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Modification and Simulation of a Fin & Tube Cooling Battery using SOLIDWORKS and ANSYS

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Abstract: Fin & Tube Heat Exchangers (battery in industrial terms) are core equipment in any production industry. Conventional Fin & Tube Heat Exchangers have a drawback of getting chocked in industries such as detergent powder production, hence reducing the heat exchanger efficiency. The objective of this research is to provide the management with a solution of re-using the chocked heat exchanger in a modified form such that the modification provides enhanced results. Benefits of such modification is reduced maintenance downtime, which is a real-life worry for the management to handle with optimization and least time consumption. The heat exchangers (conventional and modified) have been designed in SOLIDWORKS and CFD Simulation of the modified design has been carried out on ANSYS 15.0 using module FLUID FLOW (CFX). CFD simulation of the modified design has shown significant results. The modified heat exchanger is cost efficient when compared to conventional heat exchanger because there is no other way just to replace it with a new one while the modified design only needs its fins cassettes to be maintained with minimum cost.
Keywords: Fin & Tube Heat Exchanger, Cooling Battery, Solidworks, ANSYS, CFD, Modification, Fin Cassette, Cost.

I. INTRODUCTION

Heat Exchanger, as the name implies, is a mechanical equipment or device used to transfer heat from one medium to the other, for a definite purpose to be served. In industrial terms, a heat exchanger is commonly known as “Battery”, further classified on the basis of the job being fulfilled i.e. Heating Battery or Cooling Battery. Among heat exchangers, Fin & Tube Heat Exchangers are widely used in engineering industries for heat transfer applications either for heating or cooling purposes. In Fin & Tube Heat Exchangers, the heating or cooling medium – either steam or cooling water – is circulated in tubes by centralized source such as boiler or water chiller and the process medium – either heated or cooled – that is process air in this specified case is blown perpendicular to the tubes with the help of a centrifugal blower passing through the fins in the shell. In this particular case, the heat exchanger that is taken on board is the Cooling Battery.

II. LITERATURE REVIEW

The idea to carry out such modification came from the basic idea of extended surfaces [1] which discussed general properties of fins in their research. Different geometries of fins were analyzed using ANSYS Workbench. However, their research work provided basic information and foundation that would definitely help a researcher in advanced fins studies.

A different approach was carried by [2] which opted differential approach in their research concerning fins surfaces with & without embossing. The research intended to design a modified fin geometry that demonstrated optimum level of heat transfer flow patterns.

Afterwards, the effect of porosity [3] was taken on board in fins in heat exchanger applications. Effectiveness, Efficiency and Temperature Distribution were taken on board as primary variables to be examined. The main objective of this research was to attain optimum level of heat transfer using porous fins rather that non-porous fins.

Different geometries of fins were analyzed including staggered type of fins [4] in heat dissipation applications and [5] showed their work on louvered and slit types of fins for high efficiency heat exchangers concerning heat transfer on air side.

III. RESEARCH METHODOLOGY

This research introduces and emphasizes on a term “Fin Cassette”. A Fin Cassette is a slider-based fin arrangement outside the tubes of the heat exchanger which can be mounted and drawn-out whenever needed for preventive cleaning and maintenance with minimum maintenance breakdown. The designed mesh shall be a cassette slider design as shown is Figure 02, such that whenever the cleaning of the mesh is required, instead of dismantling the entire cooling battery, only the mesh is pulled out of the slider, cleaned and washed, and then inserted back into the battery. This will cost less maintenance breakdown time as compared to the former method.

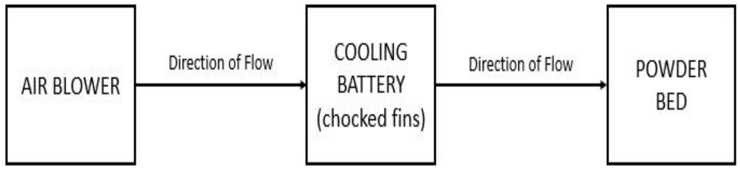

Fig. 3.1: Original Configuration

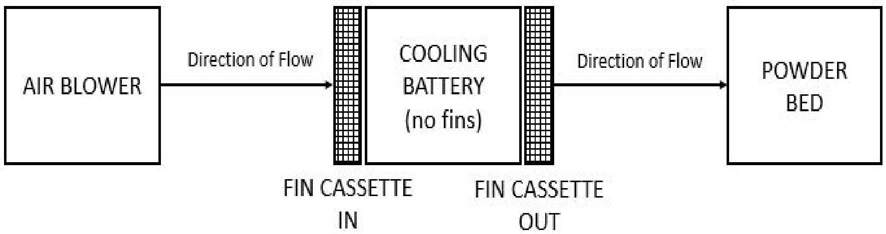

Fig.3.2: New Configuration with separate fin mesh cassette

Fluid Flow Simulation (CFD) have been carried out on mentioned software applications of modified equipment model and the results are productive and applicable. The prime advantages of such a design are maintenance ease, simplex equipment design, longer performance duration & overall Cost Reduction

IV. DESIGN & ANALYSIS

A. Design of Conventional Heat Exchanger on SOLIDWORKS

The existing heat exchanger design is a conventional fin and tube heat exchanger with a four-pass tube arrangement for the heating/cooling medium via a single inlet and single outlet header. The tubes are crowded with very fine aluminum fin mesh. The heated medium in this case is Air, which penetrates through the fins of the heat exchanger from one side, and leaves the same from the other side with a difference in temperature. The purpose for which this heat exchanger is being used is cooling of air to a certain temperature. This is why it is commonly known as COOLING BATTERY in industrial terms.

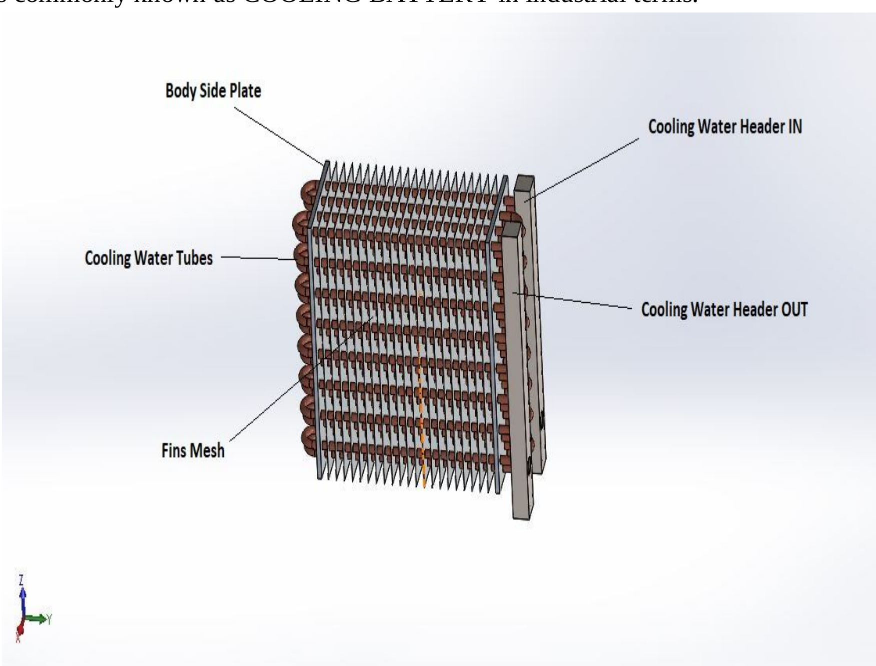

Fig: 4.1 – Nomenclature of Heat Exchanger for OLD (Existing) Design

B. Design of Modified Heat Exchanger on SOLIDWORKS

The modified heat exchanger is demonstrated in Fig: 4.2. The new design consists of two fin cassettes – one IN and one OUT – instead of the fin-mesh within the tubes.

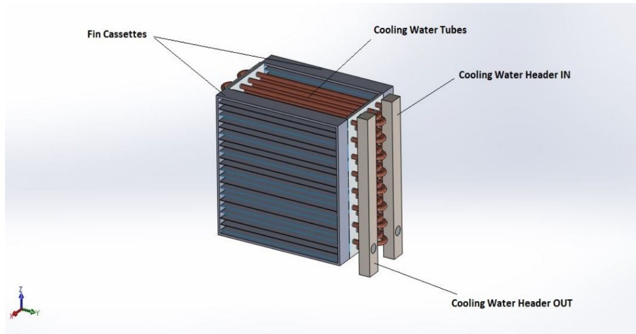

Fig: 4.2 – Nomenclature of Heat Exchanger for NEW (Modified) Design

These fin cassettes are slider-based in nature. For maintenance or washing purpose, these fin cassettes can easily be drawn out of the heat exchanger by just pulling it from the side and inserting it back within a short period of maintenance time. These fin cassettes will work as secondary fins for the same heat exchanger in the absence of actual fins.

C. CFD Analysis of Modified Heat Exchanger

It is very necessary to validate and verify the modifications on CFD. CFD stands for Computational Fluid Dynamics. It is a very handy tool in determining and validating the designs on large scales. The software used for the modified heat exchanger to execute CFD analysis is ANSYS Workbench 15.0 and the module used for the same is Fluid Flow (CFX).

It is quite impossible to execute such heavy frames on CFD software directly. Therefore, a small cross-section of the modified design has been chosen for the CFD analysis and it is assumed on the basis of its symmetry that the entire area of heat exchanger will behave ideally and as good as the cross-section.

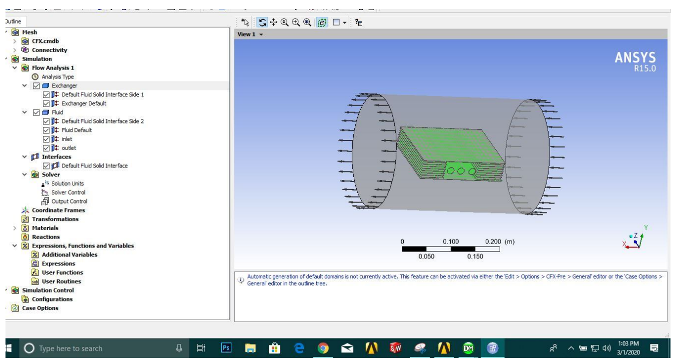

Fig: 4.3 – Flow Domains and Enclosure

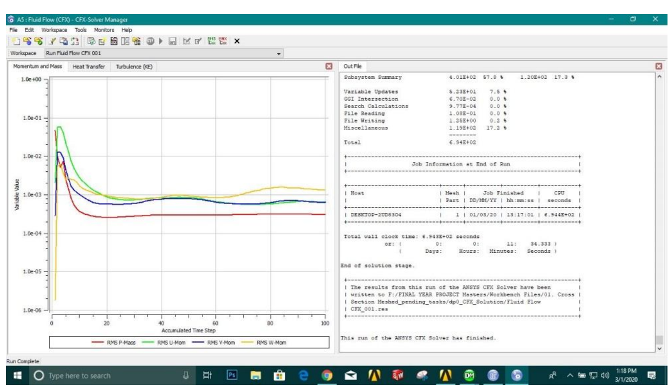

Fig: 4.4 – Execution of Successful Results

V. RESULTS & ANALYSIS

Upon successful CFD simulation, a very sophisticated laminar streamline flow can be observed for the modified design cross section. It is observed that particle flow is tangentially resisted by the fin cassette plates, thereby reducing the particle velocity and increasing residual time within the tubes for the best possible heat exchange between the media. Hence, the modified design for the provided values / variables is successfully validated and verified.

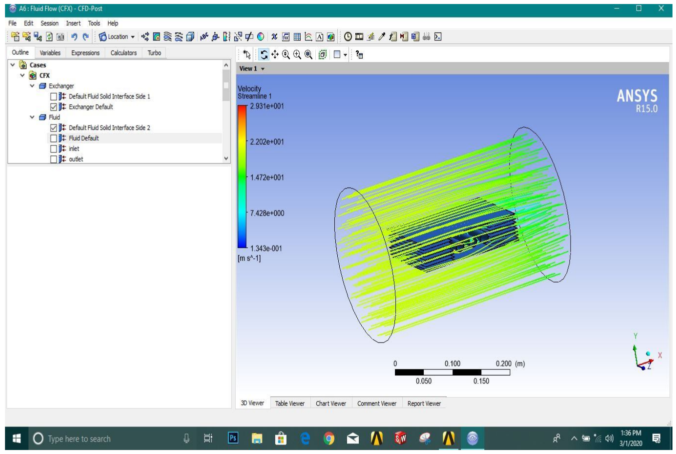

Fig: 5.1 – Streamline Flow on the Modified HX's Section

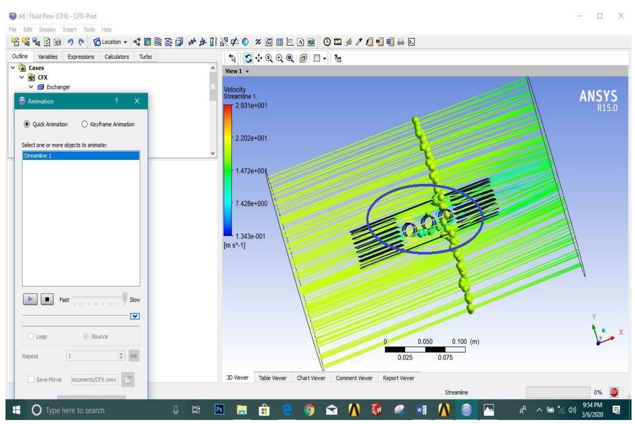

Fig: 5.2 – Particle Flow on the Modified HX's Section

VI. COMPARATIVE ANALYSIS

A. Cost Comparison

As discussed in detail, the only option available for the management is the replacement of chocked cooling battery with a new one. However, the introduction of fin-cassette design (FCD) enables us to decide over a wider range of choices.

A new cooling battery's estimated cost is around $15,000 while the fin cassette can only be fabricated locally around $1,400 which is really a drastic discount, not compromising on the material quality and process parameters.

B. Maintenance Breakdown

The fin-cassette design will enable maintenance staff to deal with the cooling battery issues with reduced maintenance downtime and increased work efficiency.

Preventive maintenance schedules can be easily set-up without halting the production process for a longer period of time in order to maintain the quality of fin-cassette.

VII. CONCLUSION

Hence, upon successful virtual analysis of the modified heat exchanger, it is concluded that such modification can be experimented on actual basis in order to acquire advantages mentioned in this research work.

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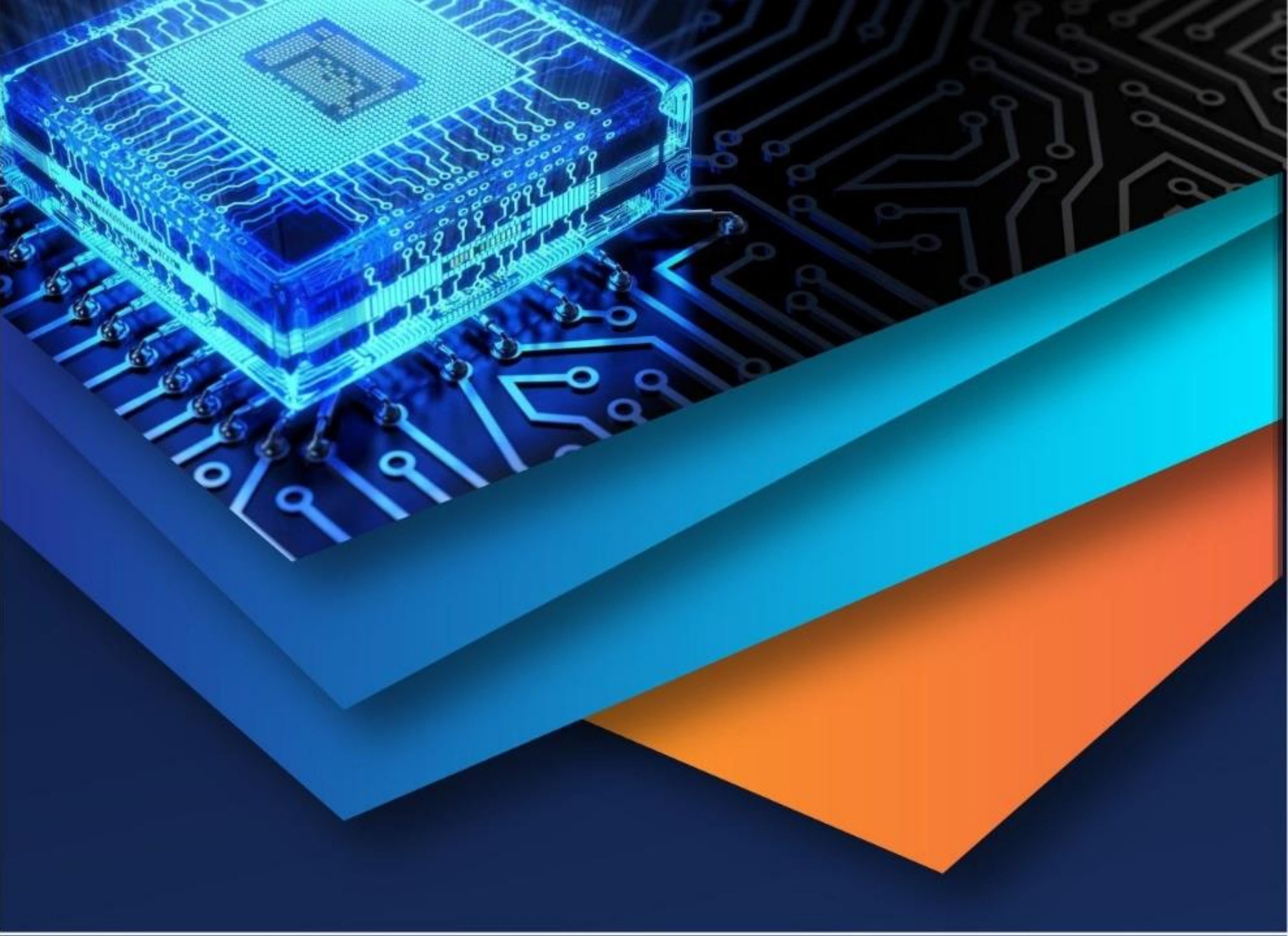

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