Proposed Research

Mixing Efficiency in Rocket Engine Injector Elements with Gas-Fluidized Metal Powder Propellants

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Introduction

Research into subscale fluidized aluminum powder hybrid engines revealed the primary performance limitation to be insufficient propellant mixing (Meyer, 1993). This type of engine relies on gas-fluidized metal powders, using class A fluidizable powders (Geldart, 1973). The fundamental principle of gas-fluidization is to flow gas through the packed bed at a rate which is at or above the terminal velocity of a single particle (Yandaizi Zhaou, 2023). By using a choked flow metal powder gas-fluidization system (Dianlong Sun, 2025) and gaseous injector designs of known gaseous mixing performance, the deviation of these designs performance when using fluidized fuel particles can be established.

It is likely that gas-fluidized propellants will not behave as ideal gaseous propellants, resulting in a general trend of decreased performance compared to predicted performance based on design characteristics. Deep cup premixed injector elements are likely to perform best during this testing, due to the high base performance and high mass flow tolerance afforded by this injector type (D. F. Calhoun, 1973), and the similarity to fluidization techniques which achieve excellent mixing performance (Yandaizi Zhaou, 2023).

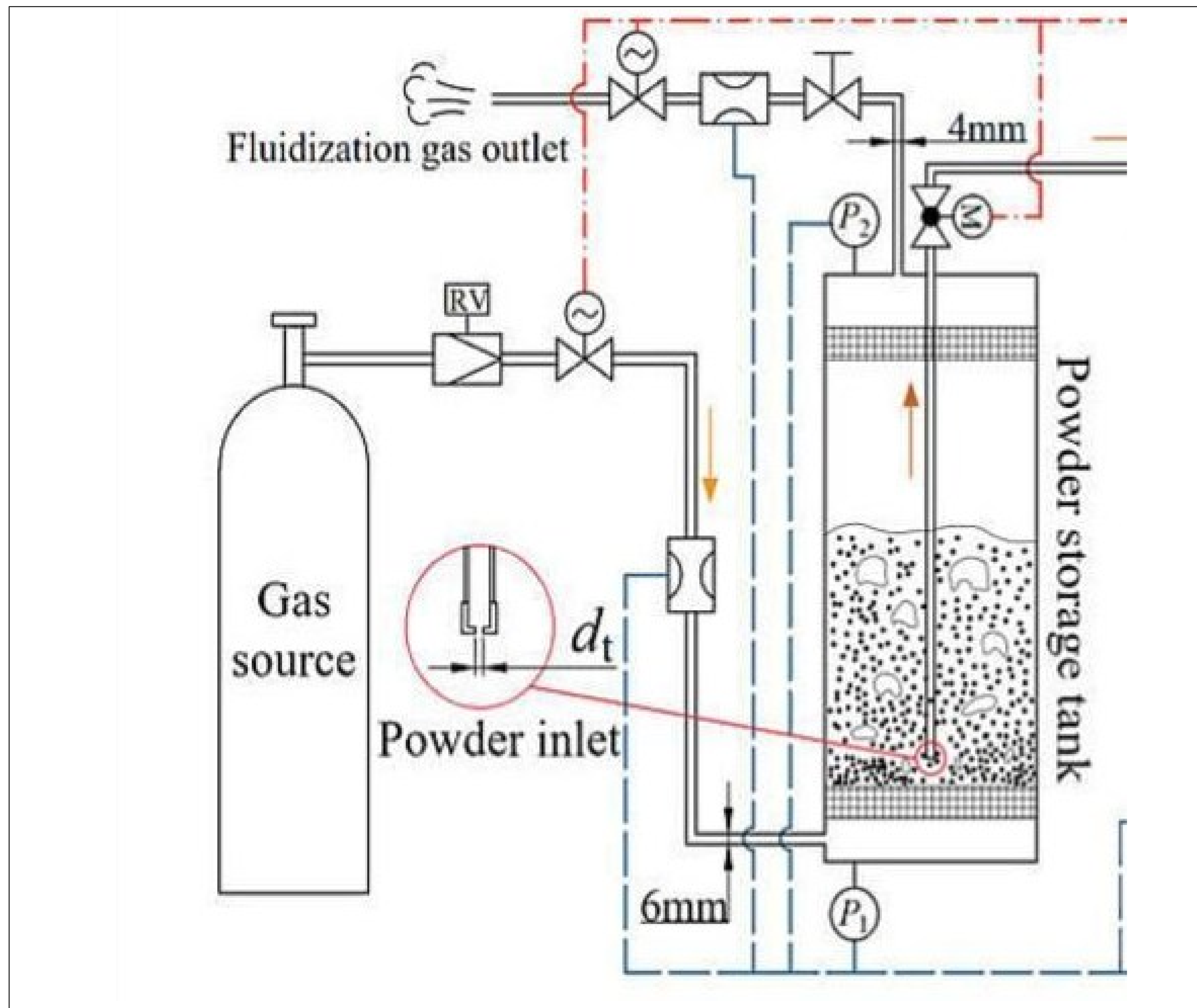

Photo Credit: Sun Et. Al., 2025

Possible Results and Conclusions

If deep-cup premixed injectors show the highest performance in terms of mixing efficiency, with the general trend of reduced performance compared to predicted gaseous propellant performance, then it can be concluded that the added tolerances afforded by this type of injector served to counteract the performance limitations of gas-fluidized powdered propellants. However, if there is not a significant reduction in mixing performance between gaseous propellants and gas-fluidized propellants, then it may be concluded that gas-fluidized propellants behave similarly to ideal gases as described by the ideal gas law, and conventional design techniques can be used without modification.

Materials & Methods

A fluidized bed fuel feeding system will be constructed according to the design and dimensions provided by Sun Et. Al., using machined aluminum flanges, an acrylic body, threaded compression rods, and copper tubes with associated fittings. This apparatus will be tested and the mass flow rate characterized using the method described by the same study which outlines the construction of the fuel feed system. Once constructed, it will be used to test the cold flow mixing performance of different rocket engine injector elements designed according to the analytical model provided by Calhoun Et. Al., using a mixing probe similar in design to the one used to validate the analytical model. The hypothesis that deep-cup premixed injector elements will demonstrate the greatest mixing efficiency will be tested, and the deviation between predicted and measured mixing performance will then be analyzed. This analysis will be conducted in search of trends in the deviation of performance of gaseous and gas-fluidized propellants.

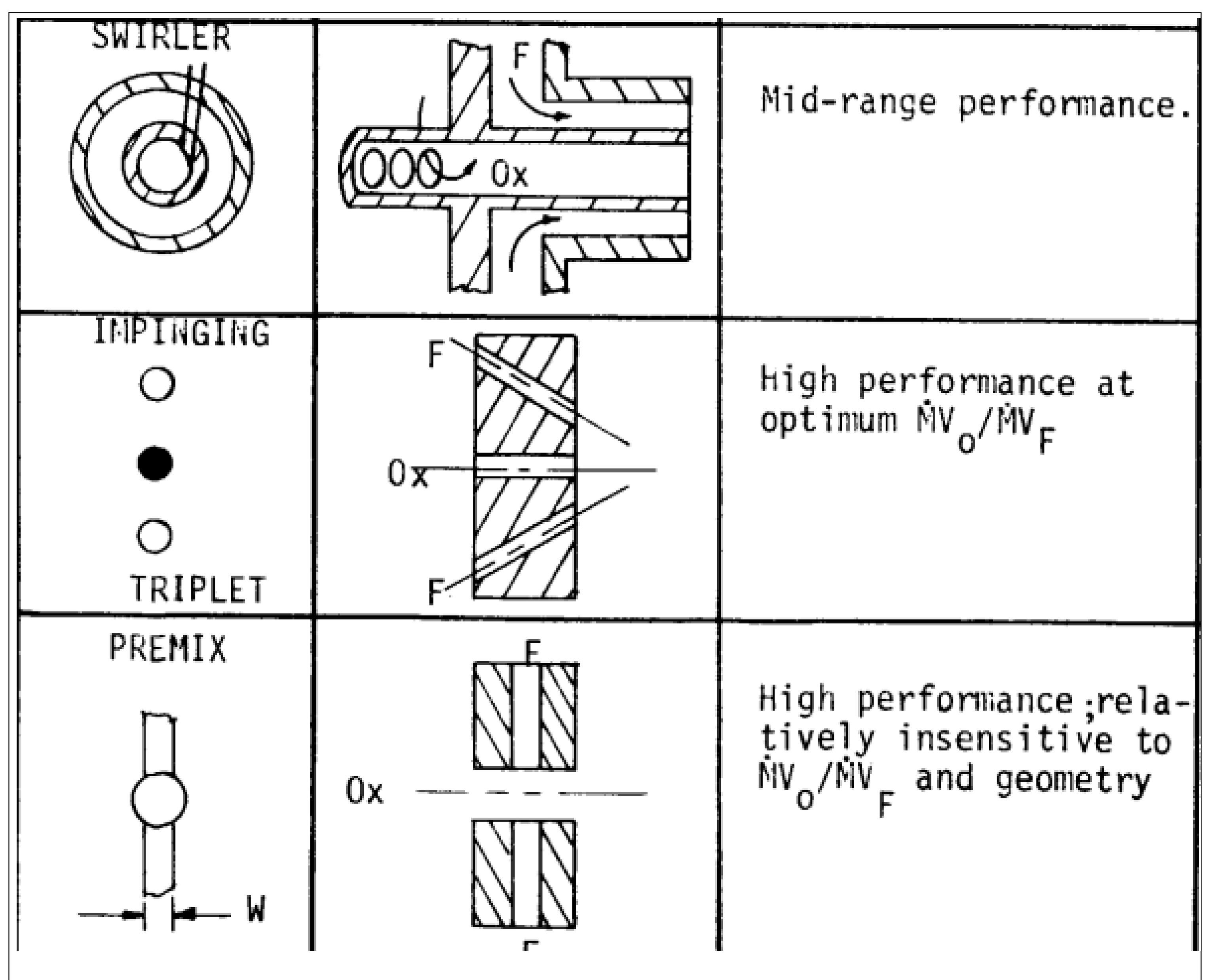

Photo Credit: Calhoon Et. Al., 1973

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