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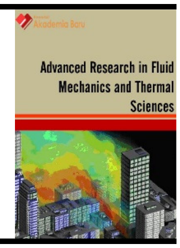

Study of Heat Transfer Characteristics on Sharp Turn Channels for Solar Collectors

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ABSTRACT

Heat transfer characteristics in sharp turn channel influenced by some of fluid flow characteristics in the channel. Fluid flow in rectangular cross section with sharp turns has its own characteristic due to changes in flow direction when through sharp turns. The flow pattern in the channel has a complex three-dimensional structure caused by centrifugal force. Local convection heat transfer rates for small surface area are expected to change significantly, for that reason why sharp bend techniques are often used on thermal equipment. In this study we have examined the heat transfer in sharp turn channels for solar collector applications. The size of the collector under study was 305 cm x 80 cm. To absorb the heat of solar radiation, in this test used iron sand as thick as 3 cm as an absorber. The iron sandbox is made of wood with a thickness of 15 mm and as a transparent cover is used 5 mm glass. The position of the air heater box is made tilted 15 degree with the aim that the airflow process can take place with the difference of input and output elevation. The barrier used is nine pieces. Arrangement of obstacles shape consists 3 types sharp multi-turns channel (angles 90-degree, 105-degree and 130-degree) and without obstacle channel as a comparison. Temperature measurements were made as much as 20 points on the flow path. The results showed that the distribution of absorber temperature for the four solar collector types tends to be the same. The highest temperature distribution can be achieved by collector with a sharp turn with a resistance angle of 130 and 105 degree, i.e. a maximum temperature of 85 degree Celsius occurs at 1-2 pm. The sharp turn of the solar collector type with the 90-degree resistance angle has slightly lower highest temperature distribution that can be achieved at 81 degree Celsius.

1. Introduction

A drying process using a solar collector has been shown to increase higher drying temperatures, lower relative humidity levels and can accelerate the decrease in water content of the dried material, compared with natural drying in direct sunlight [1]. In the drying process using a solar collector, the drying air temperature can reach 45-60 degrees Celsius [2,3]. For fruit dryers with a maximum temperature of 57 degrees Celsius requires drying time of about 24 hours (4). While in the process

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of drying the fruit with a temperature of 50 degrees Celsius, the decrease in moisture content from 80% to 9% requires a drying time of 56 hours [5]. To increase the drying rate it is done with the use of solar collector and used additional technology such as the channel bend system, so that the temperature of the solar collector can reach above 80-degree Celsius [6.7, 8]. That is why in this study we will examine the characteristics of heat transfer system on the sharp multi-turn channel for solar collector case.

The characteristics of heat transfer in sharp turn channels are influenced by some characteristics of fluid flow in the channel. Fluid flow in rectangular cross section with sharp turns has its own characteristic due to changes in flow direction when through sharp turns. Fluid flow in rectangular cross section with sharp turns has its own characteristic due to changes in flow direction when through sharp turns. The flow pattern in the channel has a complex three-dimensional structure caused by centrifugal force.

A rectangular cross-sectional channel with sharp turns is often used as a flow path on various types of thermal equipment. The flow pattern in the channel has a complex three-dimensional structure, since the flow separation is caused by sudden / sudden changes of direction from the flow within the sharp bend [9-13] especially to secondary streams caused by the centrifugal force [14-16], therefore local convection heat transfer rates for small area surfaces are expected to change significantly.

Much research has been done on high-speed streams with forced convection heat transfer. Applications of such research are usually for high technology often designed in developed countries such as the internal cooling of gas turbines. For forced heat transfer / masses, the issues examined is the Reynolds (Re) number for obtaining Nusselt (Nu) for the determination of heat transfer characteristics, and Sherwood (Sh) for the assessment of heat transfer characteristics [17,18,19]. But its application to medium technology, as well as for cooling and heating processes using energy burning fuel and is still very rare.

In the background an experimental study will be conducted to clear the flow patterns and characteristics of local (mass) heat transfer in rectangular channels with sharp turn angles under stationary conditions. Therefore, the heat transfer in the sharp turn channel in the case of solar collectors was investigated in this study. The parameters required for analyzing natural heat / mass transfer convection are the measurement of local temperature distribution, so that the flow field characteristics can be predicted.

The flow characteristics in the channel due to heating can be predicted if the temperature distribution along the channel especially at the turn can be examined. Thus for this case, the heating and measurement of fluid temperature at certain points through the test channel is the main thing in this research. To maintain the temperature stability in the test object, the heat transfer material used is iron sand with (solar) heat source or other heating source.

The fluid movement in this channel is caused by buoyancy force due to body force differences between the fluid particles. This difference is caused by the difference of density between fluid particles inside the channel when the heating takes place (20, 21). In this study the field of heater (channel wall) to be reviewed is the bottom heater. While the influence on the channel position with the gravity of the earth will be reviewed by varying the layout of channel flow towards the direction of gravity.

The purpose of this research is to optimize the heat absorption by utilizing with the technique of sharp multi-turn channel. By knowing the fluid movement characteristic and channel position, it will get an optimal heat absorbing system.

2. Methodology
2.1 Experimental Set Up

In this study the equipment used as a heat absorber medium is solar collector by utilizing, which is made from wooden frame with insulation of rubber material. As an absorber, iron sand is used. The size of the collector is 305 cm x 80 cm. On each side of the absorber box is coated with thermal insulator in the form of black colored rubber with a thickness of 10 mm. Iron sand used as a solar radiant absorber has a thickness of 3 cm. The iron sandbox is made of wood with a thickness of 15 mm and as a transparent cover is used 5 mm glass with a size of 305 cm x 80 cm. The position of the air heater box is tilted 15 degree against the horizontal axis with the aim that the airflow process can take place because of the difference in input and output elevation. In this study, the temperature distribution of quadrangle channel was modified by addition of buffer arrangement in the form of a sharp multi-turn channel (with angle of 90 degree, 105 degree and 130 degree) and collector without turns.

As measuring equipment used thermocouple and mercury thermometer that has a temperature range of 0-110 degree celcius. The position of the thermometer sensor placement or temperature measuring point is placed according to the condition of the heating conduit along the passage on the collector.

Temperature measurement is done with several variations, namely:
- Test 1, carried out with a solar collector that has a no - turning channel.
- Test 2, carried out with a solar collector that has a sharp multi-turn channel 90-degree.
- Test 3, carried out with a solar collector that has a sharp multi-turn channel 105-degree.
- Test 4, carried out with a solar collector that has a sharp multi-turn channel 130-degree.

Experimental tests are conducted in the environment by using as heating energy and temperature measurements are held at several points on the flow path

- For comparison, temperature measurements of without turns channel. The position of the temperature measurement points can be seen in Figure 1, where only 6 points of measurement is performed along the collector.
- Temperature measurements on the 90-degree sharp turn channel, using 9 obstacles and 20 thermometer sensor points. The laying of the obstacles and schematic measurement points is shown in Fig. 2.
- The temperature measurements on the 105-degree sharp turn channel also use 9 obstacles and 20 thermometer sensor points. The laying of the obstacles and schematic measurement points can be seen in Fig.3.
- For measurements temperatures of 130-degree sharp turn channel we also used 9 obstacles and 20 thermometer sensor points. The laying of the obstacles and schematic measurement points can be seen in Fig. 4.

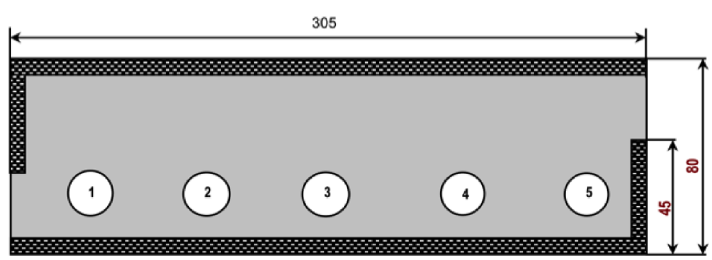

Fig. 1. The position of temperature measurement on the solar collector with a no - turning channel

Flow characteristics behavior can be predicted if the temperature distribution along the channel path, especially at turns, can be collected. Thus, the heating and measurement of fluid temperature at certain points through the test channel is the main thing done, to obtain accurate data so that analysis of research results can be done.

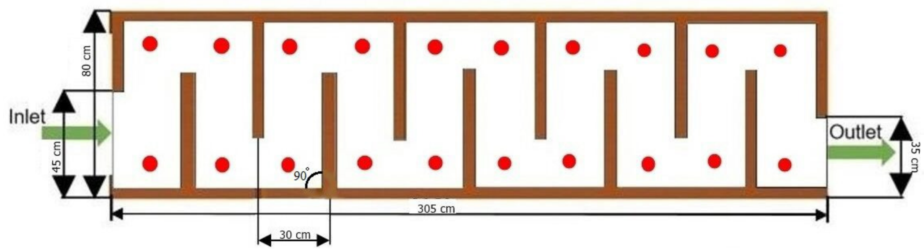

Fig. 2. Layout of obstacle and position of temperature measurement on sharp turn collector channel with 90-degree resistance angle

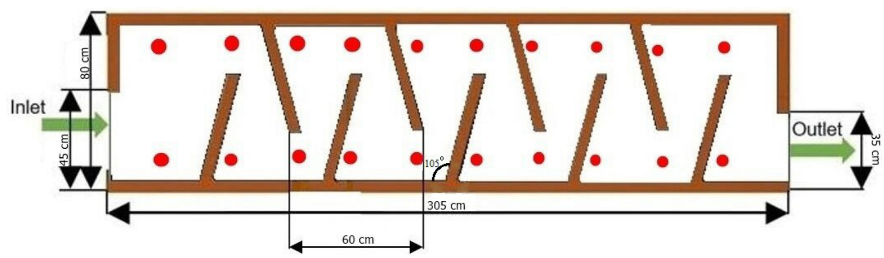

Fig. 3. Layout of obstacle and position of temperature measurement on sharp turn collector channel with 105-degree resistance angle

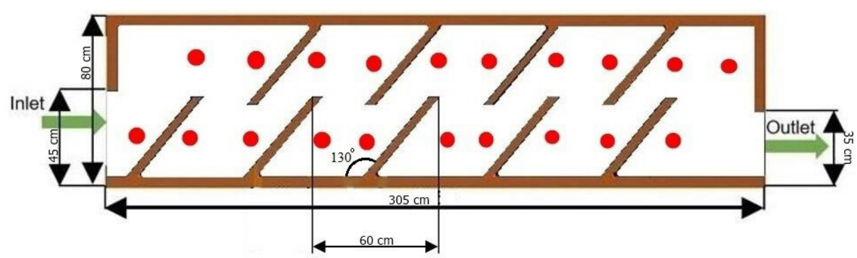

Fig. 4. Layout of obstacle and position of temperature measurement on sharp turn collector channel with 130-degree resistance angle

2.2 *Measurement Techniques and Data Analysis*

Temperature measurements on heat absorber by utilizing solar energy are conducted every half hour from 9 am to 4 pm where the intensity of solar heat during testing ranges from 700 to 900 W / m^2. At 12 am the intensity is 900 W / m^2, at 1 pm the intensity reaches 970 W / m^2 and at 2 pm the intensity is 900 W / m^2. The test is carried out with three instrument conditions that are by varying the flow position within the channel with a resistance of 90-degree, 105-degree, 130-degree and without being obstructed in the channel. From the four variations of solar collector tool that uses source of solar heat will be known the characteristics of fluid movement and distribution on the various channel position. Finally, the most optimal heat absorbing system among the three systems is obtained.

Processing or data analysis is the final stage of research methodology. The data obtained from the test then plotted in the form of graphs, which then carried out the discussion and viewed the comparison between each treatment condition.

3. Results and Discussions

The temperature distribution of the absorber along the collector heater channel affects the distribution of hot air through the channel. In this case the measurement starts from the position after the inlet until the position near the outlet.

3.1 Temperature Distribution along the Channel

The measurement results of the air temperature distribution along channels without obstacles obtained for 12 am, 1 pm and 2 pm are shown in Figure 5.

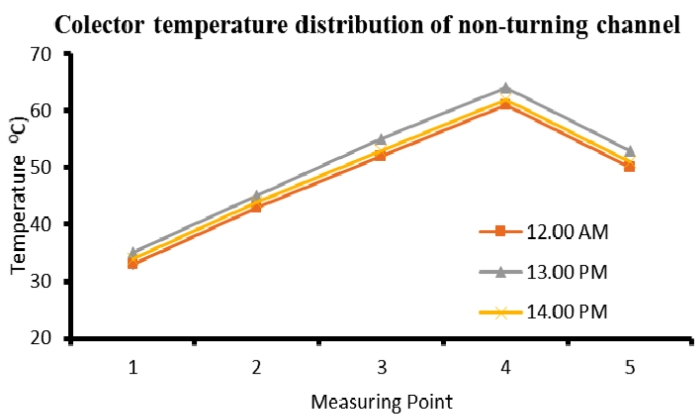

Fig. 5. Temperature distribution along the channel without obstacle with variation of measurement time

Figure 6 shows the temperature distribution measurements along 90-degree sharp turn channels for 12 am, 1 pm and at 2 pm. At 1 pm, the temperature after entering the channel at point 1 reached 44-degree Celsius. It can be explained that the overall distribution of air temperature along the channel from point 1 to point 13 tends to increase very sharply, especially in turn areas with increasing flow path length. This tendency occurs because throughout this passage there is sufficient air heating caused by a sharp turn, which resulted in the flow turbulence. The highest temperature is reached at point 14 with the temperature reaching 81 degree Celsius. From point 15 to point 20 shows the phenomenon of the descending air temperature as well as the unimpeded channel conditions, which occurs as the air velocity increases as it approaches the outlet from the collector heater channel.

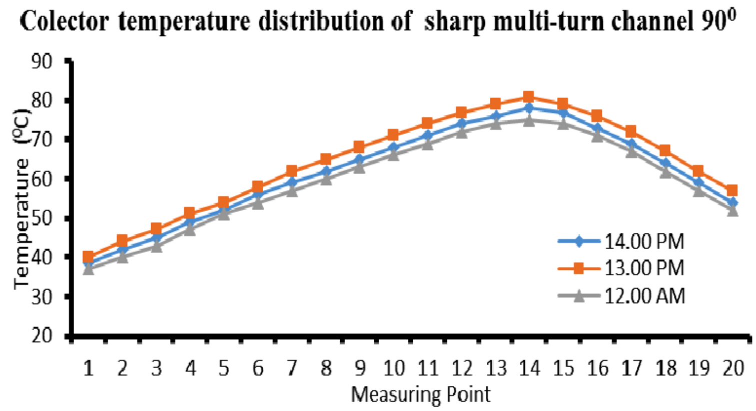

Fig. 6. Distribution of temperature along the channel with turn angle 90-degree for the time at 12 am – 2 pm.

At 2 pm the distribution of temperatures are in the range of 2-3 degree Celsius under the distribution conditions at 1 pm. This happens because the intensity of solar energy has decreased and affects the absorber temperature drop. As for the temperature distribution for the time at 12 am is the lowest temperature distribution on this channel. This happens because the heat that is possessed by the absorber is still small (the temperature is still somewhat low), the amount of radiation heat that can be absorbed is still small because the time available is still short.

Figure 7 shows the temperature distribution measurements along the 105-degree sharp turn channel at 12 am, 1 pm, and 2 pm. At three times the temperature distribution of the phenomenon is close to the same. From this result indicates that airflow at 1 pm has the highest temperature distribution. The temperature after entering the channel at point 1 has reached 43-degree Celsius. It can be explained that the overall distribution of air temperature along the channel from point 1 to point 13 tends to increase sharply, especially in turn areas. This trend is the same as the sharp turn of 90-degree channels. The highest temperature reached at point 14 with temperature reaching 84 degree Celsius. From point 15 to point 20, i.e. at the point of temperature output reaches 60 degree Celsius.

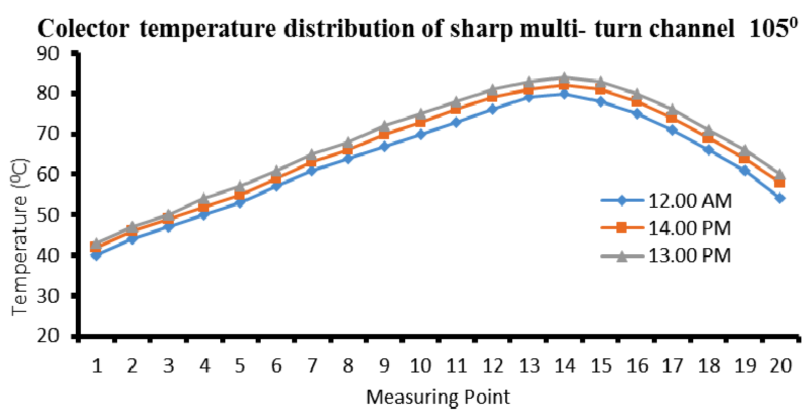

Fig. 7. Distribution of temperature along the channel with turn angle 105-degree for the time at 12 am-2 pm.

At 2 pm the temperature distribution is in the range 1-2 degree Celsius under conditions at 1 pm. Temperature distribution for 12 am is still the lowest temperature distribution. This happens because the heat that is owned by the absorber is still small (temperature is still a bit low).

Figure 8 shows the temperature measurement results along 130-degree sharp turn channels at 12 am, 1 pm and 2 pm. At these three times the temperature distribution has the tendency of a phenomenon that is close to the same. From this result indicates that the distribution of air temperature at 1 pm reaches the highest temperature distribution. The temperature after entering the channel at point 1 reaches 43 degree Celsius, it can be explained that the overall distribution of air temperature along the channel from point 1 to point 13 tends to increase sharply especially in the turning area. This trend is the same as the sharp turn channel 90-degree and 105-degree. The highest temperature is reached at 14 with temperature reaching 85 degree Celsius. From point 15 to point 20, at the point of temperature the output still reaches 61 degree Celsius.

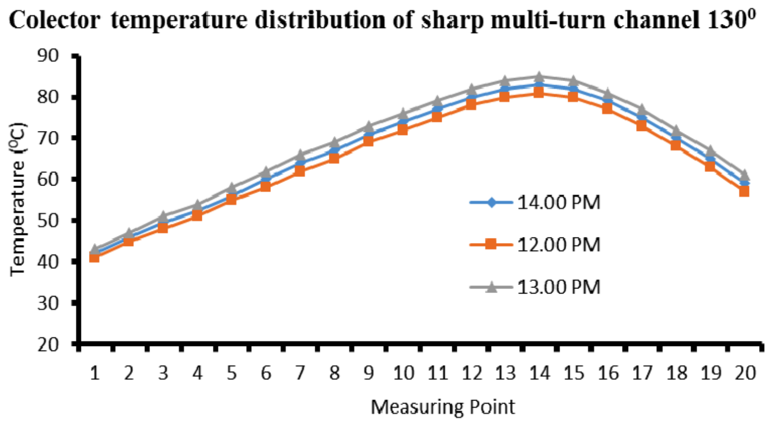

Fig. 8. Distribution of temperature along the channel with turn angle 130-degree for the time at 12 am– 2 pm

Same with conditions at 105-degree sharp turn channel, at 2 pm the temperature distribution is in the range 1 – 2 degree Celsius under the distribution conditions at 1 pm. As for the temperature distribution at 12 am is still the lowest temperature distribution, this is because the heat held by the absorber is still small (temperature is still rather low) at that time.

Same with conditions at 105-degree sharp turn channel, at 2 pm the temperature distribution is in the range 1 – 2 degree Celsius under the distribution conditions at 1 pm. As for the temperature distribution at 12 am is still the lowest temperature distribution, this is because the heat held by the absorber is still small (temperature is still rather low) at that time.

3.2 Temperature Distribution Optimization on Collector Channel

Figure 9 shows the temperature distribution of all four-collector types at the test at 1 pm. To determine which type of collector channel is the highest temperature achieved for collector air heater, we need to examine each characteristic flow pattern and the heat transfer that occurs in each collector. Collector without obstacles shows the temperature distribution patterns that occur along the channel without obstructions, indicating the lowest temperature distribution of other collector types. The temperature after entering the collector is 35 degree Celsius, the highest temperature is 64 degree Celsius and the collector-out temperature is 52 degree Celsius. For the sharp turn collector 130-degree can be seen that temperature distribution produces the highest temperature distribution

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among other collector channels, i.e. the entry temperature is 47 degree Celsius, the highest temperature is 85 degree Celsius and the output temperature is 61-degree Celsius. For the 105-degree sharp turn collector it appears that the temperature distribution produces its temperature distribution slightly below sharp bends of 130-degree with a difference of 0.5-1 degree Celsius lower. Temperature entering the collector is 46 degree Celsius, the highest temperature is 84-degree Celsius and the output temperature is 60-degree Celsius. Temperature distribution for sharp turn collectors 90-degree shows that in this channel the temperature is achieved also below the temperature distribution of 105-degree sharp turn collectors. For incoming temperature measurement is 44 degree Celsius, highest temperature 81 degree Celsius and collector output temperature become 57 degree Celsius.

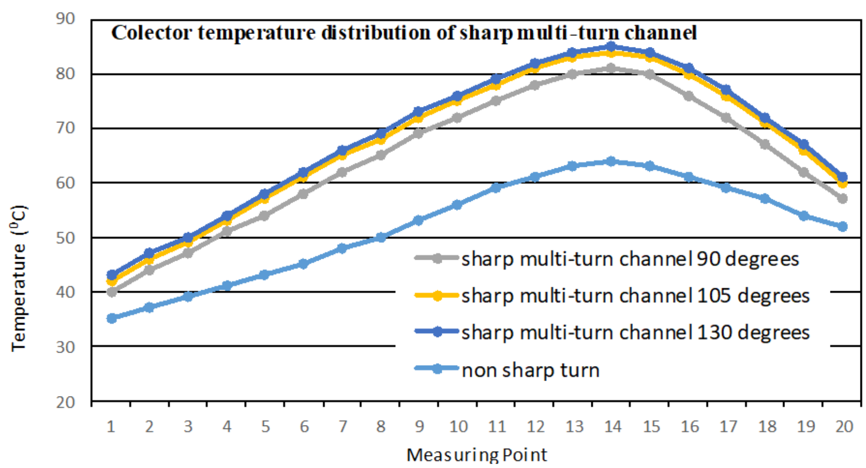

Fig. 9. Distribution of temperature along the channel with variations of passage

From the above discussion, sharp turn channel 130-degree has the highest temperature distribution along the collector and a sharp turn channel of 105-degree has slightly lower in temperature. In collectors with sharp turn channels 90-degree, the temperature distribution that can be achieved is lower than other sharp turning channels. While the collector without obstacle have the lowest temperature distribution compared to other types of channels.

According to the previous theory, the increase in fluid temperature flowing in the channel due to heating is determined by its turbulent flow rate [11, 15, 17, 18]. From this it can be stated on the basis of test results that the flow patterns in the sharp turn collector channels 130-degree and 105-degree have the highest airflow turbulence. While the flow pattern on a sharp turn collector channel 90-degree has a slightly lower airflow turbulence level.

From the above explanation it is clear that the temperature distribution achieved by collector type with 130-degree sharp turn channel has the best optimal value. As for the next sequence it is owned by collector type with 105-degree sharp turn channel and subsequently below 105-degree sharp turn channel is a sharp turn channel of 90-degree. In this case, collector without obstacles has the lowest temperature distribution.

4. Conclusions

After the analysis of the measurement results to the temperature distribution for the four types of solar heat radiation collector can be summarized as follows:

1. The highest temperature distribution can be achieved on collector type sharp turn channel of 130-degree resistance angle with maximum temperature of 85 degree Celsius at 13 pm. In the sharp turn collector with a resistance angle of 105-degree the highest temperature distribution that can be achieved is 84 degree Celsius and for 90-degree the sharp turn collector is 81 degree Celsius. While in collector type without obstacle the highest temperature that can be achieved only about 64 degrees Celsius.
2. It can be stated that flow pattern in the sharp turn channel 130-degree has the highest level of airflow turbulence followed by a sharp turn channel of 105-degree and 90-degree respectively. While the no sharp turn channel has a very low level of turbulence flow.
3. The results of this study conclude that the type of sharp turn channel collector with the 130-degree resistance angle has the optimum air heating capability.

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