

Experimental study of heat transfer enhancement of flowing water inside a circular tube having twisted tape insert

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ABSTRACT

Enhancing heat transfer surface are used in many engineering applications such as heat exchanger, air conditioning, chemical reactor and refrigeration systems ,hence many techniques have been investigated on enhancement of heat transfer rate and decrease the size and cost of the involving equipment especially in heat exchangers .One of the most important techniques used are passive heat transfer technique. These techniques when adopted in Heat exchanger proved that the overall thermal performance improved significantly. This project reviews experimental and numerical works taken by researchers on this technique such as twisted tape to enhance the thermal efficiency in heat exchangers and useful to designers implementing passive augmentation techniques in heat exchange. The twisted tape inserts are popular researched and used to strengthen the heat transfer efficiency for heat exchangers. Twisted tape inserts perform better in laminar flow than turbulent flow.

Keywords: Heat Exchanger, Enhancement of heat transfer, twisted tape, thermal efficiency

I.INTRODUCTION

Heat exchangers are used in different processes ranging from conversion, utilization & recovery of thermal energy in various industrial, commercial & domestic applications. Some common examples include steam generation, condensation in power & cogeneration plants, sensible heating & cooling in thermal processing of chemical, pharmaceutical & agricultural products, fluid heating in manufacturing & waste heat recovery etc. Increase in Heat exchanger's performance can lead to more economical design of heat exchanger which can help to make energy, material & cost savings related to a heat exchange process. The need to increase the thermal performance of heat exchangers, thereby effecting energy, material & cost savings have led to development & use of many techniques termed as Heat transfer Augmentation. These techniques are also

referred as Heat transfer Enhancement or Intensification. Augmentation techniques increase convective heat transfer by reducing the thermal resistance in a heat exchanger. Use of Heat transfer enhancement techniques lead to increase in heat transfer coefficient but at the cost of increase in pressure drop. So, while designing a heat exchanger using any of these techniques, analysis of heat transfer rate & pressure drop has to be done. Apart from this, issues like long term performance & detailed economic analysis of heat exchanger has to be studied. To achieve high heat transfer rate in an existing or new heat exchanger while taking care of the increased pumping power, several techniques have been proposed in recent years and are discussed in the chapter 3. Twisted tapes a type of passive heat transfer augmentation techniques have shown significantly good results in past studies.

II.LITERATURE REVIEW

1. M.M.K. Bhutiyaa, M.S.U. Chowdhury: This paper work deals with experimental investigations on Nusselt Number, friction factor, & thermal performance factor in a circular tube equipped with perforated twisted tape inserts. The conclusion of this paper is twisted tape inserts enhanced the heat transfer rate significant with corresponding increase in friction factor in comparison to the that of plain tube.

S Naga sarada, A.V Sita Rama Raju: This paper shows the result obtained from experimental investigations of augmentation of turbulent flow heat transfer in a horizontal tube by means of varying width twisted tape inserts with air as a working fluid. In this paper the effect of parameters such as modified twist ratio, Reynolds Number on the heat transfer & overall enhancement ratio are studied.

3 S. Liu, M. Sakr: This paper shows that twisted tape inserts platform better in laminar flow than turbulent flow. In these papers other several passive techniques of enhancement of heat transfer such as ribs, conical nozzle, & conical rings etc are explained.

4. V. Vivek, L. viveknath & N. Vinayagam: In this hydraulic experimental facility is provided for measurement of pressure drop & heat transfer coefficient in water flowing through a cylindrical annulus with single & double start helical tapes.

5. M.M. K Bhutiya , A.S. M Sayenetc : This paper based on an experimental study on to investigate the air flow friction & heat transfer characteristics in a circular tube fitted with double counter twisted tube inserts of different twist ratio for turbulent regime. The use of double counter twisted tape inserts provided significant augmentation of heat transfer by causing a high pressure drop increase. The Nusselt Number & friction factor for the tube with double counter twisted tape inserts obtained higher than those of plain tube values at the comparable Reynolds number respectively.

6. Jianet al.: proposed a center-cleared twisted tape aiming at achieving good thermo hydraulic performance. A comparative study between this type and the short-width twisted tape was performed numerically in laminar tubular flows. The computation results demonstrated that the flow resistance can be reduced by both methods; however, the thermal behaviors are very different from each other. For tubes with short width twisted tapes, the heat transfer and thermo hydraulic performance are weakened by cutting off the tape edge. Contrarily, for tubes with center-cleared twisted tapes, the heat transfer can be even enhanced in the cases with a suitable central clearance ratio. The thermal performance factor of the tube with center-cleared twisted tape can be enhanced by

7-20% as compared with the tube with conventional twisted tape. All these demonstrated that the center-cleared twisted tape is a promising technique for laminar convective heat transfer enhancement.

2. Nomenclature

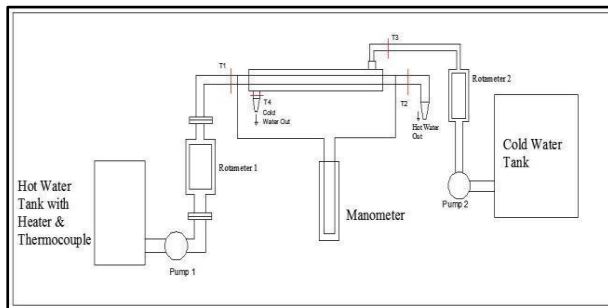
Table 1- Nomenclature

Sr. No	Nomenclature	Description	Sr. No	Nomenclature	Description
1	A	Heat transfer surface area, m ²	11	P	Pressure of flow in stationary tube, Pa
			12	ΔP	Pressure drop, N/m ²
2	C _p	Specific heat of fluid J/Kg.°C	13	Pr	Prandtl number = $\mu C_p / k$, Dimensionless
3	D _i	Inside diameter of the test tube, m	14	Q	Heat transfer rate, W
			15	Re	Reynolds number = $(\rho \times v \times d_i) / \mu$, Dimensionless
4	f	friction factor = $(\Delta p \times d_i) / (2 \times L \times \rho \times v^2)$, Dimensionless	16	R ₁	Performance evaluation criteria based on constant flow rate, Dimensionless
5	h	Convective Heat Transfer Coefficient, W/m ² -K Length of the test	17	T	Temperature, °C
			18	v	velocity of fluid, m/s
			20	Q _h	Volumetric flow rate of hot water, m ³ /s
6	K	Thermal Conductivity W/m-K	21	Q _c	Volumetric flow rate of cold water, m ³ /s
7	L	Length of the test section, m			
9	M	Mass flow rate, kg/s			
10	Nu	Nusselt number = $h d_i / k$, Dimensionless			

III. EXPERIMENTATION

Convective heat transfer through pipe is studied by inserting surfaces roughness parameter such as twisted tapes, internal fins etc. it is seen from literature review that twisted tape is of prime importance which affects the heat transfer through wall of pipe for carrying out the experimental work on the twisted tapes, test section, expt. Setup used is as shown in below.

3.1 Experimental set up

**Fig.1.Schematic Diagram of Experimental****Fig.2.Actual set up of Experiment****Tube in Tube Heat Exchanger:-**

Development of the test section is the main task of dissertation work. Here Copper tube is used at the inner side of test section having 1500 mm length and 25.4mm inside dia. At the outer side G.I pipe is used having 1500mm length and 52 mm inner dia. &at the one end of outer pipe opening for cold water and at the opposite end outlet of cold water is provided.

Pumps:-

Two centrifugal pumps are used in the experimental setup for circulating hot water from inner side of tube and other pump is used for circulating cold water at annulus side. Pumps have 0.5 HP capacities. The other specifications are as follow.

- 110 Volt, 60 Hz, 2.75 Amp
- Single Phase Motor ,1/2 HP Motor, 3400 RPM, Flow: 650 (GPH)
- Pump Inlet: 1" NPT, Pump Outlet: 1" NPT, 4-1/2" W x 5-1/2" H x 10" L
- Max Total Head: 110 Feet, Max Suction Lift: 20 Feet
- Manufactures- LAKSHMI PUMPS.

Rotameters:-

It is basically a Variable Area Meter, exactly reverse of Orifice Plate. The annular area created between the heat transfer enhancement of flowing water inside a circular tube having twisted tape insert edge of float and the edge of glass tube varies due to taper shape of the glass tube. The position of the float in the tapered glass tube varies because of the flow and it indicates the flow rate. Two rotameters are taken one for to measure cold water flow rate and other for hot water flow measurement the Range of rotameters are as 150 LPH to 1500 LPH (both).The used rotameters are manufactured by CVG TECHANOCRAFTS INDIA, MUMBAI.

Manometer:-

One manometer is used. It is U-tube manometer. The U tube manometer is filled with the carbon tetra chloride (CCl_4) as a manometric fluid. It is used to measure the pressure drop. Across inner tube of heat exchanger (test section).Flexible pipe is used to connect the limbs of manometer with the nipples of the pipe.

PT-100 RTD Sensors:-

PT 100 RTD sensors are used to temperature measurements. Four numbers of RTD-sensors used to measure inlet and outlet hot& cold water temperature. These are supplied by Sensography Company.

It is used for controlling temperature of hot water by using heater and temperature indicator circuit.

Specifications of twisted tapes:-

Table 2. Specifications of twisted tapes

Sr. No.	Width(mm)	Pitch(mm)	Length(mm)	Material
1	10	25	1500	M.S.
2	12	36	1500	M.S.
3	14	49	1500	M.S.

Sr. No	Qc LPH	Qh LPH	Temperature in C				Press ure drop in mm
			Outer Fluid (cold)		Inner Fluid (Hot)		
			Inlet T1	Outlet T2	Inlet T1	Outlet T2	
1	1050	240	31.1	31.9	31.1	44. 3	9
2	1050	312	31.1	32.1	31.1	44. 6	14
3	1050	384	31.1	32.3	31.1	44. 8	20
4	1050	456	31.1	32.4	31.1	45. 1	28
5	1050	528	31.1	32.5	31.1	45. 2	37
6	1050	600	31.1	32.6	31.1	45. 4	47
7	1050	672	31.1	32.5	31.1	45. 7	58
8	1050	744	31.1	32.4	31.1	46	65

Sr. No	Qc LPH	Qh LPH	Temperature in C				Pressure drop in mm
			Outer Fluid (cold)		Inner Fluid (Hot)		
			Inlet T1	Outlet T2	Inlet T1	Outlet T2	
1	1050	240	31.1	32	31.1	43. 8	10
2	1050	312	31.1	32.	31.1	44.	16

				1		1	
3	1050	384	31.1	32. 4	31.1	44. 4	25
4	1050	456	31.1	32. 6	31.1	44. 5	35
5	1050	528	31.1	32. 5	31.1	44. 9	46
6	1050	600	31.1	32. 4	31.1	45. 2	59
7	1050	672	31.1	32. 7	31.1	45. 4	73
8	1050	744	31.1	32. 4	31.1	45. 9	74

Sr. No	Qc LPH	Qh LPH	Temperature in C				Pressure drop in mm
			Outer Fluid (cold)		Inner Fluid (Hot)		
			Inlet T1	Outlet T2	Inlet T1	Outlet T2	
1	1050	240	31.1	31.9	31.1	44. 2	9
2	1050	312	31.1	32	31.1	44. 4	15
3	1050	384	31.1	32. 2	31.1	44. 8	23
4	1050	456	31.1	32. 4	31.1	44. 7	32
5	1050	528	31.1	32. 5	31.1	45. 1	33
6	1050	600	31.1	32. 4	31.1	45. 4	55
7	1050	672	31.1	32. 6	31.1	45. 4	68
8	1050	744	31.1	32.	31.1	45.	76

				5		8	
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Table 3- Observation table for Plain Tube

Sr. No	Qc LPH	Qh LPH	Temperature in C				Pressure drop in mm
			Outer Fluid (cold)		Inner Fluid (Hot)		
			In let T 1	Outlet T2	Inlet T1	Outlet T2	
1	1050	240	31 .1	31.9	31.1	44. 3	8
2	1050	312	31 .1	32. 1	31.1	44. 5	14
3	1050	384	31 .1	32. 2	31.1	44. 8	2
4	1050	456	31 .1	32. 3	31.1	44. 9	29
5	1050	528	31 .1	32. 4	31.1	45. 1	38
6	1050	600	31 .1	32. 4	31.1	45. 4	45
7	1050	672	31 .1	32. 5	31.1	45. 6	60
8	1050	744	31 .1	32. 6	31.1	45. 7	68

Table4. Observation table for typical twisted tape having (y/w=2.5)

VI.METHODOLOGY

- To heat the water heater is put on 48°C in a constant temperature water tank of capacity 120litres. The tank is provided with a centrifugal pump & a bypass valve for recirculation of hot water to the tank & to the experimental setup.
- To pass hot water at 48°C through the tube side of heat exchanger at desired flow rate.`
- To pass the cold water through the annulus side of heat exchanger in counter current direction at a 1050 LPH..

d) To record the water inlet and outlet temperature for both hot water & cold water and surface temperatures only after temperature of both the fluids attains a constant value.

e) To record the manometer reading

f) To repeat the procedure for different hot water flow rates ranging from 240LPH TO 744 LPH and at temperature (48°C).

VII. DATA DEDUCTION

1. Input temperature of Hot water $T_{hi} = 48.0^\circ\text{C}$
2. Output temperature of Hot water $T_{ho} = 44.30^\circ\text{C}$ Temperature of air $T_m = (T_i + T_o)/2$ OK
3. Bulk Mean Temperature of Hot water $T_b = (T_{hi} + T_{ho})/2$ $\Delta T_s = (T_s - T_m)$
4. Density $(\rho) = M/V$
5. Discharge of water $(Q) = (\text{Mass flow rate Kg/s})/\text{Density}(\rho)$ $Re = \rho V D h / \mu$
6. Mass flow rate $m \text{ (Kg/s)} = \text{Density}(\rho) \times \text{Discharge} (Q)$
7. Velocity of Hot water $(v) = \text{Discharge } Q / \text{Area of inner pipe}$
8. Reynolds Number $(Re) = (\rho \times v \times d_i) / \mu$
9. Prandtl Number $Pr = (\mu \times C_p) / k$
10. Nusselt Number $(Nu) = (h_{inner} \times d_i) / k$

VIII. RESULT AND DISCUSSION

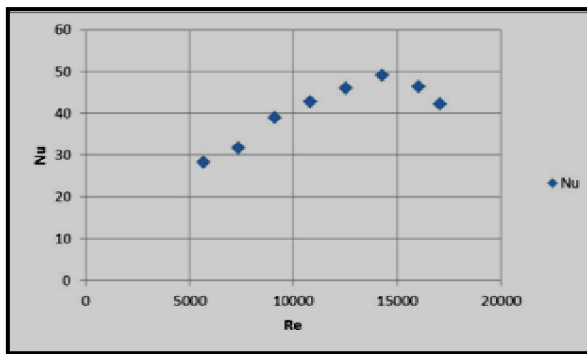
Effect of different Reynolds numbers on the Nusselt's Number, pressure drops and performance evaluation criteria R1 are studied. These parameters are considered for plain tube, typical twisted tube, and straight twisted tapes with different twist ratio. Then the comparative study was carried out. Graph 1, 2, 3 & 4 shows variation of Nusselt Number with Reynolds Number for plain tube as well as tube with typical twisted tapes. At given Reynolds Number, the Nusselt number consistently increases with in twist ratio. In graph 1 it is observed that Nusselt number for plain tube increases with Reynolds number. In Graph 2, it is observed that the Nusselt number for typical twisted tape having twist ratio of 2.5 is slightly different in trends compare with Graph1.

Friction Factor Results:- Graph 5, 6, 7, and 8 show variation of friction factor with Reynolds number for plain tube & typical twisted tapes having twist ratio of 2.5, 3 & 3.5. As found the friction factor increases with decreasing twist ratio (y/w). Because twisted tape with shorter twist length provides longer flowing path, resulting in larger tangential contact between flowing stream and tube surface. Therefore loss due to friction increases.

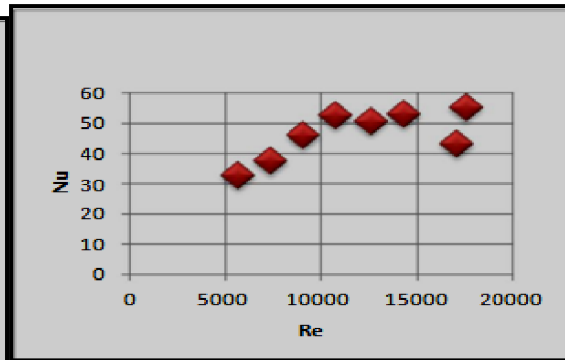
Nusselt Number Results:

Graph1:- Nu vs. Re for plain tube

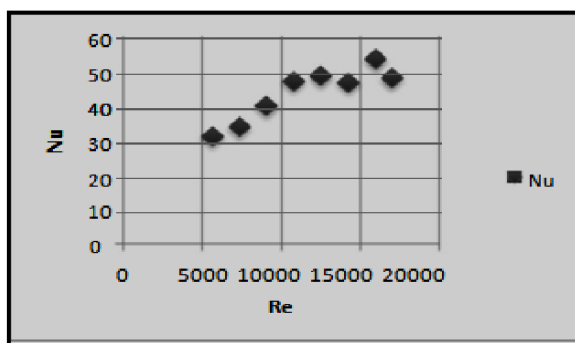
Graph2:- Nu vs. Re for Typical Twisted
Tape having ($y/w=2.5$)



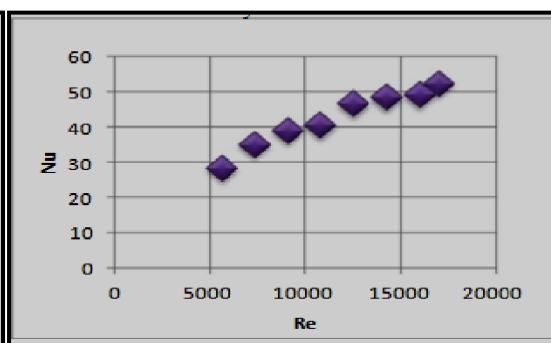
Graph3: Nu vs. Re for Typical Twisted Tape Having (y/w=3)



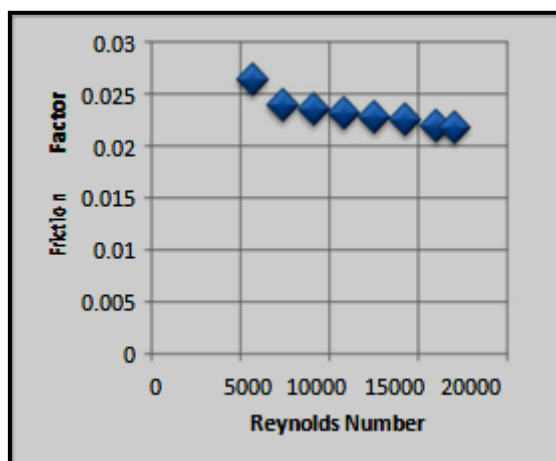
Graph4: Nu vs. Re for Typical Twisted Tape Having (y/w=3.5)



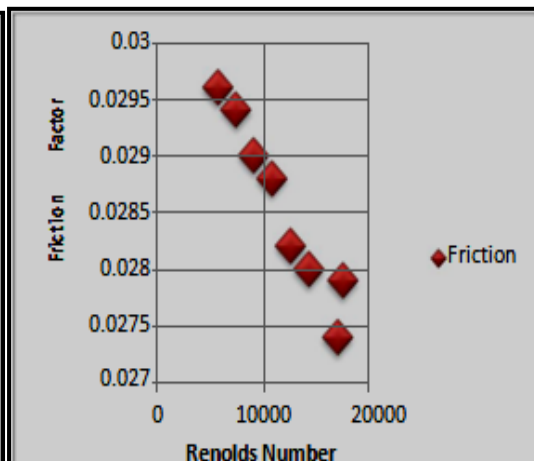
Graph 5- Friction Factor Vs Reynolds Number for Plain Tube



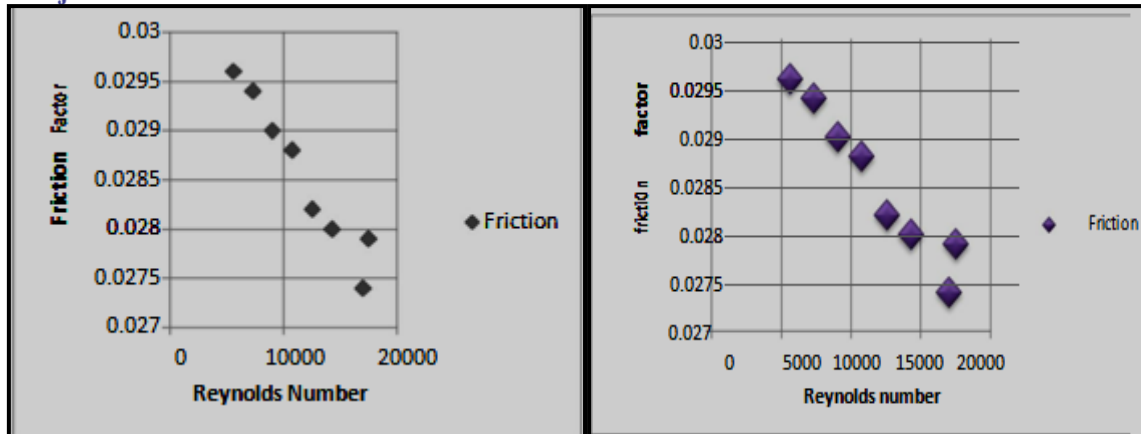
Graph7-Friction Factor Typical Twisted Tape having (y/w=2.5)



Graph8-Friction Factor Typical Twisted Tape having (y/w=3)



Graph8-Friction Factor Typical Twisted Tape having (y/w=3.5)



IX. CONCLUSION

The effects of the Typical Twisted tapes (TT) on the heat transfer enhancement and friction factor behaviors in turbulent flow regimes ($5000 \leq Re \leq 17,100$) are described. The Typical twisted tape, twisted tapes with different twist ratio ($y/w=2.5, 3$ and 3.5) are tested using the water as the working fluid. The conclusions are drawn as follows:

1. With decrease in twist ratio, Nusselt's Number increases but at the same time pressure drop also increases.
2. For higher twist ratio, show greater Nusselt's Number,
3. Heat transfer coefficient and friction factor than the lower twist ratio, because of higher degree of turbulence generated.
4. In a heat exchanger, while the inserts can be used to enhance the heat transfer rate, they also bring in an increase in the pressure drop. When the pressure drop increases, the pumping power cost also increases, thereby increasing the operating cost. So depending on the requirement, one of the above mentioned inserts can be used for heat transfer augmentation.

5.2.1 Friction Factor Results

All Pressure drop and friction factor results values are tabled in the tables 5.5 to 5.8

Table Error! No text of specified style in document..1- For plain tube

Sr.No	Qh LPH	mh (kg/sec)	Δh (m)	$\Delta P(N/m^2)$	F	Re
1	240	0.0659	0.009	53.41	0.0264	5653.0305
2	312	0.0857	0.014	82.06	0.024	7363.1325
3	384	0.1055	0.02	122.21	0.0236	9086.3047
4	456	0.1253	0.028	169.32	0.0232	10795.8861
5	528	0.1451	0.037	223.31	0.0228	12527.2348
6	600	0.1649	0.047	285.69	0.0226	14267.3974
7	672	0.1847	0.058	348.9	0.022	16007.3048
8	744	0.2045	0.065	390.262	0.0218	17020.7517

Table Error! No text of specified style in document..2-Typical Twisted Tape having ($y/w=2.5$)

Sr.No	Qh LPH	mh (kg/sec)	Δh (m)	$\Delta P(N/m^2)$	F	Re
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1	240	0.06598	0.01	59.898	0.0296	5633.392
2	312	0.0857	0.016	100.536	0.0294	7340.803
3	384	0.1055	0.025	150.19	0.029	9056.552
4	456	0.1253	0.035	210.21	0.0288	10760.545
5	528	0.1451	0.046	276.18	0.0282	12579.03
6	600	0.1649	0.059	353.93	0.028	14302.82
7	672	0.1846	0.073	442.46	0.0279	17523.39
8	744	0.1962	0.074	490.47	0.0274	17039.84

Table Error! No text of specified style in document..3-For Typical Twisted Tape having (y/w=3)

Sr.No	Qh LPH	mh (kg/sec)	Δh (m)	ΔP (N/m ²)	F	Re
1	240	0.06598	0.009	59.898	0.0296	5633.392
2	312	0.0857	0.015	100.536	0.0294	7340.803
3	384	0.1055	0.023	150.19	0.029	9056.552
4	456	0.1253	0.032	210.21	0.0288	10760.545
5	528	0.1451	0.033	276.18	0.0282	12579.03
6	600	0.1649	0.055	353.93	0.028	14302.82
7	672	0.1846	0.068	442.46	0.0279	17523.39
8	744	0.1962	0.076	490.47	0.0274	17039.84

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