Section III: Results

In the initial evaluation phase of this project, three existing injection schemes were tested: the radial, axial, and axial-triplet configurations. A decision table was developed to determine which existing scheme was most effective in producing a homogeneous distribution of fuel and oxidizer using the density comparison equations identified. The results of this testing phase are evident in Table 1, which shows that most effective schemes were the values which returned small densityFactor deviations.

Table 1

Output Values for Radial, Axial, and Axial-Triplet Decision Table

	Radial	Axial	Axial-Triplet
densityInlet (kg·m^-3)	1.218	0.984	1.191
densitySurfaceBody (kg·m^-3)	1.292	1.069	1.228
densityFactor	0.943	0.920	0.970
Deviation from 1	0.057	0.080	0.030

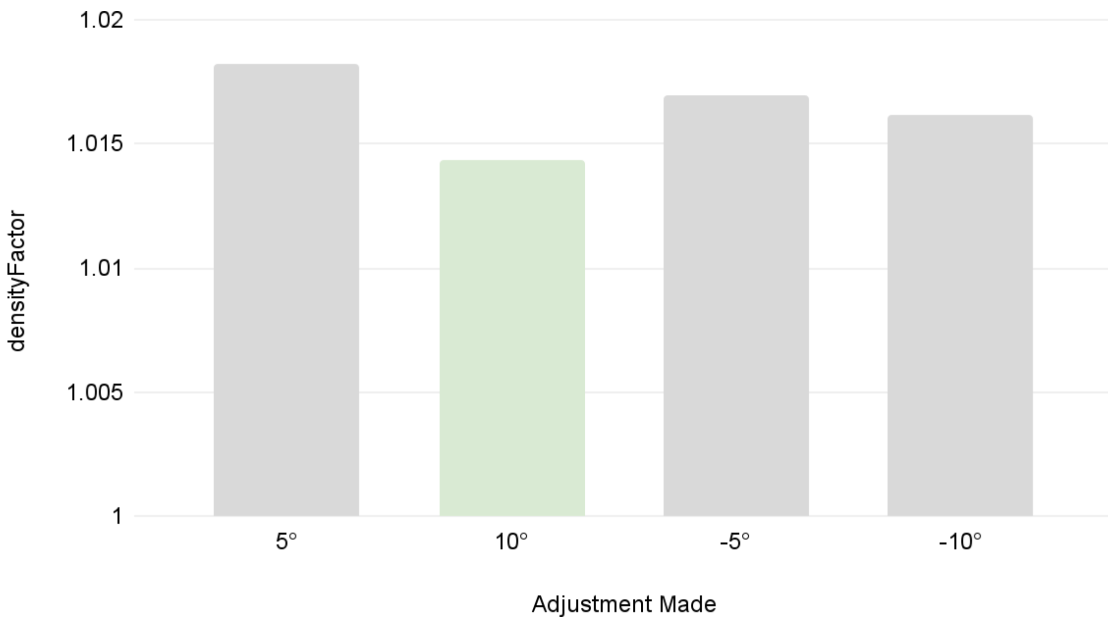
As seen in the table above, the axial-triplet injection scheme, essentially an axial configuration with three injectors rather than two, was the most effective in producing a homogeneous mixture. The average density throughout the chamber was 97% of the original density ratio evaluated at the inlet boundaries. Once this was determined, the next phase, which included iteration of the existing most effective model, was pursued.

Iteration Phase

The iteration phase of this project included adjusting several injection-specific variables (diameter, angle, and in-between injector distance). To determine their impact on mixture homogeneity using the axial-triplet injector scheme. The angles adjusted in the triplet scheme were the two outer fuel injectors, which originally lay at a perpendicular angle and were adjusted by increasing or decreasing the angle by 5 degrees.

Figure 5

Density Factor Changes by Triplet Injector Angle Adjustment

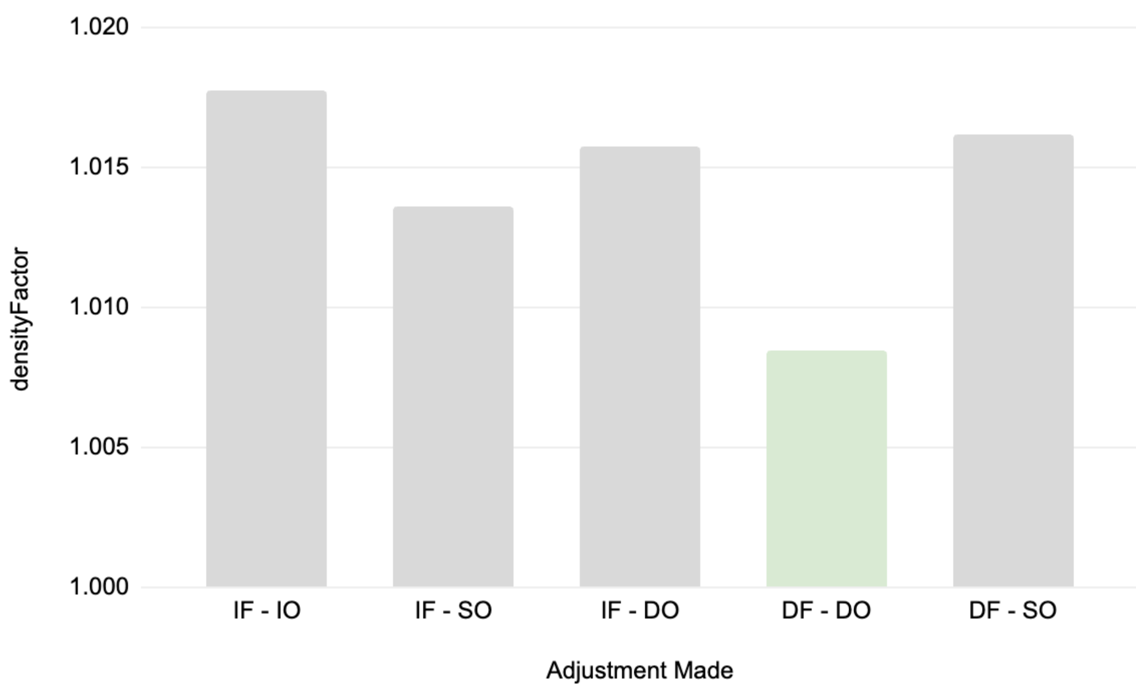


Note. Figure 5 visually represents the impact of outer fuel injector axial angle adjustments on the generated densityFactor values for each adjusted scheme. Highlighted in green is the angle adjustment with the lowest deviation from the homogeneity marker of 1, which was a 10-degree angle increase between both injectors.

In Figure 5, the density factor calculations showed that an outer fuel injector angle adjustment by 10° had the closest density factor value to 1, with a densityFactor deviation of 0.014. This adjustment was a significant improvement from the original densityFactor deviation value of 0.030. Considering that injector angle was directly proportional to distance between, this testing successfully accomplished the adjustment of angle and distance. The last iterative adjustment that took place was injector diameter. For simplicity, both fuel injectors are kept at equal diameters. With two kinds of injectors and three adjustment options (increase, decrease, or remain the same), there were 5 possible new injector adjustments, all of which changed 0.2mm intervals. All 5 injector adjustments were performed on the improved 100° adjusted injector angle configuration. Fuel is shortened to F, oxidizer to O, increase to I, decrease to D, and remain the same to S.

Figure 6

Density Factor Changes to 100° Triplet Scheme by Diameter Adjustments



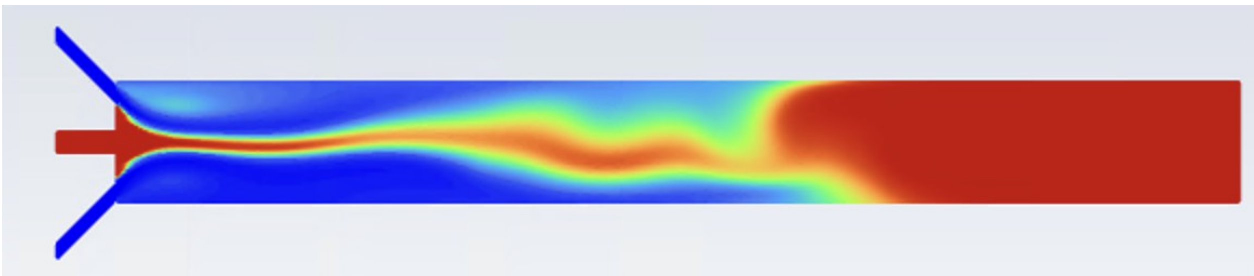
Note. Figure 6 visually represents the impact of inlet diameter adjustments on the generated densityFactor values for each adjusted scheme. Highlighted in green is the density factor with the lowest deviation from the homogeneity marker of 1, which was a decrease in all diameters of the fuel and oxidizer injectors.

In Figure 6, changes to the density factor value by adjustment to the fuel and oxidizer injector diameters are graphically expressed. From the chart, it is evident that the decrease in diameter of 0.2mm to both the fuel and oxidizer injector orifices led to a lower densityFactor deviation. The newly developed optimal density factor deviation value was recorded as 0.00848, leading to a 99.2% similarity ratio, or homogeneity level, between the injector and detonation channel density averages.

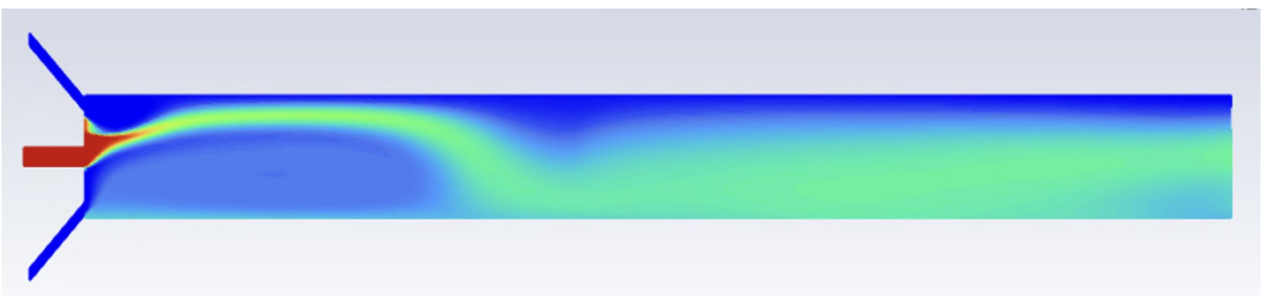
Throughout this testing process, several contours placed over the mesh of the triplet injector scheme and the other tested injection schemes were used. Using a density contour, where the oxidizer inlet holds the higher density value, the location of fuel and oxidizer particles during the given time interval can be expressed visually.

Figure 7

Triplet Injection Density Contours



(a)



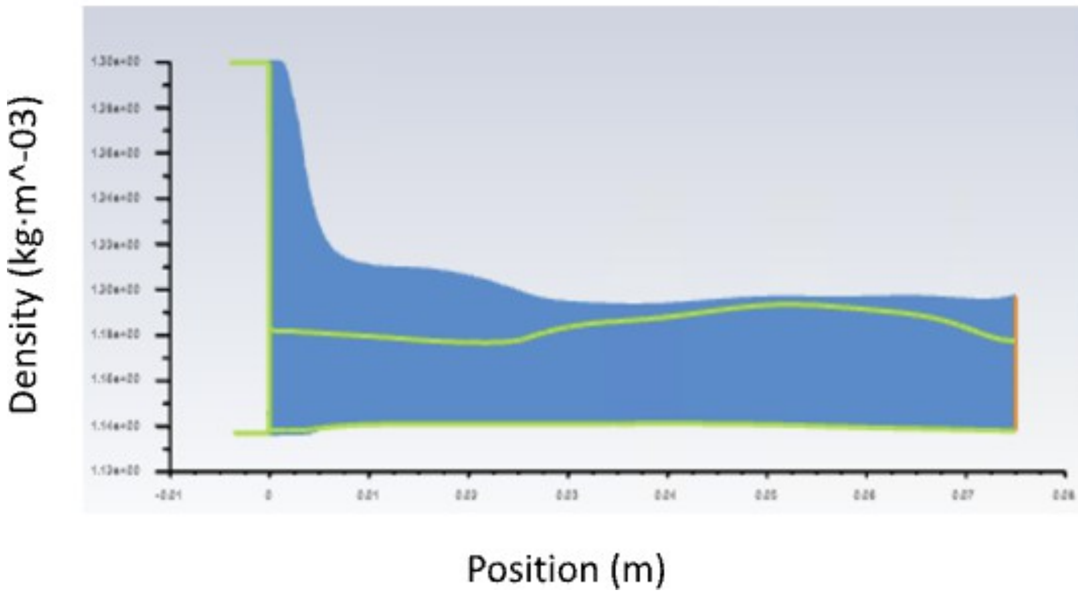
(b)

Note. Figure 7-a visually expressed the original triplet injection scheme's density contour, displaying a red-toned, higher-density oxidizer injection and a lower-density fuel injection. Figure 7-b displays the triplet injector scheme's density contour after the iterative adjustment process to improve mixture inhomogeneity in the chamber.

Figure 7 displays a visual representation of fuel and oxidizer distribution using a density contour, which can be useful in visually reinforcing the levels of improvement which the improved triplet injector design possesses. Figure 8 further expresses this distribution of density, showcasing relatively even distributions throughout the channel body when compared to the initial triplet injector density distribution visualized in Figure 9.

Figure 8

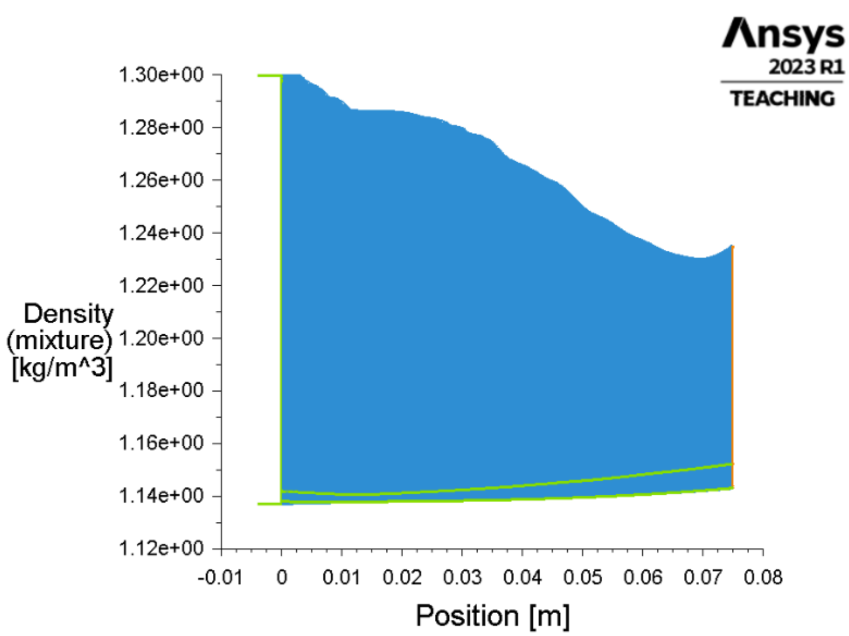
Density Distribution Within the Modified Triplet Injector Scheme



Note. Figure 8 graphically displays the density distribution throughout the chamber body regarding the modified triplet injector scheme.

Figure 9

Density Distribution Within the Original Triplet Injector Scheme



Note. Figure 9 graphically displays the density distribution throughout the chamber body regarding the original triplet injector scheme.