Experimental analysis of convective heat transfer in divergent channel

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Abstract- Many heat transfer enhanced techniques have simultaneously been developed for the improvement of energy consumption, material saving, size reduction and pumping power reduction. The effect of divergent channels is a good way to promote the flow mixing in channel flow. When if we use divergent channel then we get flow difference means low pressure drop it is also called pressure recovery. By using bump in the divergent channel it can help us to increase the heat transfer enhancement and bump surface present the highest performance of the heat transfer enhancement. The bump surface act as extended surface (fin surface) and the main purpose of extended surface to increase the heat transfer rate. The advantages of the divergent channel with internal Bumps are fluid mixing is more as compared to cylindrical pipe, pressure drop is less and boundary layer separation occurs as well as the heat transfer coefficient increases 25 to 35 % as compare to plain divergent channel. where inserts are used in the flow passage to intensify the heat transfer rate, are advantageous compared with active techniques, because the insert manufacturing process is simple and these techniques can be easily employed in an existing heat exchanger.

Keywords -Heat transfer enhancement, Divergent channel, Bump, Heat transfer rate, Heat transfer coefficient.

I INTRODUCTION

The development of high performance thermal systems has stimulated interest in methods to improve heat transfer. The study of improved heat transfer is referred to as heat transfer enhancement or intensification. The performance of conventional heat exchanger can be substantially improved by a number of enhancement techniques. A great deal of research effort has been devoted to developing apparatus and performing experiments to define the conditions under which an enhancement technique will improve heat transfer. Heat transfer enhancement technology has been widely applied to heat exchanger applications in refrigeration, automobile, process industries etc. The goal of enhanced heat transfer is to encourage or accommodate high heat fluxes. That result in reduction of heat exchanger size, which generally leads to less capital cost. Another advantage is the reduction of temperature driving force, which reduces the entropy

Generation and increases the second law efficiency. In addition, the heat transfer enhancement enables heat exchangers to operate at smaller velocity, but still achieve the same or even higher heat transfer coefficient. This means that a reduction of pressure drop, corresponding to less operating cost, may be achieved.

Use of divergent channel:

In the divergent channel, the plumes produced are greater and not stable. In addition, the acceleration of flow can effectively lead to the local increase of Gr/Re. Therefore, stronger interaction with the neighboring plumes and vortices are observed and form a complicated flow structure. This leads to a greater enhancement in the heat transfer.

In the convergent channel, it is on the contrary. The acceleration of flow can effectively lead to the local decrease of Gr/Re. The plumes produced are smaller and stable. No interactions between plumes are found. This leads a less enhancement in the heat transfer. However, the deceleration flow in the divergent channel and the acceleration in the convergent make the average Nusselt numberS approach the results of the parallel plate channel, especially when the Reynolds number is higher.

We used divergent channels for heat transfer because of it is a good way to promote the flow mixing in channel flow also if use divergent channel then we get flow difference means low pressure drop it is also called pressure recovery also the new concept we using bumps in the divergent channel it can help us to increase the heat transfer enhancement and bump surface present the highest performance of the heat transfer enhancement. The Bumps surface it can also called as artificial surface act as extended surface (fin surface) and the main purpose of extended surface to increase the heat transfer rate. The advantages of the divergent channel with internal bumps are fluid mixing is more as compared to cylindrical pipe, pressure drop is less and boundary layer separation occurs in divergent channel which will help in heat transfer.

All these advantages have made heat transfer enhancement technology attractive in heat exchanger applications. For shell and tube heat exchangers, the tube insert technology is one of the most common heat transfer enhancement technologies, particularly for the retrofit situation. With tube insert technology, additional exchangers can often be avoided and thus significant cost saving becomes possible. Furthermore as a heat exchanger becomes older, the resistance to heat transfer increases owing to fouling or scaling. These problems are more common for heat exchangers used in chemical industries and marine applications. In this case the heat transfer rate can be improved by introducing a disturbance in the fluid flow by different enhancement technologies (breaking the viscous and thermal boundary layer).

Wang.L.H, Tao.W.Q, Wang.Q.W, Wong.T.T, et al.-[1] Many heat augmentation techniques has been reviewed, these are (a) surface roughness, (b) plate baffle and wave baffle, (c) perforated baffle, (d) inclined baffle, (e) porous baffle, (f) corrugated channel, (g) twisted tape inserts, (h) discontinuous Crossed Ribs and Grooves. Most of these enhancement techniques are based on the baffle arrangement. Use of Heat transfer enhancement techniques lead to increase in heat transfer coefficient but at the cost of increase in pressure drop.

Sivakumar, K., Natarajan, E., Kulasekharan, N, et al.-[2] Thermal characteristics were tested by measuring wall temperature at selected locations, fluid temperature at the inlet and the outlet and wall static pressures at the channel inlet and the outlets.

Soo Wban Abn and Kang Pil Son, et al.-[3] found that the heat transfer can be enhanced by the use of rough surfaces. Four different shapes such as semicircle, sine wave, trapezoid, and arc were suggested to investigate the heat transfer enhancement and friction factor on rectangular duct.

C. Bi, G.H. Tang, W.Q. Tao, et al.-[4] The convective cooling heat transfer in mini-channels with dimples, cylindrical grooves and low fins is numerically studied by using the field synergy principle.

Dr. Mohammed Najm Abdullah, et al.-[5] the aim of this study is to investigate the heat transfer and pressure drop characteristics in an Eccentric Converging-Diverging Tube (ECDT) with twisted tape inserts. Experiments were conducted with tape inserts of three different twist ratios. Cold and hot water are used as working fluids in shell and tube sides, respectively. The effect of the twist ratio and other parameters on heat transfer characteristics and pressure drop are considered.

Pradip Ramdas Bodade, et *al*,[06] identified overheating can damage the system components and lead to failure of the system. The excessive heat so generated must be dissipated to surroundings to avoid such problems for smooth functioning of system. This is especially important in cooling of gas turbine blades, process industries, cooling of evaporators, thermal power plants, air conditioning equipment's, radiators of space vehicles and automobiles and modern electronic equipment's. In order to overcome this problem, thermal systems with effective emitters such as ribs, fins, baffles etc. are desirable. The need to increase the thermal performance of the systems, thereby affecting energy, material and cost savings has led to development and use of many techniques termed as "Heat transfer Augmentation". This technique is also termed as "Heat transfer Enhancement" or "Intensification". Augmentation techniques increase convective heat transfer by reducing the thermal resistance in a heat exchanger. Many heat augmentation techniques has been reviewed, these are (a) surface roughness, (b) plate baffle and wave baffle, (c) perforated baffle, (d) inclined baffle, (e) porous baffle, (f) corrugated channel, (g) twisted tape inserts, (h) discontinuous Crossed Ribs and Grooves. Most of these enhancement techniques are based on the baffle arrangement. Use of Heat transfer enhancement techniques lead to increase in heat transfer coefficient.

However, all of the above techniques will inevitably bring too much flow resistance, resulting in unnecessary power consumption. An effective method of heat transfer enhancement is required to not only improve the heat transfer greatly, but also minimize the flow resistance as much as

Possible. Recently, an effective method called dimple surface has been investigated in the literature, and all of the studies have proved that the dimple surface can significantly enhance the heat transfer without bringing too much flow resistance.

In order to improve the heat transfer efficiency and operation safety of heat transfer equipment's, many techniques have been proposed such as treated surfaces, rough surfaces, extended surfaces, swirl flow devices, shaped pipes, surface tension devices, mechanical aids, electrostatic fields, suction or injection. Most of these techniques are usually applied in macro-channels. However, all of the above techniques will inevitably bring too much flow resistance, resulting in unnecessary power consumption. An effective method of heat transfer enhancement is required to not only improve the heat transfer greatly, but also minimize the flow resistance as much as possible. Recently, an effective method called dimple surface has been investigated in the literature, and all of the studies have proved that the dimple surface can significantly enhance the heat transfer without bringing too much flow resistance.

In this project we are using divergent channels for heat transfer because of it is a good way to promote the flow mixing in channel flow also if use divergent channel then we get flow difference means low pressure drop it is also called pressure recovery also the new concept we using bumps in the divergent channel it can help us to increase the heat transfer enhancement and bump surface present the highest performance of the heat transfer enhancement. The Bumps surface it can also called as artificial surface act as extended surface (fin surface) and the main purpose of extended surface to increase the heat transfer rate. The advantages of the divergent channel with internal bumps are fluid mixing is more as compared to cylindrical pipe, pressure drop is less and boundary layer separation occurs in divergent channel which will help in to increase heat transfer rate.

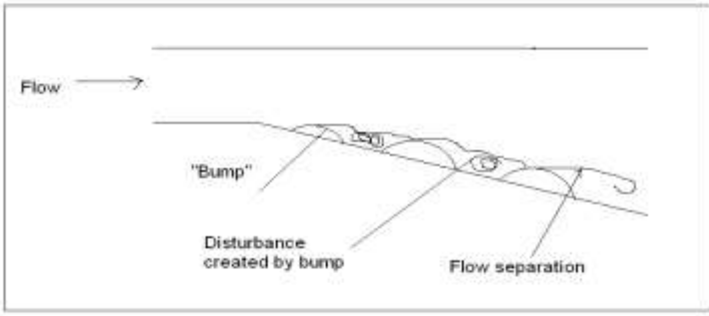


Figure .1 Creation of Disturbances in the flow

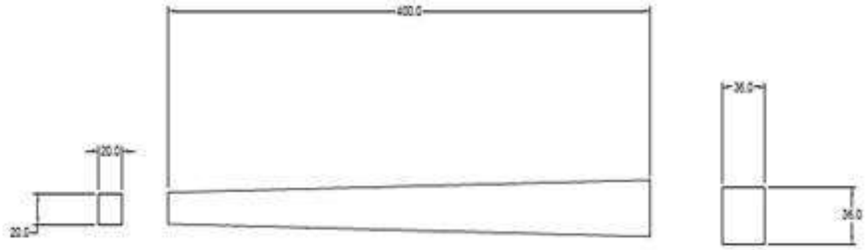


Figure 2Divergent Channel

II EXPERIMENTAL SETUP

Readings can be displayed in Pascal over the whole measurement range. Magnets at the back of the instrument enable hands-free operation, for instance, while adjusting gas heaters. Figure shows the Experimental set up of forced convection using divergent duct instead of cylindrical pipe. Divergent channel are used where pressure difference required is relatively small. The main advantage of divergent tube over cylindrical pipe is that the divergent tube has greater area than the cylindrical pipe and in divergent tube fluid mixing is proper between the flow passages. Divergent channel is suitable for wide range of Reynolds number because it posses greater amount of turbulence and to improve the heat transfer rate we can apply the passive techniques i.e., by inserting ribs, bumps, fin etc. and if turbulence in flow is more then it helps to improve the contact of air with heated pipe and this phenomena helps to improve heat transfer rate. Heat transfer rate increases with increase in internal area of channel. Also in this project to measure velocity of air inside the tube and to measure pressure, air density directly on this device. The name of this device is Testo 510 (Pressure Sensor Device). The differential pressure meter is ideally suitable for pressure measurements in the range 0 to 100 hPa. Testo 510's differential pressure measurement is temperature-compensated for accurate readings.

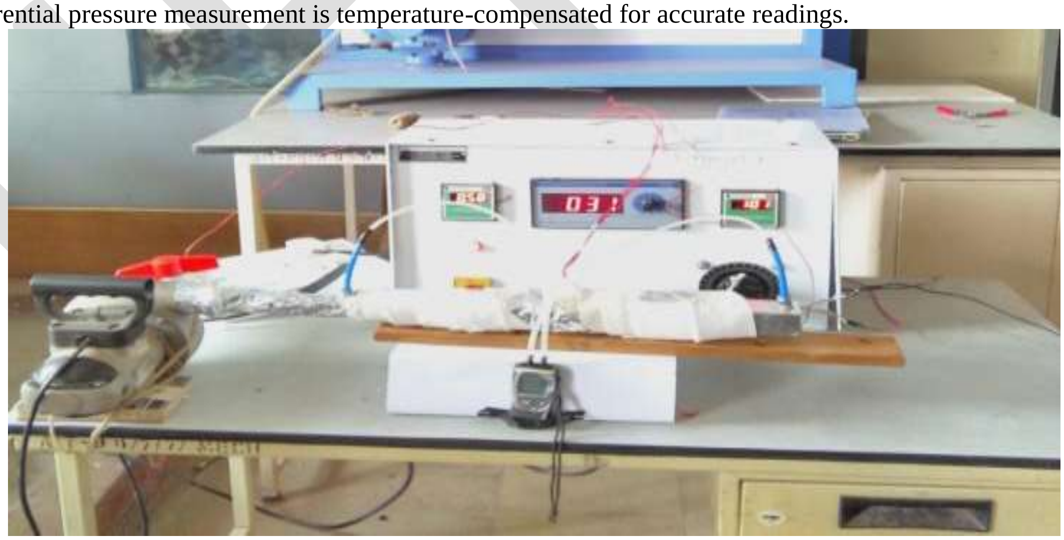


Figure.3 Experimental set up

III DATA REDUCTION

The data reduction of the measured results is summarized in the following procedures:
The local heat transfer coefficient was calculated from the total net heat transfer rate and the difference of the local wall temperature and the local bulk mean air temperature.

$$h = \frac{qa}{As(Ts - Ta)} \qquad (1)$$

$$Nu = \frac{h \times L}{K} \qquad (2)$$

As for most cases of the internal convection heat transfer, the fluid properties are evaluated at the mean temperature of the fluid in the duct. The Reynolds number was defined by

$$Re = \frac{\rho V L}{\mu} \qquad (3)$$

$$V = \frac{Q}{Ac} \qquad (4)$$

IV OBSERVATION TABLES

Sr No	Voltage [V] (Volts)	Current [I] (Amps)	Temperature in °c						Velocity [m/s]	Mass flow rate Kg/sec
			T_{in}°C	T_1°C	T_2°C	T_3°C	T_4°C	T_{out}°C		
1	60	0.35	28	63	64	66	65	38	10	0.00874
2	60	0.35	28	55	57	59	55	37	15	0.01312
3	60	0.35	28	45	46	48	47	34	20	0.01749
4	60	0.35	28	43	45	46	44	33	25	0.02187
5	60	0.35	28	38	39	41	40	32	30	0.02624

Table: 1 Divergent channel without Bumps

Sr No	Voltage [V] (Volts)	Current [I] (Amps)	Temperature in °c						Velocity [m/s]	Mass flow rate Kg/sec
			T_{in}°C	T_1°C	T_2°C	T_3°C	T_4°C	T_{out}°C		
1	60	0.35	28	51	54	56	52	36	10	0.00874
2	60	0.35	28	40	41	43	42	33	15	0.01312
3	60	0.35	28	37	38	40	39	32	20	0.01749
4	60	0.35	28	36	37	38	36	32	25	0.02187
5	60	0.35	28	35	36	37	35	31	30	0.02624

Table:2Divergent channel with Bumps

Sr No	Voltage [V] (Volts)	Current [I] (Amps)	Temperature in °c						Velocity [m/s]	Mass flow rate Kg/sec
			T_{in}°C	T_1°C	T_2°C	T_3°C	T_4°C	T_{out}°C		

1	100	0.58	28	65	68	72	66	37	10	0.00874
2	100	0.58	28	56	58	63	59	38	15	0.01312
3	100	0.58	28	49	54	55	51	35	20	0.01749
4	100	0.58	28	45	46	49	48	33	25	0.02187
5	100	0.58	28	41	43	45	44	33	30	0.02624

Table:3Divergent channel without Bumps

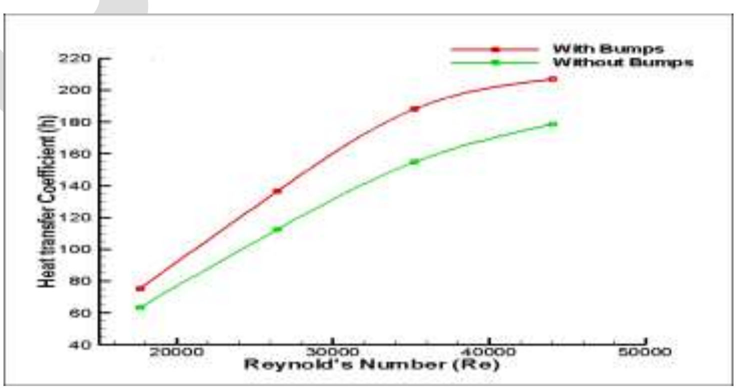
Sr No	Voltage [V] (Volts)	Current [I] (Amps)	Temperature in °c						Velocity [m/s]	Mass flow rate Kg/sec
			T_{in}°C	T_1°C	T_2°C	T_3°C	T_4°C	T_{out}°C		
1	100	0.58	28	56	60	63	58	37	10	0.00874
2	100	0.58	28	48	53	55	49	36	15	0.01312
3	100	0.58	28	43	45	47	46	34	20	0.01749
4	100	0.58	28	38	40	43	42	32	25	0.02187
5	100	0.58	28	37	39	40	39	32	30	0.02624

Table 4.Divergent channel with Bump

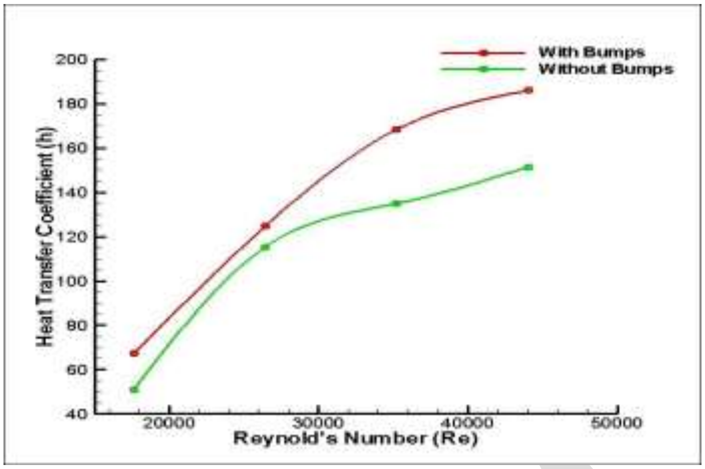
V RESULTS AND DISCUSSION

The experimentation is carried out with the divergent duct heat transfer enhancement methods. Heat transfer coefficient and Reynolds Number are calculated for all conditions. Parameters were plotted for different values of Reynolds number, for the arrangement without bumps and with bumps in the divergent duct.

Graph between plain divergent duct and divergent duct with bumps.(at 60 volt & 0.35 amp)



Graph No.1 Heat transfer coefficient Vs Reynolds Number (at 60 volt.)



Graph No.2 Heat transfer coefficient Vs Reynolds Number (at 100 volt.)

From the graph 1 and 2, it is observed that the heat transfer coefficient increases with increase in Reynolds no. As Reynolds no. increases, the air flow will cause more turbulence so due to which the heat transfer rate will increase. From the Fig.2 and 3 it is observed that the Divergent duct without using bumps gives the less heat transfer coefficient with the use of bumps in the divergent duct create more turbulence in duct which increases the heat transfer coefficient. From the above description, it can be seen that to heat transfer enhancement divergent channel with the bumps to increase up to 40 to 50 % because of the turbulent mixing in the flow near the wall by producing with help of bumps, which enhance the turbulent flow heat transfer from the wall.
Over the studied Reynolds number range and Nusselt Number align divergent channel with bumps and without bumps slightly higher Nu values than the plain divergent channel experimentally. For the divergent channel Nusselt number is about 30 to 40 % higher than the plain divergent channel within the Reynolds number range of 17621.14 to 44052.86. It is found that, over the studied Reynolds number range reasonably good agreements between the experimental Nu values have been achieved for the plain divergent channel as compare to divergent channel without bumps.

CFD WORK

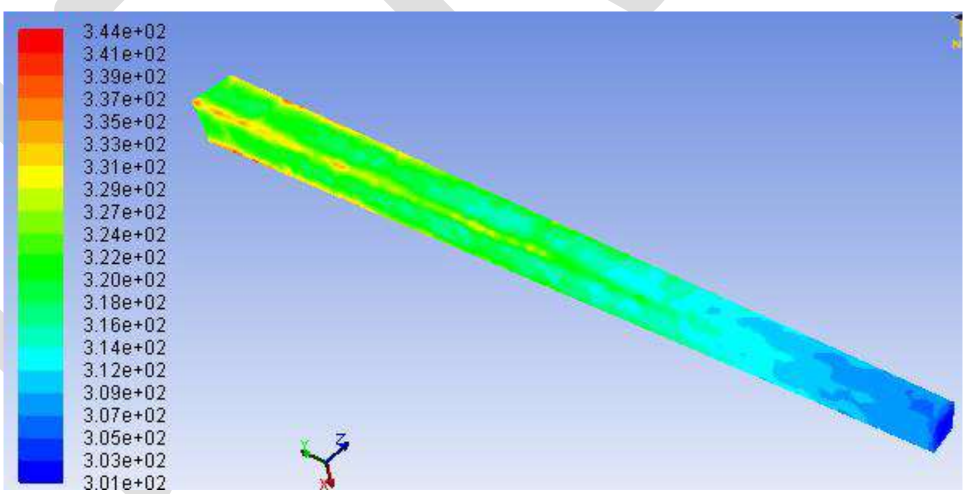


Figure 4: Static Temperature Contour Plots for 0.00874944 kg/sec

Figure.4 indicates that, wall surface temperature contours show the pattern of flow in the duct. It is seen from the figure that due to bumps behavior in the divergent channel wall temperature is a decreases from inlet to outlet along with the length of duct at all times.

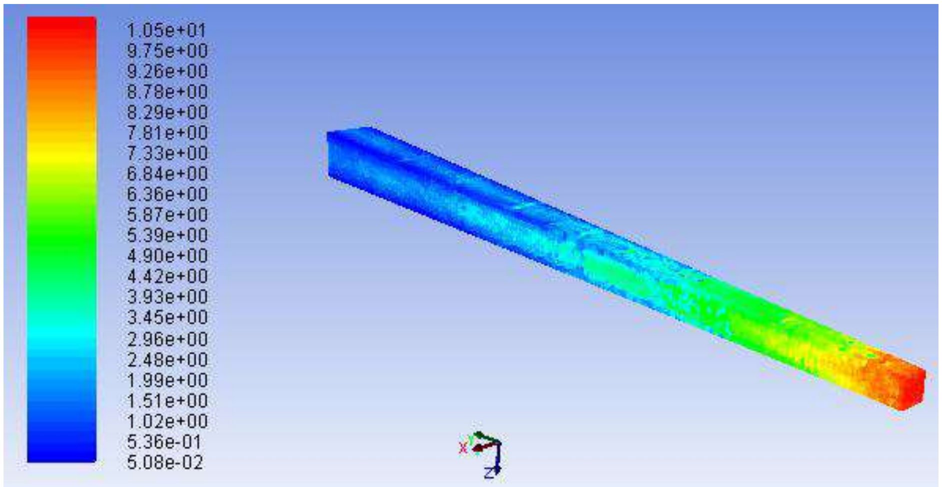


Figure 5.The Velocity Vector Plot for 0.00874944 kg/sec

It is seen from the Figure 4 that due to the bumps there is a pressure increases with decrease the velocity from inlet to outlet along with the length of divergent duct.

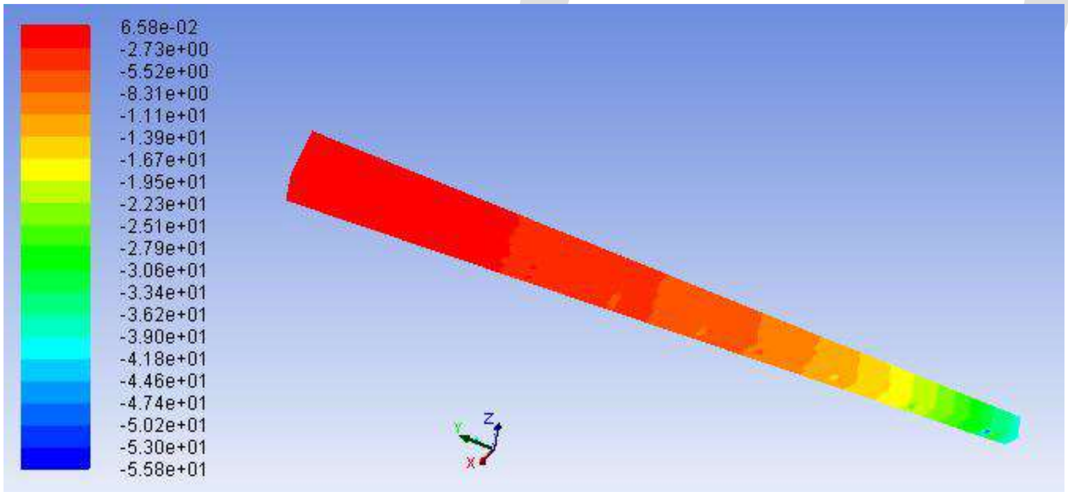


Figure 6: The Pressure plot for 0.00874944 kg/sec

Figure 6 indicates the pressure contour of divergent duct varies along the length variation. It is seen from the figure that there is increase in pressure along the length of wall, due to bumps surface in the divergent duct, while the pressure is increases from inlet to outlet.

VII CONCLUSION

1. This study focused on investigating whether the use of bumps can enhance heat transfer characteristics for a divergent duct.
2. In this experimental study we get different Reynolds numbers ranging from 17621.1454 to 44052.8634, which gives the good heat transfer enhancement.
3.The advantages of the divergent channel with internal Bumps are fluid mixing is more as compared to cylindrical pipe, pressure drop is less and boundary layer separation occurs. The main advantage of these bumps is to increase the heat transfer enhancement increases 25 to 35 % as compare to plain divergent channel.

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