Passive Mixer cum Reactor using Threaded Inserts: Investigations of flow, mixing and heat transfer characteristics

Chirag M. Khalde,[a,b] Vikram Ramanan,[c] Jitendra S. Sangwai,[a] and Vivek V. Ranade,[b]*

[a]Gas Hydrate and Flow Assurance Laboratory, Petroleum Engineering Program,
Department of Ocean Engineering, Indian Institute of Technology Madras,
Chennai 600 036, India.

[b]Multiphase Reactors and Intensification Group (mRING)
Bernal Institute, University of Limerick, Ireland and
School of Chemistry and Chemical Engineering, Queen's University Belfast, Belfast BT9 5AG
Northern Ireland, UK

[c]National Centre for Combustion Research and Development,
Indian Institute of Technology Madras,
Chennai 600 036, India.

***Corresponding Author:**
Vivek V. Ranade: V.Ranade@qub.ac.uk; Vivek.Ranade@ul.ie

Supplementary Information

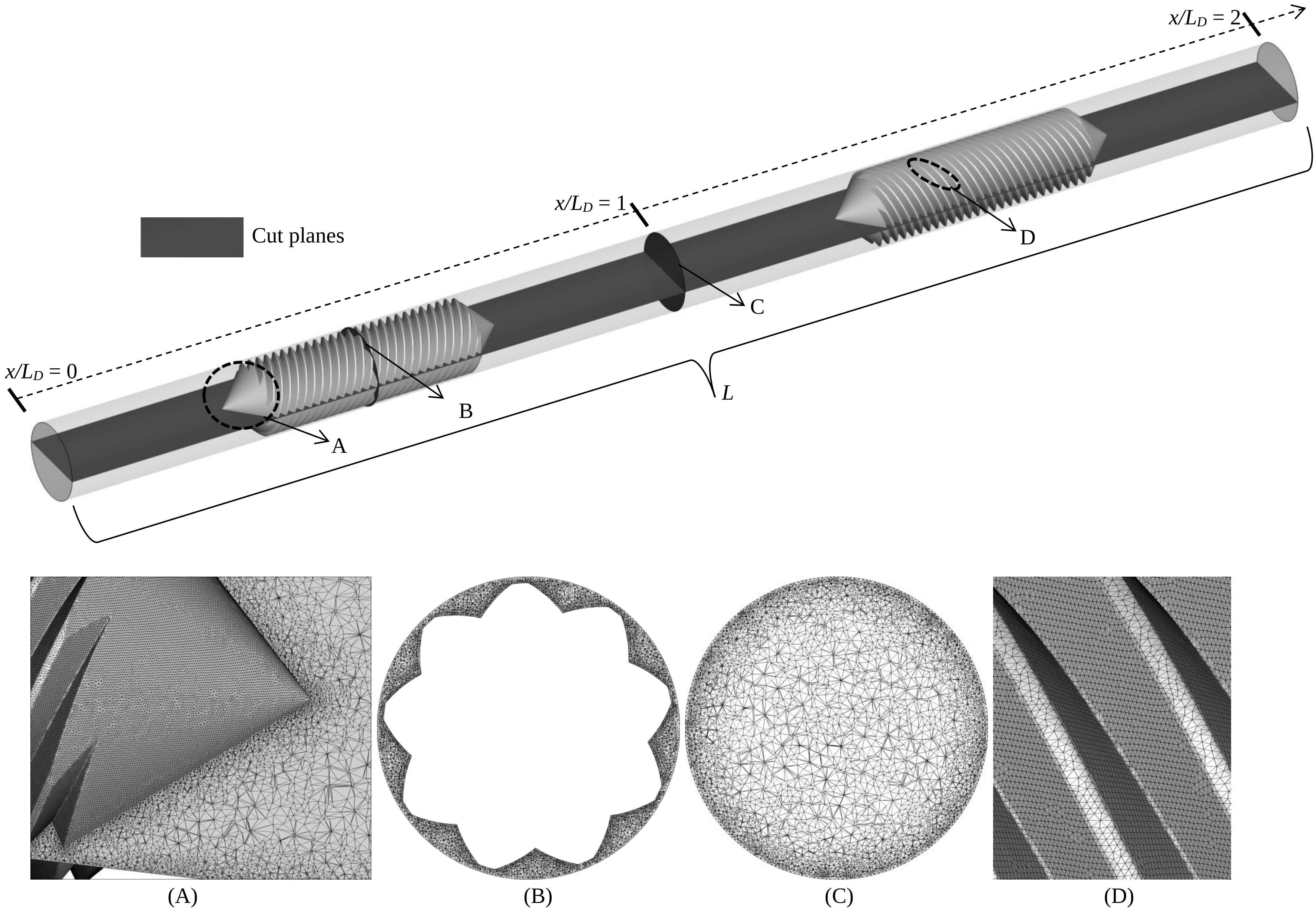
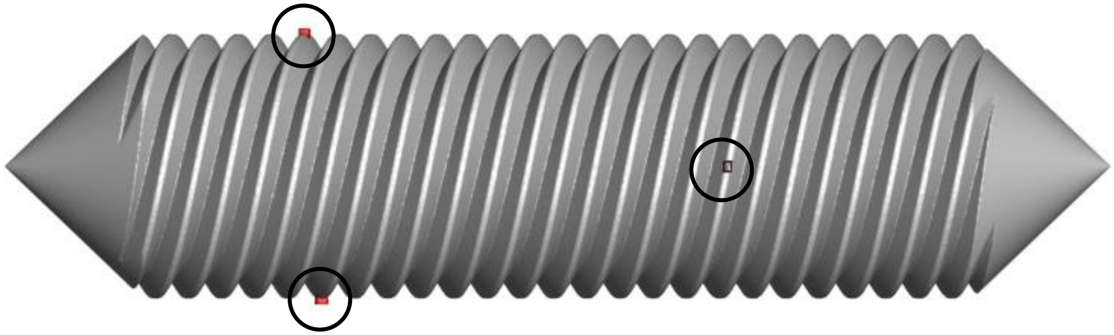
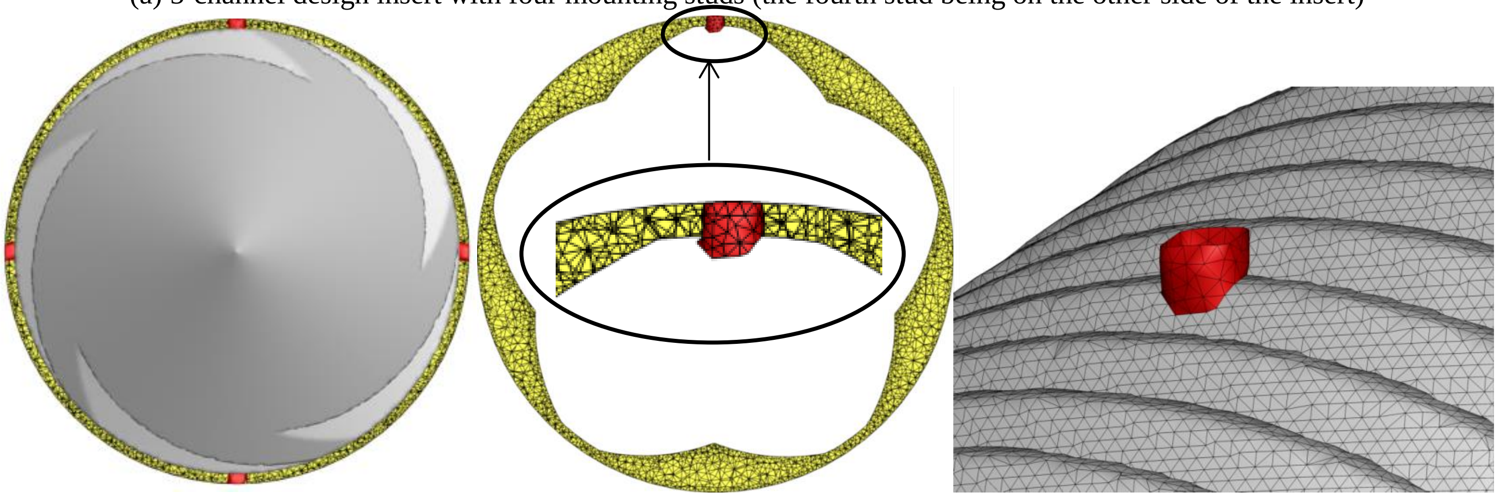


Figure S1: Unstructured grid images for 9-channel design exhibiting the cut planes at different critical regions of the domain



(a) 5-channel design insert with four mounting studs (the fourth stud being on the other side of the insert)



(b) selected domain exhibiting the grid around the stud

Figure S2: CAD design and the generated grid of 5 –channel design reactor at *Re* = 800 with inserts

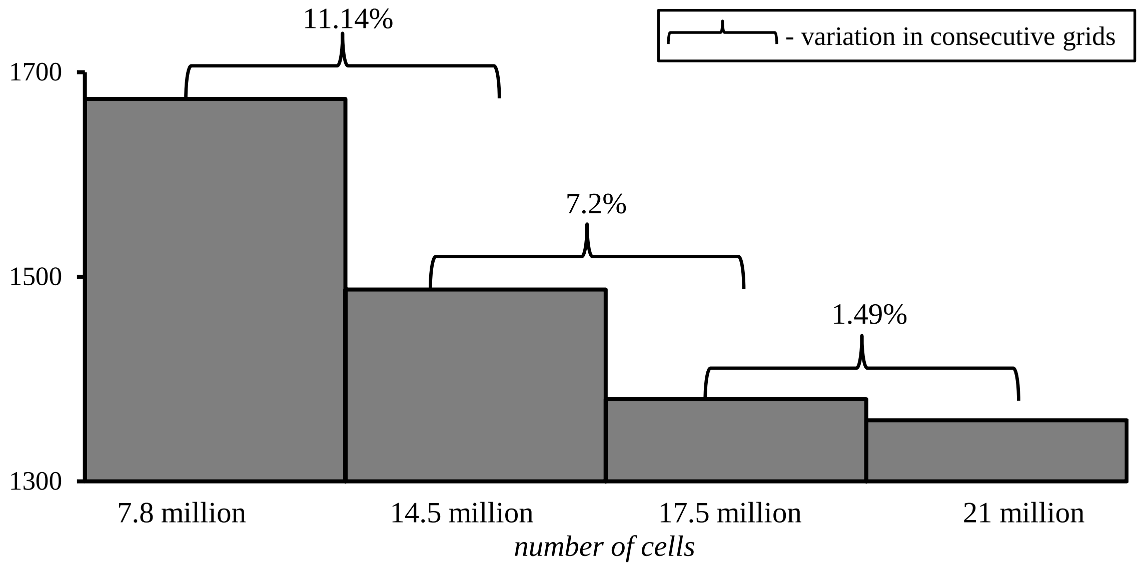


Figure S3: Grid independenasdcy studyfor 5- channel design: Variation in pressure drop for different grid sizes at *Re* = 800

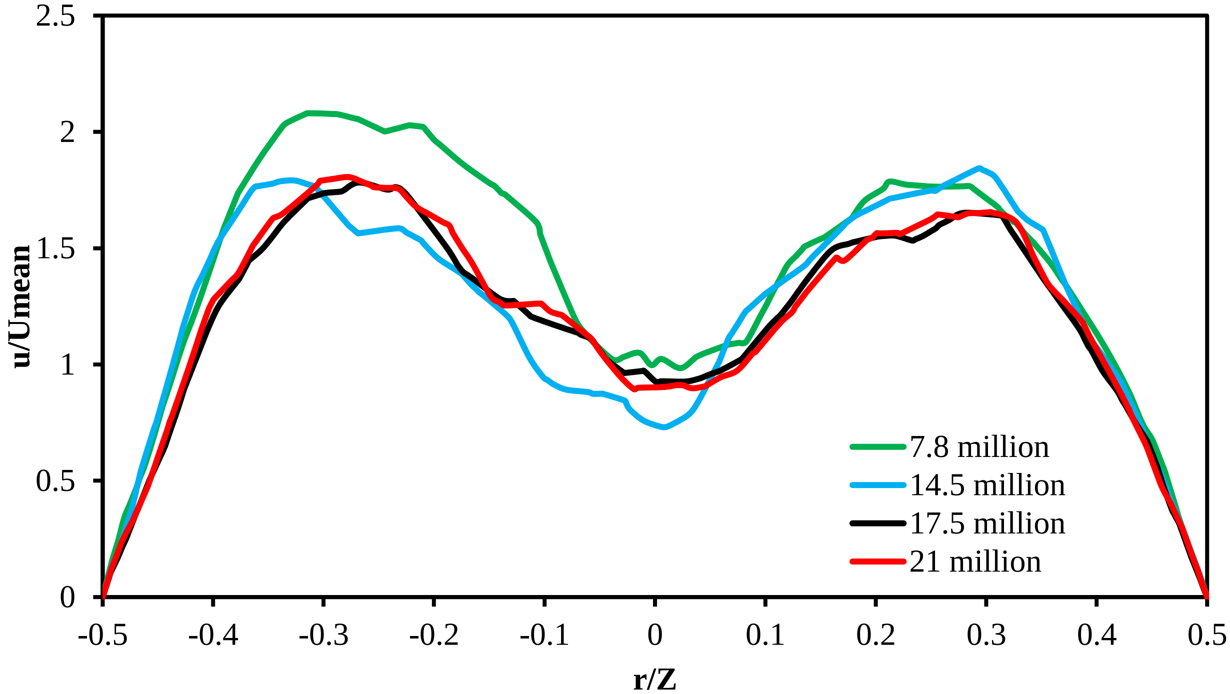


Figure S4: Grid independency studyfor 5- channel design: Velocity variation along the radial distance normal to the axis of the pipe at x/L_D=0.54 for different grid sizes at *Re* = 800

Experimental Study:

FABRICATION OF THE INSERT AND TUBE

A rod of Stainless steel (SS306) was machined on conventional lathe to generate multi-channel threading over its surface. Each configuration (for defined pitch, depth, etc.) machined for both left and right handed threading, together forming one set of passive mixer inserts of total diameter of 24.18 mm. Float glass tube of 26 mm internal diameter was used and the inserts were placed within the tube at locations as defined in Table 1 of the manuscript. Inserts were mounted within the tube using glass blowing byt providing bends (similar to studs as used in simulations). Pressure monitoring connectors were also made at selected locations. Rubber pipes have been used for supplying pressurized water through the pipe.

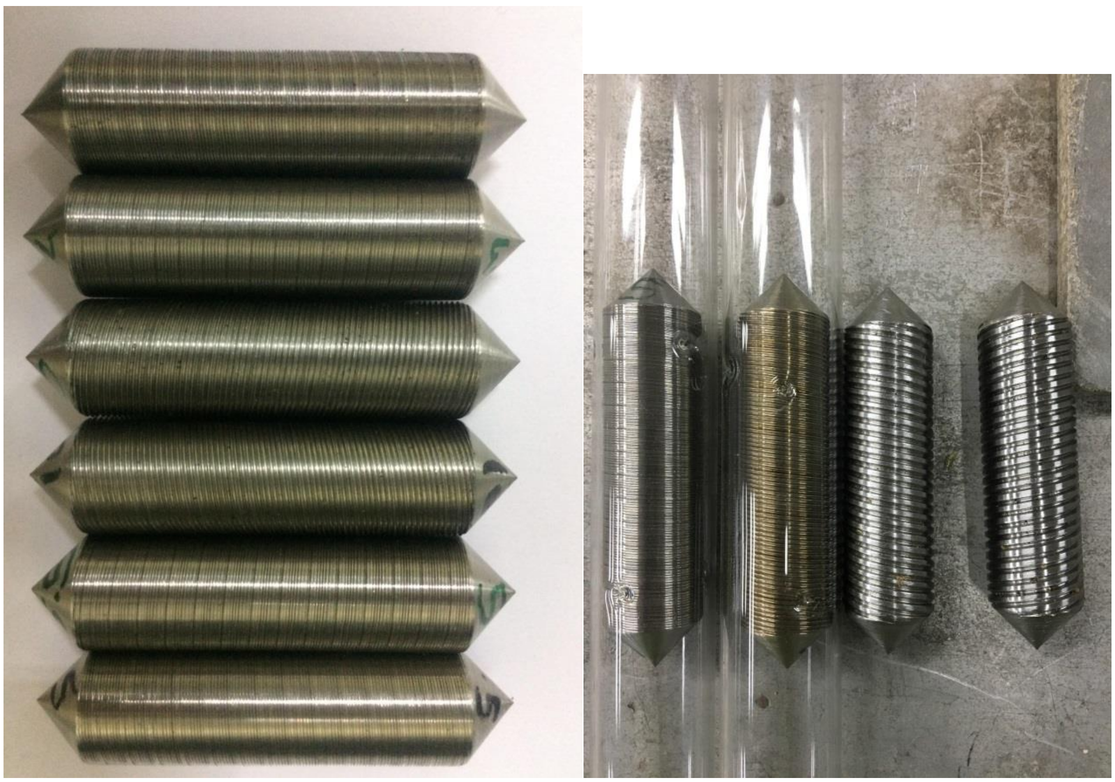


Figure S5a: Different configurations of threaded cone-cone inserts of manufactured using conventional lathe machine

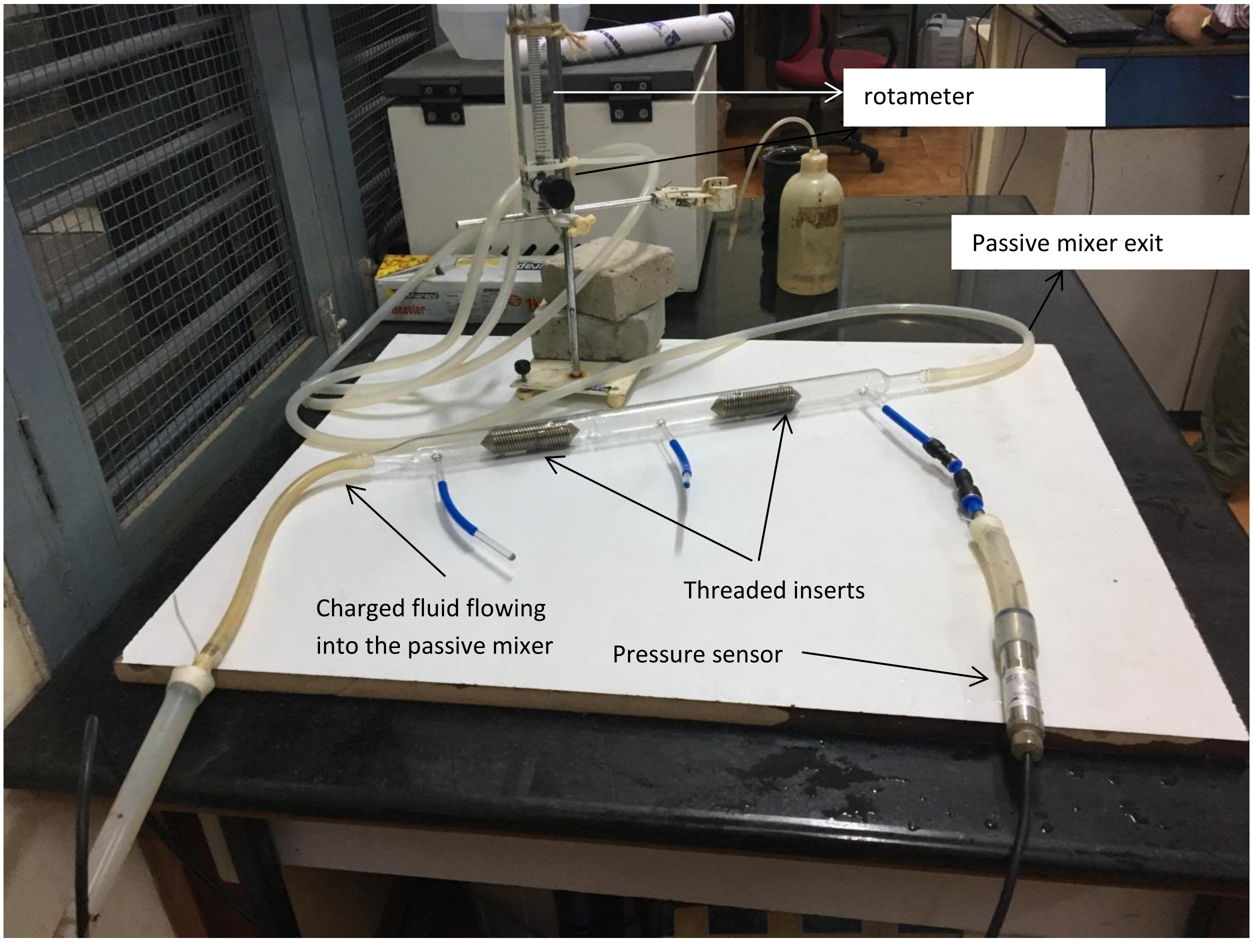


Figure S5b: Experimental Setup for measuring pressure drop for the 5-channel passive mixer

EXPERIMENTAL METHODOLOGY

The setup was mounted horizontally, with the downstream end of the setup connected to a rotameter, which is calibrated for water with a maximum flow rate of 2 litres per minute, with a least count of 0.1 litres per minute. Flow rates were also verified manually using stopwatch and 1 litre beaker. The inlet to the setup was directly connected to a water source with a valve to control the flow rate alongwith the rotameter. It was ensured that there were no entrained air bubbles in the entire setup during experimental runs. The pressure was measured by means of a piezoresistive transducer (Keller make, model no. 80748), whose output is from -5 to 5 V with maximum recordable pressure of 0.3 bar.

The pressure drop across various axial distances were measured by stabilizing the flow rate in the setup, followed by sequential acquisition of the pressure (in terms of voltage) by means of an oscilloscope. It was ensured that there were no flow disturbances nor transients (due to mounting) while sequentially recording the pressure. Experiments were repeated three times and the average has been reported in the form of Euler number.

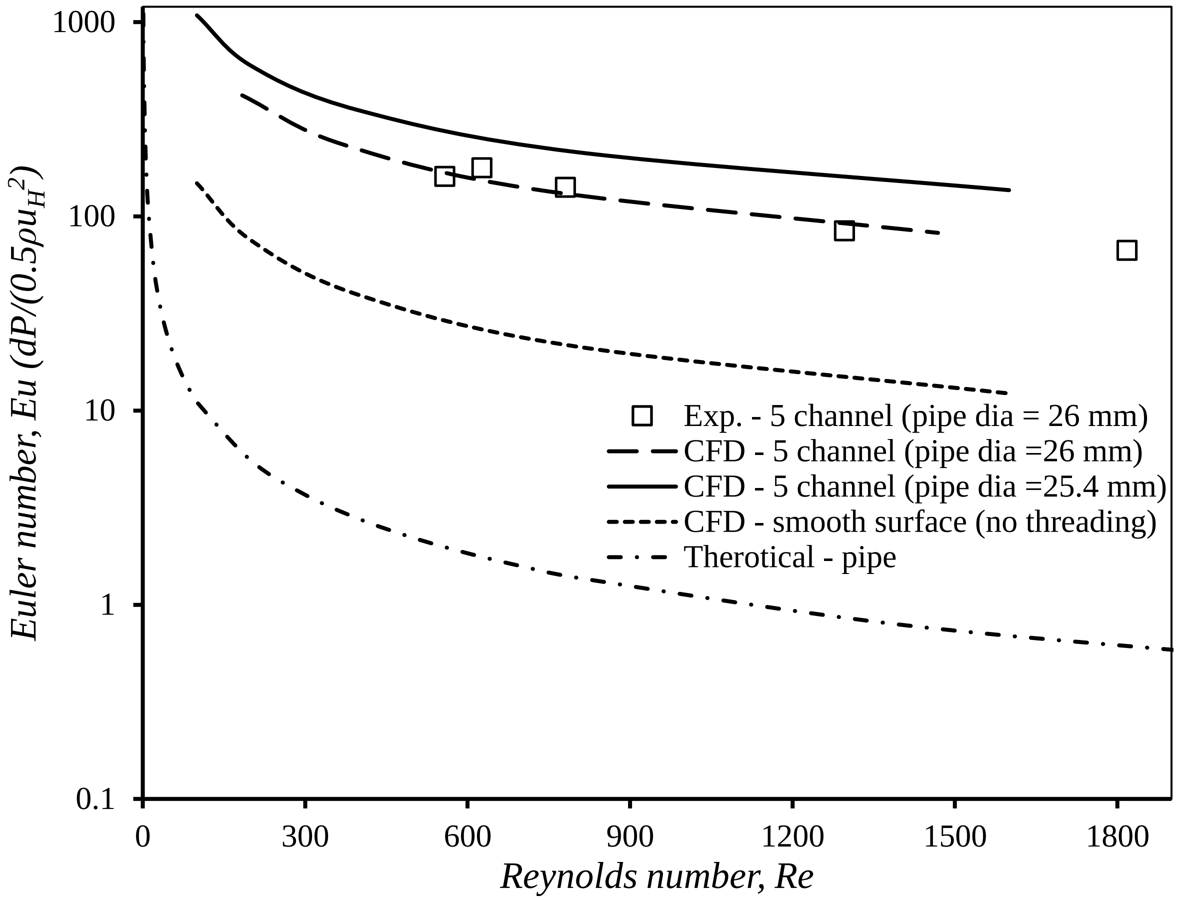


Figure S6: Comparison of Euler number (*Eu*) obtained from CFD and experiments for 5-channel design

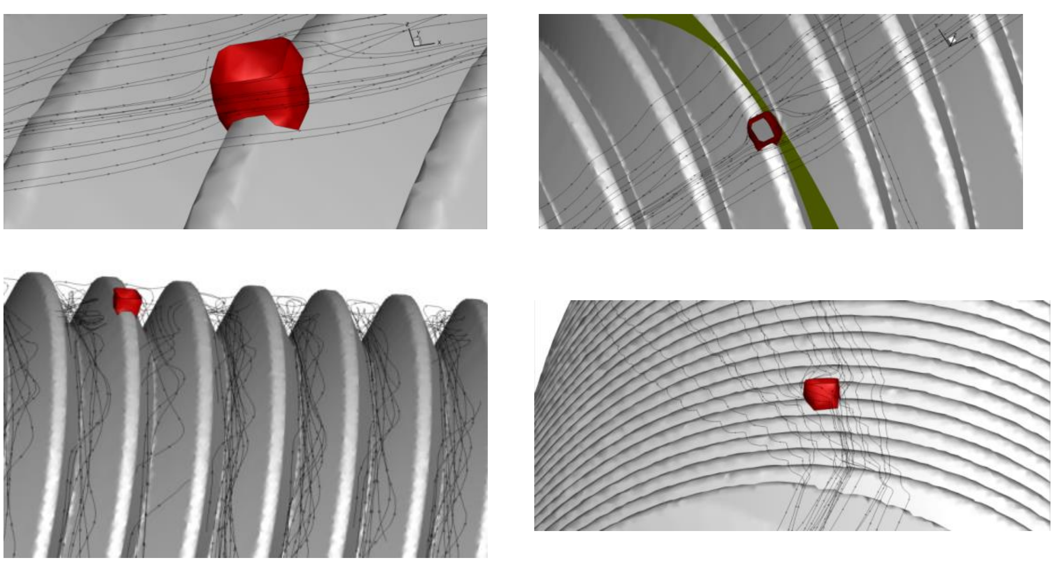


Figure S7: Path lines drawn around the stud and shown from different viewpoints for 5 –channel design reactor at Re = 800

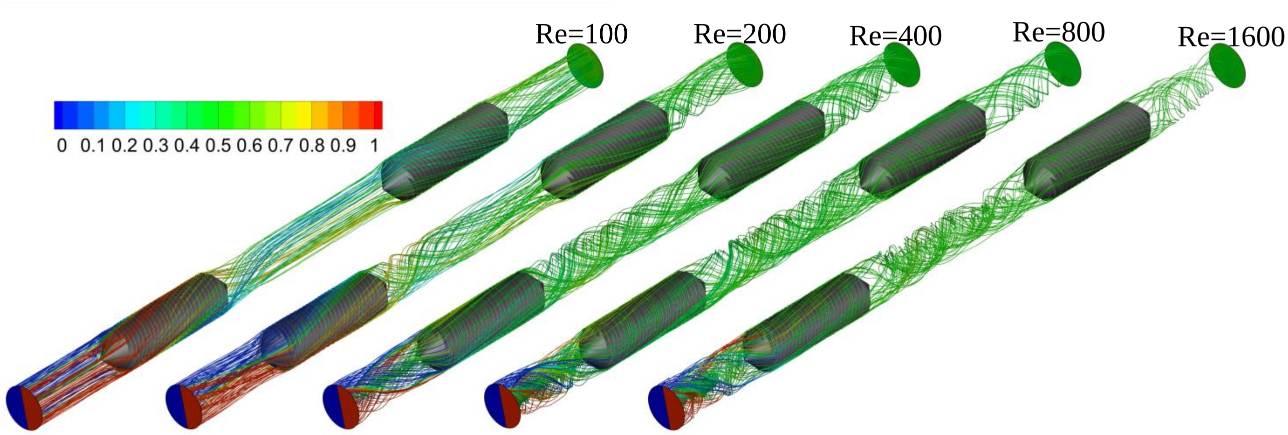


Figure S8a: Stream traces exhibiting the tracer mass fraction for 7-channel design at different *Re*

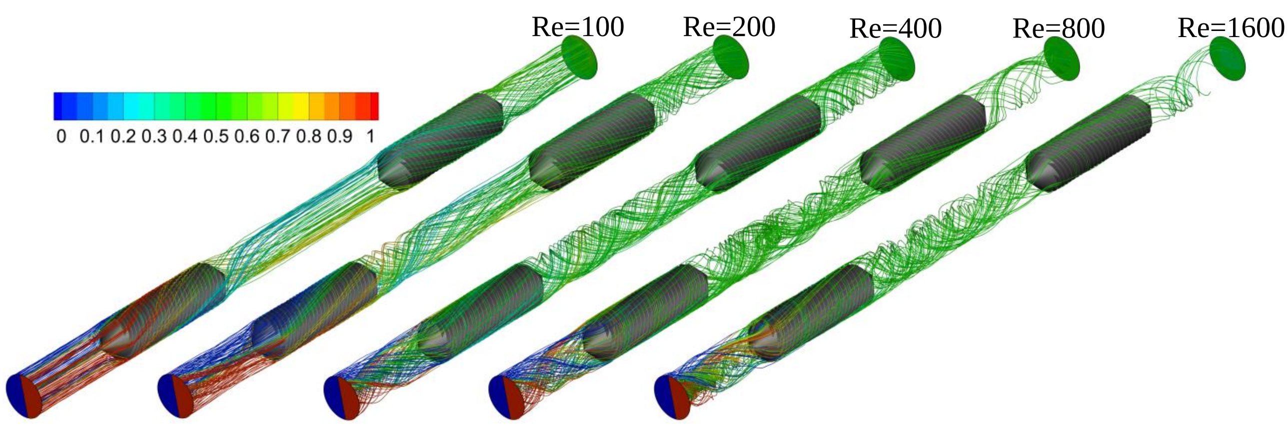


Figure S8b: Stream traces exhibiting the tracer mass fraction for 9-channel design at different *Re*

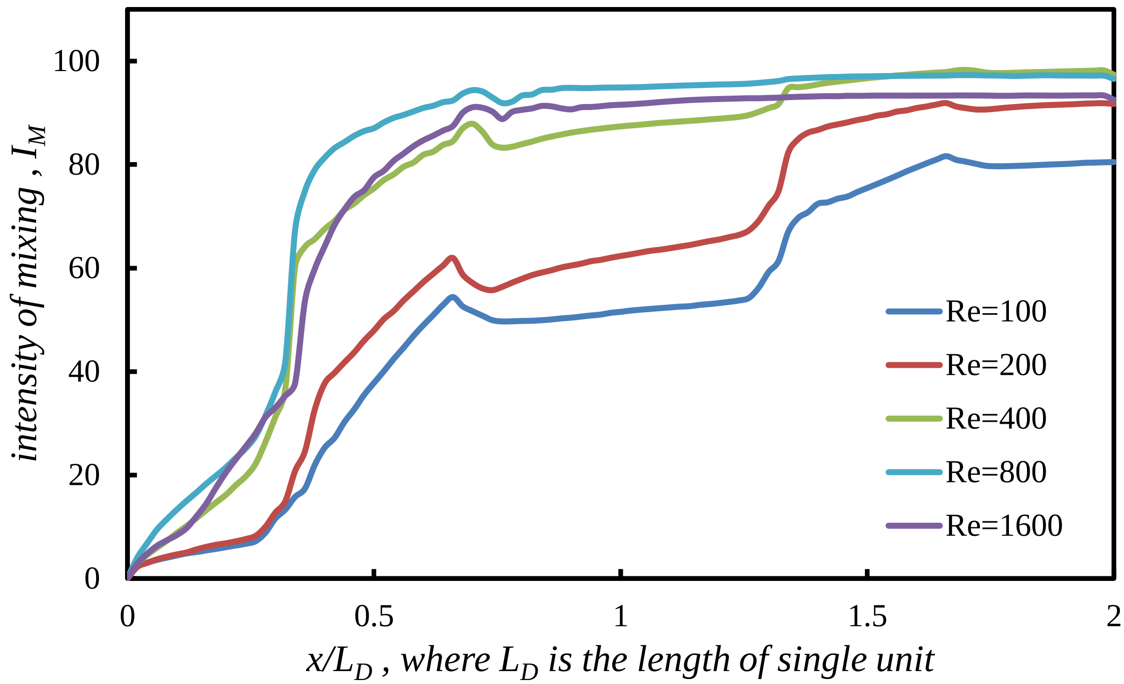


Figure S9a: Mixing intensity (I_M) variation along the length for 5-channel design with *Re*.

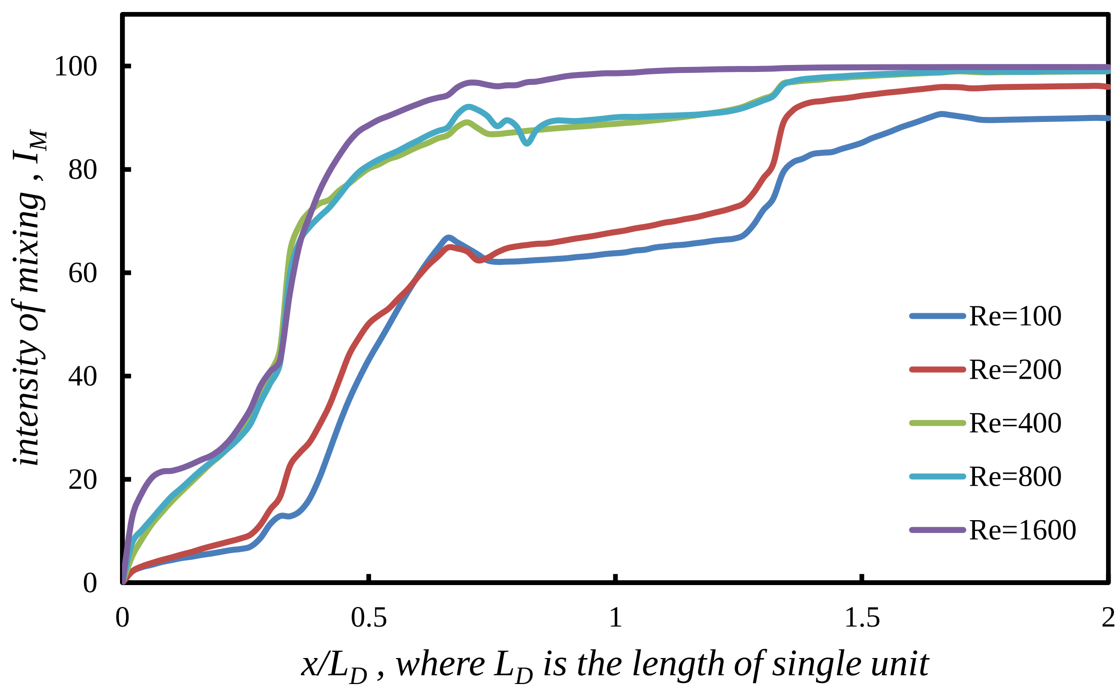


Figure S9b: Mixing intensity (I_M) variation along the length for 9-channel design with *Re*.