Theoretical Investigations on spray travel of gas cooler

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Abstract:

Spray cooler with water droplets as a spray liquid is having extensive applications in industries and scientific organizations to cool exhaust hot gases without any hot spots. The cooling occurs as a result of the direct injection of water into the cooler chamber. Water injected at high pressure is atomized into fine spray and as the droplets of the spray travel along the length of the spray cooler. Up to a particular length of the cooler, heat is transferred from the hot combustion gases to the water droplets and water evaporates from the surface of the droplet and diffuses into the hot gas. If the cooler length is more, the gas temperature will be sufficiently low and condenses the moisture present in the hot gas. In the present research paper, a 3D model of the spray cooler is considered for the numerical investigations to optimize the spray cooler length for effective cooling with minimum unevaporated droplets.

Key Words: Spray cooler, water droplets, hot exhaust gas, ANSYS-CFX

Introduction:

Spray cooler is used in many applications to cool the hot exhaust gas. A plain orifice type atomizer is considered to inject the high pressure water particles as a fine spray. Water spray uses the sensible heat of the gas to warm the droplets until they evaporate. This lowers the gas temperature as the liquid absorbs the heat energy during phase change. The vapour then continues to absorb energy as it warms to the surrounding temperature. Complete evaporation of water droplets inside the given length of the after cooler is a complicated and challenging task. Up to a particular length of the cooler, heat is transferred from the hot combustion gases to the water droplets and water evaporates from the surface of the droplet and diffuses into the hot gas. If the cooler length is more, the gas temperature will be sufficiently low and condenses the moisture present in the hot gas. In the present research paper, a 3D model of the spray cooler is considered for the numerical investigations to optimize the spray cooler length for effective cooling without any unevaporated droplets.

Numerical modelling:

An axi-symmetric 3D model of the spray cooler is considered for the numerical investigations. Simulations are carried out with commercially available ANSYS-CFX software. The input parameters considered for the analysis are shown in the table No.1.

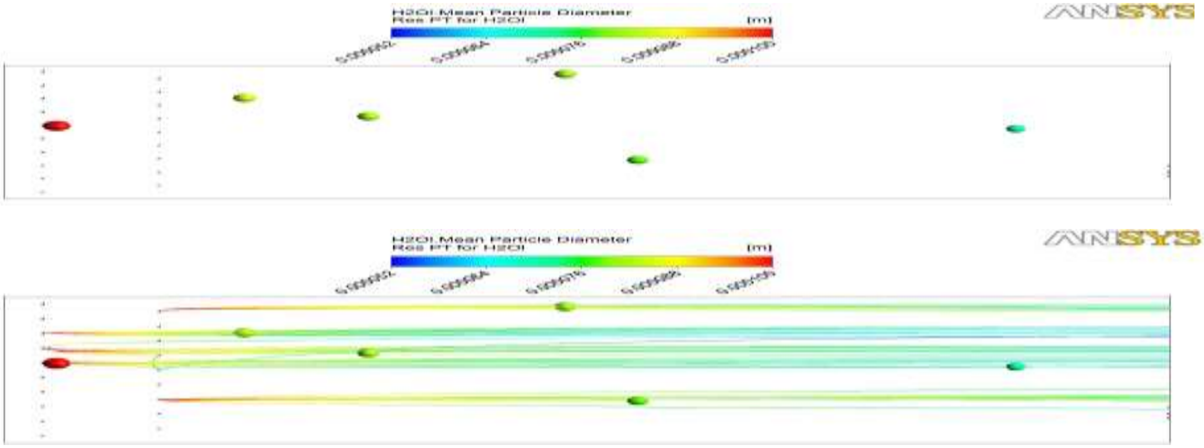
Table No.1: Input parameters of the spray cooler

Spray cooler diameter	3.0m
Length of the spray cooler	3m, 6m, 12m &18m
Injector diameter	3mm
Water mass flow rate	100kg
No of orifices	2000 in two injector planes

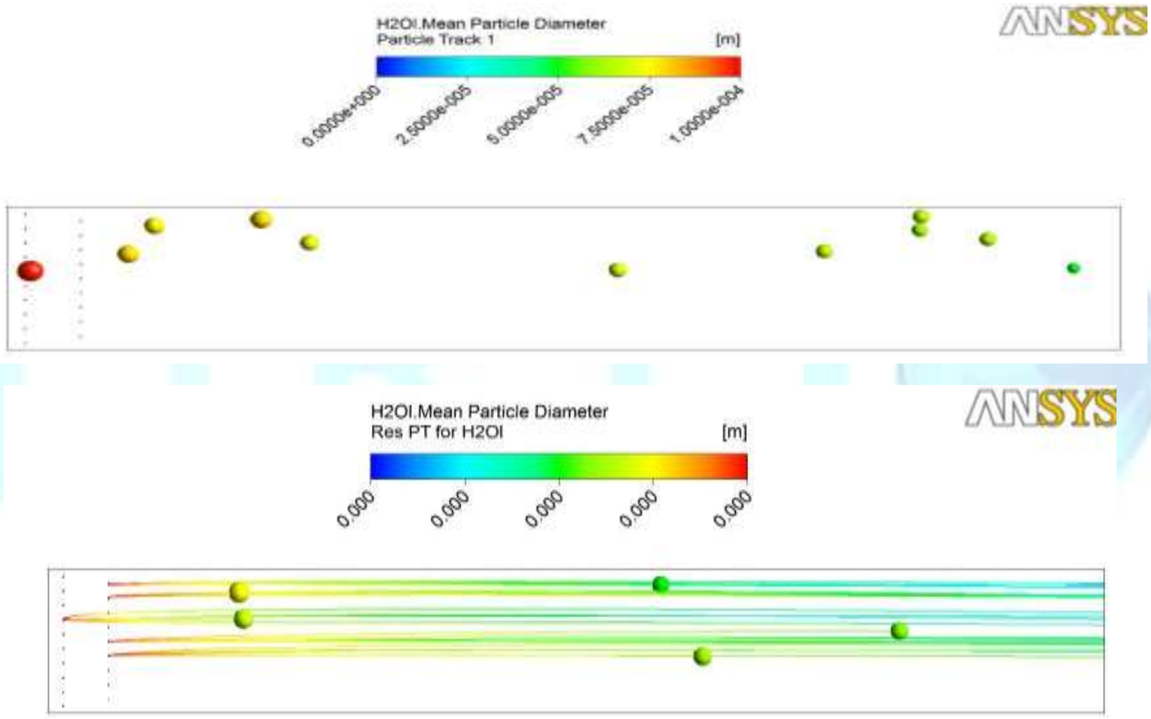
Computational simulations are carried out for different spray cooler lengths with fixed injector diameter and the injectors are arranged in different injection planes. Particles are uniformly injected with 100micron diameter and mass flow rate is divided equally among all the orifices. The enhanced TAB (ETAB) model utilizes the droplet deformation dynamics used in the standard TAB model with a new strategy for the description of the droplet breakup process. In this model, the rate of product drop creation is assumed proportional to the number of the product droplets, with the proportionality constant depends on the breakup regime. Transient simulations are carried out, choosing time step slightly higher than particle time breakup and total time for simulation more than particle traveling time required for leaving the domain from exit.

Results and Discussions:

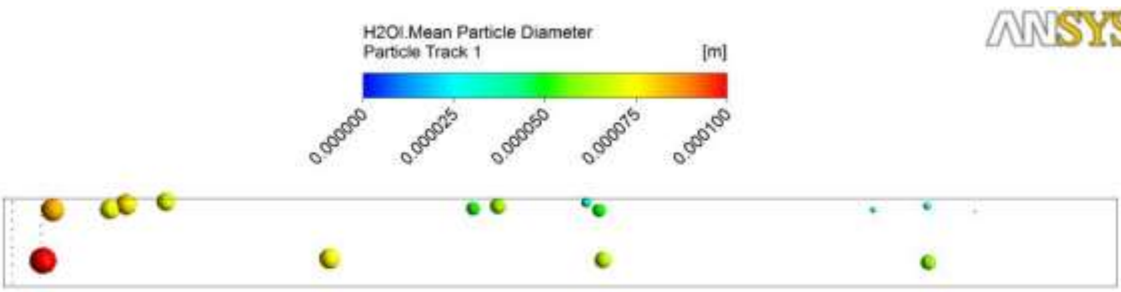
Mean particle diameter variation along cental verticle plane are represented in the figure No.: 1 to 4. The evaporation of droplet depends upon exposed heat transfer area which in turn depends upon particle diameter at that instant.Figure Nos 1 to 4: shows water droplet tracks coloured by droplet diameter

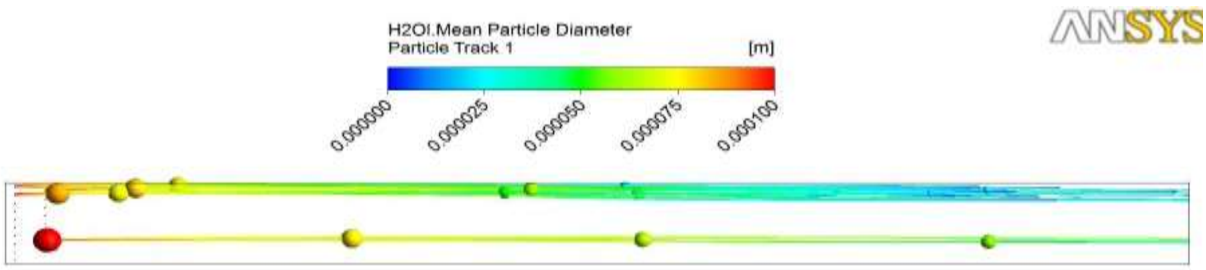


Fig(1). Case 1: spray cooler length 3m

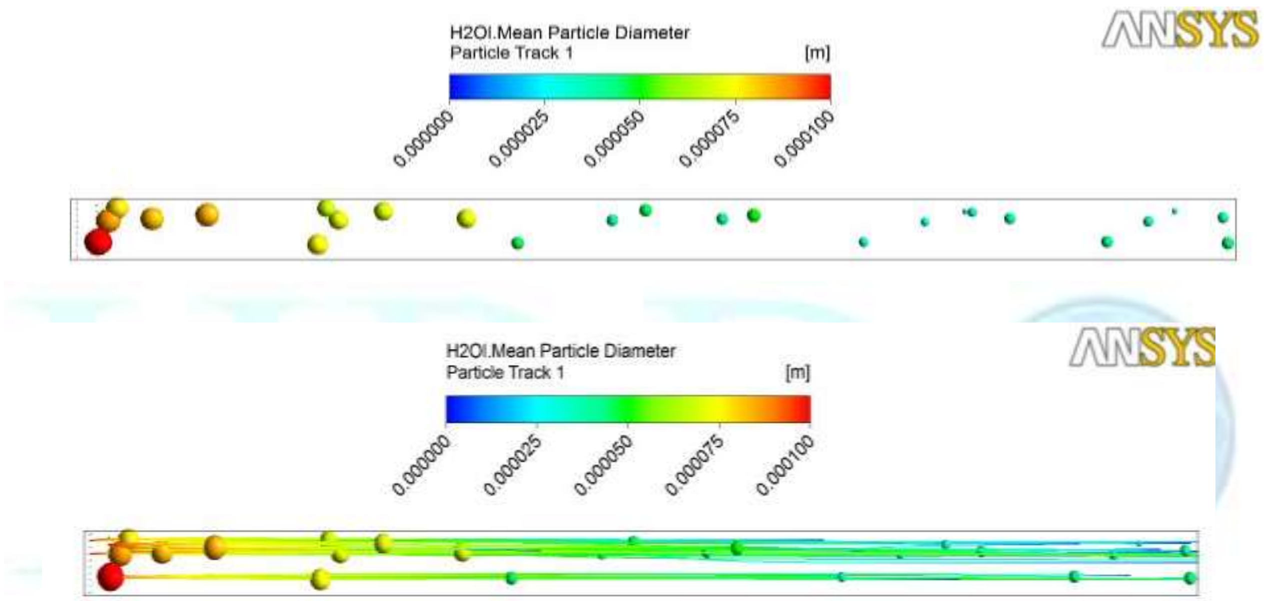


Fig(2): Case 2: spray cooler length 6m





Fig(3): Case 3: spray cooler length 12m



Fig(4):Case 4: spray cooler length 18m

Temperature contours on central vertical plane are represented figure No.:5. Below chart shows the variation for different spray cooler lengths along the central line passing through central vertical plane. It is observed that after the spray cooler length 6m, the variation of temperature with the length is almost constant and it has attained the minimum value. With the spray cooler length 18m, the area averaged temperature is 560.751K.

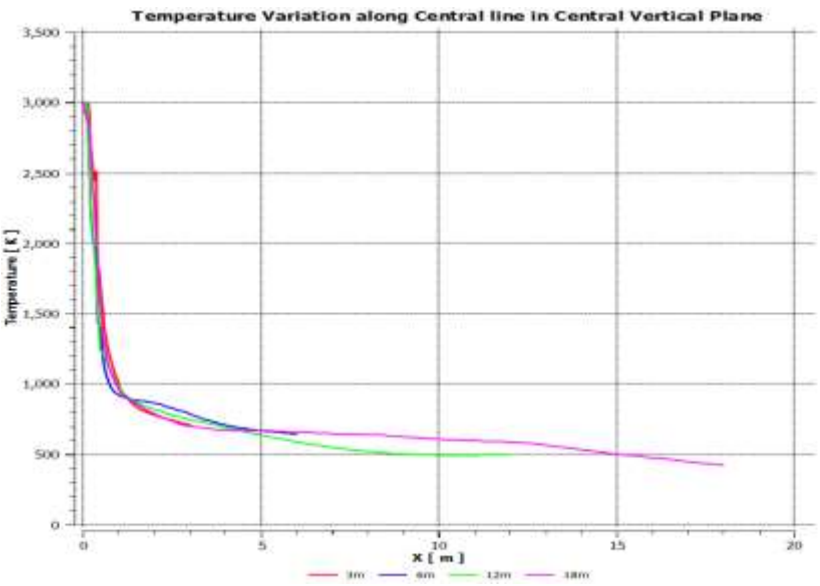


Fig (5): Temperature variation along the central vertical plane

Table No.2: Hot gas properties at the spray cooler exit

spray cooler length in m	Area averaged temperature in K	% of un evaporated water
3	836.612	34.59
6	744.435	25.31
12	660.485	12.71
18	560.751	6.76

Conclusions:

Predicted results for various spray cooler lengths 3m, 6m, 12m, & 18m are shown in the results and discussions. The static temperature variation along the spray cooler chamber is shown in the figures. In fact, a major part of the exhaust gas cooling is achieved in the initial portion of the chamber itself and the later portion makes only a minor contribution. From the table, it is observed that increase in the spray cooler length results in a slight decrease in the temperature and in the quantity of unevaporated water. Increasing the spray cooler length also involve cost escalation. Thus, increasing the spray cooler length beyond about 6m, does not add much value. From this analysis, 6m spray cooler length is optimum for the present conditions.

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