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Design And Analysis Of Nano-Fin Structure For Optimum Heat Transfer In Additive Manufacturing Applications

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Abstract
Heat transfer is the core issue in many industrial applications where the production line works continuously. The additive manufacturing and automation systems introduced by the Internet of Things as an industry 4.0, heat exchangers, and heat transfer are becoming prominent areas. Hence, this paper focuses on the design and simulation of different shapes of fins for optimum heat transfer. The wind tunnel test is carried out to analyze the designed fin shape. The proposed research design is a nano-fin structure that can be applied to colossal equipment where velocity and pressure elements are considered. Also, the paper presents the nano-droplet handling solution for wind tunnel tests.

Keywords: Heat transfer, heat exchanger, wind tunnel, additive manufacturing, Industry 4.0

1. Introduction

By way of the swiftly rising requirements for high-flux heat transfer in engineering tasks, heat transfer improvement solutions are being considerably upgraded; however, also new solutions have been getting suggested in the latest years [1]. Considerable focus has been given to the impact of applying tubes in heat exchangers, specifically relating to the turbulent flow occurrence, Air pressure drop, the ratio of heat productivity, measurements of heat exchangers, and in addition, categories of the tabulator. Indeed, there are units that, because of the advent of a spinning flow of fluid in the routine of even circulation, it is forced to and in the mode of a strong movement and raises the heat transfer level and, subsequently, the pressure drop as well as, pumping power utilization [2]. Today advancement of robust cooling solutions for different engineering gadgets is a significant concern. The authorhave analyzed convective heat transfer power during the melting event in a copper multi-finned heat sink packed with lauric acid to accentuate the thermal energy extraction from the local element of consistent volumetric heat release. The applied partial equations founded on the non-primitive dimensionless parameters in blend with preliminary and boundary circumstances have been figured out using the computational algorithm developed using C++ programming language [3]. It is necessary to apply a plate heat exchanger as an alternative heat exchanger to forecast its efficiency effectively to boost the efficiency and miniaturization of the system consumption. As per the existing design Fanning friction element was lesser than in other literature because the Fanning friction factor was influenced by geometry variables (chevron angle, pitch, height, and size) [4].
Additive production has produced a paradigm change in components design and development, rendering strategies, and prospects for geometric model flexibility and customizations [5]. The heat

exchanger structure is based on particular uses. The most prevalent types are heat pipes exchangers, straight tube and helical coil heat exchangers, and plate heat exchangers. Because of the significant number of degrees of flexibility, many studies have recently concentrated on the design improvement of shell and tube heat exchangers utilizing multi-objective algorithms, artificial neural networks, or meta-models with superior performance. They decreased capitular cost as intent features [6]. Likewise, the solutions utilized in Industry 4.0 or intelligent Industry comprises the support beams to assist the new Intelligent Industry model. Refer to Fig.1.

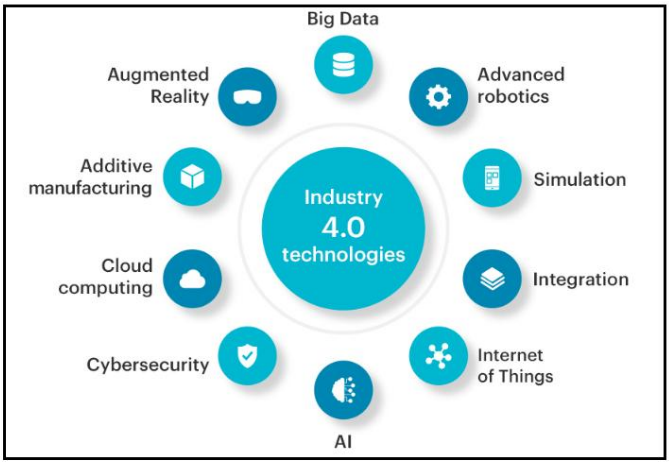

Fig. 1: Industry 4.0 Framework (Source: AuraQuantic)

The outflow speed level of thermal turbo machinery is excessive. This high-velocity tier can trigger considerable exergy deficits in consequently positioned heat exchangers, considering that, typically, heat exchangers are not always engineered for high-speed runs. For example, the structure of a steam power plant is influenced by wear-out losses credited to the collaboration of a low-pressure vapor turbine with a large Mach number wear-out flow and a condenser [7]. The heat transfer quotient in the helically coiled tube rises with the rise in Reynolds number, Dean Number, tube diameter, and circulation rate. It diminishes with the rise in coil diameter. On the reverse side, the force drop in the helically coiled tube boosts with the rise in Reynolds number, Dean Number, and flow rate and reduces with the rise in tube and coil diameter [8].

2. Literature Review

The author's study usually pertains to entropy generation and exergy evaluation of shell and tube heat exchangers, which are thoroughly examined and discussed. It can be concluded that changes in the thermos-physical properties of the fluids would decrease entropy generation and, as a result, more considerable exergy effectiveness [9]. In this research, a technique for determining thermally and chemically non-equilibrium flows has been lately created. The method is usually centered on resolving equations, incorporating the equations of continuity, energy, total energy, preservation of species, and vibrational energies. Heat fluxes, division of force on the aircraft surface, the submitter of gas-dynamic parameters in the vicinity of the forward stagnation stage, and movement of the electron focus, mainly because very well as aerodynamic pull and position of the bow shock based on the flight speed will be explored [10].

In this test, the radiator's temperature was likewise assessed at different engine rates of speed and frontal air velocities. Evaluation of engine cooling variables, such as flow rate, inlet, outlet temperature, encircling and radiator temperature, surface region, and heat dissipation rate, was first performed by applying the log mean temperature difference (LMTD) technique. Finally, the general heat transfer coefficient (OHTC) is decided. The outcomes demonstrated that using a coolant improved the radiator's overall performance for the actual engine and educational check rig [11]. The improvements in additive manufacturing (Was) systems in the previous three decades considerably affected the heat exchanger (HX) design and advancement. There is usually constant work to design effective and small heat exchangers which are lightweight and need much less material quantity. Multifunctional HXs possess various applications where heat dissipation and load-bearing capabilities will be desired [12].

By increasing the heat exchanger, thermal-hydraulic efficiency is usually the most important for energy transformation. It can be taken out through different methods, divided into active and passive methods. Improving nanotechnology in surface changes generates impressive improvements and a significant probability for heat transfer improvement in heat exchangers [13]. The overall performance of heat exchangers using different nanofluids depends primarily on the characteristics and improvement of thermo physical properties. Concerning the exclusive behavior of different nanofluids, experts possess went significant improvement. The recent research evaluations and summarizes the latest implementations of nanofluids in various choices of heat exchangers, incorporating dish heat exchangers, double-pipe heat exchangers, shell and tube heat exchangers, and cross-flow heat exchangers [14].

Heat exchangers are used in several companies, such as air fitness, car, essential oil and gas, and various additional market sectors. Heating system gear in process systems such as refineries is generally divided into two primary groups furnaces and heat exchangers. The main difference between a heater and a heat exchanger can be in the heating resource, which implies that the heating source is liquefied and gas. While in a heat exchanger, the heating source can be a warm liquid [15]. Furthermore, the heat transfer improvement (HTI) factor is usually used to reflect on the effects of the stated two parameters concurrently. Outcomes show that, although establishing circular depressions on both tubes considerably enhances the heat transfer characteristics of the heat exchanger, it raises the entropy generation level mainly because very well [16].

3. Research Methodology

With the quick advancement of miniaturization, going after heterogeneous incorporation to generate complex benefits with a massive quantity of heat dissipation offers a solid problem. Interfaces between different components can slow heat transfer and increase thermal resistance and heat accumulation. Surface change methods here consist of using prolonged surfaces or fins, treated surfaces, rough surfaces, etc. The writer evaluated a corrugation channel's flow and heat transfer functionality to uncover the heat transfer improvement system [17]. As per the research, the heat transfer effectiveness of heat exchangers is usually minimal, credited to the substantial thermal resistance of condensing droplets. By implementing the coalescence-induced droplet getting trend on a coated surface, the condensing droplets can be automatically eliminated from the heat exchanger, and the general performance can improve the heat transfer [18].

Hence, the proposed design considers wind tunnel simulation for heat transfer with the effect of the shape of fins. Fig. 2 shows the fin chamber, which can fabricate nano-fins. The wind tunnel chamber can be fabricated as a cluster of fins that can dissipate heat.

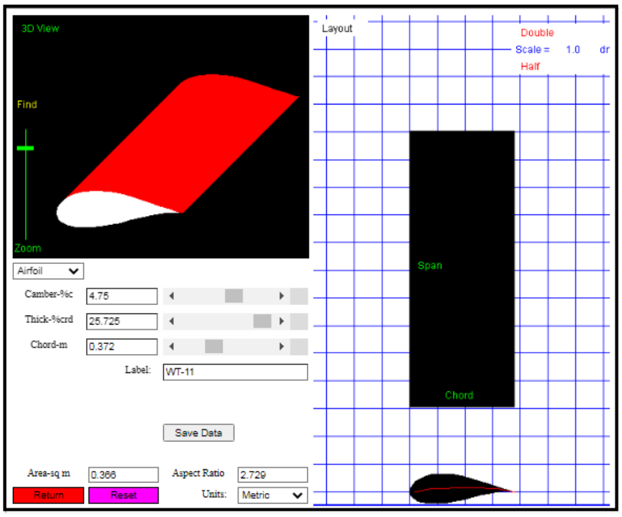

Fig. 2: Wind tunnel fin design with fixed chord (Generated by the researcher)

Even the droplets can be handled by changing the chord shape, so by increasing internal heat passage; wind force helps to transfer heat at a higher rate. The optimum thickness of fins is essential for heat transfer. The wind tunnel passage and gaps between fins and shape are essential. Instead of tube shape fins, the curved fins, as shown in Fig. 3, can transfer heat at a higher level.

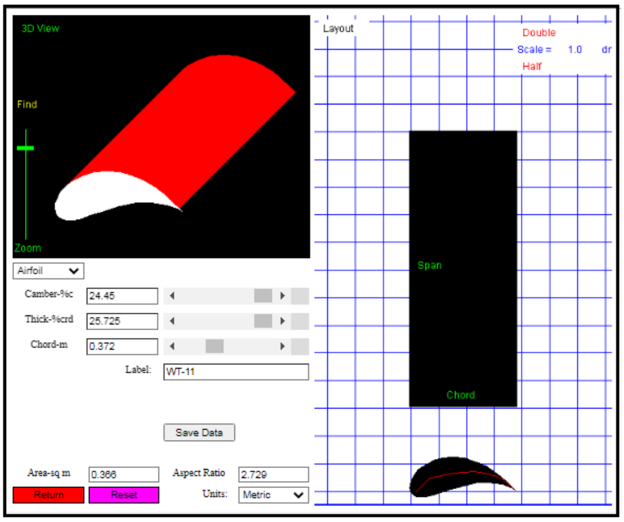

Fig. 3: Wind tunnel fin design with curve chord (Generated by the researcher)

Hence, the wind tunnel test design considers the tunnel's walls and the direction of flow through the tunnel is essential. Further to fin design, wind velocity, and pressure need to be optimum. The optimum design results are discussed in section 4 of this paper.

4. Result Discussion

To test the simulation design, we provided the velocity and pressure of the wind. The TunnelSim is used to analyze optimum wind velocity and pressure for heat transfer. The tunnel surfaces are displayed in blue color even though the preferred component is shaded yellow. Presently there are two perspectives of the tunnel: the top view and the side view. Circulation from the tunnel moves from the left side to the right side. White-color marks show the boundaries of the different portions of the tunnel. As shown in Fig.4, the bar graphs present values of the circulation parameters at these spots.

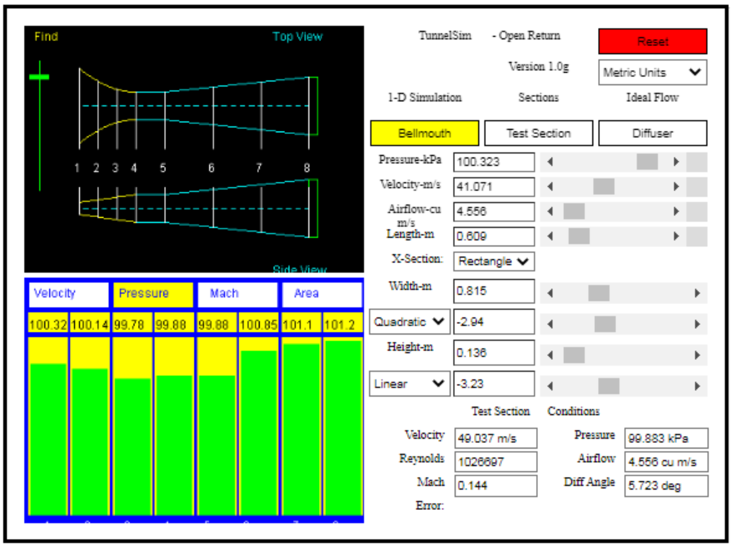

Fig. 4: Wind tunnel Test (Generated by the researcher)

The amount of circulation parameters is shown in the right panel. The speed and stationary force are appropriate throughout Bernoulli's equation, considering that the evaluation is one-dimensional. The Reynolds's number and the Mach number are determined and formulated on sea-level normal day circumstances, the regional circulation speed, and the diameter. The ventilation through the tunnel is the product of the speed and cross-sectional region. Because the air density is presumed to be consistent, the efficiency of mass gives that the air movement is consistent throughout the tunnel. The Diffuser Angle is the slope of the diffuser wall indicated in degrees. In the diffuser, the force is elevated as one approaches downstream. The negative pressure incline triggers border layer separations in natural diffusers if the diffuser angle is significantly larger than 7 degrees.

5. Conclusion

Many heat transfer techniques and heat exchanger challenges are discussed in this paper. The proposed research suggests that the optimum design of the nano-fin can handle the heat transfer rate efficiently. In the case of jumping droplets, the chord shape and thickness are critical. The presented wind tunnel simulation is also helpful for designing different industrial applications for additive manufacturing. The wind tunnel test revealed that the velocity and pressure of the wind are best utilized by the proposed nano-fin design for optimum heat transfer. As future research, the number of nano-fins required for specific applications can be designed. The proposed research can benefit Industry 4.0, where artificial intelligence automation can be deployed for seamless heat transfer monitoring and control.

References:

1. Wang, C., Lu, Q., Liu, Y., Huang, H., & Sun, J. (2023). Progressive review of heat transfer enhancement technologies in 2010–2020. Sustainable Energy Technologies and Assessments,56,103121.
2. Alizadeh, A. A., Abed, A. M., Zekri, H., Smaisim, G. F., Jalili, B., Pasha, P., & Ganji, D. D. (2023). Numerical investigation of the effect of the turbulator geometry (disturber) on heat transfer in a channel with a square section. Alexandria Engineering Journal, 69, 383-402.
3. Sheremet, M. A. (2023). Numerical Simulation of Convective Heat Transfer. Energies, 16(4), 1761.
4. Ham, J., Yong, J., Kwon, O., Bae, K., & Cho, H. (2023). Experimental investigation on heat transfer and pressure drop of brazed plate heat exchanger using LiBr solution. Applied Thermal Engineering, 225, 120161.
5. Dixit, T., Al-Hajri, E., Paul, M. C., Nithiarasu, P., & Kumar, S. (2022). High performance, microarchitected, compact heat exchanger enabled by 3D printing. Applied Thermal Engineering, 210, 118339.

6. Slimene, M. B., Poncet, S., Bessrour, J., & Kallel, F. (2022). Numerical investigation of the flow dynamics and heat transfer in a rectangular shell-and-tube heat exchanger. Case Studies in Thermal Engineering, 32, 101873.
7. Sundermeier, S., Passmann, M., aus der Wiesche, S., & Kenig, E. Y. (2022). Flow in Pillow-Plate Channels for High-Speed Turbomachinery Heat Exchangers. International Journal of Turbomachinery, Propulsion and Power, 7(2), 12.
8. Akgul, D., Mercan, H., &Dalkilic, A. S. (2022). Parametric optimization of heat transfer characteristics for helical coils. Journal of Thermal Analysis and Calorimetry, Springer, 147(22), 12577-12594.
9. Rashidi, M. M., Mahariq, I., Alhuyi Nazari, M., Accouche, O., & Bhatti, M. M. (2022). Comprehensive review on exergy analysis of shell and tube heat exchangers. Journal of Thermal Analysis and Calorimetry, 147(22), 12301-12311.
10. Molchanov, A. M., &Siluyanova, M. V. (2022, March). Calculation of Heat Transfer at the Front of an Aircraft During Hypersonic Flight. In Advances in Theory and Practice of Computational Mechanics: Proceedings of the 22nd International Conference on Computational Mechanics and Modern Applied Software Systems (CMMASS 2021) (pp. 29-45). Singapore: Springer Singapore.
11. Manan, A. N. A., Anuar, D., Khalid, M. L. A., Ismail, A. K., &Azid, I. A. (2022). Overall Heat Transfer Coefficient of Different Coolants and Frontal Air Velocity in Automotive Radiators. In Progress in Engineering Technology IV (pp. 139-146). Cham: Springer International Publishing.
12. Kaur, I., & Singh, P. (2021). State-of-the-art in heat exchanger additive manufacturing.International Journal of Heat and Mass Transfer, 178, 121600.
13. Nguyen, D. H., & Ahn, H. S. (2021). A comprehensive review on micro/nanoscale surface modification techniques for heat transfer enhancement in heat exchanger. International Journal of Heat and Mass Transfer, 178, 121601.
14. Maghrabie, H. M., Elsaid, K., Sayed, E. T., Abdelkareem, M. A., Wilberforce, T., Ramadan, M., &Olabi, A. G. (2021). Intensification of heat exchanger performance utilizing nanofluids. International Journal of Thermofluids, 10, 100071.
15. Chupradit, S., Jalil, A. T., Enina, Y., Neganov, D. A., Alhassan, M. S., Aravindhan, S., &Davarpanah, A. (2021). Use of organic and copper-based nanoparticles on the turbulator installment in a shell tube heat exchanger: a CFD-based simulation approach by using nanofluids. Journal of Nanomaterials, 2021, 1-7.
16. Cao, Y., Ayed, H., Dizaji, H. S., Hashemian, M., &Wae-hayee, M. (2021). Entropic analysis of a double helical tube heat exchanger including circular depressions on both inner and outer tube. Case Studies in Thermal Engineering, 26, 101053.
17. Guo, Z., Tao, Y. X., Nan, Y., Zhang, H., Huang, X., Cao, H., ... & Tang, N. J. (2020). An overview of heat transfer enhancement literature in 2019. Heat Transfer Research, 51(9).
18. Zhu, Y., Tso, C. Y., Ho, T. C., Leung, M. K., Yao, S., & Qiu, H. H. (2020). Heat transfer enhancement on tube surfaces with biphilic nanomorphology. Applied Thermal Engineering, 180, 115778.