has the lowest pressure loss [1]. These two datasets lead to different conclusions.

This paper uses the Chapter 6 table because it is the detailed results table and the values are repeated in the Chapter 6 discussion. The original ANSYS output files should be checked before publication or formal submission. The pressure-loss unit and the exact pressure definition (static or total pressure) should also be confirmed.

Further limitations include the absence of a reported mesh-independence assessment, experimental validation, numerical uncertainty, detailed pressure and velocity contour values, and reacting-flow calculations. The source also does not demonstrate that the modified geometry maintains the recirculation strength required for reliable flame holding. These limitations mean that the findings are comparative CFD results for the stated setup, not a complete validation of an operational afterburner design.

6. Conclusion

A comparative CFD-based assessment of solid, perforated and modified V-gutter flameholders has been presented using the numerical results in the supplied project report. The solid V-gutter recorded the highest drag force of 16.162 N. The perforated model reduced drag to 15.722 N, while the modified V-gutter achieved the lowest drag force of 13.042 N. According to the Chapter 6 pressure-loss data, the corresponding values were 604.563, 569.295 and 442.069. Relative to the solid model, the modified configuration reduced drag by approximately 19.31% and the reported pressure-loss value by approximately 26.88%.

Within the reported numerical dataset, the modified V-gutter is therefore the preferred configuration when the selection criteria are limited to drag force and pressure loss. The result should be interpreted cautiously because the source report contains conflicting pressure-loss values in its conclusion, and because flame stability and combustion performance were not established by the reported outputs. Future work should verify the pressure data, perform mesh-independence and experimental validation, and evaluate recirculation-zone dimensions, velocity and pressure fields, flame stability, blow-off limits, combustion efficiency and emissions under reacting-flow conditions.

References

[1] Department of Aeronautical Engineering, “Investigation on Drag Reduction Analysis of Flameholder in Afterburner Applications,” project report, 2026– 2027. Unpublished student project report supplied by the user.

[2] S. M. Bush and E. J. Gutmark, “Reacting and nonreacting flowfields of a V-gutter stabilized flame,” AIAA Journal, vol. 45, no. 3, pp. 662– 672, 2007, doi: 10.2514/1.22655.

[3] D. R. Umyshev, A. M. Dostiyarov, M. Y. Tumanov, and Q. Wang, “Experimental investigation ofV-gutter flameholders,”Thermal Science, vol. 21, no. 2, pp. 1011– 1019, 2017, doi:10.2298/TSCI151209072U.

[4] M. Mollaei and H. Ghassemi, “Numerical investigation of cold flow over regular and wavyV-gutters,” Proceedings of the Institution of Mechanical Engineers, Part G: Journal ofAerospace Engineering, vol. 233, no. 15, 2019, doi: 10.1177/0954410019852560.

[5] S. Srinivasan, J. J. Isaac, C. Rajashekar, and A. Arokkiaswamy, “Drag reduction of V shapedring gutter of an afterburner by tandem bluff bodies using CFD,” IOSR Journal of Mechanicaland Civil Engineering, vol. 1, no. 6, pp. 41– 50, 2012.

Author checklist before submission

- Replace the author, institution and email placeholders with the actual details.
- Verify the conflicting pressure-loss values against the original ANSYS output files.
- Confirm the pressure-loss unit and whether static or total pressure was used.
- Add the mesh size, cell count, mesh-independence results and residual convergence plots if available.
- Insert the actual mesh, geometry, velocity-contour and pressure-contour figures from the project.
- Do not claim flame-stability or combustion-efficiency improvements unless reacting-flow