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तिथि/Dated:30/05/2023

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L-122503/2023

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Name, address and nationality of the applicant

ROHIT JADHAO , NMIET SAMARTH VIDYA SANKUL,
VISHNUPURI, TALEGAON DABHADE, MAHARASHTRA
410507-410507
INDIAN

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4. कार्य का वर्ग और विवरण
Class and description of the work

LITERARY/ DRAMATIC WORK EVALUATING
AERODYNAMIC BEAD SHAPE IN A HEAT EXCHANGER
TUBE FOR IMPROVEMENT IN THE RATE OF HEAT
TRANSFER

5. कार्य का शीर्षक
Title of the work

PPT ON EVALUATING AERODYNAMIC BEAD SHAPE IN A
HEAT EXCHANGER TUBE FOR IMPROVEMENT IN THE
RATE OF HEAT TRANSFER

6. कार्य की भाषा
Language of the work

ENGLISH

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आवेदन की तिथि/Date of Application: 11/03/2022
प्राप्ति की तिथि/Date of Receipt: 11/03/2022




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Nutan Maharashtra Inst. of Engg. & Tech.



“PPT on Evaluating Aerodynamic bead shape in a heat exchanger tube for improvement in the rate of heat transfer”

Nutan Maharashtra Institute of Engineering &
Technology Talegaon Dabhade

CREATED BY

**ROHIT R. JADHAO,
MANGESH KALE ,
RAHUL PATIL**



Rohit

Organization of Report

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- In Section 1** background of project has been described & also gives a brief description of heat transfer enhancement & its technique.
- **In Section 2** includes an overall survey of research done and paper related to this topic.
 - **In Section 3** the influencing parameters to aerodynamic bead shape in a heat exchanger tube is described in details.
 - **In Section 4** the design and fabrication of actual experimental set up is described in details.
 - **In Section 5** includes details of the computational testing done on the experimental set up readings.
 - **In Section 6** includes details of result and discussion on it.
 - **In Section 7** includes the conclusion based on results which we get.
 - **In Section 8** includes the Future Scope based on project work.



Objective

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- To enhance the heat transfer augmentation with minimum pressure drop.
- To enhance the heat transfer coefficient with increasing thermal performance.
- To get numerical results for align and cross arrangement of aerodynamic bead shape surface comparing with plain tube.
- To build test rig set up for testing the performance.
- Manufacture the tube with aligns or cross arrangement of aerodynamic bead shape, which gives best performance numerically.
- To test the tube under varying mass flow rate for different Reynolds number.
- To compare the results with plain tube.



Proposed Work

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- For the validation, results derived from two differing methodologies are compared. In this thesis, computational or numerical and experimental results would be validated through comparison.
- On the basis of experimentation, the variant with new geometry with aero beads shall be proposed.



Pranav

Introduction

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The heat exchanger is an important device in almost all of the mechanical industries as in case of process industries it is key element. Thus from long time many researchers in this area are working to improve the performance of these heat exchangers in terms of heat transfer rate, keeping pressure drop in limit.

- In order to augment heat transfer and to increase thermal performance of the heat exchangers heat transfer enhancement techniques are widely used. These techniques are classified in three groups, active, passive and compound techniques.
- The literature survey in this area shows that a lot of research work has been carried out on passive techniques, specially wire coil inserts and twisted tapes. They have done experimental investigation on wire coil inserts acting alone and by varying wire thickness, coil pitch, coil separation from tube wall, wire cross section and have developed correlations for Nusselt number with different variables listed.
- The study of the papers is aimed at providing detailed information about the forced convective heat transfer coefficient and thermal field of aerodynamic








l shape-type insert in a small circular tube.

periments carried out with air as the working fluid are presented and discussed in these papers.



Literature Review





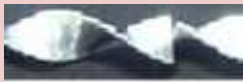

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Sr	AUTHOR NAME	TYPE OF FLOW	CONFIGURATION OF INSERTS	OBSERVATION	COMMENT
1.	Behabadi et al.	Turbulent	 PTT ($y=6, 9, 12$ and 15)	Decrease in 'y' increase the heat transfer rate. Pressure drop increases with reduction in 'y'	It is observed that the TT with 'y' = 9 gives the best 'g' with minimum pressure drop.
2	Chang et al.	Turbulent	 Regularly spaced short length TT	Heat transfer and flow resistance increase with an increase in the ' α '.	The larger ' α ' yields a higher heat transfer value and a greater flow resistance.
3	Thianpong et al.	Turbulent	 Dimpled tube fitted with TT	Heat transfer and 'f' increases with 'y' decreases.	Dimpled tube with TT gives higher heat transfer coefficient than TT.
4	P.S.Puandare et al.	Turbulent	 Conical ring with twisted tape	With $y= 3.75$ the ' η ' is 1.96.	Combined device increases the thermal performance.
5	Wongcharee et al.	Laminar	 Alternate axis Twisted tape	'Nu' increases with increase in 'Re' and fluid concentration.	TA makes more swirl in fluid flow with increased efficiency.
6	P. Murugesan et al.	Turbulent	 V-cut Twisted tape	Influence of 'DR' was more dominant than 'WR' for all 'Re'.	V cut TT gives higher transfer rate and friction factor than plain tube.
	Zhang et al.	Turbulent	 Edgefold Twisted tape	The highest performance of this TT is 140% when gap width reduces to 1 mm.	ETT with minimum α gives maximum thermal performance.



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Sr No	AUTHOR NAME	TYPE OF FLOW	CONFIGURATION OF INSERTS	OBSERVATION	COMMENT
8	Saha et al.	Turbulent	 Oblique teeth Twisted tape	At constant pumping power, the heat transfer rate is 1.55	TT with oblique teeth show high performance than TT without Oblique teeth.
9	Dr. Mohammed Ali et al.	Turbulent	 Centre wing and alternate axis Twisted tape.	Nu, f and g are higher in WTA than plain TT.	WTA will create the effect of swirling flow, and strong collision of the streams.
10	Dr. A.G.Matani et al.	Turbulent	 DTT	'Nu' and 'f' increases with decrease in 'Re'.	DTT can replace any of the TT to reduce size of the heat exchanger.
11	Radha Krishnan et al.	Laminar	 TT with rod and spacer	'Nu' is 13.5% higher than PTT and 'f' is given as 14.85.	This is well effective for laminar flow only.
12	Eiamsa-ard & Seemawute	Turbulent	 Peripheral cut-Alternate axis Twisted tape	Heat transfer rate by using PTA is 184%.	PTA provides maximum thermal performance at constant pumping power.
	Jiang Lin et al.	Turbulent	 Twin-counter/co-twisted tapes	'Nu', 'f' and 'g' increases with decrease in 'y'.	Heat transfer rate in tube with CTs are higher than those with CTs.

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Experimental Set-up

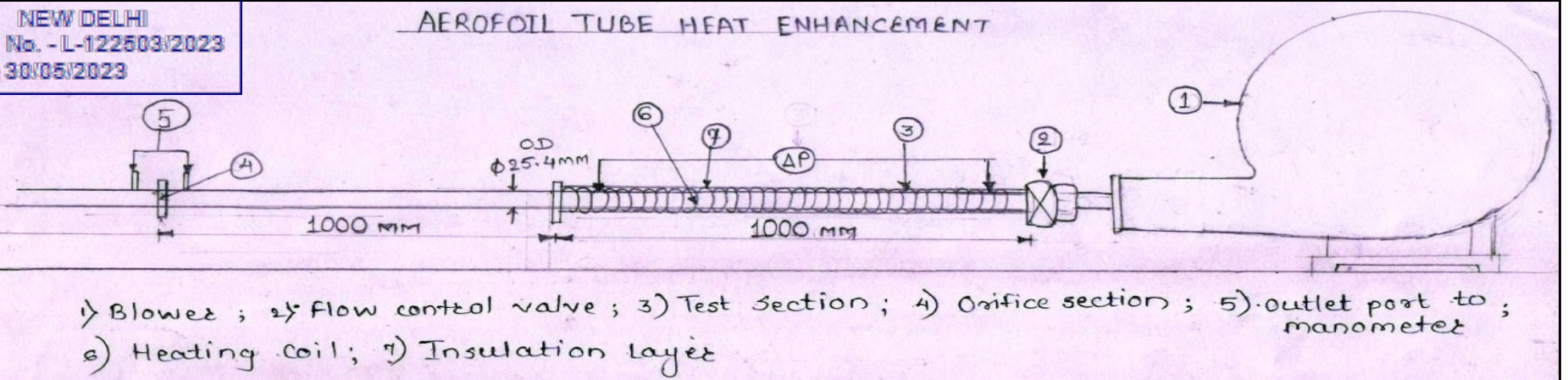
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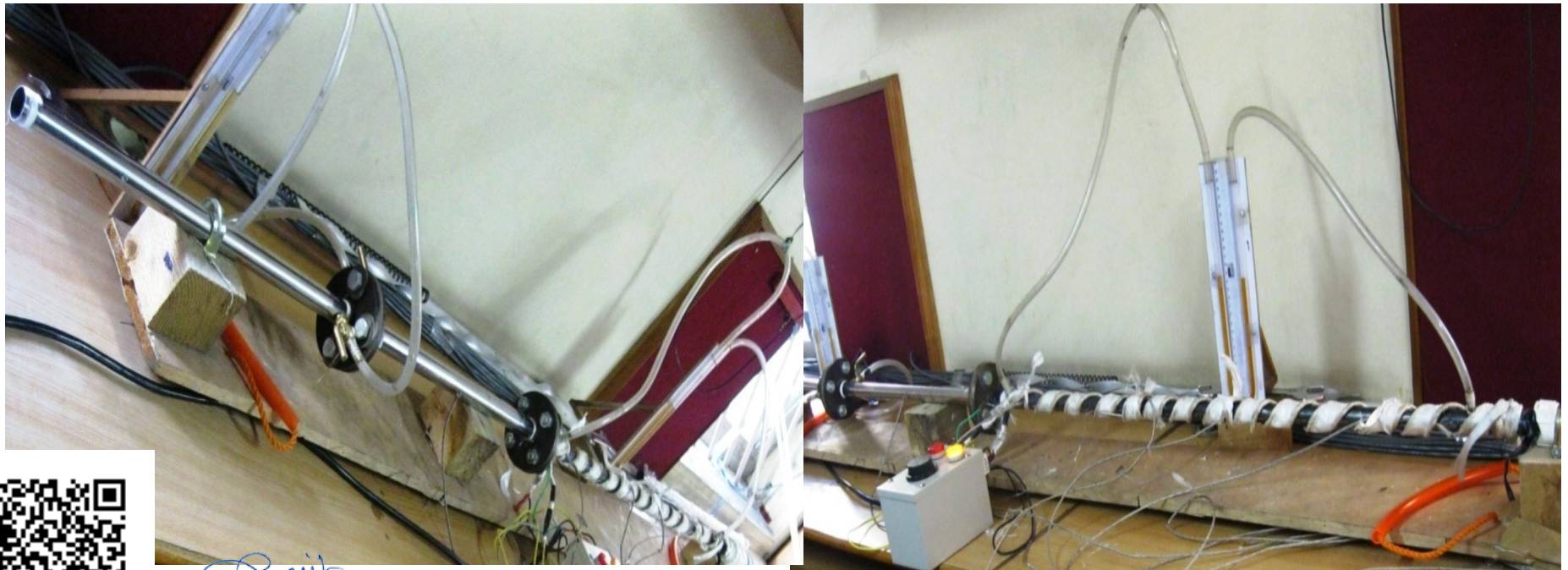
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AEROFOIL TUBE HEAT ENHANCEMENT



Schematic diagram of the Experimental Set-up



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Manufacturing of the Test Tubes

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- A plain tube of 1m length having outer diameter 22 mm & inner diameter 19 mm was prepared to use as test tube. Tube is cut by gas wire cutting method along the axis to form two halves.
- For the preparation of aerodynamic beads shape having depth is 3mm, radius 5 mm and length is 22.5 mm was cut with help of laser cutting from cold rolled closed annealed sheet.
 - These aerodynamic beads shape are welded over the inside of each half of the tube.
 - The cross arrangement is done for the test tube which is found to be effective over CFD analysis. The two halves of the tube weld by using Metal Inert Gas welding.



Components

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Blower: Blower is used to increase the air velocity. A motorized centrifugal air blower 1HP, Volts (220+6) %, 1.5amps, with speed of 2800 RPM, Maximum discharge 0.38 to 218m³/min.

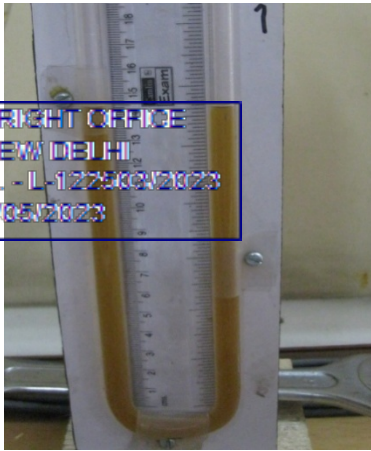


- **Control Valve :** Control valve or typical gate valve fitted at the outlet side of the blower is used to vary the mass flow rate of the air.
- **Thermocouples:** K type four Thermocouple is used to measure the surface temperature of the tube, which is having range -200 °C to 1200 °C.
- **Orifice Meter:** The diameter of the orifice is 1.25 cm and coefficient of discharge is 0.61. The two pressure tapings of the orifice meter are connected to a water U-tube manometer to indicate the pressure difference between them.



Glass Heater Coil: Flexi glass heater coil is used for the constant supply to wall surface tube.

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- **Pressure Taps:** A pressure tap is made at inlet and outlet side of the test section to facilitate the inlet and outlet air pressure for measurement. These pressure taps are connected to 'U' tube manometer through flexible transparent tubing for measuring the pressure drop between test sections.
- **Digital Multi meter:** MECO 801 is used to measure the temperature. Accuracy is about $(27 \pm) 60C$.
- **Rheostat:** Heat scam model Volt=230, Watt=3000 is used to give a control voltage and ampere to give control rate of heating by using heating coil.



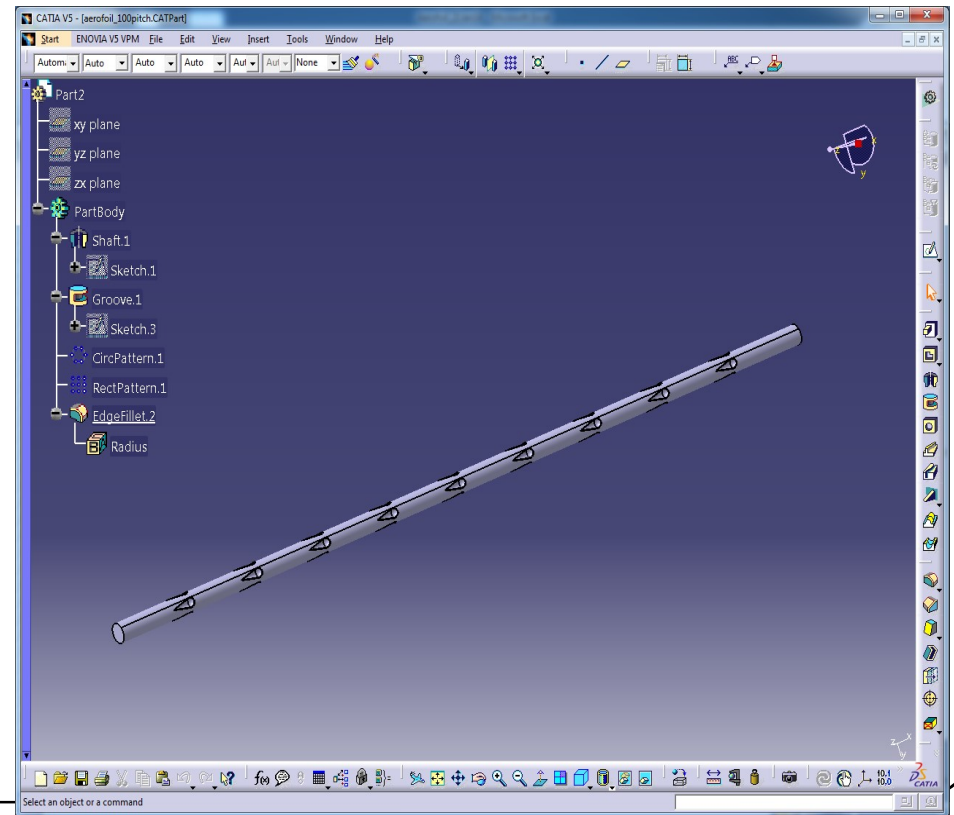
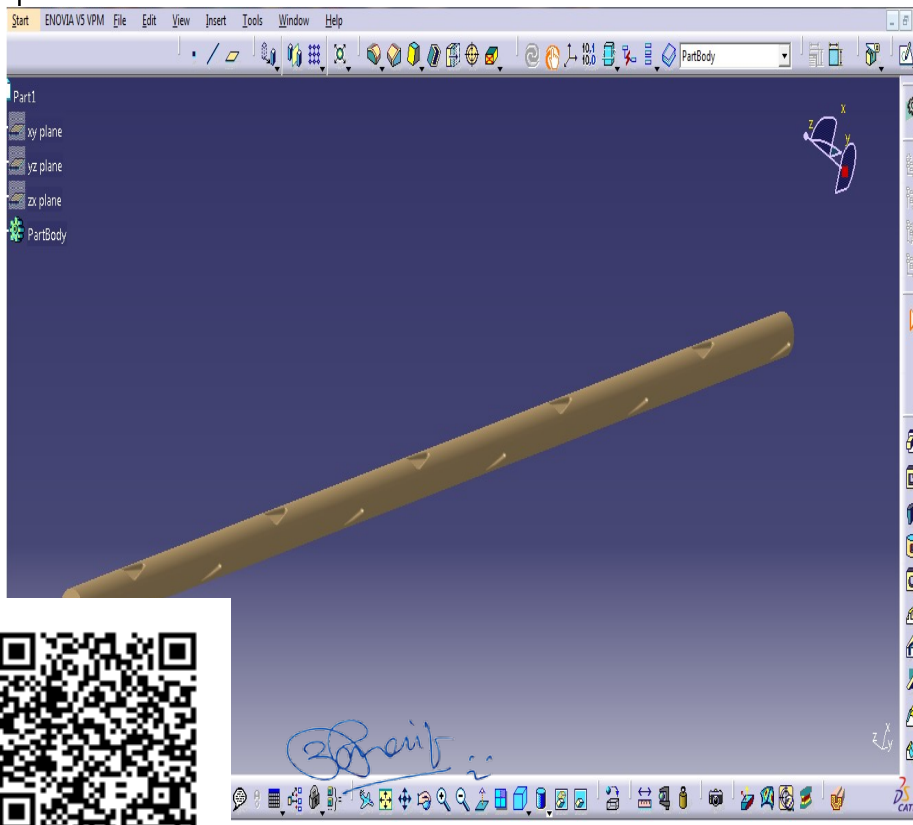
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Computational Methodology

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- The geometries of the tube and aerodynamic bead shape employed in the computation are exactly the same as those used in the experiments.
- The aerodynamic bead shape geometry and grid independence with fine meshes are generated inside the aerodynamic bead shape geometry and around the edges of it to resolve key features in the approximate size of the bead shape.

Geometries Preparation



Computational Model & Grid

The image displays a screenshot of a CAD software interface, likely ANSYS Workbench, showing a 3D model of a cylindrical part with a yellow mesh grid. The interface includes a top menu bar, a left toolbar with 'Operation' and 'Geometry' sections, a central 3D view, and a right sidebar with 'Mesh' and 'Volume' settings. A QR code and a signature are visible in the bottom left corner.

Top Menu Bar: Copyright Office, NEW DELHI, Reg. No. L/S/122509/2023, Date 03/05/2023

Left Toolbar: Operation (Mesh, Boolean, Fillet, Chamfer), Geometry (Sketch, Extrude, Revolve, Sweep, Loft, Mirror, Rotate, Translate, Scale, Move, Delete)

Right Sidebar: Mesh (Mesh, Refine, Coarsen, Merge, Split, Delete, Hide, Show, Freeze, Unfreeze, Lock, Unlock, Hide Edges, Show Edges, Hide Faces, Show Faces, Hide Volumes, Show Volumes), Volume (Volumes, Mesh Volumes, Schemes, Elements, Type, Spacing, Interval size, Options: Mesh, Remove old mesh, Remove lower mesh, Ignore size functions)

Bottom Left: QR Code, Signature: *3DPrint*

Computation Procedure or Simulation Scheme

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● **Analysis of problem:** Without Aerodynamic Bead Shape, With Aerodynamic Bead Shape & Numerical Investigations in Plain Tube with Aerodynamic Bead Shape

- **Solution Setup:** The commercial CFD software Fluent 14.5 was used for the computational solution. The mesh was read in to Fluent and setup for solution.
- **Model & Solver.**
- **Material properties and flow conditions.**
- **Boundary Conditions.**
- **Solution Methods and Controls.**

Operation

Zones

Specify Boundary Types

FLUENT 5/6

Action:

- ◆ Add
- ▼ Modify
- ◆ Delete
- ▼ Delete all

Name	Type
mass_flow_inlet.1	MASS_FLOW_INI
pressure_outlet.2	PRESSURE_OUTL
wall.3	WALL

Show labels Show colors

Name:

Type:

Entity:

Faces

Label	Type

Remove Edit



3D Print

Parameters & Properties values table

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Parameter	Unit	Reynolds Number			
		19709.59	39419.18	51244.94	67012.61
Inlet temp	deg.C	30	30	30	30
Tw	deg.C	70	70	70	70
di (inner)	mm	19	19	19	19
do (outer)	mm	22	22	22	22
Length	m	1	1	1	1
Cs area	m ²	0.000284	0.000284	0.000284	0.000284
Surface area	m ²	0.069115	0.069115	0.069115	0.069115
Velocity	m/s	15.056	30.112	39.14559	51.19039
mass	kg/s	0.005	0.01	0.013	0.017
density air	kg/m ³	1.171287	1.171287	1.171287	1.171287
Cp	J/kgK	1005	1005	1005	1005
k	W/mK	0.0242	0.0242	0.0242	0.0242
viscosity	Pa.s	0.000017	0.000017	0.000017	0.000017
		0.705992	0.705992	0.705992	0.705992
		54.5745	95.01972	117.211	145.269



3D Print

Results And Discussions

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In order to enhance the heat transfer rates and increase the system efficiency, aerodynamic bead shape geometry inside the tube have been developed and many experimental investigations have been conducted to determine their thermodynamic characteristics.

- **Comparison of Experimental Calculations for Cross arrangement Aerodynamic Bead Shape & Plain tube**

Re	To		ΔH		h		ΔP		f	
	Plain	Cross	Plain	Cross	Plain	Cross	Plain	Cross	Plain	Cross
19709.59	53.2	55.5	116.58	128.1	59.39	68.04	98.1	245.25	0.014	0.0351
39419.18	51.0	53.0	211.05	231.2	103.5	117.35	117.5	343.35	0.0042	0.0123
51244.94	50.0	51.81	261.30	284.9	126.0	141.70	206.0	588.60	0.0044	0.0125
	49.2	50.12	328.03	344.6	156.1	166.67	196.2	716.13	0.0024	0.0089



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- Comparison of Computational (Temperature based) Calculations for Cross & Align arrangement of Aerodynamic Bead Shape & Plain tube.**

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Re	To			ΔH			h		
	Plain	Align	Cross	Plain	Align	Cross	Plain	Align	Cross
19709.59	52.24	56.78	54.16	111.76	134.57	121.40	55.99	73.17	62.91
39419.18	49.87	52.74	51.20	199.69	228.54	213.06	96.10	115.49	104.85
51244.94	49.04	51.68	49.81	248.76	283.25	258.76	118.08	140.54	124.39
67012.60	48.27	50.44	48.85	312.14	349.22	322.06	146.32	169.67	152.40

- Comparison of Computational (Pressure based) Calculations for Cross & Align arrangement of Aerodynamic Bead Shape & Plain tube**

Re	ΔP		f	
	Plain	Cross	Plain	Cross
19709.59	253.98	283.842	0.0363	0.0406
39419.18	903.622	957.015	0.0323	0.0342
51244.94	1467.41	1543.88	0.0311	0.0327
67012.60	2413.76	2524.20	0.0299	0.0313

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- Enhancement Efficiency Experimental calculations for Cross arrangement Aerodynamic Bead Shape**

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m_f	Re	Nu / Nu ₀	(f/f_0)	$(f/f_0)^{1/3}$	TPF or Overall Enhancement Ratio
0.005	19709.59	1.146	2.507	1.358	1.560
0.01	39419.18	1.133	2.928	1.431	1.621
0.013	51244.94	1.124	2.840	1.416	1.591
0.017	67012.60	1.070	3.708	1.548	1.656

- Enhancement Efficiency of Computational calculations for Cross arrangement Aerodynamic Bead Shape with Plain tube**

m_f	Re	Nu / Nu ₀	(f/f_0)	$(f/f_0)^{1/3}$	TPF or Overall Enhancement Ratio
0.005	19709.59	1.124	1.059	1.019	1.146
0.01	39419.18	1.091	1.118	1.038	1.132
0.013	51244.94	1.053	1.052	1.017	1.071
0.017	67012.60	1.042	1.046	1.015	1.060

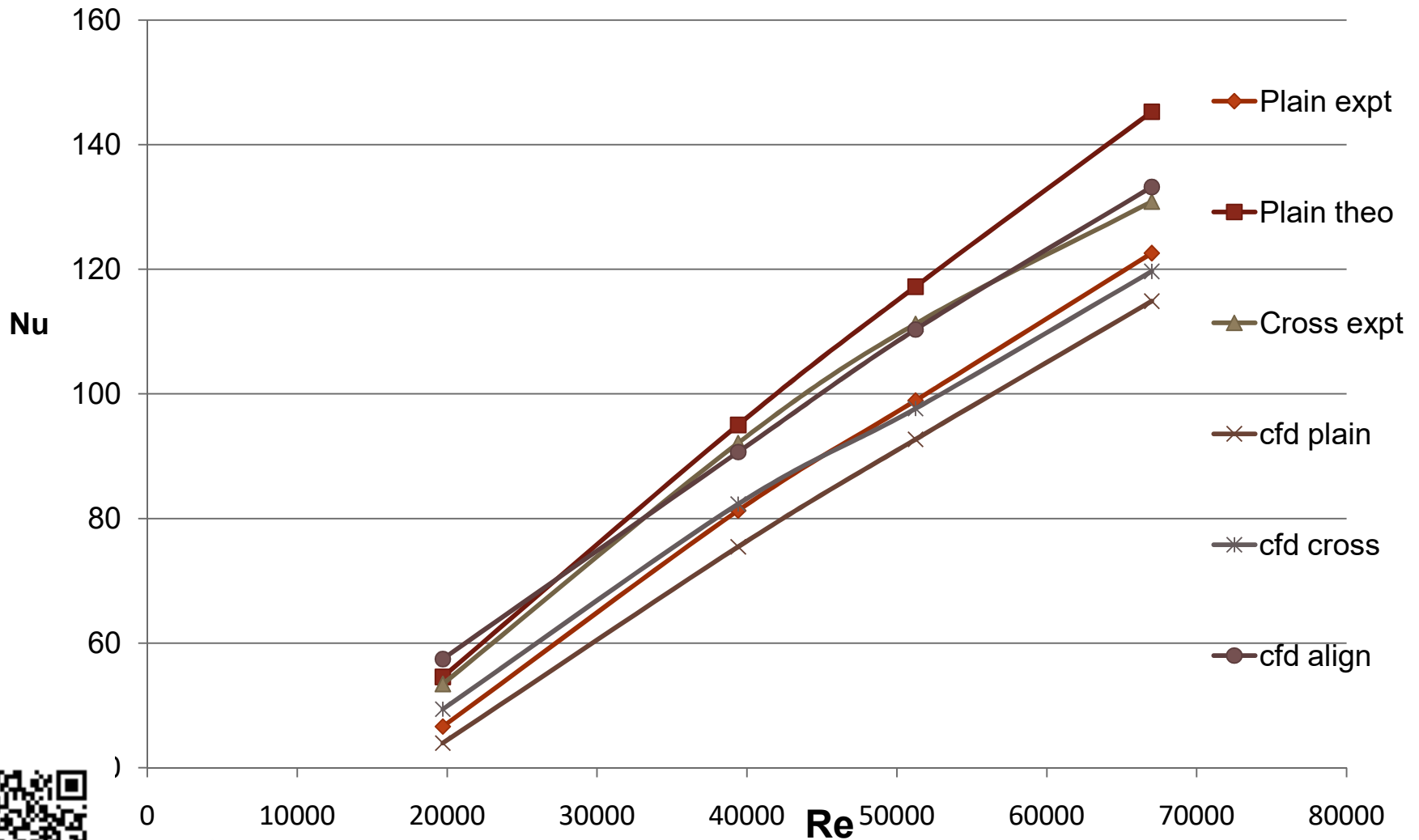


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Comparison between Variation of Nu with Re in all cases

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Nu Vs Re

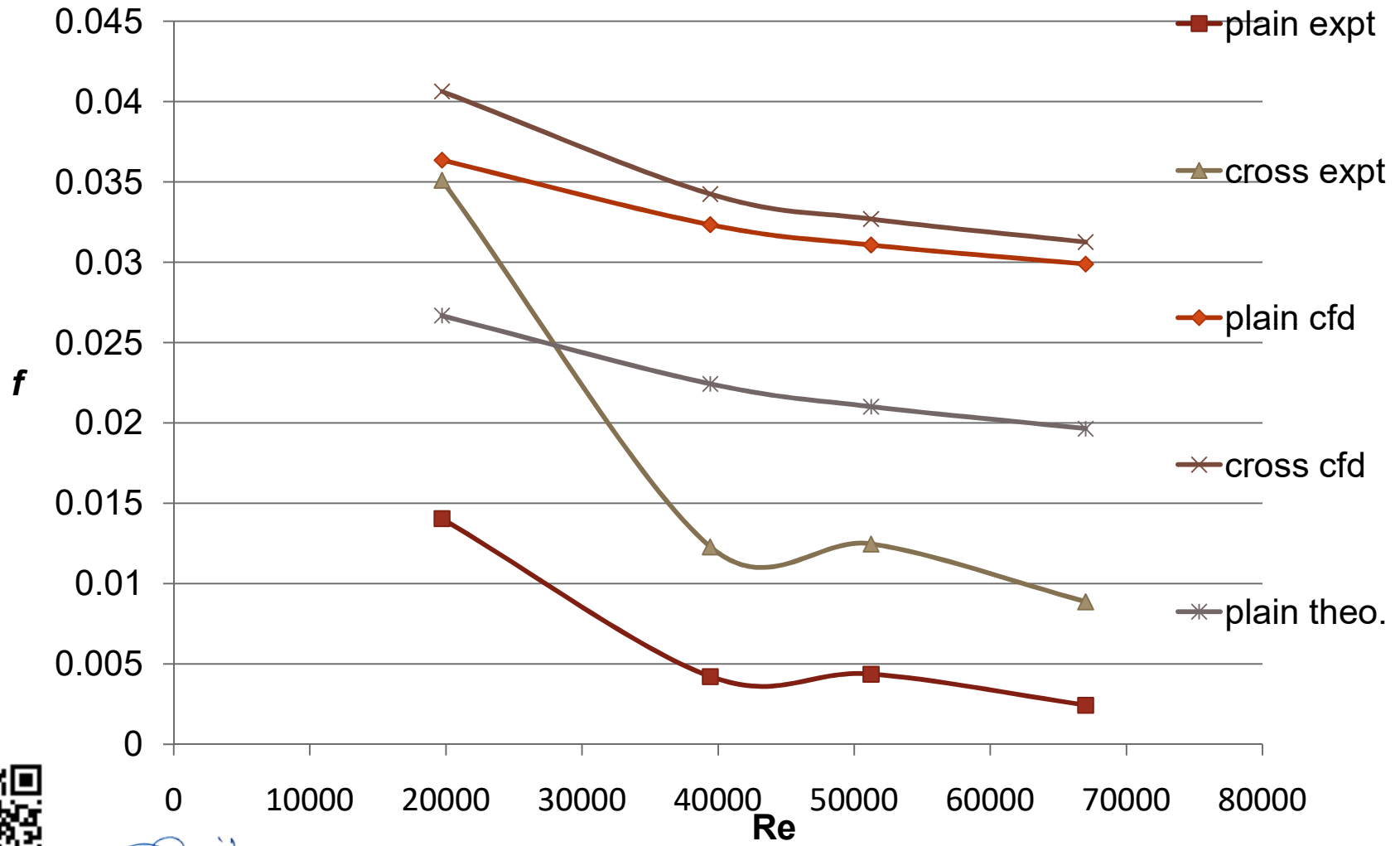


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Graph reveals that if Reynolds number increases friction factor is decreasing shows the friction factor values are calculated.

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Friction Factor vs Re



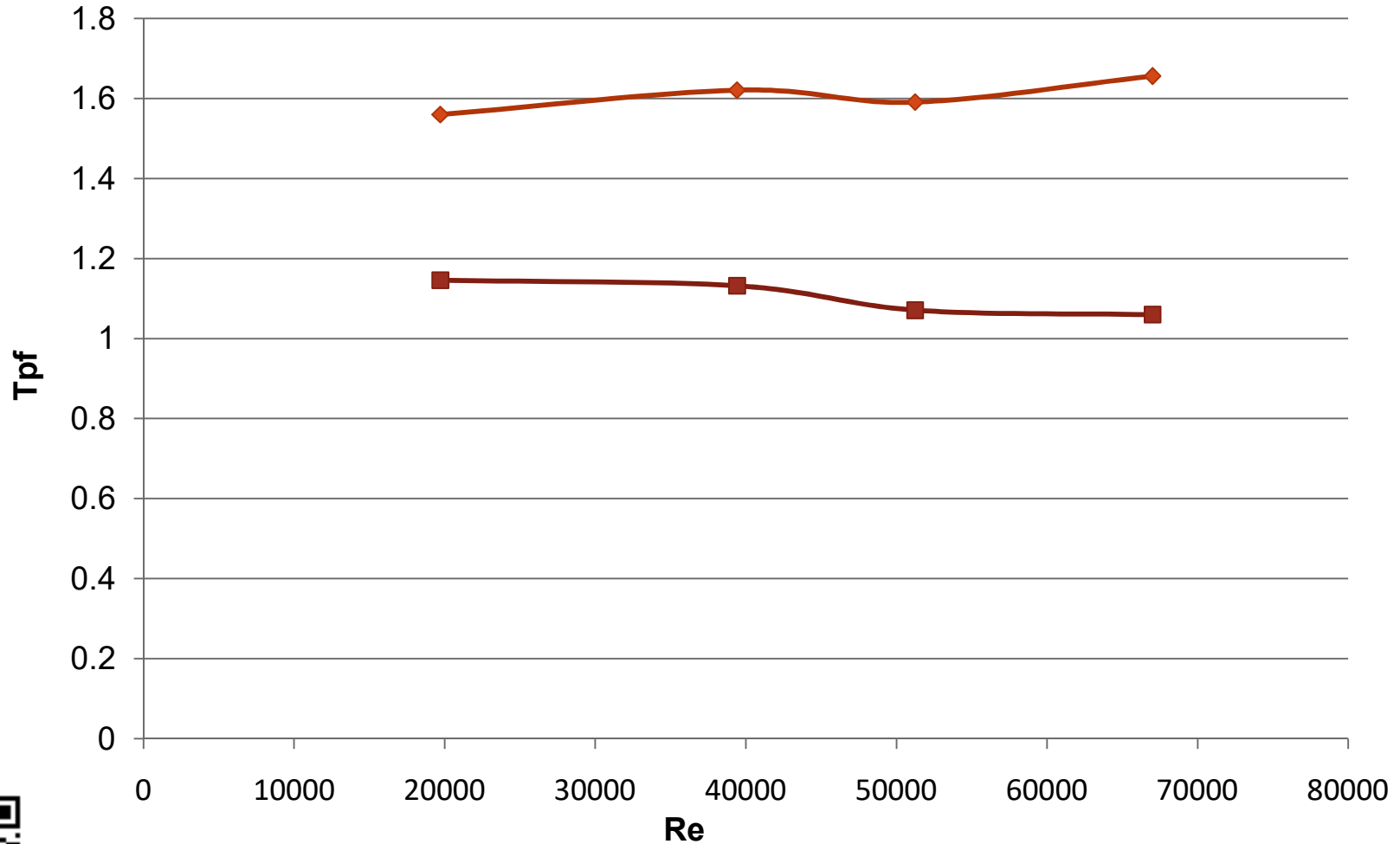
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Comparison between the Overall enhancement ratios Vs Reynolds Number of CFD values

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TPF Vs Re

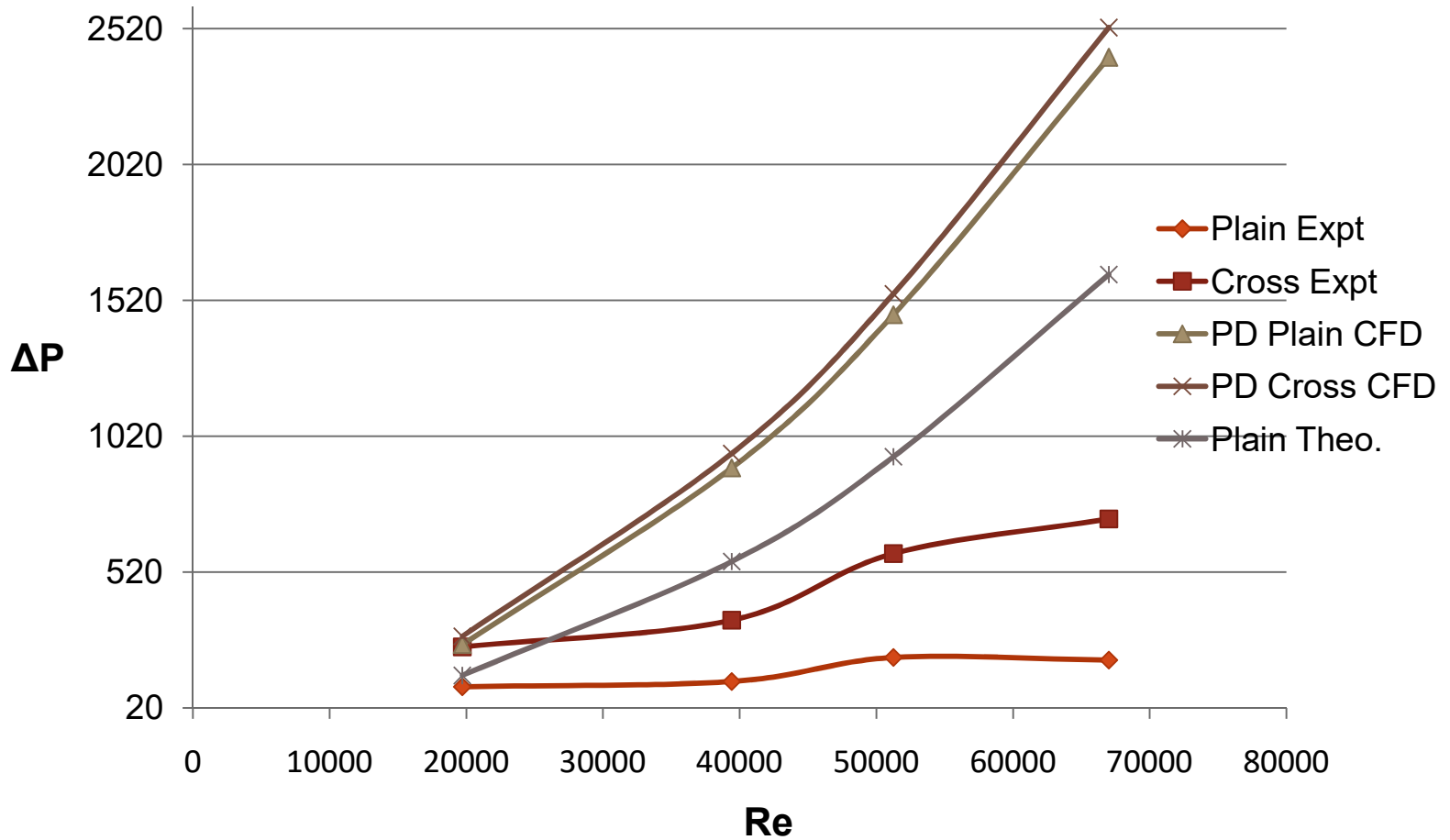


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Comparison between the Pressure Drop Vs Reynolds

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Pressure Drop Vs Re

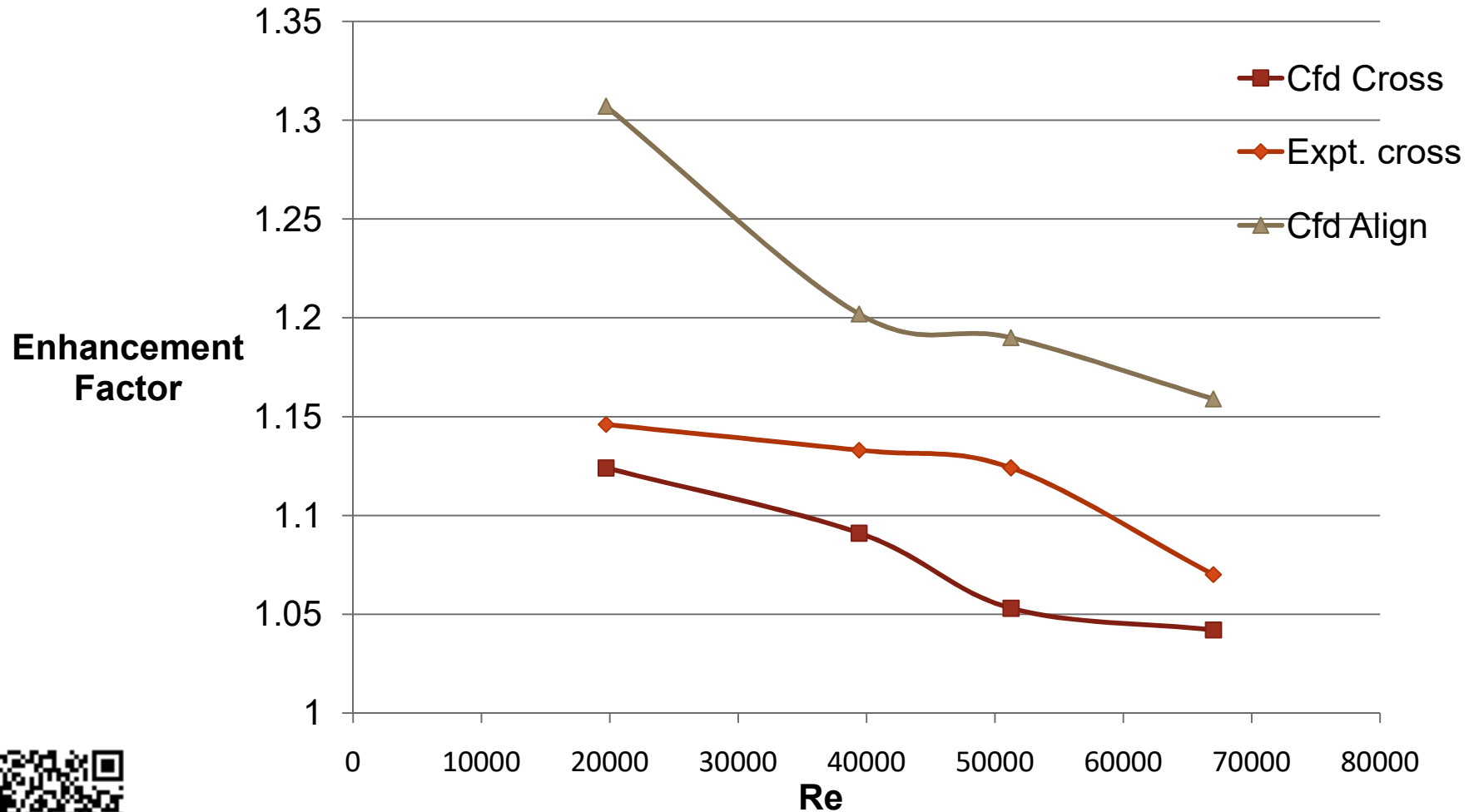


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Comparison between the Enhancement Factor Vs Re.

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Enhancement Factor Vs Re

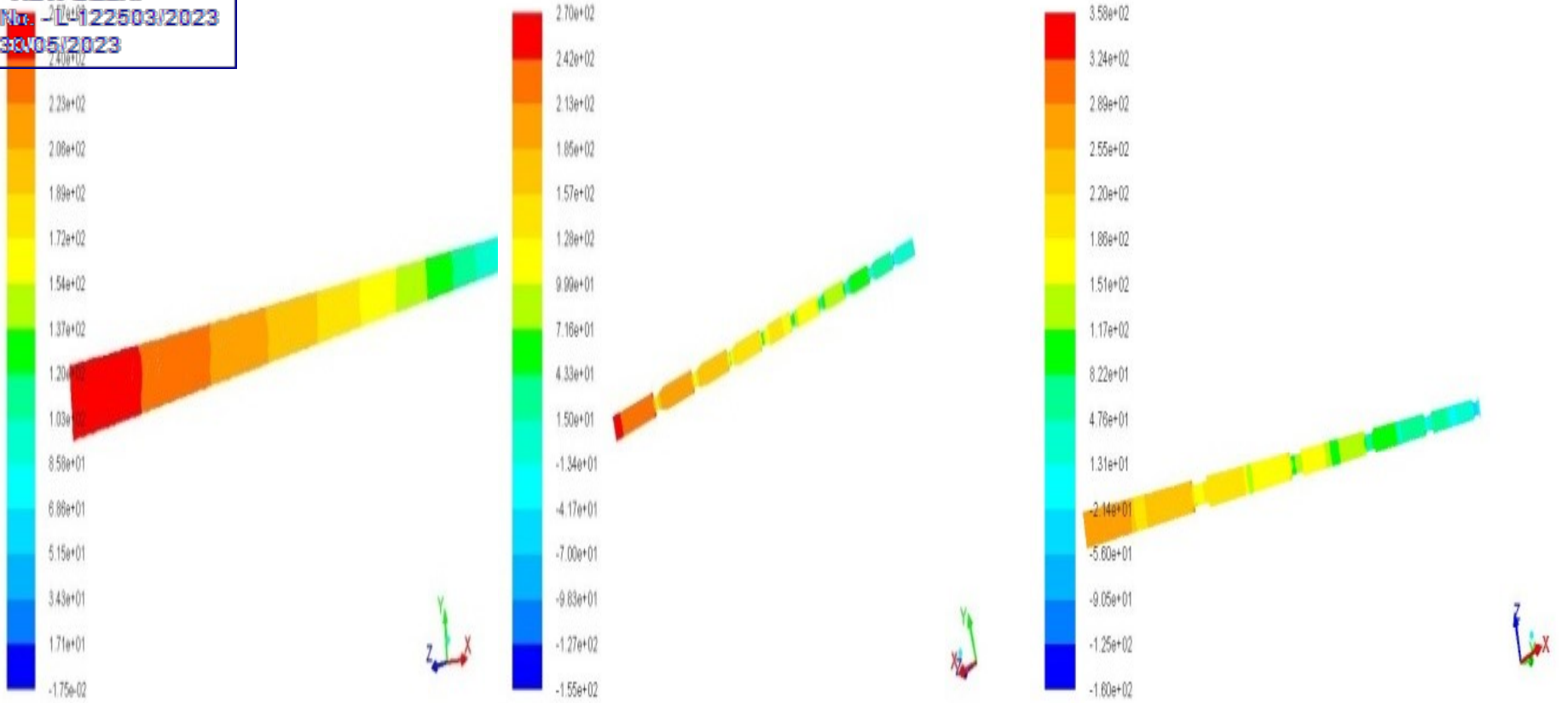


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Counters of Static Pressure:

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Case 1 For Plain tube, Align arrangement aerofoil inserts & Cross arrangement aerofoil insert at Mass flow rate: 0.005 kg/s



Contours of Static Pressure (pascal)	Jan 17, 2015 ANSYS Fluent 14.5 (3d, dp, pbns, ske)	Contours of Static Pressure (pascal)	Jan 17, 2015 ANSYS Fluent 14.5 (3d, dp, pbns, rke)	Contours of Static Pressure (pascal)	Jan 22, 2015 ANSYS Fluent 14.5 (3d, dp, pbns, rke)
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Fig 4.1.1, 4.1.2 and 4.1.3 show that the Static Pressure variations for the plain tube configuration and on align & cross arrangements configuration.

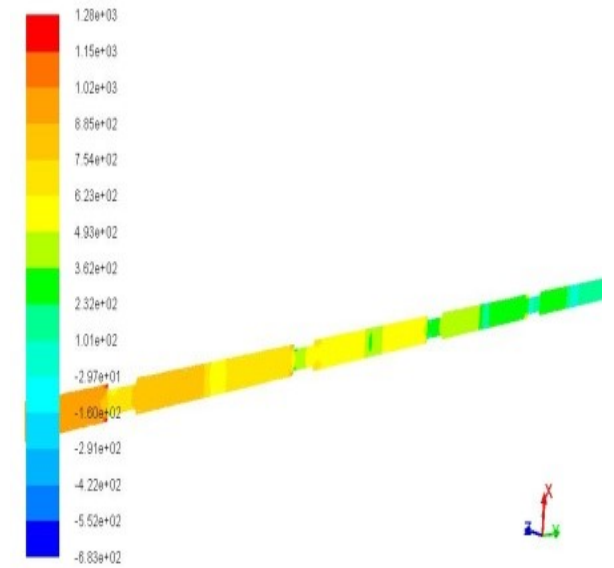
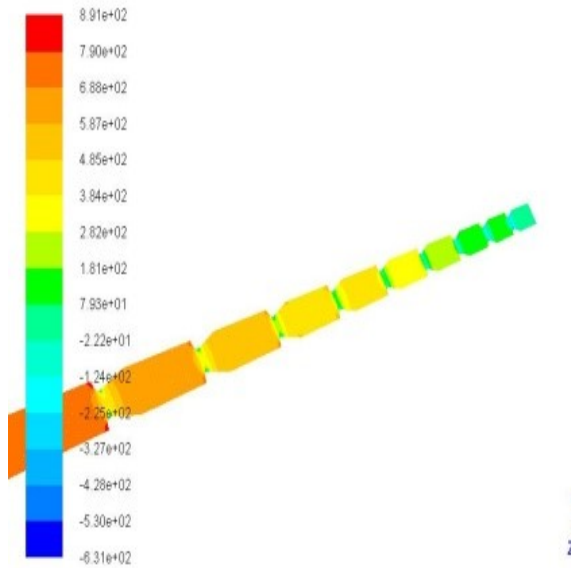
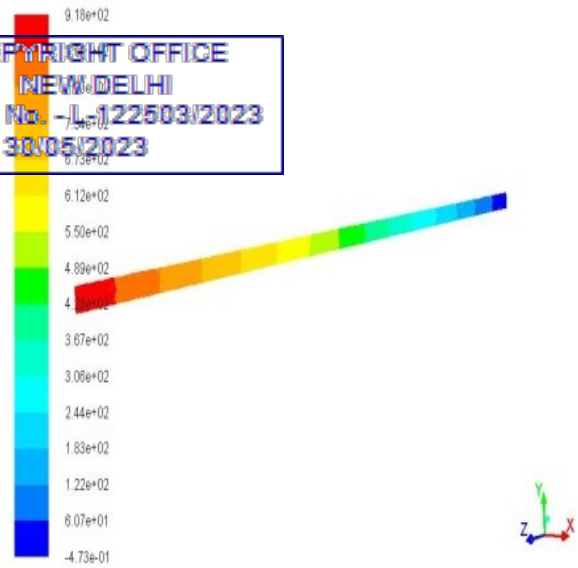
Flow Simulation of Enhancement of heat transfer in tube with different varying Reynolds numbers such as **Case 1 = 19709.59**, **= 39419.18**, **Case 3 = 51244.94**, and **Case 4 = 67012.60**.

Signature



Case 2: For Plain tube, Align arrangement aerofoil inserts & Cross arrangement aerofoil insert at Mass flow rate: 0.001 kg/s

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Contours of Static Pressure (pascal)

Jan 17, 2015
ANSYS Fluent 14.5 (3d, dp, pbns, ske)

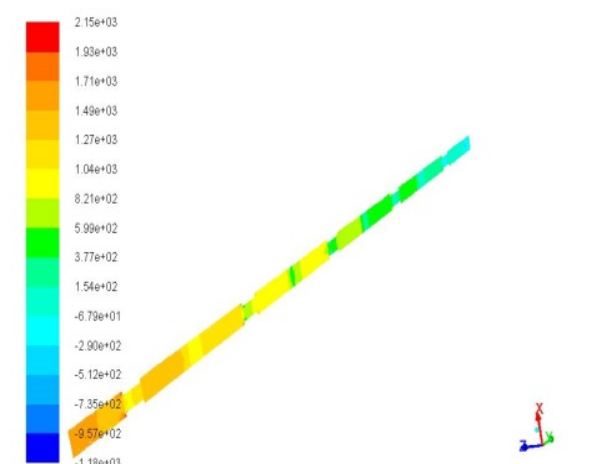
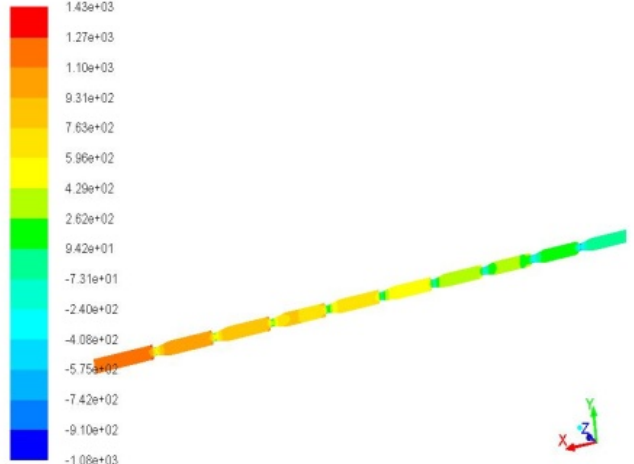
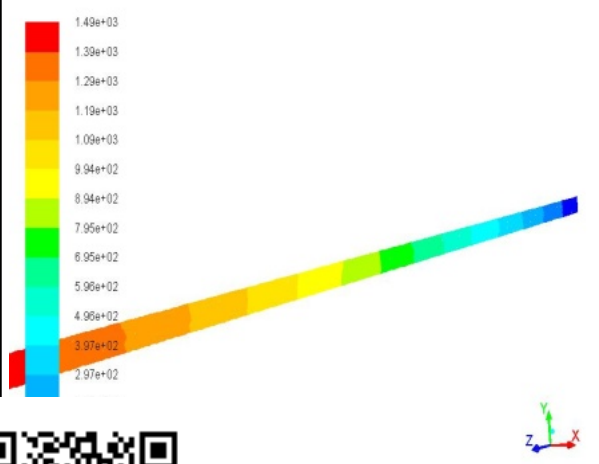
Contours of Static Pressure (pascal)

Jan 17, 2015
ANSYS Fluent 14.5 (3d, dp, pbns, rke)

Contours of Static Pressure (pascal)

Jan 22, 2015
ANSYS Fluent 14.5 (3d, dp, pbns, rke)

Case 3: For Plain tube, Align arrangement aerofoil inserts & Cross arrangement aerofoil insert at Mass flow rate: 0.013 kg/s



Contours of Static Pressure (pascal)

Jan 17, 2015
ANSYS Fluent 14.5 (3d, dp, pbns, ske)

Jan 17, 2015
ANSYS Fluent 14.5 (3d, dp, pbns, rke)

Contours of Static Pressure (pascal)

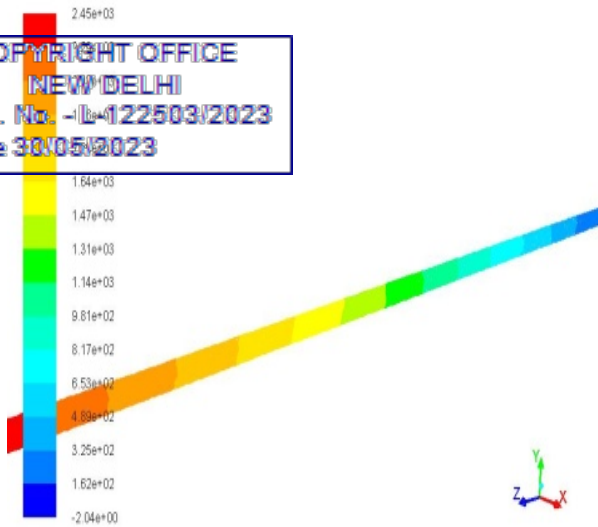
Jan 22, 2015
ANSYS Fluent 14.5 (3d, dp, pbns, rke)



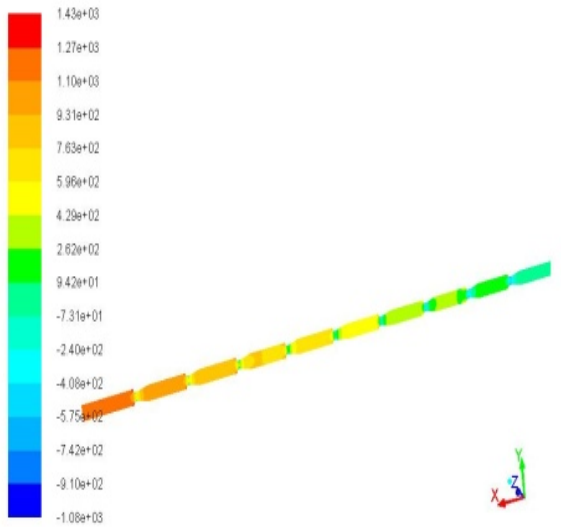
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Case 4: For Plain tube, Align arrangement aerofoil inserts & Cross arrangement aerofoil insert at Mass flow rate: 0.017 kg/s

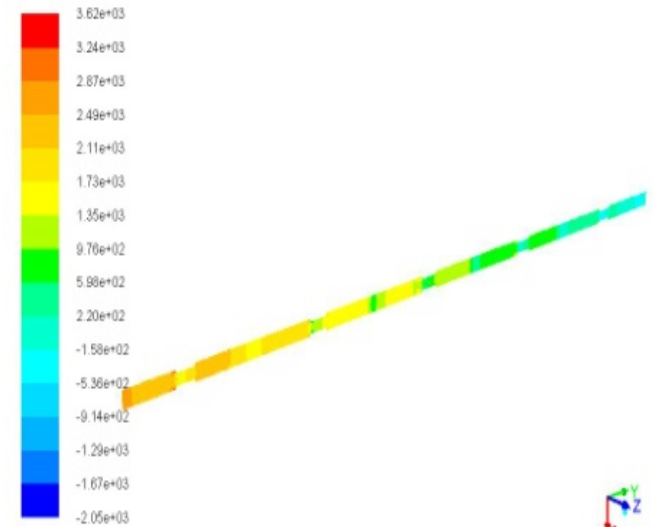
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Contours of Static Pressure (pascal) Jan 17, 2015
ANSYS Fluent 14.5 (3d, dp, pbns, ske)



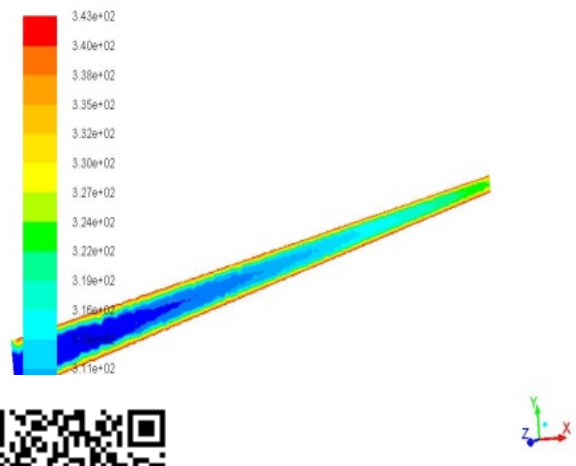
Contours of Static Pressure (pascal) Jan 17, 2015
ANSYS Fluent 14.5 (3d, dp, pbns, rke)



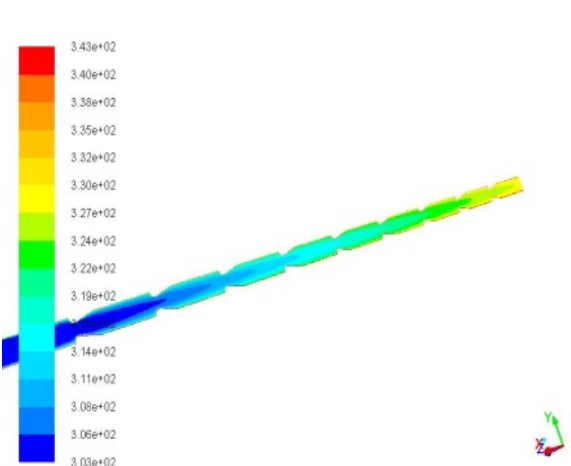
Contours of Static Pressure (pascal) Jan 21, 2015
ANSYS Fluent 14.5 (3d, dp, pbns, rke)

Contours of Static Temperature:

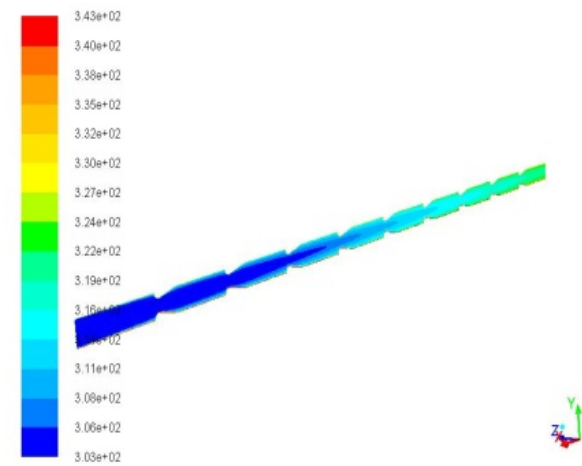
Case 1: For Plain tube, Align arrangement aerofoil inserts & Cross arrangement aerofoil insert at Mass flow rate: 0.005 kg/s



Contours of Static Temperature (k) Jan 17, 2015
ANSYS Fluent 14.5 (3d, dp, pbns, ske)



Contours of Static Temperature (k) Jan 17, 2015
ANSYS Fluent 14.5 (3d, dp, pbns, rke)



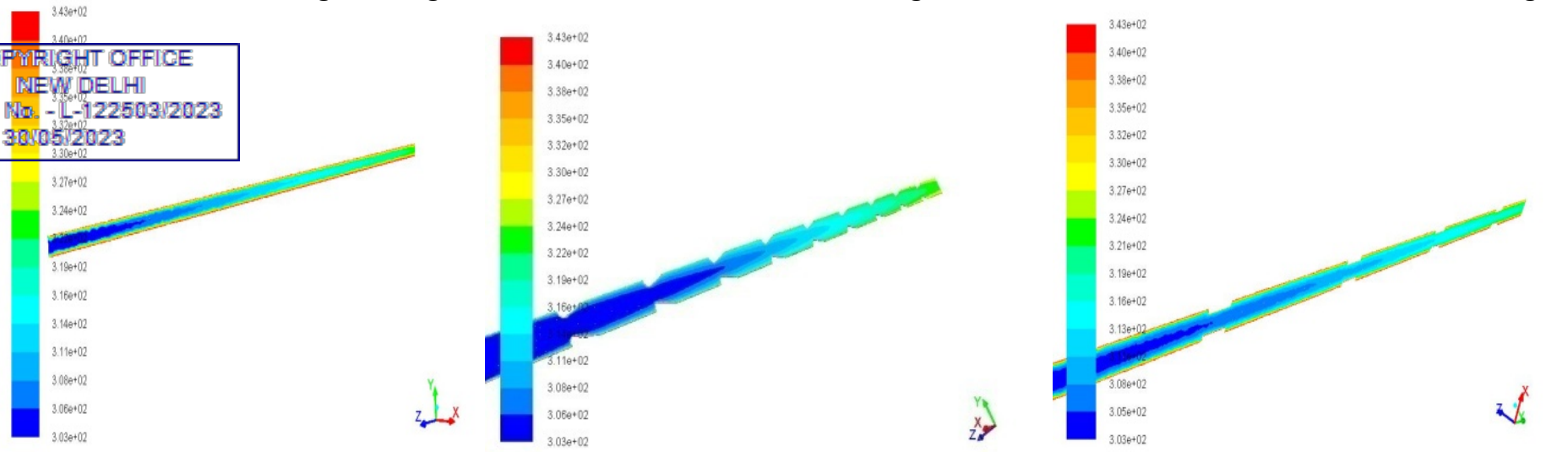
Contours of Static Temperature (k) Jan 17, 2015
ANSYS Fluent 14.5 (3d, dp, pbns, rke)



Signature

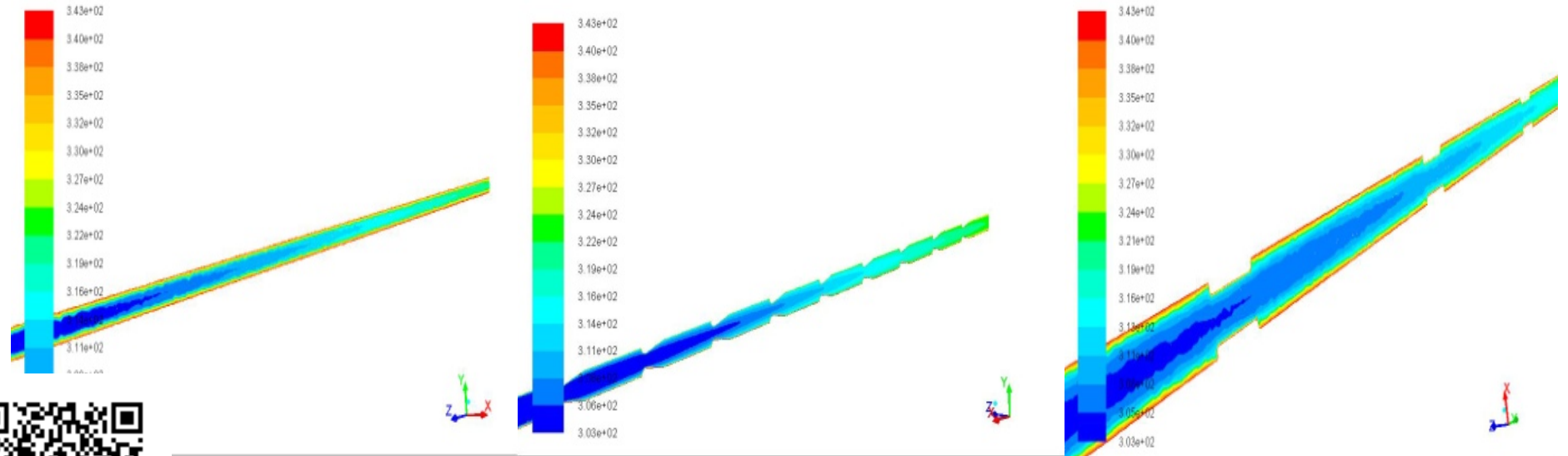
Case 2: For Plain tube, Align arrangement aerofoil inserts & Cross arrangement aerofoil insert at Mass flow rate: 0.001 kg/s


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Contours of Static Temperature (k)	Jan 17, 2015 ANSYS Fluent 14.5 (3d, dp, pbns, ske)	Contours of Static Temperature (k)	Jan 17, 2015 ANSYS Fluent 14.5 (3d, dp, pbns, rke)	Contours of Static Temperature (k)	Jan 22, 2015 ANSYS Fluent 14.5 (3d, dp, pbns, rke)
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Case 3: For Plain tube, Align arrangement aerofoil inserts & Cross arrangement aerofoil insert at Mass flow rate: 0.013 kg/s

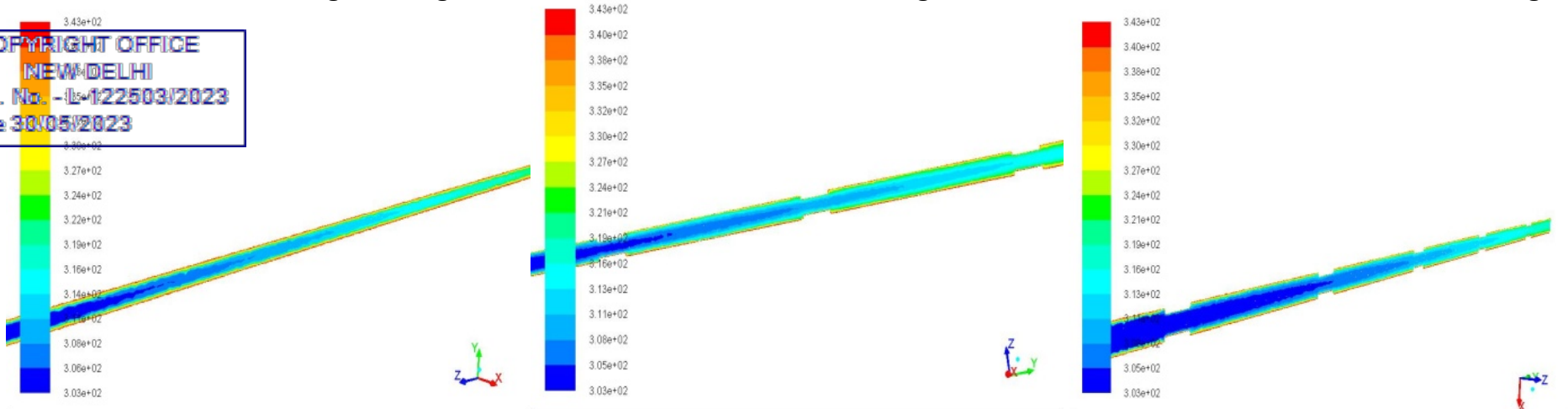


 Jan 17, 2015 ANSYS Fluent 14.5 (3d, dp, pbns, ske)	Contours of Static Temperature (k)	Jan 17, 2015 ANSYS Fluent 14.5 (3d, dp, pbns, rke)	Contours of Static Temperature (k)	Jan 22, 2015 ANSYS Fluent 14.5 (3d, dp, pbns, rke)
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Case 4: For Plain tube, Align arrangement aerofoil inserts & Cross arrangement aerofoil insert at Mass flow rate: 0.017 kg/s

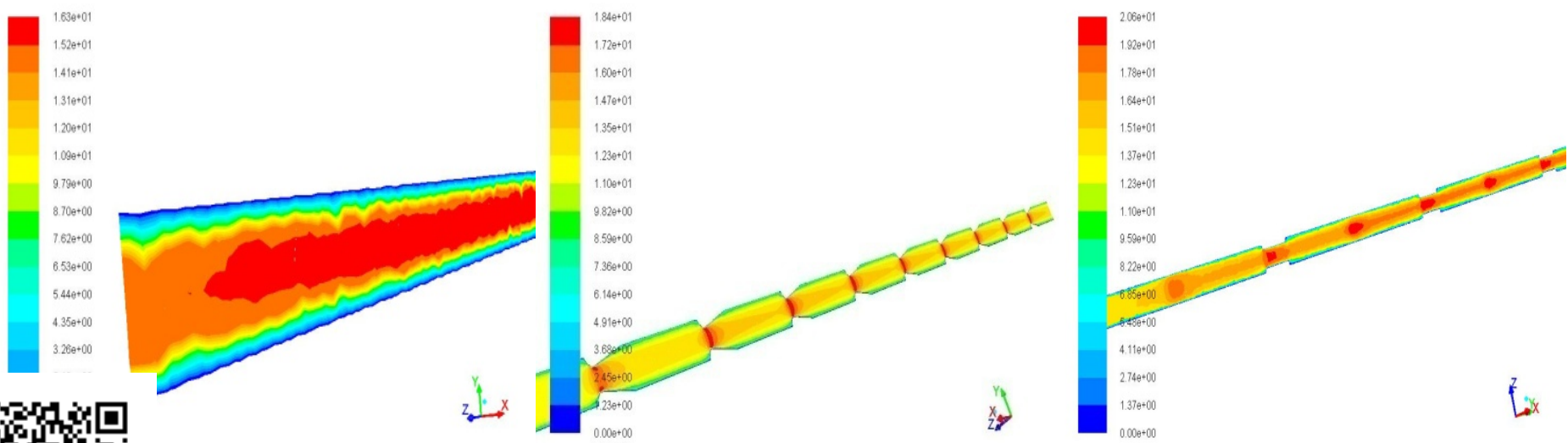
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Contours of Static Temperature (k) ANSYS Fluent 14.5 (3d, dp, pbns, ske) Jan 17, 2015	Contours of Static Temperature (k) ANSYS Fluent 14.5 (3d, dp, pbns, rke) Jan 22, 2015	Contours of Static Temperature (k) ANSYS Fluent 14.5 (3d, dp, pbns, rke) Jan 21, 2015
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Contours of Static Velocity:

Case 1: For Plain tube, Align arrangement aerofoil inserts & Cross arrangement aerofoil insert at Mass flow rate: 0.005 kg/s



Contours of Velocity Magnitude (m/s) ANSYS Fluent 14.5 (3d, dp, pbns, ske) Jan 17, 2015	Contours of Velocity Magnitude (m/s) ANSYS Fluent 14.5 (3d, dp, pbns, rke) Jan 17, 2015	Contours of Velocity Magnitude (m/s) ANSYS Fluent 14.5 (3d, dp, pbns, rke) Jan 22, 2015
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Signature

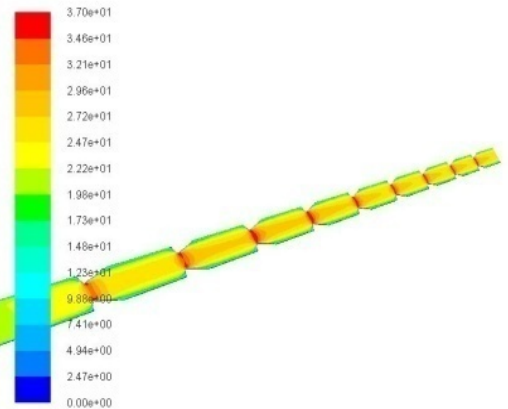
Case 2: For Plain tube, Align arrangement aerofoil inserts & Cross arrangement aerofoil insert at Mass flow rate: 0.001 kg/s

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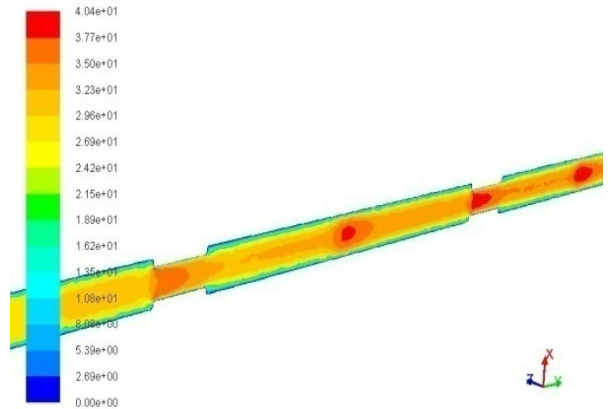
Contours of Velocity Magnitude (m/s)

Jan 17, 2015
ANSYS Fluent 14.5 (3d, dp, pbns, ske)



Contours of Velocity Magnitude (m/s)

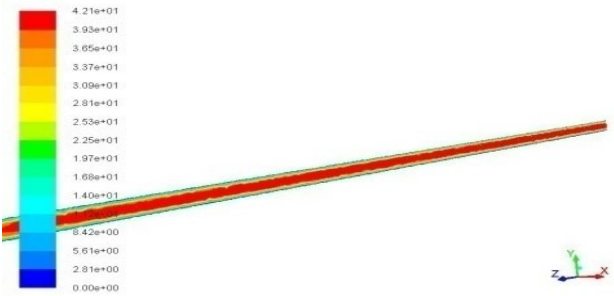
Jan 17, 2015
ANSYS Fluent 14.5 (3d, dp, pbns, rke)



Contours of Velocity Magnitude (m/s)

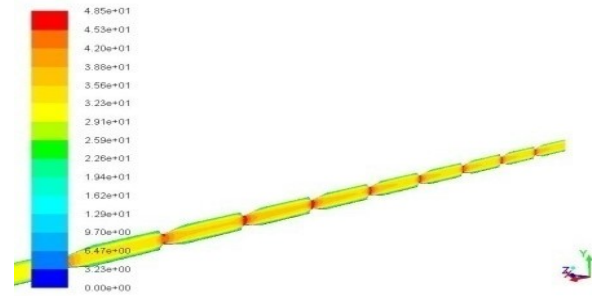
Jan 22, 2015
ANSYS Fluent 14.5 (3d, dp, pbns, rke)

Case 3: For Plain tube, Align arrangement aerofoil inserts & Cross arrangement aerofoil insert at Mass flow rate: 0.013 kg/s



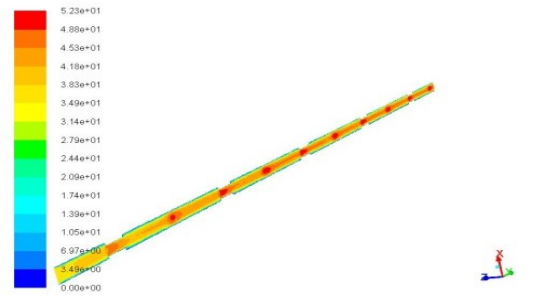
Contours of Velocity Magnitude (m/s)

Jan 17, 2015
ANSYS Fluent 14.5 (3d, dp, pbns, ske)



Contours of Velocity Magnitude (m/s)

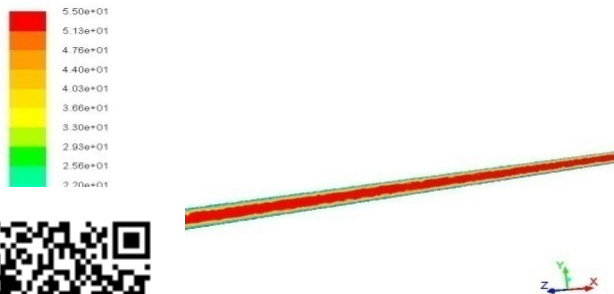
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ANSYS Fluent 14.5 (3d, dp, pbns, rke)



Contours of Velocity Magnitude (m/s)

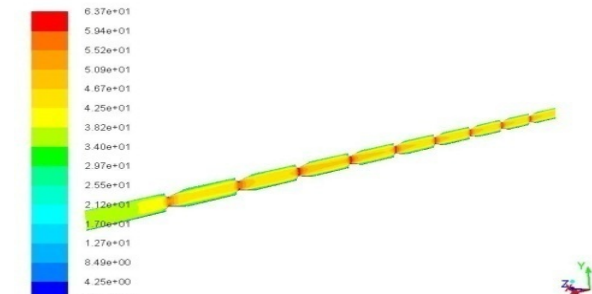
Jan 22, 2015
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Case 4: For Plain tube, Align arrangement aerofoil inserts & Cross arrangement aerofoil insert at Mass flow rate: 0.017 kg/s



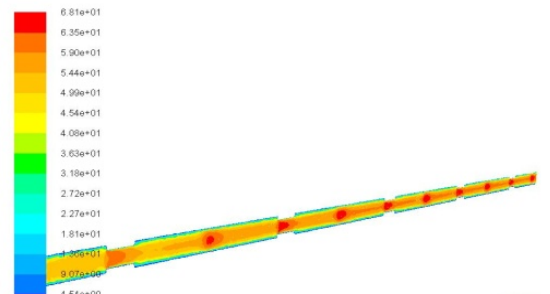
Contours of Velocity Magnitude (m/s)

Jan 17, 2015
ANSYS Fluent 14.5 (3d, dp, pbns, ske)



Contours of Velocity Magnitude (m/s)

Jan 17, 2015
ANSYS Fluent 14.5 (3d, dp, pbns, rke)



Contours of Velocity Magnitude (m/s)

Jan 21, 2015
ANSYS Fluent 14.5 (3d, dp, pbns, rke)



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Conclusions

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- This study focused on investigating whether the use of cross arrangement aerofoil inserts can enhance heat transfer characteristics for a annular channel were tested for four different Reynolds numbers ranging from 19000 to 68000 with experimentally and computationally .
- Results revealed that; average Nusselt Numbers and friction factors are considerably more with both arrangements i.e. cross and align of aerodynamic bead shape geometry inserts when compared to plain tube.
- Improvement of average Nusselt Numbers for tube with 5 to 20 % for cross arrangement of aerofoil insert & 16 to 35 % for align arrangement of aerofoil insert for four different Reynolds numbers ranging from 19000 to 68000 with respect to Plain Tube.
- The Cross arrangement & Align arrangement of aerodynamic bead shape geometries proved to give a better thermal performance than the plain tube. Also concluded that, align arrangement of aerodynamic bead shape is gives higher thermal performance as compares to cross arrangement in the cost of pressure drop.
- The pressure drop is considerably more with aerodynamic bead shape geometry with compared to plain tube; but cross arrangement of aerodynamic bead shape try gives minimize the pressure drop as compared to align arrangement of namic bead shape.



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- Similarly friction factor for plain tube is lower than aerodynamic bead shape geometry inserts in the tube. But results reveal that, if Reynolds number increases friction factor is decreasing.
- Average Enhancement efficiency $\eta = h/h_0$ is varied approximately in between 1 to 2 times with experimentally or computationally for four different Reynolds numbers ranging from 19000 to 68000 in cross arrangement as well as align arrangement of aerodynamic bead shape tube as compare with plain tube.
- The numerical computation provides reasonably good accuracy in predicting the heat transfer enhancement capability of the cross and aligns arrangements compared to the plain tube.
- Variations in experimental, computationally and Theo. values are because of manufacturing and measuring errors.



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Future Scope

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- CFD simulation is ongoing process of research that the present status of the system can be changed by having certain modification, improvement, innovation etc & it can be work with different geometries inserts as well as different Reynolds number & also can carry out the experimental studies to validate the present results.
- In the present work the geometrical changes are made configuration of aerodynamic shape arrangement.
 - For giving the maximum heat transfer enhancement with minimum pressure drop penalty it can be work with different test tube material.
 - Whereas the aerodynamic shape present in the tube are of uniform pitch and change the pitch ratio.
 - One can change the pitch ratio and elongated length of aerofoil shape to understand the behavior and influence of variations of aerodynamic shape geometries present on the circular tube.
 - Further work, part of this work will be by making efficient analysis of heat performance parameters, one can develop a correlation for the critical Reynolds number will derive for the circular tube with align and cross arrangement of dynamic bead shape geometry.
- friction factor f and Nusselt number Nu correlations will be derive with respect Reynolds number and geometric parameters.



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