CFD analysis of Micro Mixing of sunflower Biodiesel and calculating the value of NOx and SOx after Combustion

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***Abstract*: Bio-fuels are used to reduce the requirements of conventional fuels. It is also used to reduced the pollutant content after the combustion of the fuel. Different bio-fuels where used to make bio-diesel, the quality of the blend depends on the mixing of different fuels used for making the blend. In order to mix different oils, micro-channels were used. Here in this work we are using different T-section micro-channel for making sunflower oil and ethanol blend. Here we are using the three different T-section section that is simple T-section, T-section with baffles Type-1 and T-section with baffles Type-2 and finding the value of mixing index for different Reynolds number of blend. After finding the optimum geometry for the micro-mixing of blend. Here we are also measuring the value of pollutant content obtained after the combustion of sunflower-ethanol blend. Here we also calculate the value of pollutant for conventional diesel and Jatropha-ethanol blend and compare with sunflower-ethanol blend. After calculating the value of Nox and Sox value at the exit of combustion, it is found that the value of Nox and Sox is minimum in case of Sunflower-ethanol blend, and it is maximum in case of conventional Diesel.**

***Keywords*: Biodiesel, micro mixing, mixing index, NOx, SOx, Combustion**

1. Introduction

The internal-combustion engine of now a day used extensively for the generation of energy. In business and domestic utilization of the energy is increasing gradually and to reduce the adverse effect of byproduct generated due to the combustion of the conventional fuels like petrol and diesel, the efficient and effective energy conversion construct is very important. It takes place to develop economically new technique to resolve the energy crisis. That purpose exercises another fuel. Biodiesel could be a fuel that attends to point out victimization the plant seeds or fruits wastage and animal fats. These plant seeds and animal fats are unremarkably adduced because the feedstock for Biodiesel. Biodiesel typically use within the engine (vehicle engine, business and domestic appliances supported the engine). Biodiesel could be a renewable fuel and contributes to the reduction of greenhouse emission. The internal-combustion engine will all this in an exceedingly package that sturdy and fleshy with lower fuel consumption than the other first cause. However internal-combustion engines the most important contributors to atmosphere pollution downside worldwide.

To reduce the pollutant content after the combustion of the diesel different bio-fuels where made to reduce the content of the NOx (Nitric oxide), Co (carbon mono oxide), SOx (Sulphur oxide). In order to make the perfect blend different mixing system where used one is the forced turbulence system and another is the natural flow mixing system. Here in this work we are working on the natural flow mixing system. Here in this work we are using the Sunflower oil and Ethanol for making the blend. The mixing of sunflower oil and ethanol called the transesterification process. In order to make the perfect blend different researcher have tried the different geometry section for the mixing of different fluid, which called as the micro mixing of fluid.

Here in this work we have taken the T- section geometry as taken in the base paper for the mixing of the oil. With the simple T-section geometry here we have also considered the two more T- section with different baffles inside the T-section to increase the mixing time inside the section so that the blend get perfectly mixed, because the quality of the bio-diesel depends on the mixing of the fluid. After mixing the bio-diesel, here we have done the combustion of sunflower and ethanol blend and measure the value of pollutant at the exit and then it is compared with the value of pollutant obtained after the combustion of Diesel and the Jatropha-ethanol blend. Here we have calculated the value of mixing index at different Reynolds number for different T-section, section having the high value of mixing index shows the better mixing. Here we have also calculated the residual time at different Reynolds number. To analyzed the above mention case here we have develop the Numerical model of the micro mixing of the bio-diesel blend. In the below section development of the numerical model and analysis part where carried out.

2. Development of Numerical model

2.1 Solid Model

First the solid model of the T-section is developed on the basis of geometry given in the base paper the geometric parameters of T-section is shown in the below Table.

Table. 1 Showing the geometry of the T-section

Length of the inlet Channel (L_e)	400 µm
The distance between the inlet mixer and the point of mixing of the fluid	400 µm
The height of mixer	200 µm
width	100 µm
The total mixing length channel	35100 µm

Based on the above geometry here we have developed the solid model of the simple T-section Geometry. The solid model of the T-section is shown in the below fig.

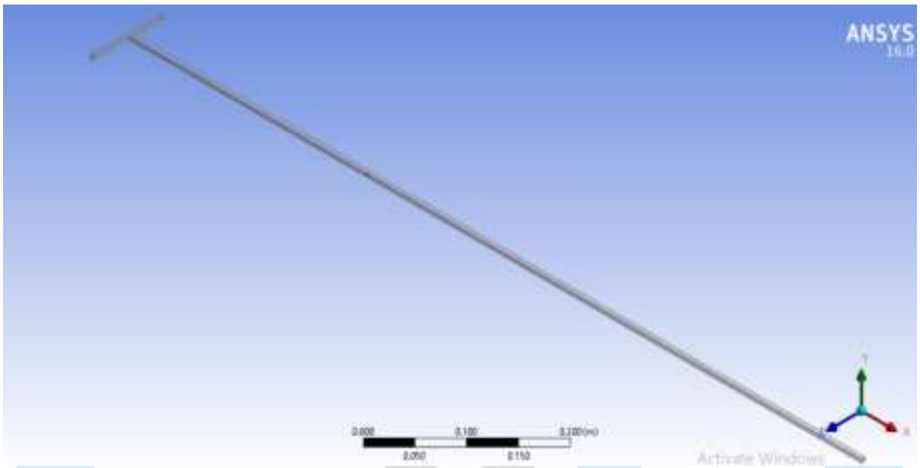

Fig.1 showing the solid model of the Simple T-section

2.2 Meshing

In order to analyze the mixing index and combustion of the different blend here we have discretized the complete body in to number of elements. The meshing of the simple T-section geometry is shown in the below fig.

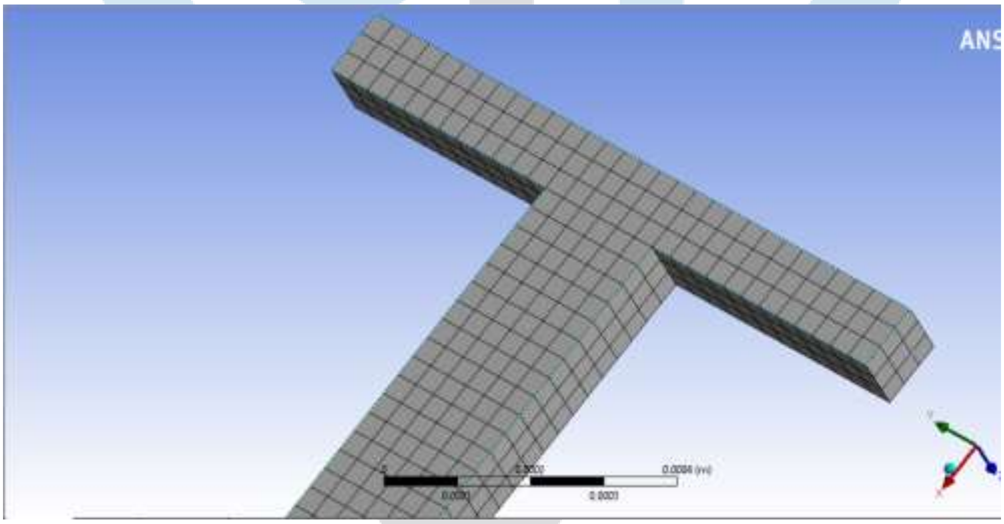

Fig.2 showing the mesh of simple T-section

3. Result

Here first we have done the analysis for the Jatropha and Ethanol mixing and then we have compared the value of mixing index for different Reynolds number. After calculating the different values of mixing index from the numerical analysis it is than compared with the value of mixing index given in the base paper for different Reynolds number to validate the current Numerical model. To analyzed the effect of Reynolds number here we have taken the different Reynolds number that is 10, 20, 30, 40, 50, 60, 70, 80, 90 and 100.

3.1 For Jatropha oil and Ethanol

- For Reynolds Number 10

The contours of the mass fraction of the Jatropha oil is shown in the below figure

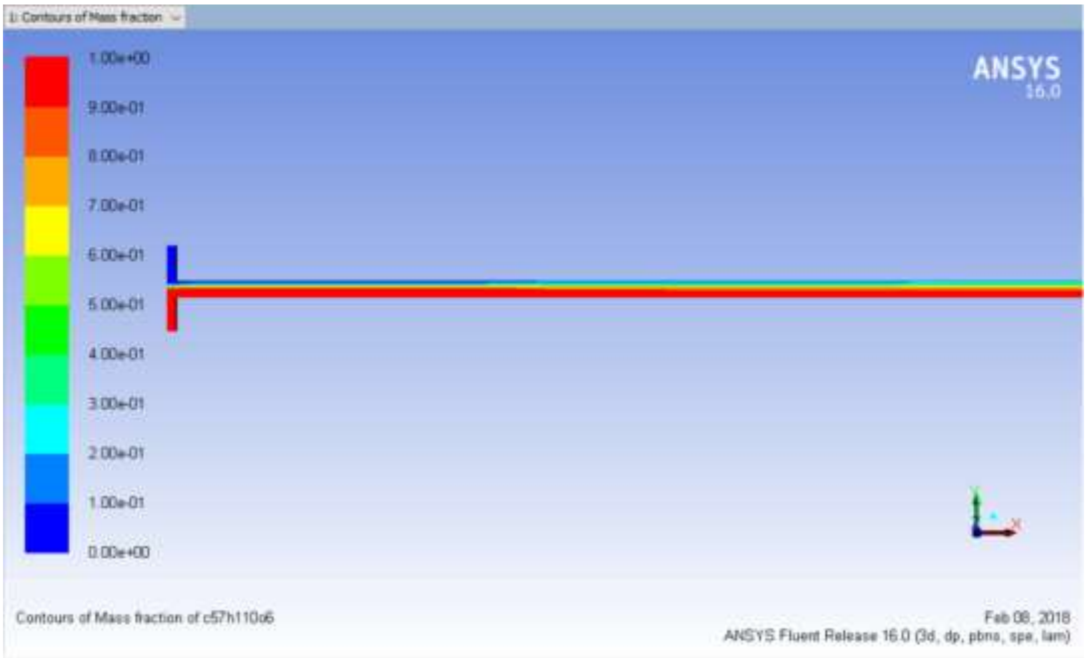

Fig.3 showing the mass fraction of the Jatropha oil

Likewise the above analysis we have calculated the value of mass fraction of Jatropha oil at different Reynolds number and Calculate the value of mixing index. To calculate the value of mixing index following formula where used. The mixing index is calculated based on the standard deviation of the mass fraction of Jatropha oil. According to the following equation

$$\sigma = \sqrt{\frac{\Sigma(Y_i - \bar{Y})}{N}} \quad (1)$$

Where Y_i is the mass fraction of oil at a particular point and $\bar{Y}$ is the average mass faction of Jatropha oil, σ is the variance off the mass fraction and N is the number of points taken to measure the mass fraction of oil. To get the efficient value of the mass fraction here we have measure the value of mass fraction of jatropha oil at 40 different points and then the submission of all the points taken place. After calculating the value of the variance for a particular Reynolds number mixing index where calculated

$$M = 1 - \sqrt{\frac{\sigma^2}{\sigma_{max}{}^2}} \quad (2)$$

Where M is the mixing index, σ is the variance of the mass fraction obtained from the equation 1 and σ_{max} is the maximum variance in a particular geometry. The value of the mixing index for the different Reynolds number obtained fron the numerical solution is shown in the below table.

Table. 2 Showing the values of the mixing index for different Reynolds number

Reynolds Number	Mixing Index Calculated through Numerical analysis
10	0.682
20	0.763
30	0.82
40	0.865
50	0.89
60	0.913
70	0.889
80	0.884
90	0.88
100	0.87

3.2 For Sunflower oil

Here in this section Sunflower oil is used to make bio-diesel, here we are mixing the sunflower oil with the ethanol and the mixing process is called the transesterification process. In order to mix the blend efficiently different geometries were tried. To increase the residence time different types of baffles were used inside the T-section so that residence time can increase. Here we are finding the value of mixing index for all the three different geometries at different Reynolds number to get best blend.

3.2.1 Case 1 For simple T-section

The solid model of simple T-section is already shown in the above section. The contours of the mass fraction of Sunflower oil for different Reynolds number is shown in the below fig.

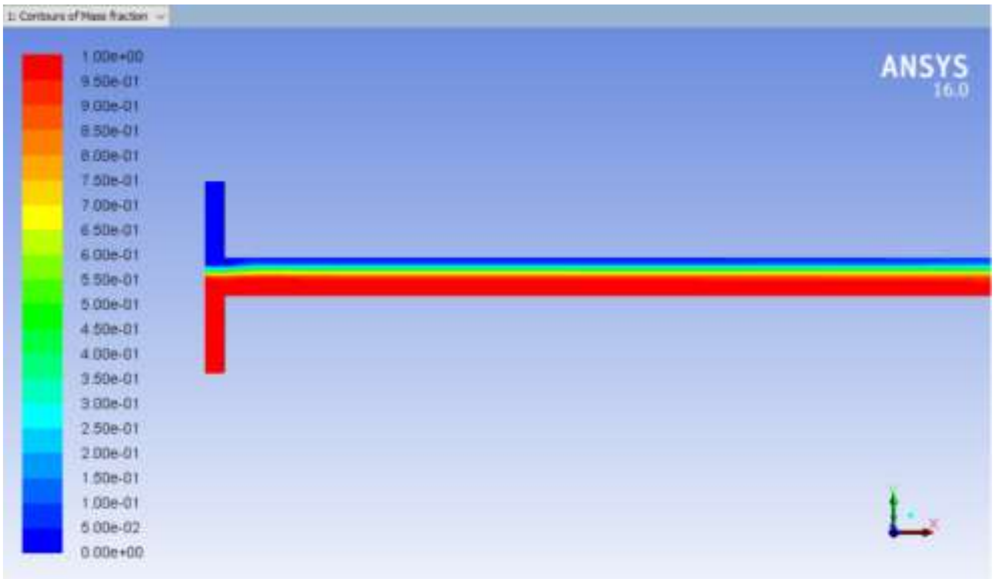

Fig.3 showing the mass fraction of sunflower oil at Re = 10

3.2.2 Case 2 T-section with Baffles Type-1

Here in this section some baffles where made inside the T-section so that the incidence time or mixing time is increased. With the increased in mixing time the quality of the blend also increase because the molecular level mixing is necessary for the perfect blend. The solid model of T-section having baffles type I is shown in the below figures. Here in this geometry the baffles are placed at both the side of inlet and in the middle portion of the section, which is shown in the below figures.

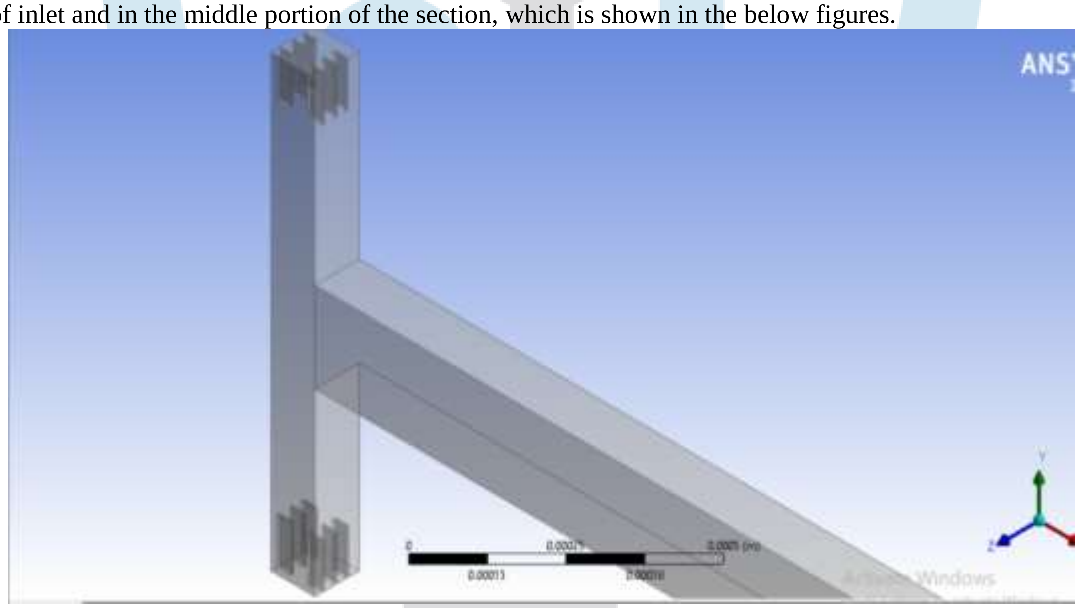

fig.4 showing the baffles at the inlet of both side of the T-section

3.2.3 T-section with Baffles Type-2

Here in this section baffles are place at the both inlet and exit of the T-section. The geometry of the T-section with baffles used in this section is shown in the below fig.

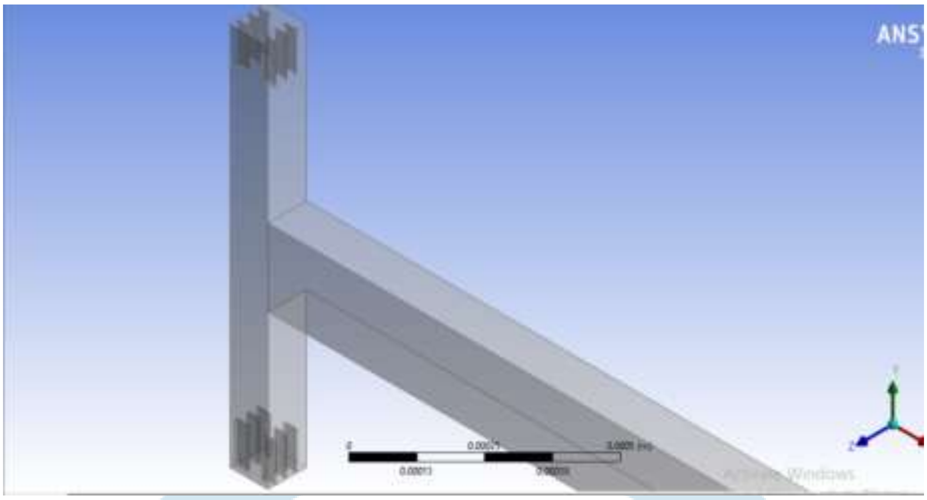

Fig.5 showing the geometry of the T-section with baffles at inlet

The value of the mass fraction of the sunflower oil for different Reynolds number is shown in the below section.

- For Reynolds Number 10

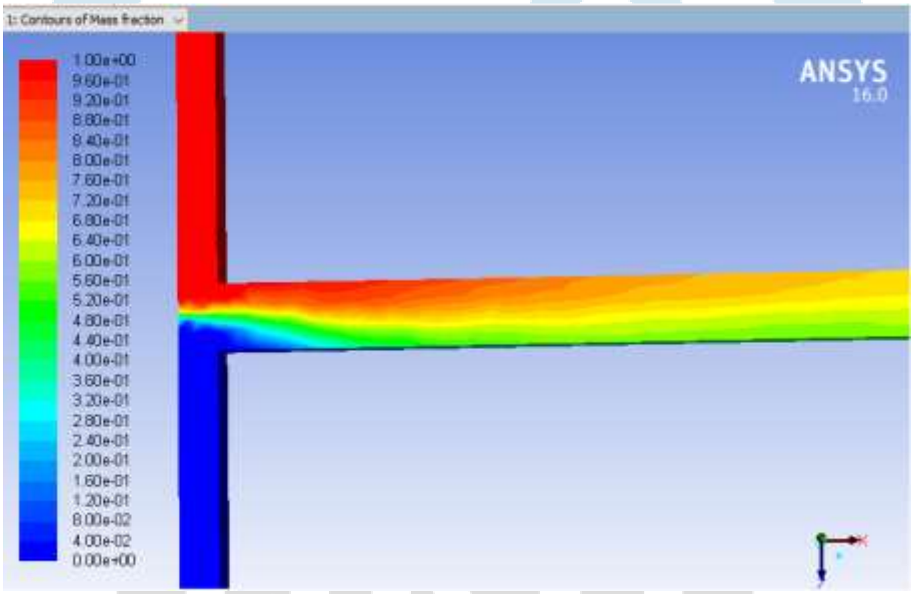

Fig.6 showing the value of the mass fraction of oil for Re = 10

After finding the value of mixing index for the three different T-section, here we have compared the value of mixing index at different Reynolds number. The geometry showing the maximum value of the mixing index is better as compared to the other geometry because it increases the molecular level mixing of the bio-diesel fuel, which increases the quality of the fuel. The comparison of mixing index for different geometry is shown in the below table.

Table.3 Showing the comparison of mixing index

Reynolds Number	Mixing index For simple T-section	Mixing index For T-section with first type baffle	Mixing index For T-section with second type baffle
10	0.652	0.68	0.66
20	0.66	0.687	0.667
30	0.668	0.691	0.672
40	0.675	0.72	0.679
50	0.69	0.79	0.7
60	0.73	0.85	0.78
70	0.71	0.81	0.75
80	0.693	0.78	0.71
90	0.686	0.71	0.691
100	0.67	0.674	0.682

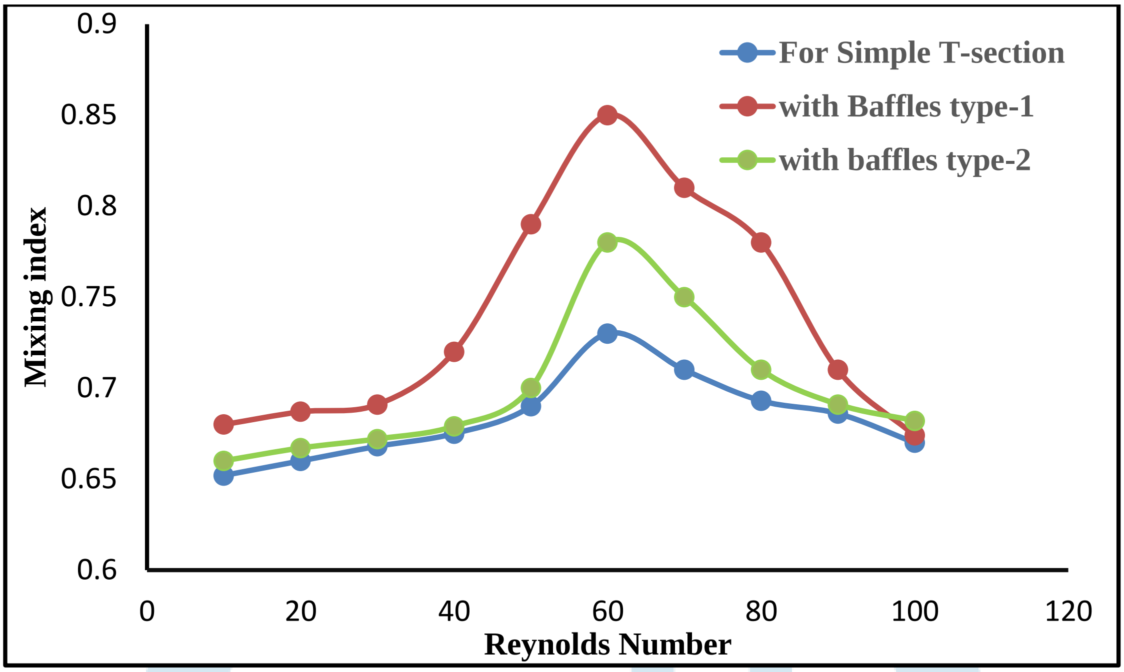

Fig.7 showing the comparison of mixing index for different geometry

From the above graph it found that the value of mixing index is maximum in case of T-section having the baffles type-1. Geometry having the baffles type-2 shows the less value of mixing index at every Reynold number as compared to the geometry having baffles type-1, but it is having the high value of mixing index as compared to the simple geometry of T-section. After making the blend, here we have also done the combustion of this blend to check the value of pollutant contain after the combustion.

4. Combustion of the Different fuel

Here in this section combustion of the sunflower-ethanol blend make in the T-section having baffles type-1 with diesel in different proportion were combust and measured the value of pollutant at the exit of the combustion. Here we have also done the combustion of the Diesel and Jatropha-ethanol blend. To reduce the complexity of the geometry for the combustion, here we have done the combustion on the 2D geometry scale.

4.1 Combustion of the sunflower-ethanol blend

Here in this section we have make mixture of sunflower-ethanol blend with diesel in different proportion. To measure the effect of sunflower-ethanol bio fuel on pollutant emission at the exit after combustion, we have make three different proportion of sunflower-ethanol blend and diesel that is 10:90, 15:85 and 20:90. Here sunflower-ethanol blend is used in proportion of 10%, 15% and 20 % with diesel and calculate the value of Nox and Sox at the exit of combustion.

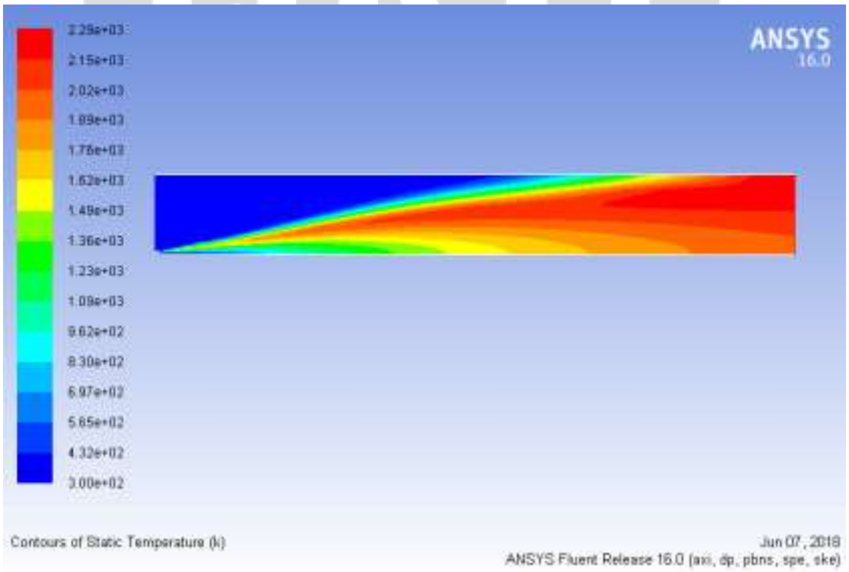

Fig.8 temperature contours of combustion of 10:90 proportions

Value of NOx and Sox for different proportion is mention in the below table.

Table.4 Value of Nox and Sox for different proportion

Blend	Nitric oxide	Sulphur oxide
10% sunflower-ethanol + 90% diesel	0.002511	0.08895
15% Bbled + 85% diesel	0.002361	0.08898
20% BD + 80% diesel	0.002163	0.08864

From the above analysis it is found that as the mass fraction of sunflower-ethanol blend increase in diesel the value of pollutant after combustion start decreasing. Here in this work value of NOx and Sox is minimum for 20:80 proportion.

5. Conclusion

- Here in all the three geometry, T-section with baffles type-1 is showing the maximum value of mixing index.
- The value of mixing index is minimum for the simple T-section geometry.
- After the combustion the value of NOx is minimum for the Sunflower-ethanol blend.
- The value of SOx is minimum for the Sunflower-ethanol blend.
- The value of NOx and Sox for sunflower is much minimum in case of Sunflower-ethanol blend as compared to the other blends and Diesel.

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