GEL- TECH INNOVATORS

Contents

Gel Fuels

01.

Gel fuels are characterised by non-Newtonian properties.

02.

Gels are liquids whose rheological properties have been altered by the addition of certain gelling agents and as a result their behaviour resembles that of solids.

Fig 1. Gelled propellant fuels, both neat and mixed with nano-particles.

03.

They behave as solids at rest and can be atomised and combusted like conventional liquid fuels when flowing under shear.

Problem Statement

The atomization of gel fuels poses a major engineering challenge, as fuel injection systems specifically designed for gels are not yet available. Conventional liquid injectors are incompatible, often clogging or delivering inconsistent flow with gel fuels, which results in incomplete combustion and reduced efficiency.

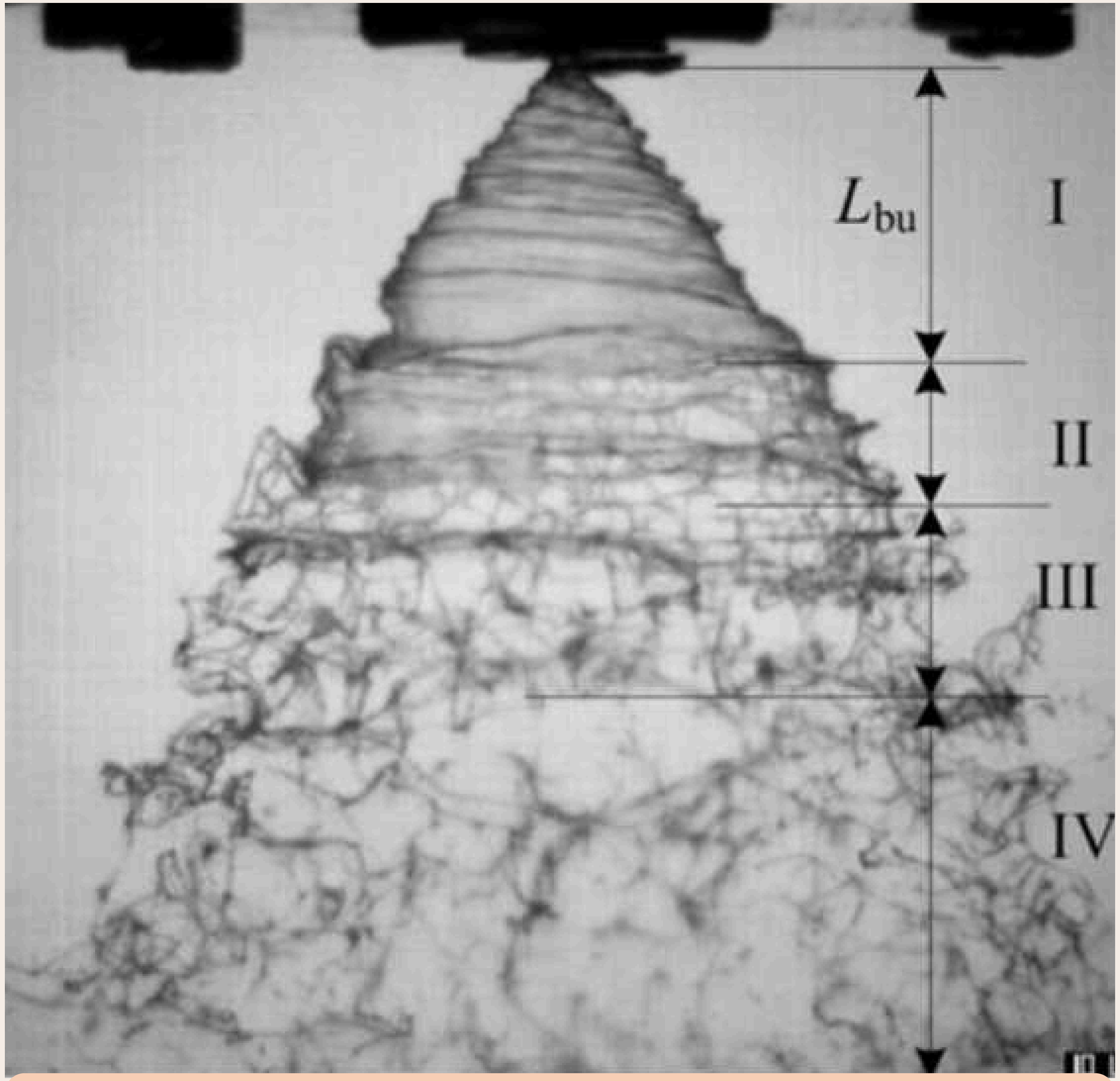


Fig 2. Gelled propellant atomisation characteristics.

Ideation process

01

Literature Review

02

Comparison of existing atomisers.

03

Design of fuel injector using shear thinning property of gels.

04

CFD analysis of proposed model.

Rheology of Gels

- The generalised Herschel-Bulkley (HB) constitutive model was found to be the most adequate for the gels studied.

$$
\begin{aligned}
\dot{\gamma} &= 0, && \text{if } \tau < \tau_0 \\
\tau &= \tau_0 + k\dot{\gamma}^n, && \text{if } \tau \geq \tau_0
\end{aligned}
$$

- Gels show thixotropy. It is characterised by a decrease in the apparent viscosity under constant shear stress or shear rate, followed by gradual recovery when the stress or the shear rate is removed.

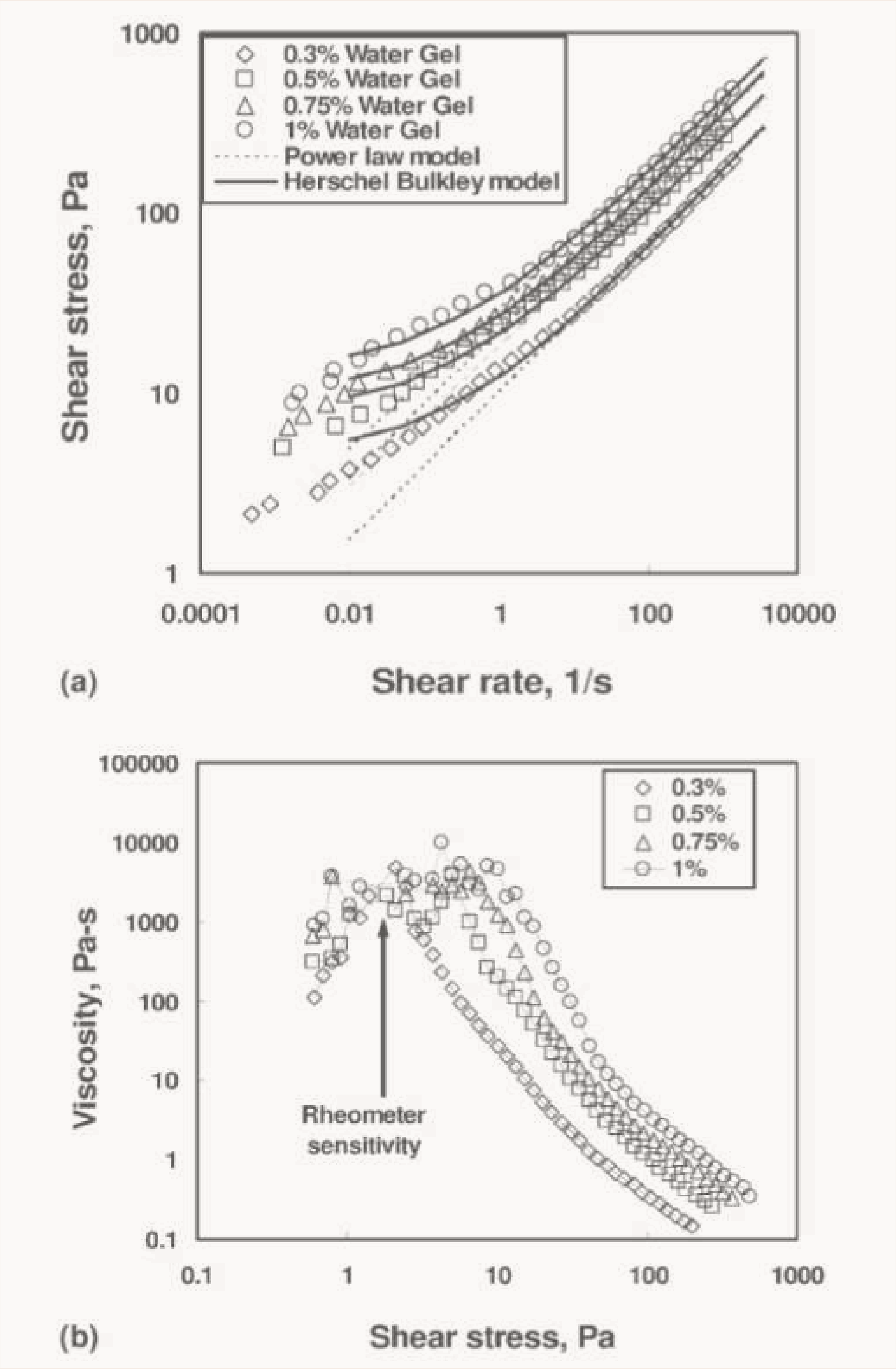


Fig 3: Flow curves for propellants with different gellant contents.

Types of Atomisers

01. Presure Swirl Atomiser

02. Ultrasonic Atomiser

03. Inpingement Jet Atomiser

04. Effervescent Atomiser

05. Air Blast Atomiser

Pressure Swirl Atomizer

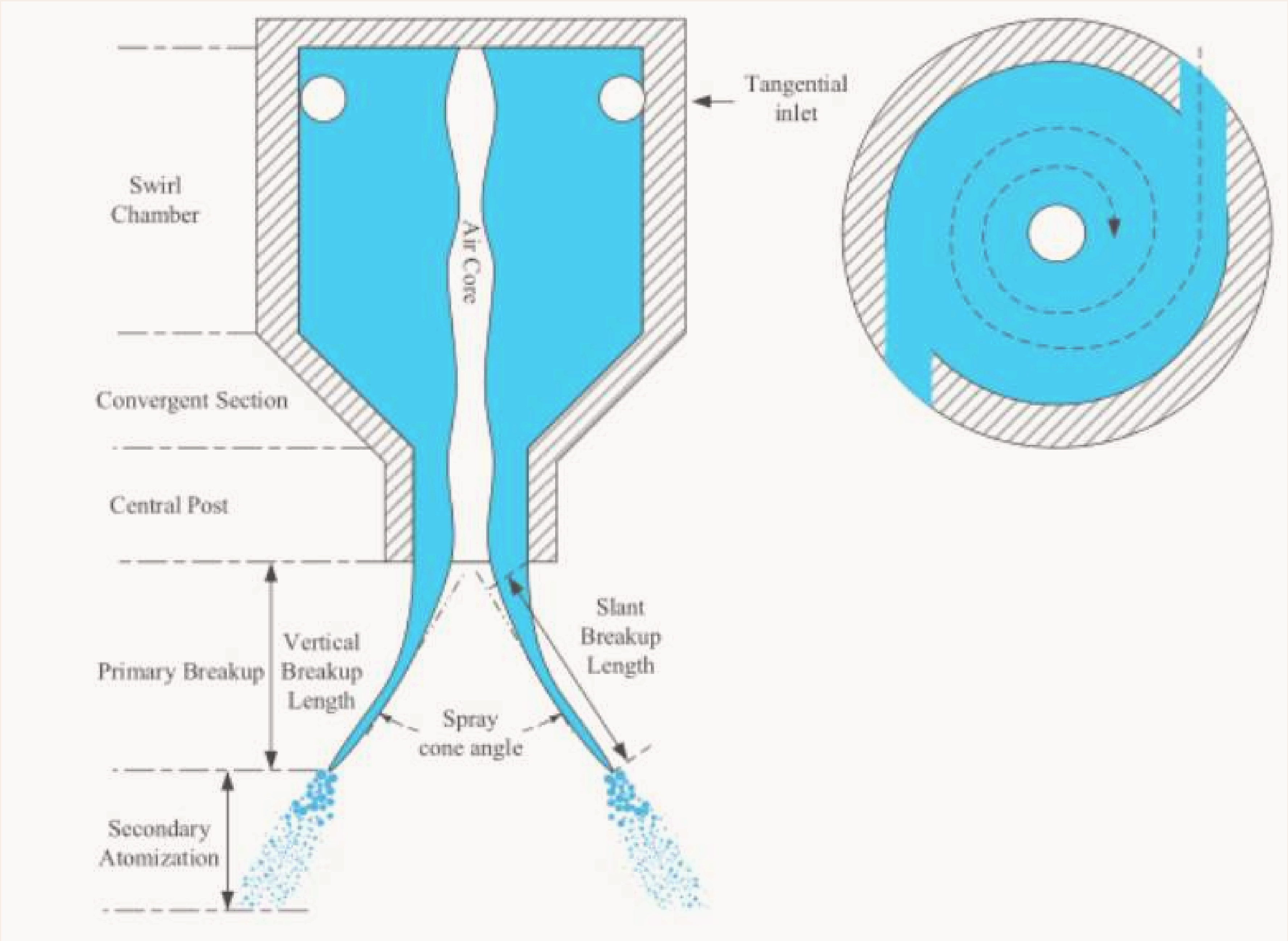


Fig 4: Schematic of the flow formed by a pressure swirl injector.

- In a swirl injector, the liquid enters the tangential inlets under the supply pressure, and angular momentum is imposed on the liquid to form a swirling motion.
- Under the action of centrifugal force, the liquid spreads out in the form of a conical sheet as soon as it leaves the nozzle.
- The disintegration of the liquid sheet is due to the growth of the unstable wave at the interface between the ambient gas and the liquid sheet.

Ultrasonic Atomiser

- Ultrasonic atomisers use high-frequency waves to generate vibrations that break liquid fuel into fine droplets, enhancing fuel-air mixing for better combustion.
- The ultrasonic waves create pressure variations that cause the fuel to atomise into a mist.
- This process allows precise control of droplet size and uniform distribution.

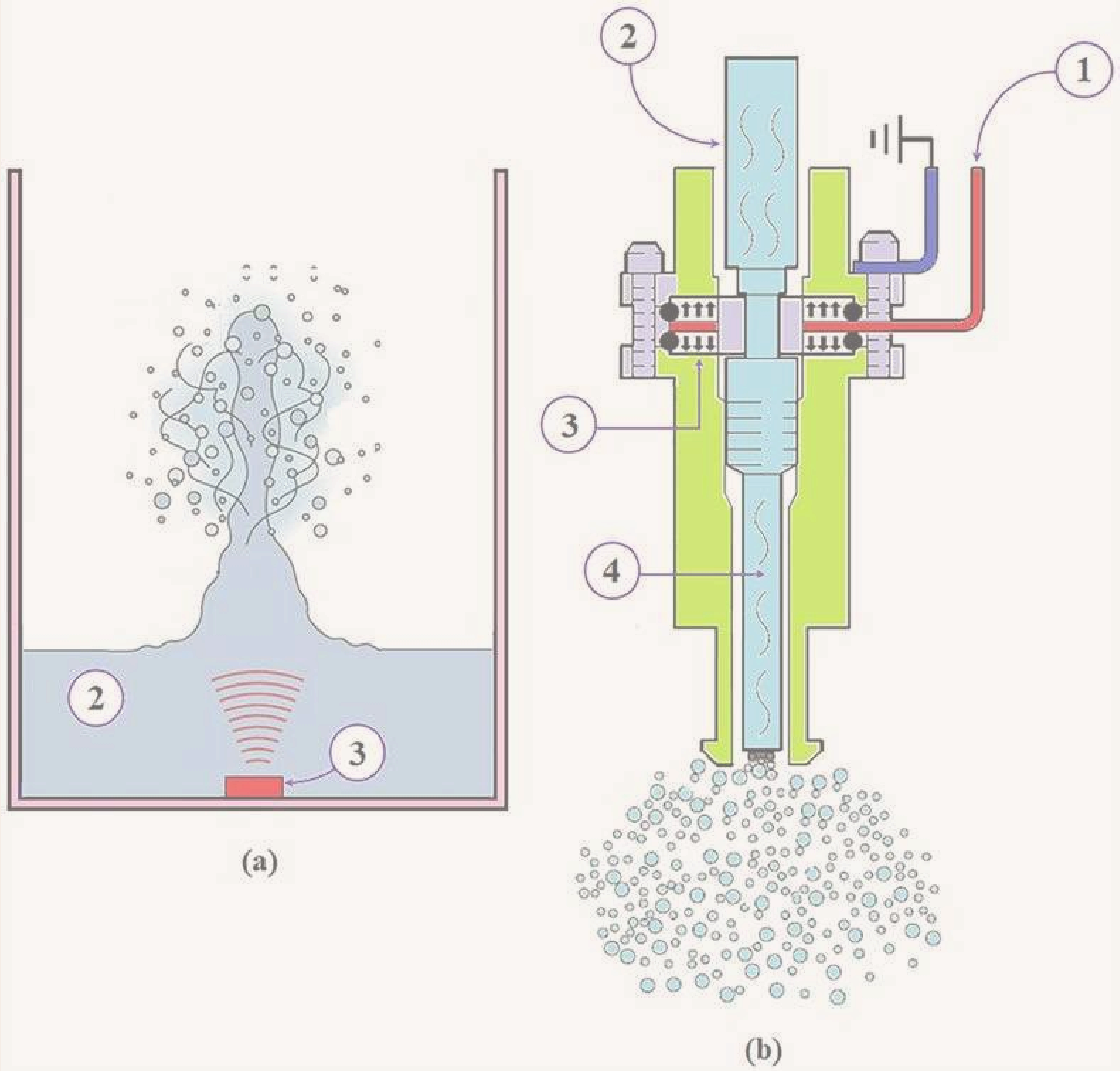


Fig 5: High-frequency ultrasonic atomizer based on the piezoelectric ceramics: a static fluid and b dynamic fluid (ultrasonic nozzle), (1) high-frequency input, (2) liquid fluid, (3) ultrasonic piezoelectric transducer, and (4) liquid fluid passage.

Impingement Jet Atomiser

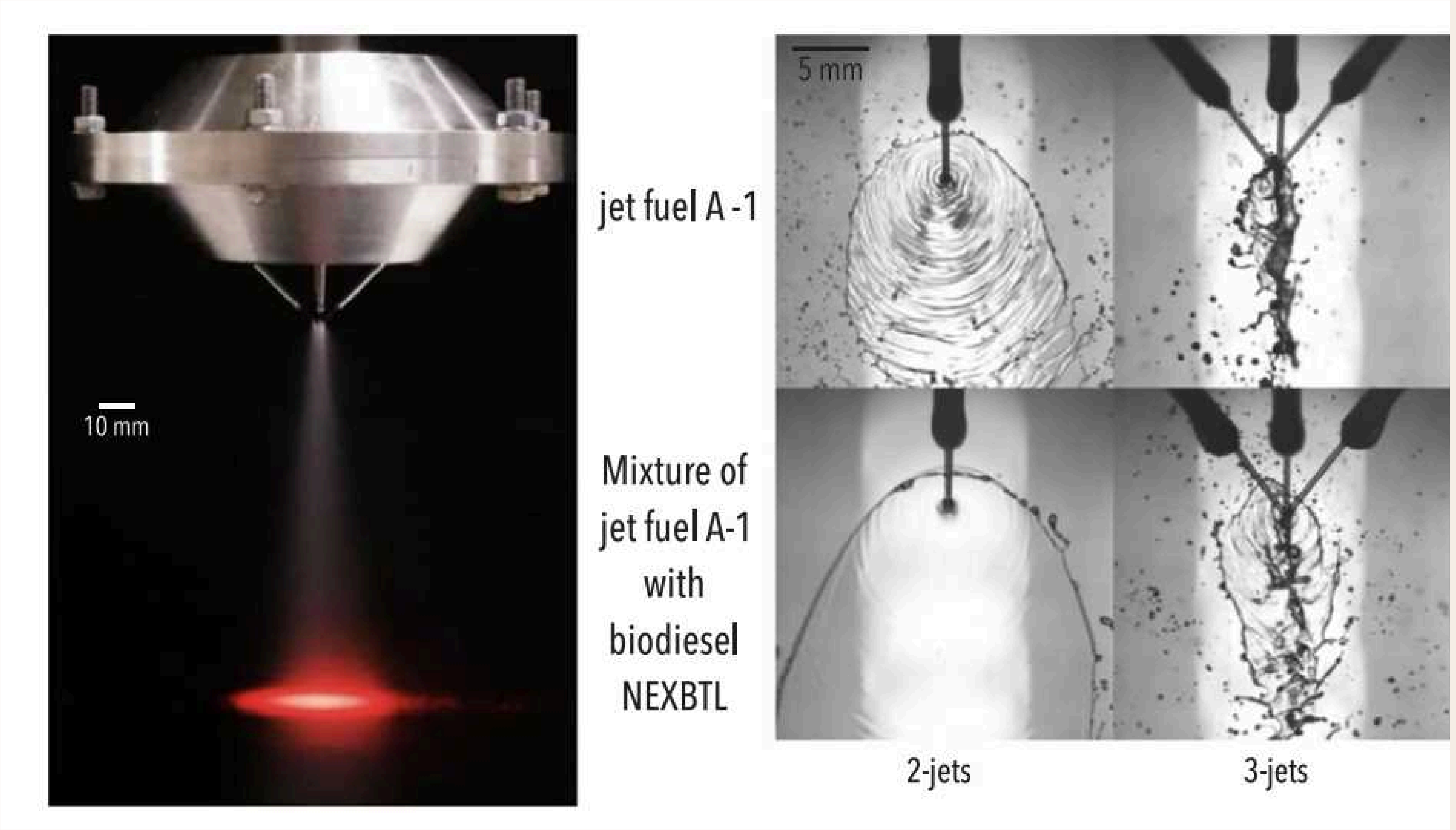


Fig 6: Injector and spray produced by the multiple impinging jets atomiser.

- An impinging jet injector is a type of rocket fuel injector that creates atomization of propellants by directing two or more jets of liquid at each other at a specific angle
- . The collision of the jets forms a fine spray or mist, which improves the mixing and combustion efficiency in the combustion chamber.
- This method of injection is often used in liquid rocket engines, where proper atomization and mixing of fuel and oxidizer are critical for efficient combustion.

Effervescent Atomisation

- Effervescent atomization is a method of twin-fluid atomization that involves bubbling a small amount of gas into the liquid before it is ejected from the atomizer.
- The atomizing gas is injected into the liquid at very low velocity to form a bubbly two-phase mixture upstream of the discharge orifice
- The efficiency of effervescent atomizers (in terms of energy needed for atomization) is found to be substantially higher than the efficiencies of pressure, rotary, and most forms of twin-fluid atomizers

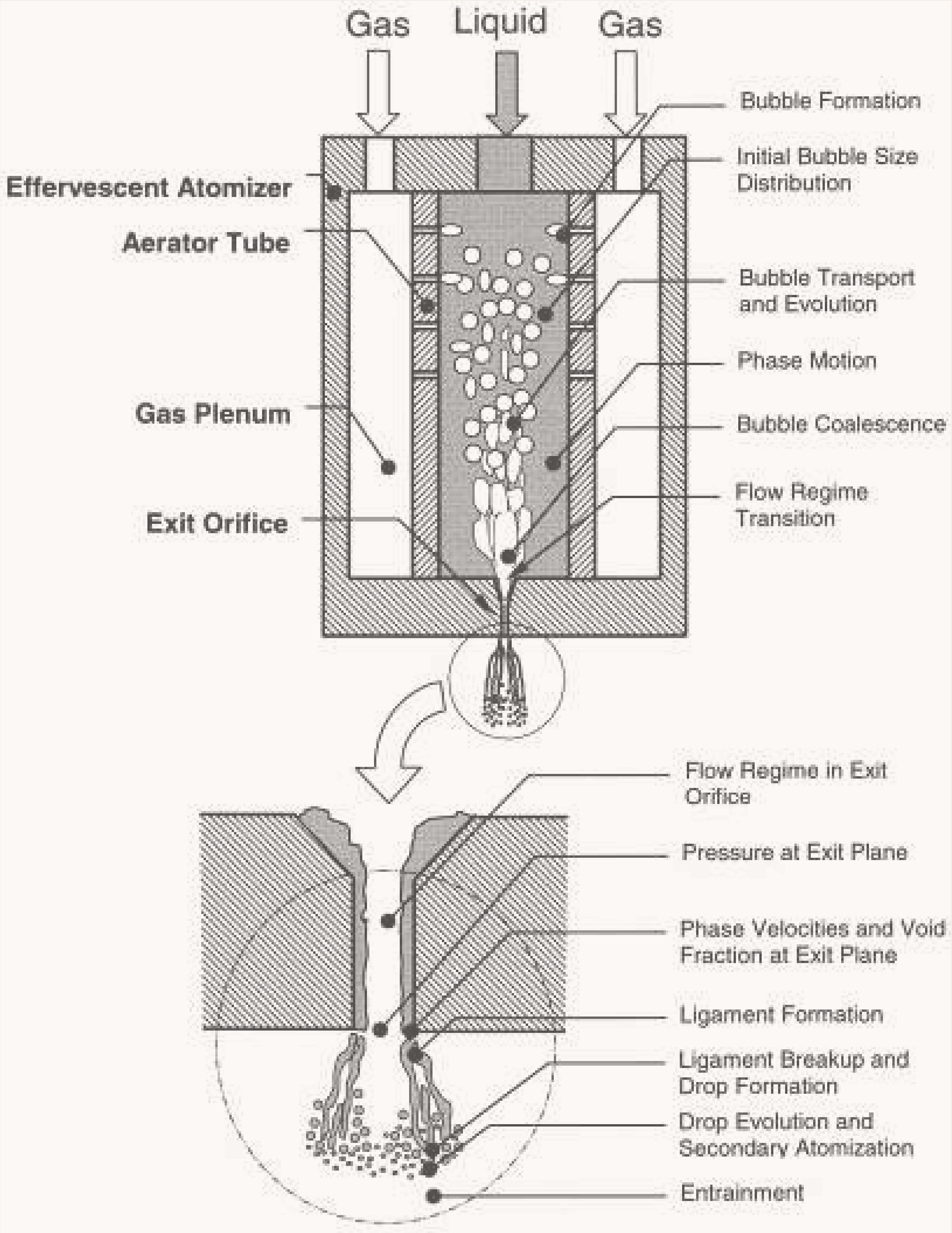


Fig 7.Fundamental two-phase two phenomena involved in effervescent atomisation.

Air Blast Atomiser

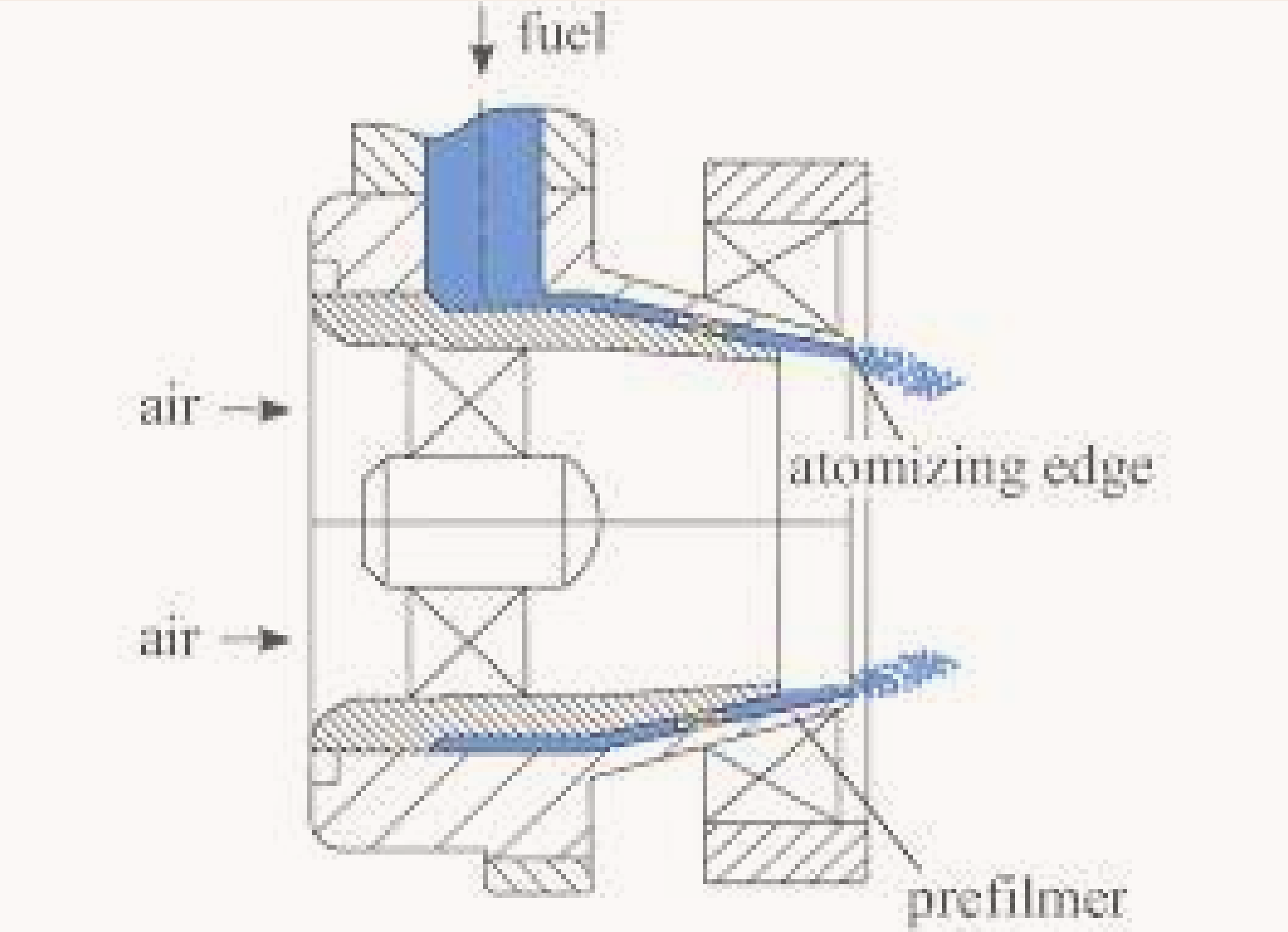
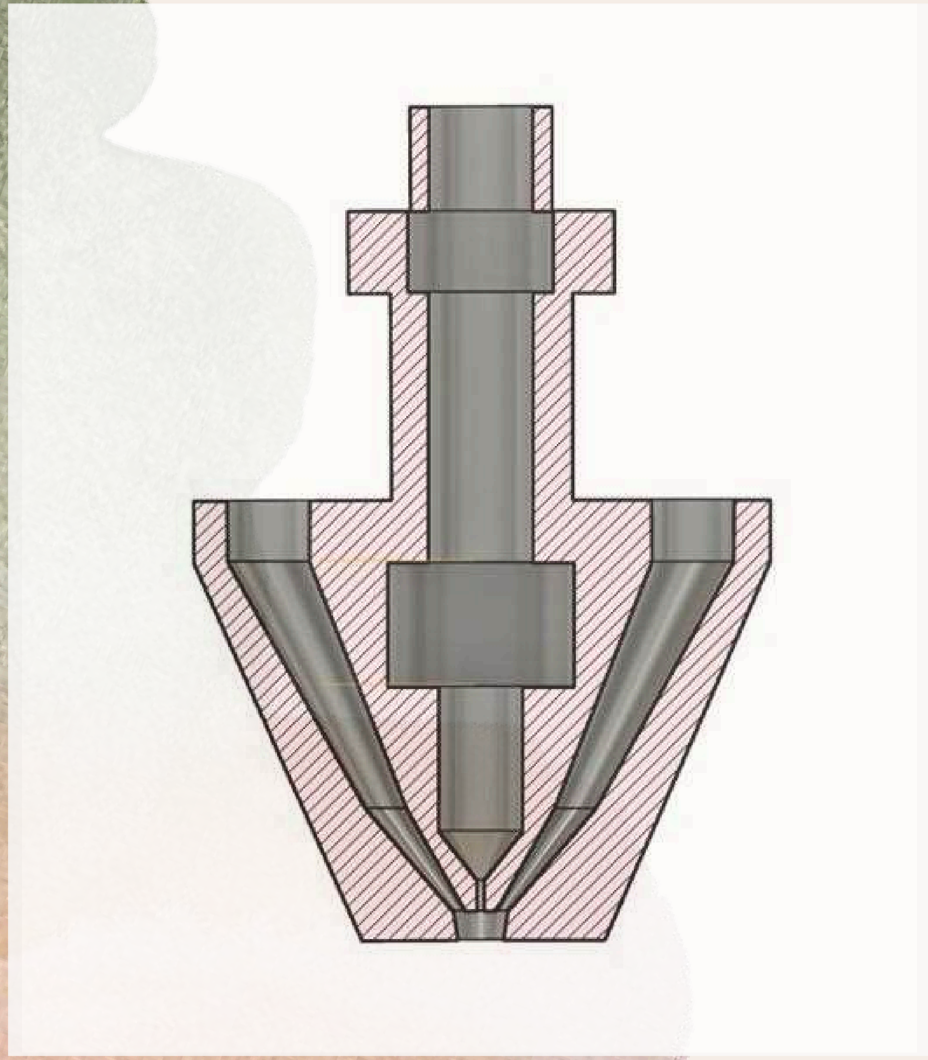
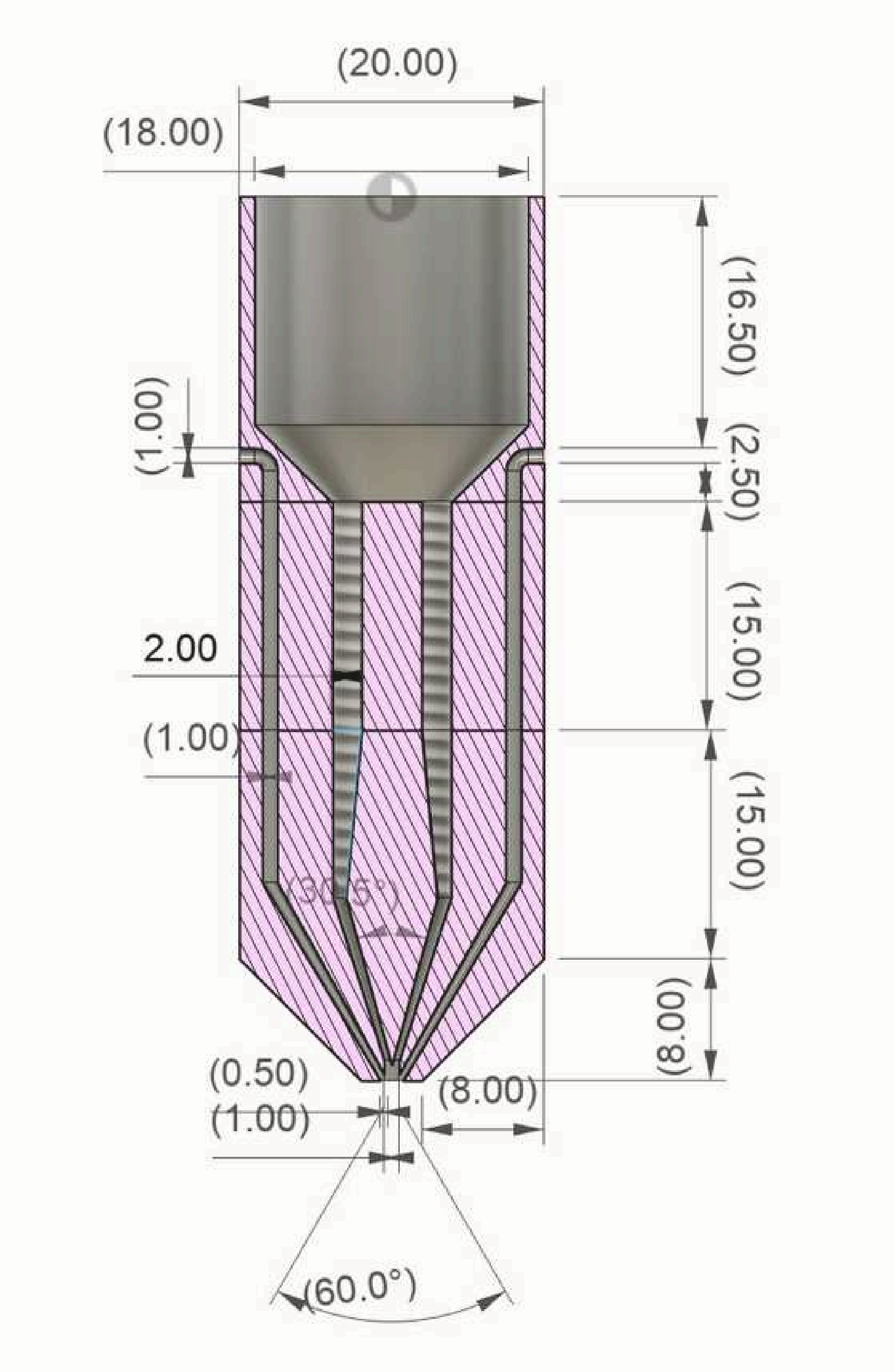


Fig 8: Schematic of Air blast atomiser.

- An air-blast atomiser is a type of atomiser used to break up liquid fuel into fine droplets by using a high-velocity airstream.
- In this process, liquid fuel is forced through a nozzle and meets a flow of high-speed air, which shears the liquid into a fine mist.
- This process enhances atomization, improving fuel-air mixing for better combustion.

Initial Ideas

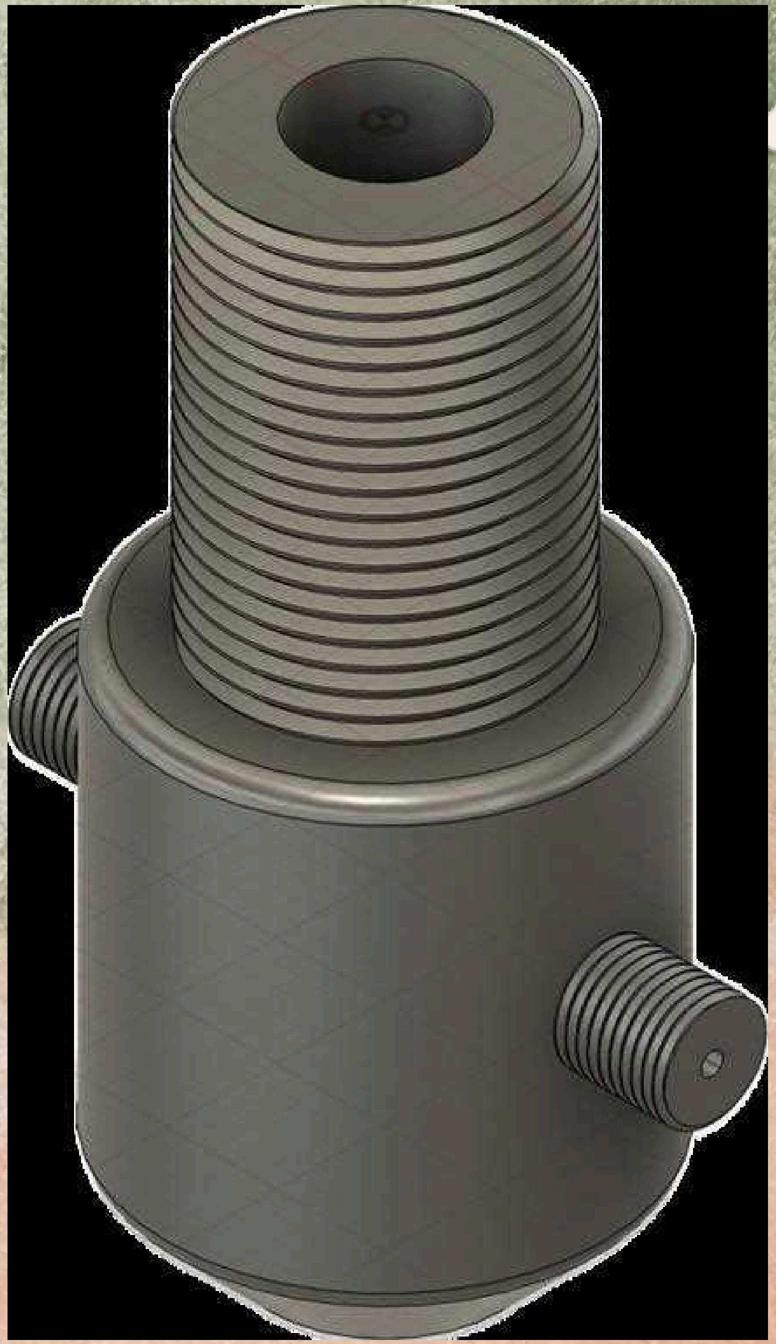


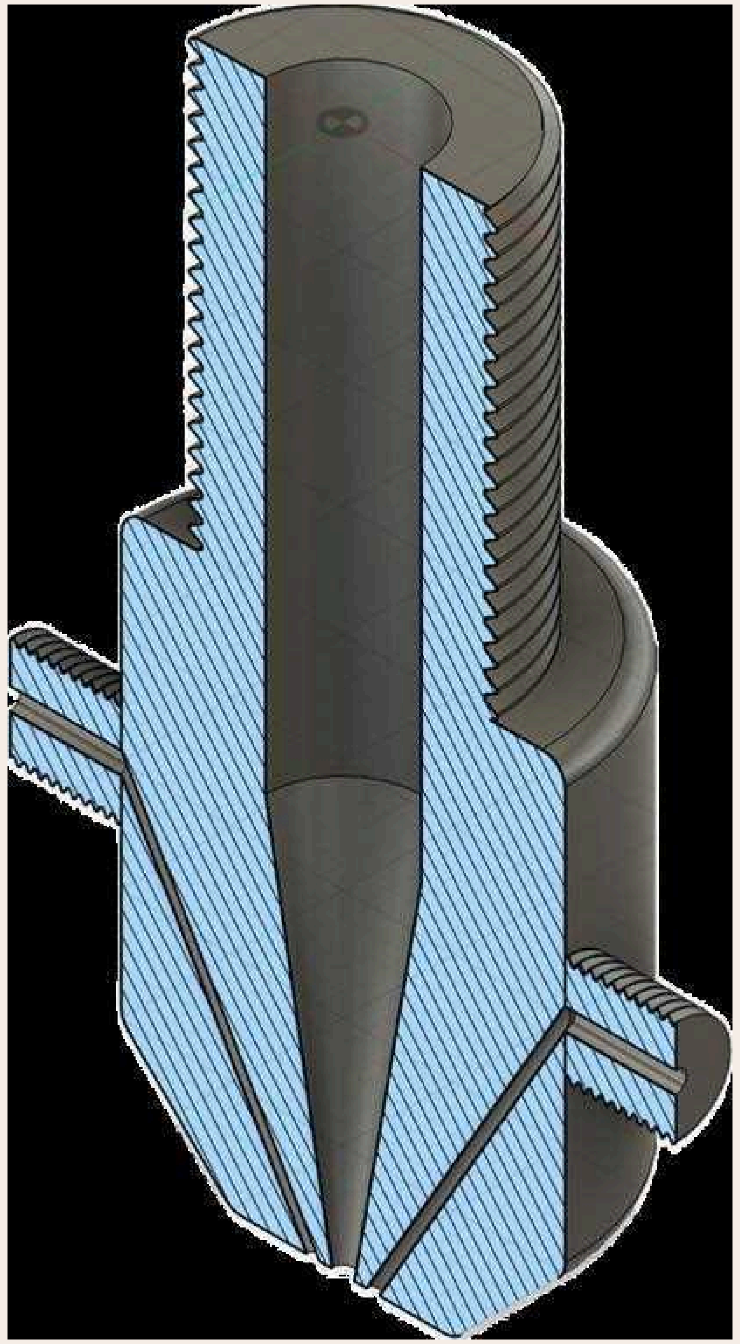


Our final idea

- We have designed an injector with an inner converging section paired with an air blast atomizer to optimize gel fuel atomization
- The gel is pumped through a fuel pipe featuring a sinusoidal wave pattern, which generates higher shear forces within the injector.
- These shear forces reduce the gel's viscosity, facilitating better atomization.
- The enhanced shear stress improves fuel breakup, ensuring finer droplets, more uniform fuel distribution, and more efficient combustion.

Air blast atomiser





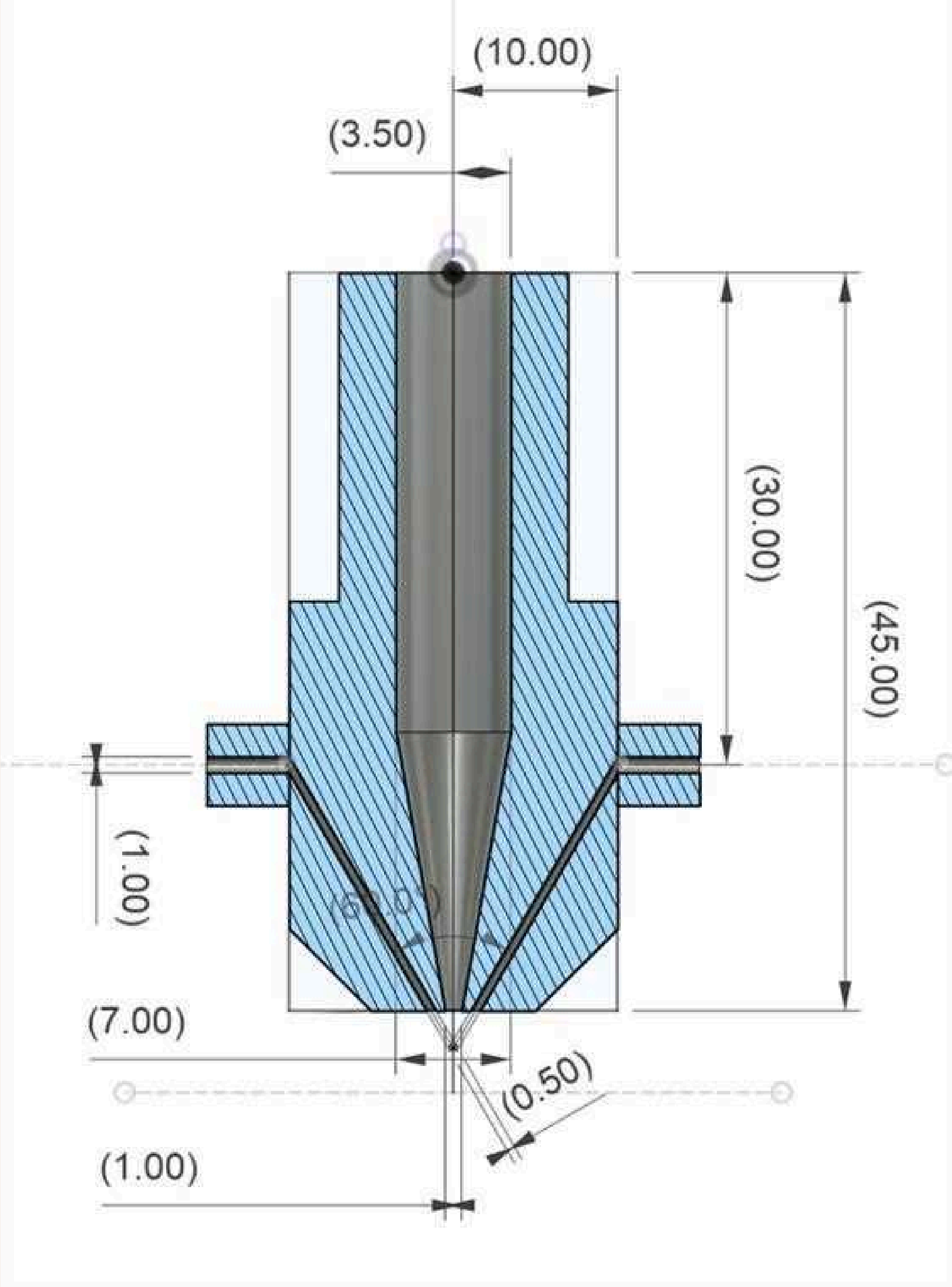
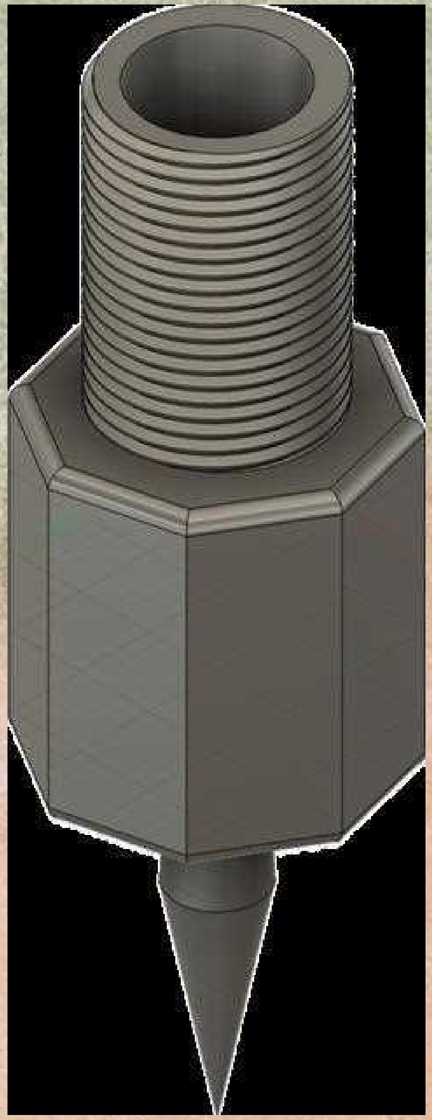
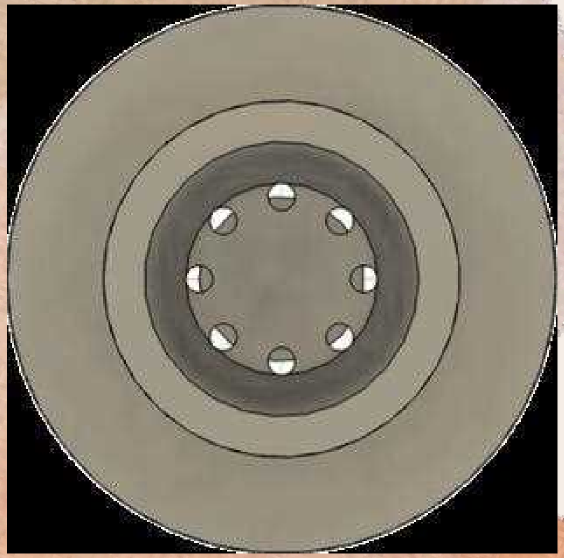


Fig 9. Vertical cross section of the air blast atomiser.

Inner- converging cone section

- Length = 65 cm.
- Number of orifice = 8 .
- Diameter of the orifice = 1 mm.
- Length of the cone = 23 mm.
- Angle of the cone =22.6 degrees.





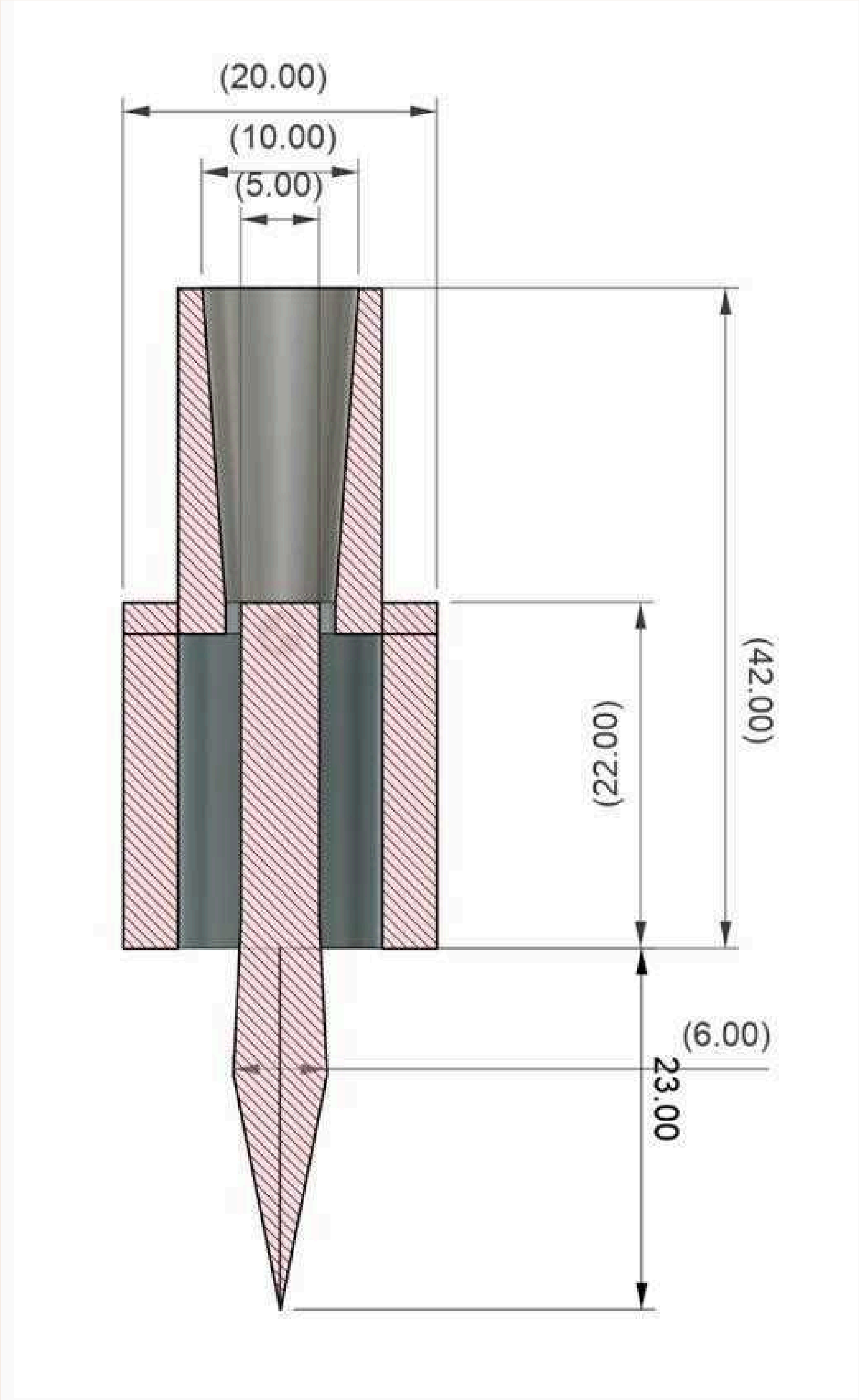


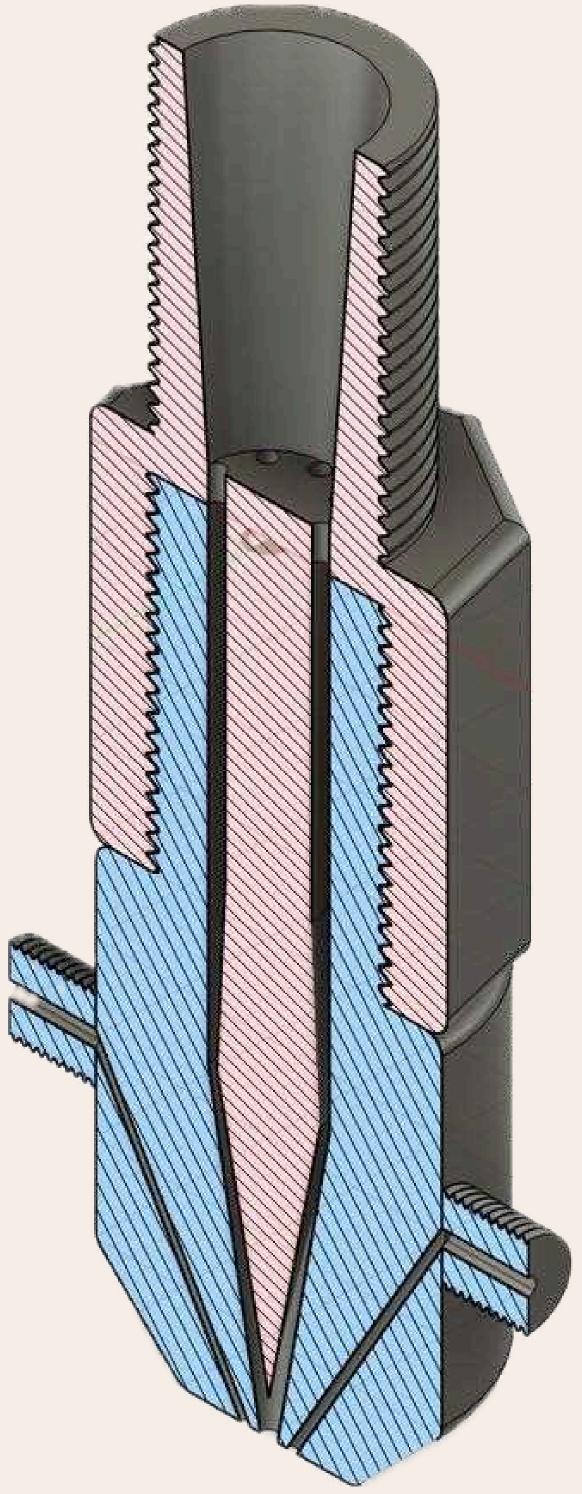
Fig 10. Vertical cross section of the Inner converging cone section.

Fuel Pipe

- Length = 33 cm.
- Sine amplitude = 2.5 mm.
- Wave length = 15 mm.
- Diameter of the inlet = 30 mm.
- Diameter of the outlet = 10 mm.

Fig 11. Vertical cross section of the Fuel pipe.

Combined Model



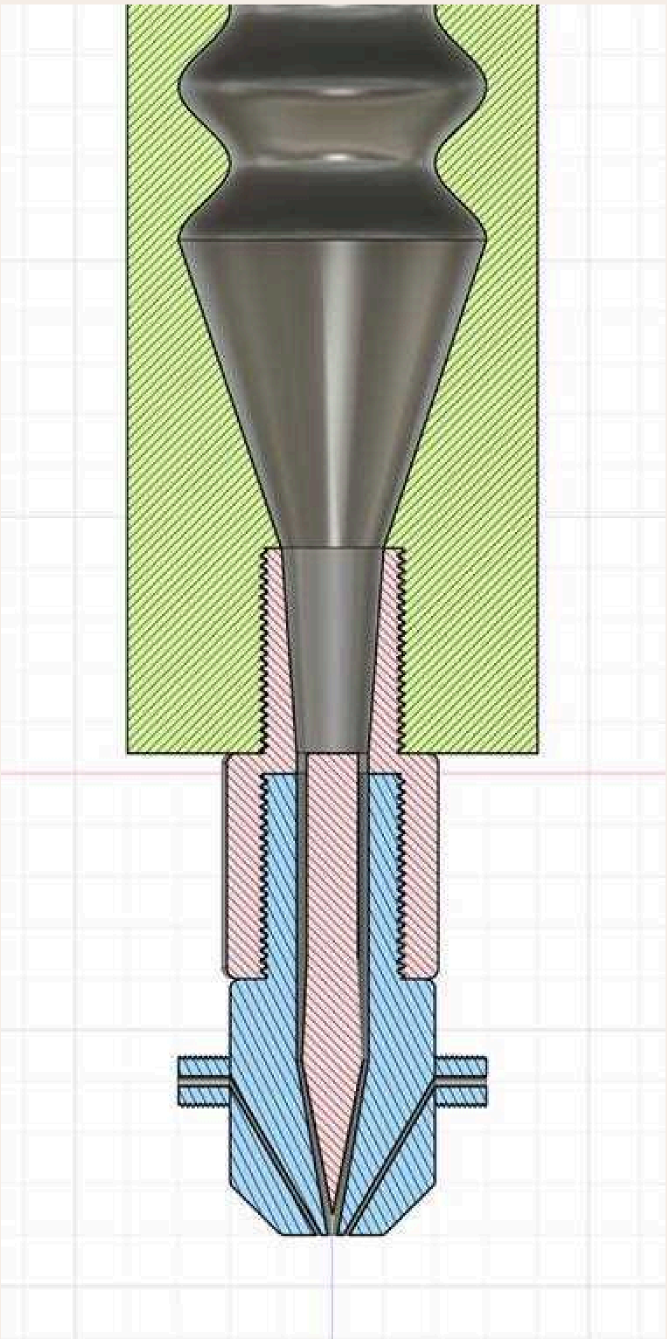


Fig 12. Vertical cross section of the Model.

CFD Analysis of Fuel pipe.

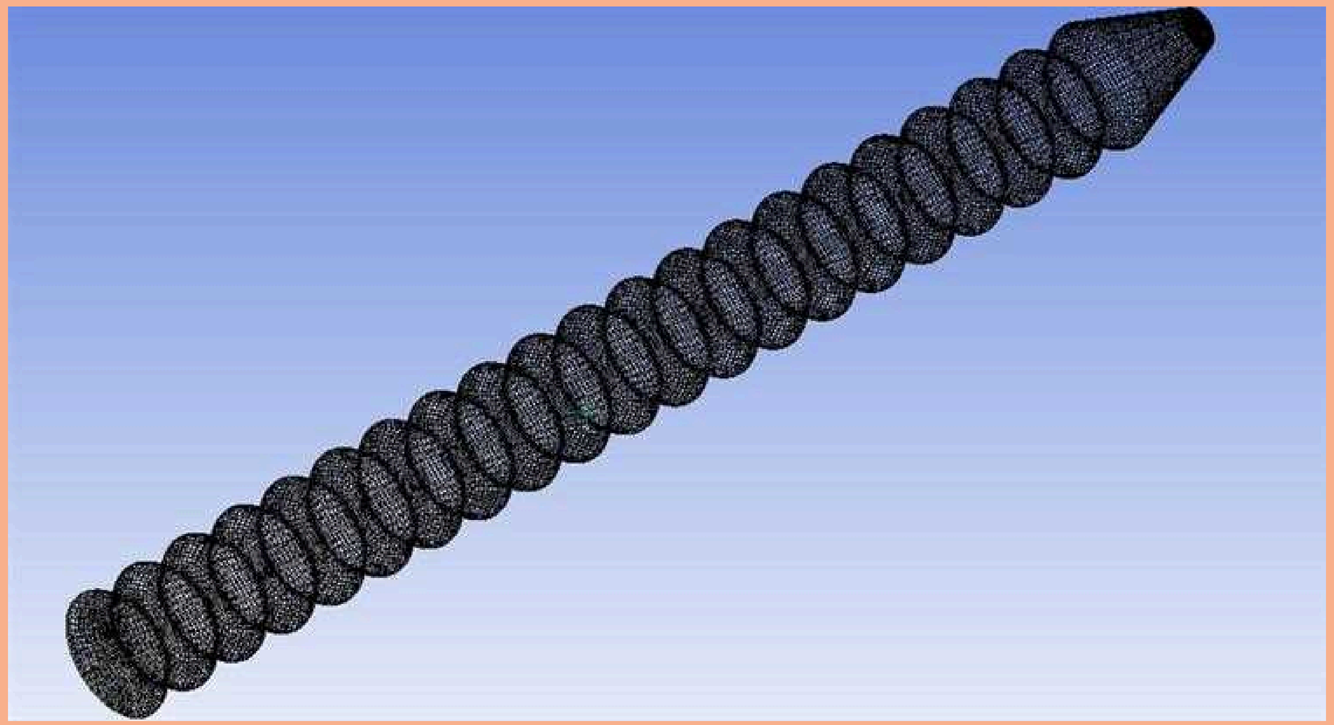


Fig 13. Meshing of fuel pipe.

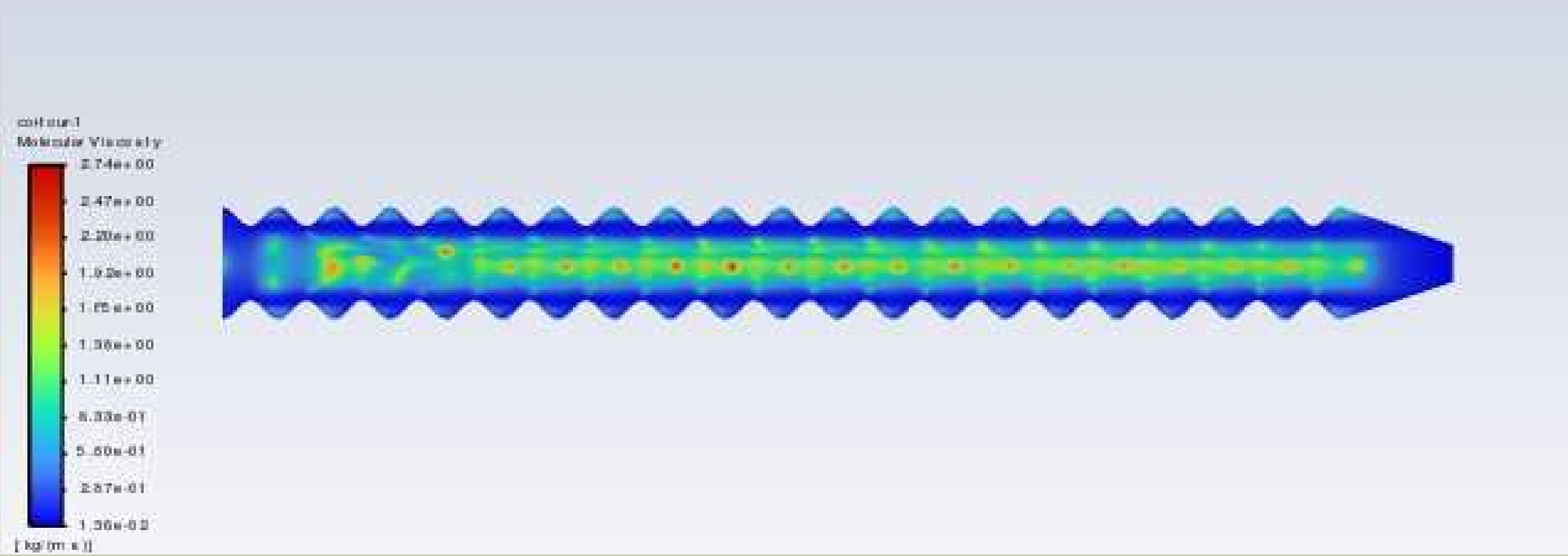


Fig 14. Molecular Viscosity Contour of fuel pipe.

CFD Analysis of Fuel pipe.

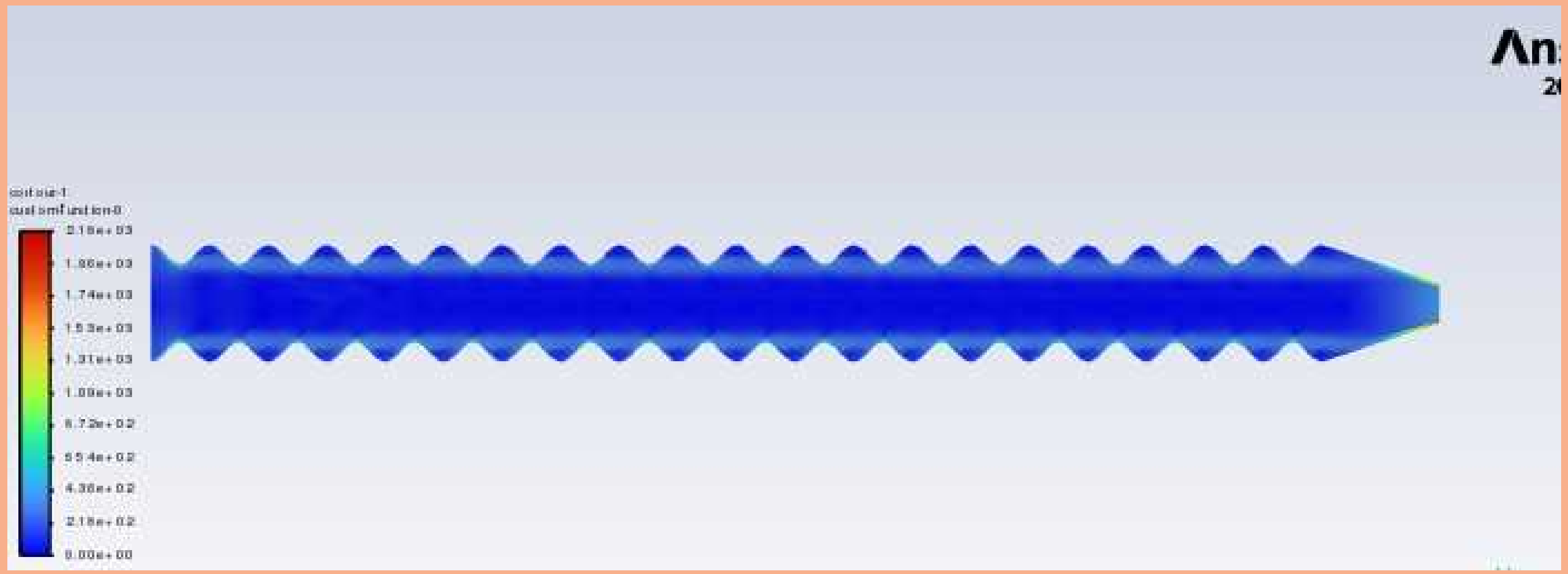


Fig 15. Shear Stress Contour.

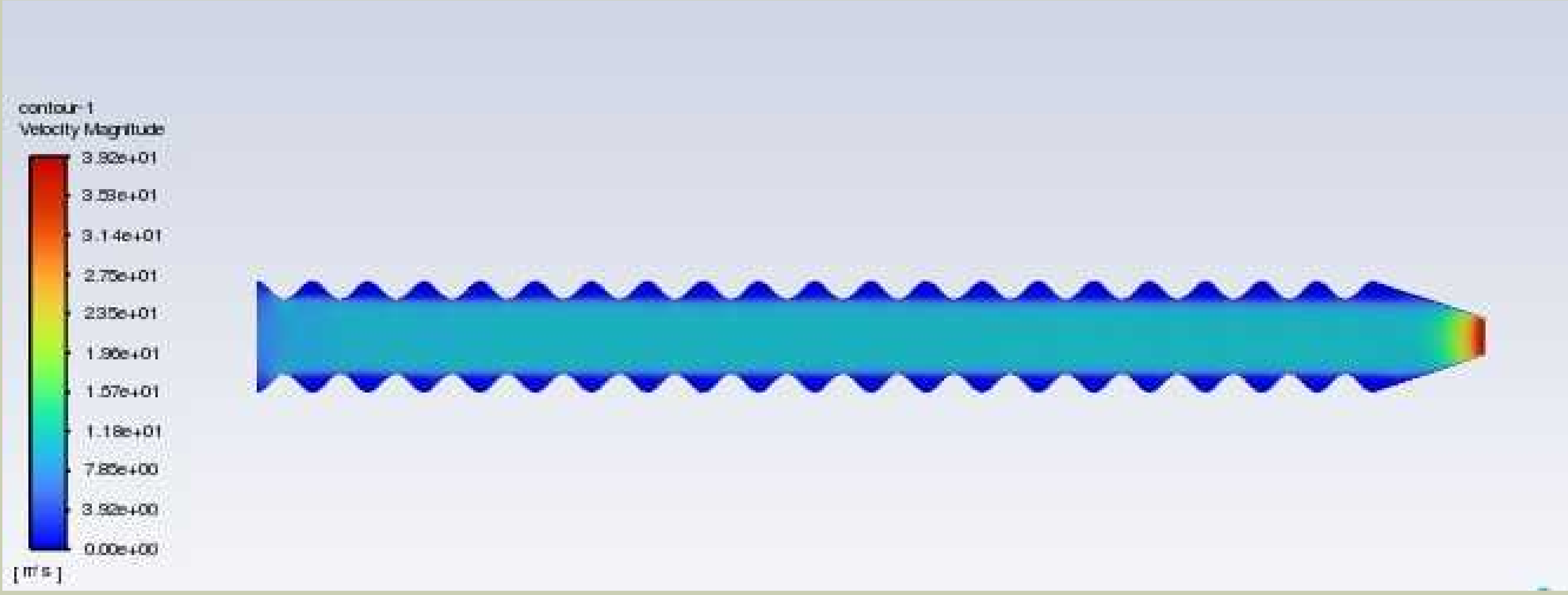


Fig 16. Velocity Plot

CFD Analysis of Fuel Pipe.

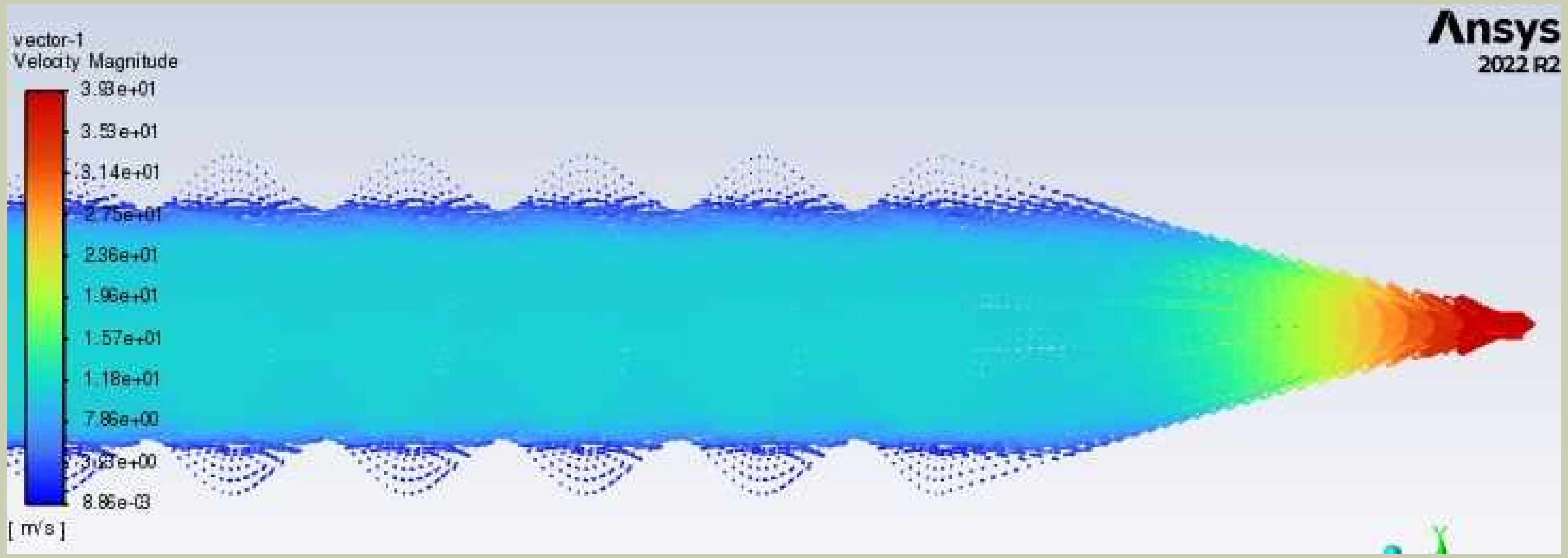


Fig 17. Velocity vector plot.

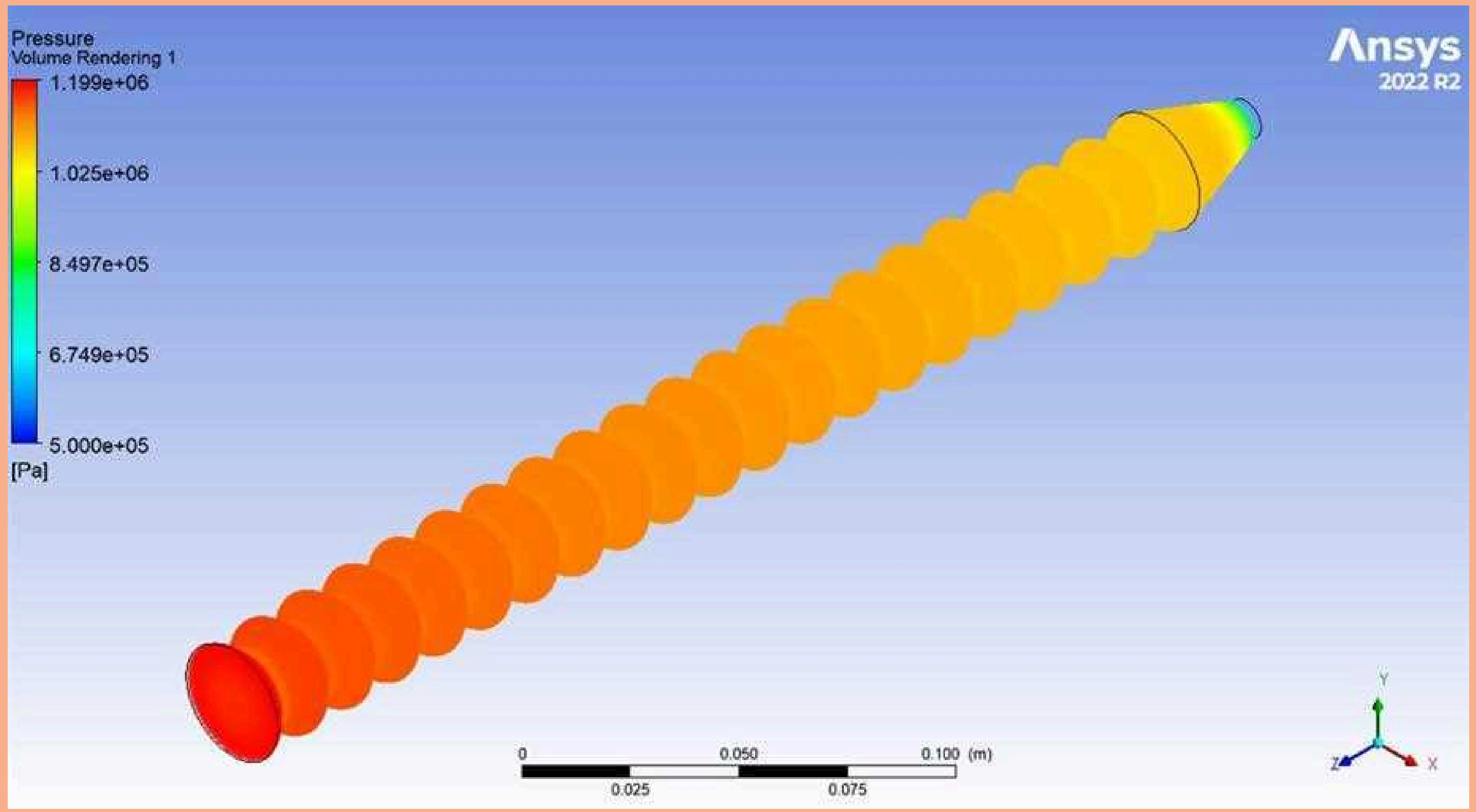


Fig 18. Static Pressure plot in 3-D.

CFD Analysis of Injector-Carreau Yasuda Model

$$\eta = H(T)\left(\eta_\infty + (\eta_0 - \eta_\infty)[1 + \gamma^2\lambda^2]^{(n-1)/2}\right)$$

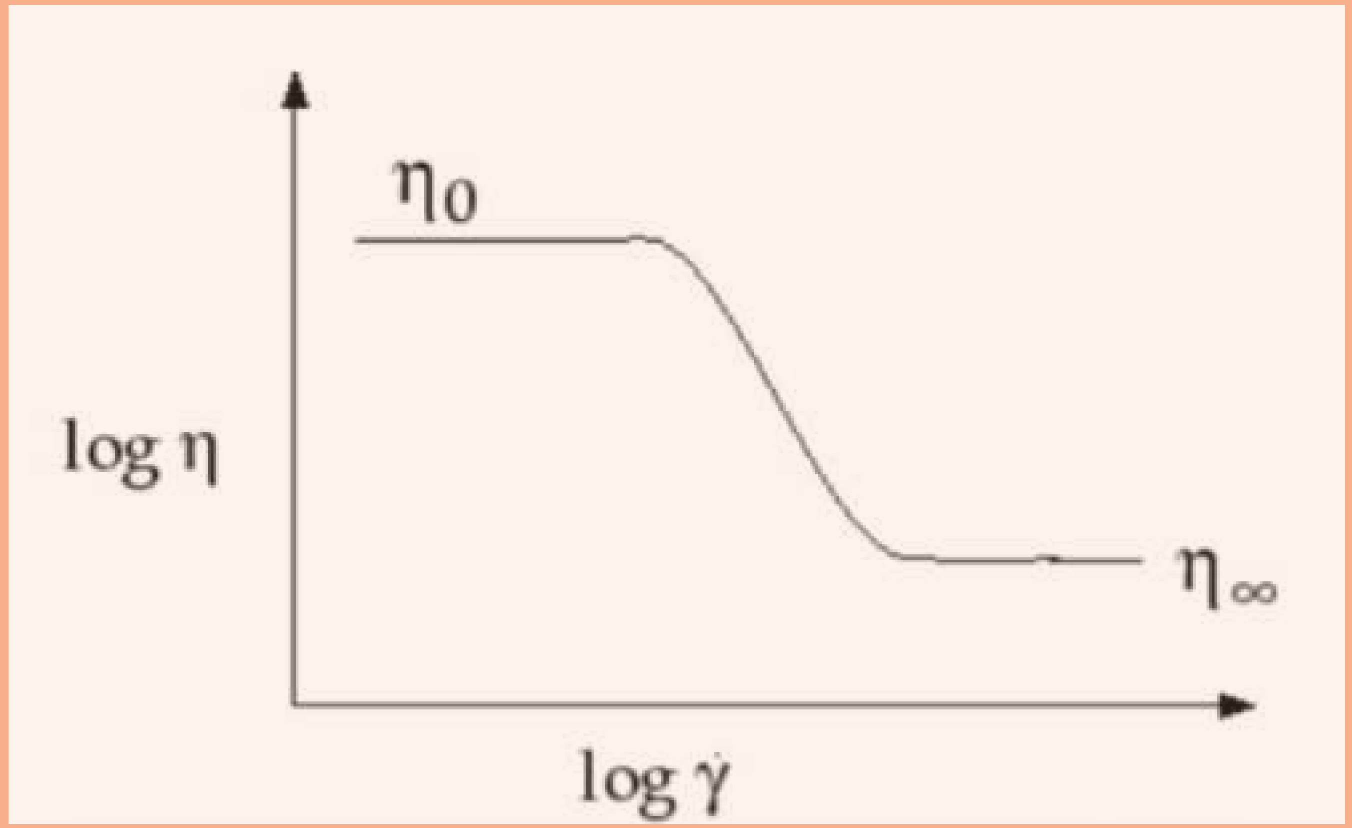


Fig 19. Variation of viscosity with shear rate according to the Carreau Model.

CFD Analysis of Injector-Carreau Yasuda Model

$$\eta = H(T)\left(\eta_\infty + (\eta_0 - \eta_\infty)[1 + \gamma^2\lambda^2]^{(n-1)/2}\right)$$

Carreau-Yasuda parameters	Value
a	1.58
λ (s)	9.48
n	0.42
η_0 (Pa.s)	40
η_∞ (Pa.s)	0.001

Fig 20. Carreau - Yasuda parameters for selected gel simulant (HPMC- 0.85%).

CFD Analysis of Injector-Carreau Yasuda Model

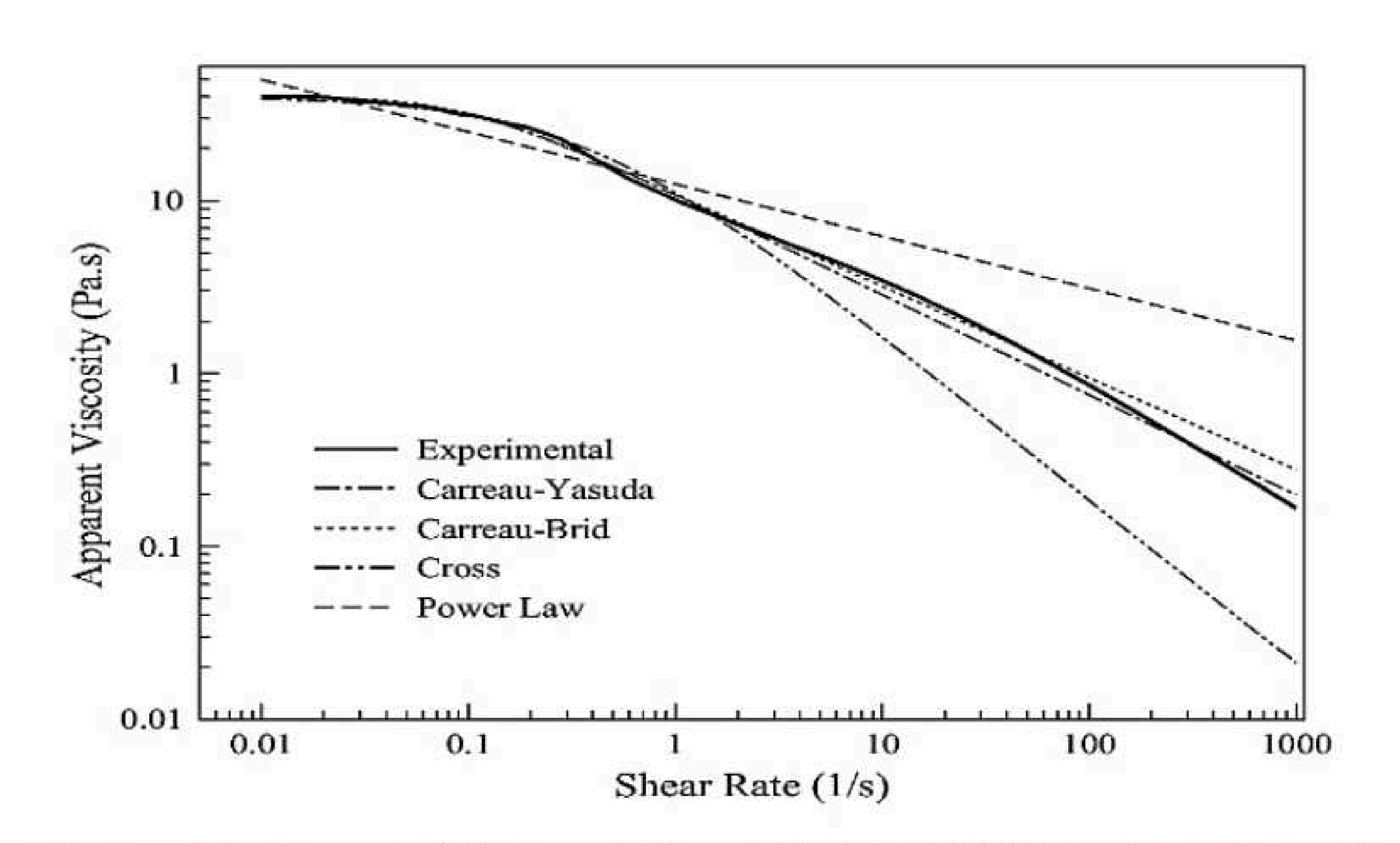


Fig 21. Curve fitting of the HPMC- 0.85% with different rheological model.

CFD Analysis of Injector.

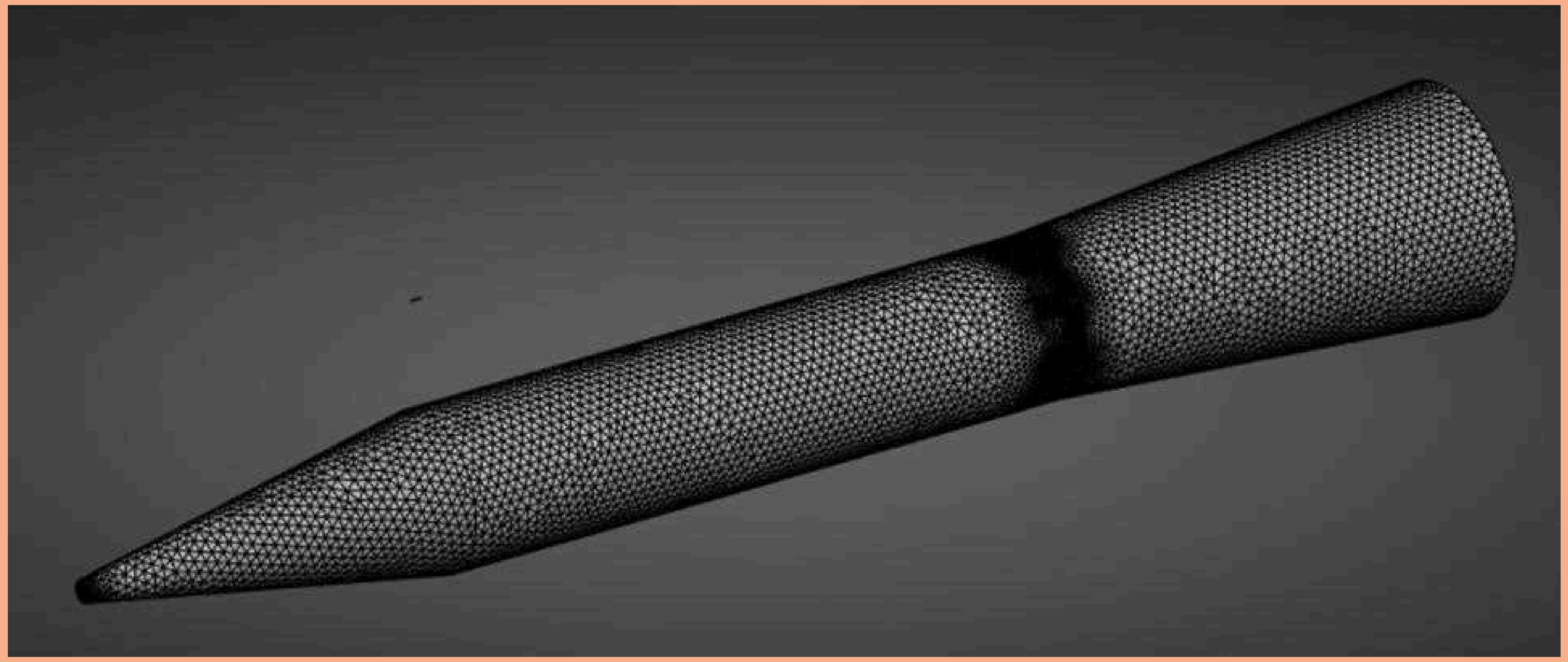


Fig 22. Internal flow of gel through injector meshing (Our design).

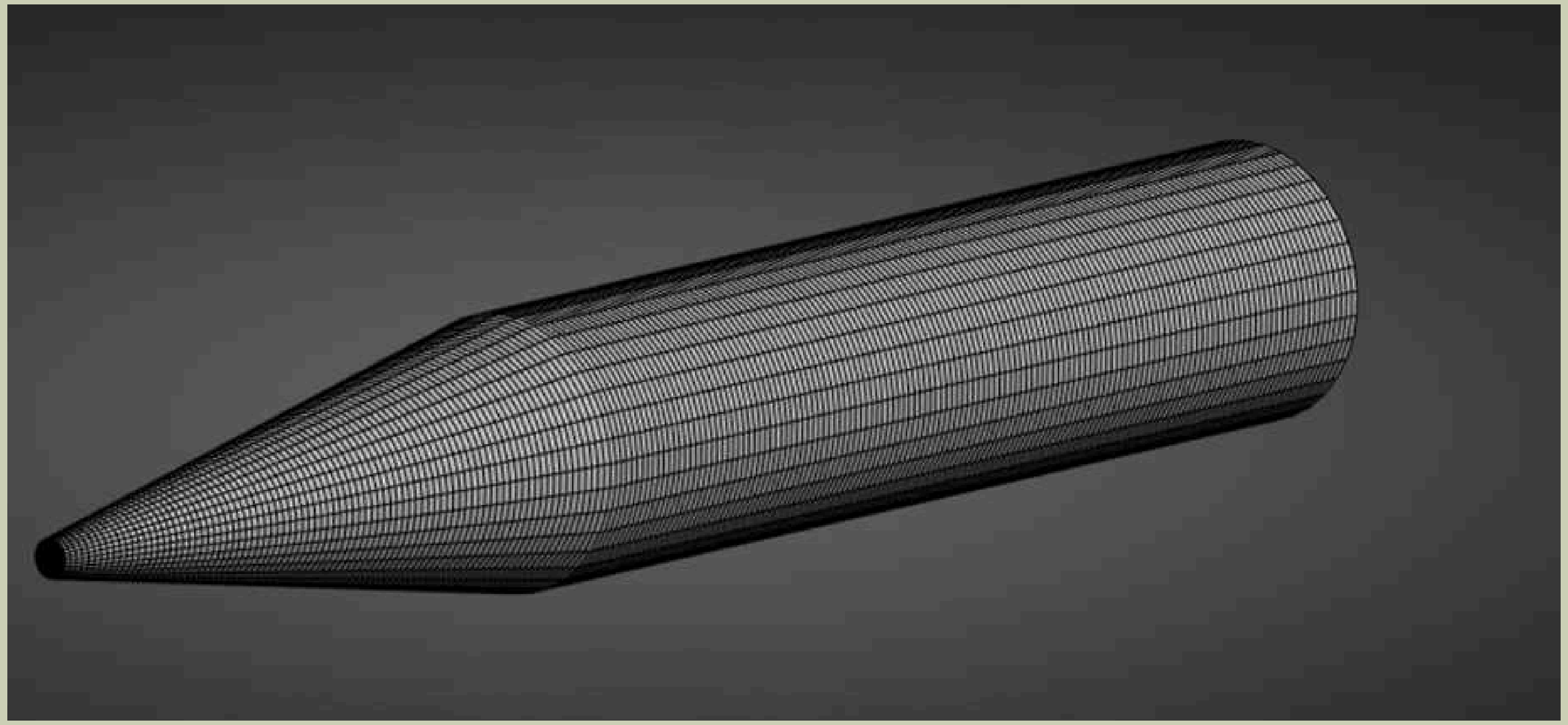


Fig 23. Internal flow of gel through injector meshing (Conventional design).

CFD Analysis of Injector.

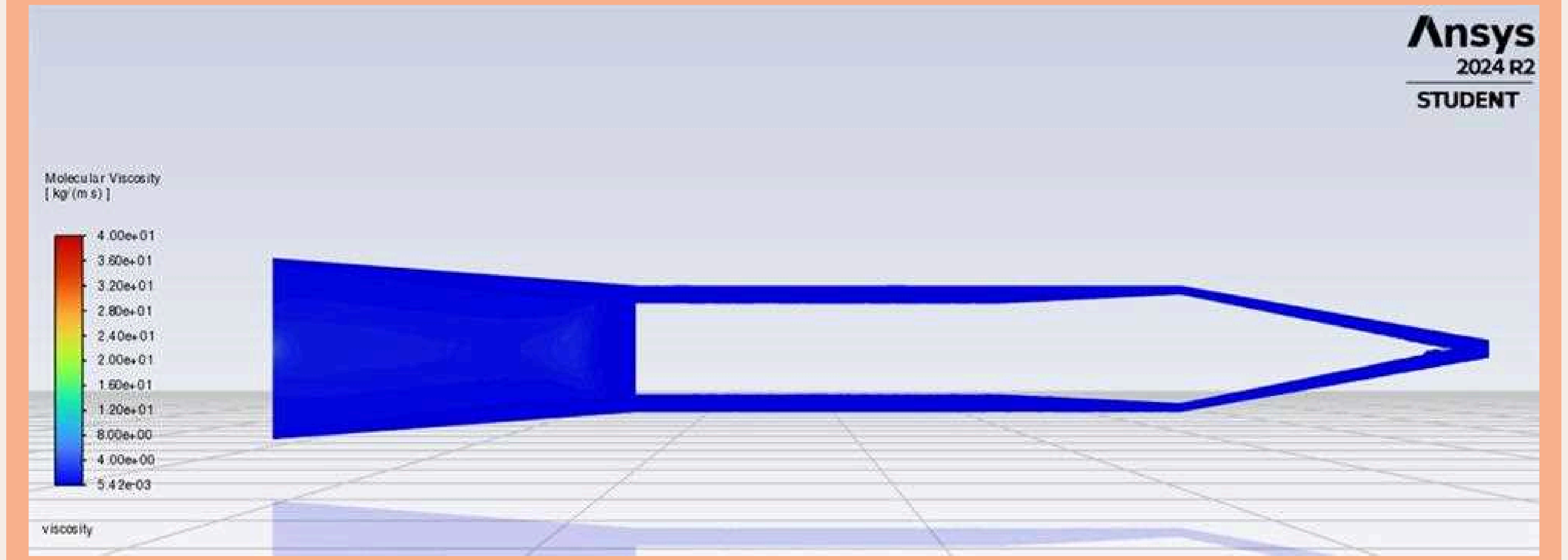


Fig 24. Viscosity contour (Our design).

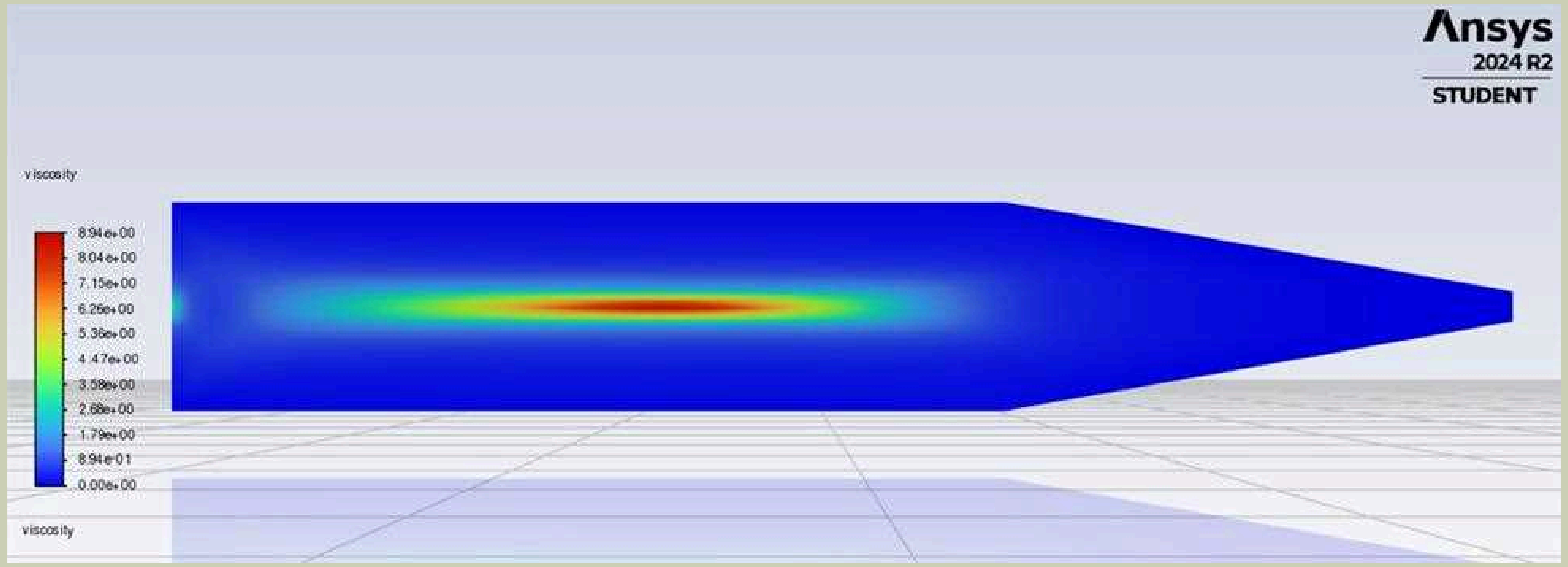


Fig 25. Viscosity contour (Conventional design).

CFD Analysis of Injector.

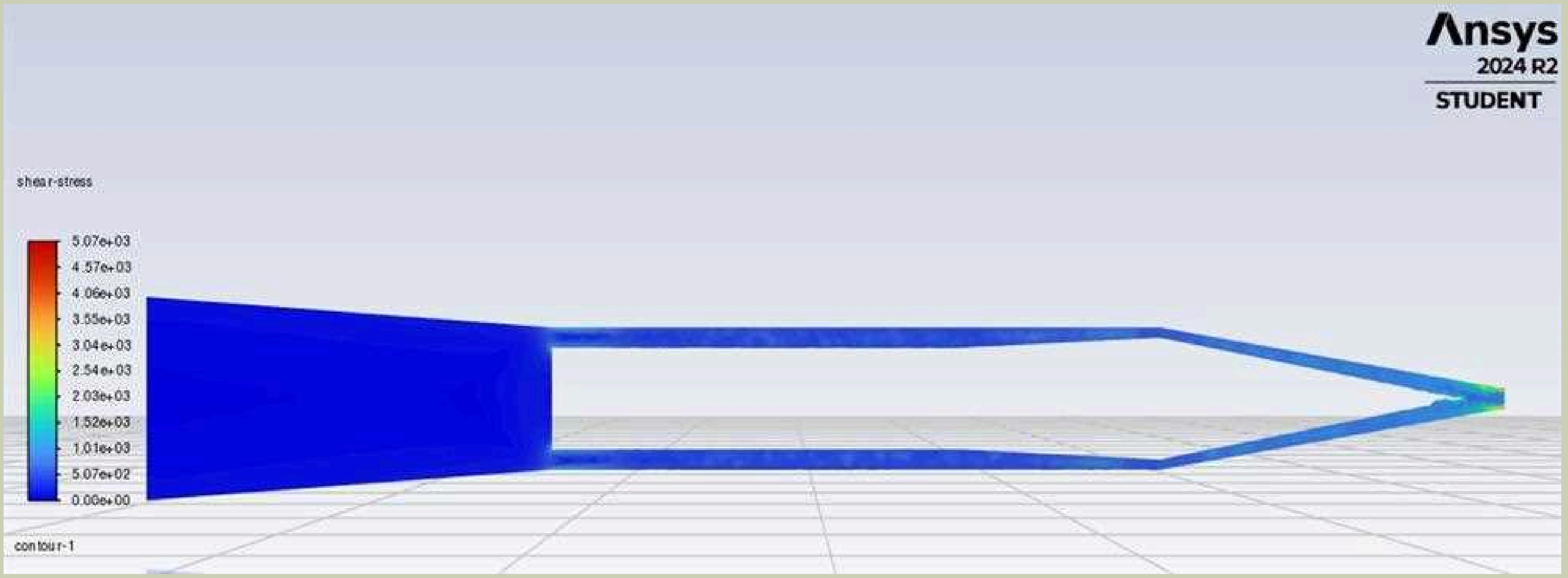


Fig 26. Shear Stress contour (Our design).

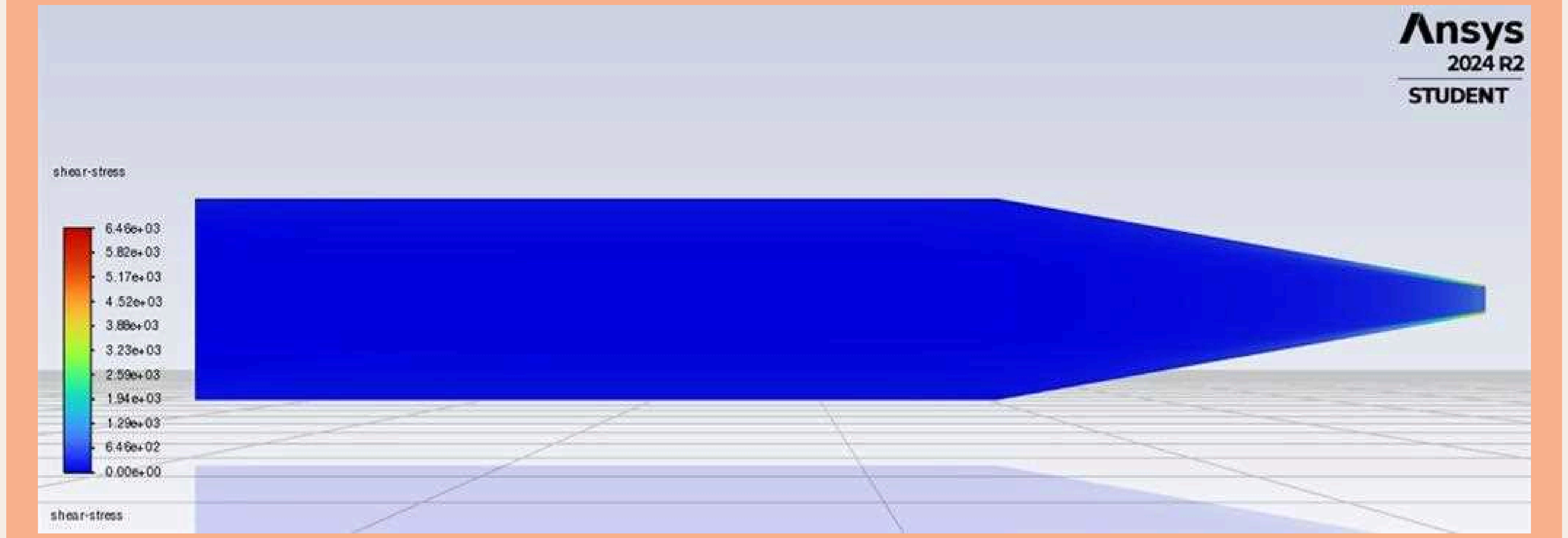


Fig 27. Shear Stress contour (Conventional design).

CFD Analysis of Injector.

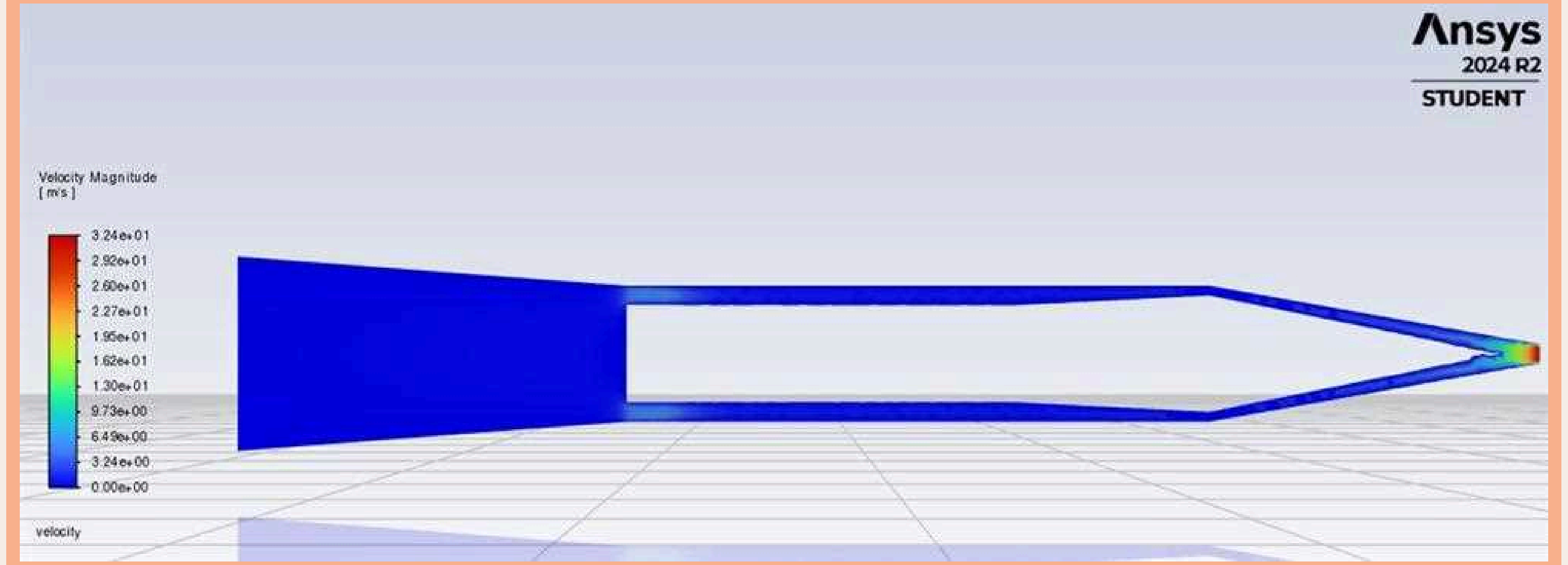


Fig 28. Velocity contour (Our Design).

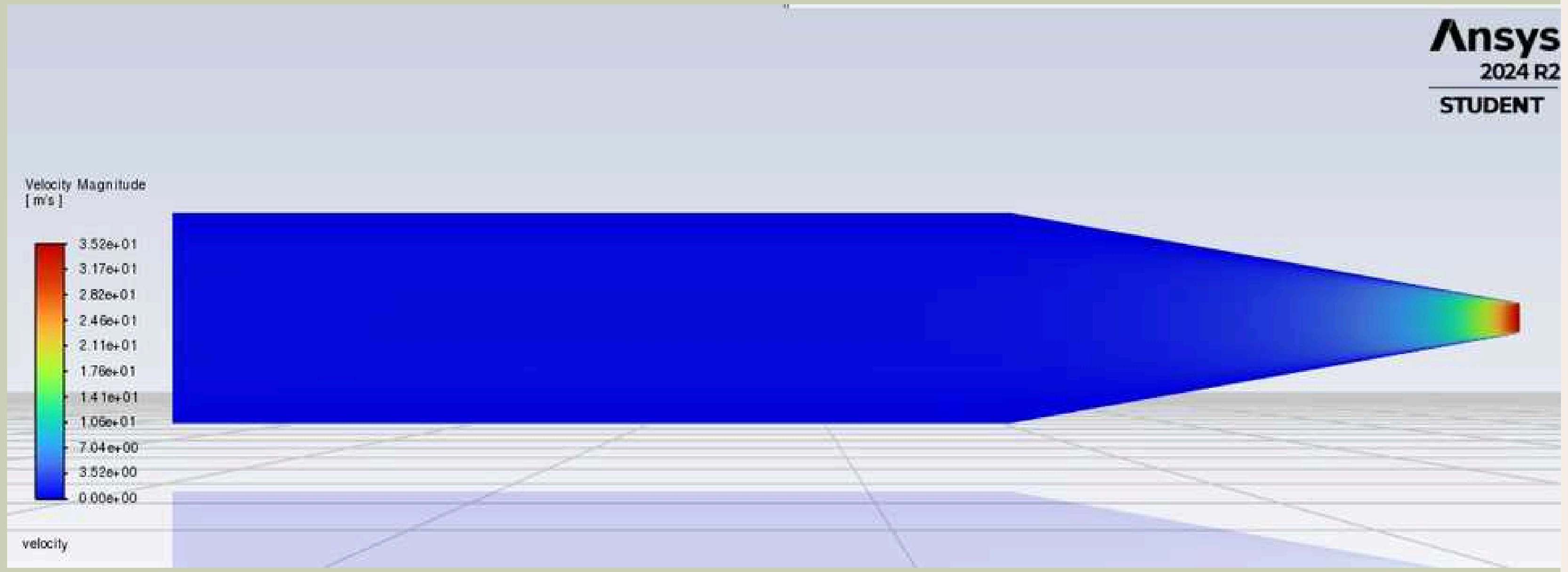


Fig 29. Velocity contour (Conventional Design).

CFD Analysis of Injector.

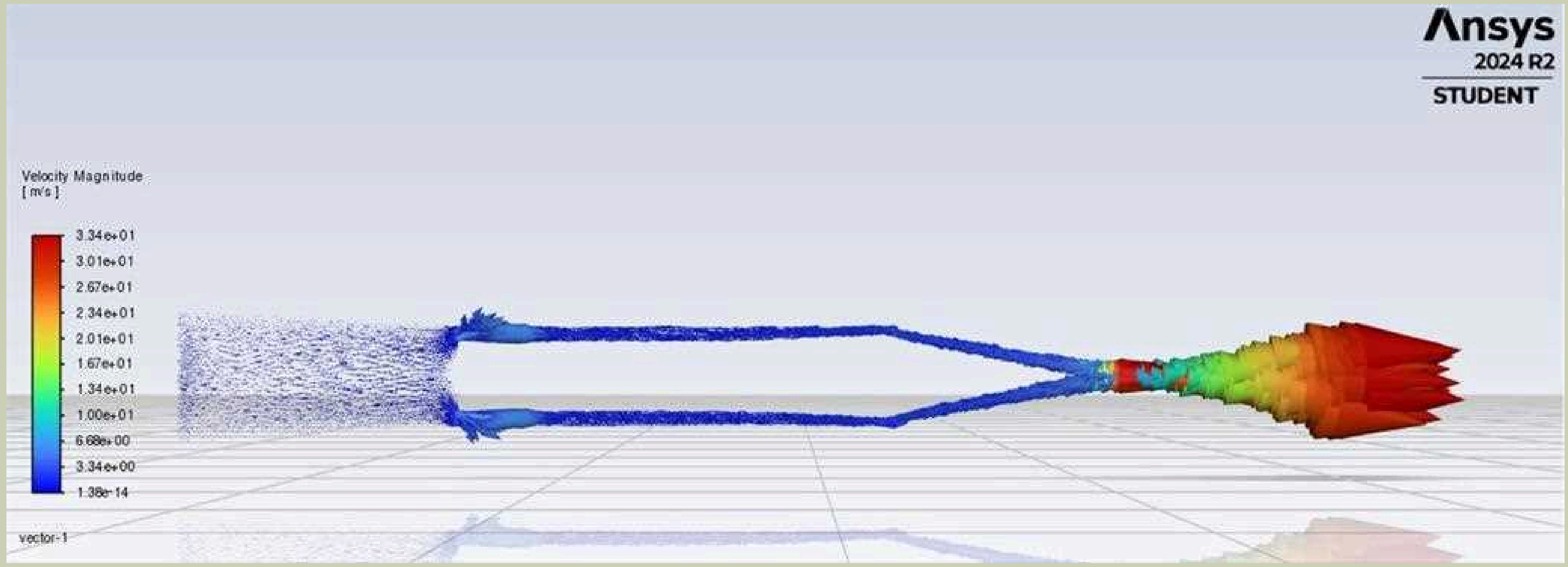


Fig 30. Velocity vectors (Our design).

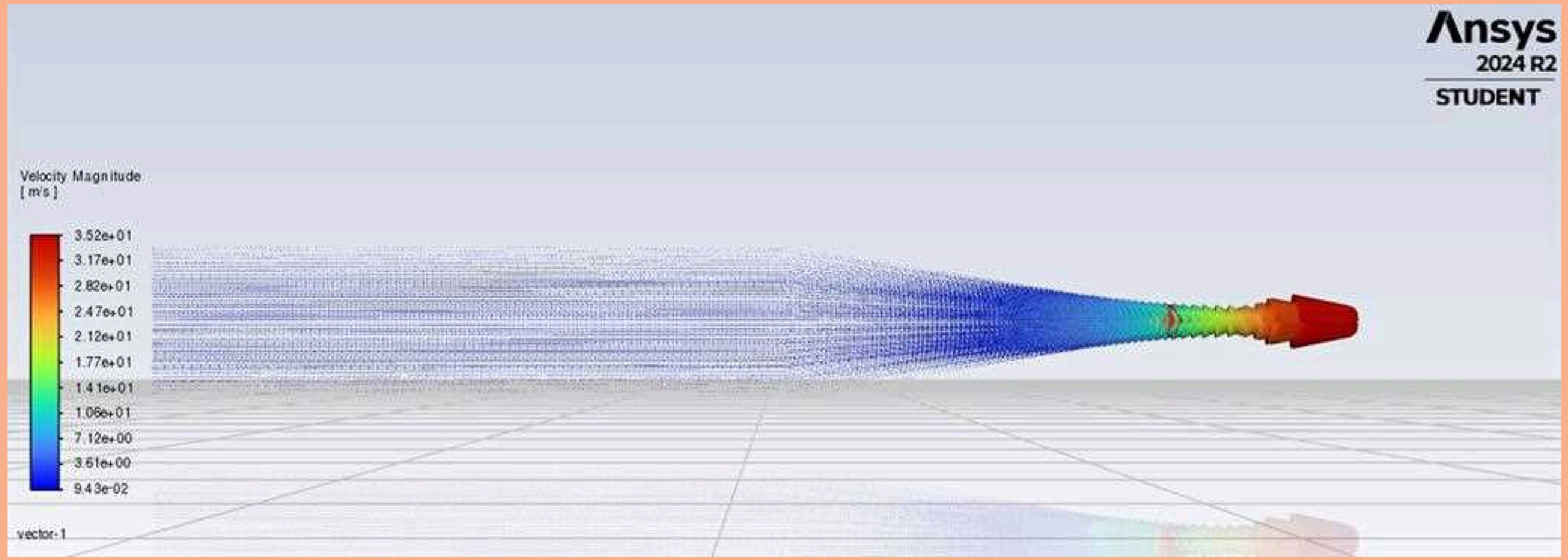


Fig 31. Velocity vectors (Conventional design).

CFD Analysis of Atomisation.

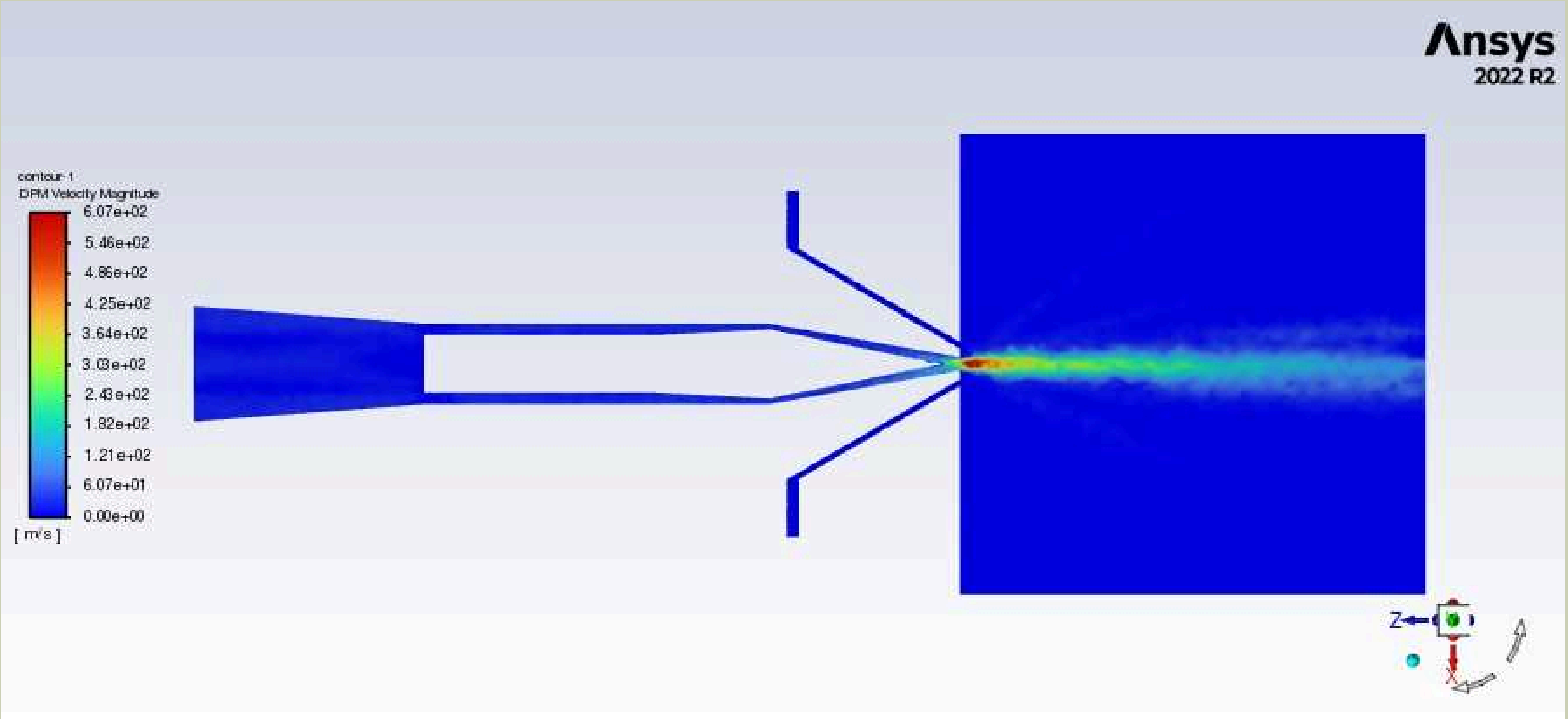


Fig 32. DPM velocity magnitude contour (Our design).

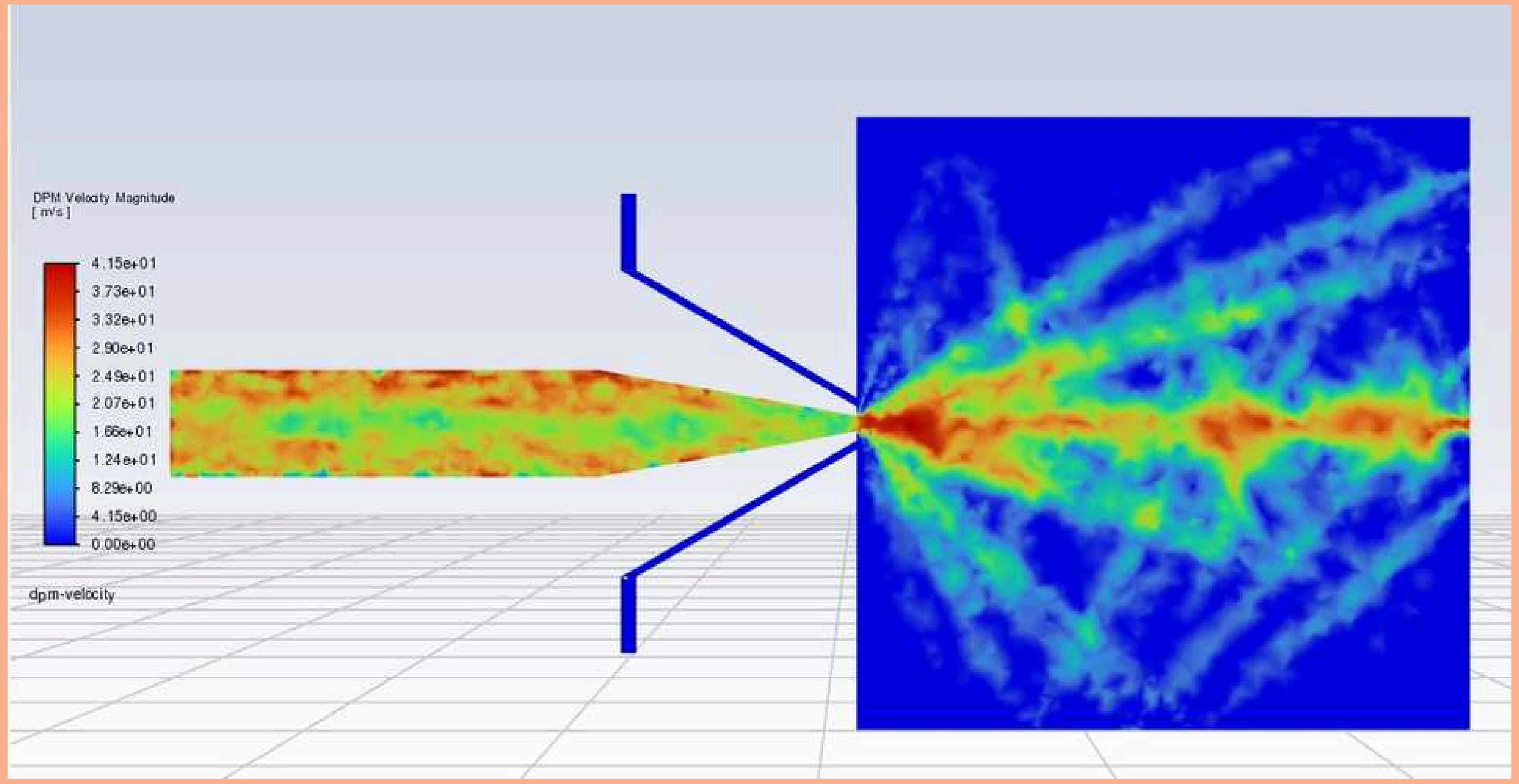


Fig 33. DPM velocity magnitude contour (Conventional design).

CFD Analysis of Atomisation.

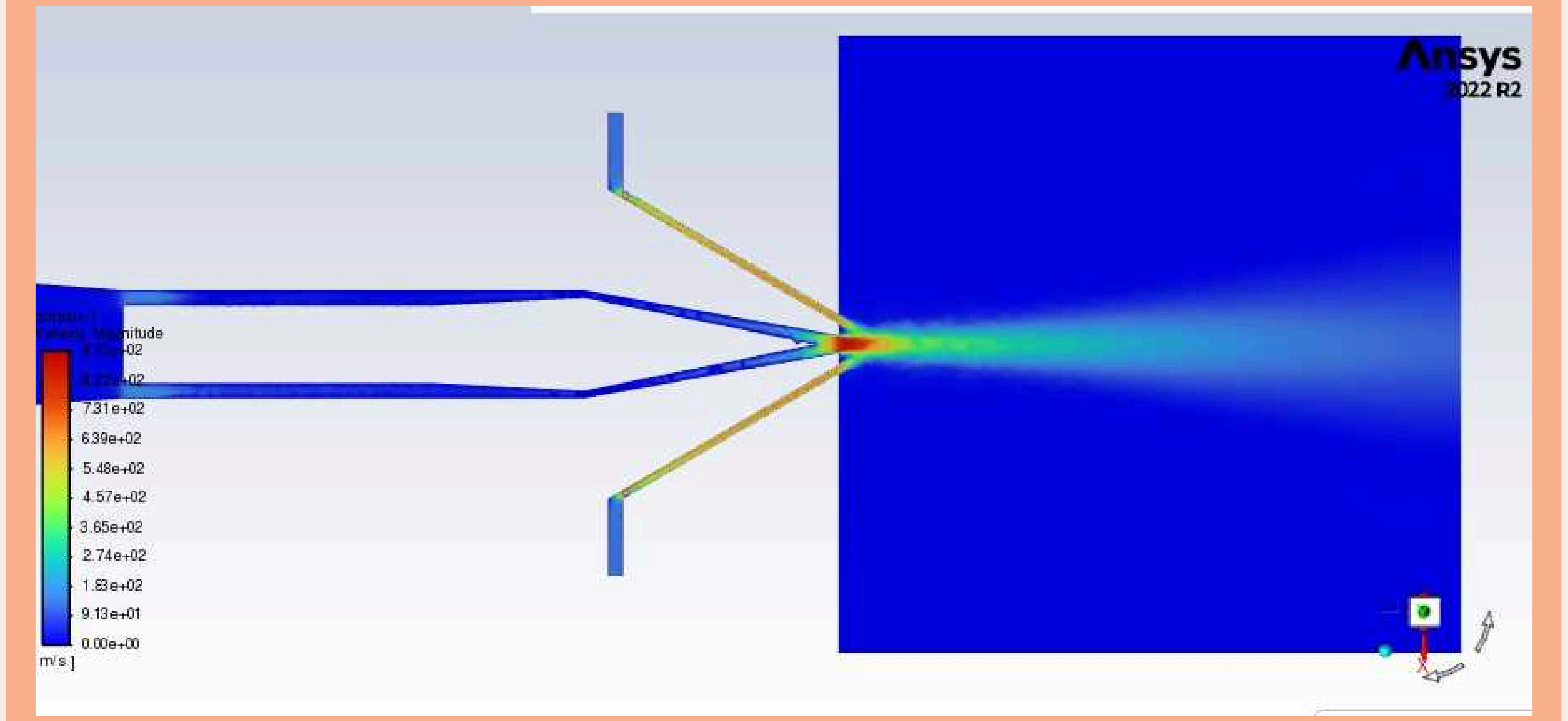


Fig 34. Velocity contour (Our design).

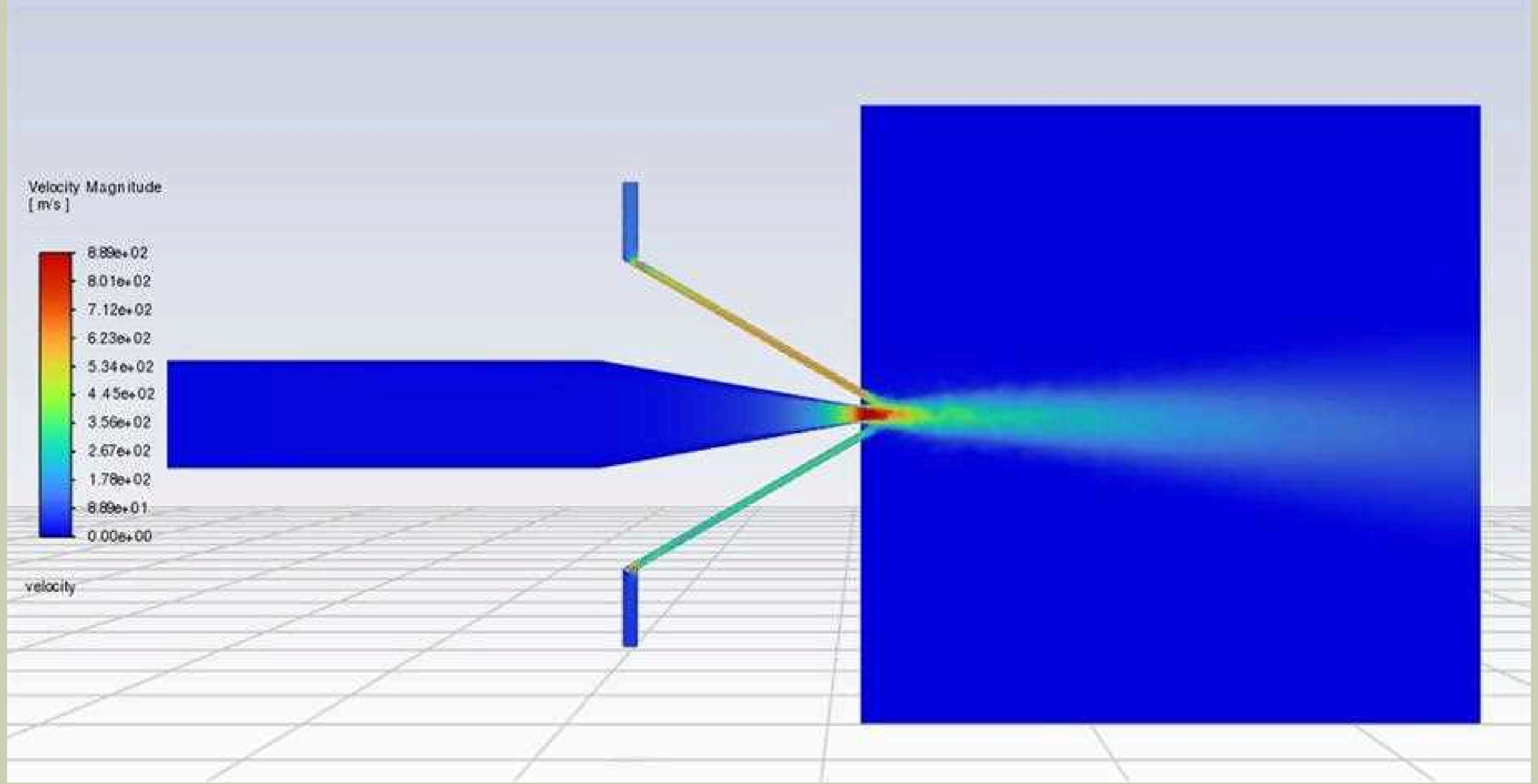


Fig 35. Velocity contour (Conventional design).

CFD Analysis of Atomisation.

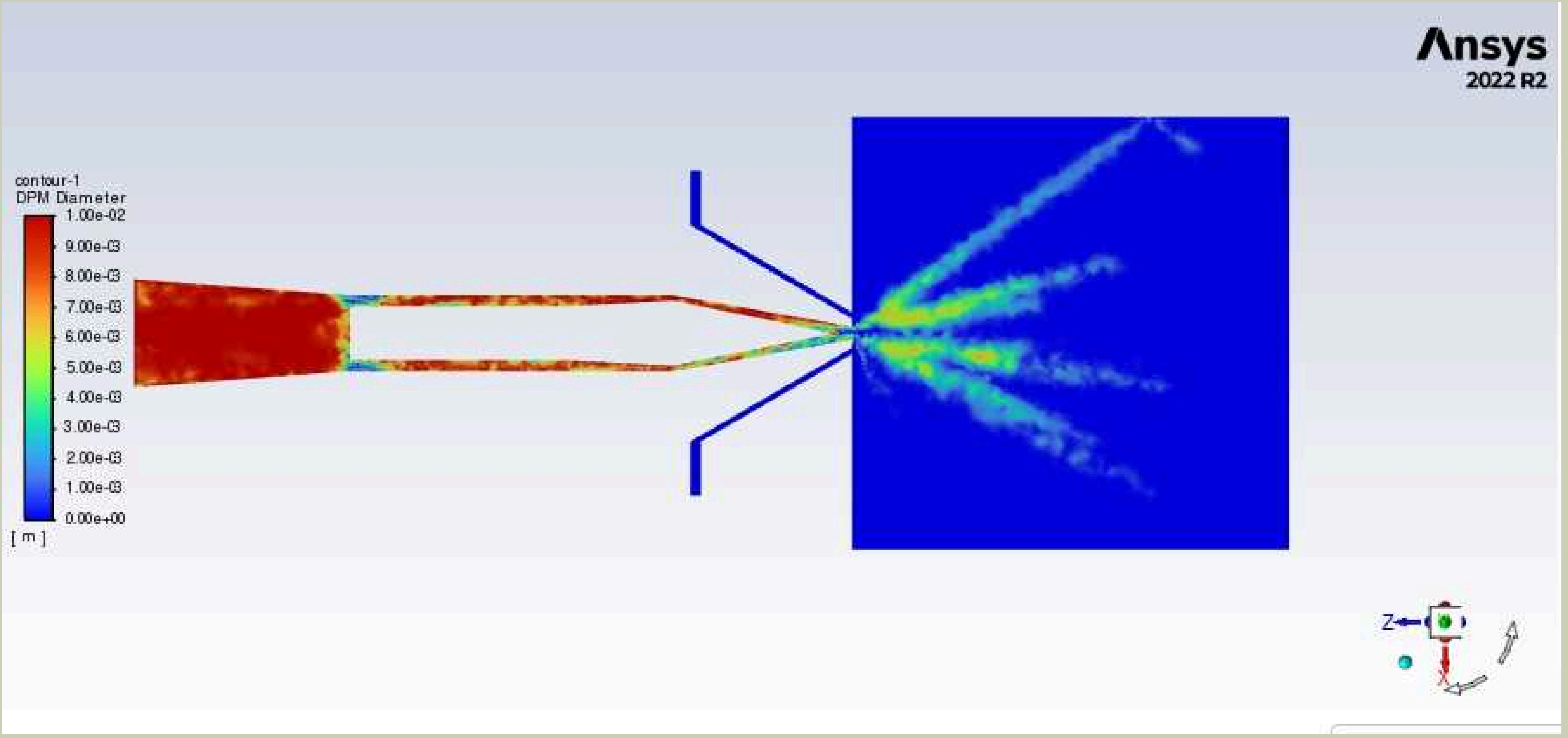


Fig 36. DPM diameter contour (Our design).

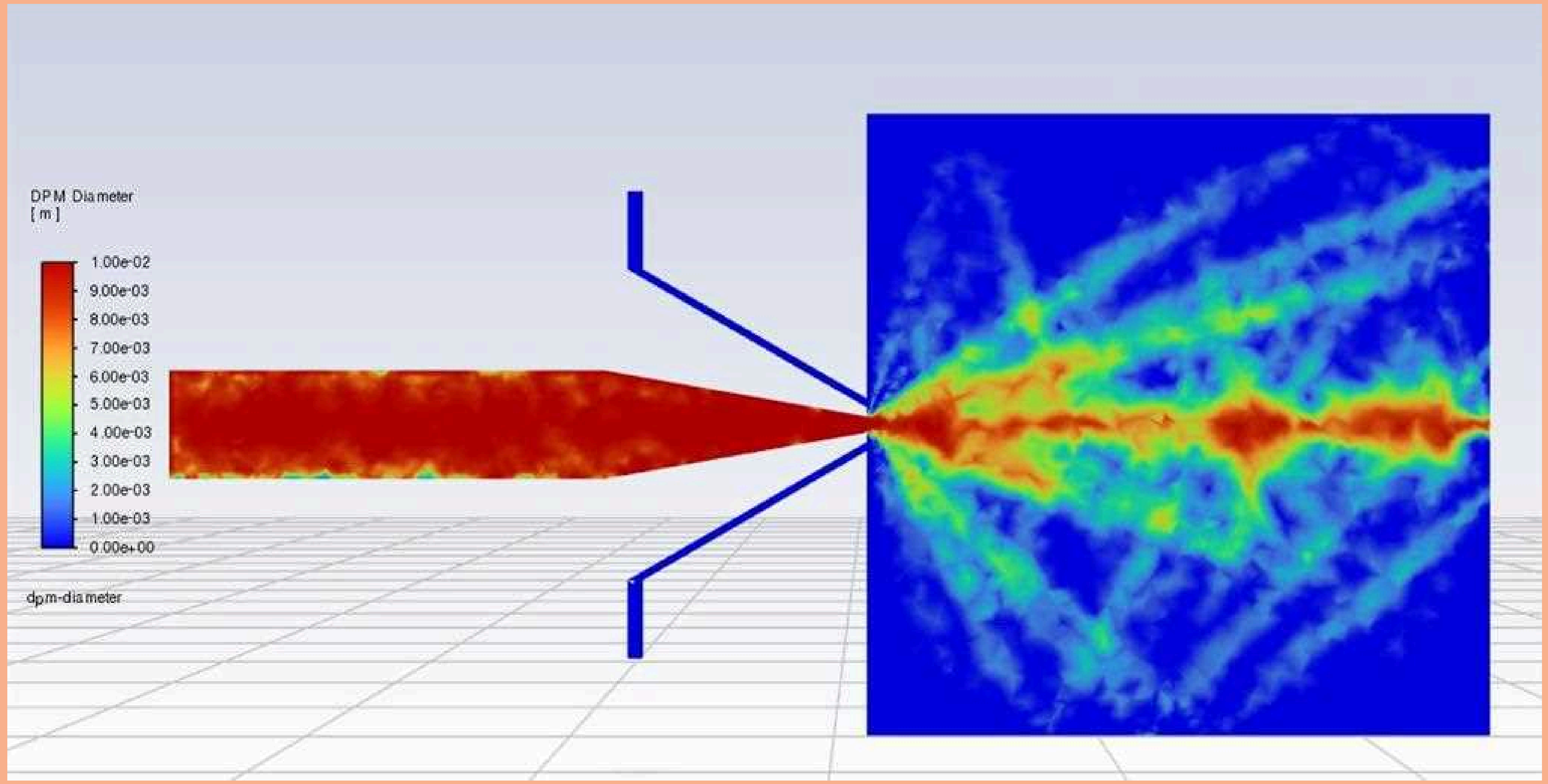


Fig 37. DPM diameter contour (Conventional design).

Results

The volume-average droplet diameter in our design was found to be three times lesser than the conventional design, indicating better atomization performance.

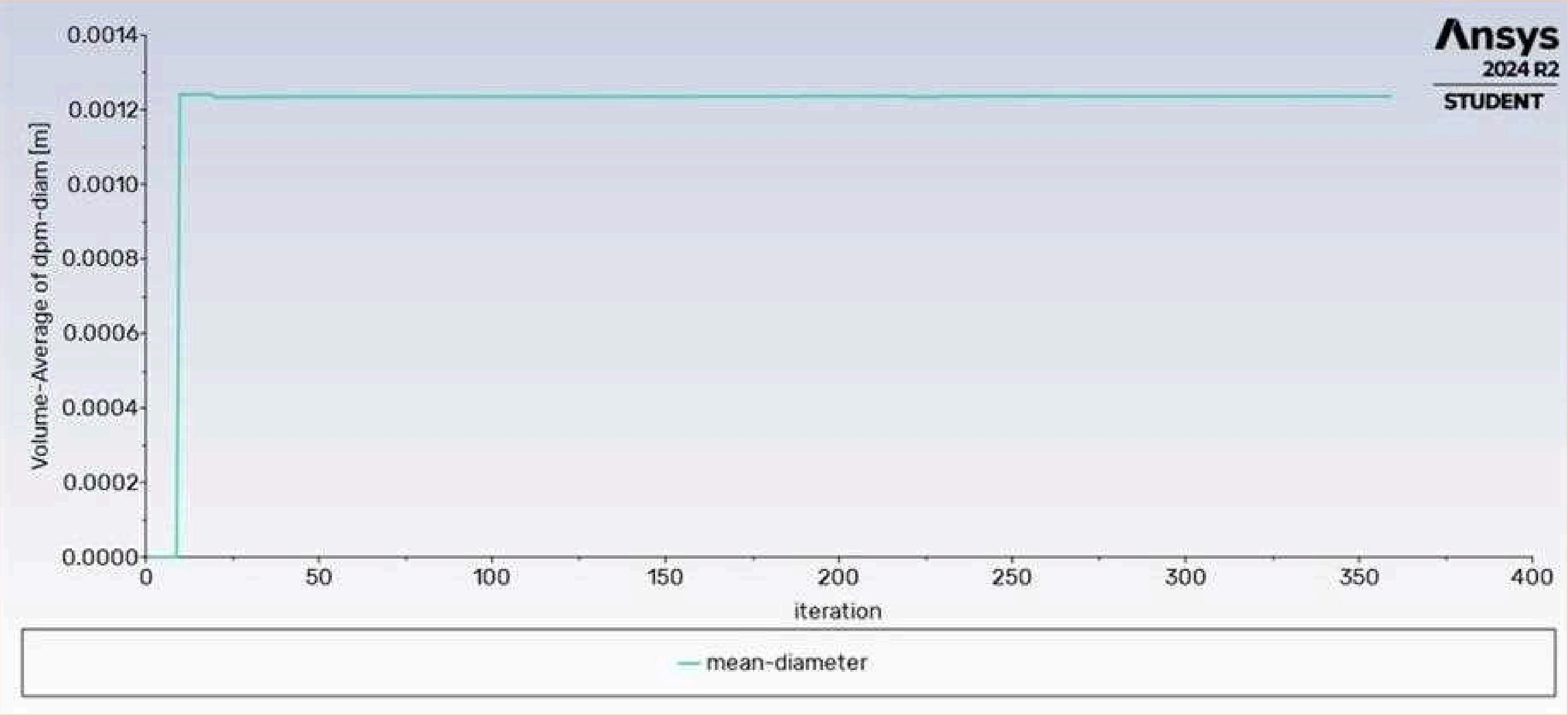


Fig 38. Volume average DPM diameter(Conventional design).

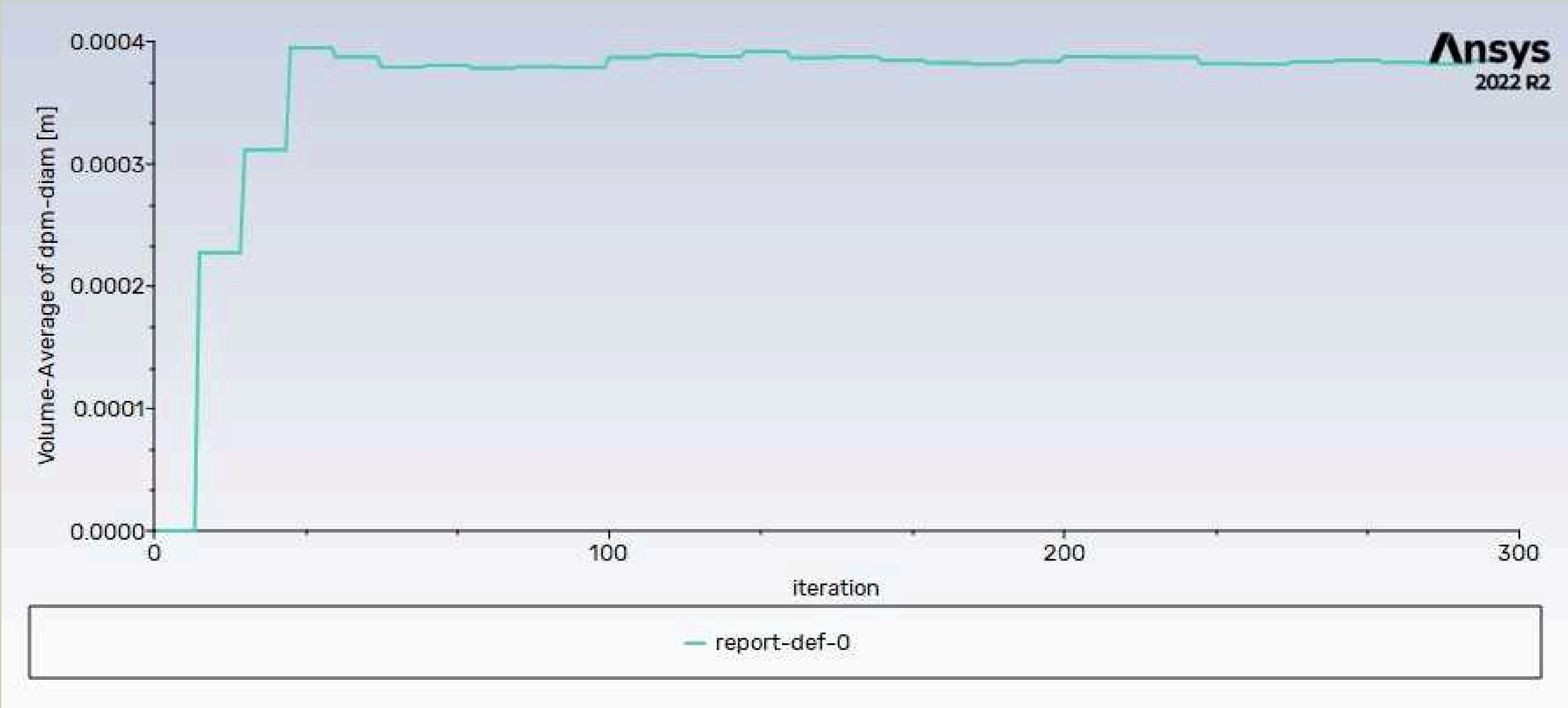


Fig 39. Volume average DPM diameter (Our design).

Website and Notion page

Fig 40. Website.

Fig 41. Notion Page.

Our Competitors

01. ***Honeywell Aerospace:*** Fuel injectors capable of operating in extreme environments with fuel temperatures ranging from -65°F to a maximum of +325°F and pressures exceeding 3,000 psi.

02. ***Woodward, Inc :*** SmartFire Ignition System: fuel control and ignition technologies can be combined for combustion solutions that improve lift-off at higher altitudes and difficult windmilling conditions.

03. ***Bosch:*** Common Rail Injectors: Ensure quiet, highly efficient combustion in any driving situation: The Bosch common rail injector precisely injects fuel directly into the combustion chamber.

04. ***Delphi Technologie:*** High pressure pump, electronically actuated injector in one assembly, High-speed, dual-valve operation for accurate injection control, High-pressure injection for optimized combustion.

05. ***Hanwha Aerospace:*** Involved in developing gel-fuel injectors for missiles as part of South Korea’s defense initiatives

Roles and responsibilities

- **MARKET ANALYSIS AND DOCUMENTATION**
  - ARGHADEEP DAS
- **WEB DEVELOPER**
  - ARGHYADIP MONDAL
- **CFD**
  - ISHAAN SHARMA
  - SUBHRO HALDER
  - SATVIK JAISWAL
- **CAD**
  - KALYANI KALAVAKUNTA
  - MILAN KUMAR

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THANK YOU VERY MUCH!